

# Autonomous Lightweight Houses: Learning from Yurts

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**ABSTRACT:** The paper investigates the possibilities and limitations of the interpretation and interpolation of the traditional architectural principles into the contemporary architecture, in order of achieving a higher level of sustainability and autonomy. It is based on a comparison between a traditional and a twentieth century house.

Yurt, traditional nomad tent from the Central Asia responds to many sustainability criteria set for a sustainable house such as natural cooling and ventilation, dematerialization, maximum volume enclosed by the minimum surface, use of innocuous materials, minimum disturbance of the terrain, use of local materials. The Dymaxion House (designed by R. B. Fuller between 1927 and 1946) bares numerous resemblances with yurts, i.e. the form, volumes/surface ratio, ventilation system, etc. On the other hand, it was designed as an entirely industrially produced artefact, implying the use of different kind of materials (mainly of them recyclable metals), etc. The traditional principles can be successfully applied in the new buildings in order to make them more energetically efficient and effective, but some adjustments are needed to be done in order to integrate them in the contemporary building processes and uses.

**Keywords:** yurt, design principles, sustainable and autonomous house

## 1. INTRODUCTION

Autonomy and lightness are characteristics of the transportable dwellings in general. This kind of dwellings developed as a response to certain lifestyles. Although the contexts are different, the responses in the two studied cases (the Yurts, traditional nomad tents from Central Asia, and Dymaxion (Wichita) House, designed by R. B. Fuller between 1927 and 1946 in the United States,) developed in the similar directions.

The inhabitants of the yurts are nomad peoples (primarily herdsmen) from Central Asia. As they need to move with their herds from pasture to pasture almost all year around, they developed a typology of house that permits them easy assembling, disassembling and transport. Yurt (*ger* in Mongolian) has a large tradition (Mongolian yurt, for example, developed from 5th to 19th century. [7]) These dwellings are easily transported and assembled: yurts of Tuvina (Siberia), are transported in four ox hides and can be erected by two or three persons in two hours and disassembled in one hour. [7]

Dymaxion House was to be a completely prefabricated, independent, low cost house, a response to the housing crisis of the 40s.

This period in the USA (1920's-1940's) was marked by the simultaneous economical crisis and the acceleration of the industrial production. The lifestyle was marked by the increasing individualism and mobility. The available job posts were shaping the migrations on the national level, and the community was losing its paper in the everyday life. The introduction of a car as a basic means of

transport and the growing network of highways improved the accessibility to the new areas.

The situation of emergency, and scarcity of both materials and housing units, that was induced by the Second World War, brought the Dymaxion into realization due to its concept of achieving "more with less".

The study is divided in two main parts. The first part deals with the features of lightness of yurts and Dymaxion House. The second part deals with the issues of autonomous building.

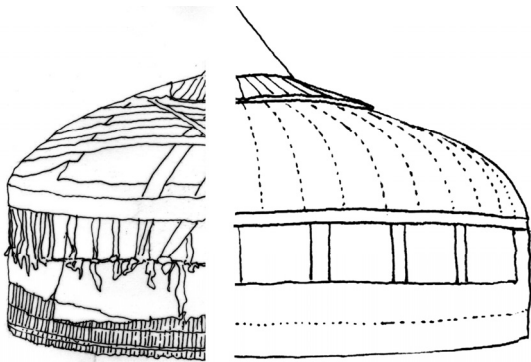
## 2. LIGHTWEIGHT HOUSE

### 2.1 Form

The circle is the figure that encloses the maximum area for the parameter length given and the sphere is a 3D figure that encloses the maximum volume for the surface area given. This implies the minimum use of the material. Both Yurts and Dymaxion house are nearly hemispherical - geometrically, they are a combination of a hemisphere and a cylinder. This combination gains functionality comparing to the pure hemisphere.

Their shape is aerodynamic and offers less resistance to wind, compared to the rectangular houses of the same volume. This is of major importance in the harsh climates of Central Asia, as well as in the United States where the tornados are often present.

Yurt builders pay close attention to the perfection of the circular plant. The deviation from the perfectly circular form can result in the breaking of the structure under the weight of snow or the force of wind. [7]



**Figure 1:** A Yurt and the Dymaxion (Wichita) House: the exterior view

In the case of Dymaxion, its early stages (4D house in 1927) were taking advantage of the hexagonal patterns. However, upon appreciating the functional characteristics of the circular prefabricated grain bin present across the United States, Fuller changes the design of the Dymaxion into the circular one. In the projects that were to follow, after the Second World War, Fuller dedicates his efforts to the development of the geodesic dome due to its high volume surface ratio, among other issues. Fuller considers sphere to be a base of the universal geometry opposing the 90-degree system widely in use.

## 2.2 Structure and shell

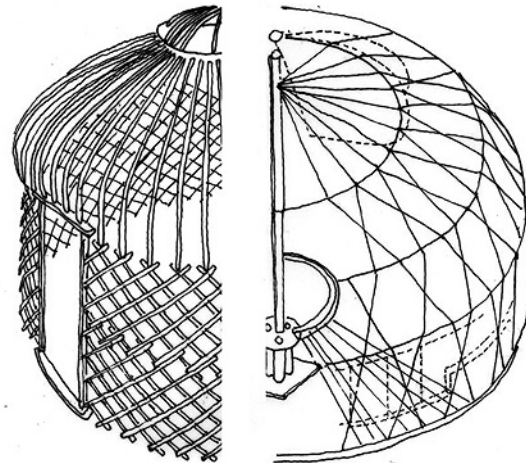
Structure and shell are designed to have the minimum weight in order to provide an easy transport.

In the case of yurts the structure consists of walls and roof. There are no foundations, a fact that minimizes the environmental impact - once the dwelling is removed nothing is left at the site. The walls are made of three or more sections of lattice of willow wands. Each lattice is easily collapsible for the transportation. The average size of the square in the lattice is 30 cm [3]. The diagonal pattern of lattices also provides stability to the yurt. Once the lattices are positioned (leaving the space for the door) and fastened by a textile stripe in the upper area, (in order to receive the tensional forces from the roof), the roof wheel (a compression ring) is placed in one or two vertical poles. The roof wheel itself has radial wooden reinforcement that maintains its circular shape. In continuation the roof poles are positioned. The roof poles may be curved by steam or straight. In Kyrgyz, the curved roof poles are stronger and are combined with light roof wheel, while in Mongolia the roof wheel is heavier and the poles are straight. The vertical poles are removed after the assembling. In the case of snow a vertical pole may be positioned under the roof wheel as a structural reinforcement. The frame may be found standardized in the stores in Ulaan Baator.

The yurt is covered with felt that is additionally pressed by the ropes and textile stripes. Felt is produced by rubbing and squeezing the moist wool together. The felt covers walls, roof and a hole in the roof. The average number of coverings is four for the

walls, two for the roof, and one for the roof wheel. [7] These numbers may vary according to the size and type of yurt.

Traditionally the felt is done by women and the wooden parts by men.



**Figure 2:** A Yurt and the Dymaxion (Wichita) House: the structure

Dymaxion starts from structurally different principles than the yurt but results in a similar shape.

The structure is composed of a central steel mast that bears the loads of the entire house and a radial net of steel tension cables. Two compression rings direct the cables in an optimum direction to support the floor platform. The cables form a triangulated grid with the aim of stabilizing the structure in all directions. The foundations are minimum - the only founded element is the central mast, and the perimeter anchors that fix the tension cables. The outer shell is of aluminium sheets providing the lightness.

Both solutions tend to minimize the weight and quantity of the material necessary for the enclosing of the internal space.

## 2.3 Materials and weight

In yurt all the materials are of organic origin - willow wands, and other type of wood (for structure, door), raw hide or animal hair ropes for the connectors between the structural elements, felt made of sheep wool and reed for the protection against the elements. The materials are chosen due to their availability, lightness and suitability for transportation. Upon their disposal they disintegrate and convert to compost, entering into the natural material cycles.

In the case of Uzbek yurts the weight of the structure is 150 kg and of felt covers about 100 kg [7].

In contrast, all the materials applied in the Dymaxion House are of industrial origin: steel, aluminium, Plexiglas, masonite. Fuller was against the use of the organic materials since he considered them to be of short useful life. Steel and aluminium were chosen due to their durability and strength. Fuller investigated the circulation of the materials

through the industrial cycles and had concluded that once incorporated in the closed production loops these materials could circulate for a long period of time through the industrial production. Steel, and especially aluminium are extremely energetically intensive in the stage of production. On the other hand, once produced they are highly recyclable which, according to Fuller, justifies their use in the house.

The weight of the house was 2700 kg, compared to the 150 t that Fuller claimed was the weight of the traditionally built house of his time.

### 3. AUTONOMOUS HOUSE

#### 3.1 Definition of an autonomous house

Autonomous house is a dwelling unit independent from the urban infrastructure such as electricity grid, sewage grid, etc. It is supposed to provide its own electricity, autonomous passive heating and cooling, make use of its grey water, as well as of rainwater, takes care of its sewage, produce compost, and in some more radical cases be independent from the food supply system.

The benefits of the construction of an autonomous house are twofold - it minimizes the use of the non-renewable resources and generation of waste, and on the long run provides the inhabitant with the economical benefits.

The concept gained importance starting the 1970's due to the energy crises.

However, a large portion of traditional buildings are autonomous, so that the movement is actually rediscovering of the already existing principles and searches for their retrofitting to the technological reality of the construction.

#### 3.2 Cooling and heating

Both Yurts and Dymaxion House are provided with the system of natural ventilation. The shape induces a "dome chilling effect"[2].

In the case on a house of a single space with a central opening in the roof, the warm air moves upwards and goes out through the hole, maintaining the internal comfort.

However, it has been noticed that the houses that in addition to the roof opening have ventilation wholes next to the floor level, experience different kind of air movement. The external air is getting warm in contact with the surface of the house. This air moves upward creating the low-pressure area next to the floor in the exterior, creating the suction effect toward the outside, and lowering the pressure in the house. As the result the external air is drawn in, through the central roof opening. This air is more compressed than the air that is being driven out through the low holes, and is therefore cooler [9]. The yurts are in some cases taking advantage of this phenomenon: the lower part, which permits the air to come in, is covered with canes to provide the privacy.

The central hole has two functions: lightning and chimney for the hearth fire, positioned directly below this opening. The hearth contains a tripod or a stove (clay or iron). Depending on the weather, time of day

and use of the dwelling, the central roof hole may be covered by a piece of felt or uncovered.

The number of felt coverings may vary according to the season - in wintertime the additional covers are used in order to preserve the thermal comfort. The climate in some areas of Central Asia is extremely harsh, for example in Ulaan Baator (Mongolia) the temperatures range from 38.2C to minus 42C. [7]

The position of the door may vary according to the tribe. In most cases the doors face south, southeast or southwest, though in the case of mountain slopes they always face downwards in order to avoid the direct impact of the wind coming down the mountain.

In the case of Dymaxion, although Fuller did start parting from this phenomenon which he realized during the construction of Dymaxion Deployment Unit, one of the antecedents of the Wichita House, later through the investigation on the aerodynamics of the house he chose to inverse the air movements. The cooling and ventilation system has several functions:

First, the 16 ft diameter vent in the roof of the house was producing the suction effect by the creation of the area of low pressure at its "tail". That way the fresh air was coming in through the openings below the windows, cooling the house and going out through the ceiling opening.

The second effect of the shape and the vent was to maximize the aerodynamics of the house (as the vent had a rotating movement and was turning its aerodynamic side towards the wind) and minimize the drag that produces the unwanted heat losses.

The third role of the vent was to protect the house in case of tornados, when an extremely low pressure in the outside could provoke the house to explode. The vent was designed in a way that permitted it to lift 1m from the house in the case of tornado, making it possible to equalize the internal and external pressure and preserve the structure and the shell.

The records say little about the heating of the house, probably due to the fact that it was not as efficient as the cooling system.

#### 3.3 Recycling System

Though both examples are characterized by the closing (or at least intention of closing of) material cycles during their useful life, their functioning in this sense is quite different.

In the case of yurts the life of its occupants depends in the large portion on the surrounding sources of resources - livestock that they are breeding are the source of food, milk, wool, the water is found in the nearby rivers and streams, etc. The waste is also integrated in the biological cycles. (However, the lifestyle of the yurt occupants also changes and is not free of the influences and artefacts from the urban environment. Nevertheless, in this paper traditional lifestyle, as preserved through the centuries, is analyzed).

Though highly dependent on nature, nomads that inhabit the yurts are highly self-sufficient regarding the urban/rural infrastructure.

In the case of Dymaxion, the strategy applied is the one of use of the technological appliances and technical systems that provides for the minimization of the use of the resources and recycling. The water

use is limited by the use of the "fog gun" instead of the classical showerhead. Fog gun is an invent that vaporises the water and minimizes its use. Fuller came to an idea for it by using his experience in the Navy when he appreciated the cleaning properties of combination of wind and sprinkled water. The fog gun uses the water at high pressure that, upon coming out of the sprinkler, gets mixed with the air and cleanses the skin. The amount of water used is minimum - it is estimated that 0.5 liters is sufficient for a shower [2].

The house roof is supplied with gaps that gather the rainwater in the perimeter channel. The water is then lead to the central reservoir for its future use.

In the toilet designed by Fuller waste was to be separated and used to produce compost. That way the amount of waste would be drastically reduced due to the small weight of the dehydrated waste. The produced substance was then to be carried to the chemical treatment for further use.

These other features were designed in order to keep the house completely "off the grid".

#### **4. CONCLUSIONS**

The Yurts and Dymaxion House belong to two different realities, but have numerous similarities regarding their form, structure, ventilation systems, etc. However, analyzing their lifecycles, major differences between these two houses are observed. The yurt is integrated in the natural material cycles, and therefore its creation, use and the disposal after the useful life, does not require additional industrial or management system. On the contrary, the second example is, although featuring numerous characteristics of an autonomous building, completely integrated in the industrial system. The functioning of this system is, in the sense of energy requirements of the production and recycling stage, incomparably more intensive and complex that the one related to yurts. For achievement of higher level of sustainability all these factors need to be taken into the consideration. The passive architecture, apart from the investigation about the achievement of the interior comfort with the minimization of the energy use, has to consider the real energy and material costs and impacts of the production and disposal related to its means.

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