

**Passive Solar Architecture: Case Study on Strategies used in Jacobs House
Designed by Frank Lloyd Wright**

by

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Abstract

Over the ages major breakthroughs made in passive solar architecture stem from technical innovations, understanding of material properties and energy flows. The emergence of net zero energy buildings represents a crucial moment in terms of energy performance of passive solar designs. Despite the technical feasibility, NZE proposals have proved to be unaffordable owing to complex technical innovations and overreliance on mechanical systems. The purpose of this study is to examine Jacobs's house designed by Frank Lloyd Wright, to rediscover ideas of the past that would be integrated to contemporary passive solar architecture. This began with a literature review, an overview of Wright's background and visit of Jacobs's house. Then, a study of five passive strategies namely: orientation, thermal mass, insulation, ventilation, and natural lighting was done. The thesis will also prove that ideas behind net zero are not new. There is need to re-examine net zero in a wider context of sustainability not to be limited to just energy calculation. Net zero energy building should not be viewed as just a passive building but rather an active social, political, and economical project as the Jacobs House demonstrates. In search for interconnectivity between our built environment and natural world, adopting Wright's principles of organic architecture will make NZE more sustainable.

Keywords

Passive solar architecture, Net zero energy building, organic architecture, affordable housing, passive strategies, passive design.

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Introduction

0.1 Forward

It could be argued that passive ideas have been there from the beginning of architecture. This thesis focuses on the work of Frank Lloyd Wright and particularly aims to assess retrospectively both Net Zero energy ideas as well as passive solar strategies in the Usonian houses. These houses worked in harmony with nature and were designed according to the principles of organic architecture, while embracing the technology of the time, and conserving energy. Net zero is not a new idea per se. The wording “net” can be viewed as an economics or a statistical term and is used as the prefix to ‘Zero’ as a measure of balance with nature. The concept of passive solar entails obeying all the rules of natural cycles of the weather in each region, location, or site. This requires an understanding of the behavior of the materials within the locality of the site while being immersed within the rules of nature. A design that supports life, brings joy to its occupants, in harmony with the natural gifts that creates a balanced form of living. The ideas behind net zero are passive solar ideas. Passive solar ideas form a key component in achievement of Net Zero. What net zero added to passive solar ideas is the ability for a building to generate power using renewable sources and also the art of balancing energy production with to consumption.

There is a shared belief that NetZero Energy Buildings are expensive and inefficient in the use of technology. Essentially the net zero buildings should be economical in the long term. However, the approach is what is making them expensive. Natural resource Canada echoes this view by stating that “Recent Canadian demonstration projects by leading-edge builders have proven that Net Zero Energy (NZE) homes are technically feasible in our cold climate. But current building approaches are complex, custom, and expensive, adding \$90-120K to the cost of a home.”¹

This thesis investigates the possibilities of applying Frank Lloyd Wright’s ideas on organic architecture to create affordable passive solar designs and by extension net zero housing research. Frank Lloyd Wright came up with the design of the first Usonian house referred to as Jacobs’s house. The Usonian house was affordable to the average American, utilized passive strategies to demonstrate his philosophy of organic architecture. Frank Lloyd Wright had figured out the sustainability principles that can inform how best to approach the design of NetZero energy buildings. Investigation will lead to discovery of passive strategies in the architectural history that can be integrated to the current contemporary net zero research. This would prove that passive strategies are the most affordable way to arrive at an affordable solution. Net zero is a critical point of history of passive solar that is a departure from the traditional role of architecture in relation to energy.

All of the passive solar principles of orientation, thermal mass, insulation, ventilation, and lighting will be investigated in the Usonian concept. Economy, culture, and technology are variables dictated by the owners and the environment they live in. Energy is universal and has no boundaries. It flows like water and air and the building is only a frame that plays along with this

¹ Natural resource Canada <http://www.nrcan.gc.ca/energy/efficiency/housing/research/5133> accessed 11-1-2016

flow. All we need is to tap into nature to meet our own needs. Application of passive strategies is the most feasible way to arrive at an affordable solution. This would require passive solar design that are simple, require no mechanical systems, and minimal maintenance.

Passive solar is a key component in achieving NZE, a building that produces as much energy as it consumes in one year. There is a lot of potential of utilizing passive solar energy in buildings by reducing the energy demands and the need for mechanical heating or cooling. This research will examine passive ideas of the past that will benefit NZE research. Passive solar architecture which has thousands of years of history is the precursor of Net Zero. The efforts and contributions of architects like Frank Lloyd Wrights as demonstrated in the Usonian house and other projects will guide the approach toward achieving a true NZE goal. The two Jacobs houses I and II designed by Wright will reveal important facts in the history of passive solar strategies. What is missing in the Usonian concept is the house ability to produce electricity, and other technical improvements present in Net Zero. Sustainability issues gained momentum during the modern architecture era, since this period had lost sight of the very principles which inspire passive architecture.

Oriental ideas of natural flow such as–Xin Tao; Buddhist philosophies are found to have influenced Wright’s principles of organic architecture. One major point architects seldom consider while designing houses is the fact that families expand and age. The Usonian houses were meant to serve a growing family at different points in their life.

0.2 Hypothesis

I argue that Frank Lloyd Wright in the Usonian house prefigured much of what is presently understood to be the principles or ideas behind Net Zero. The organic architecture philosophy initiated by Frank Lloyd Wright, intended for the building to become one with nature. A building that flows with nature, rather than fight nature, respects its rules and works in unison with them. A well-designed building ensures respect to the environment and at the same time serves the inhabitants of its space. Usonian houses were designed to support the family and met their needs at different stages of their life. The house made the family whole and one with nature. They enjoyed the gifts of nature, the flora, and fauna without losing their own identity. The houses had unique features derived from the use of natural materials, maximum natural lighting, and ventilation. Wrights organic architecture philosophy employed passive solar energy strategies to the fullest, and was based on principles that were meant to create a balance with nature. The 21st century idea of sustainability has its roots in the organic architecture by Frank Lloyd Wright. *Wright's interest in merging building with the site and using local materials parallels current sustainable best practices that emphasize energy efficiency in building construction and performance.*²

The Jacobs house in fact provides a good reference point of in contemplating a net zero energy house. Many lessons can be learnt from the Jacobs’s house about the design and construction of a net zero sustainable home. It is a house that was built with ideas of its time and available

² Krause, Linda R. “Frank Lloyd Wright: Organic Architecture for the 21st Century.” *Journal of Architecture Education* 65.1 (2011) p 82-84. Accessed Nov 06 2016.

technologies then. The idea of designing a house where energy production is balanced with consumption for a period of one year came separates net zero and Jacobs's house.

I began this thesis with the hypothesis that all Net zero energy passive energy strategies are already present in the Usonian house, and I argued that Frank Lloyd Wright with his organic architecture philosophy embraced the application of passive energy strategies. In order to attest that, this research examines the five characteristics namely orientation, massing, insulation, ventilation and natural lighting in the first Usonian house, the Jacobs House. The argument is that these strategies are important elements for us to construct true net zero energy buildings. Architects in the 21st century will learn a great deal by employing the organic architecture principles to address the issue of energy conservation and sustainability. The research will examine how Frank Lloyd Wright applied each of the five characteristics for his Usonian concept. Wright created a prototype of the Usonian house where each house met the client's requirements and was adjusted to suite different weather and site conditions across the United States. By examining these five factors, we will discover that passive strategies are not new and the subject of energy has long been part of architecture. Energy supports life and architecture protects life. Architecture negotiates with energy while at the same time exists as a result of manipulation of energy. Frank Lloyd Wright had figured this out, and there is much to be learnt from his way to create affordable net zero energy buildings. Passive solar architecture goes beyond net zero and brings about other issues like sustainability.

0.3 Boundaries of the research topic

The thesis explores selected passive solar strategies that have been applied both recently and in the past. These strategies are intended to eventually benefit research on net zero energy buildings and beyond. In the advent of industrial revolution many passive strategies were highly ignored.

The architect's work has been affected tremendously in areas like design of the envelope, decisions on style and form. Many proposals have been made in research and architectural practice with the aim of achieving the best outcome of an ideal passive solar design. The study will orchestrate how applying effective passive solar strategies can result to simple, realistic, and economical passive solar designs. Research on net zero energy is still in its infant stage, as such proposals made so far are usually complicated and sometimes unviable. Net zero forms an important reference point towards achievement of a building that is free from energy supplied by the grid which benefits the environment.

Buildings last longer than mechanical systems and technology. This presents an opportunity as well as challenge to architects in coming up with an ideal style that adequately respond to environmental sustainability concerns. According to Tom Hootman "passive design is not only an energy opportunity; it is an architectural opportunity. It is an opportunity to express the connection of energy to place and program and to make that connection beautiful, functional, and meaningful."³ The professional practice has a great potential to impact the environment by reducing greenhouse gas emission and conserve energy.

³Net Zero Energy Design: A Guide for Commercial Architecture by Tom Hootman

Passive solar strategies are not limited to the five mentioned i.e. site orientation, thermal mass, insulation, natural lighting, and natural ventilation. However, these are fundamental to an architect's work in the design of the envelope, decisions on style and form.

I explore important lessons from Jacobs's house which was essentially a passive solar design.

Potential of passive solar energy

The potential of passive solar energy is unlimited. *The earth receives 137 watts per square foot directly from the sun but, after reflections of the clouds this reduces to 100 Watts per square foot.*⁴ Most buildings consume an estimated 6 watts per square foot, which would mean that 100 watts per square foot received from the sun would power 15 stories.

Solar energy is the primary source of energy for most Net Zero Buildings Net Zero Buildings can be achieved by initiating the following strategies:

1. Harvest energy through renewable sources like solar
2. Improve energy efficiency in buildings including the mechanical and electrical systems
3. Reduce consumption by eliminating waste

This thesis focuses on how to harness the solar energy through passive design, eliminate waste and prepare the building to receiving energy through renewable sources with little or no mechanical or electrical systems. Measures to control the sun's energy and reduce the detrimental effects of it will be discussed.

Solar energy can be described as active or passive. An active solar approach emphasizes on the supply side by typically increasing the supply of energy from renewable sources. Conversely, passive energy addresses the demand side by applying technologies that reduce the demand of energy or making energy consumption more efficient.

The main drawback in tapping the potential of solar energy is that current technologies were developed when solar energy costs were low. Efficiency of photovoltaic panels range from 15-20% converted into electricity. Power generated by fossil fuels only 30 percent is converted to electricity while the rest is lost through heat or waste gas. The payback period of photovoltaic cells can vary from one to four years.

Harvesting solar thermal energy is much more efficient with 60-70%, where energy in form of infrared and ultraviolet radiation is converted to heat through hot water. The energy source is limited during winter months.

This is a clear indication that there exist tremendous opportunities of applying natural methods like passive and limiting the cost of mechanicals or other technologies that supply energy or consume energy. Net zero design is a contemporary architecture that will benefit from integrating rediscovered passive solar strategies from our architectural history. One way of

⁴ Syed Asif, *Advanced Building Technologies for Sustainability*, John Wiley & Sons, Hoboken, New Jersey, 2012

doing this is through the study of architectural innovations like Jacobs house by Frank Lloyd Wright.

0.4 Summary of the chapters

Chapter 1 begins with an overview of the history of passive solar architecture with notable episodes that were the precursor of ‘net zero’. This includes the history of passive solar energy which transitioned into the energy conservation movement of the seventies. This was followed by the environmental sustainability of the 90s and the passive house movement that came together with Net zero. The chapter cross-examines passive energy strategies of orientation, massing, insulation, ventilation, and lighting.

Chapter 2 offers an overview of the history of the Usonian concept and the work of Frank Lloyd Wright. It includes a discussion of the origins of the Usonian idea as a simplified prairie house for the common American. The study goes further and explains Wright’s philosophy of organic architecture. This leads to my thesis, antithesis, and synthesis of his concept of the Usonian house. The chapter presents the successes and failures of the Usonian concept and how this would benefit our research for passive solar strategies and to an extension net zero energy buildings.

Chapter 3 presents an in-depth study of the Jacobs house which was the first Usonian house built by Wright. A background of Herbert Jacobs’s house, its main features, and the drawings are studied. This chapter includes the views of other authors on the house and Usonian concept in general.

Chapter 4 presents a critical analysis of Jacobs’s house in terms of the five passive strategies namely orientation, thermal mass, insulation, ventilation, and lighting. I discuss the detail of the present performance of the house based on a visit to it on 17th, March 2016. I reflect on outstanding problems and what was successful.

I conclude with a synopsis of the reasons for this research, observations, and results of the study. This includes the main the main lessons learnt from the study of the Jacobs house in the quest for an economical net zero house.

Chapter 1.0

1.1 What is net zero energy building

*A Net Zero Energy Building is a building that consumes as much energy as it produces in a year through renewable sources, and also has zero carbon emission annually.*⁵ (See Figure 1 NREL definition)

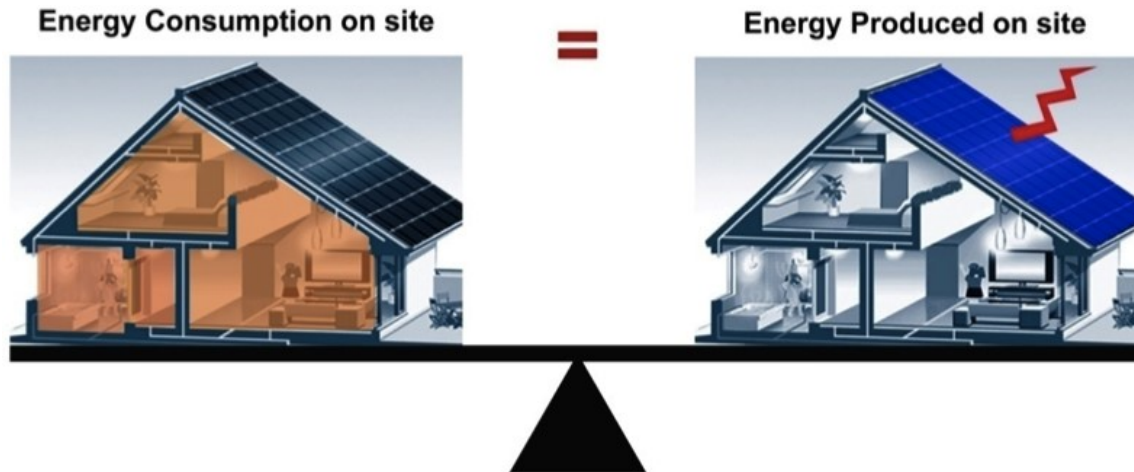


Figure 1: The National Renewable Energy Laboratory (NREL) definitions for Net Zero Energy Buildings based on energy measurement method

Net zero-energy is a term used to describe the synergy between energy efficient building and renewable energy utilization to achieve a balanced budget over annual cycle. The word net is used as a qualifier and refers to a goal, a calculated result over a defined period of time (1 year) for the balance between consumption values and electricity fed to the grid. This system of numbers is used to influence design decisions and makes many architects uncomfortable. This is a system of energy accounting for saving money, tracking bills, improving the economy and maintaining a balance with nature. This process has led to energy accounting in built environment more than ever before. The desired results are a more sustainable, healthy environment towards the promotion of wellbeing.

The national Renewable Energy Laboratory classified four definitions of net zero energy for buildings according to types of measurement, namely: *net zero site energy*, *net zero energy emissions*, and *net zero energy costs*.⁶ The definitions are for grid dependent structures to account for the balance of energy between supply and demand. These definitions are based on where you place the boundaries for the energy balance.

The net zero site energy building produces at least as much energy as it uses over the course of one year, when accounted for at that site. All measurements are taken within the site boundary and recorded at a meter.

⁵ Common Definitions for Zero Energy Buildings prepared by U.S. department of Energy, 2015

⁶ Zero Energy Buildings: A Critical Look at the Definition Preprint P. Torcellini, S. Pless, and M. Deru National Renewable Energy Laboratory p. 5

The net zero source energy building produces at least as much renewable energy as it uses over the course of a year when accounted for at the energy source. Numerous losses result from generation and transportation of electric energy. The site energy value will have to take into account energy lost from source to the site and measure this value over the course of one year.

A net zero energy emissions building produces as much emission-free renewable energy as it uses from emission producing energy sources. The energy produced offset emission from all energy used in the building over the course of one year. Energy units are measured in mass if carbon-equivalent greenhouse gas emissions related to the energy use of the building. Renewable energy generation measured against fossil fuel generation in this calculation. The main objective is to eliminate greenhouse gas emission from building operational energy.

Net zero energy cost building the amount of money the utility pay the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year. The owner receives at least as much financial credit for exported renewable energy as energy charges and utility services over the course of a year. All utility charges, service charges, fees, and taxes for either peak or low demand periods are accounted for. The utility company determines credit values of energy produced at the site that offsets building's energy consumption.

Advancement in technology and greater research in net zero energy buildings will lead to making buildings more autonomous or independent in terms of energy use from the grid, more related to the site and more sustainable. Net Zero Energy Buildings create a balance with natural resources. The more passive solar energy is utilized the less the energy demand. This also means less cost and less use of active renewable sources. When buildings generate sufficient amount of energy for their needs this translates to less demand of electric energy from the grid. There are many lessons to be learnt from the past as buildings evolve towards becoming autonomous.

Architects should not lose sight of what is fundamentally important; that is to support life. Some of the lessons we can learn from the evolution of the Usonian concept will inform the development of more feasible Net Zero Energy Buildings. It is also important to realize that net zero research is a point in the history of passive design when a goal was set to balance between energy production and consumption. The history of passive solar architecture is not static but a dynamic movement whose origins are in the past. Net zero is a milestone within the long history of passive solar architecture.

1.2 Brief History of Passive Solar Architecture

Understanding the history of passive solar architecture requires a review of trends, the main triggers and background behind this concept. Net Zero is a term that emerged in the 90s an important mark in the history of passive solar architecture. Since then, it has become a significant term in architectural practice and as such influenced the way buildings are designed in relation to energy use and the environment. The *history of passive solar architecture* can be divided into three parts: the history of *passive solar energy*, *energy conservation movement of the 70s* and the *environmental sustainability of the 90s* that led to the present net zero and passive house concepts.

1.2.1 History of Passive Solar

The practice of using passive solar is as old as architecture. The design of passive solar buildings exemplifies the practice of living in harmony with nature and the environment. The buildings were able to maintain a balance between environmental, economic and social sustainability of their inhabitants. The promotion of solar energy today creates a potential to replace the mechanical or electrical heating and cooling by incorporating knowledge and methodologies of traditional building styles that managed solar power with elegance and economy.

The relationship between architecture and energy can be traced back over thousands of years of history. John Perlin in his book *Let It Shine: The 6000-year History of Solar Technology*, reveals that the ancient Chinese, Greek, and Romans had a long history of use of passive solar energy in their architecture. Passive solar strategies are not new and principles like orienting the house to face the south in the northern hemisphere has been applied for centuries.

To prove that solar energy is not a 20th century concern John Perlin reveals a history of Stone Age Chinese architecture, which belongs to approximately 6000 years in the past. The Chinese used to build their homes in such a way that every dwelling faced south and made maximum use of solar energy during winter. This mastery in solar architecture has influenced the urban planning of Chinese cities to the present day.

Worldwide, the discovery of fossil fuels resulted in a surge of products and machinery that are dependent on it. This surge led to the diminishing use of solar dependent technologies giving way to mechanical systems that looked convenient at the time. The world economy became dependent on fossil fuels that came at low cost. Later the negative impact on the environment due to excessive use of fossil fuels began to be felt. Efforts were made to mitigate and eliminate dependence on these fuels by reverting to passive solar energy. In the 20th century the development of passive solar energy led to sustainable architecture. *History shows that sustainable architecture was triggered by the energy crisis of the 1940s, 1970s, and late 2000.*⁷ The energy crisis triggered responses by the building industry, government, and research institutions. Fernandez Galliano stated that energy accounting has become “a philosopher’s stone that would make it possible to reconcile technology & nature, economics & ecology.” According to Galliano energy injects life, process and transformation into inanimate world of matter, and thus into the world of architecture.

The United States energy crisis after World War II resulted in the construction of passive solar buildings that were in high demand in 1947. Architect George F Keck designed the first Passive solar project in 1939 at MIT. This house was known as the ‘all-glass house of tomorrow’ or House 1. It utilized both passive and active energy techniques. *The main criterion during that period was to build a house using simple technology that was efficient, reliable, and least disruptive to the environment.*⁸ Around the same timeframe, modernist architect Frank Lloyd Wright employed passive solar principles in many of his designs, most notable the design of two

⁵ William W. Braham & Dan Willis, *Architecture and Energy: Performance and Style*, Routledge, New York, 2013, p1

⁸ Anderson, B and Riorden, *The Solar Home Book*, Chelsea Green Pub Co., 1976, p19

Jacobs houses for one client in Wisconsin. The first Jacobs house was built in 1937 and was the first Usonian House. The second Jacobs House also known as the Solar Hemicycle was built in 1944.

Meanwhile during the same period, there was progress in the discovery of the use of glass and prefabricated houses with solar technologies. The success of passive solar energy at this time can be attributed to the discovery of sealed insulated windows, which became more available at reasonable cost. In 1940 George Fred Keck, an architectural engineer, built the first 'solar house' known as the Sloan House in Chicago. What followed was design of ready-built homes that were prefabricated buildings with south facing windows and overhangs that would allow sunshine in winter but block it during summer.

Another notable success in solar technology was the Bridger-Paxton building, located in Albuquerque, New Mexico, and built in 1956. It was the first commercial office building with solar water heating and passive solar design. Architect Frank Bridger and his partner, mechanical engineer Don Paxton came up with the experimental solar heated building that had a collector array on the south wall angled at 30 degrees to the vertical. *Heat from the winter sun run through water pipes in the collectors that then feed to an insulated storage tank that stored sufficient heat to run the building during the nights and cloudy days.*⁹

1.2.2 Energy conservation movement of the seventies

In 1970s, the world was faced with the oil embargo by the Organization of Petroleum Exporting Countries (OPEC). The crisis began to unfold after an earlier petroleum production peak of the late 60s. *The Arab oil embargo began on October 17, 1973 with a decrease in oil production and doubling of price per barrel of oil by OPEC.*¹⁰ The architectural profession responded with the emergence of 'passive' design styles to mitigate the energy crisis as a result of high prices of petroleum.

The rise in energy costs led to the solar architecture movement that looked for new non-polluting and free energy sources for heating as well as cooling buildings, and producing electricity. *Solar architecture movement defined energy conservation as a form of suffering (or deprivation) in 1970s that made it unsuccessful. Solar architecture was replaced by postmodern styles of 1980s and 1990s.*¹¹ The movement also faced marginalization by both President Carter and Regan who campaigned against its innovations and technologies. The two administrations suppressed documents that if known to the congress or the public would have allowed for solar energy to play a greater role. When the oil prices stabilized in the 80s, the postmodern styles of the 1980s and 1990s replaced solar architecture. Even though the conservation initiatives of the 70s were abandoned in the 80s, the awareness garnered, skills and virtues of passive design are very useful for net zero energy buildings today. There are two remarkable projects developed by two investigative teams. One is located in Illinois United States and the other located in Saskatchewan, Canada. They are described in (I) and (II) as follows:

⁹ Anderson, B and Riorden, The Solar Home Book, Chelsea Green Pub Co., 1976, p20

¹⁰ Wright, David The Passive Solar Premier, Schiffer Publishing, 2008, p VII,

¹¹ Michael Zaretsky, Precedents in Zero-Energy Design Routledge, New York, 2010 p 3-9

- I. The effects of the USA energy crisis of the 1970s spurred innovations to curb energy consumption that led to the first generation of photovoltaic (PV) panels. In 1976, the University of Illinois Urban-Champaign developed a design for the low energy house and named it “Lo-Cal House.” The term Lo-Cal means Low Calorie. The house would consume only a third of energy needed to heat an equivalent house at the time.
- II. Canada’s first major attempt towards sustainable architecture is the “Conservation House” located in Saskatchewan and built in 1977. The main achievement of the project was that it consumed less than 1/5 of the energy consumed by a comparable home at the time. The project revolutionized and acted as a catalyst to the research on energy and architecture, just like the Canada’s R-2000 program by Natural resources Canada and German’s Passivhaus standard. The successes of R-2000 and Passivhaus were realized during the environmental sustainability movement that started in the 90s.

Initiatives such as these two led to the passive house movements of the 90s, a direct result of superinsulation ideas.

1.2.3 The environmental sustainability of the 90s: Passive house movement and Net zero

In the 70s, researchers at Illinois University used the term super-insulation to develop the idea of the Lo-Cal House that finally evolved in Europe to Passivhaus. It is the same idea of superinsulation that is shared with the conservation house experiment of Saskatchewan. The Passivhaus concept developed in Germany in 1990 came much later.

Dr. Wolfgang Feist, a German physicist, founded the Passivhaus Institute in 1996 using the design principles that evolved from Saskatchewan’s Conservation House, located in Regina, Canada. Working in collaboration with Professor Bo Adamson, they developed a passive house concept as an optimization of the early superinsulation work. The result was a design criterion for a building that consumes one-tenth amount of energy compared to a standard conventional building. The passive house emphasized more on reduction of energy demands and takes advantage of solar orientation. The Passivhaus reduces thermal loads through super-insulation, air tightening envelope, good windows, and heat recovery ventilation.

In an effort to guide the building industry towards a sustainable environment, private firms and non-profit organizations came together in 1993 to create the US Green Building Council (USGBC). USGBC was charged with reducing buildings energy consumption through its, Leadership in Energy and Environmental Design (LEED) initiative. *LEED is a certification program for buildings and communities that guides their design, construction, operations and maintenance toward sustainability.*¹² The LEED certification program was launched in the year 2000. Awards points are based on the assessment of the impact of a building project on the environment. The program is voluntary and its main goal is helping the Market place advance making the environment healthier for us to live, work and play.

In Canada, Net-Zero is a pilot project based on the voluntary R-2000 building code developed by Natural Resources Canada. R-2000 standard is a performance-based standard developed by the

¹² The U.S. Green Building Council (USGBC) website: <http://www.usgbc.org/about> accessed 9-26-2016

government in collaboration with home building professionals. Typically, R-2000 houses consume 30% less energy than a standard home. Natural resources Canada made significant progress and updated the standard in 2012 to reach 50% energy efficiency.

The origins of net zero buildings are in the early 1990s and by the year 2000 the number of constructed projects rose steadily. Net zero energy buildings emerged from the surge in certification program for both LEED and green design buildings. In 2004, CMHC initiated a demonstration project to test whether net zero would work in Canada. In an initiative known as Equilibrium™ Sustainable Housing, eleven projects were constructed across Canada with teams consisting of professionals and developers. The houses were monitored for performance to advance research on net zero homes.

1.3 Passive energy Strategies

This research examines the five characteristics of passive energy, namely: orientation, thermal mass, insulation, ventilation, and natural lighting. These five factors, are essential in the design of passive solar buildings. This list is not exhaustive but fundamental to architect's work in the design of the envelope, decisions on style and form.

1.3.1 Orientation

Proper site orientation plays a major role in locating a building in a given site in terms of passive energy strategies and outcomes on sustainability. Analysis of the site and climatic conditions will reveal opportunities available and resources for a passive solar design. Historically, many authors have written on the importance of climate and location as essential factors to consider for passive solar design and good architecture. Vitruvius principles stressed on design styles that were influenced by climate, with emphasis on the orientation of the building. Analyzing issues of site orientation and massing helps in developing proper site parameters. It is important to consider the effects of microclimate and local features of a specific site during the initial planning a building project.

It is during the early phases of the project that architects have the earliest opportunity to define the building's energy consumption. Decisions on location of the windows, the most suitable form, and the available renewable sources, will need to be determined early. Opportunities for energy demand for heating, cooling, and lighting will be explored at an earlier stage of a given project. Window orientation has a large implication on the cost, energy use, and comfort in a building. As part of the envelope considerable amount of thermal energy transfer takes place through the windows. For a passive solar design to benefit from the windows one should consider the window to wall ratio. Optimizing window to wall ratio in all sides of the house will control thermal energy gains through conduction, convection, and radiation. The desired amount of natural lighting and ventilation will also be determined by the size and number of windows. A window to wall ratio (WWR) in the range of 30-50 % is required for optimal solar design and varies with geographic location. A WWR of less than 20% will not provide sufficient daylight, when WWR is over 30% the window allows much more heat loss in winter and much heat gain in summer. The goal is to minimize the energy required to make a building comfortable working

with nature and not fighting nature. To achieve preferred range of thermal and daylight performance the designer specifies and selects appropriate windows for passive solar.

During the schematic stage, key decisions like the most suitable orientation and form have a great impact on resources required during construction and operation (See figure 2). The most effective time to make changes is during the programming stage.

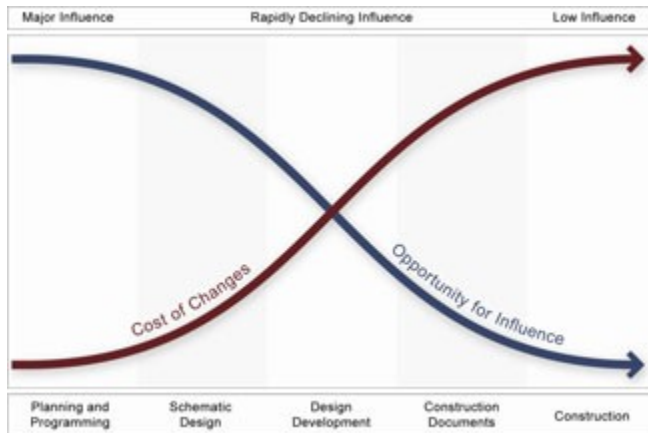


Figure 2: The most cost-effective time to make changes is during programming. Source Whole Building Design Guide (http://www.wbdg.org/design/dd_archprogramming.php)

After evaluating the various alternatives for a given climate, an architect will come up with the most suitable design form and the appropriate site orientation. Native materials of a given site, such as, timber, sand, earth, stone, and adobe will be best suited to interact with the local landscape and climate forces. Materials sources that are close to the site will translate to shorter transportation distances which mean less consumption of fossil fuels at a lesser production cost. Sustainable design parameters such as carbon footprint, energy, water, materials, waste, or habitat together with other issues like land use and economics are then addressed.

Solar responsive design strategies will only be realized through proper orientation of the house. For proper building layout factors to be considered include, suitable site free from obstructions, assessment of solar angles, both azimuth and altitude, the number of sun days during different seasons. Sun charts are used to analyze and determine the degree of shading on the building from either other buildings or obstructions like trees and vegetation.

Different approaches, tools, and methods exist to analyze the sun path in a given site:¹³

1. Graphic plots
2. Manual trigonometric methods
3. Computer based trigonometric methods often with graphical output;
4. Scale models examined using a sundial device, and natural or an artificial light source
5. Scale models using a Heliodon, a device that mechanically reproduces the geometric movement of the sun

¹³ Article "Single Issue Tools - Simple - Sun Charts" accessed 09-28-2016
http://www.esru.strath.ac.uk/Courseware/Design_tools/Sun_chart/sun-chart.htm#further_info

Norbert Lechner proposed a Heliodon that simulates the relationship between a building and the sun at a given site. *To simulate shade, shadows, sun penetration, and solar access on a scale model, a devise called heliodon is used. A heliodon simulates the relationship between the sun and a building. The three variables that affect this relationship are latitude, time of the year, and time of the day.*¹⁴ This is a tool that would help architects establish accurately the feeling of the relative position of the sun at different times of the year and therefore maintain a balance between lighting and shading the building. It is possible to determine the solar window of a given site free from any obstruction in a given altitude at different times of the month. For example, between summer (June 21st) and winter month (e.g. Dec 21st) from morning at 9.00 am and evening at 3.00 pm.

Initial site assessment of renewable energy sources and strategies available to meet energy needs are also prepared at an early stage. A basic assessment of how much of the site receives solar access during winter and summer months will guide the location of solar thermal panels and photovoltaic panels. Along with other design variables, building orientation play a major role in optimized use of energy harvested or conservation in a net zero energy building. The orientation and location of solar panels is determined at an early stage in the design. Early exploration of the design alternatives will maximize energy gains as well as ensure a sustainable environment.

1.3.2 Thermal mass

The thermal mass principle refers to a property that enables a building to absorb, store and later release (distribute) heat. Buildings that are made up of materials capable of storing solar heat for improved energy conservation and indoor comfort. Materials such as concrete and masonry have this characteristic. In the northern hemisphere when the sunlight enters the building through a south oriented window, the solar heat is absorbed by the concrete floors, masonry walls and other surfaces that fall under its path. The thermal mass is the property of any material to absorb, store and retain the solar heat. Materials with high thermal mass store and retain heat in a passive solar design. The solar heat is then distributed or circulated from collection points and storage points to other spaces inside the building through conduction, convection, and radiation. This is a completely natural process that involves the manipulation of the solar energy, directing it to meet human health needs and comfort.

An excellent ancient example to illustrate thermal mass principle is cliff dwellings in Colorado created by the ancestral Pueblo people (see Figure 3).

¹⁴ Lechner Norbert, *Heating Cooling Lighting: Sustainable Design Methods for Architects*, Wiley & Sons Inc. Hoboken, New jersey 2015, p159



Figure 3: Mesa Verde Park, Source <http://www.visitmesaverde.com/>

The south facing structure and overhang provides summer shade by blocking the sun thereby cooling the space below from the desert heat.

A passive design will lower the energy loads significantly in a net zero energy building by utilizing proper materials for thermal mass. Roof overhangs are strategically placed to shade the building during summer while thermal mass on the floors absorb heat from south facing window (See fig 4).

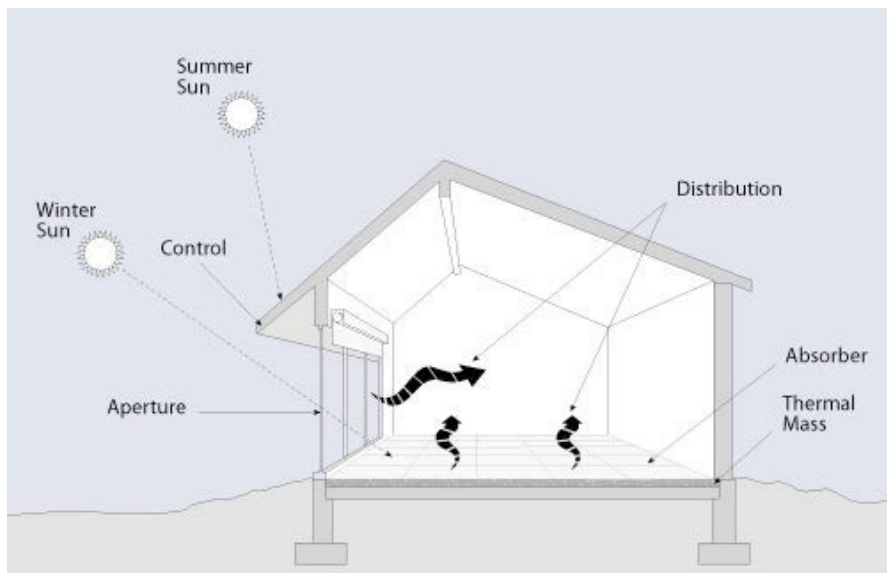


Figure 4: Thermal Mass absorbs heat through Floors and Walls. Source WBDG Building Design Guide¹⁵

It is important to consider increasing the exterior wall to floor area ratio as another key strategy for thermal mass. In terms of geometry narrow buildings are better placed for passive energy strategies since the sun rays penetrate at a sufficient depth. For passive solar design floor plate depth is very crucial. An energy efficient building should also have a high insulation to protect from heat loss and high thermal mass, and to retain the heat gained.

¹⁵ WBDG Building Design Guide, <http://www.wbdg.org/resources/psheating.php>

Thermal mass for either concrete or masonry causes delays in heat transfer where materials absorb energy slowly and hold the heat for much longer period of time. The thermal mass of concrete has the following benefits and characteristics:¹⁶

- Delays peak loads
- Reduces peak loads
- Reduces total loads in many climates and locations
- Works best in commercial building applications
- Works well in residential applications
- Works best when mass is exposed on the inside surface
- Works well regardless of the placement of mass

The end result is energy savings due to the inherent thermal mass as a result of adopting concrete or masonry as building material.

1.3.3 *Insulation*

Temperatures outside a building vary widely depending on the climatic zone and the different seasons. To maintain normal comfort levels an interior temperature of 18 to 21°C (60-70°F) is required. For successful designs, insulation is required to reduce heat gain or loss through the fabric of the structure. *The insulation value of a material is primarily due to the quantity of air spaces or pockets separating the solid parts in a material.*¹⁷ The solid portion of the voids should have low heat conductivity. Measure of thermal resistance to heat loss is expressed in terms of R-value; in other words, resistance to heat flow. The higher the R-value, the higher the resistance to heat loss. The basic insulation materials come in three forms: fiber woven like fiber glass, foam solid with air traps, particles of small pieces of material that allow air spaces between them. An example of foam air-bubbles is polyurethane and polystyrene.

Most homes are woefully under-insulated. Typically wall insulation levels are still R13 to R-19 in many areas of the country, but they should be a minimum R-30, and R-50+ is much better¹⁸. In Canada, a wood frame stud wall construction with either batts or spray applied insulation and an exterior face of rigid insulation is common. (See figure 5)

¹⁶ Concrete thinking for sustainable world, <http://www.concretethinker.com/solutions/Thermal-Mass.aspx>

¹⁷ Wright, David: *The Passive Solar Premier* Wright, Schiffer Publishing, 2008, p. 94

¹⁸ Bainbridge, David A. *Passive solar Architecture*, Chelsea Green Publishing, 2011 p. 14

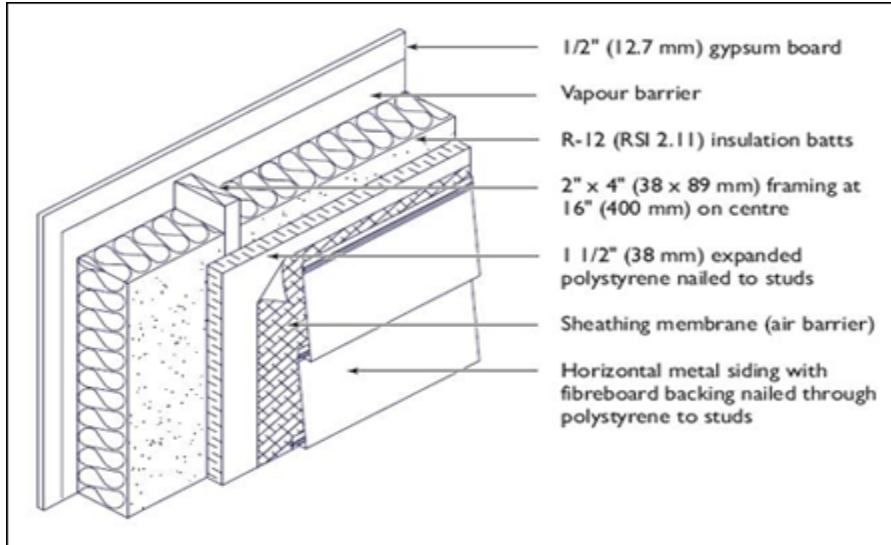


Figure 5: Effective thermal resistance: R 16.7 (RSI 2.94). Source CMHC web https://www.cmhc-schl.gc.ca/en/co/grho/grho_010.cfm

A vapor retarder is provided at the inside of the insulation such as 6mm polyethylene sheeting at the inside face of studs. An air barrier is provided at the exterior face of the stud wall making sure that it is continuous at all penetrations. Adding rigid insulation to the outside face of the studs minimizes thermal bridging.

Compared to other materials of the envelope windows are not good insulator. One of the major concerns on windows is its R-value. The R value for a single pane window is 0.9. A double pane window may achieve R value of 1.8 which is only a tenth of a typical wall. These values are one tenth of a typical well insulated wall. *To improve the insulation value, triple-glazed windows with argon gas between panes have become available with an R-value of 4.35.*¹⁹

All materials that make up the envelope including windows have the ability to absorb, reflect, and radiate heat. The relative ability of a material surface to radiate energy is called emissivity (E). Highly reflective materials have low emissivity (low-E) while dual darker colored dark colored materials have high emissivity.

Recent improvements in window technology has led to the manufacture of high performance windows in the market. High performance windows admit more light and less heat than a typical window. A high-performance window has Low-E coating, inert gas fills and insulated frame and edge components. Conventional windows solar energy gained during the day is equal to the energy lost through conduction, convection, and radiation during the night. Appropriate design of windows will ensure an optimal solar potential by managing heat gain or loss, which in turn reduces the energy costs. The low-E coating, multiple pane glass and inert gas improves the R value of the glazing assembly in a high-performance glass.

The solar spectrum consists of three parts, namely: ultraviolet light, visible light, and infrared light. They are delineated by their wavelengths where the ultraviolet radiation is considered a

¹⁹ Bainbridge, David A. *Passive solar Architecture*, Chelsea Green Publishing, 2011 p. 49

short wavelength with 310-380 nanometer, visible light has 380-780 nanometres and Infra-Red radiation has a long wavelength of 780-nanometres. The low-E coating helps to minimize the amount of ultraviolet and infrared light through the glass and allows visible light to be transmitted. Reduction in infrared radiation which is responsible for heating translates to reduction in heat loss during winter through the windows.

In addition to R-value of glass it is important to consider the glass ability to let solar heat into the interior space through the window. This is expressed in terms of solar heat gain coefficient (SHGC). *The SHGC is a measure of how much heat flows the interior of the building compared with amount that strikes it, usually ranging from 0.2-0.9.*²⁰ The solar heat gain coefficient is the fraction of incident radiation admitted through the window. For passive solar heating the higher the SHGC the more solar heat is transmitted. With the correct orientation windows that are located in the southern side of the building will need to be high SHGC for better energy capture. Windows on the east and west side will need to be low SHGC.

Another consideration of the site is to develop the correct window-to-wall ratio which is adequate to the climate. The R values of glazing is way below that of wall construction, which means that window area needs to balance the admission of light and thermal issues such as heat loss during winter and heat gain during summertime. Guidelines on thermal performance have been set by ASHRE on ratios per climate zone as stipulated in standard 90.1 energy code. The code does not consider admission of daylight. *Both the NECB 2011 (National Energy Code for Buildings) and ASHRAE 90.1 (American Society of Heating, Refrigerating and Air-Conditioning Engineers) have set the minimum benchmarks for new building construction in Canada and the United States respectively.*²¹

The main challenge of minimizing heat loss has been insulation, thermal bridging, and control of air leakage especially in the northern hemisphere. Making a building airtight and well insulated ensures that the passive solar gains are well preserved and controlled. Temperature fluctuations (either too much heat loss or too much heat gain) make rooms uncomfortable. Proper draft control minimizes damages by water vapor present in draughts. A well-insulated building is one that has minimal air infiltration which means there is reduced heat loss making the envelope more effective. The heat and air-conditioning systems work best where the envelope is airtight. Insulation such as spray foam insulation fills all cracks and crevices to eliminating air and moisture infiltration.

Airtightness and insulation need to be achieved separately and it is important not to mistake the two. Materials like fiberglass or mineral wool have excellent insulation property but allow air to pass through. Typical air leaks are as a result of unsealed or poorly sealed doors and windows, gaps around penetrations (downlights, pipes, and cables) and around envelope joints in walls or floor. However, some insulations have air-sealing properties e.g. spray foam and cellulose insulation. A single aluminum foil construction can achieve excellent airtightness but has poor insulation properties. One problem in a construction that is not airtight, is that moist air from the

²⁰ Bainbridge, David A. *Passive solar Architecture*, Chelsea Green Publishing, 2011 p. 49 paragraph 4

²¹ Guidelines of National Energy Code of Canada Website: http://www.nrc-cnrc.gc.ca/eng/publications/codes_centre/necb_2011_adaptation_guidelines.html , Accessed 02-25-2017

room can penetrate the structure causing damage if it condenses. This means that airtightness is not just an energy saving measure but also essential to prevent damage to construction.

Thermal bridging is another important consideration in designing a thermally tight building. Structural elements such as beams, columns, and slabs need to be insulated because they transmit heat through conduction. Materials that are not separated from the outside and well insulated will lose tremendous amount of heat. Use of thermal breaks for components such as window frames is the solution. Use of double-frame walls and staggered studs for exterior walls in residential houses help to overcome thermal bridging.

Relative humidity is another factor to consider for a healthy indoor environment. Proper ventilation prevents accumulation of moisture and dampness which may lead to problems such as mold. An airtight insulated building is more susceptible to mold if moisture prone areas such as kitchens, bathrooms, and laundry are not well ventilated.

The conservation movement of the seventies led to serious research projects on various methods of conserving energy and then to the development of building standards throughout the world. Research teams were formed to develop methods of controlling heat gain or loss. A visit to the site and a cross examination of the construction details of the Usonian house will reveal how important a role insulation plays. The best criteria to choose insulation is cost effectiveness, fire resistance, energy required to produce, structural practicality, and ease of installation.

1.3.4 Natural ventilation

Before employing energy consuming mechanical air conditioning systems, it is important to consider natural ventilation. All space-conditioning systems involve some basic processes to operate; energy collection, storage, distribution, and loss back to the environment. The proper size and location of all types of openings like doors windows and vents are employed as natural means of ventilating buildings. Adjustable openings ensure every space within the building adapts to various seasonal demands. Inlet and outlet of air are placed in either opposite direction or adjacent to each other. Wright never liked air-conditioning and preferred natural ways of ventilating the Usonian house through passive means.

Passive solar applications ensure the house is designed to respond effectively with the patterns of nature, where it utilizes the free energy from the sun. Working with nature and understanding nature's design tools is key to successful passive solar architecture. Natural ventilation Wind flow design barriers vacuum effect, on windows sizes use of clerestory.

A building that positively utilizes the energy of the sun for year around space conditioning involves three basic principles:²²

1. It must be designed to accept or reject solar heat when called for;
2. It must have the thermal integrity to maintain internal comfort despite the range of climatic forces acting on its weather skin;
3. It must incorporate the ability to retain the presence or absence of heat within.

²² Wright, David *The Passive Solar Premier* Wright, Schiffer Publishing, 2008, p. 56

To achieve a naturally ventilated building it is important to create comfort levels closely related to natural temperatures and humidity balance of a particular climate and season. One goal is to create structures that respond to fluctuations of nature. By placing solar gain surfaces of the right size and locations ensures effective solar gain. These structures will have to be well insulated and with adequate heat storage capacity (thermal mass). A consistent indoor temperature range is therefore maintained in spite of fluctuations of exterior environment.

Another factor to consider is maintaining a balance between a well-insulated airtight building and adequate ventilation. Air sealing of the envelope and reducing air infiltration has to be accompanied with some means of ventilation to avoid health risks to building occupants. There has been an emerging trend of tighter buildings to improve on energy efficiency and comply with the code as promoted by programs such as energy star. To balance building tight envelopes and ventilation, there has been a general consensus among building practitioners in the concept of “Building tight: Ventilate Right.”

In the area of mechanical ventilation systems especially for super-insulated passive houses heat recovery ventilators (HRV) or energy recovery ventilators (ERV) are used to maintain a healthy indoor ventilation and minimize heat and energy loss. These units provide adequate heating or cooling while recovering heat or energy for greater overall efficiency.

It is also important to avoid wasteful air-conditioning and maintain a healthy balance between interior conditioned space and ambient exterior conditions. Interior comfort levels that are not related to outside conditions may lead to health issues on the side of the occupants of a conditioned space. This is common with inefficient use of air conditioning. During summer months, an air-conditioned space may be set to 20°C while ambient exterior conditions are 40°C. This can cause a stress in human bodies due to sudden drop in temperature upon entry to such a space from outside. A common remedy to this is either to set the interior temperatures close to the exterior or set interior temperatures above 23°C. A better remedy still is to use free natural ventilation in a well-designed building.

Another method of natural ventilation is the use of a solar chimney. The system uses the solar radiation to move air upward causing air circulation and natural ventilation of a building. Wright used this principle in the design of the kitchen for the Jacobs house as it will be illustrated later. Maximizing natural conditioning that is unique to the climate will lead to less energy use, reduced technological complexity and a better environment and economy.

1.3.5 Lighting

Daylight has been a source of inspiration for many great architects like Alvar Aalto, Louis Kahn, Le Corbusier, and Frank Lloyd Wright. They mastered the interaction of light and architecture during their careers.

A naturally lit building consumes less electric energy and produces both a healthy and productive working environment. Tom Hootman urged that a Net zero energy architecture not only controls daylight for beauty and utility but, it also leverages daylight for energy. One of the challenges of

early 20th century buildings, in the period from 1950 to 1970, was the adoption of electric lighting that contributed to reduction in window areas and over-reliance on artificial lighting.

Effective daylighting includes a controlled admission of natural light from direct sunlight in a perpetually evolving pattern of outdoor illumination. Benefits of daylighting include creation of a visually stimulating, healthy, and productive indoor environment. The other advantage is reduced electric light power consumption to as much as one third.

In a passive design the fenestration or location of the doors and windows in a building, must be done in such a way as to avoid admittance of direct sun on task surfaces or occupant's eyes. Any opening of a building is considered aperture. Some apertures like doors are for circulation while windows and skylights are associated with light and ventilation. Successful daylighting depends orientation, building form, climate, window location, light controls among other factors.

In daylight design it is important to ensure that occupied spaces have sufficient light at the same time avoid undesirable side effects such as glare. Several methods are adopted to control and distribute natural lighting. Light shelves both help to shade, control and distributes amount of light from large windows. Unfortunately, horizontal overhangs do not work well with windows oriented more than 15° east or west of the equator facing. *Wing walls and, louvres and fans can be used to protect these orientations but must be carefully designed for appearance and durability.*²³ Control of window coverage in an envelope during the design plays a major role. Use of shading devices helps to reduce glare and excess contrast in workplaces. Design involves evaluating the number of windows and their sizes, types of glass, the reflectance of interior finishes and interior layout.

Daylight also involves careful balance between heat gain and heat loss, control of glare and variations associated with daylight availability. Many factors such as control the amount of light, quality of light and amount of solar heat gain depend on the quality of glazing used. Three properties are considered in choosing appropriate glazing for natural lighting: Thermal conductance U-value, solar heat gain coefficient (SHGC), and the visible transmittance (VIT or Tvis). Thermal conductance is the rate of heat flow from the hotter side to the cooler side. SHGC is how much of sun's energy striking the window is transmitted into the building. *The visible light transmittance is of great concern when considering natural light.*²⁴ The visible transmittance is the percentage of sunlight passing through glass assembly and ranges from 0.3 to 0.8.

In designing the envelope, one needs to consider optimal window to wall ratio (WW Ratio) to keep energy loads under control at the same time windows bring in daylight that penetrates the interior workspace. Narrow buildings with modest use of glass provide better opportunities for light to penetrate sufficiently through its depth and greater benefits from passive energy. During the day, one needs not to turn on the artificial lighting for a net zero energy building. Passive solar buildings designed for day-light as a dominant light source will ensure that we do not continue use of electricity during the day while nature has already provided. In design of NZEB,

²³ Bainbridge, David A. Passive solar Architecture, Chelsea Green Publishing, 2011 p. 90

²⁴ Bainbridge, David A. Passive solar Architecture, Chelsea Green Publishing, 2011 p. 142

window placement is based on energy efficiency through passive solar and daylighting strategies rather than views and facade composition.

Materials can influence the quality and quantity of lighting in each space depending on the finish and color of material. The choice of materials can influence illumination and light distribution. Glossy finishes reflect light as mirror does. Materials such as natural stone, wood, and plaster reflect light diffusely equal in all directions. Bright colors reflect light on walls and ceilings. Adoption of locally available materials that meet these properties will be a prudent measure to ensure that a net zero energy project is financially viable.

1.3.6 Other factors to consider in passive solar design.

After determining the orientation of the building, the architect's next step is to decide the location of windows, and the most suitable form. Decisions on fenestration arrangement and design of windows will follow. This includes window to wall ratios as discussed earlier. At early stages the architect decides how much of the exterior of a building is covered with openings in particular doors and windows and how these openings are arranged. Decisions about the size, shape and type is driven by aesthetic concerns and also energy efficiency.

Energy efficiency of the envelope is dependent on its thermal properties in terms of how much heat is transferred through the process conduction, convection, radiation. The surface area of exterior is dependent on the dimensions of the building or aspect ratio. Aspect ratio is the ratio of the length of the building to its width. Aspect ratio defines the buildings surface area of thermal transfer from the inside to the outside and vice versa. Aspect ratio allows comparison of different building footprints for different designs as ratio of length to width (L: W). Increase in aspect ratio means increase in surface area subject to solar radiation. In the northern hemisphere aspect ratio is larger for south facing envelope.

Another factor to consider to achieve thermal performance of a building envelope is its surface area compared to interior volume. The interior volume of a space inside the building will need to be heated or cooled has a relationship with the envelope surface that encloses the space. Compactness of a building is measured using the ratio of surface area to volume (S/V). *The less the exterior surface area to the interior volume the lower the ratio. A low ratio indicates less heat loss per unit of usable space.*²⁵ Geometric forms like spheres or domes have low surface to volume ratio but hard to construct. Rectangles are mostly preferred compared to other shapes. A building that has a simple box and compact has less thermal transfer for a given volume compared a complex form with many corners, surfaces, and sides. A simple box compromises the architectural look may not fulfil the functional needs of a building. The ideal approach is to minimize the surface area of a building without compromising, fictional, structural, and aesthetic requirements.

²⁵ Wright, David The Passive Solar Premier Wright, Schiffer Publishing, 2008, p. 88

Chapter 2.0

2.1 The Aim of the Research: The Usonian house and passive solar architecture

The main purpose of this research is to find ways of making passive solar buildings (by extension net zero energy buildings) affordable, less dependent on mechanical systems, and more dependent on passive strategies. Modern day net zero energy buildings have become more sophisticated in terms of the way they are built and sometimes out of reach in terms of affordability. This research examines the Usonian-I, the Jacobs house which was Frank Lloyd Wright innovation of a house that was an all-natural, affordable, and representative of his philosophy of organic architecture.

Wright believed that buildings should be made from the land. These beliefs were avant garde and are still very applicable today. Wright's innovative approach to construction of Usonian houses guided by principles of organic architecture would benefit present day construction of net zero buildings. A brief history of Frank Lloyd Wright reveals some of these approaches, passive strategies, and origins of his ideas for Usonian house.

2.2 Brief History of Frank Lloyd Wright and the Usonian concept

Frank Lloyd Wright (1867-1959) was a highly accomplished modern architect who developed a distinct American style and came up with a philosophy known as organic architecture. He was born in 1867 in Richland Centre, Wisconsin USA. His father, William Cary Wright, was a Universalist preacher and an early advocate for the abolition of slavery and any law or practice deemed harmful to society, like capital punishment.

William Cary Wright was a man of many talents—a practicing lawyer, music teacher, politician, educator, and clergyman—constantly looking for new outlets. Reverend Wright was an excellent public speaker, his oratory skill made him win a prize for delivering the eulogy for Abraham Lincoln in April 1865. William C. Wright had a considerable impact on his son through music as a source of inspiration. *Wright sensitivity to structure, form, and composition owed as much to music as to other influences*²⁶. He often urged his clients to include space for pianos, which can be attributed to his father's influence. One could also argue that Wright's oratory skills were acquired from his interaction with his father. William Wright met Ana Jones (Frank Lloyd Wright's mother) while he was a superintendent of schools for Richland County.

Frank Lloyd Wright's mother, Anna Lloyd Jones was a teacher, from a large Welsh family that settled in Spring Green, Wisconsin. She wanted her son to become an architect. For this reason, she purchased Froebel blocks that Wright played with as a child. German educator Friedrich Froebel invented the game for the very young. Froebelian toys consisted of geometric blocks to assemble in different ways that encouraged a child's sense of three dimensional compositions, and paper to fold in various shapes. The Froebel system is a great source of Wright's inspiration due to its powerful geometry which Wright himself acknowledged.

²⁶ Frank Lloyd Wright, *His Life and His Architecture*, John Wiley & Sons, New York, 1979 p. 14- 15

At age eleven, Frank Lloyd Wright spent summer holidays at his uncle's Wisconsin farm to learn how to work. It is during this time that he developed an interest in becoming an architect, and developed a desire for simplicity that would yield to a broader, deeper natural comfort. The farm brought him closer to nature and organic simplicity. The training in the farm exposed Wright on how things grow in a simple, natural, and harmonious order to become beautiful. To describe the prairie landscape, Wright stated, "*I loved the prairie by instinct as itself a great simplicity; the trees, flowers, and sky were thrilling by contrast.*"²⁷ He was against the idea of densely populated cities, which would involve cutting this spacious landscape into small lots of 50 feet or make it a money-making venture.

Early in his career Frank Lloyd Wright focused on residential housing right from the time he worked with his mentor Louis Sullivan. Wright handled all residential projects at Adler & Sullivan, including the design of Sullivan's own house, while the firm concentrated on larger commercial projects. According to Wright, a typical American dwelling of 1893 had no identity or connection to nature making him long for a chance to build a "sensible house." Most houses at the time imitated European styles and Wright refused to accept what he termed as the confusion created by the eclectic styles and the many European imports that were rising throughout the Midwest. Wright thought the houses of the Victorian era lied about everything "*It had no sense of unity at all nor any such sense of space as should belong to a free people.... It was stuck into thoughtless fashion...it had no sense of earth than a "modernist house."*" To take one of these homes way would improve the landscape and help clear the atmosphere."²⁸ Instead of imitating the European style Wright saw a need for design of houses that matched the prairie landscape.

Wright was a member of the arts and craft movement that further inspired his thoughts and ideas. This movement consisted of Chicago architects who embraced designs that echoed the flat wide prairie landscape of the Midwest. The movement inadvertently came to be known as "prairie school of architecture." Thus, Wright came up with the "prairie style" built from 1893 to 1910, as an ideal American house that was organic and represented American values. The prairie houses planted the new American architecture that embraced the natural use of materials and eliminated the insignificant elements. The houses as per Wright were meant to reflect the characteristics of individual owners and not just a style of ancient times. The Prairie house utilized mass-produced material and equipment, with an open concept design away from compartmentalization of the traditional Victorian style. The prairie style had fewer details with plain walls large living rooms with perimeter heating. The idea was to achieve comfort, convenience, and spaciousness. All these were to be done economically as a reflection of the new American way of life.

In the early 1900s, a new Union of South Africa was established. This triggered calls for naming United States USONA (United States of North America). Samuel Butler came up with the name Usonia. America had become synonymous with United States both at home and abroad and so Butler suggested the name Usonia. The idea to adopt the name Usonia came to Wrights mind when he made a trip to Europe. He adopted this name for his vision and new style of homes to

²⁷ Frank Lloyd Wright, *The natural House*, Horizon Press NY 1954, p. 15

²⁸ Frank Lloyd Wright, *The natural House*, Horizon Press NY 1954, p. 14

identify United States, making it distinct from the rest of North American (like Canada and Mexico).

2.3 Why build the Usonian house?

The Usonian house concept was born out of Wright's ideas developed in the design of the Prairie Style like the Robbie house. The Prairie house emphasized the horizontal, distribution, and composition of a single-family house making it a natural part of the landscape. The Usonian house was much less in size and scale, only containing the most necessary facilities for accommodation. The house came soon after America suffered the great depression between 1929 and 1936. In 1937, a young journalist Herbert Jacobs, his wife Katherine and young daughter approached Wright to design a simple affordable house. The total cost of the house came to \$5,500 including architect's fees \$450. Wright designed the house as an experiment and developed the Usonian vision, which also was an authentic American architecture available to ordinary working people. Therefore, the main drivers behind the Usonia house were the economy, American cultural identity and organic architecture as well as many features of a Prairie house.

In his attempt to create an affordable home, Wright created houses that required minimal skilled labor which made them more affordable, and made the houses one-story. The house emphasized one of Wright's principles of simplicity that eliminated items like ornaments, basements, and had a simple flat roof. This was a major attempt to create a cost-effective residence manageable to the average American. Wright's intent with the design of the Usonian house was to make it practical and simple. To do this Wright developed a modular type of design where parts of the house were prefabricated and only assembled on site, just like an assembly line to cut down on cost of construction. The design was a prototype that would allow for mass production making the houses cheaper.

The house was designed to the human scale in every regard, which he termed as the true building scale for human comfort. *Wright called this, "the elimination of insignificant,"* elimination of the useless to make a dwelling fit for human habitation in modern terms. The idea of elimination of insignificant elements is borrowed from the Japanese prints as well as from the use of natural materials. Wright preferred the horizontal so that the dweller of the house enjoyed freedom to move about in the space or build over space.

Wright also had promoted the idea of the spirit of democracy with freedom of the individual. To achieve this, he created a new design with features separate from the traditional house. This he did by removing the attic the porch, and the basement. Wright created a single spacious, harmonious unit out of living room, dining room, and kitchen, with appropriate entry conveniences. The bedrooms were convenient to the bathroom and were approached in a segregated separate extended wing. The spaces were flooded with sunlight due to the floor-to-ceiling doors and windows at the bedrooms.

The philosophy also created houses affordable to an average American with less bank loan and this reflects the American democracy of freedom. The houses had a free-flowing space unlike the restrictive 'boxes' of room partitions in the earlier designs of the Victorian era. Wright

introduced this open concept design for convenience, comfort, and economy. The occupants would enjoy great functionality of the interactive spaces created. Wright believed that each house has a central space that was the most important and all other spaces were designed around it. In the case of the prairie house, the central space was the dining where owners entertained guests and it acted as an assembly space. The Usonian house eliminated the dining and the central space was the kitchen, which Wright called the workspace.

2.4 Philosophy of Organic Architecture

Frank Lloyd Wright came up with the philosophy of organic architecture based on the abrupt changes in the American landscape resulting from industrialization. He intended to guide and inspire the architectural profession into the future of the practice in relation to all aspects of design considerations such as nature, materials, space etc.

Wright saw a building as an expression of the materials used. He preferred materials that belonged to the site, and related to the earth. Thus, the building appears to grow out of the landscape and identify with the ground just as plants or trees in a site. The house was in harmony with nature and its surroundings in line with Wright's philosophy of organic architecture. He described it by stating that; *“In the ancient order there was little thought of the economy of materials. The more massive the whole structure looked the better it liked to the ancients. But seen in the light of these new economic interior forces, conserved by the tensile strength of a sheet of plastic or any interweaving of strands of steel in the machine age, the older order was as sick with weight as the Buonarotti dome.”*²⁹ The machine age came with its new materials and the economic forces that would influence the practice of modern architecture. This would lead to lighter buildings more in line with modern lifestyles without the excesses of the past. The economy of materials became a major factor that influenced the outcome of Wright's design decisions.

Every Usonian house was different although each design was customized to adapt to its surroundings. The ideal of plasticity was developed and emphasized in the treatment of a building as one whole unit as Wright learnt from Sullivan. Wright referred to Sullivan as “Lieber Meister” which means “beloved master” to acknowledge his work. By plastic Wright meant the art such as clay sculpture, in which material formation or deformation occurs to become a new permanent shape. He uses the term continuity stating that, *“Continuity in aesthetic sense is the natural means to archive truly organic architecture by machine technique or by any other natural technique. A direct means to express, objectify and bring natural form to architecture.”*³⁰ Wright uses the word continuity to mean plasticity. Once continuity in architecture is fully grasped the aesthetic and structure become one. A new structural reality where steel tension enables the creation of a continuous support system of branches like in a tree. This manifests in a new physical form like a mesh in a steel building structure that was lighter and safe. A physical reality where form and function become one as in organic architecture.

²⁹Frank Lloyd Wright, *The natural House*, Horizon Press NY 1954, p. 58

³⁰ Frank Lloyd Wright, *The natural House*, Horizon Press NY 1954, P 19

Wright's designs had a motif at every scale where there is a repetition of structural elements through the design and this made the design look one by imitating nature. The motif spread from structural systems, like walls, floors, ceilings to furniture. He called this continuity, an imitation of what nature does. Many of Wright's houses got names that described nature. For instance, the Honeycomb house, the Falling Waters, Hollyhock House etc. The Honeycomb house has a beautiful interior with a designed motif of a hexagon. The Falling Waters was built partly over a water fall. The Hollyhock was a Mayan revival style. Barnsdall, its owner, named the house after her favorite flower "Hollyhock." A hollyhock motif is implemented throughout the façade and interiors.

The structural system for the Usonian houses consisted of the inside wall and an outside wall made of the same material with wallpaper vapor barrier sandwiched between them. This created an architecture with the same materials of the inside and the outside. The nature of materials was direct, straightforward, and honest. Wright recommended the use of materials that were from the site, no painting, no gutter system, or trim. The Jacobs house represents a simple organic form for the middle-class families. The house was integral to the life of its inhabitants, designed according to the family size, to grow or expand with the family. The design brought out dignity and pride of the family in their own environment, which they share as individuals.

Frank Lloyd Wright's proposition on the way to address the issues of architecture at the time can be found in the chapter titled "*In the Nature of Material: A Philosophy*" of his book *The Natural House*. He describes the state of architecture by stating, "*We no longer have architecture. At least no buildings with integrity. We only have only economic crimes in its name. ...we will take each of the five new resources in order, as with the five fingers of the hand. All are new integrities to be used if we will make living easier and better today.*"³¹ Architecture would need to evolve and transformed to reflect the new resources, economy, and relevant meaning. To reflect the new realities of a progressive America at the time. The American identity was at stake and something had to be done.

Wright proposed five resources to address the issue of integrity in architecture to make life easier and better:

1. *The interior space-concept, first great integrity, is the first great resource.*³² The room is seen as architecture. Architecture became more real, livable space where the inside and outside became one and integrated. A building that is one with nature and grows out of the site that is "organic." This is a departure from the tradition of viewing architecture from outside or inside of a space.
2. Glass is a superior: material property of glass kept air out but maintained visual contact. It was through glass that the first integrity is realized where the ground and the building relate to each other through intimacy and openness. *This dawning sense of the Within as reality when it is clearly seen as Nature will by way of glass make the garden be the building as much as the building will be the garden: the sky as treasured a feature of daily indoor life as*

³¹ Frank Lloyd Wright, *The natural House*, Horizon Press NY 1954, P 50

³² Frank Lloyd Wright, *The natural House*, Horizon Press NY 1954, P 49

*the ground itself.*³³ The glass enables a new sense of interior space where one views a full spectrum of nature from the inside through a large window from floor to ceiling. The inside of a house is no longer a confined cave.

3. *Another reality continuity...the resource essential to modern architecture destined to cut down this outrageous waste and mass lying, is the principle of continuity.*³⁴ Walls, ceilings, floors become part of each other to become one thing or one entity not separate entities. Steel is either bolted or welded together to become one thing. Concrete, a mixture of gravel, steel cement and sand is casted to become one body. Elements of the building engrained in such a way that it is difficult to tell where one begins or ends, thereby becoming continuous. This is in comparison with the post and beam construction to create a building structure in the classic architecture.
4. *Materials for their own sake...this is found by recognizing the nature of materials used in construction.*³⁵ Material physical properties dictate how a building will look. A steel building will not look like a stone building. The architect proceeds in his work guided by the nature of materials from the beginning. Consider structural properties in design and natural patterns. The architects must exercise a well-trained imagination to see in each material, either natural or compounded plastics, their own inherent style. Beauty of the materials is a direct result of how well they are used.
5. *Integral ornament... We have arrived at in integral ornament - the nature pattern of actual construction. Ornament meaning not only surface qualified by human imagination but imagination giving natural pattern to structure.*³⁶ When referring to integral ornament Wright referred to following nature's pattern in construction of the building. The expression of structure as a pattern true to the nature of materials of the materials out of which they were made. Ornament meaning not the surface qualified by human imagination but imagination giving natural pattern to structure. The flow, natural rhythm of form is like poetry.

Frank Lloyd Wright made major contributions to energy conservation in the area of technology. Wright was against air-conditioning and believed that a house should cool itself naturally obeying nature in every way. He was not against heating but designed radiant a floor heating system for the Usonian house. This system eliminated the use of radiator that consumed interior space. Most of Wright's houses were passively heated and he tried to minimize the use of mechanical heating system as much as possible.

The new philosophy of architecture for Wright is where "architects are no longer tied to the Greek space but were free to enter into the space of Einstein." A new era of experimentation to realize the true human values that never existed before. Wright was not alone in developing organic architecture ideas which embodied Emerson's transcendental philosophy.

³³ Frank Lloyd Wright, *The natural House*, Horizon Press NY 1954, P 53

³⁴ Frank Lloyd Wright, *The natural House*, Horizon Press NY 1954, P 54

³⁵ Frank Lloyd Wright, *The natural House*, Horizon Press NY 1954, P 59-61

³⁶ Frank Lloyd Wright, *The natural House*, Horizon Press NY 1954, P 63-64

Transcendentalist and organic architecture

Transcendentalism was a philosophical movement in United States that protested against that state of intellectualism and spirituality between 1820s and 1830s. Transcendentalism connected the philosophy and literary ideas of Romanticism with Unitarianism, which denies the doctrine of Trinity, Origin of sin, the miracles, and deity of Jesus Christ, and everlasting punishment.³⁷ Romanticism was opposed to Classicism in architecture, painting, literature, or music that is characterized by order, harmony, and rationality. It embraced medieval, individualism, spontaneous and emotional approaches to arts.

Wright's ideas of organic architecture were influenced by his mentor Louis Sullivan. Naomi Tanabe Uechi in her book *Evolving Transcendentalism in Literature and Architecture*, describes Wright as a transcendentalist. In the book, she links architects Frank Heyling Furness, Louis Henry Sullivan, and Frank Lloyd Wright, and asserts that the three were inspired by transcendentalists such as Ralph Waldo Emerson, Henry David Thoreau, and Walt Whitman. Naomi quotes John Harbeson architectural history magazine *Philadelphia Victorian Architecture 1860-1890* about the relationships among the transcendental architects which states: *Frank Furness may be considered the architectural grandfather of Louis Sullivan, and spiritual grandfather of Frank Lloyd Wright.*³⁸ The three architects embodied the concepts of Nature, American identity, and Universalism in their architecture.

Wright's maternal great grandfather, Jenkin Lloyd Jones, was one of the founders of the Armenian sect of Utilitarianism in Wales. Most of Wright's relatives were either Unitarians or Emersonians. Evidence of Wright's Transcendentalist ideas can be found in one of his Sunday talks in 1952 to his apprentices, where he cited Emerson's words from 'American Scholar' by saying "*The American Scholar was our thesis in architecture in literature enunciated by Emerson at Harvard so many years ago. Emerson encouraged independence of American culture away from the European cultural practices.*"³⁹ This formed part of what embodied Wright's ideas on more natural organic architecture philosophy.

Although Wright was mentored by Sullivan who coined the slogan, "form follows function" he changed this to "form and function are one." Organic architecture philosophy therefore was coined from the teachings of Sullivan. In the 21st century's age of passive solar architecture it would be correct to say "form follows energy." The dictionary defines organic as characteristic of, pertaining to or derived from living organism. Organic is characterized by systematic arrangement of parts; organized elements fitting together into a unified, organic whole.

Organic architecture is the interpretation of nature's principles in buildings that are in harmony with nature, blended with nature to become part of it. This is where Wright explains that aesthetics and structure become one as in nature. Emphasis was in its natural performance, one

³⁷ Naomi Tanabe Uechi, *Evolving Transcendentalism in Literature and Architecture*, Cambridge Scholars Publishing 2013, p 2

³⁸ Naomi Tanabe Uechi, *Evolving Transcendentalism in Literature and Architecture*, Cambridge Scholars Publishing 2013, p 9

³⁹ *Ibid* p 3

that is integral to the environment, part of its site and its time. The house was integral to the nature of materials, properties of materials as well as, maintaining harmony between design and its form. Material property of glass dictate the way glass is used. The nature of material such as stone or wooden dictated the form in design of the building. Wright used natural motifs for certain building elements such as glass art window designs which were repeated throughout the house. Wright believed that the shape of a building should reflect its primary function such as a bank or an office.

An understanding of properties of materials that are near the site is paramount. Naturally occurring material save on energy and transportation costs. The embodied energy invested in production of these materials will also need to be considered. Use of locally available materials cut on cost and make building more affordable. A lesson we can learn from the philosophy of organic architecture by Wright.

2.5 The reception of Usonian principles

The little Jacobs house was the first installation of Usonian ideas borrowed from Japan, which attracted a lot of excitement and curiosity from the USA professional circles. Articles on radiant heat began to appear in testimonial journals. Wright called it gravity heat coming up from beneath as naturally as heat rises. Most Usonian buildings adopted the heating system where they learnt how to proportion the heat correctly for varying climate conditions. “There is no other ideal heat. Not even heat from the sun.”

Jacobs’s house received national publicity between 1936 and 1938. However, Wright designed many Usonian houses, and only built twenty-five. Though in 1941, World War II stopped residential construction, the Usonia brought their greatest return in 1947 when Wright practice surged spectacularly.

The Usonians were more often in the outskirts of the town, or large wood lots taking advantage of irregular spectacular sites (hillsides, lakeshores, and ravines). Usonians were also known nationwide in fourteen states from Massachusetts to California and Washington to Alabama. Wright was an advocate for decentralization in planning of cities. Through his Broadacre city model, Wright demonstrated an economic logic where individuals built each house in a cost-effective way. All this happened by taking full advantage of the natural gifts of nature and having consideration for energy conservation.

The style looked more modern and perhaps influenced by the international style. Wright’s work in both the prairie style and the later Usonian style influenced the European internationalists such as Mies Van der Rohe, Walter Gropius, and Karl Schneider. They admitted Prairie buildings influenced them as depicted in Wrights 1910 and 1911 Wasmuth publications. The main difference between the Usonia and the international style was that *in their aesthetic theories Europeans specifically embraced and attempted to widen a philosophical bleach between nature and architecture. If Wright aimed to work with nature, they designed against it. Wright wanted to integrate building and site.*⁴⁰ For internationalist the distance from the primitive nature measured

⁴⁰ Frank Lloyd Wright, *His Life and His Architecture*, John Wiley & Sons, New York, 1979 p. 247

civilization, such that the further you are from nature the more civilized you were. *Their houses, which Corbusier dubbed “machines for living,” were rational logical and precise to be sure, the epitome of factionalism, in a very mechanistic way.* Wrights buildings were built for the place and nowhere else, whereas houses designed by modernists like Corbusier had no relationship with the site. To work with nature meant that the site and the house had merged to become one. The Usonian house even though following the same system, was tailor-made for the site or the place. The system is what Wright called the grammar and circulation of parts. Parts that were tailored to meet the needs of the clients and dictated by the environment where a house is located.

Wright’s influence on the internationalists was not without controversy. As Jacobs house was being constructed it attracted visitors from across United States among them Walter Gropius. A Madison architect had invited Walter Gropius, the high priest of Germany’s Bauhaus school of modernist architecture to the site without first informing Wright as protocol dictated. In his book, Jacobs wrote that *Wright loathed the international style, considering it unintelligent, misconceived imitation of his organic architecture. Scornfully Wright turned away and refused to have anything to do with Gropius. What Wright saw as a breach of etiquette in failure to ask for permission to visit the house under construction, and then the request that he act as a guide to an advocate of a kind of architecture he not only detested but considered an apprehending plagiarism of his own style-was too much for Wright’s unusual urbanity.*⁴¹ This example shows how Wright was not in favor of the direction in which some modernists took or the way the interpreted his work.

After the Jacobs house Wright was not content in repeating the same Jacobs plan, but began to explore new directions and other geometric styles. The results of this exploration brought about different styles of the prototype. Historian John Sergeant, identified five types of Usonian houses:

1. The *Polliwog Usonian*⁴² type - T and L shaped plan is the plan of the Jacobs house with in-line bedrooms in the tail at right angles to the public spaces in the main mass and utilities at the elbow. The universal space (the living room is the header while the bedrooms are the tail.
2. *The diagonal Usonian plan*⁴³ has a terrace, a wing, or just a single room juttied off at an oblique or acute angle with or without hexagonal module. An example is Panshin house project.
3. The third is *the in-line plan*⁴⁴ like the polliwog but minus the tail, an elaborated block if rectangle with bedrooms clustered at one end or to one side. An example is Goetsch-Winkler house.
4. The fourth was *the hexagonal Usonian*⁴⁵ like the Hanna house, which either grouped the bedrooms if the structure was essentially solid, mass or strung them along the wing if the

⁴¹ Herbert Jacobs with Katherine Jacobs, *Building with Frank Lloyd Wright*, Chronicle books Prism edition, San Francisco 1978, p.36

⁴² John Sergeant, *Frank Lloyd Wright Usonian Houses*, Watson-Guptill Publications, New York, 1976 p. 40

⁴³ John Sergeant, *Frank Lloyd Wright Usonian Houses*, Watson-Guptill Publications, New York, 1976 p. 51

⁴⁴ John Sergeant, *Frank Lloyd Wright Usonian Houses*, Watson-Guptill Publications, New York, 1976 p. 52

⁴⁵ John Sergeant, *Frank Lloyd Wright Usonian Houses*, Watson-Guptill Publications, New York, 1976 p. 60

hexagon was more complete. It was the first of the hexagonal designs completed in 1937 in Palo Alto, California.

5. Last style was *the Raised Usonian*⁴⁶ used for the edge of ravines or water. Here part of the house was elevated on masonry piers with three possibilities for public spaces.

The most elegantly developed T shaped polliwog style was Stanley Rosebaum house built in Florence Alabama at a cost of 12,000 in 1939. Alvin Rosenbaum, a Taliesin apprentice, in his book *Usonia: Frank Lloyd Wright's Design for America* describes how the house transformed their family during his childhood. Rosenbaum who grew up in Wrights house also gives an account of how he witnessed the seminal regional planning exercise of the early Tennessee Valley Authority. Rosebaum shows a direct relationship between the Wrights Broadacre idea and grand projects like the Tennessee valley Authority and Muscle Shoals. The grand plan proposed by Henry Ford in 1920s was realized in 1930s for Florence and its sister towns of Sheffield and Tusculumbia (an amalgam known as Marshal Shoals) all in Tennessee valley.

The diagonal Usonian plan was a polliwog plan with diagonal elements. A good example is the Marcus house project in Dallas Texas built in 1937. Sergeant describes it as “an immensely long, horizontal house with 28 by 64 feet living area designed to attune with the breadth of the vista of the Texas prairie.”⁴⁷

The third style was the in-line plan. Built in 1939, Goetsch-Winkler house style was the in-line plan like the polliwog but minus the tail. Wright designed the house for two teachers in Okemos, Michigan that costed \$9500. The house was part of a community scheme made up of eight professors of Michigan State University who owned a 40-acre tract of land. *Goetsch-Winkler cottage, Okemos, Michigan States College. It was originally part of a group of seven, the remaining six of which were never built because of the F.H.A. decided they would not stand.*⁴⁸

The fourth was the hexagonal Usonian. *Wright repeatedly asserted that that the hexagon was more natural to human movement, allowing greater special freedom than the square.*⁴⁹ An example of this was Stanford university professor Paul Hanna at Palo Alto, California where he used axes and walls 60 and 120-degree angles.

The fifth category was the Raised Usonians, with masonry piers in the plan. A good example is the Lloyd Lewis house built in 1940 at Libertyville Illinois. The house is raised of the ground to avert dampness and possibility of flooding since it is in the bank of Des Plains River.

Another significant Wrights style was the Suntop Homes Ardmore built in 1939, in Pennsylvania. The design, made up of four private dwelling units with an entrance each, such that neighbors were completely unaware each other's activities. The Quadruple homes were an innovation in land use where normal land use was 8-19 people increased to 30 people. Only one dwelling unit was built at cost of \$4000 per unit making it a total of \$16000 for the four. The real

⁴⁶ John Sergeant, Frank Lloyd Wright Usonian Houses, Watson-Guptill Publications, New York, 1976 p. 66

⁴⁷ John Sergeant, Frank Lloyd Wright Usonian Houses, Watson-Guptill Publications, New York, 1976 p. 51

⁴⁸ Sixty years of living architecture: the work of Frank Lloyd Wright, Catalog of an exhibition held October 22 - December 13, 1953 at the Solomon R. Guggenheim Museum, New York, Published 1953

⁴⁹ Frank Lloyd Wright, His Life and His Architecture, John Wiley & Sons, New York, 1979 p. 250

estate industry did not take up the idea, however it still holds potential for land-and energy-hungry cities.

The Usonian assumed the family to be in Wright's words, "a little private club." The Jacobs house and its offspring made a statement of detachment only to outsiders -the inside was certainly domestic. It was typical for Wright to hide the house entrance to the visitor as in Jacobs's house, which faces its own compound and encloses the courtyard. All these different types of Usonian house share these common features.

Another common feature of the Usonian houses was the motif that exemplifies his organic architecture philosophy, in other words the structural system of continuity. The motif would run throughout the design as many components coming together into one organic whole which Wright described as plasticity.

The success of the Usonian concept resulting from using prefabrication would require the construction of several houses executed all at once to take advantage of economy of scale especially if projects are in the same location. Houses were tailor-made and customized to meet different family needs and functions. The design offered freedom of movement as compared to the previous "boxment" of the previous eclectic style. Usonian dwellings blends with the ground, where the garden begins the house leaves. A new sense of Space, Light and Freedom of the USA.

Authors like Loren Pope of Falls Church, Virginia, wrote about his residence in 1940 as "*a continuous succession of mysteries... leading you on beyond what your eyes can see... The house gives you a sense of protection, but never of being closed in.*"⁵⁰ One gets the sense of how the Usonian house changed the perception of a traditional house in terms of habits and looks. The old formalities and customs of the Victorian era were changing. The new houses accommodated domestic entertainment where the houses could accommodate cocktail parties, buffet meal, and barbeque. The house would accommodate both traditional and progressive lifestyles. Progressive way of raising children and a temptation of being together as a family is how Jacobs described the house.

Wright used popular journals to disseminate his concepts. They were published in professional journals like the Architectural Forum by Myers, the House Beautiful by Elizabeth Gordon that targeted architecture and house builders. Wright also wrote articles in Ladies Home Journal in 1901 and later with his Taliesin apprentices wrote columns printed in the Wisconsin newspapers. Wright goal was to raise awareness and propagate a sense of space, promote organic architecture.

Wright's Usonian projects had to overcome some resistance from financial institutions. After the war, there are many changes taking place in American way of life socially and economically. This affected the design of the new house for three reasons⁵¹

1. There emerged a freer attitude about children
2. There was a new woman's role with more activity outside the home; and

⁵⁰ Frank Lloyd Wright, *His Life and His Architecture*, John Wiley & Sons, New York, 1979 p. 256

⁵¹ John Sergeant, *Frank Lloyd Wright's Usonian Houses: A Case for Organic Architecture* P 138

3. With the proliferation of external functions, less time was spent in the home.

All these changes meant that the general population especially the working class needed dwellings that worked more efficiently at an operative level, were easy to maintain and called for minimum housekeeping. The families had become more progressive and with this came other changes, like the elimination of servants who worked for the traditional family. The new house therefore required an overhaul to meet these demands.

The housing market and financial institutions tended to be conservative in the way they issued loans and opposed development of the progressive ideas as presented by modern architects. Frank Lloyd Wright's Usonian houses were no exception. *The financial situation was dominated by the Federal Housing Administration (FHA) and tended to frustrate this needs.*⁵² A study by Irvin Rosow revealed that loan officials disapproved houses that did not conform to the neighborhood in architectural style. FHA tended to use cubic footage method to establish the value of the house. This formula undervalued modern houses. On the other hand, the FHA and banks favored traditional houses to secure loans with the argument that traditional house were predictable in terms of resale value. They hoped to avoid the uncertainties presented by the modern houses viewing them as a risky.

Many large firms adopted the traditional eclectic work during the same period. The academic institutions were in dilemma of teaching modern ideas mainly due to concerns about future employment for students in the market. Wright referred to this approach as miseducation. Irving Rosow's thesis on "modern architecture and social change" also found out that clients, who built modern houses in 1940s, were mainly better educated professionals than in business. The clients had more interest in leisure activities, active in both political and community activities, and had a professional working wife. Most clients were young couples, professionals, and journalists.

Wright was also anti-war (Second World War 1939-1945) and was fearful that the war would again destroy his practice which was recovering from the great depression. Japan, Germany, and Italy are countries that had welcomed his architecture. His argument was that American real defense was in building a truly democratic society, ordered decentralization, social reintegration with the ground and in a natural capitalist economy. Wright wrote several antiwar essays to express his opposition and encouraged resistance to the draft among his apprentice. *Nineteen of Wrights apprentices were drafted and entered the armed forces, Howe, Weston and Davy Davison were sentenced to prison for refusing to be grafted.*⁵³ His antiwar rhetoric caused problems with the FBI forced him to abandon Taliesin West temporarily for the period between 1940 and 1945.

During this period, only a few projects came into Wright's office some of which were crucial to the final phase of his life. In 1943, at the age of 76, Wright was commissioned to design Guggenheim museum to house Solomon R. Guggenheim collection of Non-Objective painting, one of the most comprehensive collection of modern abstract paintings in the world.

⁵² John Sergeant, Frank Lloyd Wright's Usonian Houses: A Case for Organic Architecture P 139

⁵³ Robert McCarter, Frank Lloyd Wright, Reaktion Books 2006, Pg. 158

The following year, 1944, Wright was commissioned by Herbert Jacobs's family to build their second home, Solar Hemicycle. Another extraordinary design with energy-efficiency concepts of Usonian house but 2-storey curved, semicircular plan layout. The inner side opened to the warm south by continuous full height glazing, and its outer edge closed to the cold north winds by solid rock wall and earth berm.⁵⁴

The same year Wright built the Research Tower of the Johnson Wax Building in Racine, his first realization of tree-concept of cantilevering the floor structure from a central massive core column.

Henry Luce publication the *Architectural Forum* in 1951 was dedicated to Wright's work like the Johnson Wax Research Tower, the Florida Southern Collage Buildings, and five Usonian Houses including the second Herbert Jacobs House, the "Solar Hemicycle." Wright wrote *the machine has yet nowhere given to America the flower of indigenous culture. The machine has so far produced for us only weeds of a civilization.*⁵⁵ Wright describes negative effects of industrialization in relation to culture of the Americans in terms identity and sense of community. The first Jacobs house emphasized on affordability whereas the second house, Solar Hemicycle, was more on energy efficiency.

In January 1951, Frank Lloyd Wright launched the largest exhibition of his work that started in Philadelphia. The exhibition name was *Sixty years of Living Architecture*, took the form of a tour in Europe that began in Palazzo Strozzi Florence Italy in June 1951. The exhibition travelled to Switzerland, France, Germany, and Holland in two years. It also covered New York, Mexico City, Chicago, and Los Angeles.

In New York (1953), the exhibition took place in the sites that finally became the Guggenheim museum. There were two temporary structures elected, namely the New York Usonian house and the Pavilion to house the Exhibition. Mumford, an American historian and literary critic took advantage of the 1953 exhibition to write an extended evaluation of Frank Lloyd Wright's work. The Usonian house at the exhibition puzzled many visitors, owing to its many innovations such as open concept plans, extensive glazing, and sunlight light, integrated indirect lighting, built in storage and furnishings, central open kitchen, combined living and dining. The exposed materials and its modular construction all originated with Wright.

An article in New Yorker titled "A Phoenix Too Infrequent" Mumford expressed concerns that Wright imposed *his design ego on all aspects of the client's life.*⁵⁶ This is after a brief stay in Hanna House, the first non-rectangular structure, also called the "Honeycomb House" designed by Wright. Mumford reacted to the Trapezoid-shaped beds and special liners. Wright's response to the criticism by calling it *an insult to his clients and said that his clients had answered this charge, through the hundreds of letters he had received from them, telling how their houses had dramatically changed their lives for the better.*⁵⁷

⁵⁴ Robert McCarter, Frank Lloyd Wright, Reaktion Books 2006, Pg. 160-161

⁵⁵ Robert McCarter, Frank Lloyd Wright, Reaktion Books 2006, Pg. 171

⁵⁶ Frank Lloyd Wright Robert McCarter Reaktion Books 2006 P 184-185

⁵⁷ Frank Lloyd Wright Robert McCarter Reaktion Books 2006 P 184-186

During the last years of his life, Wright realized the largest number of Usonian houses. It was his endeavor to reach out to the American public *exemplified by his outpouring of articles during 1950s presenting his ideas free of charge for anyone who wished to employ them.*⁵⁸ Homemaker and Homebuilder magazines such as House Beautiful, House and Garden, House and Home Life were such examples that where he revealed high design secrets. The final twenty-five years was when hundreds of Usonian houses were designed, and they represent the ideals embodied in his Broadacre city and Usonia. The standard the houses set revolutionized the way American homes are designed which transformed the building industry since Wrights death.

Wright noted in his book the Natural House, that what we need most in architecture today is the very thing that we needed most in life -Integrity... *Just as a human being so integrity is the deepest quality in a building. The Usonian house, aims to a natural performance, one that is integral to the site; integral to the environment, integral to the life of its inhabitants.*⁵⁹

In 1958 Wright suffered a stroke and cataracts that obscured his eyesight in the last years. The last project on his drawing board was simple and affordable prefabricated concrete-block house for his friend Marshall Erdmann's construction company. This exemplifies his love and faith in the Usonian house.

2.6 Thesis antithesis and synthesis of Frank Lloyd wright's Usonian House

Thesis

The Usonian design was a deliberate attempt to address the issue of economy to meet the housing needs of an average citizen. I believe Frank Lloyd Wright succeeded in using architecture to improve the well-being of ordinary citizens, make them enjoy life and appreciate nature and surroundings. Wrights describes the mission that drove architecture as: *"the Mission of an architect-of architecture- is to help people how to understand how to make life more beautiful, the world a better one for living in, and to give reason, rhyme, and meaning to life."*⁶⁰ The architects have a major role to play in helping their clients set priorities with the resources they had at their disposal to live in harmony with the environment.

The house allowed future expansion from a young family with one child to a family with two children boy and a girl. The house to reflect American values of democracy, culture, and organic architecture. About American Lifestyle Wrights stated that *"our people do not know how to live, they imagine that idiosyncrasies to be their tastes their prejudices to their predilections and their ignorance to the virtues - where any beauty of living is concern."* The society's previous lifestyle was put into question. A new progressive way of thinking was to emerge in terms of setting priorities.

⁵⁸ Ibid p 197

⁵⁹ Wrights natural house (1951) in Wright Collected writings 1894-1930 ed pfieffer, iv, p9

⁶⁰ Frank Lloyd Wright talk at the university of California, April 17, 1957

It is important to note that prior to the great depression America had enjoyed a booming market, “the rolling 20s” which came to a climax in 1929 when the stock market clashed. The habits of a booming economy are what led to Americans behavior in what Wright refers to as *idiosyncrasies*. The machine age enabled mass production of modern materials and easy transportation to the side. The mass production of building components made the houses affordable due to the economics of scale.

Wright also favored the use of natural materials that are close to the site, which translates to less transportation costs. Use of local labor was also key to Wright’s houses. Individual owners could construct their own Usonian houses since the design required minimal skilled labor. The organic architecture, representative of the family values and abilities. Architecture that belongs to the place, materials of the place and respects nature with the environment.

The other great idea is that these houses were designed to grow i.e. could accommodate future expansion depending on the size of the family and economic status. This is a major point overlooked in the 21st century architecture. Wright also had promoted the idea of the spirit of democracy with freedom of an individual as an individual. The individual family continues to flourish and realize their own dream of home ownership. A home that represents their status of society, their own tastes, and income level.

Wright was against urban sprawls, traffic congestion and centralized city cores. In 1932, Wright began a series of publications and lectures notably “The Disappearing City. He described the old city as “some tumor grown malignant.... menace to future of humanity.” To create a more expansive, humanly city with greater freedom to move at will, Wright came up with a solution that he characterized as modern need for space and movement. There was born the Broadacre city of tomorrow that would disperse functions across carefully planned countryside where markets, businesses, cultural and community facilities linked by road. Wright proposed land distribution where individual family had an acre of land in their possession. The design of road network would link homes with schools, places of work. This would integrate all forms of production, distribution, self-improvement within a radius of fifty miles from home. Wrights Usonian idea was born at the same time with Broadacre city of 50,000 people.

These suburban affordable homes would exemplify the American values of democracy in home ownership, harmonious and enlightened society. The mode of transportation was that of a car, or even faster the plane, along with other forms of modern communication would spell the end of the centralized city. Wright believed that the integral whole composes the great city that embraced the whole country.

Antithesis

The original Usonian house is the only one that was true to Wrights original ideas. The cost element seemed to become uncontrollable as the concept emerged with time. After building over 100 houses all over the USA, the cost of Usonian house had risen from original \$5500 to the range \$12,000-\$75000 depending on the program extent. Some extended programs costed \$100,000. The time span was between 1938 for the original house to 1954 (12-year period). It’s also important to note that America was emerging from the great depression and as the years

went by the individuals could afford more. At the same time, the Usonian design was continuously improved to fit the needs of different families at different times and different economic conditions.

Wright continued to devise new forms of construction, and designed for an increasing amount of client that were interested in a “do-it-yourself” activity as an initiative to keep the costs down. Only an initial contact with the architect was required, and the skill level of construction was minimal as most parts were prefabricated from the factory. The houses gradually gained acceptance with federal housing authority and prewar banks. Clients were impressed by the Broadacre idea and formed Usonian societies that enjoyed much influence in the regions they were located.

The idea of an individual family within the broad acre concept was that each family owned at least an acre of land. This type of concept would be hard to sell in today’s urban planning realities. A suburban Usonian concept would not be popular to land developers whose main objective is to make profits with minimal use of land. Although a decentralized city would lead to a more sustainable environment, the idea is still a hard sell to today’s governments and local authorities who rely on taxes. High densities translate to higher taxes with less infrastructure, such as roads, water supplies and sewer. These resources are shared in a dense city that makes them less expensive.

In the detailing of the exterior wall, ceilings and floors, one of the major drawbacks was insulation. The whole design was a test of innovative technology of its time. The principle of continuity in design of truly organic architecture was pushed to the limits. In spite of the innovative gravity heating system, a system of retaining this heat in the structure was kind of ignored.

Synthesis

Are Frank Lloyd Wright’s ideas relevant to 21st century families? Instead of moving to a new house why not expand the one you have? Passive ideas are quite relevant to today’s sustainable designs.

Many lessons can be drawn from Frank Lloyd Wright on energy efficient house that utilizes passive strategies. The Jacobs house II which he referred to as “solar Hemicycle” built in 1946-48 is passively solar heated and naturally cooled. Natural materials were applied consistently in line with organic architectural principles in a way that conserves energy. Wright contributed toward affordability with Jacobs I and towards energy in Jacobs II.

The Usonian concept has a lot to offer to the modern quest for sustainable and passive solar design movement. Many design features of the house use strategies that promote passive energy form the sun significantly reduce energy consumption. Wrights philosophy of organic architecture would be quite beneficial to the environment. A building that works in harmony with nature, a building that belongs to a place, made from materials close to the site embodies these principles. One of the solution is to take a Usonian house, update the design to the current

technology and style then incorporate the Net Zero ideas. The performance of the Usonian house in terms of orientation, thermal mass, insulation, ventilation, and lighting can be analyzed to establish benefits to the research of passive solar architecture. A simple affordable building is sustainable. The benefits go beyond energy whether net zero or even net plus buildings that taps energy from the sun. Solar as a sustainable energy source helps mitigate overreliance on fossil fuels that deplete the environment.

The Broadacre idea on city planning is still feasible if it is tied with the economic and social factors of a given region. Those families that love farming can farm, those who love the landscape are free to do so. Energy conservation is possible with many alternatives as opposed to a congested city. Initial investment on infrastructure maybe higher but whatever is put in place is sustainable with a lesser population.

Affordable housing is another key issue that affects families up to this day. The broad acre idea is family focused where families are left to evolve, build communities to meet their needs and abilities. Energy is a shared commodity just like water sewers and roads. Schools, religion, entertainment, work, and play are all interconnected.

2.7 Sustainability, passive energy ideas and organic architecture

Frank Lloyd Wright came up with the philosophy of organic architecture. He redefined architecture in the context of time as defined by the transition to machine age. This is by stating that “a great architect is not necessarily a great poet, he must be an interpreter of history, his day and his age.” Today the machine age, with fossil fuels has brought us to where we are in twenty first century. As an interpreter of history and our age architect will have to face the challenges of transitioning to present demand on energy for our buildings.

The idea is to look at the Usonian House Jacobs house from an energy perspective (passive energy) to come up with the most economical passive solar building. There are many lessons we can draw from the Usonian House. One of which is designing affordable housing for middle income people using Wrights principles of organic architecture. The houses are environmentally friendly, rely heavily on passive energy strategies, and constructed from materials that belong to the place as well as natural materials.

There are two main ideas: the passive energy ideas and the organic architecture ideas. Both ideas are not new to architecture and have been there for generations. The organic architecture component started with Frank Lloyd Wright.

The environmental movement was born out of overreliance on the fossil fuels that became a threat to the environment. In the 21st century we’ve become aware of clean energy and the impact on our built environment. The demand for a sustainable development is the main drive that takes us back to organic architecture. *Sustainable development is meeting the needs of the present without compromising ability of future generations to meet their own needs.*⁶¹

⁶¹ Norbert Lechner, Heating Cooling Lighting: Sustainable Design Methods for Architects, John Wiley & Sons, New Jersey, 2015 p. 23

This is due to concerns for global warming, the effects of climate change, the diminishing fossil fuels, and the pollution which have become more alarming to scientists and environmentalists. Buildings present a significant opportunity to reduce energy consumption and reduce Green House Gas Emission. The natural resources are becoming scarce; we are becoming more aware about the earth's carrying capacity and the need to maintain resources that ecosystems can support. To protect the ecosystem, we need to follow the principles of organic architecture for a sustainable future of our built environment. Sustainable development involves will reduction in energy demand, use of renewable resources, and minimal use of fossil fuels.

Adoption of organic architecture could make a great contribution to sustainable development (or even sustainable architecture). Sustainability is wide and incorporates energy issues and solar issues. During the 1960s the topic of energy was considered as trivial concern. Architects in the 21st century have the opportunity and responsibility to design in an energy conserving manner. Norbert Lechner illustrated the relationship between solar issues, energy issues and all sustainable issues that can be addressed through sustainable architecture. (See fig 6)

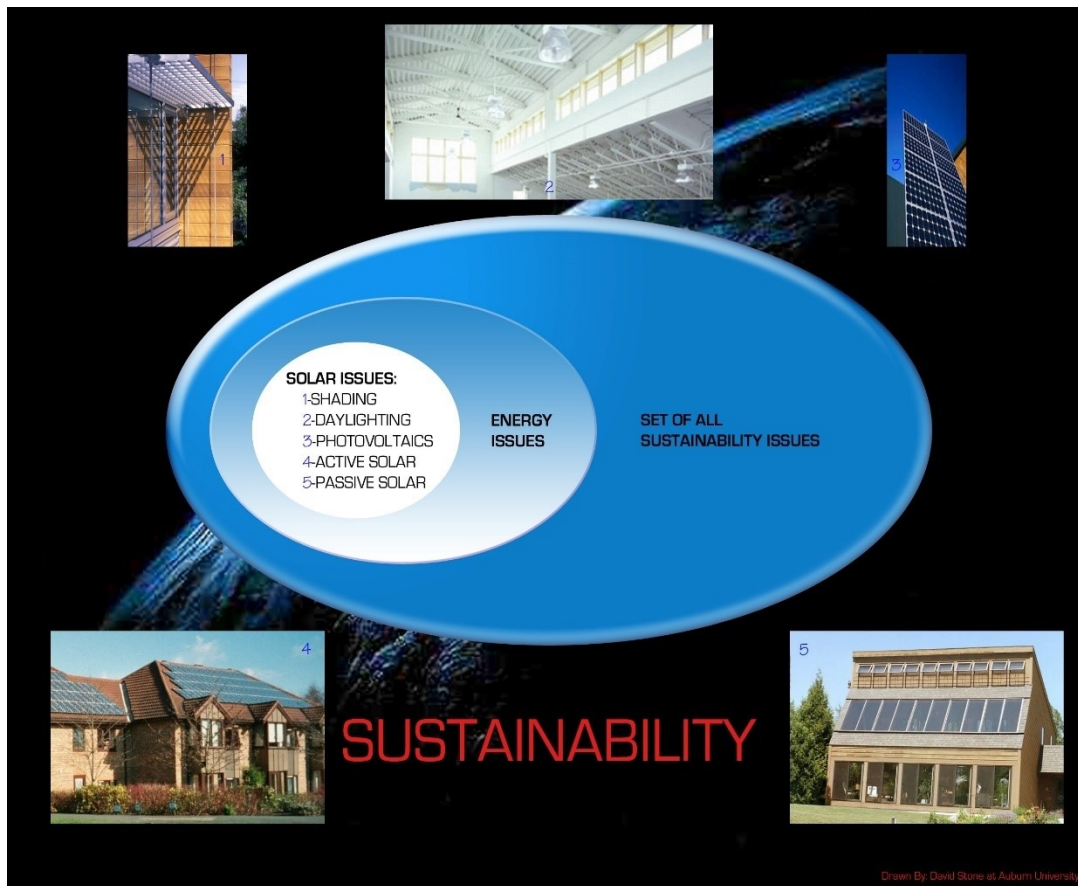


Figure 6 Sustainable architecture: Source: <http://www.heliadons.org/Solar%20Poster.html>

According to Norbert, *sustainable design includes a large set of issues and energy issues are a large subset thereof. The solar issues are much larger subset of energy issues than most people realize.*⁶² Solar issue include shading, daylighting, photovoltaics, active solar, and passive solar.

A good combination both passive solar and active solar energy sources that are free, with reduced energy demands creates a sustainable design. Shading controls the amount of daylight during summer. Photovoltaics generate electricity, while heat is generated passively to warm the buildings. The cost of photovoltaics has gradually been dropping making it easier to produce electricity on site and less dependent on the grid.

The architectural component in the new age of net zero energy buildings or net plus buildings has caught many architect's attention. It is the right time to re-examine organic architecture to come up with more economical passive solar or even net zero energy buildings. Organic architecture supports nature and therefore sustainable and offers great solutions for coming up with a sustainable building environment. Design of Net Zero Energy Buildings in line with organic architectural philosophy will contribute significantly in the combat of environmental challenges. It is through these principles of organic architecture that NZE buildings will become truly sustainable. Embodied energy issues will need to be considered for this to happen. Material manufacture and processes that they undergo during manufacturing up to transportation to the site consume considerable amount of energy. Adopting locally available materials as suggested by organic architectural principles will significantly minimize energy use.

Although industrialization brought in a variety of materials and technics, it focused primarily on mass production, efficiency, and human labor. With industrialization, little consideration was given to climate and we relied heavily on fossil fuels to create a comfortable human environment. Thus, there was an overreliance on mechanical systems as opposed to natural passive systems of the past.

The goal for energy is to drastically reduce consumption, which in turn will reduce the need to extract fossil fuels. To focus on sustainability, architects and developers will need to give special attention to passive energy strategies. Organic architecture supports sustainable architecture which supports a balance between environmental, social, and economic issues.

⁶² Norbert Lechner, *Heating Cooling Lighting: Sustainable Design Methods for Architects*, John Wiley & Sons, New Jersey, 2015 p. 14

Chapter 3.0

3.1 Jacobs House: Drawings and Restoration

Background Hebert Jacob and Usonian house features

In describing the Usonia house Wright points out that *“The house of moderate cost is not only America’s major architectural problem but the most difficult for her major architects. In our country, the chief obstacle to the real solution of a moderate cost house problem is the fact that our people do not really know how to live. They imagine their idiosyncrasies to their “tastes,” their prejudices to be their predilections, and their ignorance to be virtue, -where any beauty of living is concern.”*⁶³ This was Wright’s effort to create an affordable home for an average American, which began with the design of the Jacobs House. A simple house suitable for the living conditions of the American family. More emphasis was put on the essentials of living in the house in simplified terms; a house which exemplifies not so much tastes but the true beauty of modest living. This meant a transformation of lifestyle.

The first Herbert Jacobs house at Madison (sensible house) Wisconsin also known as Jacobs House was the first Usonian house built in 1937. The house was designed for a young journalist Herbert Jacobs, his wife Katherine and their young daughter. The total cost came to \$5,500 including architect’s fees \$450. Wright explains simplifications made to achieve their goal by stating that: *it is not only necessary to get rid of unnecessary complications in construction, necessary to use work in mill to good advantage, necessary to eliminate so far as possible, field labor which is always expensive - it is necessary to consolidate and simplify the three appurtenance systems-heating, lighting and sanitation.*⁶⁴ Simplification was the answer to the American lifestyle, idiosyncrasies that led to overspending, on items that were not of propriety to middle income families. Jacobs had to first see life in simple terms to realize a modest dwelling and take advantage of the era they lived in.

Simplification was a means to using style to achieve gracious living for clients like the Jacobs and coming up with a suitable size for the house that was sensible. Wright took measures to cut on labor and materials in addition to technological measures of consolidating three appurtenance systems of heating, lighting, and sanitation. These innovations in electrical and mechanical systems were economically designed to meet the space needs of its occupants and their comfort.

The heating system introduced by Wright consisted of wrought iron pipe network laid in the sand under the concrete floor slab. A boiler is used to heat the water running in the pipes and is located in the basement accessed through a narrow staircase between the kitchen and the bathrooms (see fig 7). Wright called the system gravity heat eliminated radiators or hot air ductwork systems that consumed space.

⁶³ Frank Lloyd Wright, *The Natural House*, Horizon Press NY 1954, p. 79

⁶⁴ Ibid p. 81



Figure 7: Wright watches the testing of the floor heating system source: Usonia 1 Jacobs House web, http://www.usonia1.com/01_hist.html

The next thing Wright addressed was the unnecessary complications in construction. The mode of construction was such that every stage is completed in one simple operation for both inside and outside. Many components were prefabricated at the factory to minimize the labor on the construction site. The mass production of these components would result into a reduction of the cost. The construction was made with the use of the new tools, such as machinery. Construction materials used were mainly wood, brick, cement, paper, and glass. The finish materials for the walls were the same for the inside and outside, to be in harmony with the environment. The roof was designed simply as a flat roof eliminating hips, valleys, or even other complications like dormer windows. These complications according to Wright would threaten the life of the roof.

Wright also stated that construction should be grammatical for the house to be considered a work of art. The flow between the constituent parts of the house was essential for it to become one whole shape and form. *The grammar of the house is its manifest articulation of all its parts.*⁶⁵ All limitations of an architect will be considered at this stage be it budget, feelings and design language of his own. This goes back to the term organic architecture where building materials for construction are both natural and belonging to the site. Materials suitable for the environment in which the house belongs and part of the environment.

The design of the envelope also ties the interior space of the house with nature through its windows. The windows not only bring natural lighting but also created a sense of place, a connection between the inside and the outside. The spaces were flooded with light from floor to ceiling. Wright compares the system of fenestration of the envelope to the human eye, which is part of the face. The doors and windows were brought in prefabricated form at the factory and looked one, as well as inseparable to the eye.

Wright described the houses built by the government and promoted by journals at the time as expedient. To add integrity to the house the design is not just a style that is practical and convenient, but suitable to the living conditions of its occupants. The life of the individuals that dwell in the house form the core basis of the design. This would add to the sense of morality to

⁶⁵ Ibid p. 181

the design as opposed to just mere convenience. The experience of occupants and how the spaces met their individual living dynamics must be well articulated. Wright called it “gracious living” as opposed to an eclectic design copied from the past or borrowed from Europe. The focus in this case is the family or occupants of the house to meet their daily needs.

In so doing Wrights Usonian design eliminated these nine items from the contemporary design of the time:⁶⁶

1. *Visible roofs are expensive and unnecessary.* The roof dormer, the attic, and false height below were eliminated.
2. *The garage is no longer necessary as cars are made.* Wright preferred a carport in its place made of a simple shed with two walls on either side.
3. Space was always a plague spot steam warmed concrete mat four inches thick laid directly on the ground over growth filling the walls set upon that is better. With this came the elimination of the basement.
4. *Interior trim is no longer necessary.*
5. *We need no radiators, no light fixtures. We will heat the house the “hypocaust” way-in or between floors. We can make wiring system itself be the light fixture, throwing light upon and down the ceiling.* The under-floor heating system was introduced. Lighting system will thus be indirect, except for a few outlets for floor lamps.
6. Furniture, pictures, and bric-a-brac are unnecessary because the walls can be made to include them or be them.
7. No painting at all. Wood best preserves itself. A coating of clear resinous oil would be enough. Only a floor mat of concrete squares needs waxing.
8. No plastering in the building.
9. No gutters, no downspouts.

These items were eliminated to cut on cost and achieve the natural simplicity of organic architecture for a true American society. Cutting down the excesses and remaining with the essentials was the means to realize an affordable home. The spirit of democracy guided Wright’s vision in the design of the Usonian house. The idea of a common man is given freedom to realize his potentials as an individual. Wright hoped to create a new sense of space light and freedom for Americans.

3.2 The drawings

3.2.1 Floor Plans and site plan

Plans for the Usonian house were prepared to cater for the needs of a young and growing family with room for future expansion. The Usonian plans are shaped like polliwogs, which is an L-

⁶⁶ Frank Lloyd Wright, *The Natural House*, Horizon Press NY 1954, Ibid p. 82

shape with a shorter or longer tail (see figure 8). The tail size would vary with the size of the family. According to Wright the body of the Polliwog is the living room and Kitchen. The bedrooms form the tail and can either be one, two, or three bedrooms with a bathroom conveniently placed.

Site plan is such that the L-shape encloses a garden accessible to both the living room and the bedroom wings. This gives the house a south and east exposure.

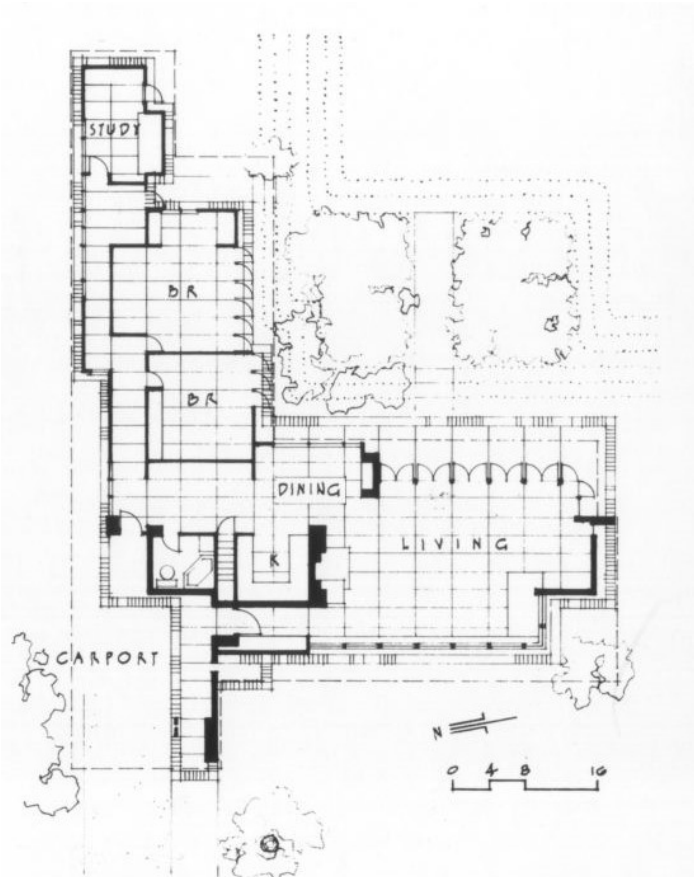


Figure 8: Floor plan Jacobs House

A big living room

The living is made to feel enlarged by providing a wide view of the garden through floor to ceiling windows. The fireplace is centralized, between the living rooms and the dining space, facing the kitchen. Furnishings include open shelves, a dining table in the alcove, benches and living room tables that are built in.

Cooking and dining space

The cooking and dining spaces are adjacent to the living room. The space is organized to provide easy access and direct communication between the dining and the large living room. The chimney was set away from the exterior wall within the living area to make work easier. The new location of the chimney defies traditional approach of placing it on the exterior wall for the classical houses that preceded.

Kitchen

For the kitchen, the housewife was the central figure in the design of the kitchen in her domestic establishment. She became the hostess “instead of being the kitchen-mechanic behind enclosed doors.”⁶⁷ The size of the kitchen was made small and more preference was given to creating space for living areas. The size of the Usonian kitchen could vary depending on the owner’s priorities, but in proportion to the rest of the house. Wright called it a workspace and made it become part of the living room.

The natural air current is set up towards the kitchen as towards the chimney, no cooking ardors escaping back into the house.

2 bedrooms plus a workshop (future bedroom) and a single bathroom

Wright was very concern about the children’s welfare inside the home and stated that the architect should provide a playroom in addition to speeding space. Often children’s needs are kind of neglected. For children bedrooms were small rooms next to a bathroom. Boys and girl’s bedrooms were made separate. To Wright a compact three-bedroom house was about the maximum.

The playroom is planned as part indoors and part outdoors to give children more liberty for play and other indoor activities. Children may go a lot further in life than ‘Pa’ and ‘Ma’ ever went when they grew up. After 40 or 35 a home is not as important to the parents as it is to the children. “... a child should grow up in building conditions that are harmonious, lives in an atmosphere that contributes to serenity and well-being and to the consciousness of those things which are excellent, in childhood. What a pity that parents have children so fast, so inconsiderately, that the architect must put them into little cells, double decker them, and shove them off into the tail of the house....”⁶⁸ This statement show how Wright advocated for the children’s growth and how a house can influence its occupant’s lifestyle and relationships in the family. The main focus of his design was the development and wellbeing of the children at tender age of learning when they are more alert and conscious of the surroundings.

Relationship between the house and the family

The layout of Jacobs’s house supports family activities in many ways. The Living room is a central meeting place for a family retreat, for entertaining guests in an all-inclusive atmosphere. The L-shaped layout with a view to the courtyard from the kitchen, living rooms and bedrooms creates a safe environment to monitor kids.

The entrance looks private from the west side of the house, prevents onlookers from view of family activities. One can only see the clerestory windows of the living room, the overhanging roof of the carport from the road facing east. The entrance door is also hidden. The backyard which is also the courtyard is protected by trees on the southern side of the house enhancing more privacy.

⁶⁷ Frank Lloyd Wright, *The Natural House*, Horizon Press NY 1954, p. 166

⁶⁸ *Ibid* p. 169

The new technology is extended in scale and comfort; a single house suited for prefabrication because the factory can go to the house.

The design of the elevations unlike the traditional approach created a dwelling place that is flat parallel to the ground in harmony with the prairie landscape (see Sections 10a & Elevation 10b). The horizontal line signified freedom of man on this earth; a true earth line of human life according to Wright.

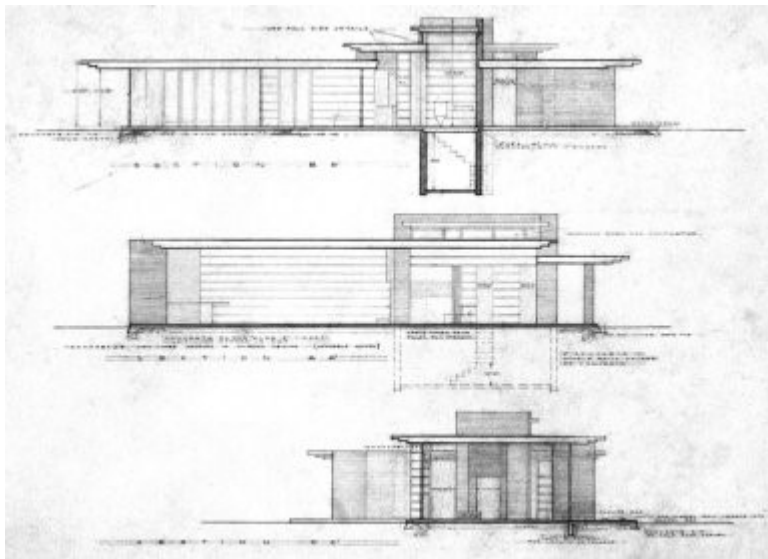


Figure 10a Sections Jacobs House

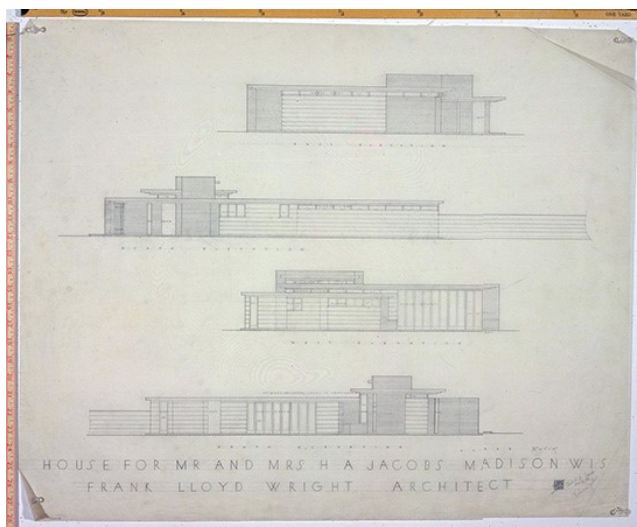


Figure 10b Elevations Jacobs House @ FLW foundation 2013

One of the greatest inventions of the Usonian house was the floor heating system on the ground, which Wright called gravity heat. The floor heating system consisted of pipes filled with steam or hot water in a rock ballast bed beneath the concrete floor. The heat naturally rises through the floor slab heating the interior spaces above it.

This idea was borrowed from the Japanese Baron Okula where Wright visited in 1914 while working on the Imperial Hotel project. The hotel had a Korean guest room where the floor had a unique heating system. The heat came from underneath the floor in between floor ducts back and forth making the room indescribably comfortable. Korean room meant a room heated under the floor in Japan. For the hotel design, Wright adopted this principle by ordering an electric heating element beneath bathrooms in the Imperial hotel to explore this idea further. The tile floor and built-in tile baths were thus always warm. This eliminated the use of radiators, electrical heating fixtures that were dangerous to the bathrooms then. A temperature of 65deg F was archives which in Wright words was true natural condition much healthier created condition for human comfort.

3.3 The construction of the Jacobs House

An account by Herbert and Katherine Jacobs as Wright's first clients for the Usonian house reveals interesting experiences at every stage of its construction. The young couple in 1936 presented a challenge to Frank Lloyd Wright to design a house that would cost \$5000 at the height of the great depression. Jacobs book titled "Building with Frank Lloyd Wright" share experiences of how it was to build two houses with Frank Lloyd Wright. The two houses (Jacobs I and Jacobs II) not only became world famous architecturally, but also both were pioneering structures at a modest cost in the housing field.

The 1930s was a period of economic turmoil for both Wright and his young clients. In 1932 Wright, faced with no client on sight, ventured into creating the Taliesin Fellowship for 20 young men and women who would live in Taliesin as apprentices in architecture. The students as Wrights enthusiast also paid yearly fees of \$600 which was raised to \$1000 for working and learning under Wright's direction. Wright believed that an architect could design a better wall for instance if he knew the skill it took to lay one up. As such the students learnt skills in carpentry, plastering, steam fitting, and plumbing among others. Years later Jacobs' own daughter joined the Taliesin fellowship as an apprentice.

Jacobs describes how with a meager salary of \$20 per week as a journalist, they had virtually no money while dealing with this "architect of millionaires." Jacobs build and lived in two Wrights designed houses at moderate cost. To Jacob's astonishment, the two houses became world famous architecturally that "*A Swiss magazine editor called them the best prototypes of true environmental houses.*"⁶⁹ Jacobs further states that their story gives important pointers to economies in an industry plagued by high cost, partly the result of inflated, unthinking demands of clients offered no reasonable alternative. The challenges of the 21st century housing still

⁶⁹ Herbert Jacobs with Katherine Jacobs, Building with Frank Lloyd Wright, Chronicle books Prism edition, San Francisco 1978, p. 3

revolve between how much we earn, environmental degradation, and few solutions available for affordable housing.

It is also important to qualify the word affordable housing in present day context. One way of looking at it is a house that meets the needs of low to moderate income earners. The main goal is to achieve a sustainable, low energy affordable house. *Canada Mortgage and Housing Company (CMHC) defines affordable housing as shelter whose costs account for less than 30 per cent of before-tax household income*⁷⁰. Affordable housing is different from social housing in that in social housing is rental units subsidized by the government.

The Jacobs spent \$5500 for their house in 1937 earning a salary of \$20 per week. The cost of this house comes to approximately \$95,000 in 2017. This is much a challenge to us in 2017 as it was to Frank Lloyd Wright in 1937. Once this is realized in principle the next step would be to design and cost this house using the present-day standards and materials.

The two Jacobs houses designed by Wright brings to us where to begin in addressing the issues of energy reduction and sustainable living through organic architecture.

Jacobs describes innovations in the 1st Usonian house that include a carport, floor heating, corner windows, grouping of activities in a central stack, a concrete mat, and partnered wall. All these innovations that started with Jacobs's house were completely new in 1936 but were incorporated later into the mainstream of the American house. Jacobs described the gravity heat as intriguing; piping was laid directly on a gravel bed, one than half buried in it, and the concrete mat laid on top.

The second Jacobs house was called: solar hemisphere. It was built in 1946-48, five years after its design the house had little similarity with the Usonian concept. *Wright used the earth instead of blank wall against the north wind for privacy. Gone were the sharp angles of the plan instead a single flowing space reaching out to embrace the garden and to gather in the solar energy production in the bosom of glass. Into the space were hung the sleeping quarters treaded like temporary intruders- no doors and depending on the main single floor heating system. Entry to this single room is through a tunnel through the earth berm-quiet, simple and low key- and you're in a great dazzling sunlight and sun heated curved flowing space.*⁷¹ This house utilized true passive solar energy strategies invented for energy conservation. The house had the efficiencies of the Usonian house with a different layout. It was 2-storeys with a curved semicircular plan layout. This is another prototype for an outstanding passive strategy to emulate with its innovations that would work effectively even in the 21st century.

Jacobs describes in details his experiences as a client from the kick off meeting with Wright, the design process up to the challenges during actual construction of the house. Jacobs is more elaborate in explaining how the gravity heat worked than was Wrights himself. The system had been used by Koreans for centuries, *who kept floor and house warm by winding the smoke from a*

⁷⁰ CMHC website- https://www.cmhc-schl.gc.ca/en/inpr/afhoce/afhoce_021.cfm

⁷¹ Herbert Jacobs with Katherine Jacobs, *Building with Frank Lloyd Wright*, Chronicle books Prism edition, San Francisco 1978, p. ix

small fire through a maze of hollow tiles under the floor before the smoke reached the chimney. The type of heating would eliminate expensive space consuming radiators or hot air ducts, and produce ductless, even temperatures throughout. The system would lead to a comfortable floor with absence of draft. Instead of using smoke Wright used steam passing with cast iron pipe network under a concrete floor slab.

Orientation was a major factor to the design process. At first the Jacobs picked up a lot at west end of Madison, which costed \$800, for the size of 60 feet wide and 120 feet deep. The money was an inheritance from Hebert Jacobs's great aunt. Due to the depression, the skilled labor, materials, and mortgage money came cheap. However, this location was to change at the time of developing the working drawings. Wright made an abrupt change and informed the Jacobs that they had to purchase a different lot that would fit the new house. Wright had designed the house to fit the full 60feet width of the lot with no room for a setback. Two alternative lots were suggested, with the suitable dimensions 120 feet both way. After a few days of negotiation, they chose the corner lot at an additional cost of 800 dollars. It was purchased with money that Jacobs had set aside as reserve savings in case of extra cost during construction.

The new site came with an improved orientation for the house and a better view. The wall of the door-windows of the living room faced east. As Jacobs puts it *“Thus we would have to welcome the morning sun in fall, winter, and spring, pouring in the warm and cheer us, and would be spared the burning rays of afternoon entering those windows in summer.”*⁷² As one enters from the streets, the ground a slope downwards and provides a great unobstructed view of the hill since it's higher than future houses when looking from the garden side.

The other interesting design was the entry to the house, which was an amazing break from tradition. “This house turns its back to the street” was what Wright told Jacob and Katherine in September 1937, to describe the violent break from the American middle class housing concepts of the design at the time. This house opened its arms to the garden side for the entire wall opposite the street side. The garden side wall had glassed doors running up nine feet to the ceiling.

The Jacobs house would be different, not designed to impress the neighbors, but designed to make life pleasant to its occupants. The front was just a plane exterior wood with no elaborate imposing façade a break from tradition. People would not peep through the curtain windows to see inside. There was no sacrifice of the lot to create a front lawn.

Sense of space and sense of shelter are the two major contributions of modern architecture. The band of small windows under the roof (called the system of fenestration) enabled the viewer to see the ceiling extended beyond the walls. The big four feet overhang gave a feeling of shelter without which you cannot get when there is no overhang visible from the inside. The bedrooms were located at a right angle from the living spaces to ensure privacy. These ideas came so fast that the Jacobs could not comprehend the design at first. How it would be like to have a master

⁷² Herbert Jacobs with Katherine Jacobs, *Building with Frank Lloyd Wright*, Chronicle books Prism edition, San Francisco 1978, p.18

bedroom with exterior glass doors from floor to ceiling that exposed the view of the garden was still a mystery.

Jacobs continues to narrate about the construction process, challenges to the contractor and the curiosity the house attracted to visitors who streamed the site during and after its completion.

At first, Wright had suggested to the contractor to build the roof first then put the house under it instead of working in the conventional way. For this reason, the contractor, named Grove, declined. Wright's thinking was probably moving towards the mass production of future Usonian houses with standardized walls, with windows that could be more easily and cheaply built in a factory and then delivered to the site. In an article on the Jacobs house Wright predicted this measure would bring down the cost to \$3500, but it was never tried.

The other challenge to the contractor was with the specifications. Wright specified cheap pine boards for the vertical core boards forming the center of the sandwich wall. Carpenters had to brace the core boards to prevent them from falling which made it impossible to nail them into the concrete mat. For the 6-foot high bedrooms, this was easier than the 9-foot living room. All the core boards had slots within the width of the board, to receive a three-inch fin binding them to the mat. For later Usonian houses he used a more expensive plywood, which made construction easier.

As the roof and wall became visible, word about the strange new dwelling spread so fast that it attracted dozens of curious visitors to the site. The stream of people continued to come to the site even after the completion of the construction. Jacobs explains "*when we dropped by late in the afternoon we would find a dozen persons wandering around, gaping, measuring and bothering workmen with questions... worker on their part, soon learned to answer questions on the run, with a noncommittal 'don't know.'*"⁷³ The carpenters enjoyed showing off the sandwich wall by striking approvingly with the fists when some of the walls were complete. Jacobs also pretended to be a visitor to save himself from being asked questions and also to help them pick up scathing and bewildered comments. Throughout the building period they remained spectators rather than participants.

Jacobs explained how the house attracted enough attention not only from the American public but also internationally. His relationship with Frank Lloyd Wright was that of a client and an associate who used his journalist skills to write Wright's biography.

⁷³ Herbert Jacobs with Katherine Jacobs, *Building with Frank Lloyd Wright*, Chronicle books Prism edition, San Francisco 1978, p.36

Chapter 4.0

4.1 Critical analysis of the Jacobs house-in the light of the five concepts of orientation, massing insulation ventilation and lighting

This chapter brings us back to re-examine the five characteristics explained in chapter one to analyze the Usonian house in light of the five passive strategies, namely orientation, thermal mass, Insulation, ventilation and natural lighting

4.1.1 Orientation

The solar orientation of the Jacobs house is such that the bedrooms' wing faces the south and the living wing faces the east. The main entrance is on the west side of the building next to the carport at the left corner side of the L-shaped plan. As described by Wright "this house turns its back to the street," and even to this day this statement holds. The house still defies tradition today; one can hardly tell where the entrance door is as you approach it from the street side. See fig.11a and fig.11b of showing the street side of western view.



Figure 11a Western View from the road side



Figure 11b View from the street side - site is sloping towards the east side

There is a gentle slope as you approach the entrance next to the carport. A narrow corridor leads you to a large living room which has large floor to ceiling windows on the east side, while clerestory windows run on the west side living space.

The site slopes toward the east side in such a way that the lower end is on the eastern side while the west side is highest at the corner of the carport. To construct the building, the western side was cut and filled. A similar cut was done on the north side even though this was higher than the south side. The site was highly recommended by Wrights to the Jacobs as ideal and favorable.

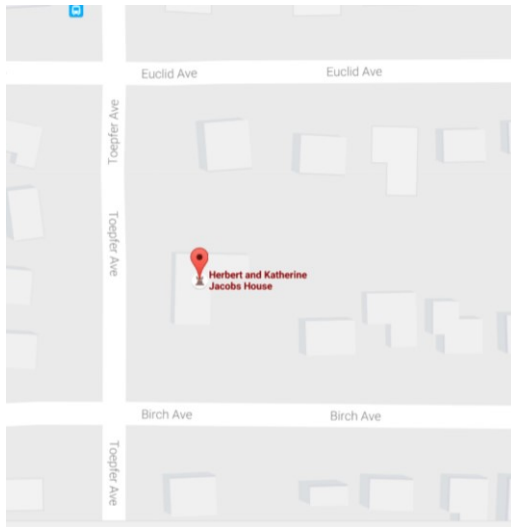


Figure 12 Google map



Figure 13 Birds eye view from SW via google-trees planted on north and western side visible



Figure 14 Bedroom windows facing the south while the Livingroom door windows face the east

The site topography reveals the notable features of the surrounding development, such as landscape, wind direction and other characteristics. The winds blow predominantly from the northwest side this site during winter. There are limited number of windows on this side of the wall made of brick. The owner has planted trees on the northern side to further reduce the effects of the cold winds (See fig 12, 13, &14). The trees around the site creates a microclimate by shade during summer months controlling the amount of sunlight coming from the south and east side.

Wright stated that the proper orientation of the house is the first condition for lighting the house. Proper orientation allows ample lighting with special consideration to the path of the sun as it goes from east to west. Natural lighting is controlled to serve the needs of the specific spaces, while minimizing the use of artificial lighting.

The Usonian concept was developed at the same time as the Broadacre city idea. This brings us back to the way we plan our cities. For proper or ideal orientation to be achieved city planners and developers will have to come up with a policy that supports sustainable living. To benefit

from organic architecture philosophies policy makers working with architects will have to address the long-term goals to serve the best interests of families that form the real foundation of any society. The core family needs should be addressed at both micro level and macro level. Needs of the individual family are key to any success for a country. Frank Lloyd Wright demonstrated this very well with the Usonian concept.

The site topography will reveal the notable features of surrounding development such as bodies of water, landscape wind direction, and other characteristics. The direction of the wind and its intensity is affected by hills, valleys and other natural factors.

4.1.2 Thermal mass

As stated earlier the thermal mass principle works best on materials that can store solar heat for energy conservation. Frank Lloyd Wright did this by using a concrete slab floor with a 2ft x 4ft grid line. For the living room the abundant eastern sun rays enter through the floor to ceiling window/door not only lights the room but allows occupants enjoy the warmth of the morning sun. A similar thing happens to the dining space at the alcove area. The generous roof overhang controls the amount of light that penetrates the spaces as the sun rises throughout the day by providing shade. Occupants in bedrooms and the study also experiences similar scenario.

The floor can store the heat that will later warm the spaces at night through the thermal mass effect. As stated by Luis Fernandez-Galiano, Frank Lloyd Wright saw the sun as “heat rather than light.” This statement is true for the Jacobs house where even the chimney is at the center of the service core. The chimney distributes heat from the center of the interior space to the living room. Many houses had chimneys located on the perimeter wall.

Wright went an extra step by installing gravity system heat. A network of cast-iron pipes had been installed to heat the floor spaces by running hot water through them. The floor heating system ensured even distribution of heat throughout the house. It is also scientifically proven that water is capable of storing heat for prolonged period. Which further translates into more energy being conserved. Water is also capable of retaining heat more than air with the same amount of heat. Water complements the concrete and brick masonry walls which absorbs heat from the solar heat during the day and release this heat during the night. This maintains constant temperatures at the same time minimizes the amount of heat required to keep the house warm.

A visit to the site revealed that the owner noticed that the grass that grew around the house was always green during winter. So, when the owner did the remodeling the water pipes were installed and cast in the middle of the slab. Wright had placed the cast iron pipes below the slab on sand. This resulted into heat loss from the slab both from the sides and below the slab. This extra heat was being lost on the sides causing the grass to retain the green color during winter. By relocating the pipework in the slab ensured and adding insulation ensured that most of the heat would not escape making the system more efficient.

Restoration of the Jacobs house

The Jacobs House is currently owned by art historian James Dennis, who has restored the house to its present state. The restoration maintained Frank Lloyd Wright's original design as much as possible. Dennis replaced the floor slab to the living room with casted the pipes into the concrete slab (See figure 15). Insulation was added underneath this slab, a measure taken to ensure minimal heat losses. After contacting John Heifer, the restoration Architect, he indicated that "the heat went down as well as up, so much so that grass was growing (and green) 5ft from the edge of the slab throughout the winter...we tried out beat to insulate where we could."

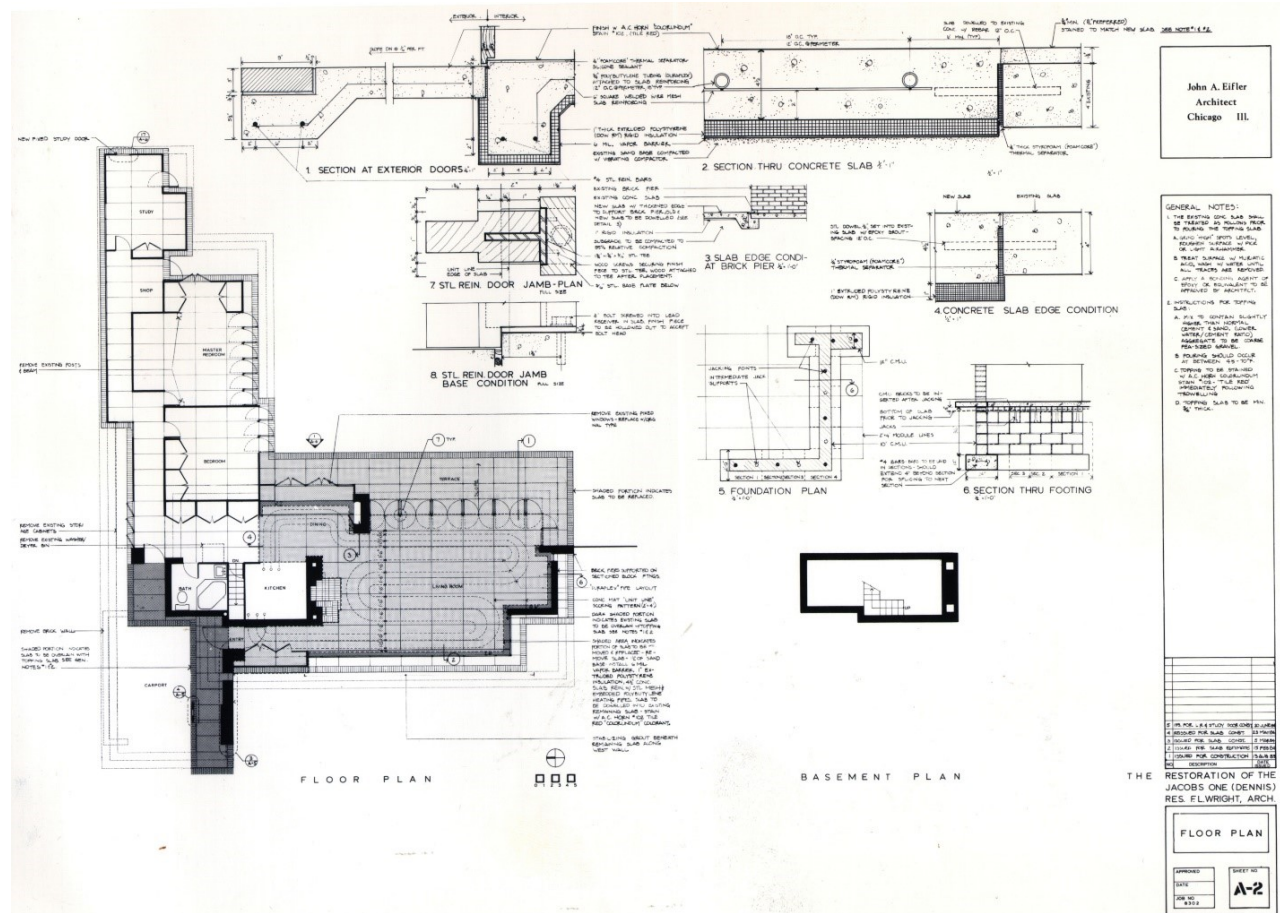


Figure 15 Floor slab to the living room with casted the pipes into the concrete slab

Additional restoration includes replacement of the of 1/4" single glass plate to the living room doors and windows with thermal glazing (double glazing). Insulation was also introduced throughout the roof.

This type of approach demonstrates the significant benefits of using a passive approach to heating and adding the extra heat into the slab using Wright's gravity system. A passive design will lower the energy loads significantly taking us closer to a net zero energy building by utilizing proper materials for thermal mass. Roof overhangs are strategically placed to shade the building during summer while thermal mass on the floors absorb heat from south facing window.

4.1.3 Insulation and heating

Whether it is a very cold or very hot climate the overhead is where the insulation occurs in a building. With a modern air-conditioning and heating system you can imagine almost any condition. Wright believed that the best *insulation for the roof and walls in hot climate is nearly the same as the best insulation for roof and walls for cold climates. White top surfaces reflect heat are economical, tough roof insulation to withstand the sun*⁷⁴

The way Wright addressed the insulation issue is through an innovative floor heating. In cold climates like Wisconsin, Wright envisioned that by introducing the heating system embedded in the concrete limited insulation was needed. As a consequence, the walls had limited insulation. The current owner added insulation to the floor and roof during remodeling to minimize heat losses. See fig 16 and 17

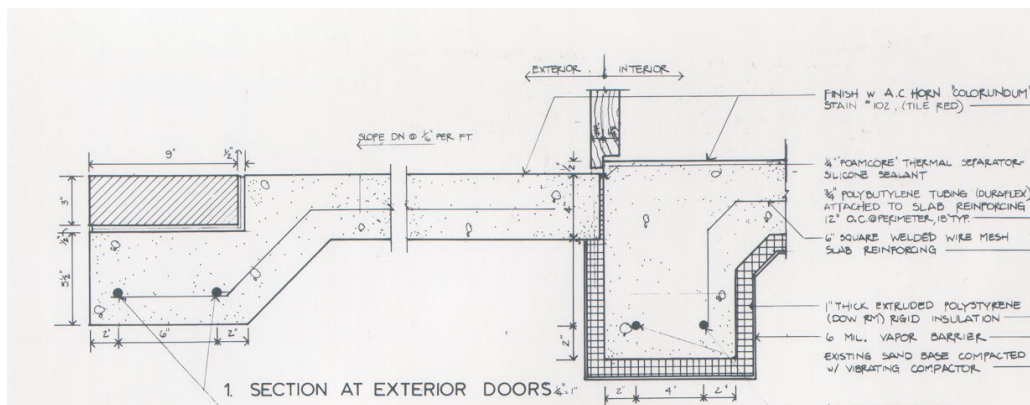


Figure 16 Insulation to the floor (1" thick extruded polystyrene rigid insulation with 6" vapor barrier)

⁷⁴ Frank Lloyd Wright, *The Natural House*, Horizon, NY, 1954, p 159

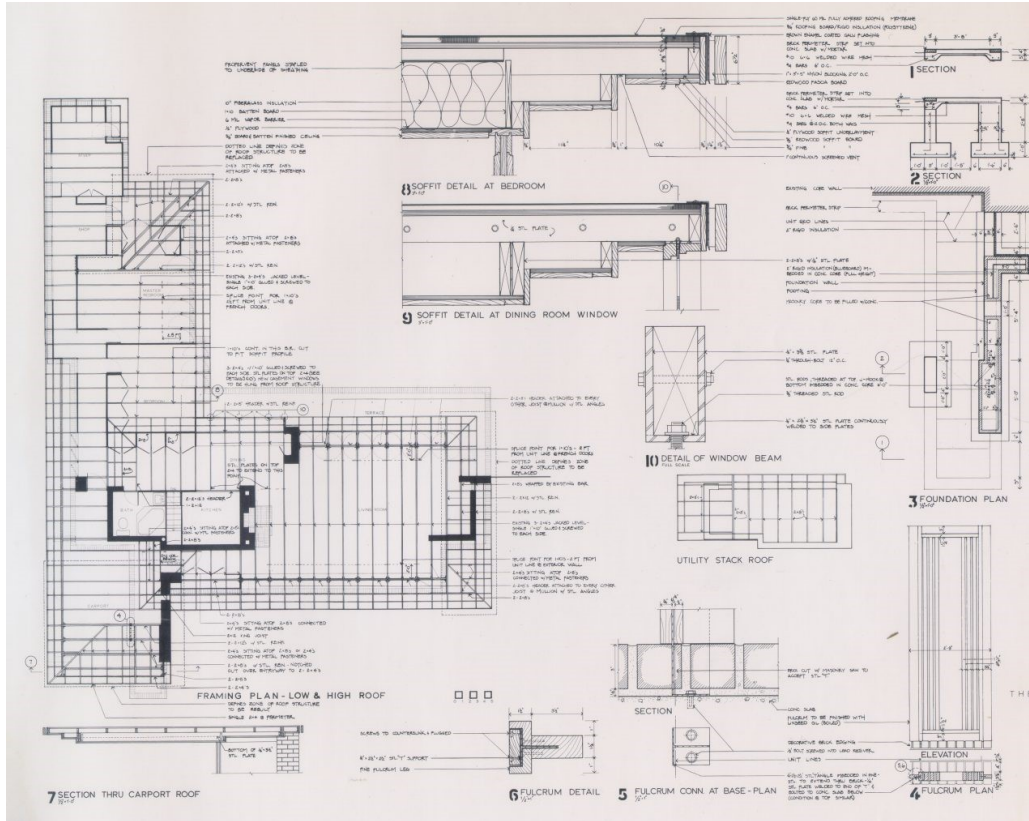


Figure 17 Roof insulation added by current owner as shown in soffit detail 8

*When you have the floor warm- heat by Gravity-Insulation of walls becomes a comparatively insignificant. You may open the windows in cold weather and still be comfortable because if your feet are warm and you seat warm, you are warm.*⁷⁵ This is what Wright believed, however practically speaking this may not achieve present day heating requirements. The heat supplied by gravity heat only partially compensates for heat lost through the walls.

The R value for a plywood $\frac{3}{4}$ inch plywood is 1.25. Considering the R value for board and batten wall as 0.8 on either side of the sandwich wall, the overall R value of the 2 $\frac{1}{2}$ inch wall come to about R-5. This insulation therefore will not be considered adequate for the walls in present day building standards. Replacement of the of $\frac{1}{4}$ " single glass plate to the living room doors and windows with thermal glazing (double glazing) by the owner definitely improved the insulation. The R-value for double pane window is 1.8 as compared with 0.9 of single pane window. The windows are good for passive heating terms. The solar heat gain coefficient (SHGC) for a double-glazed wood frame window is 0.58.

Today's insulation materials are cheaper component of construction. The geothermal heating system for a berm-type house will be economical for a net zero energy building as compared to a basement. Gravity heating proposed by Frank Lloyd Wright has a better heat distribution

⁷⁵ Frank Lloyd Wright, *The Natural House*, Horizon, NY, 1954, p 159 paragraph 2

throughout the building. Added insulation to the walls roofs and floors ensures that less heat is lost making the house energy efficient.

4.1.4 Ventilation

The kitchen is laid out in the service core made of brick work, where all walls support the storage cabinets, or appliances and kitchen worktop. These clerestory windows allowed odors to escape while at the same time ventilated the kitchen. Next to the kitchen is a short set of steps that led down to the cellar where heating, fuel, and laundry are located. The bathroom falls right at the end of this service core.

In the Usonian plan Wright called the kitchen a workplace which meant a place exclusively for cooking activities. The kitchen *became an alcove of the living room but higher for good ventilation and spaciousness. The kitchen being one of the places where smells originated, we made that the ventilating flue of the whole house by carrying it higher than the living room. All the air from surrounding house was thus drawn up through the kitchen itself.*⁷⁶ The idea of making the ceiling higher repeated in the bathroom to allow for ventilation by the clerestory windows.



Figure 18 Clerestory window opening at Kitchen near the ceiling that creates a ventilating flue



Figure 19 Free flow of air between Dining-Kitchen spaces shown

By calling it a ventilating flue, Wright presents the innovative ventilation strategy employed in the design. The natural air current escapes the clerestory window when opened as shown in figure 18. The cooking odors and stale air escape without getting back into other spaces in the house. There is free air flow between the dining and the kitchen (Fig. 19), and the connecting corridor with the living room. The temperature and pressure difference causes the air to move

⁷⁶ Frank Lloyd Wright, *The Natural House*, Horizon, NY, 1954, p166

upward through stack effect. The design of windows in terms of layout and height directs the flow of air (breezes) from one window to the other.

Natural ventilation is the key to the Usonian plan. Wright preferred natural ways of controlling the temperature and at the same time allowing air circulation. *To me air conditioning is a dangerous circumstance. Extreme changes in temperatures that tear down a building also tear down a human body.*⁷⁷ Wrights recommended intelligent care in decisions on air-conditioning. The less the temperature difference with the surroundings, the better for the human body. Wrights recommended intelligent care in decisions on air-conditioning. The less the temperature difference with the surroundings, the better for the human body. The natural air current is set up towards the kitchen as towards the chimney, no cooking odors escaping back into the house. Figure 20 shows the air current escaping through the high-level window rendering the spaces cool when the windows are opened.

⁷⁷ Wright 1954: 175.

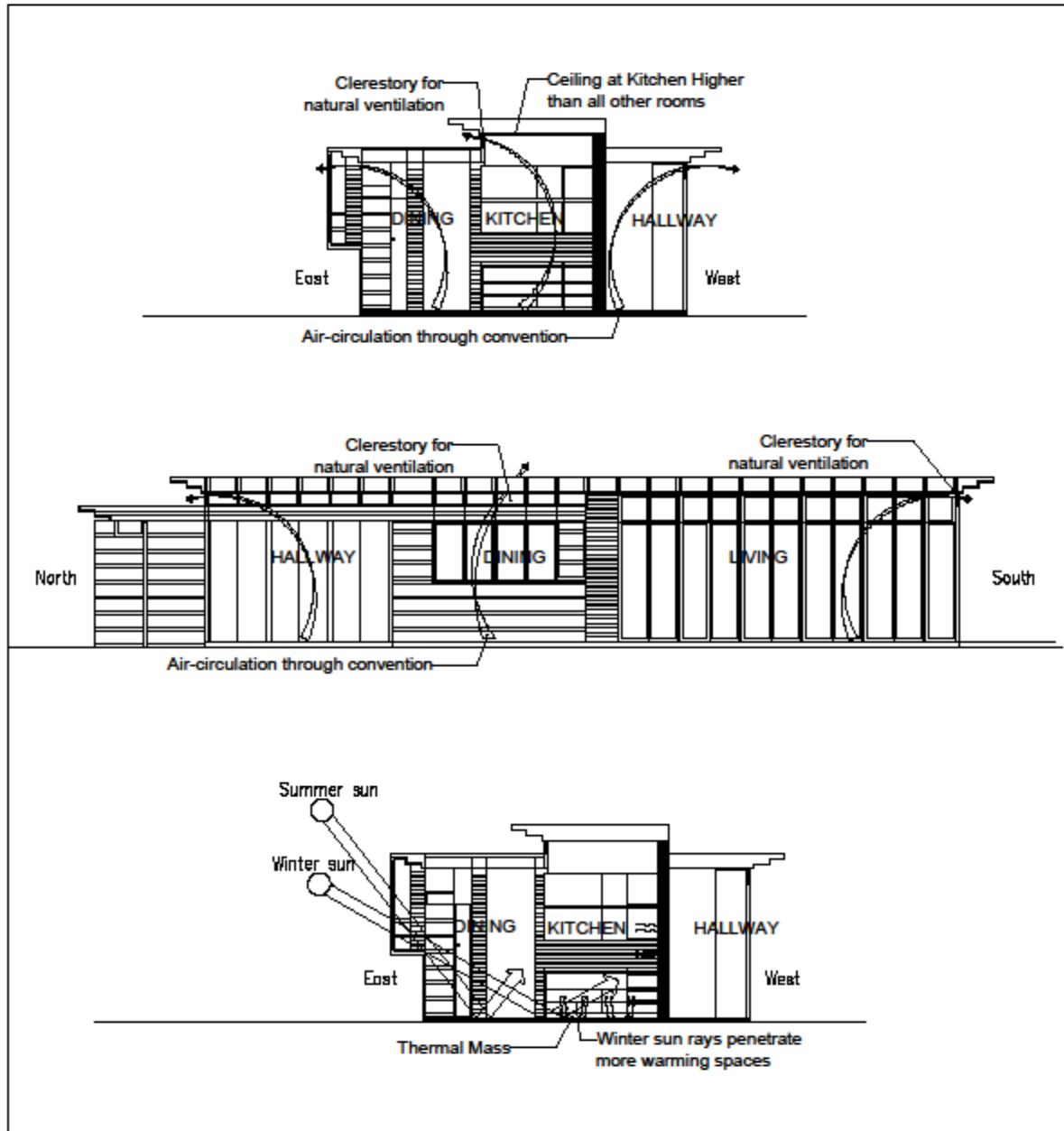


Figure 20 natural air current escapes the clerestory window when opened. Ceiling height at the Kitchen is higher than the living room and this helps in ventilating the space. During winter, abundant eastern sun rays enter through the window. The floor slab stores the heat that will later warm the spaces at night through the thermal mass effect.

4.1.5 Lighting

*The best way to light a house is Gods way-the natural way. Utilize day lighting and at night make it as nearly like day as possible.*⁷⁸ This statement is true for the Usonian concept and well demonstrated in Jacob's house. The way the house was oriented, the generous windows for the east facing living spaces, and the south facing bedroom windows. The house is sited in such a way that during winter the sun passes across the expansive glass providing sufficient light and heat. The lighting was well controlled through shading provided by the roof overhang. To the north side has a clerestory windows which serves as a lantern to illuminate the spaces. The electric lights are uniformly distributed to illuminate well at night at the same time maximizes the use of natural lighting during the day.

The west facing walls of the living room have clerestory windows that allowed limited lighting of the space (Fig. 21a & b). During the afternoons, limited western sun rays comes enters the living room and also acts as a vent. Locating the windows high enough controls the amount of light penetration. The overhanging roof also provides extra shading to allow light to come in only in the evenings when the sun is setting.



Figure 21a Interior of Living room facing the south. Generous windows facing east on the left.



Figure 21b Interior of Living room facing the north. West facing clerestory on the left

In the northern hemisphere, the sun moves from east to west and meets the earth's surface at low peak angle to the south. The overhanging roof prevents unwanted solar gain during the summer season, while at the same time allowing the winter sun to penetrate the interiors thereby creating the necessary warmth. Wright took full advantage of the sun and called it "the great luminary of life." The Jacobs house is naturally lit and well planned to ensure that the natural lighting is well distributed to serve the needs of its occupants without requiring artificial lighting. This approach minimizes the energy consumption in form of lighting. The artificial lighting complements the natural one; artificial lighting is well distributed by means of a well-designed track lighting in the living room. The track lighting extends from the middle of the kitchen and dining alcove to the living room on the south side, then continues along the enclosed storage spaces on the opposite northern side. The wiring of this track lighting is concealed in the piping and is part of the

⁷⁸ Wright 1954: 154

design. This makes maintenance easier as well as making the track lighting a special design feature.

Another interesting marriage between the artificial lighting and natural lighting is at the dining alcove area. Concealed lamps immediately above the table supplement the track lighting at the same time located adjacent to the bay window, forming a part of a light shelve structure for natural lighting during the day (See Figure 22). The bay window is facing the south which means that shelve lighting structure reduces light intensity as well as helps distribute the natural lighting to required areas in the kitchen space.



Figure 22 Concealed lamps immediately above the table supplement the track lighting and natural light from the bay window

It is very important for architects to assess the course of the sun at any given site to determine how well to harvest natural light and distribute it evenly to all spaces in a house. According to Wright *the architect needs to have a feeling for the course of the sun as it goes east to west.*⁷⁹

A closer look at the elevations of Jacobs house will reveal how Wright designed its envelope and a measure of how much natural light the windows bring in. The table 1 below shows an approximation of window surface areas for each elevation. From the areas one can analyze the window to wall ratio (WW R) to indicate the amount of natural light that comes in through the windows.

Elevation	Window area (square meters)
North	8.0
South	22.6
East	52.9
West	4.0
Total Surface area of windows	87.5

The table 1: Shows an approximation of window surface areas for each elevation.

⁷⁹ Frank Lloyd Wright, *The Natural House*, Horizon, NY, 1954, p154

The wall perimeter is 75m with wall heights that vary (2.4, 3.0 4.8). The total surface area of the perimeter wall comes to 236.2 square meter. See figure 23 Elevations of Jacobs house.

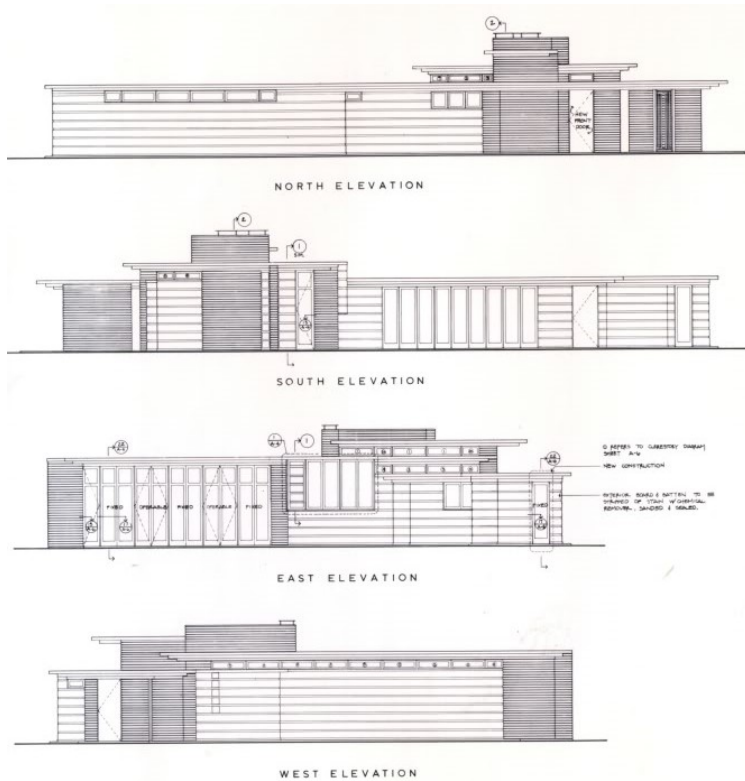


Figure 23 Jacobs house current elevations

The window to wall ratio comes to 37% (i.e. $87.8/236.2 = 0.37$). This ratio is for the overall house. It is also important to note that for the east elevation window area is more with the majority of windows in the living room.

Proper orientation maximizes benefits from the sun when solar cycles of a given site are predetermined using appropriate tools. The accurate degree of lighting balanced with shading will be achieved by adoption of tools like the heliodon. Such tools make architects decisions on the design more predictable and necessary justification for those decisions. The goal of minimizing the artificial lighting in this case is highly achievable and will lead to healthier buildings. Wright recommended that ordinarily the house should be 30° - 60° to the south so that every room has sunlight during the day. With the use of a Heliodon this will be well illustrated in a model to allow for architects to do the necessary adjustments to the design to fit into the site and ensure every room receives naturally lighting.

Frank Lloyd Wright believed that the best way to light a house was God's way. As such he made sure that every room in a house receives ample natural light during the day.

4.2 Observation

As Luis Fernandez Galliano puts it Energy has become a philosopher's stone that would make it possible to reconcile technology and nature, economics and ecology.

The definition of NetZero is to establish an energy balance. An autonomous building is a noble design goal, although the current NetZero buildings are more expensive than the house that meets the standard codes. The main objective was to search for the most economical way of arriving at a net zero building by using passive energy strategies. To discover the ways of addressing the cost issue it was important to study the Jacobs house which was built at a time of depression in order to come up with a feasible NetZero house. Through the study of Jacobs house architects will learn what is important, the well-being of the inhabitants of a building. It's important to understand the Jacobs house and improve on its design principles and execution to come up with an up to date version of an affordable net zero energy home without compromising the architectural integrity.

Although the term nets zero emerged in the 90s, the history of NetZero cannot be separated from the history of passive solar energy. The history of passive solar energy, the energy conservation movement of the seventies and the most recent environmental sustainability of the nineties are all inter-connected. The ideas behind the three movements are not new. Passive solar history is as old as architecture. The development of passives solar technologies was slowed down by the discovery of fossil fuels, the world wars, and politics, amongst other reasons.

Site orientation comes first. The layout of the buildings has been emphasized by many architects throughout the history of passive solar architecture. During the early phases of a project, it is crucial to analyze and study the solar patterns using appropriate technology, viable renewable energy resources, and use natural materials that are closest to the site. These recommendations will ensure great success for a NetZero energy building. Thermal mass is highly dependent on local climate and orientation. In the northern hemisphere when the sun reaches the wall and floor surfaces it generates heat during the day and stores it to warm the house at night. Interior materials with appropriate thermal properties will store passive solar energy. Proper insulation will minimize heat losses in a well-constructed airtight building envelope. Advancement in insulation technologies as in passive house design have made it possible to achieve net zero energy buildings for extreme climates as in the northern hemisphere.

Natural methods of ventilation will replace the overreliance on mechanical methods if Net Zero energy buildings are well promoted. Wright was against air-conditioning and preferred natural methods. For cold winter climates heat is needed to warm the houses. Significant achievements have been made to reduce the heat demand through well insulated and sealed envelopes. This has led to drastic reduction in both heating and cooling loads. Most over insulated passive houses today use heat recovery ventilators and energy recovery ventilators. More needs to be done to make these technologies simplified and user friendly. The Jacobs house is a clear demonstration of a house without any form of mechanical ventilation is achievable. However the passive house with an airtight envelope and controlled ventilation make them superior.

Benefits of utilizing natural lighting for a net zero energy building are reduced energy consumption that lead to substantial savings. Other benefits include protected human health and a productive work environment. The lighting in Jacobs's house is natural due to its abundant windows matched with minimal artificial lighting. There is an interplay between light and shade governed by the design of the roof, the location, and size of the windows. Adoption of latest technologies like use of high performance doors and windows appropriately during the design will improve thermal performance and energy efficiency for net zero energy buildings.

The philosophy of organic architecture ties all these passive strategies together. Organic architecture by Frank Lloyd Wright's brings about the reconciliation of technology, nature, economics, and ecology. Frank Lloyd Wright's houses belonged to the place, were part of nature. Issues of global warming and the negative effects of the built environment will be resolved by adopting this philosophy. The most economical NetZero energy buildings may be realized if all stake holders lead by architects embrace organic architecture philosophies.

Chapter 2 presented a history of Frank Lloyd Wright's philosophy of organic architecture and later the Usonian concept. Wright's philosophy of organic architecture has roots from his utilitarian family beliefs and some of the influences include his father's music interest, Froebelian toys introduced by his mother, and Wright's love of nature.

The Usonian concept came from ideas developed from earlier Prairie style for the rich as an authentic American architecture available to a common person. Starting with the Jacobs house Wright came up with a simplified prototype design, with the use of natural materials, in the spirit of democracy and freedom of individual family. This was a departure from the previous era of highly ornamental styles like the Victorian houses that were borrowed from Europe.

Wright successfully created an America identity through transcendental ideas derived from Frank Furness and his mentor Louis Sullivan. Transcendentalists like Ralph Waldo Emerson, Henry David Thoreau, and Walt Whitman embodied the concepts of nature, American identity, and Universalism in their architecture. These concepts permeated Wright's organic architecture philosophy.

Wright was against sprawls, traffic congestion and centralized city cores and came up with the Broad Acre city ideas, which were born at the same time as the Usonian concept. The Usonian concept was the idea of affordable suburban development in a decentralized urban plan, just as promoted by the Broad Acre proposal. Community based low density cities are more sustainable and more environmentally friendly.

In Chapter 3 Frank Lloyd Wright identifies the house of moderate cost as a major architectural problem in America. Wright characterized the problem as idiosyncrasies confused with tastes, predilection in place of prejudices, and ignorance to become a virtue. These harsh words come at a time that America had experienced the great depression. The Usonian concept came at a time when America was still struggling to recover and regain its former glory. It was an attempt to instill virtues, a new culture that embodied the spirit of democracy. The Usonian house was to be a reflection of an authentic American way of life.

The Jacobs house became Wright's solution towards a radical change in approach by shredding the excesses of the past. By elimination of the insignificant Wright simplified the approach to architecture by re-examining all the processes from design to construction. The Jacobs house was a radical experiment with a young couple and also an opportunity to instill gracious living by creating a sensible size of a house. The theme was to meet the needs of a growing family and using his beliefs in organic architecture as a platform. The design was truly organic, belonged to the place, where the materials were all matched both for the inside and the outside. It's not built to impress the neighbors but to serve the interests, needs of a growing family and at the same time make life pleasant for them. The innovative gravity heating system was used with the revolutionary sandwich wall system. The use of the machine to fabricate all the components made for easier erection at the site. This new approach spread and influenced the way houses were designed not only in America but also internationally. European internationalists like Walter Gropius, Mies Van de Rohe, and Karl Schneider admitted having been influenced by Wright. This was not without controversy as seen with the visit of modernist architects like Walter Gropius.

Organic architecture brings about a marriage between design of buildings and nature. Organic architecture imitates nature and works with it. The building and its components are blended together with the surroundings and become one with it. The resultant is what Frank Lloyd Wright called 'grammar'. This architecture creates a harmonious relationship with its site, climate, and overall environment. The rhetorical term organic emerged from the environmental crisis and the debate there after which lead to reinventions and revisions of the core principles of planning in architecture. Organic architecture a design process of nature where new solutions based on unique site conditions of a project are created.

The Jacobs house and the evolution of the Usonia creates a roadmap for which the NetZero will have to follow. A prototype that underwent stages of continuous improvement in the hands of a dedicated apprentice and loyal clients such as the Jacobs. This is seen by contributions of historians like John Sergeant. All the passive strategies were evident. For the Jacobs house the board and batten sandwich wall was created with an assumption that the gravity heat would compensate for lack of insulation. Although the design did not perform as expected for the extreme Wisconsin weather, the sandwich wall offers an alternative wall system that could be improved. The current owner has incorporated insulation for the roof and the floor slabs, which has tremendously improved the designs performance. The quality of the window's design has contributed to this improvement when the owner changed from single to double pane windows. The design is still capable to accommodate changes in technology.

4.3 Summary of passive strategies

As for orientation, the choice of a lot plays a significant part in the success of a true net zero energy building. Frank Lloyd Wright clearly demonstrated this as seen in chapter 3 where the Jacobs had purchase a different lot to suit the design. This presents a case to city planning, and developers during the lot layout. Lessons can be drawn from the ancient Chinese and the Romans to create passive cities. Sufficient spaces to allow green spaces, trees for shading and more

family focused designs the like Usonian houses. In terms of orientation the Jacobs house is successful.

Early analysis of a sites' topography reveals notable features such as landscape, wind direction, and other characteristics. By adopting appropriate tools for analyzing the solar patterns in a given site, it becomes easy to come up with the most feasible layout to tap into the passive solar energy resources.

In regards to massing the floor of the Jacobs house is able to hold some solar heat during the day in the winter and this is complemented by the gravity heat system. The walls are made of wood which does not retain much heat. The owner made positive changes by casting the water pipes in the concrete slab to replace the previous pipes that were laid under the slab. Considering the number of years, the cast iron pipes were in place it is reasonable to conclude this this method is a success.

It is also apparent that insulation was an issue in the Jacobs house. The current owner added insulation to the roof and the slab to prevent heat loss. Insulation of the wooden walls still remains a challenge in terms of heat loss. Even though the gravity heat warms the spaces sufficiently, much energy could be conserved if insulation was incorporated. This poses a design challenge on how to add insulation without compromising the original design. Although the sandwich wall was acceptable at the time it was constructed, it has insufficient insulation by today's standards. The sandwich wall is still a brilliant innovation.

Ventilation is a great success in the Jacobs house. The house is naturally ventilated and operates successfully today's as per Wright's design. Air circulation is well controlled by natural means as demonstrated by the design of openings and heights of the various spaces.

The Jacobs house as with other Usonian houses is naturally light. There is also an interplay between the natural and artificial lighting.

Chapter 5.0

5.1 Conclusions

The main goal of this research has been that of addressing the relevance of some of the many passive strategies that can be adopted for the achievement of a true passive solar design. These strategies will benefit the approach ongoing research of NZE that is considered important milestone in the history of passive solar architecture.

The Jacobs House is a fundamental precedent from this point of view.

First of all, it is affordable, i.e. the issue of cost constitutes one the primary concerns of the designer, to respond to the necessity of a client. Affordability is fundamental because it allows for a building solution to be adopted by a larger community of individuals. Once the clients are empowered they can make choices lifestyle, raise their families, and hence it will allow a building to have political significance.

Secondly the Jacobs House aims to be “as passive as possible” in the sense that it tries to reach an almost complete autonomy from mechanical systems operated by sources of energies that rely on net-systems (like electricity) and fossil-fuels.

I have identified 5 Passive strategies: Orientation, Thermal Mass, Insulation, Natural Ventilation, and Lighting.

The Jacobs House still depends on net-systems as for what concerns heating, artificial lighting, sewage, water and certainly it does not give back to the “system” the same amount of energy that is necessary for its performance. But the ideal purposes for which it was designed and built show a radical concern about passive building systems and political and economic matters.

The history of passive energy illustrates that the essence of the term NetZero is not new. The passive strategies are as old as architecture. Many human dwellings and settlements have been designed imagining an equilibrium – if not harmony – with the environment and its resources. Frank Lloyd Wright figured this out and came up with his philosophy of organic architecture.

But the NetZero building is not just a passive building: it is rather an active social, political, and economical project as the Jacobs House demonstrates. Effort will have to be made to make NZE buildings more sustainable by adopting principles of organic architecture.

The Jacobs House represents an important turning point in the history of “sustainable” architecture: it shows that a radical shift can be imagined even if we have to rely on many productive processes and systems that are not fully NetZero. A turning point from the Victorian designs to the modernist houses.

The overall performance of Wright’s passive strategies shows that they were certainly successful. The Jacobs House was the initial experiment that informed a large-scale Usonian project. It’s a “show case” for how to approach the research on NetZero house using passive strategies. The radical nature of NetZero house is its ability to produce energy it consumes to

complement other sources of energy such as the grid. Borrowing ideas from the Jacobs house will propel the research of passive solar architecture to greater heights.

There are successes and failures in the Jacobs House and I hope I have been able to clarify and explore them in this thesis.

In these conclusions, it is important for me to restate that there are many reasons why the Jacobs House's project took place in the office of Frank Lloyd Wright. His innovative research on the idea of "organic architecture" is fundamental from this point of view. But there were also many economic and political reasons involved in the decision to develop this kind of research. The politics of war had affected Wright's career and he was considered an anti-establishment architect. Moreover, many of his Usonia clients were denied mortgages for political reasons. The architect and the client wanted to work in harmony, not only with the sun and the seasons but also with the financial institutions and all "stakeholders" of a difficult economic situation. They wanted to create an affordable housing project to be promoted together with the construction industries, to ensure a successful economic and political outcome. The Jacobs House project is not just a technical and idealistic research but also a political and economic one.

Today the main reason for the slow advancement of technology in the research on NetZero buildings has a lot to do with the global economy and the fossil fuels politics. All what is happening globally is difficult to comprehend from an architectural point of view. And yet we have to make this effort as Wright tried do.

Can we say that the world has come to realize the dangers about the excessive use of the fossil fuels and the negative effects of global warming? We, as architects, must contribute to the creation of this awareness.

The architectural profession and the academic environment will need to fully embrace this type of research today.

One suggestion would be to create a prototype in continuity with the Jacobs house project in collaboration with a team of experts who can carry on the experiment with different scenarios. The lessons that can be learnt at every stage can be monitored by all the "stakeholders" in direct connection with the architects. Stakeholders such as Authorities Having Jurisdictions, Financial Institutions, and professional bodies will need to collaborate in support of such initiative.

The scale of the net zero project will have to be large enough to create a community for low income housing, cooperative, or even private development. Borrowing a leaf from Frank Lloyd Wright's Broadacre model will present opportunities for cutting down the cost due to economies of scale. This type of models will allow for innovations and testing of applicable byelaws. 21st century technology does allow for easier and faster explorations of multiple ideas and simulation of energy needs. Within this type of development all the passive strategies will be adequately addressed for better outcomes.

Our current building challenges can be overcome. Architecture should not shy away from energy issues since energy plays a major role in our livelihood. Architecture integrates many professionals both inside and outside the building industry.

The “organic architecture” principles defined by Frank Lloyd Wright will have to be adapted to our contemporary problems but they can bring our buildings closer to what he called “nature,” that is a concept that we have the task to rethink afresh.

By doing so will the environment be sustainable? What is the relationship between NetZero building and sustainability research?

This is the definition of the NetZero building today:

ASHRAE defines a Net Zero Energy Building as a building that produces as much energy as it uses when measured at the site.⁸⁰

This is the definition of Sustainable building today:

Green building (also known as **green construction** or **sustainable building**) refers to both a structure and the using of processes that are **environmentally responsible** and **resource-efficient** throughout a building's life-cycle: from siting to design, construction, operation, maintenance, renovation, and demolition. In other words, green building design involves finding the balance between homebuilding and the sustainable environment. This requires close cooperation of the design team, the architects, the engineers, and the client at all project stages. The Green Building practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Market Transformation Program and certification.⁸¹

The NetZero principles and strategies, considering the meaning of the term “net zero” could be, at least theoretically, much more radical than the Sustainable ones. They are obviously strongly interrelated principles, relating one with the other; but we should not lose the radical meaning implied in the terms: “Zero” should not simply be the result of a numerical balance between numbers. The “net” is certainly irrevocable and irreversible.

The Jacobs House project shows that very broad political, economic, and moreover human idealizations are necessary to carry on a specific technical solution. Likewise, NetZero energy buildings will have to face similar challenges, as it marks an epoch in the passive solar architecture history.

Wright was certainly rooted in his context, and fully aware of passive limitations, and yet he was a visionary architect. This thesis suggests that the coming together of these qualities is necessary to create the idea of a resilient community of individuals that can adapt to rather unpredictable conditions.

⁸⁰ ASHRE Vision 2020 Report: Producing Net Zero Energy Buildings, Prepared by ASHRE Vision 2020 Ad Hoc Committee, 2008 p. 3

⁸¹ https://en.wikipedia.org/wiki/Green_building

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