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Understanding Net Zero Energy Building Concept Through Precedents from Different Climate Zones

Farshid Roudi

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Approval of the Institute of Graduate Studies and Research

Prof. Dr. Serhan Çiftçioğlu
Acting Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Architecture.

Prof. Dr. Özgür Dinçyürek
Chair, Department of Architecture

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Architecture.

Asst. Prof. Dr. Harun Sevinç
Supervisor

Examining Committee

1. Asst. Prof. Dr. Polat Hançer
2. Asst. Prof. Dr. Harun Sevinç
3. Asst. Prof. Dr. Pınar Uluçay

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ABSTRACT

The building sector accumulates approximately a third of the final energy consumption. Consequently, the improvement of the energy efficiency in buildings has become an essential instrument in the energy policies to ensure the energy supply in the mid to long term moreover is the most cost effective strategy available for reducing carbon dioxide emissions. The International Energy Agency asserts that `energy efficiency improvements in buildings, appliances, transport, industry and power generation represent the largest and least costly savings' in emissions.

Much of the stress people impose on the earth is manifested in the way architects design, construct, and use in built environments; that means buildings and cities must play a vital role in shaping sustainable future. Net zero energy buildings are tools in shaping this future. They are as much representatives of a global approach to build environment as they are exemplary buildings. The lessons they can teach about the power of integrated design and delivery, and about the true interconnectivity between human built environment and the natural world, can be applied to a diverse range of sustainable solutions, such as net zero waste and sustainable water balances in buildings and communities.

There is a powerful synergy between net zero energy objectives and other holistic sustainable goals. They all require a focus on performance and an integrated delivery process. Many strategies that reduce energy use can also have a positive impact on indoor environmental quality and, thus, the health and well-being of occupants. The

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net zero energy approach can be taken to any scale and positively affect the way build and live in communities and cities.

One of the ways to introduce net zero energy is through a simple conceptual equation, which states that net zero energy equals the accumulation of passive design plus energy efficient building systems plus renewable energy systems, all over an integrated process. On the other point of view designing and building a net zero energy building means that from beginning, energy demands and energy generation must be consistently kept in balance.

This thesis specified some of design requirements of energy efficiency to reach the most cost effective technique intended for minimizing carbon dioxide emissions. Moreover this thesis mostly focused on evaluation of some design requirements of net zero energy building in different climate zones by goals of understanding which kind of requirements better fit each building’s unique climate zone.

Keywords: Net zero energy building, Energy efficiency, Design requirement

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ÖZ

İnşaat sektörü, enerji tüketiminin yaklaşık olarak üçte birini oluşturmaktadır. Sonuç olarak, binalardaki enerji verimliliğinin artması, uzun vadede mevcut olan enerji gereksinimini sağlamak adına önem teşkil etmekle birlikte, karbondioksit emisyonlarının maliyetinin azaltılması adına çok önemli stratejik bir enerji politikası sağlamaktadır. Uluslararası Enerji Ajansı "binalardaki enerji verimliliğini iyileştirmek, ev aletlerinde, ulaşımda, sanayide ve enerji üretiminde en düşük maliyette enerji tasarrufu ile gerçekleşebileceğini' ileri sürmektedir.

İnsanın stres durumunun mimari çizimlerine yansımakla birlikte, inşaat ve çevreye uygulayacağı mimari binayı oluşturmada bunu yansıtabileceği görülebilmekte; bu da binaların ve şehirlerin geleceğini sürdürülebilmesinde ve şekillendirebilmesinde hayati bir rol oynadığı anlamına gelmektedir. Net sıfır enerji binaları, geleceğin şekillenmesinde önemli araçlardandır. Bu tarz binalar küresel gelişimde örnek teşkil eden yapılardır. Bu tarz binalar bütünleşmiş tasarım gücünü öğretebilmekte, doğal dünyada insan ve çevre arasındaki doğru birleşimi ve çözümü uygulayabilmektedir. Buna en güzel örnek de boşa harcanmayan sıfır tüketimli ve su tasarruflu binalardır.

Net sıfır enerji hedefleri ve diğer bütüncül sürdürülebilir hedefler arasında güçlü bir sinerji vardır. Hepsi performans ve bütünleşmiş teslim işlemi gerektirir. Enerji kullanımını azaltmak, kapalı çevre kalitesi üzerinde olumlu bir etkiye sahip olabileceği gibi, sağlık ve refahı da sağlayabilmektedir. Net sıfır enerji yaklaşımı her ölçekte alınabilen ve olumlu etkilerle yaşanabilir toplumlar ve şehirler inşa edebilmektedir.

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Net sıfır enerji tanımını anlamanın en basit kavramsal yolu şu şekilde izah edilir; pasif tasarım, verimli enerji sistemleri ve yenilenebilir enerji sistemlerinin entegreli bir şekilde çalışması sürecidir. Bir başka görüşle izah edilecek olursak, net sıfır enerji binasının yapılma sürecinin ilk aşamasından itibaren, enerji taleplerinin ve olası enerji gereksinimlerinin veyahut üretiminin dengede tutulması ön plandadir.

Bu tez karbondioksit emisyonlarını en aza indirmek için tasarlanmış en uygun maliyetli tekniğe ulaşmak için enerji verimliliğini ve tasarım gereksinimlerinin birkaçı üzerinde durdu. Ayrıca bu tez'de, net sıfır enerji binasının farklı iklim bölgelerinde farklı amaçlar doğrultusunda her binanın bazı tasarım gereksinimleri üzerinde durulmuştur.

Anahtar Kelimeler: Net sıfır enerji binaları, Enerji verimliliği, Tasarım gereksinimi

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I am heartily thankful to my supervisor, Asst. Prof. Dr. Harun Sevinc, whose encouragement, supervision and support from the preliminary to the concluding level enabled me to develop an understanding of the subject.

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Chapter 1

INTRODUCTION

Net zero energy is a measure of a building's energy performance, whereby it produces as much or more renewable energy as it uses over the course of a year in operation. Two key concepts make up this definition of net zero energy. First, net means that nonrenewable energy sources may be used; but over the course of a year, enough renewable energy must be generated. The second key concept is operation. The period for measuring performance is one year of operation, to include all seasonal variations. It is possible to demonstrate a net zero energy in design. During the design process stage, the important criteria for achieving net zero energy building are the target of this study.

1.1 Research Problem

In this study research problem is concerned with the requirements of achieving net zero energy building in different climate zones. Also the growing energy prices, number of people and energy consumption with limited energy sources caused the interest about buildings with low energy consumption.

Moreover net zero energy building is not categorized in different climate zones, this study is conducted to cover this gap. Net Zero Energy Building in different climate zones has different requirements which desire for any construction, but such a desire can't be make without considering all building aspects like: design, construction and performance. For achieving the goal of Net Zero Energy Building

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like establishing carbon neutral building first of all have to reach a significant reduction of load and efficiency of the system, after that met loads remain by onsite energy generation.

1.2 Research Aim and Questions

The research questions of the study are:

What are the important criteria for achieving net zero energy building?

How could net zero energy building be achieved in different climate zones?

The aim of this research is assessing the net zero energy building requirement in three main climate zones. For achieving this goal, a comprehensive research of the relevant literature is done as well some cases are employed for better illustration of the topic. Net zero energy buildings significantly reduce energy requirements by implementing energy-efficient design strategies, such as optimization of the building envelope, smart and efficient system selection and design of renewable energy.

1.3 Research Structure of the Thesis

The initial part presents the theoretical structure. The second chapter is the literature review part: It includes basically a wide broad literature review on books, technical journal papers, article, documents, and thesis and research projects in net zero energy issues.

The third chapter is the analysis of selected case studies from different climate zones like Canada and Switzerland (cold climate zone), United Kingdom and Germany (moderate climate zone) and La Reunion Island (hot humid climate zone) where the improvement and industry implementation of very energy-efficient building methods as net zero building concepts is presented. Also the

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analysis about the results from the different climate zones and case studies is presented in this chapter.

The conclusion part (chapter 4) will focus on your possibilities and limitations to improve the final user approval and reveal them as platform of the enhancement of net zero-energy buildings.

1.4 Research Methodology

In this study methodology is based on literature review in combination with experimental study in order to collect data which are gathered from books, articles and scientific journals related to the aim of the study for better understanding the concept of net zero energy building. So data analysis had been done in order to find out the special requires of net zero energy building of each specific climate zone.

1.5 Limitation and Scope

Obtaining net zero energy building requires a good design, construction process and operation stages, but due to time limitation only design process will be considered and the study is about requirements and application of net zero energy buildings. The scope of this research is based on three main climate zones exemplified with five case studies, due to some difficulties in accessing the relevant cases that exactly fit the purpose of the study. These cases are chosen on the cold, moderate and hot-humid climate zone. Moreover, this study considers the relationship between energy efficiency issues and Net Zero Energy Building Requirements.

1.6 Literature Review

It is truly hard to identify a building that could be named the Net Zero Energy/Emission building. One reason for that is perhaps absolutely no Energy

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Building is a novel concept in construction, because this concept sounds to be very modern, because till now district heat and power warmed up having timber or maybe straw and lighted with candles along with also pets were used as energy sources in buildings.

Even so, in the late 70s and commencing eighties several articles have been published under the topic of net zero energy buildings like: ‘net zero energy house’, ‘a natural energy autonomous house’ or even ‘a strength self-sufficient house’. It had been time when outcomes from the oil crisis started to be recognizable with the concern of the fossil fuels sources along with power use turned to be argued. Nevertheless, those documents were mainly concentrated on the energy effective equipment and unaggressive solutions applied inside the building. Furthermore, simply energy demand with regard to domestic hot water, space heating and cooling were accounted in the ‘net zero’, that are applied in real cases of net zero energy buildings.

Within the decades, diverse Net Zero Energy Houses were defined and weighed, but pretty much in every paper the net zero energy building either was described in a different way or maybe no description was utilized. Usually, the approaches net zero energy objectives were attained become considerably affected the net zero energy building definition. Freshly, lacking of common understanding and common definition pertaining to net zero vitality building became recognizable, since this building concept is viewed as an effective option for decreasing the vitality use and greenhouse gas emissions since building area.

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The key objective is usually to give an overview of current Net Zero Energy Building descriptions. The evaluation displays that Net Zero Energy Building is really a multifarious idea defined by extensive variety of conditions and terminologies. Using resemblance and also differences in the explanation on the obtainable universal literature, a variety of methods intended for net zero energy creating vary explanations.

In many articles allocated in which Net Zero Energy Building regularly highlights deficiency of common knowledge of what need to be equal to ‘net zero’. This challenge has recently been broadly argued in many journals on the other hand, the issue: should “net zero” consider the energy, the energy or the CO2 emissions or it could be energy fees, still has not been absolutely solved.

Overall description for Net Zero Energy Building specified by the U.S. Department of Energy (DOE) Building Technologies Program: "A net zero-energy building is a commercial or residential building with significantly energy decline desires over efficiency gains such that the equilibrium of energy desires can be provided with renewable strategies.” However they also point out clearly undefined ‘net zero’ (Torcellini et al., 2006).

The Publication "NET ZERO ENERGY BUILDINGS" published in 2013 discussed the appropriate energy policy for the future and the growing concerns about climate change. On the one hand, the building, maintenance, and operation of constructions during their life cycle consume huge volumes of energy and causes emissions. On the other hand, alertness and established measures for all sorts of constructions can reduce the level of consumption and emissions.

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Moreover, the book titled "Net Zero Energy Design" published in 2013 discusses the architecture of the commercial buildings, and concentrates on: How is it possible to achieve the goal of a net zero energy commercial building? This book is focus on personal project experience of Thomas Hootman, a member of national renewable energy laboratory, who studied about net zero energy buildings.

There are two papers which focus on the net zero energy buildings: The first one is "Criteria for Definition of Net Zero Energy Buildings" published in 2010; it is about the idea of a Net Zero Energy Building.

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Chapter 2

ENERGY EFFICIENCY ISSUES

In 2010 European Commission and Parliament, the recast adopted guidelines for energy performance of buildings which requires that all new buildings after 2020 should be "nearly net zero energy buildings". A nearly net zero energy building has a very high-energy performance and that an on-site or nearby renewable energy supply should cover a significant portion of its energy needs. Also in September 2010, the California Public Utilities Commission setting up an action plan Zero Net Energy, calling for net zero energy residential buildings by 2020 and net zero energy commercial buildings by 2030. Leveraging a network of diverse stakeholders, the action plan defines net zero energy as a necessary goal. So these are the answers of importance of net zero energy buildings (Hootman T, 2013).

2.1 Net Zero Energy Building

The decrease in the building’s running costs and reduction of environmental footprint are the main advantages of net zero energy building. This influences sustainability of environment as well as safe of energy. During the process of design and construction of the buildings, more investment and energy are needed to energy efficiency improvement. However, if the improvement of the energy efficiency is achieved by low cost actions, it can lead to some important advantages (Hoyle, 2011).

The power demand reduction for services, heat exchangers, electrical energy, and heating generation would lead in decline in costs and increase in the savings for these

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kinds of buildings in comparison with the typical ones. In a building with net zero energy, a high portion of the extra and unnecessary costs of the building can be covered by the cost savings from the services systems. In the buildings which the simple systems of services are employed the costs of connections and care are reduced by a considerable share. The window technology, the ventilation, the thermal insulation, and the current criteria of construction determine the significance of extra investment in net zero energy technology. The attempts to be successful are all influenced by the previous experiences of technologies for net zero energy building.

By way of the market demands for net zero energy buildings increases and the providers of such buildings gain experiences, the extra costs will fall. The independence of current technology in construction, any net zero energy building over its lifetime is considered as an economic investment.

2.1.1 Definition of Net Zero Energy Building

The buildings with net zero energy have economic, social and environmental advantages. They provide, simultaneously, the least life cycle expenditures and the greatest market value. These buildings, also, offer a new criterion for buildings with high performance. The net zero energy buildings can represent greater quality for internal environments which improves the inhabitants' quality of life. They, moreover, would intense environmental profits associated with resource and energy conservation and reduce the emission of greenhouse gas dramatically. All these tangible benefits can offer a solution for the global challenges of humanity and make a better future planet (Marszal et al., 2011).

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Generally, the energy performance of a building is measured by net zero energy, since it generates as much or in some cases even more renewable energy as it consumes during a year in operation. This definition of net zero energy is made up of two main concepts. Firstly, net means that sources of nonrenewable energy e.g. nuclear and fossil fuel may be consumed; but during a year, the generation of renewable energy must be enough to exceed or compensate the nonrenewable energy usage. By zero energy it doesn't mean building energy utilizes zero energy consumption; reasonably, it refers to attaining a position of net zero energy that includes demands of full program. Operation is the other main concept. Here the operational aim is net zero energy. The optimal period to assess performance is one year, because during this period all seasonal changes can be involved and measured. The demonstration of a net zero energy in design is possible. Actually, this is a part of the procedure to attain net zero energy. But actual assessed operation is needed to achieve a correct goal means net zero energy.

The procedure to goal is altered by using the word "operation" in the definition. It shows both the project's delivery and design are involved. Simultaneously this develops the process, and by aligning the operations, residents, owner, delivery professionals, and construction it applies a more combined process in total. Net zero energy designing is only one step; in fact the main goal is the operation.

Buildings with net zero energy systems, primarily, consume very low energy. The highlighting of this fact is significant. Net zero energy's objective is not to protect sufficient renewable energy for a project without considering the efficiency of energy. This is an unstylish and very expensive solution. Using very low energy is

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the characteristics of net zero energy buildings. These houses have to meet their energy needs during a year and generate adequate devoted renewable energy. Four approaches have been defined by the National Renewable Energy Laboratory of U.S (NREL) to measure and describe net zero energy for buildings: costs of net zero energy, net zero source energy, emissions of net zero energy, and net zero site energy (Hootman, 2013).

2.1.1.1 Net Zero Site Energy Building

Allocated for at the site, a building with net zero site energy system generates at least as much renewable energy as it consumes during a year. The measurement is done quite literally at the site; that is, if a building site is limited to a boundary, the site energy measurement will be attained by measuring and adding up all amount of the energy consumed within the boundary (see Figure 1).

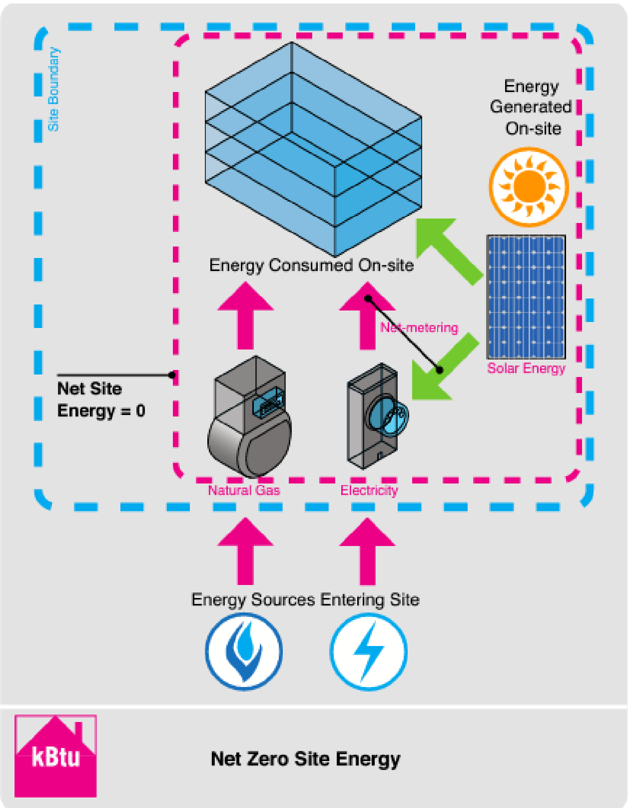

Figure 1: Net Zero Site Energy Diagram (Hootman T, 2013)

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This is the most frequently employed and explicit measure for net zero energy. Since, it indicates what would be recorded at the meter. And, it can be easily accounted for because the elements which are necessary for other net zero energy measures are not required here (Hootman T, 2013).

2.1.1.2 Net Zero Source Energy Building

When net zero source energy buildings are accounted for at the source of energy, they can generate renewable energy as much as their use during a year. The related factors to this measure provide energy to a site. For instance, at the source it receives about three times more energy from grid-based electricity and coal-fired in comparison with what is measured and delivered at the site.

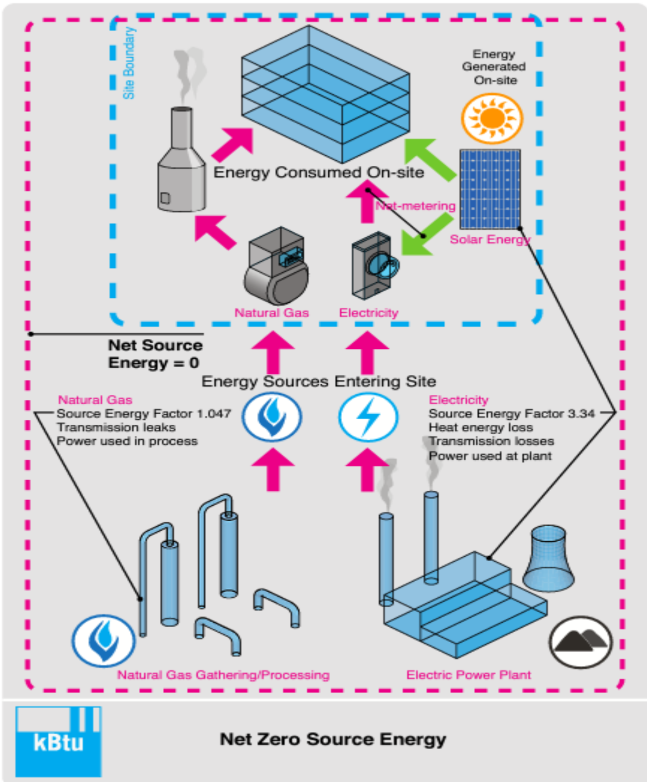

Figure 2: Net Zero Source Energy Diagram (Hootman, 2013).

The reason is many losses are resulted from generation and transportation of electricity, as displayed in figure 2. Thus, a perfect picture of energy usage is given

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by source energy. To assess use of source energy, the determination of a site to source energy factor is needed for every energy source consumed and employed to the site energy worth.

2.1.1.3 Net Zero Energy Emissions Building

A building with net zero energy emissions creates sufficient renewable energy without emissions to compensate releases from all energy consumed in the building for a year. Whereas the measures to assess the source and site energy are energy units, energy emissions are evaluated in form of greenhouse gas emissions with carbon-equivalent correlated with the building's energy use.

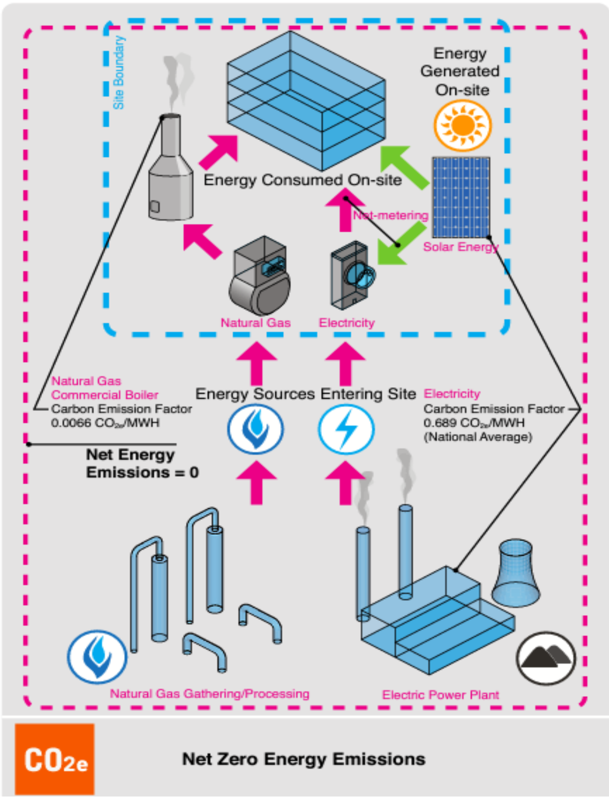

Figure 3: Net Zero Energy Emissions Diagram (Hootman, 2013)

As illustrated in figure 3, the application of a carbon emission element to the use of site energy, for fuel or energy source employed in a project, is necessary to determine the amount of energy emissions. In this estimation, the emissions from

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fossil fuel are offset by generation of renewable energy (Hootman, 2013). The main worth of a net zero energy building is quantified by the definition of net zero energy, so it carries crucial significance: the emissions of greenhouse gas removal from building operational energy. To consider a building with energy operation for a building carbon-neutral one way is provided by this definition.

2.2.1.4 Net Zero Energy Cost Building

The amount of financial credits that a building with net zero energy costs gets for exported renewable energy is at least as much it is charged for the utilization of energy and energy services for a year (see Figure 4). Several parameters are needed to be followed to observe this definition. On the side of utility cost, fees, peak demand charges, the rate structure for energy use, and taxes are included. With respect to the time of use rate structures are charged by some utilities, which must be factored in.

Briefly, to observe and apply this measure, charges of all energy and energy services on the utility bill must be involved. The credited value by utility company for any renewable energy which has been exported to the grid is a factor that must be followed on the credit side. Ideally, before using grid based electricity, an important part of renewable energy and also peak demand would be offset by the on-site renewable energy. However, it is noteworthy to mention that the generation of renewable energy is extremely changing and in real time may not match up reliably with peak demand and energy use. To this end, possibly the implementation of strategies and systems to reduce effective demand and manage demand, respectively, are inevitable. The utility companies will apply their own net metering plans that describe how generation of on-site renewable energy is qualified.

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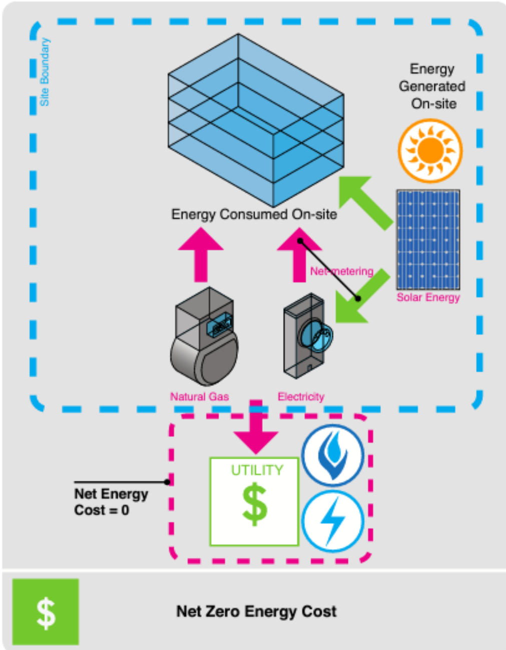

Figure 4: Net zero energy costs diagram (Hootman, 2013)

Based on whether the grid-based electricity is imported or on-site renewable energy is exported by the building, net metering provides the conditions for meters to run both backward and forward. A one-to-one exchange of exported and imported electricity are allowed by correct net metering electricity, this permits to credit renewable energy with the retail rate which is identical for the imported electricity from the grid. However, sometimes some utilities credit excess exported renewable energy on monthly or annual basis at wholesale rates not retail rates.It’s also necessary to mention that the complete economic picture of a net zero energy building is not given by the definition of net zero energy cost. It explains exactly the net price that is charged by using the nonrenewable energy. One vital component ignored by this measure is the investments which are done in the renewable energy systems. As just a building with net zero energy still consumes energy, the other buildings with net zero energy cost would suffer renewable energy expenditures. The identification of a main value for a net zero energy building is one of the key advantages of this measure: energy cost savings (Hootman, 2013).

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2.1.2 Classification of Net Zero Energy Buildings

To measure net zero energy it is crucial to have standardized descriptions and procedures. With a unified method the industry can design buildings and measure the effects of their operation. The four definitions given in the proceeding section represent many ways to get to a building with a net zero energy systems. These approaches are not only equitable but in some cases even comparable. The classification system has been categorized into four classes by National Renewable Energy Laboratory of U.S; from A to D and prioritization of the renewable energy application is done in such a way that the higher value is placed on applications of high-priority renewable energy. To reach net zero energy, some facilities are granted to the buildings which may have troubles achieving it. Use of National Renewable Energy Laboratory system in combination with the four classified definitions, allows a building to attain one or more at a particular classification level (Hootman, 2013). Furthermore, the reduction in the demand side is a prerequisite which National Renewable Energy Laboratory classification system emphasizes it. This emphasis reflects the significant need to have a building with net zero energy which use energy at a very low level. Then, the system arranges the renewable energy application depending on its nature and place relative to the building. The troubles of combining renewable energy with the net zero energy is generally quantified by the classifications.

Classification A

Summary: A building with low energy use which generates adequate renewable energy from sources placed within the building footprint to get at least one net zero energy definition. The application of this classification is done only for specific

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buildings. Sample Scenarios ■ Photovoltaic systems set on the façade or roof of the building. ■ Solar thermal systems set on the façade or roof of the building. ■ Wind turbines integrated into, or set to, the building.

Classification B

Summary: A building with low energy use which generates adequate renewable energy from sources placed within the project's site to get at least one net zero energy definition. According to the definition, the site border includes campus scenarios where the systems of renewable energy are placed on ordinarily owned contiguous property i.e. easements separate ordinarily owned property. This classification may be applied to single or multiple buildings. Sample Scenarios: ■ Photovoltaic systems set on the parking areas or ground-set. ■ Solar thermal systems ground-set on the site. ■ Wind turbines on towers set on the site. ■ Biomass collected on-site and employed to on-site energy generation.

Classification C

Summary: A building with low energy use which firstly makes use of on-site renewable energy as bases within the building footprint, then in order to generate adequate on-site energy to get at least one net zero energy definition it must import sufficient off-site renewable energy. This classification can be applied to single or multiple buildings. Sample Scenarios ■ Biomass which is imported on-site and utilized for the generation of electricity. ■ Biomass that is imported on-site and utilized for the generation of thermal energy.

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Classification D

Summary: A building with low energy use which firstly makes use of on-site renewable energy from bases in the building outline, then in order to generate adequate on-site energy it uses off-site renewable energy, but buys off-site renewable energy to get emission or source net zero energy definition. It cannot achieve the other definitions i.e. site or cost. This classification can be applied to single or multiple buildings. Sample Scenarios: ■ bought certificates for renewable.

2.1.3 Strategies to a zero net energy building

Strategies were studied, verified, evaluated, retested and assessed. There could also be interactions amongst strategies, which mean that a notion studied in one stage might impact another notion endeavored under a dissimilar stage. Also, strategies might neutralize each other or be useless. Step 1 concentrated on costless strategies because they produce natural resources, like daylight, or include strategies that improve the performance of the systems and envelope. Step 2 concentrated on strategies with energy efficiency which decrease energy consumption. Step 3 studied systems which produce renewable energy to power the building. Step 4 concentrated on operations of building, a key step in attaining Net Zero Energy Building. This is the point where educational outreach and policy turn into a fundamental part of keeping the behavior of low energy consumption.

To meet energy objectives and fine tune plans, the analysis of simple payback and energy modelling must be conducted. In the meeting that the owner, the contractor, the design team, and the user all come together, the analysis outcomes are discussed and the future horizon is determined. It is essential to mention that strategies must be assessed early. However, when cost plays a crucial role as a determining factor, to

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measure market cost more accurately some flexibility is required. This may need to reconsider strategies later in the process. At the final phase of design development, many strategies were admitted for net zero energy buildings, but other strategies which were more reliant on market cost, were reevaluated during the phase of construction documentation and even during construction (see Figure 5) (Zimmermann et al., 2013).

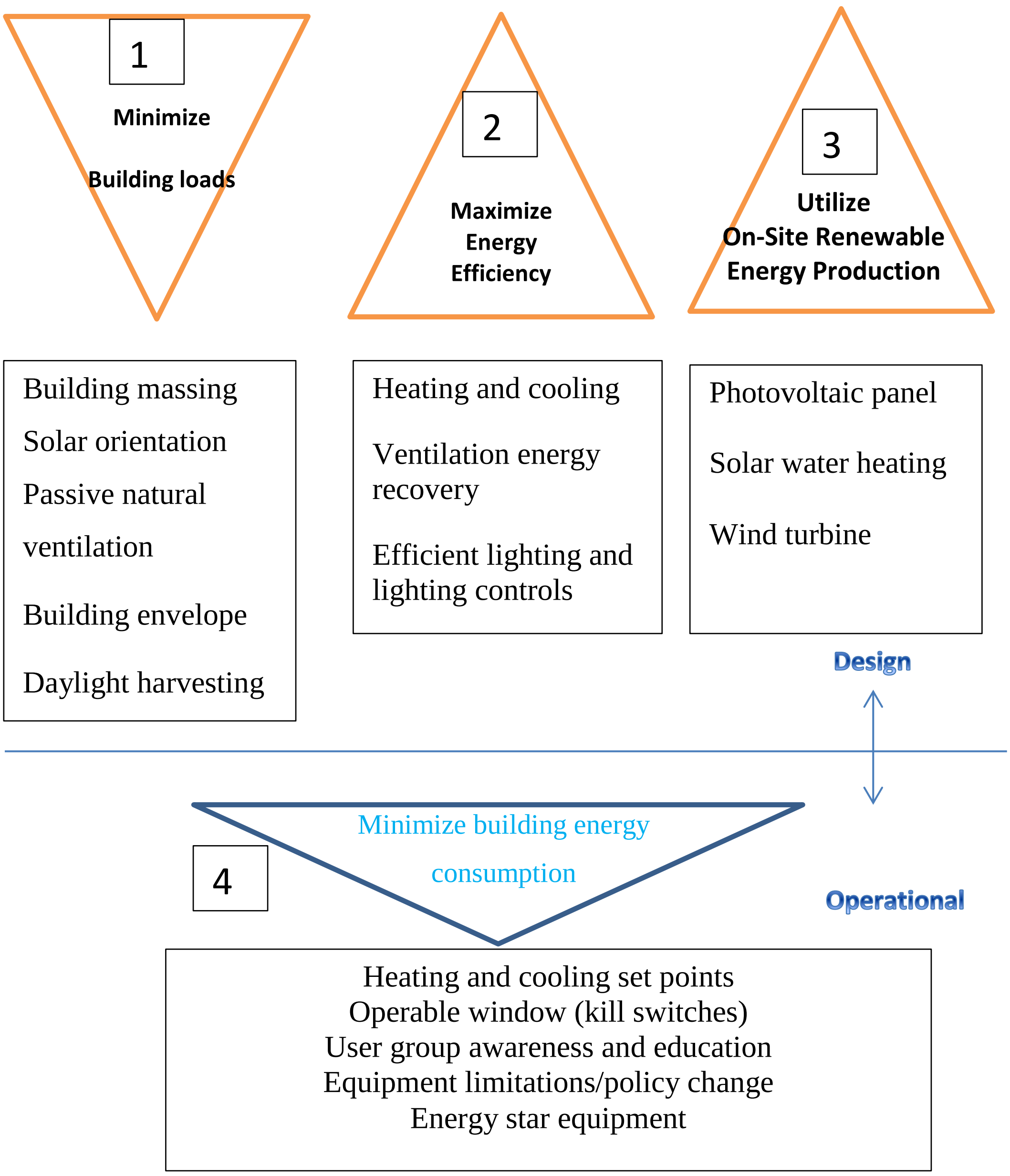

Figure 5: Strategies to a zero net energy building (Drawn by author)

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2.2 Requirements

Some important requirement will be presented which are necessary for net zero energy building, such as building massing components, building envelope, passive solar heat gain, heat recovery ventilation, building airtightness and use of renewable energy.

2.2.1 Building Massing – Compactness (low A/V –ratio)

The energy requirements of a building are extremely influenced by building form. In general, considerations and the internal layout determine the volume of a building. Besides, as the permitted total volume is defined by plot ratio and site occupancy index, this agent should be considered the planning legislation specifications and constructing. However, the building envelope architectural design usually has some leeway.

The heat losses are affected directly by surface areas of different sizes: for a given volume, the areas with smaller envelope will require lower heating. And vice versa: for a given volume, the areas with larger envelope will require greater thermal insulation. This relationship is noticed directly in the design and the concept of compactness can quantify it. To assess the compactness, the heat-transferring enclosing surface area (A) to the heated volume of the building (V) ratio (= A/V ratio) is required. From the geometrical perspective, the ideal form is represented by a sphere; but an orthogonal structure believes that a cube is best. Divergence from these optimal forms causes distinctions with respect to the building's heating requirement. The heated volume does not include storage rooms, utility, unheated circulation zones, garages, etc. and consequently should be thermally excluded from

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the heated volumes. From the energy perspective, the building's heated parts volume is relevant not the gross volume compactness (Figure 6).

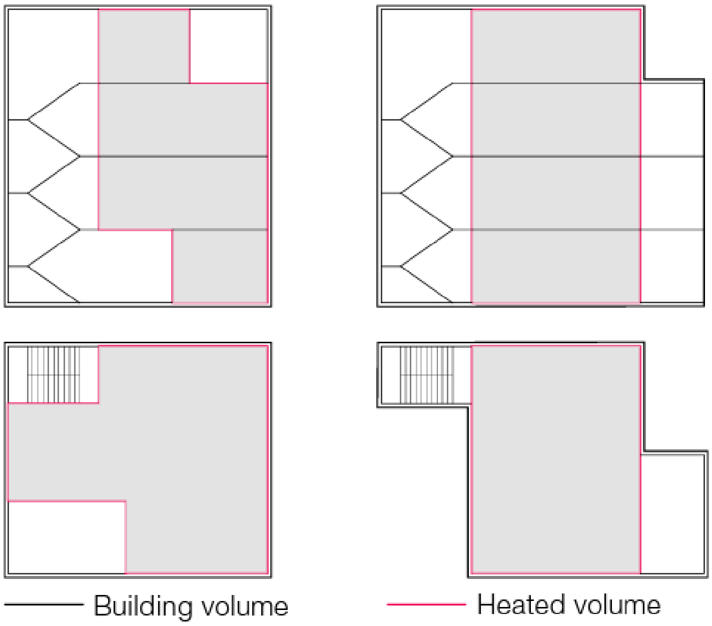

Figure 6: Building volume and heated part (Hegge et al., 2008)

The construction expenditures would be positively affected by a small facade surface area. But struggling to attain a high compactness has its restrictions – the point in which visual contact with the external world and daylight situations are weakened. Theoretically, the volume increases are improved and promoted by the degree of compactness. For instance, in the apartment blocks' big units the transmission heat losses are much lower than separate houses with the same floor space (Hegge et al., 2008).

2.2.4.2 Building Envelope (low U-value)

The inside of the building is separated from the outside environment by a physical barrier which is called building envelope. The separation is done with the major functions of fundamental support and controlling moisture, air, and heat flows. It

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usually includes roofing, walls, windows, foundations, and doors which all are the exterior elements of the building (Giuseppe, 2013).

2.2.2.1 Exterior Walls

Walls, as one of the major fractions of a building envelope, should provide acoustic and thermal comfort inside a building. They are expected not to compromise the building's aesthetics. In tall multistorey buildings with high ratio between whole external envelope and wall, R-value, of the wall as thermal resistance is important by means of it impacts the structure's utilization of energy worryingly. However, the effect of interface links and factor of framing is not considered. The higher chance of surface belongs to the walls with thermal insulation (Aelenei et al., 2008).

Passive solar walls (Trombe walls)

The trombe walls are normally utilized in extreme climate zone. They gain and conduct the solar energy effectively into the indoor spaces. Phase change material (PCM) centered trombe walls have been studied (Tyagi et al., 2007). A transwall (Figure 7) is a kind of wall which is transparent modular and provides not only dwelling space illumination but heating. The appropriate place for both transwall and trombe wall has to be located exactly behind the wall's south facing glazing. A transwall includes water in a parallel glass walls container and has a parallel plate to the glass wall at the center which is partly absorbing. Thus, it absorbs and transmits solar energy partially. A trombe wall includes either water or masonry in opaque containers and does not transfer solar energy (Nayak, 2003).

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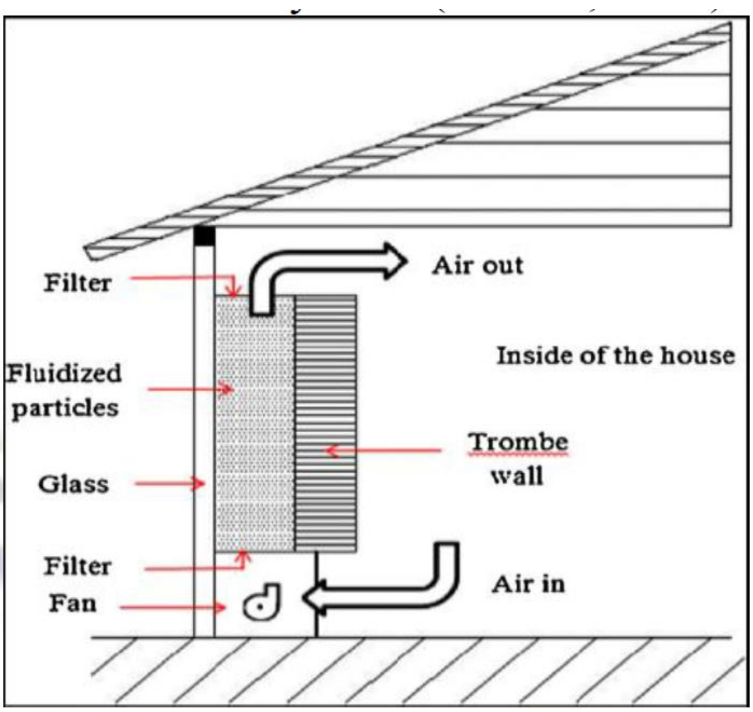

Figure 7: Passive Solar Walls or Trombe Wall (Sadineni et al., 2011)

Walls with latent heat storage

Light weight wall structures are incorporated in the (PCM) to enhance the capacity of thermal storage. The PCM is filled usually in concrete or gypsum walls. Permeable material for example plasterboard has higher potential to change material impregnation phase compared to pumice concrete blocks. Only a 30% ratio of phase change material weight in gypsum is allowed by the microencapsulation of phase change material in wall construction material. Composite materials have experienced an advent at recent years. Phase change material weight can be encapsulated up to 60% compared to PCM and non-PCM based gypsum board for interior wall lining. The composite materials concluded that the maximum room temperature can be lowered by 4°C if the phase change material based wall lining is used, as the heating demand during night is reduced the heat storage systems (Figure 8) (Kuznik,2009).

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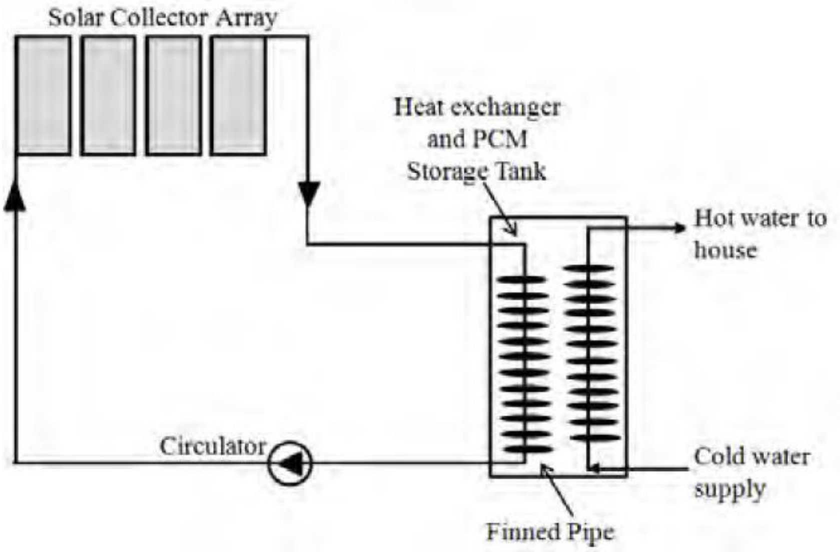

Figure 8: Latent heat storage systems (Murray, 2011)

Building mass walls

Thermal mass walls shown in figure 9 include 5 cm of concrete facing the outside, 10 cm of concrete in the inside, and 5 cm of sandwiched styrofoam extruded polystyrene board insulation in between. The assembly is held together by 40 cm fiber composite connectors in center. T-Mass walls are highly energy efficient, and one of the important factors is the plastic connectors. "Steel connectors, which quickly conduct heat, are employed by other systems. They significantly decrease the R-value and as a result the walls' energy efficiency." Thermal mass walls have two forms: poured and precast. Panels of precast are produced at a plant and transported to the job site (Asa, 2005).

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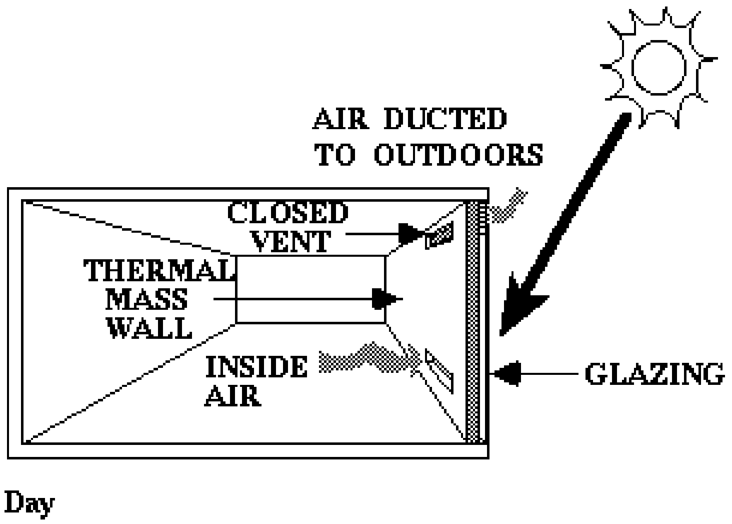

Figure 9: Thermal Mass Walls systems (Chivers, 2009)

Riverdale Net Zero Deep Wall System

A system with a double-stud wall which forms a 406 mm cavity and in order to get an impressive insulation is filled with insulation of blown-in cellulose is known as the Riverdale Net Zero Deep Wall System. The composition of the wall has been illustrated in (Figure 10) (Insight,2010).

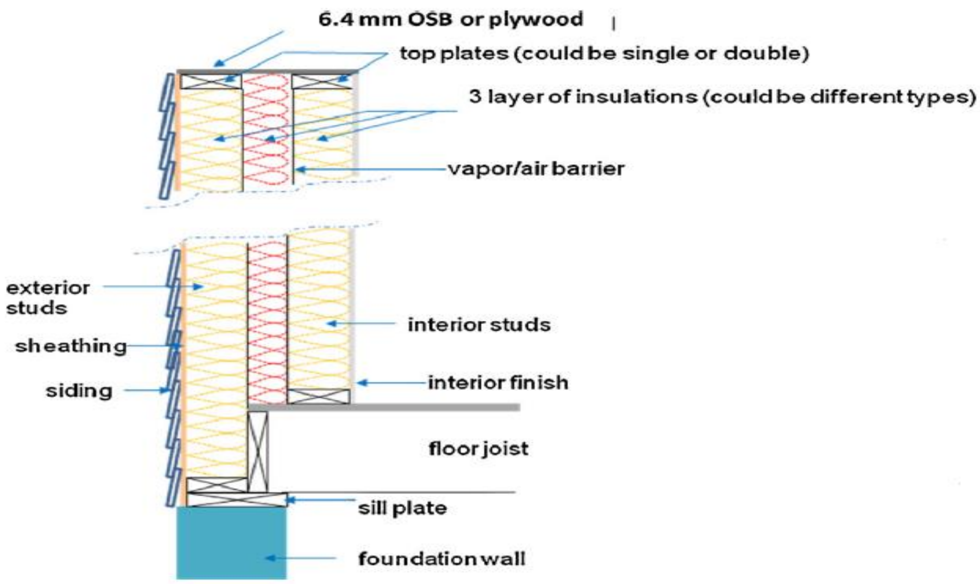

Figure 10: Cross-Section of Riverdale Net Zero Deep Wall System (Kosnya, 2014).

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2.2.2.2 Roofs

One of the highly susceptible parts of the building envelopes to solar radiation and environmental changes are roofs. Thus, they influence the interior comfort conditions for the inhabitants. In sport complexes, auditoriums, and similar buildings with large roof area, roofs are accounted for great amounts of heat gain and loss.The efforts to increase the buildings' total thermal performance by reducing in the U-value throughout the years highlight the importance of roofs thermal performance. A number of very effective roofs for net zero energy building design is provided in this section.

Lightweight roofs

Lightweight aluminum standing seam roofing systems (LASRS) are widely employed for government and commercial buildings because they are very economical. By using light colored paint for roofs and adding thermal insulation the characteristics of these roofs would be improved. It was found that the surfaces with lighter colors like brown, white, green, and off-white yielded 2.5%, 9.3%, 1.3%, and 8.8% decrease in cooling loads, respectively, in comparison with black-painted LASRS surface.

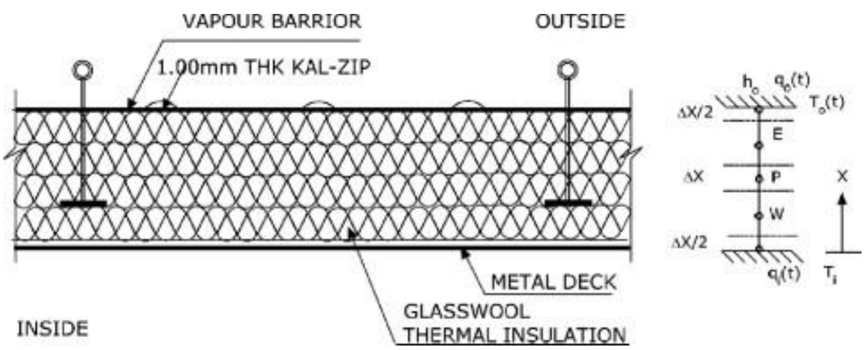

Figure 11: Section of the lightweight roof system (Han, 2009)

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Findings of recent investigations have shown that because of the interstitial condensation which there is in the glass fiber layer, the LASRS systems with glass fiber insulation are not appropriate for humid and hot climates. Other materials of thermal insulation like polystyrene, polyurethane or a mixture of them have been assessed (see Figure 11) (Han, 2009).

Solar-reflective/cool roofs

The roofs with high infrared emittance and solar reflectance characteristics are cool roofs or solar-reflective roofs (Figure 12). They keep the temperature of the roof surface at lower degrees and prevent the heat transmission into the building. The thermal performance of these roofs is affected by two properties of surface: solar reflectance and infrared emittance.

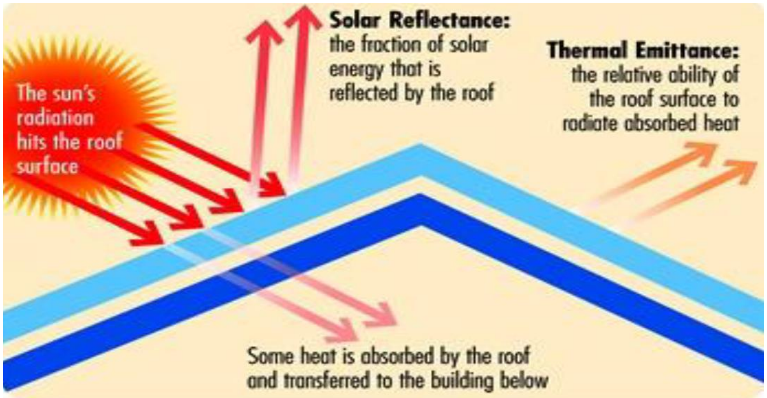

Figure 12: Working of Solar reflective roofs (Steuben, 2011)

A cool roof does not need to be white. There are darker colored pigments which are used by lots of "cool color" products. These pigments are extremely echoic in the near infrared, non-visible, part of the solar range. As a white roof intensely reflects not only visible but non-visible, near infrared, sunlight, it will usually be cooler than a roof with cool colors. The coolness of a roof is determined by the two major

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characteristics: thermal emittance (TE) and solar reflectance (SR). They both are valued on a measure from 0 to 1, where 1 is the most emissive or reflective (Steuben, 2011).

Photovoltaic roofs

To integrate photovoltaics into building some important efforts have been made during the recent years. Roofing materials are replaced by photovoltaic (PV) roof tiles. PVs are mounted exactly on the roof structure (Figure 13). Fiber-cement roof slates or ceramic tiles contain crystalline silicon with glued solar cells. There is another form of roof-integrated system which includes a photovoltaic element i.e. glass-glass laminate. This system is situated with a plastic holding tray fixed to the roof (Bahaj, 2003).

Figure 13: Photovoltaic Roof System (Sharma, 2014)

Photovoltaic roof systems have the capability to absorb solar energy from the rays of sun and generate electric power for commercial and residential buildings. In the regions with the strongest sunlight, PV roof systems are used more commonly to increase sustainability, generate clean energy, and to reduce utility bills (KKY, 2006).

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2.2.2.3 Windows

The openings in a building envelope, primarily windows, are referred as fenestration. The fenestration shows a crucial significance in providing optimal illumination levels and thermal comfort in a building. From an architectural perspective, they play a vital role in making the building design more aesthetic. In recent years, glazing technologies have experienced substantial advances. Units of insulating glass, solar control glasses, low emissivity coatings, aerogels, evacuated glazing, gas cavity fills, developments in spacer and frame designs insulation level, floor area, etc. are all included in glazing technologies. Low U-value windows with high overall transmission of solar energy are preferred for passive solar heating applications. There must be a tradeoff between solar transmittance and U-value in a way that lower U-values reduce the solar transmissions.

Windows Performance Parameters

The appropriate indices of performance of windows must be specified by designers to determine the window's preferred performance. The designer should not only know what the different performance indices aim to assess, but should understand how to compute and evaluate these indices and specify the interest parameters.

Three Generations of Advanced Window Glazing:

The high thermal performance, dynamic glazing and building integrated photovoltaic glazing are explained in below:

High Thermal Performance Glazing

The inside and outside heat flux of the building is reduced by fenestration systems with low U-factors. U from-factors of 0.20 to ≥ 0.10 are achieved by U-factor low-e

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full frame performance of 0.50 to 0.254. They improve on common dual pane systems. To achieve these benchmarks, there are well-established and multiple methods (Figure 14,15), with the highest achievement found in at least three separated coated panes i.e. with inner panes of either suspended or glass covered films, having the maximum commercial success (Brandon, 2010).

Figure 14: Cutaway of triple- pane insulated glass unit (Sharma, 2014)

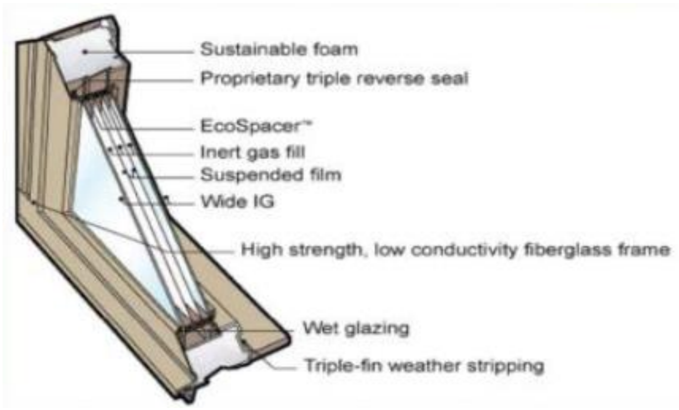

Figure 15: Cutaway of a quad pane window including the frame (Sharma, 2014)

Dynamic Glazing

Dynamic glazing when it is necessary to offset needs for heating energy permits solar heat, rejects solar gain to decrease cooling loads, perhaps diminish a building's demand for peak electricity, and offsets to great extent of lighting needs of a building during daylight hours. To this end, the coefficient of window's solar heat gain may differ from about 0.50 to 0.05. The trigger for switching in this performance can be run either passively or actively (Brandon, 2010).

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Building integrated photovoltaic glazing

The energy efficient fenestration's last generation produces its own renewable energy, and efficiently reduces the total consumption of the building. Third product is usually identified as building integrated photovoltaics (BIPV) (Figure 16). BIPV comes in two key forms: transparent, and partly opaque or light transmitting. As applied today, light conducting BIPV includes solar cells built from dense crystalline silicon as poly-crystalline or single wafers (Figure 17). Under full sun, about 10 to 12 Watts m² of photovoltaic array is delivered by them. This kind of technology is mostly appropriate for areas which do not require light transmittance e.g. spandrels or shading areas like sunshades and overhangs (Brandon, 2010).

Figure 16: Image of light through BIPV Product (Sharma, 2014)

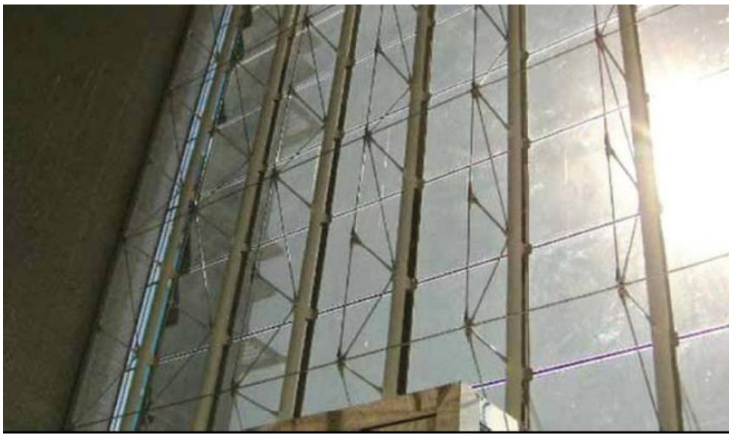

Figure 17: Image of building integrated photovoltaic glazing (Sharma, 2014)

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2.2.2.4 Doors

Windows have more effect than doors on the building's consumption of energy unless the doors are simply garden doors or patio as there are a few numbers of them. They come in various materials; heat flow is decreased by some of them better than others. For instance, based on insulation material and style, metal doors are more useful and competent compared to wooden doors. If the doors are not fitted properly, no matter what their material is, energy losses will increase and the home will be uncomfortable and drafty. Heat losses may occur through patio doors' glass, between the frame, door, and sill, through the door and frame, through doors with windows, and between rough frame openings and the door frame (Figure 18).If the doors could be chosen carefully, located, installed and maintained properly the heat losses through doors would reduce. By providing windbreaks, locating door at house's leeward side or not putting a door on the prevailing winds' path can decrease heat loss. The other choice is to use an airlock vestibule which entraps the air between the outside and the inside of the house.

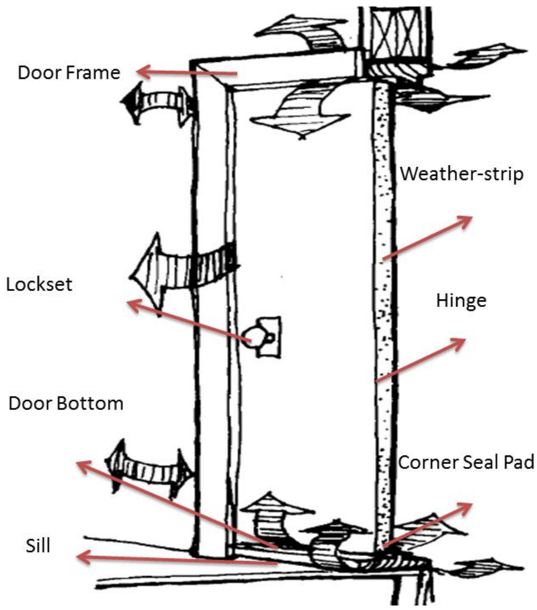

Figure 18: Door frame and rough frame opening (Canada, 2004)

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The accurate designing and installation of storm doors are very important as they will increase protection from weather, as well as degree of efficiency. The key air leakage contributors are inappropriately located strike plates, missing or worn weather stripping, warped doors which no longer touch the stops, and frames that no more fit the door fittingly. A competent do-it-yourself or a carpenter can correct all these shortages. A new door with energy-effective insulation must be used instead of seriously deteriorated door. Choose units with good quality and install them accurately (Canada, 2004).

Briefly, significant items of doors that must be considered for energy efficiency are:

• Cores of materials that preserve high values of insulating;

• Vinyl, wood, or metal frames which are thermally broken;

• Weather stripping manufactured from durable, high-performance materials;

• Low air leakage rates, for systems with pre-hung doors;

• Materials for maintenance-free framing; and

• A double glazing minimum with at least 12 mm air space or high energy rating.

2.2.3 Passive solar heat gain

In the moderate and cold regions of the planet it is chiefly significant to secure pleasant internal conditions by using suitable measures when external temperatures are low. The principal goal is to preserve the needed heat inside the home by making a building envelope which has been optimized. To assess the heat flows and specify the relationship between heat gains and losses during a year, a thermal balance can be drawn up for the building (Figure 19).

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To differentiate between heat losses of transmittance and ventilation is needed to assess the loss factors. Internal heat sources i.e. waste heat generated by people, lighting, and electrical appliances, and energy gains are on the gains side, because solar radiation enters through building's transparent sections (see Figure 20). This balance should be out in the evening as far as possible by the properties of the building envelope. The heating requirement is determined by the dissimilarity between the two sides of the equation. This difference also forms the foundation for computing the most important requirement of energy according to the Energy Conservation Act. While, first and foremost, type of use determines the interior heat sources, the building's optimization potential relies on maximizing the solar gains and minimizing the losses (Hegge et al., 2008).

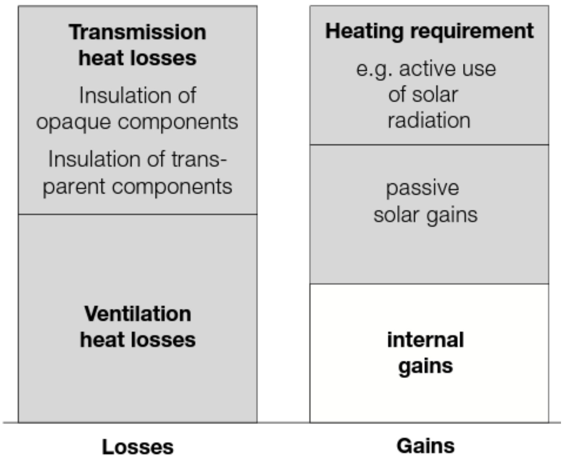

Figure 19: Relationship between heat losses and heat gains (Hegge et al., 2008)

To assess the passive thermal performance of a building via its outer shell, the enclosing surfaces' average thermal resistance contributing to the transmission can be served as the target variable. This gives a sign of the transfer heat losses to be anticipated. Moreover, when the outside temperature is low, providing fresh air from

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outside represents another factor of loss which carries higher degrees of significance as the rate of air change increases.

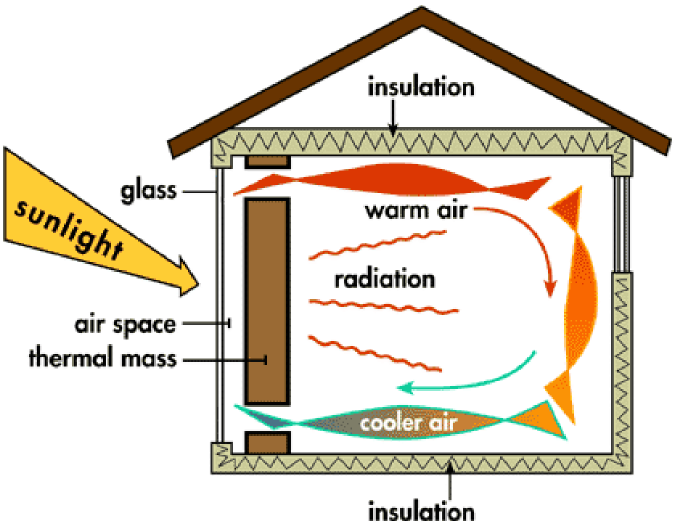

Figure 20: Passive solar heat gain system (Ltd, 2009)

Finally, the potential for the passive use of solar radiation is expressed by the glazing proportion with respect to the orientation. In addition, supplying heat systems like solar thermal system and the direct flow of thermal energy via the building envelope are becoming more important. Building envelope's components are predominantly relevant. In order to increase the building's thermal performance in winter, the next elements should be synchronized with each other:

- Geometry of envelope and surface optimization
- Opaque elements' thermal insulation
- Transparent elements' thermal insulation
- Passive use of solar radiation
- Minimizing heat losses resulted from ventilation
- Gains obtained from active solar thermal energy

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2.2.4 Heat Recovery Ventilation

Heat recovery means an energy recovery system or an air-to-air heat which refers to a process through which the energy i.e. heat/mass, is recovered from a high temperature stream to a low temperature one that is economical and efficient to run. In other words, recovery of energy or heat is any means that eliminates in terms of extracts, salvages or recovers heat/mass from an air stream and transmits it to another one. This refers to the fact that the energy that could be lost otherwise is employed to heat the entering air, and help to keep a comfortable temperature. Whereas, in industries, it is known as HRV (Heat Recovery Ventilation) (Idayu et al., 2012).

About 60 to 95% of the exhaust air's heat is recovered by heat recovery systems and have considerably enhanced the buildings' energy effectiveness. To recover heat from exhaust air in ventilation, there are some concepts and possibilities. The selected concept relies on the possibilities of how to employ the recovered energy. To recover a portion of the energy loss, heat recovery systems are utilized. This system offers not only energy saving, but also provides some benefits and does not generate heat and decreases heat loss which is reasonably cost efficient. In window-less rooms such as toilets and bathrooms and where the open windows are risky from security perspective, this system also offers efficient ventilation. By passing the system of heat transmittance and replacing interior air with fresh outside air, it can also work as ventilation system in summer. While, in winter, it can decrease inside moisture, as due to cooler outdoor air, the air humidity will be relatively low. The energy for fresh air treatment is certainly saved by heat recovery system and the effectiveness of the heat recovery system is often utilized to compute the energy saving.

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A building's usual heat recovery system includes ducts for outgoing stale air and incoming fresh air, two blower fans, and a core of heat exchanger, where energy or heat is transmitted from one stream to the other; the fresh air is supplied by heat exchanger core and the stale air is exhausted by one of the blower fans. A typical system of heat recovery is indicated in Figure 21 which has been installed in ventilation system. In the core, depending on the season the exhausted air precools or preheats the fresh air stream automatically. Fresh air stream distributes to the inside of the buildings. The incoming and outgoing air passes next to each other but they are not mixed in the heat exchanger. They are usually installed within the inside of the building or in a roof space, use internal air before discharging to the outside to recover heat and warm the entering air. In a more developed design of the system, from time to time the outgoing air is filtered to protect interior components and the heat exchanger, and the incoming air is filtered to decrease the occurrence of pollen and dust.

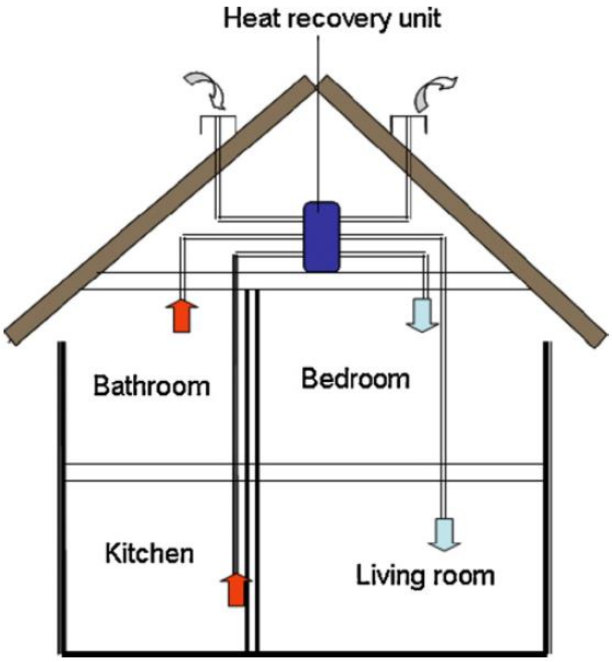

Figure 21: Heat recovery system (Idayu et al., 2012)

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The heat recovery system is also used to build HVAC systems of energy recovery, where exhaust heat of the building is returned to the system of comfort conditioning. During warm and cold weather the building supply is reduced and raised, respectively, by this device by transmitting energy between exhaust air streams and the ventilation air supply (Idayu et al., 2012).

2.2.5 Daylight harvesting

In efforts to enhance the use of daylighting, its proponents have concentrated mainly on its potential for saving of energy. Due to technical improvements over the past years, equipment for electric lighting has become more energy effective and standards of lighting energy have indicated this. In spite of this advancement, however, in large buildings lighting is known as the main energy consumer (Boubekri, 2008). Daylighting is capable of reducing the used amount of electric energy for lighting and lowering peak demand and decreasing cooling loads which is created by heat that lighting fixtures release into the space. Regardless of these considerable advantages, in the most of the buildings daylighting is not a typical feature of architecture. Some of the daylighting supporters propose that the discussions about daylighting must no more be centered on energy savings since that method has not proved efficiently; rather, the discussions should concentrate on the advantages of daylighting for well-being and health.

Daylight has two mechanisms: skylight, where the sky is the source, and sunlight, where sun is the source. Majority of the existing systems of daylighting are aimed to get sunlight and let it in to the building. On a sunny day, 1 m^2 of a building could be struck by as much as 100 000 lumen, which can illuminate 100 000 lux. If the strategy of daylighting were 100% effective, that could be a sufficient luminous

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energy to lighten 100 m^2 at 1000 lux. The optimization of the distribution system's efficiency is the major challenge in each daylighting strategy and, therefore, minimizing the collecting area's size. There is no daylighting system with 100% effectiveness. So, the system's efficiency is linearly proportional to the size of the collecting area, (Figure 22) (Boubekri, 2008).

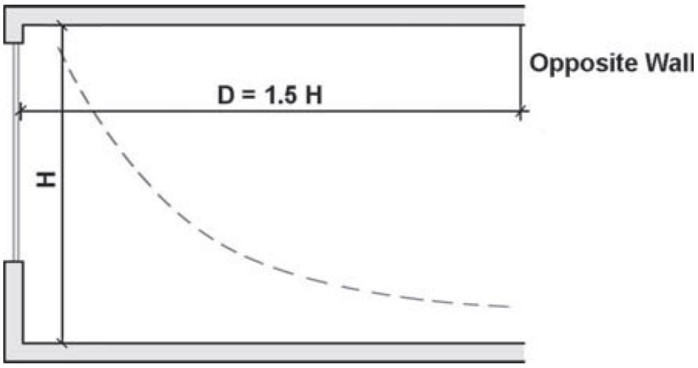

Figure 22: The efficient depth of sunlight infiltration (Boubekri, 2008)

Strategies of daylighting are divided into two groups. The first contributes to systems with side lighting, where light is brought from a building's side into the inside space. The simplest sample of the strategy is window. Top lighting systems are included in the second group, where light is brought from a building's top and distributed into the inside. The simplest sample of such a system is a skylight (Figure 23, 24).

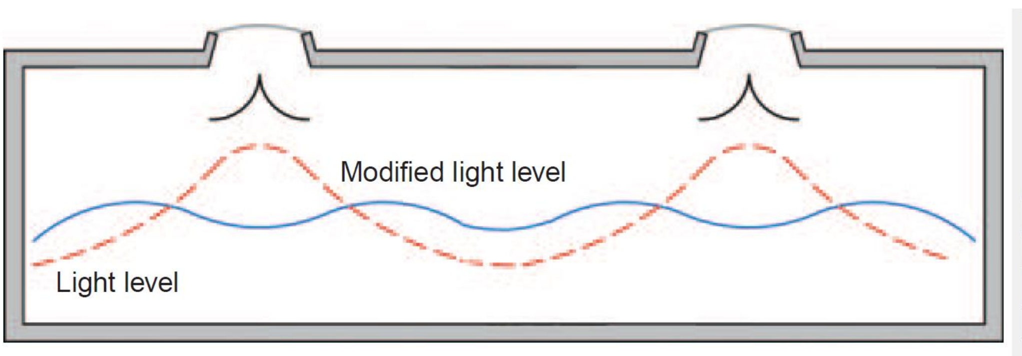

Figure 23: Modified sunlight structure (Boubekri, 2008)

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An effective strategy of daylighting is one that not only makes daylight levels maximum in the buildings inside but makes the luminous environment quality optimal for the residents. Daylighting design does not include just light levels maximization. Too much sunlight in the inside can be very uncomfortable for the inhabitants of the building. The control of light levels and the distribution and the direction of the light is the main issue in daylighting design.

Traditional side windows lead to the uneven natural light distribution, and most systems of side lighting are designed to overcome this problem. Efficient systems of side lighting (Figure 24) work by increasing so much daylight levels away from the windows and decreasing them in areas near the windows, consequently, daylight distribution will be more balanced throughout the room. A viable strategy of side lighting is offered by adding devices like prisms, light shelves, or mirrored louvers to the window glazing because these devices have the ability to send light toward the back of the room and further away from the window wall (Boubekri, 2008).

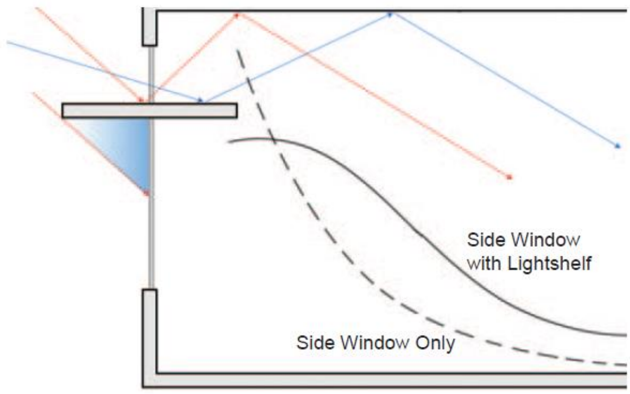

Figure 24: Daylight penetrations from a combined light system (Boubekri, 2008)

One of the easiest top lighting strategies is called a skylight system which shows in figure 25. It regularly offers a slanted or horizontal opening in a building's roof and

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is designed in a way that can get sunlight when the sun is high, spread the light from the sky vault's zenithal area, and under the skylight introduce it into the part of the room. This daylighting method can be applied only for single storey buildings or a multi-storey building's top floor. Uniform daylight distribution can be obtained by numerous skylights consistently distributed across the ceiling (Boubekri, 2008).

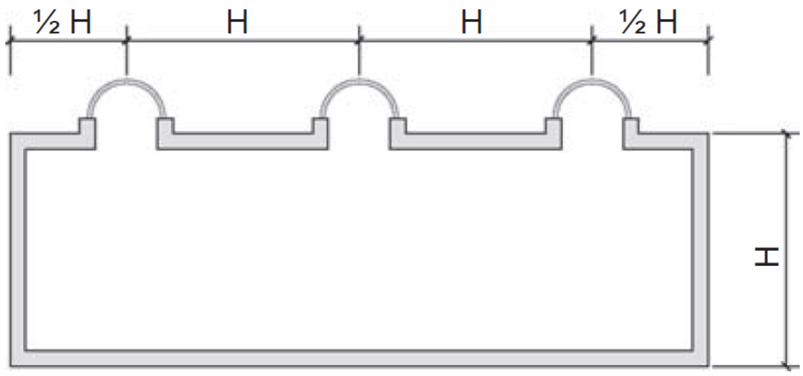

Figure 25: Principle regarding Spacing Skylights (Boubekri, 2008)

2.2.6 Building Airtightness

External shells of building must be airtight. The opponents' widespread points of view rely on the wrong assumption that joints of building ensure the building's residential units ventilation and the air supply. Still, the exchange of air via external joints can differ in a very broad range based on the temperature and wind pressure. Under calm winds and mild weather conditions, air exchange is not adequate in very porous buildings which have strong drafts. Instead, joint air currents include some disadvantages: e.g. permeable shells of building cause a high percentage of all building damage. The other disadvantages have needlessly high heat losses and not sufficient sound insulation. In passive houses airtightness is chiefly high: a ventilation system guarantees the necessary air exchange. At the worst situation, joint ventilation is an irritant and could cause significantly greater amount of heat losses as

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the incoming air through joints is inefficient in terms of heat recovery (Waltjen, 2008).

2.2.7 Utilize On-Site Renewable Energy

Renewable energy sources generate power which can be considered as wind, solar, and geothermal energy. Such resources can generate energy through wind-powered turbines, photovoltaic arrays and other by products like digester gas, municipal solid waste and landfill gas. Using renewable energy world-wide is very important because it does not only affect sustainable economic growth, but prevents global climate change (Kemal, 2012).

2.2.7.1 Solar Energy

An inexhaustible source of clean energy is represented by solar energy that makes the local energy independent, and via photovoltaics (PV) technology the electric power is available to anyone anywhere on the earth. Solar is undeniably the energy power that supports life on the planet for all animals, people, and plants. To make the miracle of life possible the earth is positioned at the exact orbit and distance from the sun and is basically a gigantic solar collector. Earth collects sun's radiant energy in the electromagnetic radiation form. All energy which is consumed on the earth for a year is less than energy that sunlight strikes the planet in one hour (Bridgewater, 2009).

Thermal, electrical i.e. PV, and chemical e.g. photosynthesis processes can convert solar energy. Collecting solar energy naturally needs relatively high initial capital cost equipment. However, during the solar equipment's lifetime, these systems show that they are cost competitive, particularly since there are no repetitive fuel costs, as in comparison with conventional technologies of energy (Foster, 2010).

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To provide electricity for locations outside the typical electrical grid, PV systems, or solar electric power, are a viable and cost-effective solution. Photovoltaic power systems have been employed nearly everywhere, from the equator to the poles. Still, for the remote sites where more conventional alternatives are not very competitive, the higher capital cost of PV is most cost effective. PVs offer real solutions to many problems of power supply in remote and space remote earthly applications. Portable electronic devices along the larger power applications may charge their batteries getting their power directly from solar cells or use solar cells. Through photovoltaic effect process, electricity can be generated from sunlight, where “photo” refers to light and “voltaic” to voltage. The term explains a process through which the direct electrical current is generated from the sun’s radiant energy. The PV effect can happen in gaseous, liquid, or solid material; but, it is in solids, particularly semiconductor materials, that conventional conversion effectiveness has been found. Solar cells are built from various semiconductor materials and covered with particular additives (Foster, 2010).

Grid-Tied PV

Large-scale central generation changes to small-scale distributed generation and this is represented by grid-tied PV. The simplest photovoltaic system is the on-grid PV system. There is no need for energy storage and the system only back-feeds into the prevailing electrical grid (shows in Figure 26). The off-grid market is influenced by this growth, the production of larger and higher voltage modules majority of module manufacturers have stopped their smaller, battery-charging photovoltaic modules production (Foster, 2010).

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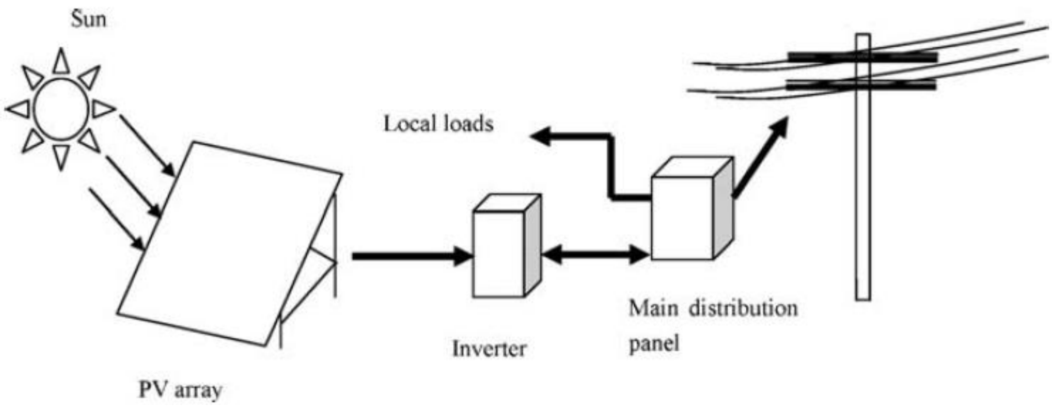

Figure 26: Grid-connected PV power system with no storage (Eltawil et al., 2010)

The simple yet elegant utility-interactive photovoltaic systems consist of an inverter, a device of connecting to the electric grid, a PV array which generates DC power, an inverter, and other balance of systems. During the daytime, the inverter converts the generated DC electricity from the photovoltaic modules to AC and fed into the power distribution system of building, and the building loads are supplied by it. The utility power grid contains any excess solar power. The conventional utility grid supplies the building loads when there is no solar power. Systems of grid-tied photovoltaic have some benefits over off-grid systems:

• Lower costs. These systems that show in figure 27 are quite simple and are connected to the standard AC wiring. Merely two modules are needed: the inverter, with overcurrent protection and associated wiring, and the PV modules.

• No energy storage. Because when the photovoltaic system is offline the power is provided by the utility grid, no energy storage is needed. The grid efficiently is the bank of energy-storage, and delivers energy when the loads surpass on-site generation and receives energy when a surplus is generated.

• Peak shaving. Normally, PV peak power production and sunlight coincide with utility at the periods of afternoon peak loading; the utility benefits from solar peak shaving. If the temperature is very high the efficiency of PVs is decreasing. PVs

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require air-cooling. Systems of grid-tied PV lead to a reduction in peak of daytime peaking utilities while do not affect off-peak energy sales. By having utility bills the customer gains while helping to decrease the utility peaking loads (Salom et al., 2013).

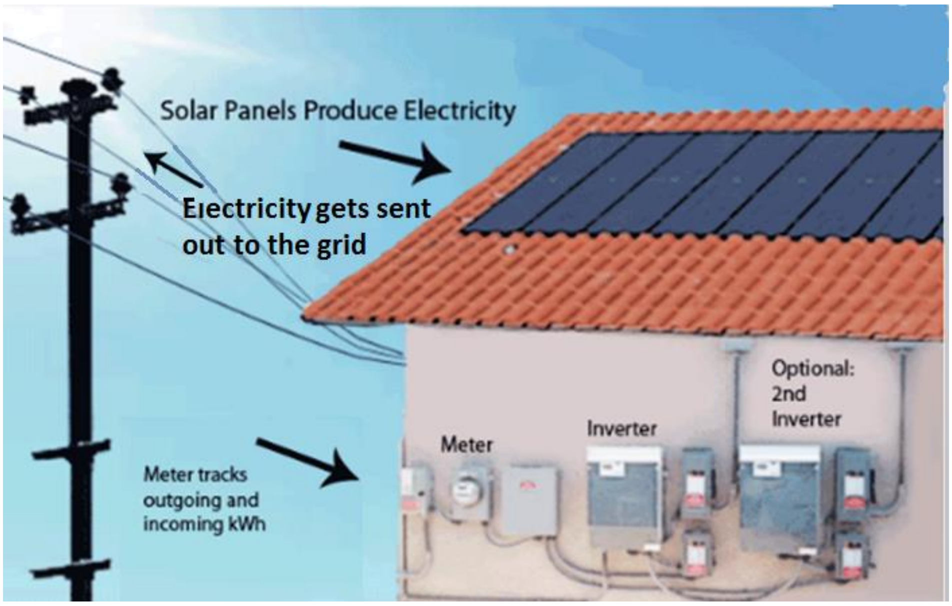

Figure 27: Grid tied systems (Pierro, 2012)

Off-Grid

The system's design is in way that keeps in view the available energy from the sun and the necessary household load. The presentation of the whole model for sizing of whole photovoltaic system determines the storage capacity of battery, the required photovoltaic power rating, size of charge controller and inverter to accomplish the required load. When the power grid goes down, these systems let the solar power be stored in batteries for use. Furthermore, when the sun is shining they generate power to cover the grid power and will conduct extra power to the grid of bank to be utilized later (see Figure 28). For a system which is backed up by off-grid battery,

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you should pay for the back-up of battery and also the extra energy that you generate can't be replaced by credit (Holton, 2013).

Figure 28: Off grid systems (Pierro, 2012)

2.2.7.2 Wind Energy

It is one of the very substantial and quickly evolving sources of renewable energy all over the world. Latest advancements in technology, environment related impacts, use of fossil fuel, and the nonstop growth in the sources of conventional energy have decreased costs of wind energy to economically pleasing levels, and as a result, in many enterprises the farms of wind energy are considered as an alternative source of energy (Sen, 2008). This growth includes numerous technological and scientific factors:

– The energy of wind is plentiful; the wind is endless. So, it is an actually renewable resource,

– The energy of wind is clean; turbines which function by wind do not pollute the environment. The harmful materials are not released into the environment by the

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turbines and they do not create waste. They reduce the emission of greenhouse gasses substantially.

– The industry of wind power has huge potential in production and employment (Sabonnadière, 2009).

Generated energy from wind is a function of its speed, which makes this kind of energy discontinuous and hard to schedule. The network operators must consider the specific constraints and problems caused by its insertion into the electricity grid. In fact, the restrictions will be limited as long as this sort of production remains marginal. For a long period of time, the degrading of the voltage quality on the system and the production of power were the only "restrictions" on wind farms. Today, because of ongoing growth and noteworthy progress in terms of installed power, wind farms are subject to progressively strict technical necessities set out in the rules to connect to the networks explained on the network managers' initiative (Sabonnadière, 2009). Wind energy is converted into electrical energy by wind turbines. This is done in two phasees (Figure 29):

– At the turbine's level, this eliminates a fraction of the wind's dynamic energy which is available to be converted into mechanical energy,

– At the generator's level, this gets mechanical energy and changes it into electrical energy which is transferred to the utility grid.

So, the energy should be converted and transmitted at a balanced level provided that there is inertial storage possibility at the cost of turbine's acceleration (Sabonnadière, 2009).

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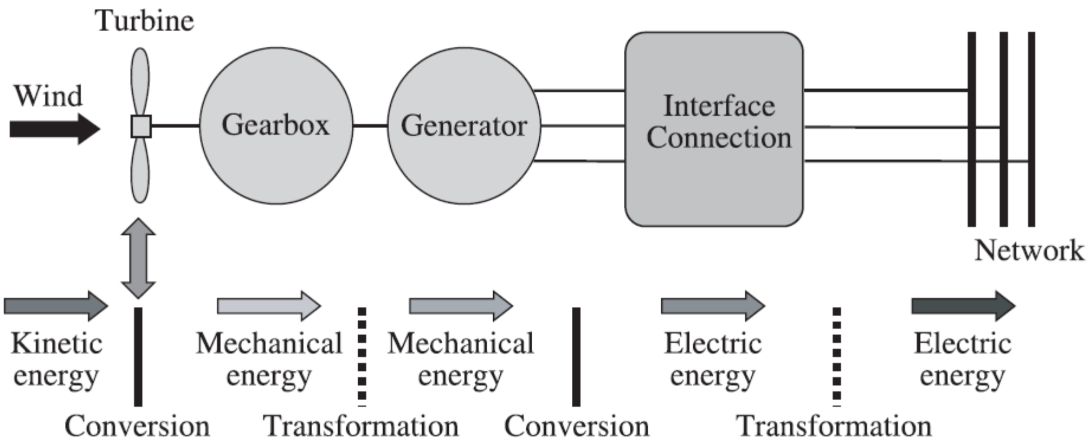

Figure 29: Principle of energy conversion (Sabonnadière, 2009)

2.2.7.3 Geothermal Energy

Heat is collected and transferred from the earth via a series of fluid-filled, buried pipes running to the building by geothermal heating and cooling systems, where the heat is focused for internal use. Ground source heat pump (GSHP) do not generate heat through ignition, they just transfer heat from one place to another (Omer, 2008).

Geothermal heat pumps

Heat can be provided economically and effectively with low emissions by heat pumps (see Figure 30). In 1800s, the heat pump concept was recognized for the first time, and has been applied for higher temperature commercial devices like refrigerators. A heat pump produces useable heat at a temperature which is appropriate to keep a convenient environment within a space.

Heat pumps transmit more thermal energy than is required for operation. This is the most attractive features of these pumps. Geothermal heat pumps which are also known as ground source heat pumps, geo exchange heat pumps, systems of earth

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energy, earth-coupled heat pumps, ground-coupled heat pumps, and ground-source systems, include three key systems:

- Geothermal heat pump: Transfers heat between ground and building and adjusts its temperature.
- Earth connection: Simplifies extraction of heat from the ground through a loop of heat exchanger for using in the unit of heat pump.
- System of internal heat distribution: Distributes and heat conditions throughout the space.

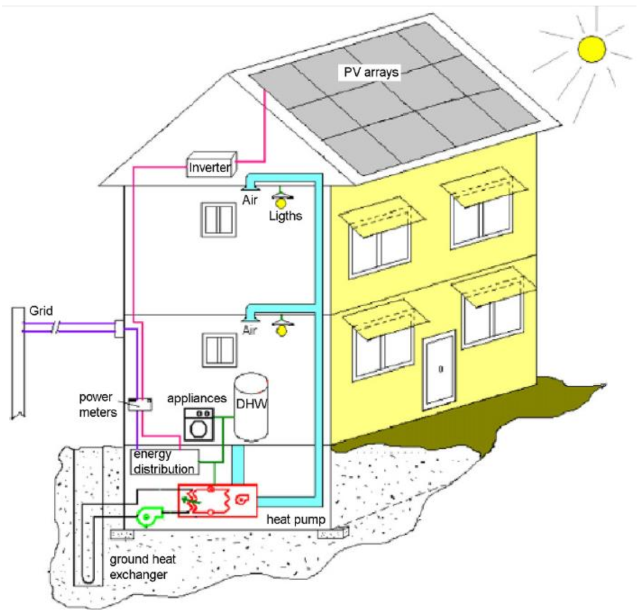

Figure 30: Schematic geothermal heat pumps (Stuart et al., 2013)

Heat pump systems

Heat pumps work by electricity to run compressors that offer the needed function for the focus and transference of thermal energy. The cycle of vapor-compression refrigeration is the cycle that basic heat pumps operate on. The fluid which works inside the heat pump is typically a refrigerant, with the choice reliant on the GHP system's total aspects and requirements. The thermal energy is moved between the

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heated space and the earth by a GHP. It controls temperature and pressure by means of expansion and compression. In a heat pump five main elements are incorporated (Figure 31): expansion valve, compressor, two heat exchangers, and reversing valve.

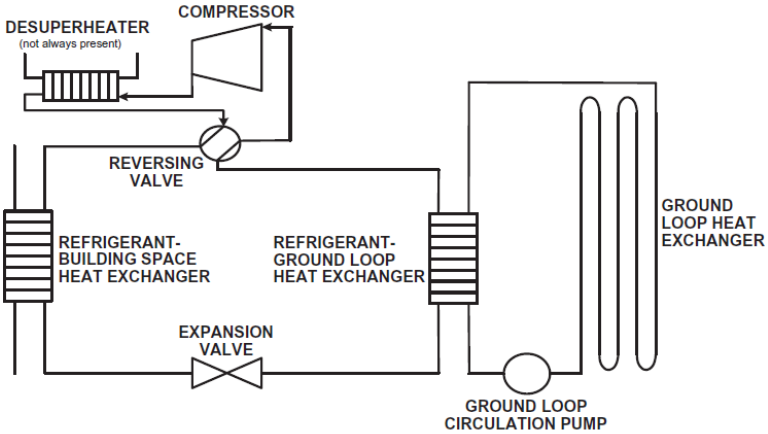

Figure 31: Basic layout of geothermal heat pump system (Stuart et al., 2013)

There are also a variety of other minor accessories and components like controls, piping, and fans that contribute in operation. Geothermal heat pumps operate to generate heat as follows:

1. Thermal energy is taken out of the earth and transmitted to the evaporator.

2. Evaporator enters inside the unit cold refrigerant of heat pump, a liquid/vapor state which is dominated by liquid. Heat is transmitted from the earth link to the refrigerant and forces it to boil and become a vapor with low pressure; the temperature rises to some extent.

3. The pressure increases inside the compressor. The vapor enters a compressor that is driven electrically, and this result in a vapor with high pressure and temperature.

4. Vapor with high temperature enters the condenser. The higher temperature of refrigerant compared to the space, induces heat transmission from the refrigerant to

the building. The high temperature, high pressure liquid is yielded when refrigerant cools and condenses.

5. Temperature declines when hot liquid bypasses through an expansion valve that decreases its pressure. To start another cycle the refrigerant enters the evaporator.

The thermal energy is removed from a space by cooling mode of majority of systems and is rejected to the ground. In this mode, the fluid is conducted in the opposite direction in the cycle by a reversing valve. The heat exchangers are inverted, with the earth connection the heat exchanger of the building becomes the evaporator and heat exchanger the condenser, with the earth connection. Duper heater is a supplementary heat exchanger that exists in some systems. It conducts heat to a hot-water tank. It is placed at the exit of compressor and transmits heat from the compressed vapor to water circulating via a hot water tank, which decreases or removes the energy needed for water heating.

Merit is typically assessed in terms of energy effectiveness, the generated energy output to driving energy input ratio, in percent. More product heat compared to the input driving energy is delivered by heat pumps, so this description yields energy effectiveness more than 100%. To escape this, the coefficient of performance (COP) term is applied for heat pumps, expressed as the ratio of product thermal energy to input driving energy. The range of COPs for geothermal heat pumps is generally from 3 to 6, with the worth reliant on the earth link setups, earth aspects, system sizes, local climate, installation depths, and other features (Stuart et al., 2013).

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Types of heat pumps

Heating and cooling distribution, thermodynamic cycle, and heat source basify heat pumps.

•Air-to-air heat pumps. This kind of heat pump is very usual and is chiefly appropriate for unitary heat pumps which are factory-built.

•Water-to-air heat pumps. These pumps depend on water as the source of heat and sink, and utilize air to transfer heat to or from the acclimatized space. They contain the following items:

- Solar-assisted heat pumps, they depend on solar energy with low-temperature as the source of heat;

- Ground-water heat pumps, they utilize ground-water from wells as a source of heat and/or sink;

- Surface water heat pumps, they employ surface water from a pond, stream, or lake as a source of heat or sink;

•Water-to-water heat pumps. These kinds of heat pumps consume water as the source of heat and sink for cooling and heating. Cooling and heating switch can be completed in the refrigerant circuit, but it is regularly more appropriate to do the changeover in the water circuits. To make central heating and cooling plant numerous water-to-water heat pumps would be collected together to assist a number of air-handling units. This application has benefits for central maintenance, flexibility, better control, and redundancy. Ground-couplet heat pumps. They employ the ground as a source of heat and sink. A heat pump may contain a heat exchanger of refrigerant-to-water or may be direct-expansion (DX). In systems with this type of heat exchangers, a water or antifreeze liquid is driven through vertical, horizontal, or spiral pipes implanted in the ground. Refrigerant is used by DX ground-coupled heat

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pumps in direct-expansion, flooded, or circuits with recirculation evaporator for the ground pipe spirals. A hybrid ground-coupled heat pump is a discrepancy that applies an air-cooled condenser or cooling tower to decrease the overall annual rejection of heat to the ground coupling (Sarbu, 2014).

2.2.5 Requirement for different climate zone

2.2.5.1 Cold Climate Zone

Some important requirements of cold climate zone are presented in following sentences.

Building mass

According to the climate the most crucial is winter heating even though summer cooling could not be neglected. A combination of strategies like passive solar, mass construction and well insulation altogether offer a perfect solution. For winter heating of the thermal mass best solar access is one of requirements. Consequently, presence of good internal thermal mass is advantageous in decreasing and minimizing the inside temperature. Thermal mass is considered to be one the most important requirements of passive solar plan. Thermal mass catches the surplus heating throughout sunlit, and returns the heat to the space during night period. Intended for having maximum efficiency, thermally massive components must have a big surface range, and thickness according to their ideal diurnal heat capacity. Also throughout the summer thermal mass is advantageous. In the course of the day, it absorbs the heat from interior space, moderates the interior temperature rise. At the night time, it gives up its kept heat to control. Buildings that are deprived of passive solar or have a little till can gain from high mass construction in the case of being

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well insulated. Though, they react gradually to heating input and are more suitable for homes that are highly occupied.

Heat recovery systems

Heat provision is the most well thought-out aspect of buildings in the cold climate region. If the required fresh air amount is beyond a certain level and humidification is required, mechanical ventilation with a heat recovery system is essential in ensuring comfort. On the other hand if there is any requirements for cooling, renewable sources must be applied. During the winter, hotness of soil can be applied for warming incoming air through underground registers or pipes placed on the earth. The need for the hot water can be met by the solar thermal system that is even useful in providing auxiliary heating all through the transitional phases. By reason of the low-slung general temperature all year period, the soil is considered as possible renewable cooling source (Hausladen et al., 2011).

Ventilation

If thermal comfort is not needed highly and simple technology is adequate, natural ventilation with radiator heating may possibly be applied. Provision ought to be done for to ease arrival of air casement windows, baffle plates or ventilation radiators. Potential storage masses should be activated thermally; this is a basic prerequisite in the case of low air exchange requirements. Mechanical ventilation can theoretically be applied in cooling indoor spaces to some extent.

Heating/cooling convectors

If there is any need for active cooling in a small area, one option is to practice a cooling convector united with natural ventilation. A convector could also be applied

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for heating of an area. In this way, the individual rooms' climate can be excellently synchronized. The cooling convector combined with mechanical ventilation can be applied in moderate or high cooling loads.

2.2.5.2 Moderate Climate Zone

The most important aspect in the moderate climate zone is finding the middle ground surface-to-volume ratio among spread heat loss, daylight provision and natural ventilation. In conventional building with a moderate depth is desirable. In order to reduce heat transmission loss from the external case surface, atria and conservatories can be applied via establishing a thermal buffer zone. Very high buildings are specified by high wind loads, which cause difficulties in natural ventilation. More technical systems are needed in high buildings, as well as large shaft areas. The solar radiation absorbed by the façade is depending highly on the building orientation and even the nearby buildings height. A north-south orientation is desirable for the reason that solar gain in winter is optimal in this case unwanted solar radiation incidence during the summer is minimized. Furthermore it permits well shading of the south facade by using of horizontal slats. The clearance area must be a slightly bigger on the south side, although closeness to other constructions on the east and west directions moderates solar loads in summer (Hausladen et al., 2011).

Building mass

Thermal mass is superlatively placed in the building and located where it still could be wide-open to sunlight in winter on the other hand insulation must be done for avoiding heat loss. The thermal mass receives warmth passively by means of the sun or in addition by interior heating systems in day time. Heat kept in the mass is then returned back into the inner area at night. It is vital that it be applied in combination

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of the standard basses of passive solar strategy.Thermal mass can be applied in different forms. A concrete slab foundation either set covered or uncovered with conductive materials e.g. tiles; is a straight forward answer. The other innovative technique is placing inside the masonry facade of a timber-framed house. In this climate zone thermal mass is best must use over a large space instead of huge sizes or thicknesses. Trombe wall, normally fabricated of concrete or masonry, are positioned in a straight line amongst the south-facing opening and the inner area. Night insulation usage heightens the effectiveness of this method significantly. Once comfort during day is a desired aim of design, thermocirculator vents may offer heat to increase the air hotness in the area (Hausladen et al., 2011).

Passive solar energy gain

Glazing amount during winter and solar participation during summer can dictate transmission heat loss. Abundant daylight provision ought to be guaranteed through placing the window lintels in height (Hausladen et al., 2011).

Moreover in such a climate, evade absorptive ingredients, or ingredients which are in effect of freeze-thaw acts: rain and humidity penetration is typically on disclosure. Winter insulation necessities are comparable with cold environments, however the winter is not very severe, surface/volume and insulation criterions are not severe. Interior heat circulation is balanced by high heat capacity of interior. Vapor obstacle on hot adjacent avoids condensation.

Heat recovery systems

In the moderate climate area, the heating provision and renewable cooling have importance. In the cases of high air exchange, mechanical ventilation with heat

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recovery ought to be set up to preserve energy and increase comfort. As a result of low temperature, the soil could be utilized as a renewable source of cooling by earth masses or underground registers. Combined with a heat pump, this method can be applied for heating. If hot water is required, a solar thermal structure would be delivered. If it is adequately bulky, the solar thermal structure can be applied for auxiliary heating in transitional phases (Hausladen et al., 2011).

Decentralized ventilation

Rooms have increasing necessity for air, or need for upgrading of ventilation system, in this case the most suitable ventilation system is facade-integrated that is decentralized. These are useful for recovery of heat, for conditioning of incoming air or providing a desirable ventilation level. Maintenance costs of such systems are comparatively high. If all the spaces of the building are in need of mechanical ventilation, in general more efficient and cost-effective systems are considered to be centralized systems.

2.2.5.3 Hot-Humid Climate Zone

The most important function of facade concept in hot-humid climate is preventing solar input. Sun protection coating has importance because in low altitude light gain is abundant through the whole year and there is no need for passive solar in winter. On the west, east, and south facades, generating solar energy is good. For preventing transmission heat gain the façade must be provided by thermal protection; the outward wall is allowed to absorb low amounts of radiation. Walls are not as important in hot-humid climate as in other climates. Walls primary function is screening from insects as well as being flexible in wind penetration, instead of acting as thermal obstacles. Folding window -wall is a good solution. Light weight walls are

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the best for thermal lag by the function of making re-radiation of heat at night and condensation in the morning. Materials must be prevented from of deterioration caused by moisture (Hausladen et al., 2011).

Building mass

The use of thermal mass is the most challenging in this environment where night temperatures remain elevated. It is used like transitory heat sink. But, it has to be advantageously located to avert overheating. It must be placed in an area that is not directly exposed to solar gain and moreover let sufficient ventilation during night for carrying away kept energy without aggregating interior temperatures. If it is going to be applied at all it must be applied cautious amounts and must not be very thick.

Ventilation

Hot climate requires most cooling and moistening. As a result of dew point matters, a combination of surface cooling systems, mechanical ventilation and dehumidifying of incoming air can be applied. In providing hot water there is need for heating. In some cases, it can be provided by solar collectors. High annual temperature in this climate result in high soil temperature that is usable for precooling. Solar cooling approaches are applicable in the summer. Desiccant cooling structures are advisable, first of all due to their dehumidifying function. Photovoltaic structures can be applied because of the high radiation results. In an ideal world, they must be fixed on the flat angle on top of the ceiling (Hausladen et al., 2011).

Cooling ceilings

Where cooling loads are higher than usual, a cooling ceiling mechanical ventilation structure can be used for ensuring comfortable temperature in room. A dependable

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system is needed for dehumidifying the arriving air; if not the dew point parameter will work against the cooling enactment.

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Chapter 3

ANALYSIS OF NET ZERO ENERGY HOUSE IN DIFFERENT COUNTRIES AND CLIMATE ZONE

The case studies main selection is centered about small inhabited building comparison from unlike climate zones. From the cold climate zone Ecoterra Home in Canada and Residential House, CH in Switzerland are selected as case studies. From a moderate climate zone Light House in England and Klee House are selected as case studies. From a hot humid climate zone Enerpos University in Saint-Pierre in La Réunion Island, located in the Indian Ocean east of Madagascar, is selected as a case study. The case studies were selected from various climate zones and are a comparison about the requirement of net zero energy buildings, advantages and disadvantages (Figure 32).

Figure 32: Location of case studies (Kästle, 2014)

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3.1 Cold climate zone: Ecoterra Home, Canada

Figure 33: Building view of Ecoterra home (Voss et al., 2013)

3.1.1 Climate of the location

About 100 kilometers to the east of Montreal, in Quebec, the house was constructed in late 2007. It is the nineth largest city in North America and the second largest city in Canada. Montreal is located near the Atlantic Ocean where some different climatic sections are combined; as a result, Montreal has a distinct and changeable climate for each season during a year. Montreal's weather (see Figure 34), is like the other Canadian cities. It is characterized by relatively short, wet and hot summer and long cold winters (GlobeMedia, 2014). This building because of its climate requires heating, air-ventilation, hot-water supply and electricity generation.

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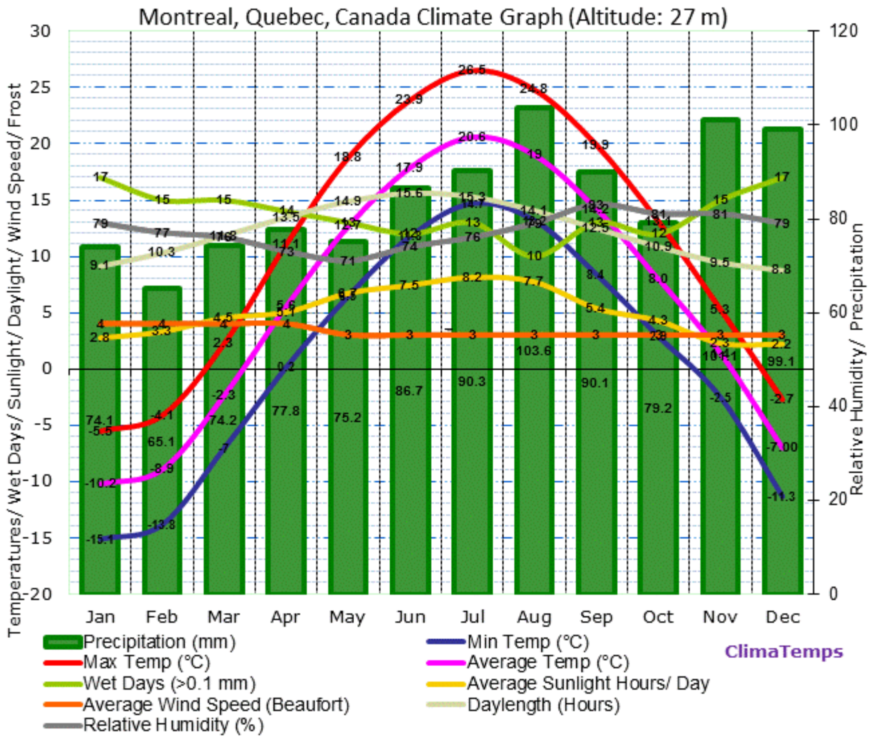

Figure 34: Montreal, Canada Climate Graph (GlobeMedia, 2014)

3.1.2 Description of project

Masa Noguchi, the architect, designed a 141 m^2 home in Montreal and constructed a home with grid-connected system which generates sufficient energy to use in a year i.e. a net-zero energy home, and provides a low environmental effect, considerable conservation of resource, considerations which are affordable, and healthy indoor environment. By employing pre-engineered modular parts of factory, the building unites technology of renewable energy with techniques of energy effective construction to optimize building quality and decrease the environmental effect at the site. The prefabrication method, and techniques and technologies used, have instant applications, particularly for the export market of Europe under Super E® i.e. The Super E® House Program is designed to support exporters of Canada to offer healthy and energy-effective housing to other countries.

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The home’s entire annual need for energy is foretold to be as much as the annual production of on-site which is generated from renewable energy sources: PV electrical panels, geothermal heat pump, passive and active solar space and water heating. The requirement of energy for a household expected to be only 17% of the average Canadian home need. ÉcoTerra home contains a kitchen, dining room, two-piece bathroom with laundry and living room on the main floor shown in figure 35, and an office, four-piece bathroom, and two bedrooms on the second floor shown in figure 36. The basement is incomplete shown in figure 37. To evaluate the building’s performance during the first year of residence the energy production and consumption of water and energy will be monitored (see figure 38) (GlobeMedia, 2014).

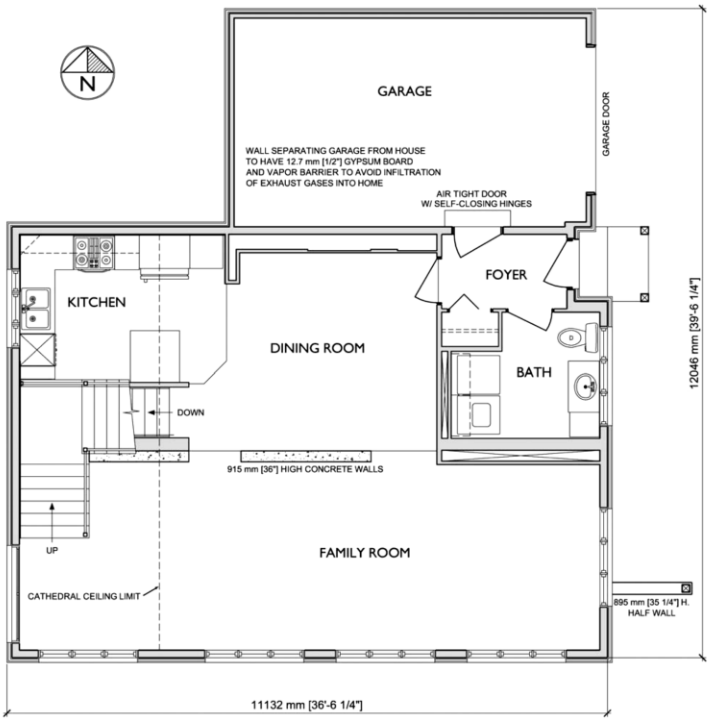

Figure 35: First floor plan of ÉcoTerra (CMHC, 2007)

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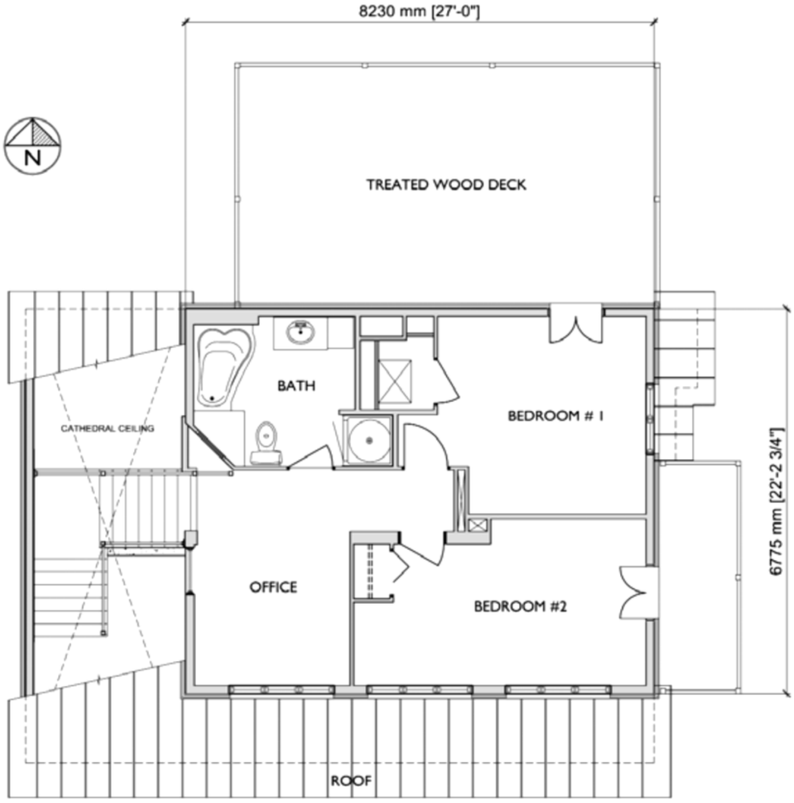

Figure 36: Second floor plan of ÉcoTerra (CMHC, 2007)

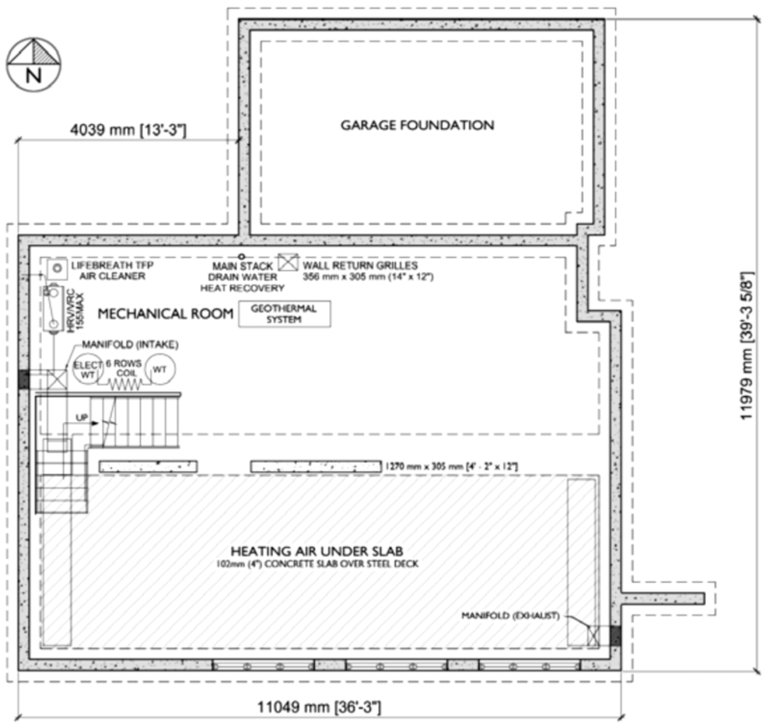

Figure 37: Basement floor plan of ÉcoTerra (CMHC, 2007)

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The point for the EcoTerra home are as following:
1 Fresh air
2 BIPV/T system
3 Air duct
4 Heated supply air
5 Waste air 6, Fresh air
7 Heat transmission to heat pump
8 Exhaust air
9 Heat by thermal concrete core activation
10 Ground water heat pump
11 Geothermal probes
12 Storage tank
13 Heat exchanger i.e. warm air from BIPV/T
14 Hot water storage
15 Electric heater
16 Well water supply
17 Hot water supply
18 Waste water
19 It is noteworthy to state that flexible and fixed system of sun protection is not reflected in the building balance.

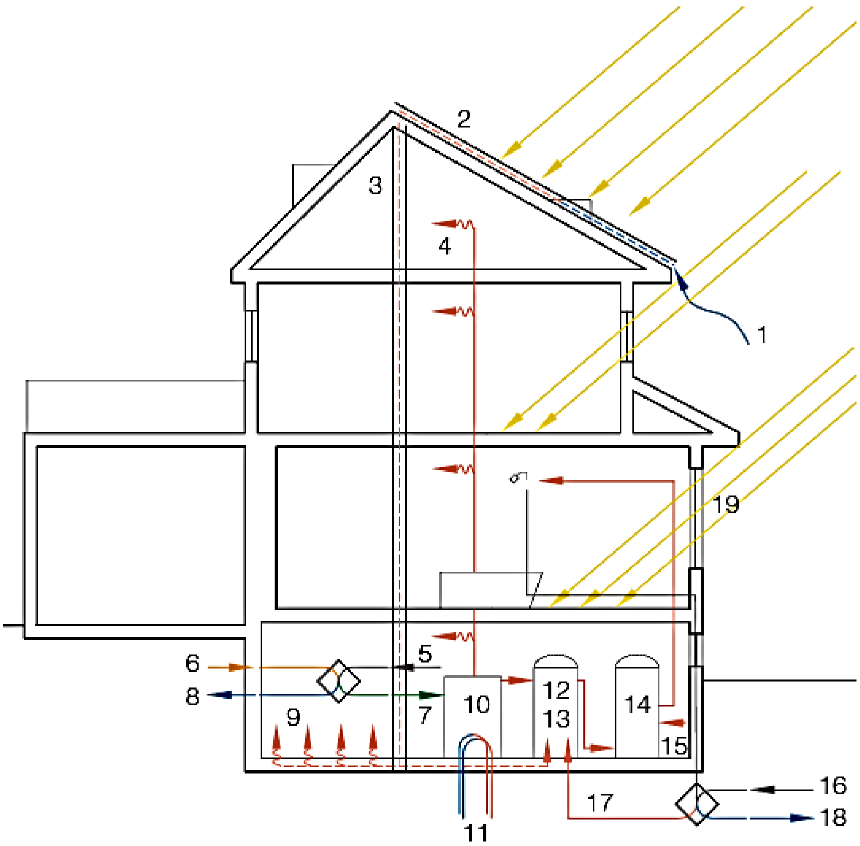

Figure 38: Cross-section showing building technical services concept, scale 1:250 (Voss et al., 2013)

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3.1.3 Minimize Building loads

The analysis in this section is relevant to Ecoterra home and requirement of net zero energy building.

3.1.3.1 Compactness (A/V ratio)

The single family house with two stories is a wooden frame building except for the shell of basement, the foundations, and the base plate. The prefabricated components are protected with panels of polystyrene rigid foam i.e. under the roof 33 cm, in the external walls 20 cm. The key section of the building was pre-manufactured in seven modules. Only one day was needed to erect the home on site. The aspect ratio of floor plan is about 1.4.

3.1.3.2 Building envelope (U-value)

The opaque envelope's selection was created on simulations of buildings and gets U-values from 0.17 to 0.13 $W/m^2 K$, as the cover of slightly higher consumption by larger hybrid collectors is appeared to be more economical. Similarly the windows include low-emission and triple glazing filled with argon, and have a U-value of 1.25 $W/m^2 K$ for window in combination with the plastic frames.

3.1.3.3 Building Orientation

More than 40 % of the central facade, faced towards the south, is coated. Generally, 15 % of the front's 230 m^2 are coated, which provides a great volume of daylight entrance in the rooms. In the deep core solid slab in the cellar, through numerous stainless steel ducts, the air passes through from the BIPV/T roof, so the heat is distributed in the slab. A hard solid wall on the ground floor of the light-weight building house functions as thermal storage. Roofs which have an overhanging and automatic outside sun shelter shade the south-facing windows and avoid overheating in summer.

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3.1.3.4 Passive heating, cooling, ventilation

Heating demands are decreased by a heat exchanger of waste water which is linked to a heat collector. Ventilation heating losses are reduced by a mechanical ventilation system which has about 70 % heat recovery. To modify the ventilators' electricity demand, they can be functioned at three different speeds. The particular power consumption average is 0.68 W/m^3h. Economic fluorescent lamps and effective household appliances are standard fittings' part. A building automation system records the figures of unlike energy consumption and regulates all systems' operation.

3.1.3.5 Daylighting harvesting

Daylighting has got extraordinary attention, with the large windows which are facing to south and open spaces which increase penetration of light on the main floor (Figure 39). Roof overhangs are the components which are employed to stop overheating from solar gain. Selected materials for the home aid to reduce inside air pollutants, like volatile organic compounds (VOCs). Lots of inside finishes are factory employed to decrease air pollution of on-site and increase interior air quality.

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Figure 39: View from south (Voss et al., 2013)

3.1.4 Maximize Energy Efficiency

Some strategies utilized for minimizing energy efficiency are explained in below.

3.1.4.1 Heating and cooling

Heat storage, a particularly improved hybrid collector plant, BIPV/T, and a heat pump were included in the energy concept. The main heating system is the 11-kW ground water heat pump. The source of heat contains two boreholes with 76-metre-deep including U-probes which are back-filled with a brine mixture. When it is necessary, heat recovery from waste water transmits heat via a heat exchanger to the heat collector or the supply air and supplements pre-heating. A hot water storage tank is fed indirectly by the heat pump of the same size via the 227 l heat collector. Moreover, the heat pump contains an electric secondary heater (9.6 kW) and a heating component in the tank of hot water for domestic hot water (DHW).

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3.1.4.2 Ventilation energy recovery

The basis for the net zero energy method is formed by inactive use of solar gains and a totally insulated, air-tight exterior envelope i.e. air-tightness value 0.9 h-1. One of the health characteristics of the home is airtight building joined with a system of heat recovery ventilator (HRV). The good air quality, appropriate humidity levels, and enhanced thermal comfort are provided.

Alongside the ridge, a heat exchanger uses the collected warm air by a distributor to warm the process water. Thermal energy is further conducted to the concrete slab's vacant core, then kept by the high thermal mass of concrete, and gradually freed into the living space. The roof's circulated air does not go into the living rooms and is, consequently, not employed to condition or by the ventilation plant's heat recovery system. The temperature of air can increase up to 30 °C above its temperature when passes into the roof. The flow rate can be controlled by a inconstant speed fan, and so, the temperature raise. In summer night, air can be utilized to cool the interior spaces (Leaders et al., 2014).

3.1.4.3 Efficient Lighting and Lighting Control

Equivalent values for single-family dwellings with a steady balance of energy are on average about 50 % lower. Approximately the same amount is valid for the household electricity consumption, which is quite high, 20 kWh/m^2 NFA, together with lighting (5 kWh/m^2). The energy consumption by lighting, all technical plants and home appliances which consists the amount of annual total electricity consumption is 54 kWh/m ^{2}NFA or 12,400 kWh and is, therefore, obviously more than the simulated demand values of 9800 kWh/a. The objectives of zero energy are not attained:

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3.1.5 Utilize on-site renewable energy production

Some strategies utilizes for renewable energy explained in below.

3.1.5.1 Photovoltaic Panel

The solar electricity plant which is grid-connected, combined flush in two sloped roofs, and its larger part faces south at a 30 ° angle, includes 21 panels totally with shapeless silicon cells. Each cell has a nominal capacity of 136 W. The entire capacity is 2.85 kWp. Outdoor air passes through a 3.8 cm hollow below the PV elements via openings in the roof space.

The PV system which measures 55 m^2 does not have the ability to meet the energy demand. In 2010 it generated merely 2600 kWh, and therefore, in spite of the high global radiation which is 1270 kWh/m^2 annually, fell short of estimations that expected an electricity production of ca. 3400 kWh/a. The shadows of the neighboring trees and snow on the solar roofs caused this difference. To have the roof skin with an identical look and to better combine the PV modules, less effective thin layer modules based on amorphous silicon were used. The usage of cells with mono-crystalline, which was initially taken into account, would have made the energy generation of about 7300 kWh/m^2 possible. If, besides this, the problem of shade had been resolved, the household systems estimated consumption of energy would have been balanced. The garage heating is not included.

3.1.5.2 Solar water heating

Solar electricity plants combined with thermal air collectors are ventilated mechanically by heat recovery and ground water heat pump (see Figure 40).

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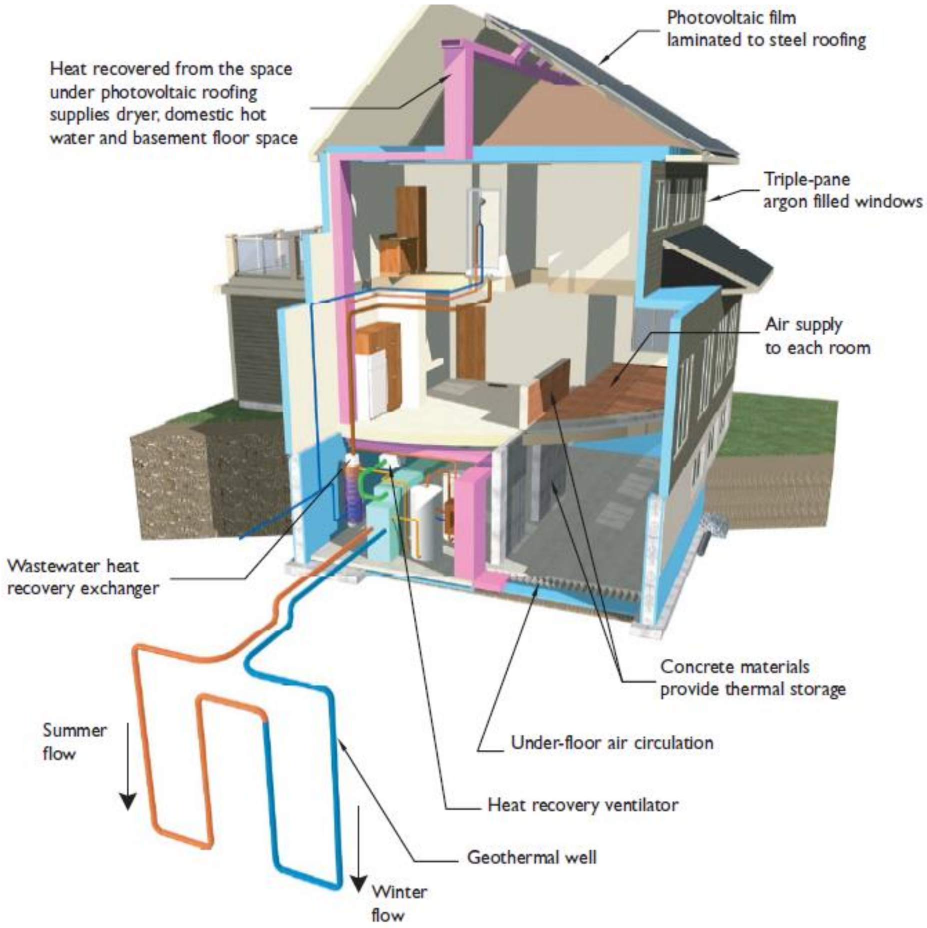

Figure 40: Cross-section of ÉcoTerra, showing space and water heating technology (CMHC, 2007)

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3.2 Cold climate zone: Residential House CH, Switzerland

Figure 41: Building south-west view of Residential House, CH (Voss et al., 2013)

3.2.1 Climate of the location

Riehen is a municipality in the canton of Basel-Stadt in Switzerland. Riehen is one of three major municipalities in the canton. On average of 123.3 days of a year are rainy or snowy in Riehen. With an average of 88 mm (3.5 in) of rain or snow June is the dampest month. Riehen's weather is shown in figure 42.

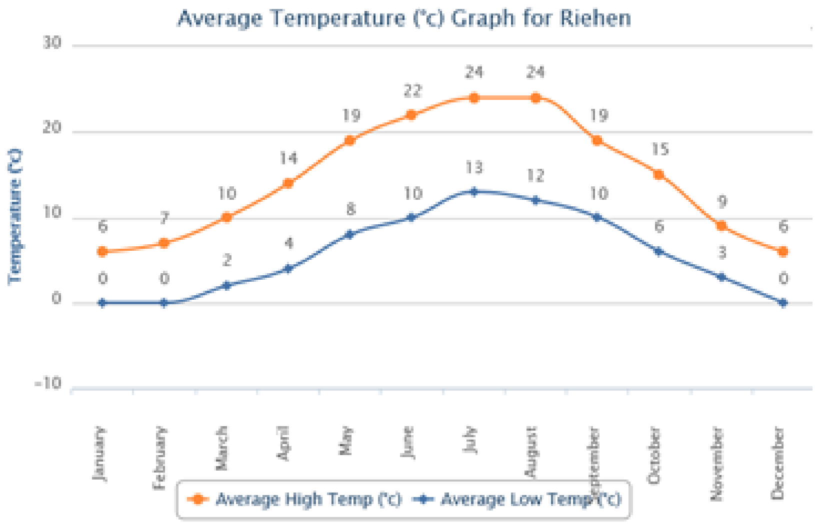

Figure 42: Average temperature for Riehen, Switzerland (GlobeMedia, 2014)

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3.2.2 Description of project

Wood-frame is a two-family house located in Riehen of Switzerland, designed by Setz Architektur, Ruperswil and received assistance grant from administrative district of Basel. Any building that applies ecological and economic dimensions of sustainability is the beneficiary of receiving financial and technical support under the program of pilot and demonstration buildings for a 2000-watt society in the Basel pilot region. The geothermal and solar energy is used in this building; surplus of energy is made in the yearly balance. Its structure is like a cube, outward is covered by wood, and the architectural scheme is demonstrative of 6000 Swiss small inhabited houses recently finalized by late 2010 (Voss et al., 2013).

The ecological and economic features of the design are noteworthy. A prominent aspect is the pre-weathered wood facade prepared of jagged cut white pine cladding attained to the wood frame. Spaces amongst the wood frame are filled with 38 cm insulated mineral wool. Residential house encompasses an office, bathroom, bedroom, patio, kitchen, living room and dining room on the ground floor (Figure 43), five bedrooms, and a kitchen, a bathroom, and a dining room on the first floor (Figure 44). Residential House, CH section (see figure 45).

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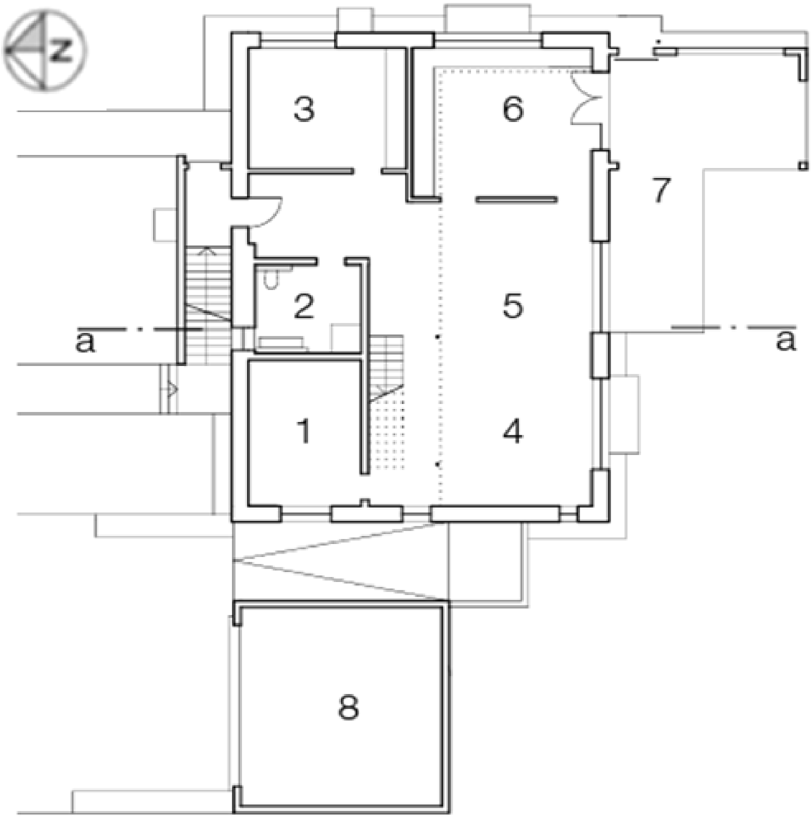

Figure 43: Main floor plan of the Residential House, CH, scale 1:500, 1Office 2 Bathroom 3 Room 4 Living area 5 Dining area 6 Kitchen 7 Patio 8 Garage (Voss et al., 2013)

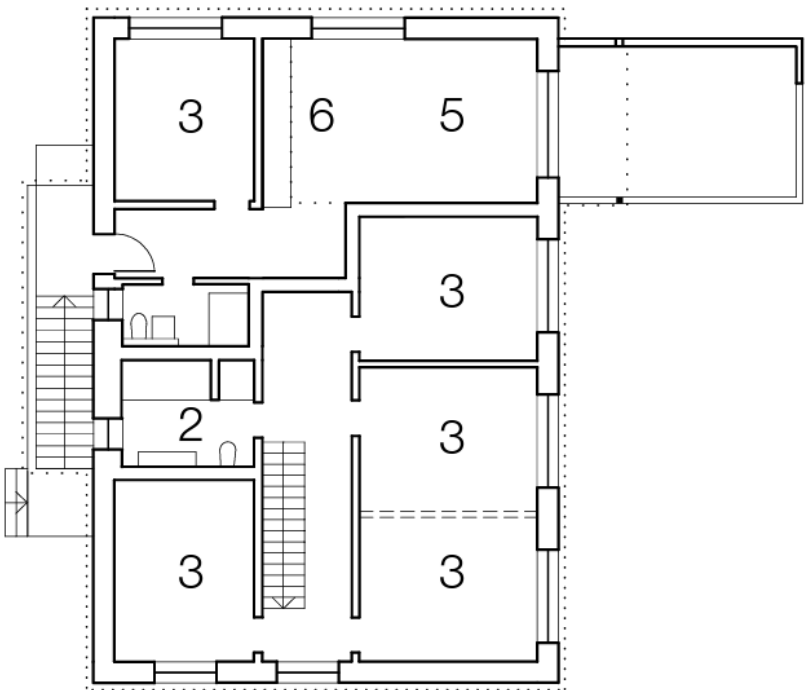

Figure 44: First floor plan of the Residential House, CH, scale 1:500, 2 Bathroom 3 Room 5 Dining areas 6 Kitchen (Voss et al., 2013)

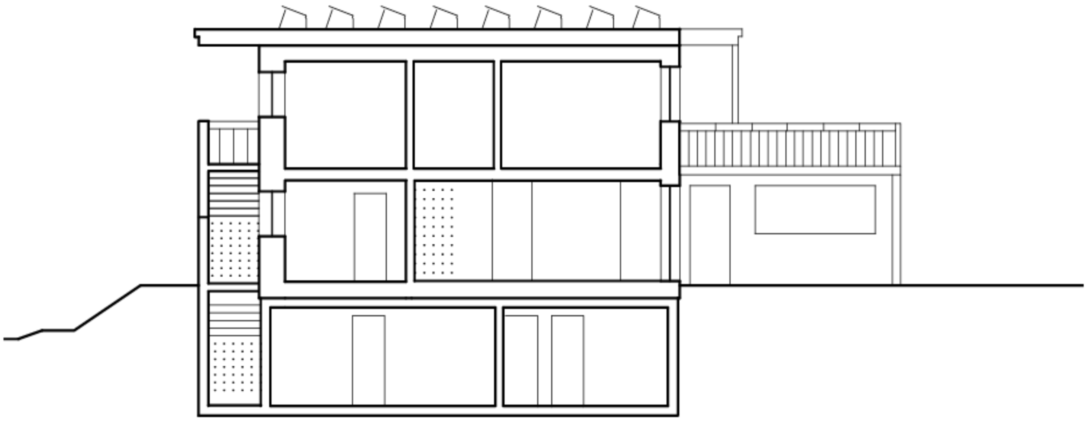

Figure 45: Section a-a Residential House, CH, scale 1:500 (Voss et al., 2013)

3.2.3 Minimize Building loads

Residential house is analyzed in this section, CH and condition of achieving net zero energy houses.

3.2.3.1 Compactness (A/V ratio)

Its compact shape, moderately sized openings, and lack of both projecting elements and recesses reflect the design approach. The specific features of the building like compact shape, medium size openings, without projecting materials and recesses, altogether convey efficiency maximization approach is applied. Some other eco-friendly features include applying natural and non-hazardous building resources and rainwater storage. The aspect ratio of ground plan is approximately 0.54.

3.2.3.2 Building envelope (U-value)

An opaque sealed building envelope (air tightness: n_{50} = 0.5/h) decrease the electricity usage. The opaque envelope's choice was generated on virtual reality of buildings and has U-values from 0.19 W/m^2 K, In the same way the windows embrace low-emission and triple glazing filled with argon, and in arrangement with frames get a U-value of 0.84 W/m ^{2} K for window (Voss et al., 2013).

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3.2.3.3 Building Orientation

Consumption data Analysis displays that operation of house has need of more energy than was anticipated in planning. By examination of the progress once-a-month, it was obvious that the photovoltaic system was adjusted for generating maximum electricity and was not prioritized for self-consumption coverage. The angle and alignment of the solar panels is optimized according to the solar electricity feed-in credits and flat roof offers the freedom of the design to the planners. This caused lots of energy excess from April to September, despite the fact there is a substantial shortage in winter months between November and February. Generation and consumption are consistent merely in March and October.

3.2.3.4 Passive heating, cooling, ventilation

Roughly 60 % of yearly hot water demands are provided by the solar thermal collector. The rest of heating demands are provided by the heat pump. During the winter, the air outside is provided by the ventilation system, which is heated before by U-shaped polyethylene pipe. It is functioning as a geothermal exchanger of heat.

A central ventilation system as well as heat recovery guarantees keeping ventilation losses low and air quality, influential standards of attaining MINERGIE-P status is met in this condition. When the building envelope was finished and three month after inhabiting it, airborne pollutant rates for formaldehyde and rates of total volatile organic compounds (TVOC) were examined, all the measures are 50% lesser than the suggested guiding principle of the Swiss Federal Office of Public Health. A comfortable inner climate is produced by the ventilation system and the supplied

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chilled air as well as outside shading in summer avoids overheating. There is no need to alter energy consuming habits for generating more energy (Voss et al., 2013).

3.2.3.5 Daylighting harvesting

Big windows alongside the southern facade give the opportunity of plenty daylight intake in internal places and backing the usage of passive solar energy (Figure 46). Fewer and minor windows are designed at the northern façade. The needed shading is provided by the exterior blinds and special rooftop overhangs.

Figure 46: View from south-west Residential House, CH (Voss et al., 2013)

3.2.4 Maximize Energy Efficiency

The concept of energy and the positive energy equilibrium are established on the building's effectiveness as set by the MINERGIE-P label. A series of factors are engaged in low demands for heating: very compact building design; an opaque and sealed building envelope (air tightness: n_{50} = 0.5/h) and extremely insulated by 38 cm of mineral wool; thermal windows with a heat transmission measurement of 0.84 W/m^2 K; and a ventilation method with effective heat retrieval and flat collectors of

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solar energy. Moreover, well-organized home applications decrease electricity consumption (Voss et al., 2013).

3.2.4.1 Heating and cooling

The heat pump not often works from April to September for the reason that higher temperatures and solar thermal collectors provide hot water. That is why, the imbalance is intensified. Electricity is only balanced by house and ventilation energy intake. The comparatively great electricity consumption for a MINERGIE-P building indicates neither predominantly high preservation measures nor remarkably strong power consumption. The positive energy balance to some extend pays compensation of embodied energy crosswise the building's life cycle. Nonetheless, the excess is inadequate to completely recompense embodied energy (Figure 47).

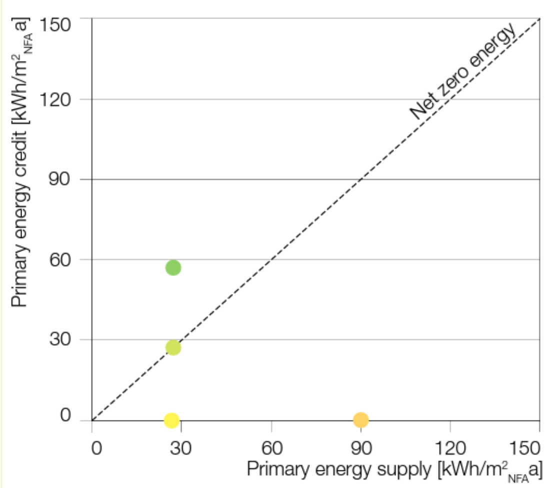

Figure 47: Energy evaluation of Residential House, CH (Voss et al., 2013)

The Net-ZEB-29 standard encompasses the subsequent characteristics:

Metered yearly entire prime energy consumption containing house electricity (87 kWh/m ^{2} a)

Energy self-sufficiency from commendable periodic yields (60 kWh/m ^{2} a)

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- Seasonal recompense of left over consumption
- Yearly energy excess, public grid feed-in (28 kWh/m^2)

3.2.4.2 Ventilation energy recovery

For controlling room temperature underfloor heating system is a good option. In summer, air supply can be inverted to somewhat cold and release some of the heat in winter to the earth (Figure 48). Simple systems are applied to meet residential necessities. Simple and affective procedure offers higher comfort.

Figure 48: View from north-west of Residential House, CH (Voss et al., 2013)

3.2.5 Utilize on-site renewable energy production

Some strategies utilizing renewable energy are described further down.

3.2.5.1 Photovoltaic Panel

The photovoltaic units cover 84 m^2 and are disposed at 10 degrees; the flat thermal collectors are sloping at about 30 degrees. The attached systems are not detectable on the street level and won't damage the cube-like exterior design of the building. Yearly energy balance of the building is positive. Overall, the solar system generates around 30 % extra electricity than spent it for heating, hot water, ventilation, and all

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the power is needed for household activities of a family inhabiting in a two bedroom flat. The PV structure is attached to the grid. Because the only energy source is electricity, consuming and generating can be balance in a straight line without any consideration of main energy weighting issues. Self-produced electricity is straightly related to grid source (Voss et al., 2013).

3.2.5.2 Geothermal energy

Geothermal energy is mined by a 120 meter deep hole and works as a source of heating for a brine/water heat pump, in addition to pre-cold supply air during summer.

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3.3 Moderate climate zone: Light House, United Kingdom

Figure 49: Building view of light house (Kingspan, 2007)

3.3.1 Climate of the location

Watford is a borough and town in Hertfordshire, England, located 27 km northwest of central London.The Watford's climate (Figure 50, 51) is normally moderate; moderated by existing winds of southwest over the North Atlantic Current; more than half of the days are cloudy (Stark, 2015). The building requires heating, air-ventilation and electricity because of the local climate condition.

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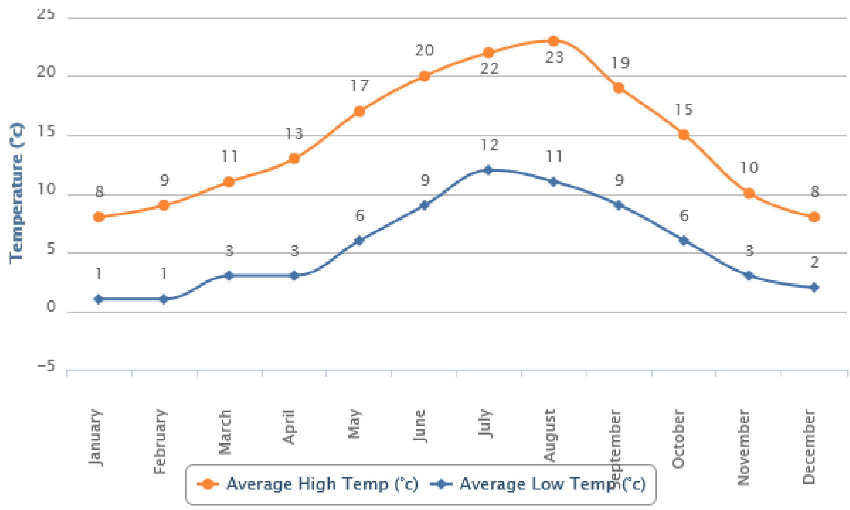

Figure 50: Average Temperature (°C) graph for Watford (Stark, 2015)

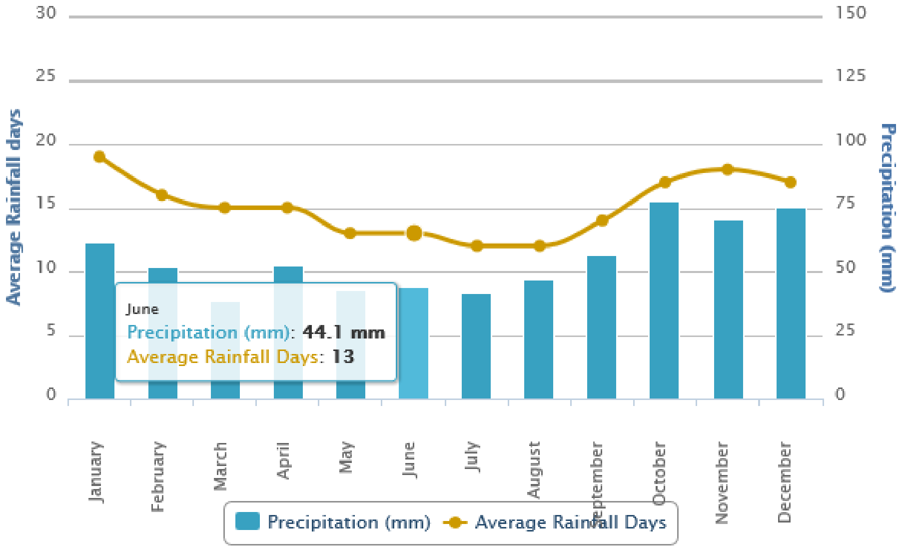

Figure 51: Average rainfall of Watford (Stark, 2015)

3.3.2 Description of project

Great Britain's first zero carbon building was a demonstration project of housing which was designed by Sheppard Robson and known as the "Lighthouse". It was constructed to observe the British "Code for Sustainable Homes" (CHS) standards. A main notion behind this house is to emphasize on solar energy's active use by employing of vacuum tube collectors and PV modules which are integrated in the

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roof skin. The slope of shed roof from north to south and slightly moves into the southern facade with no amendment in materials, give this home its distinctive look. This active gesture, as well as the large sweet chestnut wood use in both main and secondary structure, shows that this kind of structure is getting far away from the rather unemotional, classic British gesture of housing architectural design. The house is projected to symbolize the goal for a new start in both energy and architecture in the UK.

Throughout the whole process of planning, whether connecting to materials, construction, or energy consumption highest importance was given to complete and effective use of resources. A concept like passive house concept decreased the energy demands and solar collectors or a wood pellet boiler cover heating demands. The complete primary use of energy is covered by a PV system such as the domestic power demands during a year.

UK government has specified zero carbon as the standard. All new houses must be designed and built with respect to this standard by 2016. This standard and the other necessities of level 6 of CSH were achieved by the Kingspan Lighthouse. It achieved this goal by focusing on features like water use, pollution, consumption of energy, waste, the amount of emitted carbon dioxide, management, sustainable materials use, well-being, ecology, health, and surface water run-off. The Kingspan Lighthouse is net zero carbon i.e. it has no supplies of carbon energy for water heating and space and all demand of electrical power for home, such as appliances and electrical cooking. Rainwater harvesting or systems of water recycling provide about 30 % of the water in the house. This is in the same line with the Code's requirement which

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states that each person should not consume more than around 80 liters of drinkable water per day.

Figure 52: Plans and section of light house (Kingspan, 2007)

The property contains solar control and renewable energy, inactive cooling and mechanical ventilation and heat recovery (MVHR), and water efficiency techniques, which provide a flexible, adaptable space considered for up-to-date living, automatically integrating sustainability. A simple barn-like form contains the $93m^2$ structure, two bedroom house, and two-and-a-half story, and is derived from a roof with 40 degree, which houses a PV array. The central space is enveloped with a large, top-lit, open plan, double-height living space, and the sleeping accommodation at ground floor by the sweeping roof (Figure 52). The living space utilizes a wooden entrance structure in a way that floors can be located between left opens or the frames as needed.

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3.1.3.3 Minimize Building loads

The analysis in this section is relevant to light house and requirement of net zero energy building.

3.1.3.3.1 Compactness (A/V ratio)

This building is a demonstration one, so it is a temporary building; it doesn't have a cellar and has a wooden screw pile foundations. The balances can be detached after building destruction. The house strength is served by a floating slab covered with an immense concrete structure on ground floor level not a standard concrete slab. The inside flexibility in all three dimensions allows long term and varied use by diverse inhabitants, and thus inspires what is known as social sustainability. Nearly all the materials employed were selected with sustainability in opinion. Most of the elements can be recycled or have been resulted from recycling procedures.

3.1.3.3.2 Building envelope (U-value)

The premade wooden sandwich components with 39-cm thickness that make up the roof and wall include polyurethane hard foam insulation with 22 cm thickness core between two interior and two exterior panels of oriented strand board (OSB: structural wood panel) and get a U-value of 0.11 W/m^2K. In building the exterior walls maintenance was taken to decrease bridges with thermal characteristics to a complete minimum. Reveals and corners of building along openings obtained extra insulation. High level of air-tightness is contributed to vestibules at both entrances which function as zones of thermal buffer. A test of pressure estimated a value of 0.8 h -1 50 for the building (Kingspan, 2007).

The windows which are insulated with wooden frames have low-e covered triple argon gas filled glazing with a U-value of 0.7 W/m^2K for window. The field of study

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is a level of gallery that oversees the areas of living on the main floor. A middle open stairway crosses the several levels and ends at the clerestory windows which are facing to north. Consequently, daylight falls from the mezzanine down to the ground floor rooms, where a lavatory and the bedrooms are situated. This level also includes storage facilities, a utility room, and a bike shed. The boiler's waste heat, which is situated at the storage room, can be used for drying clothes.

To line the interior walls the fiber cement panels and gypsum board are used. They contain materials of phase change to make better room climate in summer. The concept of ventilation and daylight as well as the inside layout are integrated. A stack effect is created by the central stairway which is a light and air shaft, and the glazed "wind catcher" at roof level. So, permits inactive cooling as well as natural ventilation. When it is open, it accumulates cold outside air and conducts it from open living rooms to the ground floor bedrooms. Warm air that extends and increases can flee through controlled openings (Kingspan, 2007).

Use of LED lights at the outside and compact fluorescent lamps in the inside decreases energy consumption. The energy rating of all the appliances of household is A++. The amount of water which flows through the washbasin and shower to 8 1/min is reduced by water-saving taps, which indicates savings of 50 % compared to a typical house. For doing laundry and watering the garden rainwater is used, and grey water is used for restrooms with a dual flushing system's help. Energy monitors show all consumption of energy together with general information to make energy effectiveness more simply comprehensible and to raise user knowledge.

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3.3.3.3 Building Orientation

The structural shape of the lighthouse design is a “simple barn-like form” with a curved roof. The linear form of the Lighthouse is oriented along the east-west axis. The wide south facing roof is slopped 40° to have the capacity for the PV array.

3.3.3.4 Passive heating, cooling, ventilation

The Lighthouse contains an automated ventilation system which its factor of heat recovery is 88 %. With a 3.31 W/ (m ^{3} /h) value, the whole plant’s efficiency of electrical energy lags behind standard plants electrical energy effectiveness (Figure 53). The room heat is absorbed by phase changing material in the ceilings. To do this they are reformed from solid to liquid by microscopic capsules fixed in the board.

This course of action is inverted when the night air makes the room cooler, functioning with the wind catcher’s inactive system. Ventilation and passive cooling are secured by the wind catcher (see Figure 54) which is situated on the roof top, above the central hole over the stairway. By using any 2 of its 4 chambers, it gathers the wind from any direction. When it is opened, the cool air falls into the house core down to ground floor ‘turbo charging’ the effect of natural stack. The remaining two uncharged chambers discharge stale and hot air from the sleeping accommodation of ground floor and living space. The daylight together with sky sights mirrored in its polished fins are brought into the house plan by wind catcher which is fully glazed. The points for the Light House are as following:

1 Passive extraction of heat
1 Passive cooling / ventilation
2 Photovoltaic system
3 Solar thermal collectors
4 Fresh air
5 Exhaust air
6 Heat recovery

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7 Waste air
8 Supply air
9 Wood pellet boiler
10 Buffer tank
11 Grey water recycling

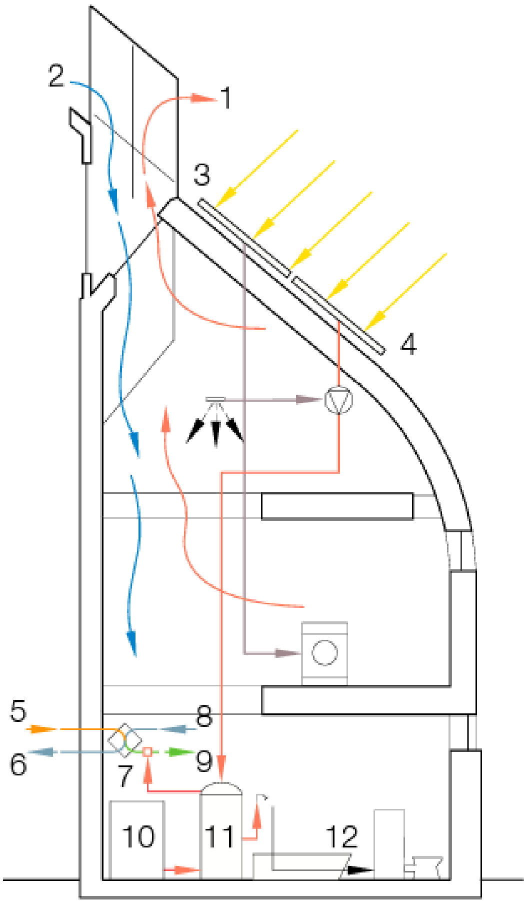

Figure 53: Technical concept in section, scale 1:200 (Voss et al., 2013)

Figure 54: Wind catcher (Kingspan, 2007)

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3.3.3.5 Daylighting harvesting

Southern façade of the building contains few openings to protect the house from overheating, which most of its parts are constructed in lightweight. Just about 18 % of the house's whole facade zone is glazed, and a main fraction of the glazing is done in the façade at western entrance. Visual privacy and sun protection are provided by sliding shutters. They include a 90% maximum decrease factor but can be slid away totally to permit solar gains, when needed.

3.3.4 Maximize Energy Efficiency

Some strategies utilizes for minimizing energy efficiency explained in below.

3.3.4.1 Heating and cooling

An automatically fed 10 kW timber pellet boiler together with the system of 4 m^2 vacuum tube accumulator and a 201 buffer tank cover the energy demand for space heating and domestic hot water. It is linked to the mechanical ventilation's air intake duct via the heat exchanger. Space heating heats the insides. The period of pellet boiler use should be merely for about six weeks of the year.

The integration of the area of pellet storage takes place in the small house. If pellet were stored outside, they could get humid or damp, and this would harm the boiler's automatic system and would generate less heating energy. Due to theoretically decreasing space in the house, the storage area of a pellet is limited to a volume of 0.25 m^3. According to primary energy, a 4.7 kWp PV system mounted on rooftop balances the total annual supply of energy (see Figure 55).

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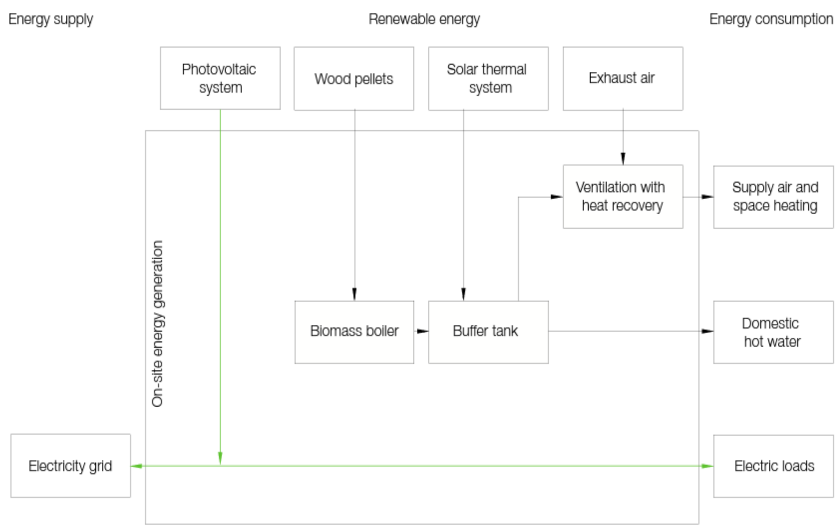

Figure 55: Technical schematic of energy provision (Voss et al., 2013)

3.3.4.2 Ventilation energy recovery

The passive ventilation system is achieved through locating wind catcher at the middle of the house. It is centrally placed on the roof and above the central void of the staircase in order to ventilate the upper and lower floors and in the same time will work as a secure ventilation system. Moreover, the location of it helps the passive cooling system works efficiently combined with the selective thermal mass system by catching the cold air and forcing it down into the house to replace the hot air and allowing it to escape.

3.3.4.3 Efficient Lighting and Lighting Control

Efficient lighting and lighting control is achieved by providing window view in the dining room, clerestory window in the kitchen, and stacked row of vertical windows on the living room. A large sliding glass door in the living room is opened to a small balcony that can extend the living space to the outdoors. The handrail of the balcony is made of glass to allow more daylight into the interior space. On the north façade, there are two sidelight vertical windows located on the bottom and top of the

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staircase to link the living area and the work area. Finally, to ensure a high quality luminous environment, a daylight factor of 1.5-2% is provided throughout the house.

3.3.5 Utilize on-site renewable energy production

Some strategies utilize renewable energy explained in below.

3.3.5.1 Photovoltaic Panel

The consequential final energy credits or debits and consumption of energy are recorded by a “smart meter system”. This lets the identification of the individual energy consumers and draws attention to chiefly high savings or consumption. Using British Standard Assessment Procedure (SAP), the Lighthouse’s requirements of energy were estimated during the design phase. The amount of energy which annually is required for pumps, ventilation, lighting, and the other usual energy users is around 52 kWh/m^2NFA. With a main energy feature in terms of the energy directive EN 15 603 this denotes 163 kWh prim /m^2NFA. This is equalized by a supposed output of energy of 192 kWh prim /m^2NFA from the 4.7 kWp array of solar energy (see Figure 56). The extra energy generated can be transferred to the national grid and offset the equivalent of primary energy for the pellets, which is nearly about 3 kWh prim /m^2NFA.

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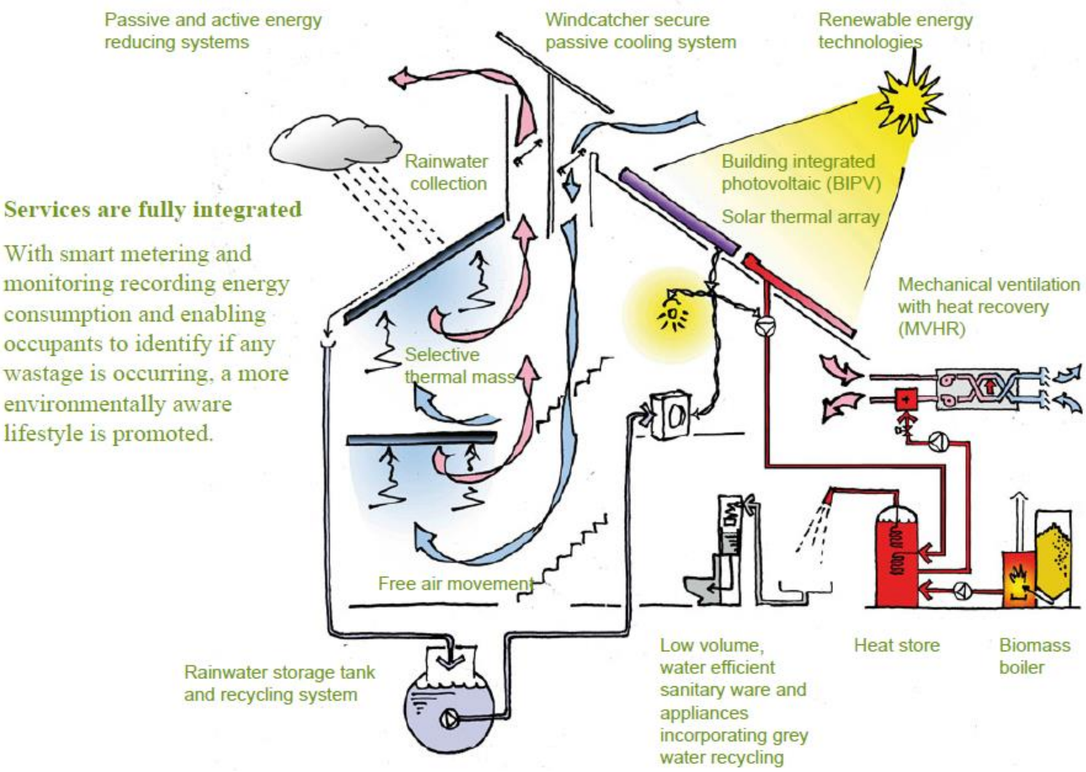

Figure 56: Energy supply of light house (Kingspan, 2007)

3.3.5.2 The Biomass Boiler

Unlike the traditional approach to passive heating in UK, the Lighthouse was designed with passive and active solar strategies and systems that operate differently on a seasonal basis. The solar thermal system shifts from passive mode in cooling and ventilation in summer to active mechanical mode for heating and ventilation in winter. This is achieved through the biomass boiler. The boiler uses wood pellets to provide both heating in the interior space and hot water in winter. To overcome the issue of "(electricity sapping) tumble dryer", the boiler is placed in the utility room in the lower floor to provide a drying area.

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3.4 Moderate climate zone: Klee house, Germany

Figure 57: Building south –east view of Klee house (Kingspan, 2007)

3.4.1 Climate of the location

The building is placed alongside Paul Klee Street in the Vauban district of Freiburg, Germany, where the climate is hot and moderate. Freiburg receives plenty of rainfall during the year, even during the driest period of the year receives lots of rainfall (see figure 58). The average yearly temperature is 13.4°C. Approximately 887 mm of rain falls per annum (Schwarz, 2012).

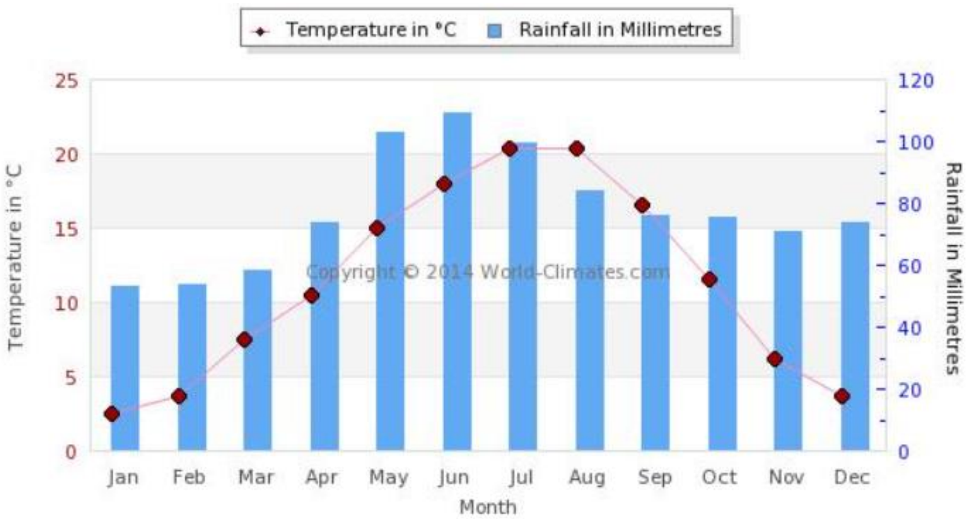

Figure 58: Average Rainfall and Temperature in Freiburg (Climates, 2014)

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3.4.2 Description of project

Twenty-four parties grouped together shaped an association in 2006 for building two multi-generational households according to the 2000-watt society requirements'. “Klee house” apartment buildings main design, situated alongside Paul Klee Street in the Freiburg, Germany, is consuming a middling of less than 500 watts of prime energy request per person and for housing usage. Both passive house design and consistent energy conservation enable reducing energy consumption to cover primary energy generation by a combination of small-scale combined heat and power plant, solar thermal collectors, photovoltaic systems, and acquiring shares in external wind power systems. Entirely yearly consumption-related emissions could be counterbalanced from renewable energy sources as requisite in 2000-watt association principles.

The project is centered on the Plan Living and Working, one of the primary 4 passive buildings in Germany, correspondingly designed and constructed in Vauban seven years before by same designers and engineers. Alike to the former plan, effectiveness has an important role in every design characteristics of the Kleehäuser, in respect to 3-D plan, structure, and expenses and above all, operative energy and its expenses.

Two vacation studios flat, thirteen in private owned studio flat, and ten rent payment studios flat with a total net floor space of 2520 m2 were made in two constructions of different height beneath the terms of a cooperative construction contract (Figure 59). The benefits of the cooperative contain the cooperative usage of area like a workstation, a shared recreational room with kitchen, washing rooms with washers and dryers, and an orchard (see figure 60). Different than purchasing completed apartments or buildings from developers, the owner association benefits financially from property taxes comprising only a fixed sum based on the property and not the completed building.

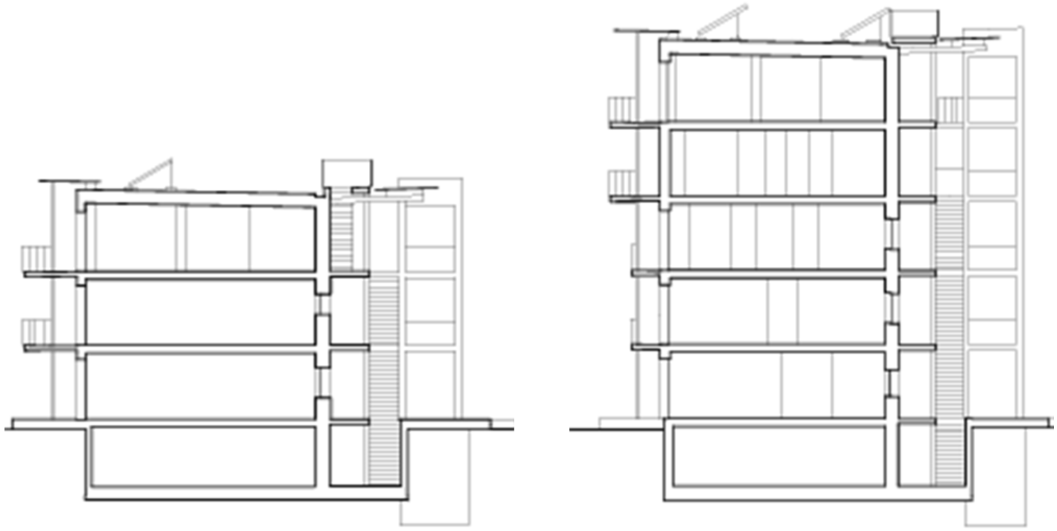

Figure 59: Section a-a of Klee house (Voss et al., 2013)

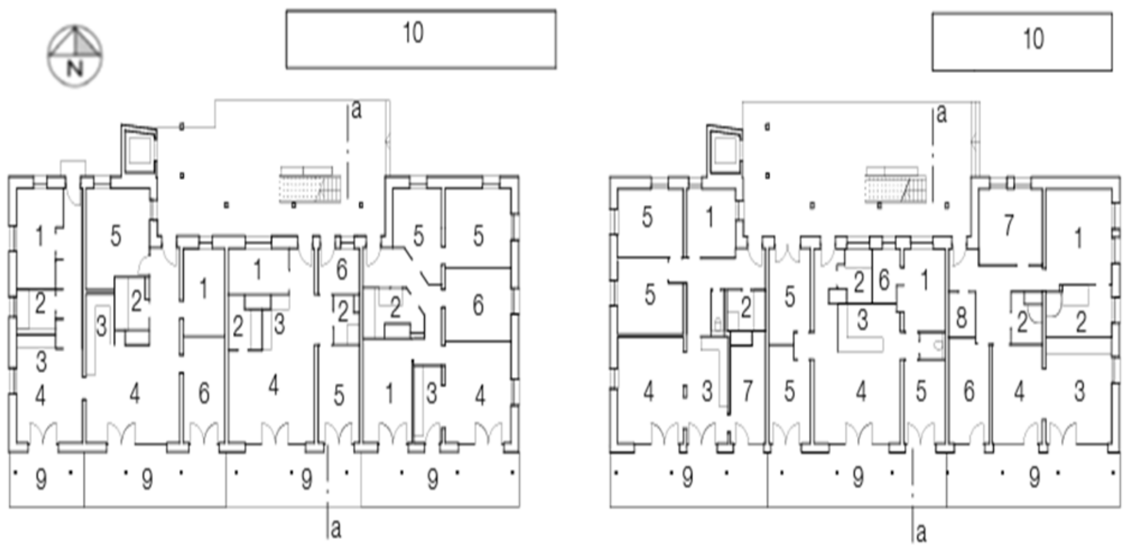

Figure 60: Plan of Klee house, 1 Bedroom 2 Bathroom 3 Kitchen 4 Living area 5 Playroom 6 Office 7 Guest room 8 Storage room 9 Balcony 10 Bicycles storage (Voss et al., 2013)

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3.4.3 Minimize Building loads

The analysis in this section is relevant to Klee house and requirement of net zero energy building.

3.4.3.1 Compactness (A/V ratio)

The actual structure type permits flexibly locating load-bearing dividers to make places with different widths based on the construction of module building that make it possible to join or even separate the units of the apartment. The inner space and finishes of the apartment is according to the requirements of the owner.

Figure 61: Access balcony with photovoltaics inclined southwards (Voss et al., 2013)

3.4.3.2 Building envelope (U-value)

The external strengthened cement walls and the light-weight infill wooden body building have the insulation of many coatings of mineral wool with thickness of approximately 30 cm. The heat transfer coefficient of the outer wall is 0.17 W/m^2K.

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Cover gable-end facades are coated with natural wood or steel panels. The raw resources create a patina for years, are eco-friendly, and there is no need to replace for years. These have economic and material investments in the operating period of the two constructions according to the primary design principles. Snowy fiber cement panels and triple-glazed wooden body windows are positioned interchangeably alongside the vivid balcony and outer pathway facades. Expanded polystyrene insulation (EPS) with the 30 cm width is placed amongst the reinforced concrete roof and the wide top planting. In general, the lower ground floor is used as a public space, is involved in the thermal envelope and completely insulated by stiff foam boards. The supply and exhaust air structure ducts characteristics upgrade thermal insulation for decreasing heat loss (Voss et al., 2013).

3.4.3.3 Building Orientation

Same principle is followed in the layout: living areas are in general leaning towards the south and other spaces are leaning toward the north (Figure 62).

Figure 62: South- East view of Klee House (Voss et al., 2013)

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3.4.3.4 Passive heating, cooling, ventilation

Favorable inner air quality is provided by the supply and exhaust air ventilation structure. A switch installed at entrance of each flat for adjustment of air flow as prerequisite is based on three settings. During winter, inner air is usually dry when it is switched naturally, but constantly. Klee house inhabitants can turn off the ventilation and keep humidity when lacking, so that moisture levels in the house commonly are more than 40 %. In selected apartments, loam render is applied as a humidity buffer that helps in maintenance of desirable humidity levels (Voss et al., 2013).

In calculation of yearly balance of energy, the needed gas for heating and generating of electricity is counterbalanced against feed-in credits of electricity from the photovoltaic structure, the joint heat and power plant, and the exterior turbines of wind. The calculation of the balance sheet prime energy weighting factors and CO_2 equivalents, are used. The primary energy weighting factor of electricity has altered from 2.60 to 2.70 in 2009, which result in a decrease in credits of electricity, in conclusion, the calculation of the balance sheet is affected adversely. Even though primary energy request (electricity component) amplified a little, the credit component was meaningfully lesser. The increase in the share of renewable energies in the electricity grid is expected to carry on, which will adversely affect the general balance sheet of the Klee house in the long period. An unexpected cold weather at the beginning and end of the 2010 caused an upsurge in consumption of gas by the joint heat and power plant (see figure 63).

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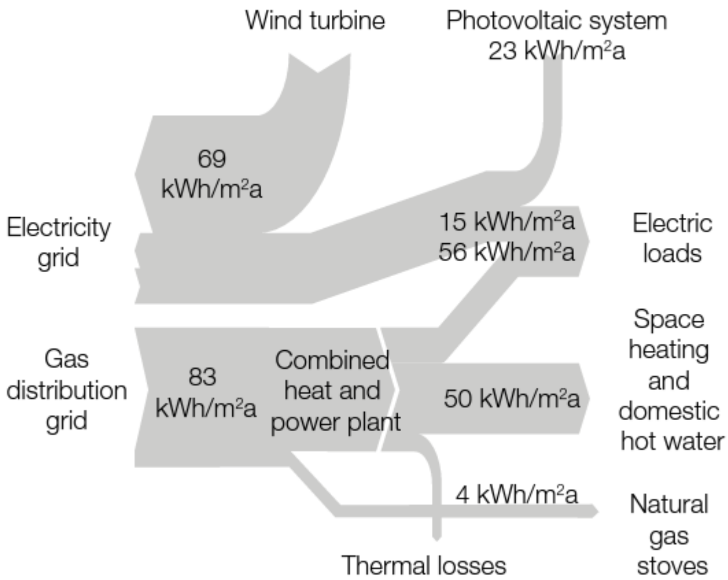

Figure 63: Flow quantity and weighting of individual loads and generation for electricity and heat (Voss et al., 2013)

In case of high heating demands, it works the whole daytime. On the other hand, its ranking (12W/m^2NFA) is satisfactory. Although the primary energy request upsurges as a result, the quantity of produced electricity is likewise more than the previous years. Simultaneously, lower solar radiation decreases the quantity of created solar power.

3.4.3.5 Daylighting harvesting

Highly glazed facades south-facing get the most of passive sun gains in wintertime. Cantilevered balconies facing the south and stretching out about two meters make available shading and avert overheating during the summer (Figure 66). The other facades have minor window surfaces. The similar principal is followed in the layout: in general living areas are south oriented, the other spaces are located on the northern part of the house.

3.4.4 Maximize Energy Efficiency

Some approaches that are used in minimizing energy efficiency described in below.

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3.4.4.1 Heating and cooling

A natural gas united heat and power plant with the electrical ranking of 14 kW and a thermal ranking of 30 kW produces enough electricity for self-usage, and surplus heat is useful in heating necessities. However further solar thermal structures decreases runtimes, and therefore, cost efficiency of the joint heat and power plant, and it is decided to put in flat collectors covering 61.2m^2. They transmit heat into a 3900 I solar storing tank with exterior heat exchanger attached to the small heating net situated in the middle of the two houses.

3.4.4.2 Ventilation energy recovery

A ventilation system produces the airtight constructions with a measured air flow that is heated at 20° C using the heat recovery system (85 %).

3.4.4.3 Efficient Lighting and Lighting Control

Energy-effective elevators, well-organized building utensils, and energy saving or LED inner and outer lighting likewise decrease electricity ingestion. Moreover, inhabitants used to avoid needless standby loads and switch off lights and ventilation systems when is not necessary. Natural gas ovens and energy-saving home applications are applied in all studios (Voss et al., 2013).

3.4.5 Utilize on-site renewable energy production

Strategies associated with the employment of renewable energy are described below.

3.4.5.1 Photovoltaic Panel

Furthermore, a 23 kWp flat roof-mount photovoltaic system offers electricity and balances a quota of the joint heat and power plant’s CO2 releases. Three purchased shares in a 6300 kW el wind power structure positioned in neighboring of St. Peter in Black Forest. Meanwhile the structures aren’t located in near to the constructions, primary energy adding up around 200,000 kWh per annum flows completely in the

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public electricity grid, where it increases the renewable portion of the electricity mixture. Therefore, the wind turbines are included in the electricity grid (Voss et al., 2013).

Furthermore, the CO_2 balance must be at best counterbalanced whichever by self-produced renewable energy or buying stocks in off-site facilities. Correspondingly, the mediocre heat transmission coefficient of the construction envelope should be at least 45 % fewer than requisite by the German Energy Savings Directive 2002. The heat transmission coefficient of the Klee House is 0.21 $W/m^2 K$. The owner associations empowers all inhabitants to have big freezers, five washing machines, seldom drying rooms in the cellars, and then, expressively decrease electricity consuming and acquiring expenses.

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3.5 Hot humid climate: University building, LA Reunion Island

Figure 64: Building view of University building, LA Reunion Island (Voss et al., 2013)

3.5.1 Climate of the location

Situated in the French tropical Island of La Reunion in the Indian Ocean was inaugurated in January 2009. The construction is situated at University of Reunion Island's Saint Pierre Campus and was aimed from the beginning to be a net zero energy plan with air conditioning systems which are mixed-mode in some areas. The Saint Pierre's climatic conditions are categorized in figure 65 (Desigua, 2014). Constantly high temperature in all seasons from December to April, high precipitation, high humidity in all seasons; because of its climate conditions, the building requires cooling, air ventilation and electricity.

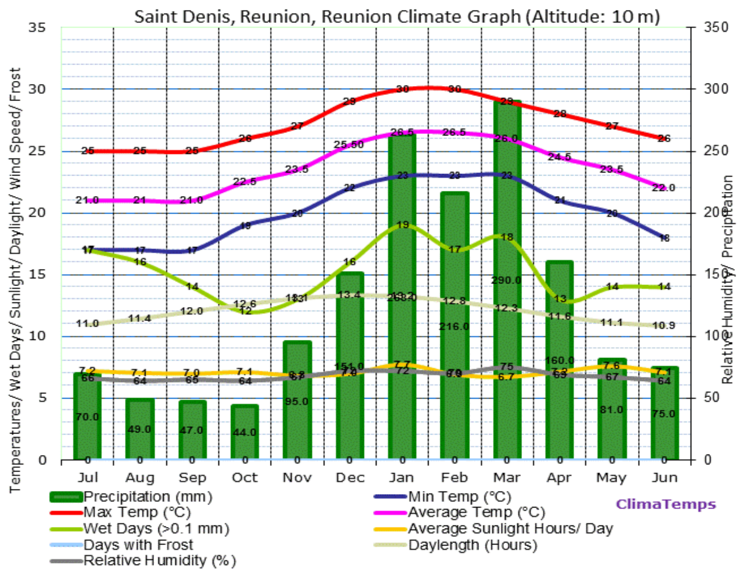

Figure 65: Climate conditions in Saint-Pierre, La Reunion (Desigua, 2014)

3.5.2 Description of project

In January 2009, the La Reunion's first zero energy building was installed in the south of the island i.e. Saint-Pierre campus. It is a university building that includes two floors, which has been split into two similar sections parted by a vegetated patio, comprised of a management area with an assembly room and 7 offices, 2 computer rooms and 5 classrooms for a total net 625 m² floor area (Figure 66). The core aspect of the building is to apply inactive devices to get visual and thermal comfort in the structure. Simulated lighting and air-conditioning should be employed as a last option (Garde, 2011).

To prevent heated air penetration, the construction is enclosed, 3m band, by vegetation when the natural ventilation mode is used. To use thermal winds during summer the central facades are north south faced and because of glass louvers which have the benefits of airflow regulation, their porosity is 30%, while offering shield against break-ins and cyclones. The opening percentage in a façade is defined as the porosity. The PERENE tool, a particular standard of design in La Reunion gives 20

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% as the minimum rate for the porosity to make sure an adequate natural ventilation of the spaces. In the management area, the ventilation was being cut off by the central corridor with offices around it. The project's original aspect was to set up interior louvers which improve the inside airflow, providing an inside porosity of 30% (Figure 67). The instalment of big ceiling fans in all spaces was another innovation, like fans with air-conditioning. The ceiling fans usage ensures an extra speed of air during the windless days and permits a temporary period before using active systems of air conditioning (Desigua, 2014).

1 Ante space
1 Foyer
2 Utility/storage room
3 Seminar room
4 Forum
5 Office
6 Meeting room
7 Void, forum
8 Covered walkway

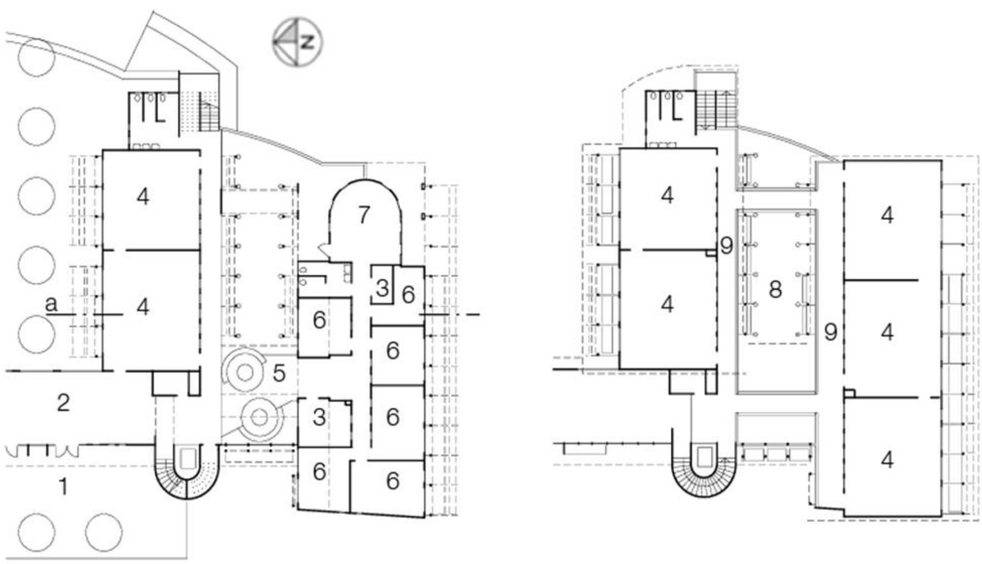

Figure 66: Ground and first floor plan, scale 1:750 (Voss et al., 2013)

9 Photovoltaics and fixed sun protection
10 Summer sun

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11 Winter sun
12 Fixed sun protection: wood louvers
13 Louvered glass windows: 30 % transmission factor
14 Cross ventilation
15 Ventilator

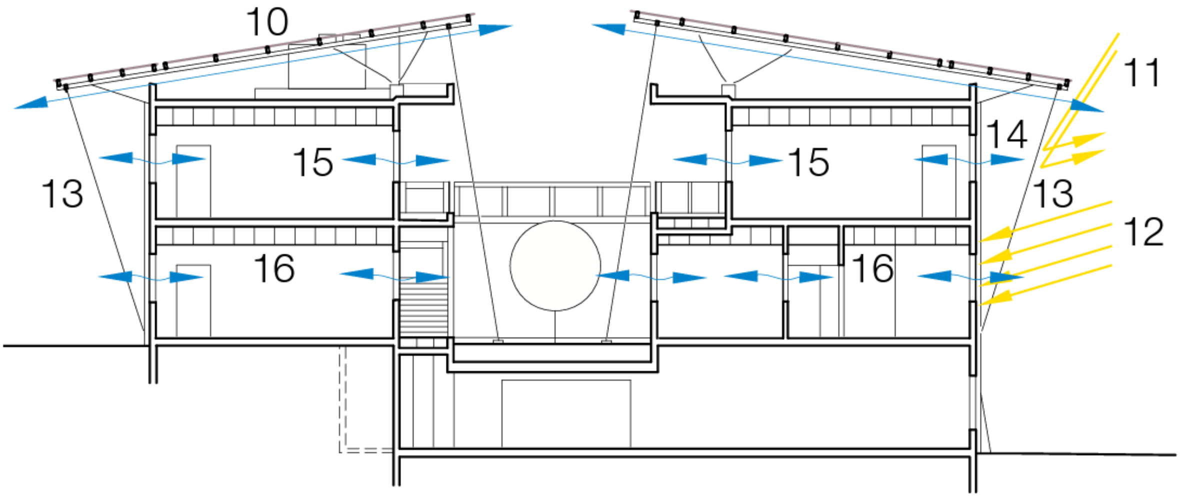

Figure 67: Section, scale 1:500 (Voss et al., 2013)

Due to consistently high temperatures, there is hardly no need for heating. However, air conditioning is a must, especially during the hot and humid summer between December and March, with temperatures averaging at 25°C and humidity over 70%.

3.5.3 Minimize Building loads

The analysis in this section is relevant to Enerpos university and requirement of net zero energy building.

3.5.3.1 Compactness (A/V ratio)

The structure of building includes strengthened concrete. No insulation is done on southern and northern walls. As there is a minor difference between the inside and outside temperature, gains or losses of heat transmittance are insignificant. Though, low heat absorption and shading for uninsulated walls is of critical importance. The external ambient temperature must be higher than the outside surface temperature, to

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stop heat flow's transmission. In the southern hemisphere, facades faced the north need shelter from direct sunlight. Fixed timber louvers as sun protection and cantilevered roof extending 2.40 m accomplish this and act as a shelter. The PV systems are set up on top of wavy sheet metallic roof decking raised above and offering shade for the two building volumes below. Ceilings contain a light insulation layer of 10 cm polystyrene. Uplifting the apparently light structures of roof increases ventilation under the PV systems, which in relation to strong intake and high external temperatures contribute to solar yield. The inclination of roof backs pulling air from the interior courtyard between the two building volumes via the wind currents of usual sea-borne, and consequently, eases indoor passive ventilation.

All class rooms include two outside walls and are indeed ventilated via louvered windows with single pane that can be manually modified to manage air flow based on the building volumes' layout with their interior yard and enclosed access walkways. The louvered glass provides better security in comparison to customary openable windows. They are similarly employed in the management zone and are located within walls between hallways and offices, where the natural cross-ventilation is provided by them through the building.

3.5.3.2 Building envelope (U-value)

Regarding the building envelope, a ventilated BIPV i.e. building integrating PV, over-roof and a 10 cm polystyrene layer insulate the roof; the walls are concrete made; the timber strips shading protects north and south facades from sunlight; a wooden siding and mineral wood insulate the east and west gables. The BIPV roof permits the generation of 70 000 kWh/y. The building is entirely checked with meters of energy by category of use to assess the building's real consumption during

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residence. The initial outcomes give an energy index of 30 kWh/m²NFA; the construction generates nearly four times more energy than it consumes (Desigua, 2014).

3.5.3.3 Building Orientation

The north-south orientation of the main facades limits the amount of sunlight falling on the easterly and westerly gables which are perpendicular to the breezes which blow during the hot season.

3.5.3.4 Passive heating, cooling, ventilation

The wide application of simulation tools aided mainly to improve the inactive components and add central architectural notions for a building with net zero energy in a subtropical climate, like sun protection and natural ventilation (Figure 68). Load matching was of minor significance. The outcome is that the house uses one fifth of the similar standard buildings' energy. Systems of air conditioning are typically not needed, even at the year's warmest days. High levels of convenient of indoors and excellent feedback are reported by inner velocity of air velocity, as well as a user survey relied on closely 2,000 questionnaires and recorded air temperature data, and relative humidity.

A landscaped indoor courtyard separates the building with two stories into two parallel strips. The whole area of floor with 1425 m^2 includes a management area with five seminar rooms on the ground and upper floors, seven offices at ground level, and an underground garage. For access and recreation the internal courtyard has a significant role.

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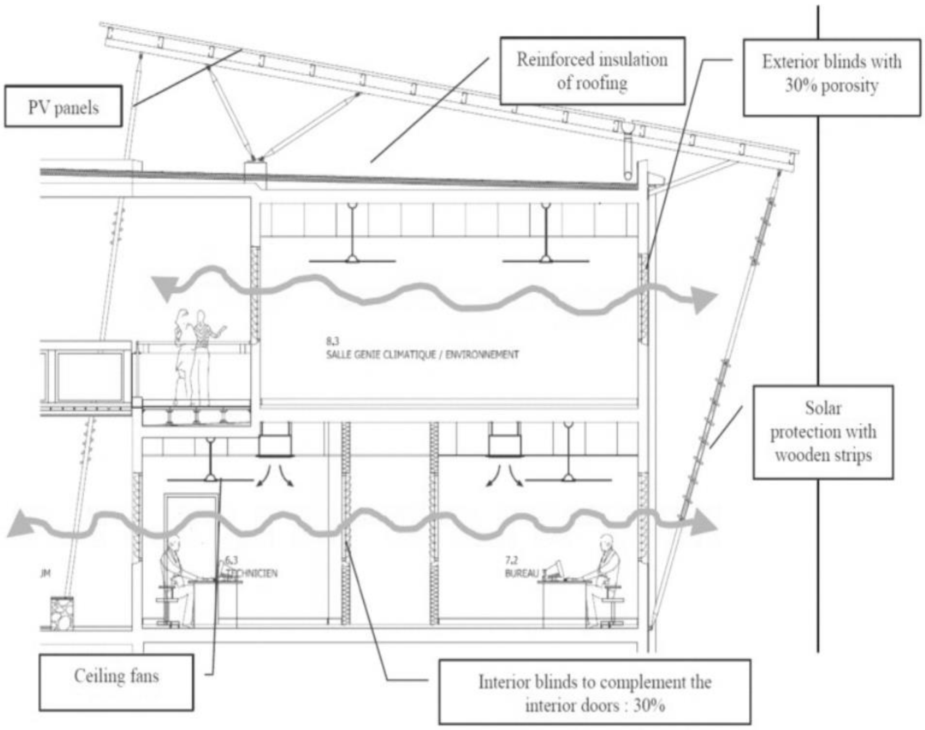

Figure 68: Utilization of wind (Desigua, 2014)

30 % of facades are comprised by windows. The facades face to north and south, to make benefits from sea winds. An indigenous vegetation of three meter wide succeeding the construction perimeter stops ambient air from heating up too much as it arrives the building. To avoid the too much heat radiation of asphalt surfaces which are too close to the building the parking spaces are situated under the building. Besides, during tropical downpours the unpaved surfaces increase drainage.

Inside air flow is increased by natural ventilation. Actually, natural ventilation itself is partly enhanced by fans. This leads to more dissipation of body heat by people through evaporate cooling and convection, and this makes them to feel more relaxed and happy even at higher temperatures. The LED-type lighting which is cautiously utilized in office spaces uses only 4.4 W/m^2 and includes an illuminance of 300 Lux. Lights are automatically turned off in seminar rooms two hours after lectures are arranged to finish (Yip et al., 2013).

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3.5.3.5 Daylighting harvesting

Sheltered walkways which are facing to the interior courtyard offer access to the construction and are benefited by ambient daylight, although are offering shadow for each other and neighboring windows. Simulations that are optimizing the shading impact and interior spaces natural lighting are the basis for the spacing between louvers. The findings indicated that from 8 a.m. to 6 p.m. i.e. during class hours, two to the seminar rooms needed no simulated lighting. The east and west facades which have no shade include outside wood cladding, also 4 cm of mineral wool that matches inside. Ceiling heights are used to insulate them. Due to its especial resilience and restricted number of rainy days in the region, all wood is utilized in original and is untreated (Leaders et al., 2014).

3.5.4 Maximize Energy Efficiency

Some strategies utilizes for minimizing energy efficiency explained in below.

3.5.4.1 Heating and cooling

The comfort in summer similarly becomes a significant point: the troubles for winter comfort are simply resolved in buildings with very low consumption, but summer discomfort can be created by the high insulation and the airtightness. This subject is particularly essential in a long term view since climate change is probable to strengthen this problem. The methods used to make sure summer comfort in France are like those in tropical climates. Mobile or fixed solar shelters are included to the buildings, as in “Kyoto” high school, “Pole Solere”, or the primary school in Pantin. A buffer area is made with a double skin fabricated of wood strips and a planted zone that produce a heat protection from the street, in the residence “Ilet du Centre”. There is no demand for hot water heating or space heating. Still, a shower was not included for cyclists. Utilities and metering concept of electricity are kept simple since it is the

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only source of energy (see Figure 69). The huge solar yield covers entire consumption per month; moreover, a very large surplus is generated. Obviously, user consumption is predominated factor, and monthly compensation is due to consistent many year solar intake and lack of space heating or hot water demand.

Metered annual consumption of entire primary energy, 106 kWh/m²a

Building-specific consumption of primary energy, 36 kWh/m²a

Consumption beyond the usage of self-generated solar electricity which covers the monthly self-demands, 106 kWh/m²a.

Annual energy surplus grid feed-in 154 kWh/m^2.

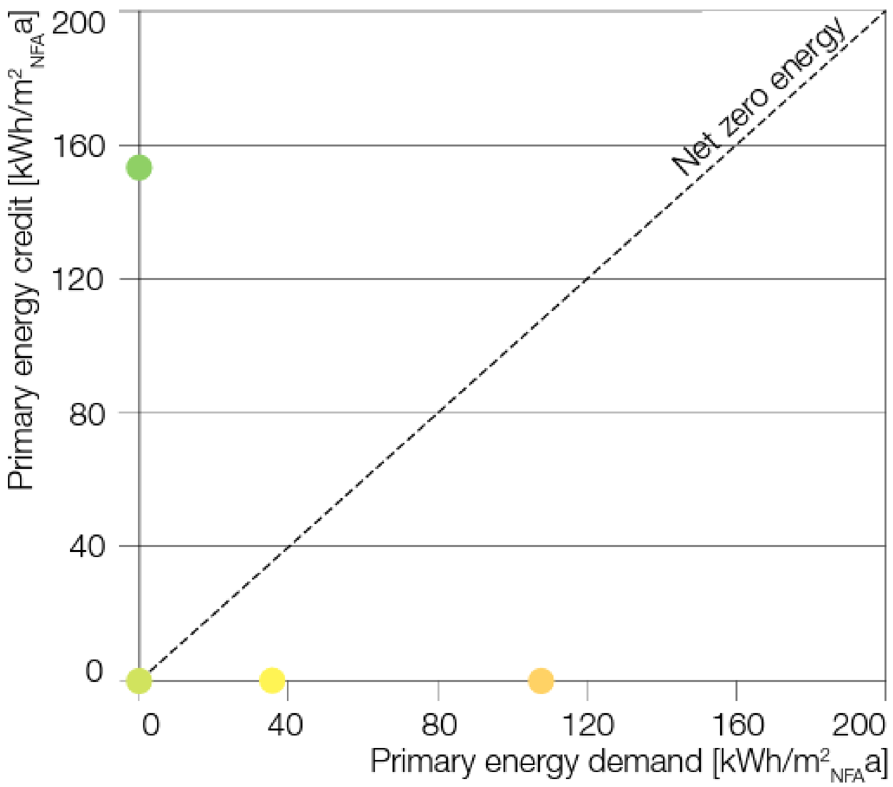

Figure 69: Energy evaluation of Enerpos University (Voss et al., 2013)

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3.5.4.2 Ventilation energy recovery

During especial windless hot days, individual office spaces and computer classrooms are cooled and dehumidified by a central air-conditioning system. The usage of air conditioners in computer rooms is restricted to about six weeks per year because of ceiling fans and natural ventilation, and presently isn't even needed in remaining spaces. The similar buildings' air conditioning systems on the campus of university normally are operating nine months per year.

3.5.4.3 Efficient Lighting and Lighting Control

One half of the surfaces of the roof face the north, the other half are oriented towards to south. Due to high angle of sun and the slight roof slope, yield difference is relatively small at only 8 %. Window has eleven mobile single pane louvers 700 ≈ 1400 mm^2 wall constructions: 140 mm strengthened concrete without insulation (Figure 70).

Figure 70: Section, wall with louvered windows, scale 1:20 (Voss et al., 2013)

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3.5.5 Utilize on-site renewable energy production

Some strategies related to the utilization of Renewable energy are explained below.

3.5.5.1 Photovoltaic Panel

A PV system which covers 350 m^2 with a rating of 50 kWp is integrated into the roof structure of the two constructions, sloped at 9°. All loads of electricity are checked. First estimations show that the entire consumption of electric power is 32 kWh m^2 NFA, that is meaningfully less than the objective of 70 kWh/m^2 NFA. The PV systems produce almost 70,000 kWh/a (1,428 kWh/kWp). The computed solar outcome is only under 80 kWh/m^2 NFA, noticeably greater than consumption. Consumption and generation of electricity are extremely synchronous because of low seasonal differences in consumption of electricity, steadily high solar intake, and the fact that the constructions are mostly used during daytime.

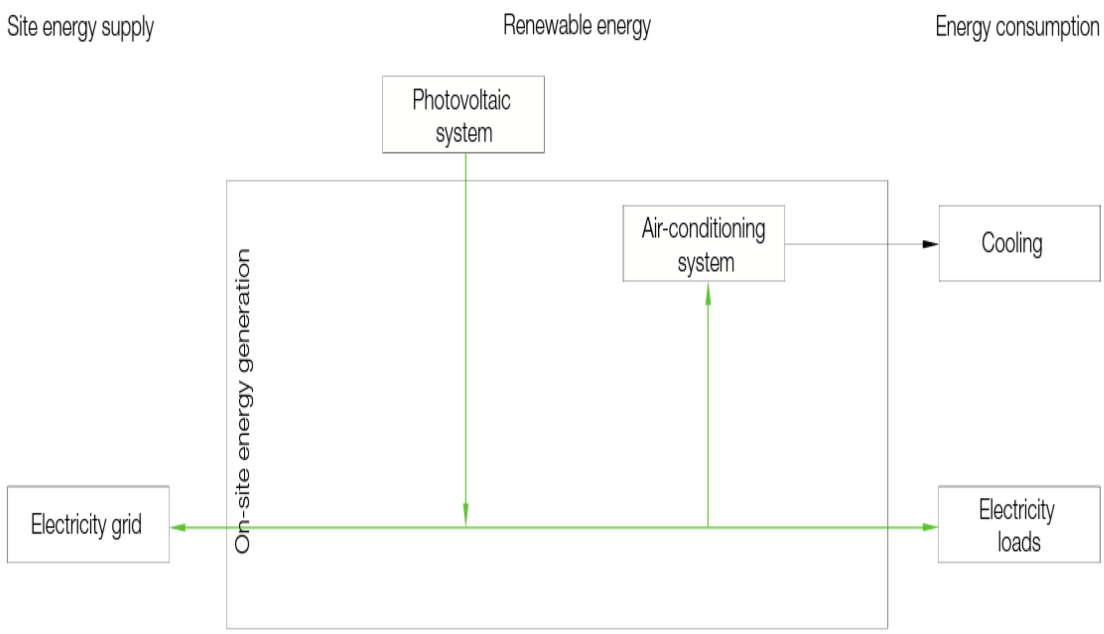

Figure 71: Technical schematic of energy provision (Voss et al., 2013)

The island's context of energy is very complex because the demand of energy is rising annually with a percentage of 4%. Due to La Reunion's insularity, it has to offer its full generation of electricity (see figure 71). It is one of the most polluting in the world because it is mostly generated by fossil fuels. An electrical kilowatt-hour produces around 820g of CO_2. The energy demand of tertiary and housing buildings includes 30% of the island's total energy consumption. Regarding fossil fuels decline and the global warming, the building sector's consumption of energy must be reduced and renewable energy sources must be found.

3.2 Analysis

An analysis of different climate zones case studies will be presented in this section.

3.2.1 General information

Table 1: General information

Information	**Cold**		**Moderate**		**Hot-Humid**
Location	Canada	Switzerland	United Kingdom	Germany	La Reunion Island
Project	Ecoterra Home	Residential House, CH	Light House	Klee House	Enerpos University
Annual mean temperature at site	6.0 ° C	8.1 °C	10.4 °C	11.6 °C	25 °C
Building type	Residential	Residential	Residential	Residential Complex	University
Context	Rural	Suburban	Suburban	Suburban	Suburban
Completion Date	2007	2007	2008	2006	2009

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3.2.2 Utilize On-Site Renewable Energy

Because of different climate zones, the utilization of design strategies in each climate zone is totally different, so each climate zone has potential for specific utilization or production of renewable energy. On the other point of view the strategies for reducing energy wasting will be also different, and even the sense of thermal comfort will be different. As presented in table 2, the most important aspect in decreasing the energy waste and increasing the thermal comfort for instance in cold climate is enhancing thermal mass of building envelope. On the other hand, in hot humid climate it is focused more on sunlight control and increase of the natural ventilation efficiency. But in moderate climate, strategies that are useful in both hot and cold climate must be applied.

Table 2: Utilize On-Site Renewable Energy focus of case studies

Cold Climate Zone		Moderate Climate Zone		Hot-Humid Climate Zone
Ecoterra Home	**Residential House,CH**	**Light House**	**Klee House**	**Enerpos University**
-BIPV/T (solar electricity plant with joined thermal air collector) -mechanical ventilation by heat recovery -ground water heat pump -growth and activation of thermal storage mass.	-mechanical ventilation with heat recovery -solar thermal collectors -brine/water heat pump, -photovoltaics	-passive house components -mechanical ventilation by heat recovery -photovoltaic system -biomass boiler -ecological building materials	-combination of small-scale combined heat and power plant - solar thermal collectors - photovoltaic systems - acquiring shares in external wind power systems - controllable supply and exhaust air ventilation system	-Photovoltaic system -sun protection model -natural ventilation -ceiling fans -use of natural daylight -efficient artificial lighting

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3.2.3 Compactness (A/V – ratio)

The compactness of a building is indicated by the surface area to volume (A/V) ratio. This ratio, between the external surface area and the internal volume of a building, has a considerable influence on the overall energy demand. The table 3 illustrates the influence of form and size on the A/V ratio. The best compactness ratio in the table is considered in the hot humid climate case with the A/V ratio of $0.32 m^2/ m^3$, and for cold climate case and moderate climate case A/V ratio is nearly same because of heating demand is utilized in both climate zones.

Also from thermal mass point of view in cold climate zone, in case Ecoterra Home by utilizing open structure and by locating 8 cm massive concrete on the floor and interior brick on the vertical wall in south facing of building, these strategies altogether helped storing heat and moderating interior temperature. In this climate in case of Residential House again by utilizing concrete in external envelope in south facade and compact shape reach to passive solar heat gain through the increase of thermal mass.

In moderate climate zone also utilizes from south orientation for passive solar heat gain and in case Light House for absorbing heat by mutate liquid instead of solid within tiny capsules built-in the board utilizes phase change material in ceiling. This process is reversed when the room is cooled with the night air, working with the passive system of the wind catcher. And in Klee House fiber cements board is used in the walls and also in the ceiling reinforced concrete is used and even for the building envelope rigid foam panel is used.

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In hot-humid climate exposed thermal mass is already present inside the building. The insulation was installed on the exterior of the existing thermal mass not to hinder its function of moderating the internal conditions.

Table 3: Compactness of case studies

Climate/ Building parameter	Cold climate zone		Moderate climate zone		Hot-Humid Climate zone
Case Studies	**Ecoterra Home**	**Residential House, CH**	**Light House**	**Klee House complex**	**Enerpos University**
Net Floor Area, NFA	230 m^2	302 m^2	79 m^2	2520 m^2	781 m^2
Gross Floor Area, GFA	250 m^2	315 m^2	93 m^2	2965 m^2	1425 m^2
Gross volume, V	700 m^3	1600 m^3	432 m^3	10,909 m^3	3847 m^3
Building Envelope, A	544 m^2	858 m^2	375 m^2	4402 m^2	1234 m^2
Surface to volume ratio, A/V	0.78 m^2/m^3	0.54 m^2/m^3	0.87 m^2/m^3	0.40 m^2/m^3	0.32 m^2/m^3

3.2.4 Building envelope, insulation on wall, roof and window

High resistance to heat flow (low U-value) is important in climate where energy using services are used to maintain a large temperatures difference between indoors and outdoors. In the table 4, the windows U-value in hot humid climate zone is less important and mean U-value building envelope in hot humid climate is high in comparison to the other case studies because in this climate zone heating demands is

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not important. Whilst the window and mean U-value of building envelope in other climate zones is low, they can achieve better energy saving results.

Table 4: Building envelopes of case studies located in three different climate zones

U-value	Cold Climate zone		Moderate climate zone		Hot-humid climate zone
Case studies	**Ecoterra Home**	**Residential House, CH**	**Light House**	**Klee House**	**Enerpos University**
Exterior wall	0.16	0.12	0.11	0.17	0.67 - 3.30 **
Windows	1.25	0.84	0.70	0.98	6.00
Roof surface	0.16	0.11	0.11	0.11	0.43
Skylights			0.72		
Floor slab	0.66	0.10	0.11	0.18	0.26
Mean U-value, building envelope	0.27	0.19	0.17	0.21	2.90

*In this table all amount is W/m^2K

**In case 3, Enerpos university the 0.67 is for East- West exterior walls and 3.30 for North – South exterior walls.

3.2.5 Building Orientation and Daylighting

Table 5 shows the advantages of utilizing orientation from different climate zones in different buildings. In cold and moderate climate zones the main utilization is the south direction of buildings for daylighting and passive solar energy, light house direction is an exception in moderate climate zone which main elevation is faced to the west because of neighborhood location, but utilization of solar energy is same as others. In contrast in hot-humid climate zone the direction of building depends on wind utilization so as mentioned in table 5 it is oriented towards north and south.

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Table 5: Building Orientation and daylighting of case studies

Cold climate zone	**Ecoterra Home**	More than 40 % of the main facade, oriented towards the south, is glazed. Overall, 15 % of the facade's 230 m^2 are glazed, providing a high amount of daylight intake in the rooms.
	Residential House, CH	Large windows along the southern garden facade permit ample daylight intake in interior spaces and support the use of passive solar energy. The northern facade has significantly fewer and smaller windows. External blinds and occasional roof overhangs provide required shading
Moderate climate zone	**Light House**	Oriented along the east-west axis. Shading to the west elevation is provided by retractable shutters restricting direct sunlight, minimizing heat gain in the summer.
	Klee House	Extensively glazed facades are facing to south optimize passive solar energy gains in winter. Cantilevered balconies oriented towards the south and extending up to two meters provide shade and prevent overheating in summer.
Hot-humid climate	**Enerpos University**	Windows comprise 30 % of facades and are oriented towards the north and south, in order to take advantage of winds from the sea.

3.2.6 Heating, Cooling System

As presented in table 6, in cold climate zone which Ecoterra Home and Residential House is located, the heating has a great importance. That is the reason why geothermal energy like ground water heat pump system was used here. But in moderate climate zone which Light House and Klee House is located, heating demand has less importance than cold climate. For this reason an automatically fed 10kw wood pellet boiler and natural gas combined heat and power plant is used. In contrast, in hot-humid climate zone which Enerpos University is located, heating is not important. The air-conditioning like ceiling fans is required for cooling demand.

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Moreover annual electricity supply of these five cases is provided by photovoltaic panels.

Table 6: Heating, Cooling System of case studies in three main climate zones

Cold climate zone	**Ecoterra Home**	-An 11-kW the ground water heat pump act as a main heating system. -The grid-linked solar electricity plant, which is integrated balanced in two sloped roofs, the greater part of which faces to south at a 30° angle, contains a total of 21 panels by amorphous silicon cells each with a nominal capacity of 136 W. The full volume is 2.85 kW p.
	Residential House, CH	-Geothermal energy is extracted via a 120 meter deep borehole and serves as a heat source for a brine/water heat pump, as well as to pre-chill supply air in summer. - The 14.4 kW p photovoltaic system serves to cover remaining energy demands and is installed on the flat roof similar to the 7.5-m ^{2} solar collectors..
Moderate climate zone	**Light House**	-The energy demand for space heating and domestic hot water is covered by an automatically fed 10 kW wood pellet boiler. -The pellet storage part is integrated in the small house. -In terms of primary energy, a rooftop-mount 4.7 kW photovoltaic system offsets the total annual energy supply.
	Klee House	-A natural gas combined with heat and power plant and with an electrical rating of 14 kW and a thermal rating of 30 kW generates electricity for self-demand coverage, and waste heat is used to cover heating requirements. -A 23 kWp flat roof-mount photovoltaic system provides electricity and offsets a portion of the combined heat and power plant's CO_2 emissions.
Hot-humid climate zone	**Enerpos University**	-A central air-conditioning system serves to cool and dehumidifies individual office spaces. -Because of natural ventilation and ceiling fans, usage of air conditioners in workstation rooms has been limited to a runtime of 0.11 per year and at present isn't even essential in remaining spaces. -A photovoltaic system coating 350 m^2 and with a rating of 50 kW p is integrated into the roof structure of the two buildings

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3.2.7 Energy balance

The amount of energy production and consumption of the cases have been illustrated in table 7. In hot humid climate zone which Enerpos University is located in electricity generation is two times more than its consumption. In other words, consumption and generation of electricity are extremely synchronous because of low seasonal differences in consumption of electricity, steadily high solar intake, and the fact that the building is mostly used during daytime. Furthermore, the building does not need space heating and there is not any demand for hot water. In moderate climate zone in case of Light House the energy saving is about 20 % more than its energy consumption because of the consequential final energy credits or debits and energy consumption is recorded by a "smart meter system". This lets the identification of the individual energy consumers and draws attention to chiefly high savings or consumption. But in case of Klee House energy production and generation is equal. The reason is energy production in cold seasons is more than other seasons because of low solar radiation in this season. In cold climate zones and in case of Ecoterra Home compared to other case does not include energy saving than the case of Residential House which has a 30 % energy saving. The reasons are as the following factors: site energy consummation, higher water heating and space heating consumption. Moreover, the users set up a workshop in the garage, which was not originally planned and electrical installation caused more energy consumption.

The passive use of solar gain and the completely insulated, airtight external envelopes from basis of net zero energy approach has more importance in cold and moderate climate zone. Large window along southern façade permit ample daylight intake in interior space and support the use of passive solar energy.

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Table 7: Energy balance analysis of case studies in different climate zones

Climate zone	Cold		Moderate		Hot-humid
Case studies	**Ecoterra Home**	**Residential House, CH**	**Light House**	**Klee House**	**Enerpos University**
Supply infrastructure	electricity grid	electricity grid	electricity grid, delivery of wood pellets	electricity grid, gas grid	electricity grid
Energy source supply	Electricity	Electricity	Wood pellets, electricity	Natural gas, electricity	Electricity
Feed-in infrastructure	electricity grid	electricity grid	electricity grid	electricity grid	electricity grid
Feed-in energy source	Electricity	Electricity	Electricity	Electricity	Electricity
Space heating consumption	42	11	22	14	-
Water heating consumption	26	14	16	10	-
Site energy consumption for heat	34	5	-	61	-
Electricity consumption	54	29	52	26	32
Total primary energy consumption	65	87	166	152	106
Total primary energy generation	13	115	192	148	260

*Grid infrastructure and energy sources
*Consumption parameters kWh/m^2

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Chapter 4

CONCLUSION

This research tries to find the answer to following questions: First, What are the important criteria for achieving net zero energy building? And, how could net zero energy building be achieved in different climate zones? Net Zero Energy Buildings have the promising potential to significantly reduce the energy use and as well as to increase the overall share of renewable energy.

Moreover, in different climate zone the five cases which were considered in the study employ the distinct logically net zero energy building strategies to achieve the same goal. Strategies like alternative energy source (solar PV, ground water heat pump), passive solar design strategies, high performance of building envelope, lighting and daylighting and low energy consumption which are considered to be components of net zero energy building. It uses highly sustainable materials as well as it possesses excellent indoor environment quality and its design measures include optimization of solar energy collection, storage and shading, plus natural ventilation and advanced daylighting measures.

Based on the analysis conducted on three main climate zone some important requirements are presented in following table to achieve net zero energy building. There are some similarities between these cases: they all have employed PV system to generate electricity, and all have provided good thermal comfort for the indoor

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spaces. To sum up the hot-humid climate zone requirements for net zero energy building is different in comparison to moderate and cold climate zone. Heating demand is impacting the building structure in different climate zones.

Table 8: Some of important requirement for achieving net zero energy building in different climate zone

Cold climate zone	**Moderate climate zone**	**Hot-humid climate zone**
-Photovoltaics/BIPVT -Ground water heat pump -Growth and activation of thermal storage mass -Mechanical ventilation by heat recovery -Solar thermal collectors -South oriented building -Large south-facing windows -High thermal insulation -Passive charge concrete slab & brick wall -Internal thermal mass -Heavy weight structure	-Photovoltaic -Biomass boiler -Ecological building materials -Mechanical ventilation by heat recovery -Solar thermal collectors -Acquiring shares in external wind power systems -South-facing windows -South oriented building -high thermal insulation -Passive solar heating and lighting -Internal thermal mass -Heavy weight structure	-Photovoltaic -Sun protection model -Natural ventilation -Ceiling fans -Mechanical ventilation and dehumidifying -Use of natural daylight -Thermal mass applied cautious amounts and must not be very thick -Lightweight structure -Building orientation for utilizing sea wind

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REFERENCES

Aelenei, D. H. F. (2008). Analysis of the condensation risk on exterior surface of building envelopes. *Energy and Buildings*, 1866-1871.

Asa, F. (2005, 11 3). Retrieved 10 21, 2014, from HousingZone: http://www.housingzone.com/

Bahaj, A.S. (2003). Photovoltaic roofing: issues of design and integration into buildings. *Renewable Energy*, 2195-2204.

Boubekri, M. (2008). *Daylighting, Architecture and Health Building Design Strategies.* Oxford: Elsevier Ltd.

Brandon, T. (2010). Developing The Next Three Generation of Zero Energy Windows. *Technology Officer at Serious Materials*, 6.

Bridgewater, A. (2009). *Renewable Energy for Your Home.* U.K: Ulysses Press.

Canada, N. R. (2004). Consumer's Guide To Buying Energy-Efficient Windows and Doors. *Canadian Cataloguing in Publication Data*, 34-37.

Chivers, R. (2009). *Passive Solar Design*. Retrieved 01 05, 2015, from Passive Solar Design: http://passivesolar.sustainablesources.com/

`

Climate, C. (2014). world travel. Retrieved 11 17, 2014, from Copenhagen Climate and weather: http://www.wordtravels.com/Cities/Denmark/Copenhagen/Climate

CMHC. (2007). *ÉcoTerra™ — Eastman, Quebec*. Retrieved 01 12, 2015, from Canada Mortgage and Housing Corporation: http://www.cmhc-schl.gc.ca/odpub/pdf/65594.pdf

Desigua. (2014). *Saint Denis, Reunion Climate & Temperature*. Retrieved 01 12, 2015, from climatemps: http://www.reunion.climatemps.com/

Eltawil, M. M.Z. Z. (2010). Grid-connected photovoltaic power systems: Technical and potential problems—A review. *Renewable and Sustainable Energy Reviews*, 112–129.

Foster, R. M. G. (2010). *Solar Energy: renewable Energy and the Environment.* London: CRC Press.

Garde, M. D. (2013). *Annex 52 Case studies Recommended building solutions.* Copenhagen: Energy conservation in Buildings and community systems program.

Giuseppe, E. D. (2013). *Nearly Zero Energy Buildings and Proliferation of Microorganisms.* Italy: Springer briefs in applied sciences and technology.

GlobeMedia. (2014). *Weather in Montreal*. Retrieved 01 12, 2015, from Expat Arrivals : http://www.expatarrivals.com/canada/montreal/weather-in-montreal

Hausladen, G. P. L. (2011). Building to Suit the Climate. Munich: Birkhäuser .

Han, J. L. L. (2009). Investigation on the thermal performance of different lightweight roofing structures and its effect on space cooling load. Thermal Engineering, 2491-2499.

Hegge, M. M. F. (2008). *Energy Manual Sustainable Architecture.* Munich: Birkhäuser Verlag AG.

Holton, W. (2013). *On-Grid vs Off-Grid Solar (A comparison*. Retrieved 01 06, 2015, from anapode solar: https://www.anapode.com/content/On-GridVsOff-Grid

Hootman, T. (2013). *Net Zero Energy Design, A guide for Commercial Architecture.* Canada: John Wiley & Sons.

Hoyle, B. (2011). *Low Energy Building Engineering.* Delhi: The English Press.

Idayu, A. M. S. R. (2012). Review on heat recovery technologies for building applications. *Renewable and Sustainable Energy Reviews*, 1241-1255.

`

Insight, E. T. (2010). *Riverdale NetZero Deep Wall System*. Retrieved 8 12, 2013, from Wall System: http://www.cmhc-schl.gc.ca

Kästle, K. (2014). *Political Map of the World*. Retrieved 01 12, 2015, from Time around the Globe : http://www.nationsonline.org/oneworld/map/world_map2.htm

Kemal, B. K. (2012). Availibility of renewable energy sources in Turkey:Current situation, potential, government policies and the EU perspective. *Energy Policy.*, Vol. 42.

Kingspan. (2007). *Light house by Potton.* London: Potton Building Dreams.

KKY, L. (2006). Green, reflective, and photovoltaic roofs. *National Research Council Canada*, 44-54.

Kosnya, J. A. A. (2014). A review of high R-value wood framed and composite wood wall technologies using advanced insulation techniques. *Energy and Buildings*, 441–456.

Kuznik, F. V. J. (2009). Experimental assessment of a phase change material for wall building use. *Applied Energy*, 2038-2046.

Leaders, F. G.T. (2014). *Towards Net Zero Energy Solar Buildings.* Le Tampon: IEA Joint SHC Task 40 / ECBCS Annex 52.

`

Ltd, I. (2009). *Passive Solar Heating*. Retrieved 01 21, 2015, from HVAC building control fire saftey: http://www.iklimnet.com/save/passive_solar_heating.html

Marszal, A. J. P. H. (2011). Zero Energy Building - A review of definitions and calculation methodologies. *Energy and Buildings*, 971- 979.

Murray, R. L. D. (2011). Design of a Latent Heat Energy Storage System Coupled with a Domestic Hot Water Solar Thermal System. *Solar Thermal Applications*, 3757-3764.

Nayak, J. (2003). Transwall versus trombe wall: Relative performance studies. *Energy Conversion and Management*, 389-393.

Omer, A. M. (2008). Ground-source heat pumps systems and applications. *Renewable and Sustainable Energy Reviews*, 344-371.

Pierro. (2012). *What is the difference between an Off-Grid and On-Grid System?* Retrieved 01 18, 2015, from R.E. Pierro Construction: http://www.pierrosolar.com/home/about-us

Sabonnadière, J.C. (2009). *Renewable Energies.* London: ISTE Ltd.

Sarbu, I. C. S. (2014). General review of ground-source heat pump systems for heating and cooling of buildings. *Energy and Buildings*, 441-454.

`

Sadineni, S. B. S. M. (2011). Passive building energy savings: A review of building envelope components. *Renewable and Sustainable Energy Reviews*, 3617-3631.

Salom, J. A. J. (2013). *Analysis of load match and grid interaction indicators in Net Zero Energy Buildings with high resolution data* . Barcelona: Energy and building committee.

Schwarz, T. (2012). Climate: Freiburg im Breisgau. Retrieved 10 8, 2014, from climate-data.org: http://en.climate-data.org/info/privacy/

Sen, Z. (2008). *Solar Energy Fundamentals and Modeling Techniques.* London: Springer.

Sharma, S. K. (2014). Zero Energy Building Envelope Components: A Review. *International Journal of Engineering Research and Applications*, 662-678.

Stark, A. (2015). *Watford*. Retrieved 01 12, 2015, from weather underground: http://www.wunderground.com/weather-forecast/UK/Watford.html

Steuben, M. J. (2011). *Cool Roofing Information for Home and Building Owners*. Retrieved 01 05, 2015, from Cool Roof Rating Council : http://coolroofs.org/resources/home-building-owners

Stuart, J. S. B. V. (2013). Geothermal heat pump systems: Status review and comparison with other heating options. *Applied Energy*, 341-348.

Torcellini, P., Pless, S., Deru, M., & Crawley, D. (2006, 06 01). *Zero Energy Buildings: A Critical Look at the Definition; Preprint* . Retrieved 10 22, 2014, from SciTech Connect: http://www.osti.gov/scitech/biblio/883663

Tyagi, V., B. D. (2007). PCM thermal storage in buildings: a state of art. *Renewable and Sustainable Energy Reviews*, 1146-1166.

Voss, K., E. M. (2013). *Net Zero Energy Buildings.* Munich: The German National Library.

Waltjen, T. (2008). *Details for Passive Houses.* Verlag/Wien: Springer.

Yip, S., S. C. (2013). Use of Net Zero Energy solution sets for the redesign of the Reunion Island Enerpos Building in Christchurch. *Conference of International Building Performance Simulation Association*, 2791-2798.

Zimmermann, J., Y. d. (2013). A Zero Net Energy Building Pilot study:Low Energy Strategies for Weygand Residence Hall at Bridgewater State University. *PERKINS+WILL Research journal*, 70-90.