Passivhaus Design versus the Code for Sustainable Homes

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I would like to thank my professor ------, at ------University, who has been essential in supporting my through this research, encouraging me through the problems I faced throughout the paper and aggravated me to work hard.
Dedication

I dedicate this research to my family, especially to my Parents. Their time, energy, and assistance were essential to the completion of my study. I wish to thanks all of my class fellows who supported me in completing this paper. I learned about the enthusiasm, energy, and inspiration that one can acquire from achievement of someone else. I hope to perform this research with me long after current study has expanded our understanding of incidental education. Particular thanks to my educational professor, [Dr.____Name____], for his/her support and dedication throughout the study.
Declaration

I [], make sure that this paper and its complete material has been personal, unsupported attempt and has not been submitted or published earlier. Moreover, it defines my perception and take on the issue and is does not give the perception of the University.

Signature: _________________

Dated: _________________
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Executive Summary

Energy and building legislation is pushing for a forward thinking construction industry, this is causing developers and architects with real issues. What are the difference between Passivhaus design standards and the code for sustainable homes and can these standards complement one another?

Passivhaus design is an energy performance standard developed in Germany and is built upon the simplicity of building design that produces good thermal performance, airtightness and mechanical ventilation. Whereas the code for sustainable homes is a UK government led mechanism for addressing the sustainability of a home and addresses a number of environmental issues not only energy performance and CO2 emissions but also elements including water and recycling, health and well-being and pollution. Usually a Passivhaus will achieve a code for sustainable homes rating level of 3 or 4. This means that it is an ideal methodology for achieving a higher level of overall code rating whilst minimising the cost of renewable.

To understand and get to the bottom of these issues, it is necessary to research this topic from numerous angles to ascertain an effective conclusion. From developed knowledge of Passivhaus design strategies and visits to Passivhaus homes in the UK will provide a first-hand assessment, including the advantages and disadvantages of living in or with a Passivhaus designed sustainable home. To developing relationships with code for sustainable homes assessors and critically appraise their approach to Passivhaus house projects in the UK.

Ideally these energy performance and design standards and forward thinking criteria should work to complement each other and be re-addressed to provide a more sustainable design
for the future homes. Industry led development of products, construction techniques and ultimately the quality of buildings will benefit the consumer and the environmental impact.
Chapter 1: Introduction

Many governments have developed and revised building codes to drive local, national and international carbon dioxide reduction targets. In the UK, the Code for Sustainable Homes (CSH) is in use. The Code has six levels, with mandatory minimum standards for energy efficiency and water efficiency at each level. The timetable for strengthening standards in the Code requires all new dwellings to have a 44% improvement over the 2006 regulations by 2013, and to be zero carbon (Level 6) by 2016. Its target of zero carbon is not clearly defined yet, and a consultation on this is ongoing. Since May 2008, a minimum of Level 3 became mandatory for new dwellings where public sector funding is involved in England, all new dwellings promoted or supported by the Welsh Government or their sponsored bodies, and for new self-contained social housing in Northern Ireland. Despite the UK's central government's ambition that the CSH becomes the single national standard for the design and construction of sustainable homes, Scotland has been using Eco-homes (the predecessor of CSH), and in October 2010 introduced new regulations for dwellings. Scotland’s new regulations are based on ‘The Sullivan Report’ and require staged improvements in carbon reduction compared to 2007 levels. The target is for a 30% reduction in 2010; 60% in 2013, and net zero carbon emissions for heating, hot water, lighting and ventilation in 2016/17, if practical (Abe & Carl, 2012).

1.1 Context/ Background

It is evident from research that there are elements where the code for sustainable homes and Passivhaus that overlap. These elements should be identified and critically analysed to
develop a well rounded and non-bias opinion to which conclusions will be drawn that provide an understanding and calculated evaluation of both concepts.

PassivHaus design is an energy performance standard developed in Germany and is built upon the simplicity of building design that produces good thermal performance, airtightness and mechanical ventilation. Whereas the code for sustainable homes is a UK government led mechanism for addressing the sustainability of a home and addresses a number of environmental issues not only energy performance and CO2 emissions but also elements including water and recycling, health and well-being and pollution.

1.1.1 What is Passivhaus?

Passivhaus design standards create homes with extremely low energy needs. Passivhaus describes a specific energy performance concept of a building. A Passivhaus design home is optimised in its thermal performance in such a way it does not need or use a conventional heating system. The heating requirement is mainly covered by solar and internal heat gains. Energy losses through ventilation are significantly reduced by the use of mechanically controlled ventilation of living spaces combined with a high efficient heat recovery system.

1.1.2 Why is Passivhaus relevant in the UK?

There is a growing interest in passive house in the UK. The high standards of energy efficiency achieved can meet government targets for lower carbon homes. There is also a marketing advantage since the homes are exclusive, adaptable design which requires little to no energy for heating or cooling, thus lowering energy bills and the demand on fossil fuels.

Doors, windows, boilers and other equipment used in Passivhaus are being designed
manufactured by UK companies which will make installations cost-effective. The passive house design provides health benefits due to mechanical ventilation systems which allow a high quality of fresh air to circulate without opening windows and reducing comfort levels.

There are currently only 8 credited Passivhaus designed homes within the UK, however approximately 25,000 around Europe. The UK technical data from these sustainable developments is currently limited as they have only been constructed within the last 10 years. However a good indoor climate and comfort without using a lot of energy.

1.1.3 What is the code for sustainable homes?

The code is intended as a single national standard to guide industry in the design and construction of sustainable homes. It is a means of driving continuous improvement, greater innovation and exemplary achievement in sustainable home building.

There are six levels of sustainability (one being the lowest, six the highest) achieved by measuring performance in areas such as energy use, water consumption, and waste. Legislation introduced in May 2008 states that all new homes must now be marked with such an assessment.

Whilst there is no minimum standard for the private sector, but all public housing must achieve at least code level 3. Minimum standards are set to rise in the new future and the government expects that all UK housing should achieve level 6 (carbon neutral) by 2016.

What is the government's standard assessment procedure (SAP) for energy rating of dwellings?

SAP is a UK government methodology for calculation of the energy performance of buildings. It is a since April 2006, SAP has to be performed on all new build residential
dwellings in order to comply with the 2006 part L building regulations.

SAP is the calculation of energy performance of new dwellings on a scale from one to 120, based on the annual energy costs for space and water heating. Also to calculate the carbon index on a scale of 0.0 to 10.0 based on the annual CO2 emissions associated with space and water heating.

1.2 Research Question/ Hypothesis
Hypothesis
Is energy savings in Passivhaus dwellings are accurately presented by the code for sustainable homes rating?

1.3 Aims of the Research
One of the first aims is to understand what is a Passivhaus home is and why it is deemed positive or negative within a global sustainable future for housing development.

Ascertain what calculations and design criteria are necessary to gain Passivhaus accreditation. To understands the concept, theory and calculations behinds the CODE and Passivhaus Design. The overall aim of this paper is to evaluate the existing relationship between passive house and the code for sustainable homes and develop a working knowledge of calculations and criteria when related to energy performance.

To collect data from UK-based case studies and investigation of the potential for Passivhaus design and the code for sustainable homes to complement each other.
1.4 Objectives of the Research

The objective of this dissertation is to gather an understanding of numbers issues: To introduce and analysis the use of the code for sustainable homes assessment of Passivhaus Projects. If Passivhaus homes are considered to be a European standard for energy performance and sustainability, then why aren’t more houses built in the UK based upon these design ideas and construction principles. Establishing what is considered to make a home sustainable and what is the perceptions of these ideas from the perspective of:

The End user:

To ascertain whether the end user appreciates the environmental impact of a non-sustainable home. To investigate if these ideas are practical, how they work, if they are effective and what are the cost saving benefits.

1.5 The Housing Developer

To discover if housing developers being forced to buy into these sustainable and environmental ideas by government dictation or do these ideas offer practical solutions and to what cost to the developer and or the end-user.

1.6 The Architect or Designer

To ascertain if an architect or designer can introduce these sustainable ideas of energy performance without compromising on the design and are there enough high energy performing products available on the market without escalating the cost of the build. Are these ideas and concepts practical in their realisation and can they be easily provided to the construction industry.
1.7 Product Development Companies

Are companies developing and investing in the right products to enable architects or designers to integrate these solutions in a cost-effective manner to their housing designs. Is there enough technical training and knowledge within the industry to allow product development and does this technology development have backing from investors or the government.

To ascertain what building professionals need to do in the UK to assure cost-effective and motivate the industry to provide good solutions. To understand if there is a good level of training and information provided to develop the Passivhaus concept.

To confirm if the UK government sustainability targets are they realistic in their approach and development of these ideas or concepts and identifying criteria of the code for sustainable homes that can be met by passive house design.
Chapter 2 Literature Review

2.1 Code for Sustainable Home

The embodied energy of building material can be taken as the total primary energy consumed over its life cycle. This would normally include extraction, manufacturing and transportation. Ideally the boundaries would be set from the extraction of raw materials until the end of the product’s lifetime (including energy from manufacturing, transport, energy to manufacture capital equipment, heating and lighting of factory, maintenance, disposal etc) known as ‘cradle to grave’. It has become common practice to specify the embodied energy as ‘cradle-to-gate’ which includes all energy until the product leaves the factory gate. The final boundary condition is cradle-to-site which includes all of the energy consumed until the product has reached the point of use. Transportation energy embodied in materials: Embodied energy also includes the transportation energy consumed in moving the materials within and between each stage in the process. Evaluation of embodied energy through analysis has been undertaken by a number of researchers, (Cheryl, Charlie & Michael, 2012), in order to establish figures for particular materials. However the transportation component is often assessed using generalised assumptions, which are not always easily identifiable.

Several evaluators have looked at the potential for low carbon standards to reduce energy/CO₂ emissions in European countries. Result show that the impact of the standards to raise the environmental performance of UK housing has been limited. This is due to low levels of compliance. In 2007, the top 20 UK home builders achieved an average score of just 8.5 per cent for their commitment to Eco-Homes (Tooraj & Michael, 2011). They only built to the minimum required standards of Eco-Homes, and largely only where required to do so by planning or funding agreements in spite of a review to help increase compliance; and the
introduction of mandatory minimum standards, evidence shows wide gaps between the expected performance of many dwellings during the planning stage and the actual performance in use. Achieving the zero carbon level in 100% of dwellings constructed from 2016 onwards is currently one or the biggest challenges in the industry. The need is for solutions to (a) reduce energy demand through the fabric design, services and occupants, and (b) increase supply from low carbon energy sources.

To put the challenge in context it is worth looking at the achievements of the Passivehaus standard since it is one of the oldest and most demanding standards regarding energy demand reduction. Except for the role of renewable energy sources, it is also closely related to the zero carbon level in both the CSH, and the 2010 Scottish regulations, in emissions for heating, lighting and ventilation (Smith, Ferrari, & Jenkins, 2011). Passivehaus requires: excellent insulation with minimal thermal bridges utilisation of solar and internal gains, air tightness and indoor air quality provided by highly efficient mechanical ventilation with heat recovery. It requires a total energy demand for space healing and coding that is less than 15 kWh/m²/yr treated floor area. It is a complete standard in the sense that achievement is based on certification of the completed building as opposed to enforcement at the planning stage.

Although the Standard point to a significant potential for designers and dents to give low carbon standards, it is interesting to note that only a relatively small number of dwelling have achieved the standard. Since 1991, when the first Passivehaus Standard building was completed, only 1826 dwelling, had been documented by May 2009, and an estimated 19,132 buildings across Europe had met the standard (Seyfang, 2010). The relatively small number could be party explained by the voluntary basis on which the Passivehaus standard is implemented. It could also
be linked to barriers to achieving low carbon targets that are experienced in countries across Europe. The common barriers identified are:

1. A gap in the skills and knowledge base: Most developers, builders, and architects are aware of low carbon building issues, but lack in-depth understanding and ability to deliver them. The training of most of them predates current low carbon standards. Inadequate knowledge means they may not adequately promote and and/or readily access the necessary technologies (Roe & Saglie, 2011).

2. Lack of motivation and interest: There is a widespread lack of in-depth interest in low carbon issues by professionals. For developers, low carbon standards may not be attractive, given the limited returns. The stepped strengthening of the standards can encourage developers to aim for the required minimum (Peter, 2010).

3. Cost and perceived cost: Division of labour during construction and lack of local solutions can all result in higher costs. Many developers perceive the costs of low Carbon technologies to be high, despite the low marginal cost if solutions are incorporated early in design. Governments may pay higher grants if housing associations exceed minimum targets, but these may not fully cover the extra construction cost.

4. Regulatory bureaucracies: It can be hard to get planning consent for some renewable technologies in conservation area.

5. Lack of technology and standard solutions: Low carbon solutions exist, but are not produced and/or available locally in all regions. There is a lack of ready standard solutions on a wide scale.
6. Legislation differences: Differences in standards in different codes across local and national governments can be confusing.

7. Uncoordinated efforts: Lack of cooperation between industry player’s and uncoordinated promotion of low carbon standards by the many bodies doing so may result in inconsistent messages to stakeholders.

8. Split incentives: Owners may not invest in energy efficiency then tenants pay the bills. Tenants may not invest in property they don’t own. While split incentives are possible for housing associations for new dwellings, it may be difficult to earn back low carbon investments from rent (Painuly, 2001). For existing dwellings, a decrease of energy costs can make up for increase in rent to cover the investments.

9. Information on benefits and user behaviour: Information on low carbon benefits is not widespread and feedback on energy use has been power in the past. User behaviour is often ignored in target projections.

What measures are UK institutions taking to tackle the existing challenges, to promote low carbon housing; they have put efforts into making advance announcements for future further tightening of standard and minimum requirements for new buildings, including the expected dates for their introduction. This has encouraged the industry to investigate possibilities and develop timely solutions (Ottmar et al, 2011). To meet the education and training requirements of the European Energy Performance of Building Directive (EPBD), the UK government set a target of having 2000 Domestic Energy Assessors accredited by various UK bodies. A similar scheme has been established to train assessors to use the Code for Sustainable Homes.
In 2010, the Building Standard Division of Scotland commissioned the Mackintosh School of Architecture and 55 North Architecture to prepare Guidance for Living in a Low Carton Home that could be included in building regulations.

Other promotion instruments have included; energy certification, demonstration projects local planning requirements: and financial schemes Demonstration projects are a very practical way to learn about low carbon dwellings (Nacer et al, 2012). Economic and financial incentives (erect funding, taxes, soft loans, and green mortgages) to give the development towards low carbon dwellings are very efficient. UK governments have set compliance requirements tom housing receiving direct public funding as part of the investment. Higher local planning requirements can encourage higher compliance of standards. Another instrument is persuasion on the benefits of low carbon to change opinions and attitudes.

To transform the market to zero carbon by 2016, today’s challenge is to close the current gaps between regulatory requirements; implementation by many players in the production of dwellings and performance in use To do so in the affordable housing sector is particularly important in the context of the already existing challenge of providing adequate housing in the sector (Michael, Charlie & Ernst, 2012). Although competition amongst market parties is likely to drive widespread uptake of low carbon standards in future, there is no guarantee that this will happen.

In the UK, the 2008 Climate Change Act required an 80% reduction in CO2 emissions by 2050 from 1990 level. To mitigate CO2 emissions from buildings fabric, the Department for Communities and Local Government has announced a strategic decision and published the Code
for Sustainable Homes, ‘A Step Change in the Sustainable Home Building Practice, 2006’ referred to in this paper as ‘the Code’.

Windows are defining features of buildings, and they are extremely useful multi-function devices which provide views, ventilation and passive solar gain, a means of escape, security and daylight gain. However, they can have a negative impact on CO2 emissions from building envelopes and energy consumption such as in the summer, they allow unwanted heat from the sun to pass into conditioned areas; and in winter they lose heat to the environment. Conventional residential windows are responsible for about 47% of the heat lost from building envelopes (Maliene & Malys, 2009).

Because of the importance of windows in reducing heat and energy consumption in buildings, considerable attention has been given to improving their performance. Novel window technologies hold the promise of drastically reducing or eliminating heat gain and loss attributed to windows and in addition increasing the overall energy efficiency of homes.

The objective of this paper is to provide an overview of the impact of the Code for Sustainable Homes in terms of future requirements for residential windows and areas of future research for windows’ performance (Magali & Arnaud, 2011). It also presents an investigation of advanced window technologies that could help to meet the requirements of the highest sustainability Code Level 6 standards.

2.2 The Code for Sustainable Homes

To mitigate heat loss from building fabric, on 13 December 2006, the Department for Communities and Local Government has announced a strategic decision and published the Code for Sustainable Homes referred to in this paper as ‘the Code’, ‘A Step Change in the Sustainable
Home Building Practice; 2006’. The Code replaced Ecohomes1 for assessment of new housing in the UK.

The Code affects social housing providers and private house builders. Since April 2007, as a commercial incentive to attract buyers and sell more houses, a private developer of any new home in England and Wales has been able to decide whether their proposals should be assessed against the Code (Lisa & Chris, 2011). The Code measures the sustainability of a new home against categories of sustainable design, rating the ‘whole home’ as a complete package and uses a 1–6 star rating system to communicate the overall sustainability performance of a new home.

The Code-level points are awarded across nine key design categories, as follows:

- Energy efficiency/CO2 (minimum mandatory standard at all levels)
- Water efficiency (minimum mandatory standard at all levels)
- Surface water management
- Site waste management
- Household waste management
- Use of materials (minimum standard at Code entry level, 1)
- Health and well-being
- Ecology
- Lifetime homes (applies to Code level 6 only)

Each category has specific assessment criteria, which must be met for credit to be awarded. In addition for five of these assessment issues, Materials, Surface Water Run-Off,
Waste, Energy, CO2 and Water, the minimum standards are set which must be achieved before the lowest level of the Code can be awarded. However, for Energy/CO2 and Water minimum standards are required at each level of the Code Energy and Carbon Dioxide are based on the target emission rate (TER) as used in the Part L1A of the 2006 Building Regulations. This means for Level 1 the home will have to be 10% more energy efficient than one built to the 2006 Building Regulations standards (Jonathan & Ann, 2011).

2.3 Energy performance certificates
Under the Energy Performance of Building Directive, 1 August 2007, the UK Government introduced Energy Performance Certificates. These certificates indicate the environmental impact of a home and how energy efficient it is on a scale of ‘A’ to ‘G’. An ‘A’-rated home is the most energy efficient and has lowest CO2 emissions (Jerry, 2009). By 2009, Energy Performance Certificates will be mandatory for all new and existing homes when sold or leased. It will be required to be providing these certificates at the point of purchase or sale.

2.4 Building fabric heat loss characteristics
U-values are used to compare the fabric heat loss characteristics of different key elements of the building shell; some of the key elements of a typical two-storey detached house have a lower thermal transmittance (U-value) and are better insulating than others. Windows are extremely useful multi-function devices, giving views, ventilation, passive solar gain, daylight gain, means of escape and security (Janet & Adam, 2012). Unfortunately, the high U-values of glazing systems are difficult to reduce and remain the main source of heat loss from buildings.
These result in high energy consumption in winter, and summer if air conditioning is used, and consequently are a source of high CO2 emission.

Figure shows the heat loss rate from four key building elements (ceiling, flooring, windows and external wall); the heat loss through windows accounts for approximately half the total heat loss in the building (Ireland, 2008).

Heat loss rate from key building elements, ceiling, flooring, windows and external wall

Under the Code assessment procedure, any doors with a large expanse of glazing, such as patio doors, should be assessed as windows and similarly for glazed area, conservatories and rooflights (Hocine & Stephen, 2010). Compliance with the highest levels of the Code will only be possible if measures are taken to improve the energy efficiency of a building and incorporate efficient window technologies. In this regard, it is important to identify appropriate technologies to manufacture energy-efficient windows, which will also improve the visual and thermal comfort of the occupants.
2.5 Window Requirements for the Code for Sustainable Homes

In the UK, the window energy rating is a method of assessing the complete window (frame and gaskets etc., as well as the double-glazed unit) to produce a single number, the energy index. Windows are weak elements when it comes to keeping heat in the building and each window tested is of a standard 1480 by 1230 mm size with a central mullion and single-side opening configuration. According to the British Fenestration Rating Council (BFRC), the energy performance of windows is characterised by an energy index, which takes into account three factors (Fiedler & Addie, 2008). First is the thermal transmittance (U-value, W/m2k), which measures the heat loss characteristics of the window system. Second is the solar heat gain coefficient (SHGC; g-value, W/m2k), which measures how well the window blocks heat caused by sunlight. The g-value generally ranges between 0 and 1, where 1 is low shading and zero is high shading. The lower the number, the less heat gain there is through the window system. The final factor is air leakage (L50 value, W/m2k), which assesses the air leakage (m3/h/m2) through the window when subjected to a pressure difference across it of 50Pa; this is converted into a ventilation heat loss rate.

A large amount of work around the world is being done to carry out the energy rating and labelling of windows. Many researchers have given energy-rating equations in terms of window parameters like thermal transmittance (U-value), solar heat gains coefficient (g-value) and air leakage, for their local climatic conditions (Engel et al, 2005). In the UK, the BFRC has derived a formula for the energy index from these three factors (U-value, g-value and L50 value) as follows:
Energy index = 218.6g = (68.5U = I50)

Each one of these factors must be measured to determine the energy index of a window and where it sits on an A-G Energy.

2.6 Window Design

There are many window designs used in domestic situations (conservatories, skylight, bay, tilt and turn, shaped and casement) and there are many factors influencing the design and performance of these windows. It is focuses on the energy efficiency criteria of windows for residential buildings, but this is not to suggest that other factors are of lesser importance (Earthship Biotecture, 2012).

In order to maintain a comfortable indoor environment, energy gained or lost through windows must be compensated for by heating or cooling systems. The glass and frame of a window are highly conductive and are considered to be crucial factors in determining the overall energy efficiency, since they lose heat through three linked forms of heat transfer, by forced and natural convection at the inner and outer surface of the window, conduction through materials of the window and thermal radiation also from the surface of the window (Dorn, 2007).

Therefore, one focus for improving the thermal performance of widows has been to control the thermal radiation losses. The BFRC, the independent body, which is leading the development and application of window energy rating in the UK, has suggested that the following factors also affect the heat loss through windows: type of glazing material, number of glazing layers, size of the cavity between the glazing layers, type of gas in the cavity between the glazing layers, design, material and type of frame and the other components (David, 2012).
Factors affecting the window design and performance

Heat loss by conduction

Convective heat loss

Dry air or argon gas

Inner Pane

Outer Pane

21°C Inside

0°C Outside

Thermal radiation

Glazing separator and seal

Rubber

Frame
Different glazing type and energy performance comparison

2.7 Window Glazing Types and Energy Performance

Above figure show the type of glass, which are commonly used in residential windows. Daniel, (2011) has investigated an annual energy performance of different glazing types using wood or Vinyl frame in a typical American house in two different climates. The result shown in Figure 7b shows that, triple low-solar-gain low-e appeared to be the most energy-efficient glazing system, with U-value of 0.28 W/m2K, SGHC of 0.25 W/m2K and Visible transmittance of 0.40 W/m2K. In the UK, the use of double-glazed window is virtually standard practice, due to their excellent thermal and acoustic properties.
More than three sheets of glass can be used, but the window system then begins to become impractical due to the increased size, weight and cost of the units. However, Bere: architects have developed a House of the Future, Comfort Haus, which is a very highly insulated and air tight building, which eliminates the need for a heat source and maintains a comfortable temperature all year-round (Dale & Newman, 2009). To achieve this energy conservation level, the house is fitted with super insulated airtight frames with triple-glazed windows with average U-values of 0.73 W/m² K. This also contributes to the house’s airtight structure (0.6 air changes per hour), which is 14 times better than the current building regulations.

Window frames types and energy performance

The type of window frames commonly used in residential buildings’ windows. Curran, (2012) examined an annual energy performance of a typical American house with different frame types, using identical double glass, low-e type. The result shown in Figure 6b shows that, insulated fibreglass
Frame was the most energy-efficient frame, with U-value of 0.26 W/m² K, SGHC of 0.31 W/m² K and visible transmittance of 0.55 W/m² K. Above figure shows the U-value for a single-glazed and a double-glazed window set in a metal or timber frame. The U-values are also shown for a highly insulated and super insulated window. It is clear that when the window is well insulated, the U-value is lower. Therefore, compliance with the highest levels of the Code will only be possible, if window manufacturers adopt innovative technologies to improve the energy efficiency of windows to meet the BFRC rating levels, rating A or better.
2.8 Changes to window designs and novel window technologies to meet code level 6

In order to meet rating A, many window designers and manufacturers use novel window technologies, such as warm-edge spacer, gas filling and low emissivity (low-e) coatings, which have been developed to help improve the energy performance of houses. In America, window manufacturers have used a range of advanced technologies to construct ENERGY STAR4-qualified windows (Brenda, 2011).

The work of author has investigated energy efficiency for next generation windows’ technologies up to the year 2020. It has shown that the next generation windows’ technologies should be dynamic and can become energy producers, by integrating PV. By 2020, it is likely that windows will be ‘smart’ and will operate in conjunction with the surrounding building environment as part of an integrated system (Amory et al, 2011). These windows will be extremely energy efficient, and will adjust their insulation properties according to energy needs. Using holographic techniques, windows will be able to direct outside light to particular areas of the interior space, to provide natural light in the work environment.
2.9 Electrochromic Technology

Electrochromic windows technology can electronically control the amount of daylight and solar heat gain through windows; darkened and lightened electronically. This capability allows the windows to be used as energy-saving devices in a house. The electrochromic technology has potential for reducing energy consumption in a house by a significant amount. Because it is dependent of the seasons, winter or summer, darkening or lightening the windows provides more or less solar heating to the living space (Adrian & Michael, 2011). However, the challenge in fabricating electrochromic windows is in achieving low costs, high durability and practical sizes.

2.10 Passive House Design

“The Passive House standard originated from a conversation in May 1988 between Professors Bo Adamson of Lund University, Sweden, and Wolfgang Feist of the Institut für Wohnen und Umwelt Institute for Housing and the Environment. Their concept was developed through a number of research projects, aided by financial assistance from the German state of Hesse (Alison & Walter, 2011). The eventual building of four row houses (also known as terraced houses or town homes) was designed for four private clients by architect’s professor Bott, Ridder and Westermeyer. The first Passivhaus buildings were built in Darmstadt, Germany, in 1990, and occupied the following year. In September 1996 the Passivhaus-Institut was founded in Darmstadt to promote and control the standard. Since then, an estimated 15,000 Passive Houses have been built, most of them in Germany and Austria, with most others in Scandinavia and various other EU countries.”
2.11 The Passive House Standard

The requirements of the Passive House standard are very specific. In order to achieve certification as a Passive House, a project must demonstrate compliance with the following requirements:

- Airtight building shell ≤ 0.6 ACH @ 50 pascal pressure, measured by blower-door test
- Annual heat demand requirement ≤ 15 kWh/m²/year (4.75 kBtu/ft²/yr)
- Cooling demand requirement ≤ 15 kWh/m²/year (4.75 kBtu/ft²/yr)
- Primary Energy ≤ 120 kWh/m²/year (38.1 kBtu/ft²/yr)

In addition, the following are recommendations, varying with climate:

- Window unit u-value. 0.8 W/m²/K (U-Factor = 0.14; R = 7.1)
- Ventilation system with heat recovery with 75% efficiency with low electric consumption @ 0.45 Wh/m³ (0.013 Wh/ft³)
- Thermal Bridge Free Construction. 0.01 W/mK (0.006 Btu/(fthF)
2.12 Applying the Passive House Standard

In order to demonstrate compliance with the standard, projects are modelled using the Passive House Institutes’ software tool, Passive House Planning Package (PHPP). The PHPP tool contains years of thoughtful research and application from Europe, and more recently from North America, to help planners determine energy balance and optimise building systems to meet loads from gains and losses. It is well advised to utilise the services of a Certified Passive House Consultant (CPHC) to assist in modelling and managing the iterations of various design approaches. Using the PHPP software tool without training is not advised (Adrian & Michael, 2011).

In addition to the requirements and recommendations noted earlier, principles of thermal comfort, indoor air quality and moisture management are inherent in the Passive House standard. Successful designs carefully manage the requirements and recommendations, balancing them
with first costs, to achieve a superior indoor environment (Alison & Walter, 2011). Selection of construction materials finishes and furnishings are even more important in a Passive House due to the tightness of the home. Increasingly, selection of low chemical, zero VOC and non-toxic products and systems are incorporated in these designs. Proper ventilation design, also due to the airtightness, is vitally important to a successful project.

2.13 Lessons Learned by Category
   The following lessons are not in any particular order of importance and it might be said that each of them are equally important as each of them carry consequences for achieving or not achieving Passive House certification (Cheryl, Charlie & Michael, 2012).

2.14 Air Tightness
   Air tightness may well be the most important challenge and lesson for US application of the Passive House standard. Whether building new or approaching a retrofit project, the importance of attention to detail and quality assurance and control cannot be overstated. Measured Energy Star certified homes perform in the 3-6 ACH at n50 (variations are for different climate zones) (Bon & Hutchinson, 2000). These homes only represent about 17% of all new US homes in 2008 (not all are homes are tested or verified) and a much smaller fraction of all US homes. By some estimates, average US homes may perform 2 or more times worse in air tightness than the typical German home.

   In existing construction—retrofit applications, air tightness can be one of the most difficult challenges. Depending on the scope of work involved in the retrofit, it may even be impossible. Bronwyn Barry, an energy analyst with Quantum Builders of Berkeley, California
learned on the retrofit of the Larkspur residence that while air tightness was going to be a challenge, her team was able to overcome it and achieve better than 0.6 ACH at 50 Pa. One of the ways Quantum Builders overcame the air tightness challenge was to build a mock-up wall section for testing. This proved to be not only good preparation, but it also proved this approach would work at full scale (Alison & Walter, 2011).

2.15 Heating ventilating and air conditioning (HVAC)

HVAC challenges are a bit harder to boil down into lessons learned with the Passive House standard. This is primarily because every system is so sized and designed for a very specific building, envelope, orientation and climate that the lessons are rarely transferable, with the exception of possibly broad approaches (systems used) or a similar building types, and scale, in the same climate. Mostly people want to know that the system chosen, along with whatever backup may have been included, is going to work or worked (Amory et al, 2011). Answers to questions about how well they are working (actually achieving the modelled energy performance results) are not well known at this time, due to the limited number of projects completed and even less monitored.

One example with some performance results is the Waldsee BioHaus project in Bemidji, Minnesota. BioHaus is a light commercial structure for Concordia Language Villages designed by architect Stephan Tanner of INTEP. BioHaus is performing slightly beyond expectations at just 12,000 Kwh/yr (total energy) at 400 m2 (5,000 ft2) this equates to about 30 Kwh/m²/yr. BioHaus used an earth to air fresh air pre-temping and has a bypass for a flat plate heat recovery to avoid winter freeze up – a main issue to consider in climate zone 7. Review of the building management system has shown that it has worked at temperatures of 30 below F. author (2005)
noted that “One still pays a premium (for the earth tube and flat plate heat recovery) and a duct base electrical booster heater is much cheaper” (Brenda, 2011).

Both the BioHaus and the recent retrofit of Amory Lovins’ 1984 Rocky Mountain Institute headquarters in Old Snowmass, Colorado used a super efficient (85%) heat recovery ventilator (HRV) made in Germany. While these European products are becoming increasingly available via distributors in the US, it is apparent that the real winner will be US manufacturers that see a market for superefficient HVAC systems, made at sizes that can scale to the lower end of the energy demand for homes and small buildings (Choguill, 2007).

In a recent conversation with Amory Lovins about the key lessons learned in his 1984 passive design, he noted flexibility as number one. Designing in the ability to adapt the home and office over the past 28 years as new technologies were introduced has proven invaluable. Specific examples he cited include the installation of piping in the slab for a radiant heating system, which was never used for over 25 years—and was recently “charged” via solar thermal and a compact boiler as a backup for design days (Curran, 2012). Another example is the ¾” intentional gap between heavy timber beams and the exposed interior roof decking—this gap was quite useful in wiring for several lighting retrofits and recently for installation of hundreds of energy monitoring points.

The building envelope, which includes walls, roof, floor slab and fenestration, is another critical category of challenges and lessons in applying the Passive House standard. The approach to detailing discussed earlier is one of the keys to success—is the detail buildable? How will quality be assured? Are there alternate approaches to achieving the same thermal envelope? Are materials readily available?
Whether using double studs, structural insulated panels, ICF’s or I-joists for walls, the insulation(s) used, and the ability to achieve a quality installation of them, is of critical importance. Other challenges with the envelope design in new construction are less often to do with which insulation or how much insulation, but have to do with detailing for elimination (minimisation) of thermal bridging (Dale & Newman, 2009).

One of the challenges faced by Wagner Zaun Architecture in the design of the Skyline House was the thermal envelope. Because the client didn’t choose to pursue the Passive House approach until the construction drawings phase, there were limitations to any rearrangement in orientation and fenestration.

While the ultimate performance of the Skyline House is superior to most (75% better than a typical code-compliant home), it was not able to meet the Passive House standard. The blower test came in at 0.7 ACH at 50 Pa, and the heating energy demand was 23 kWh/m2a (7.3 kBtu/f2/yr).

However, as noted by the architect, Rachel Wagner, we have been monitoring the energy consumption of the Skyline House and the occupant comfort/experience, and it is a huge success. In retrofit applications, one of lessons learned in the Larkspur remodel was that the significance of thermal bridging and an un-insulated slab could not be overcome without adding more insulation (Deakin & Allwinkle, 2007).
2.16 They simply could not reach the Annual Heat Demand requirement without adding insulation on top of the slab and to the exterior walls. The thermal bridging on Larkspur became one of the larger conductive losses (per the PHPP model) after the retrofit (Elizabeth & Jake, 2010).

2.17 Passive House Planning Package (PHPP)

As there are relatively few projects that have been modelled with the PHPP tool in the US, the lessons learned were harder to extract. As noted earlier, it is clearly important that the tool be applied as early in the conceptual or pre-design phase as possible (Engel et al, 2005). While this seems obvious, it was surprising how many teams didn’t think to, or the client didn’t express interest in, Passive House until much later in the design or even construction phases.

Another lesson noted by Rachel Wagner is that you should not underestimate the importance of passive solar application. The passive solar opportunity should be maximised, as it
can push a project below the desired 15 kWh/m² annual energy demand. One must use the PHPP software to evaluate the effectiveness of the passive solar strategies (Evans & Jones, 2008). “It is amassing to watch the dance between heat gained and heat lost (through the windows), via the software” – Rachel Wagner. One suggestion from the author’s view is that to encourage wider and earlier adoption and use, PHPP should ideally be improved to include a much more user-friendly “front-end” interface and perhaps be written in another software code to get away from the current Excel based format. Although Excel is widely used and understood, there is danger in misuse unless cells are “locked-out” from changes (Farshad, 2009).

2.18 Cost

The cost effectiveness for a retrofit project to meet Passive House standard is a difficult challenge. It seems to depend primarily on the scope of the retrofit before adding Passive House requirements. In other words, if a project is already anticipating a siding replacement, window replacement, and perhaps some insulation or air barrier work, then the overall incremental costs (i.e., the difference between a code compliant window and a super window for example) are the costs that need to be considered for payback. Establishing this baseline is an important step in calculating overall cost effectiveness (Francois, 2011).

2.19 Lessons Learned by Phase

Many of the lessons learned in applying the Passive House standard in the US can be traced to the design phase. The phrase “design phase” used here is broadly describing all of the activities from pre-design through construction documents.

The application of the PHPP modelling tool early (and often) was a key lesson cited by one party interviewed. In their case, the assumptions about insulation level were discovered to be
inadequate when modelled in PHPP during the construction phase. Similar to other modelling tools, PHPP was designed to inform the design process, not document or verify it. The quality of the detailing and product specification can often be linked to procurement and construction phase issues (Hocine & Stephen, 2010).

On several projects, air tightness and thermal bridge detailing led to omissions or constructability issues in subsequent phases. When these areas were not well thought-out and detailed on paper, they ended up needing to be resolved in the field, sometimes with compromising results. Several projects were not able to meet the blower door test requirement or the heating/cooling energy demand requirement as a result.

Quality assurance and control during construction was a close second to design phase lessons most often stated by designers, builders and owners. Even with very good quality construction details and specifications, follow-through with assuring compliance with details and product procurement can prove quite challenging (Jacob & Ace, 2012). Inexperienced suppliers and subcontractors have sometimes resorted to alternate construction methods or materials due to perceived or real constructability issues and even substituted products where either unfamiliarity or availability (possibly cost) was claimed. For certain the Passive House standard is aggressive. It may well be the world’s most aggressive energy design standard. It is also proven to work—on thousands of homes and buildings, in challenging climates. However, it is the intent with which the team (owner, builder, designer and all supporting cast members) approaches the application of the standard, which most likely determines the outcome. In other words, if you set your goals low—you’re likely to meet them.
2.20 Comparing the Code for Sustainable Homes and Passive House Design

It can never be compare directly the standard of Passivhaus with the sustainable homes Code. Passivhaus is considered as a performance of a standard of the energy where the code is an assessment of environmental methodology crossing the performance of environment entirely concerned to an inclusive of building for instance site management’ construction, materials used in construction’s consideration, building water consumption, recycle bin provision and so on. The methodology Passivhaus was formulated in the era of 1990s and has since turned out to be ‘the standard of world leading with concerned to design of construction and efficient energy (BRE London) (Lisa & Chris, 2011). It is considered as an attempt, examined and an approach that is successful in order to construct and design an energy building at very low level that comprises along with thousands of instances constructed over the last twenty years everywhere in the Europe. The performance of energy plus criteria of saving of carbon concerned to the sustainable code for the homes are founded over SAP. Nevertheless, BREEAM and Passivhaus or the Passivhaus and complimentary Code is considered as a place that is very good in order to commence when starting out in order to accomplish the degree 4, 5 or 6 ratings of Code.

2.21 Energy Use

Consumption of Energy of a Passivhaus is evaluated by utilising the Planning Package Passivhaus. The PHPP is considered as tools of design permitting planners that is specialist in order to evaluate and figure out the demand of the energy for buildings of low energy. It was formulated by utilising simulations dynamic that was then corroborated by the results of monitoring of finished houses passively over the last twenty years. The consequence outcome is considered as a model that is simplified which matches the results that is authentic with the effort
that is justifiable effort for the acquisition of data. This research has proven that if the methodology of Passivhaus is followed through from the stage of earliest design then savings of the energy for heating space of adequate to 75% equated to 2010 building are accomplishable (Magali & Arnaud, 2011).

Consumption of Energy is evaluated by utilising SAP. - SAP was formulated in the era of 1980s from a home’s study with comparatively insulation of poor level and hence heat loss of high levels in order to formulate an instrument in order to demonstrate compliancy with the regulations of Building Part L. It is not considered as the precise concerning the areas that turned out to be vital in dwellings that is very well-insulated. Research has demonstrated that SAP has a predicting the building energy demand that has track record which is poor generally and especially for the buildings of low energy (Maliene & Malys, 2009). - SAP plays down the importance of air tightness and insulation and presumes internal gains of prominent degrees, leading designer in order to consider they have accomplished a limit of that is lower sensibly over the loss of heat when as a matter of fact they don’t it. Differences of adequate to 300% are not considered as untypical. Nowadays there is a consensus that is wide within professionals of construction that SAP as a tool of design is considered undesirable in order to predict the energy demand of the buildings that are low energy.

2.22 Carbon Saving
Carbon savings calculations are founded over calculations of PHPP. The standard of Passivhaus defines primary energy consumption of an upper limit that is inclusive of the usage of all energy inside the dwellings and they are inclusive of, hot water heating, all appliances and lighting. Just the efficiency of the energy concerned to the design of the building that pertains to be actual is permitted in this computation (i.e. no carbon offset from onsite energy generation).
For the calculation of the code of carbon saving that is based over SAP as an improved percentage of the design that pertains to be existent as equated to a notional design. It can be shown by compliance that a range of measurements that is inclusive of the efficiency of the energy and offset carbon via renewable onsite. In order to accomplish and attain carbon emissions code 5 from 'regulated energy use' must be cut down by the amount of 100% either by the efficiency of energy or renewable that are onsite - when figured out in SAP (McLean & Korol, 2004).

2.23 Fuel Poverty

Per its definition, by utilising the standard of Passivhaus will cut down the demand of energy to advanced level less than 15kWh/m²/year. In other words it can be said that a Passivhaus can be heated with less than 1.5 litter of heating oil/m²/year. For a 64m² flat of two beds this would outcome in heating costs entirely on per annum for £38 it is based over a heating price of oil for 40pence per litter. Due to these reflection savings concerned to the design, quality and orientation related to the fabric of building (and not bolt-on high tech kit with shorter lifespan) these savings of energy will be accomplishable over the building lifetime i.e. 80 years. All over the last research of 20 years over the project of construction has demonstrated that these savings of energy are accomplishable realistically (Michael, Charlie & Ernst, 2012). For renters living in Passivhaus’s this will intend cost of reduction greatly and it will constitute them less assailable in order to variation in the cost of fuel in the future.
Camden Passivhaus

Research accomplished over the examples that are built of the dwellings code 4, 5 and 6, where the construction standard methods have been matched with the onsite renewable installation demonstrates and establishes that those dwellings have fallen short as match with their expectations on a regular basis concerned to savings of fuel (Molly, 2012). All the fields that are more prominent it has been shown by the studies that consumption of the energy on actual basis is more probably to be 1, 5 to 3 times as prominent as and as a matter of fact not much more modest than that of building standard. In accession, it is considered as a practice that is well known in order to demonstrate compliance of code by the photo voltaic panel’s installation. Although this cuts down the emissions of carbon in SAP, generally the tenants do not provide the advantage, but only the provider that are registered by the building’s owner as the generated energy on site is instantly sold back into the grid through meter of landlord. For the renters in a code 5 house it is considered as not unusual in order to have minimum to almost no savings of energy when equated to a building of standard. In those cases that is pertains to be
worst, where the pumps of heat have been installed in order to cut down carbon emissions, cost of actual fuel could be substantially more prominent as of the higher costs 3x concerned to electricity when the comparison amongst gas is considered (McLean & Korol, 2004).

**2.24 Future Climate Change**

There is a scientific unanimity overwhelming that the variation has been seen in climate and that the variation are associated to greenhouse emissions of gas globally – summer’s drier and winter’s wetter will have the affect over the buildings that are subsisting plus the requirements of new ones that are altered. Whatsoever the climate variation causes, we will required in order to adjust or accommodate our buildings so that they can match the temperatures at higher degrees, weather that is extreme to a greater extent and rainfall variation (Magali & Arnaud, 2011). As per the data of scientific aspect for the climate variation in South West is probably in order to induce a rise in a temperatures that is average by the degrees 4-6 above the next 80 years. Research that is accomplished in Europe and UK has demonstrated that the principles pertains to similar that assist in order to reduce the demand of energy of a Passivhaus in winter assistants for reducing the overheating risk in the season of summer. Moreover the standard of Passivhaus determines a limit for heating up in order to ascertain thermal comfort that is optimum in the summer and also in winter as well. Simultaneously it will be considered as the prone to a lesser extent to the consequences from climate variation in future and arising mean temperatures.

There are no necessities and demands in the SAP or code concerning in order to heating up outside the requirements of Regulation of Building. TSB’s research shows that if the consequences from variation in the future climate are not conceived at the soonest stage of
design then costly adjustments will be needed in the future (i.e. air conditioning that enhances emissions of carbon and the demand of energy) and in the case that is worst and furnish the unusable building substantially before the finishing of its life of economy that is useful.

### Comparison of the energy use of the existing care home building with the Passivhaus extension per square metre

<table>
<thead>
<tr>
<th>Energy figures from the existing building compared in m2 with the now Passivhaus building</th>
<th>TFA - Total floor area (m²)</th>
<th>Annual Heat Demand (kWh/m²/a)</th>
<th>Primary Energy Use (kWh/m²/a)</th>
<th>CO₂ emissions (kg/m²/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing building (Current energy figure)</td>
<td>1317</td>
<td>288</td>
<td>588</td>
<td>156</td>
</tr>
<tr>
<td>New extension built to Passivhaus standard (IHP Results)</td>
<td>2271</td>
<td>13</td>
<td>77</td>
<td>19</td>
</tr>
<tr>
<td>Reductions: (The Passivhaus extension compared to the existing building, in relation to m²)</td>
<td></td>
<td></td>
<td>95%</td>
<td>87%</td>
</tr>
</tbody>
</table>

### 2.6 Healthy Living Space

The methodology of Passivhaus is founded and grounded over the principle of making a living environment healthy with input of the energy that is minimal. Thermal comfort that is optimum plus air quality that is interior are considered as the two criteria of the design that pertains to be significant. Thermal comfort is ascertained by the bridge free thermally, air tight, construction on extremely isolated and performance that has prominent doors and windows along with the objective in order to present a free environment of draft with no 'cold spots' during the
house (Maliene & Malys, 2009). This will invalidate any risk of influence growth and so on and ascertain a living environment that is considered healthy. Indoor air quality that is Optimum is accomplished by high quality utilisation, certified independently systems of ventilations in summer that is matched with ventilation naturally through windows. Filters inside this system can be utilised in order to filter the air incoming from spores plus other particles in order to assist the residents who endure from asthma or allergies. Passivhauses are well known for their indoor air quality and excellent comfort. There are no necessities and demands with respect to the SAP or code concerning to indoor air quality and to thermal comfort beyond the requirements of Building Regulation.

2.27 Cost

A Passivhaus Typical costs would be in the area of £1400/m² that is grounded over the experience of G&S from the project that built Passivhaus in the South West)

In conformity with studies from the typical costs of BRE for a dwelling of code 5 are in the area of >£1400/m² (Magali & Arnaud, 2011).

2.28 Case Study

The development of intelligent green architecture is currently seen as an in important task in the field of architecture. But how should we define "intelligent green architecture"? And how can we resolve the complex and contradictory relationship between the attributes of "intelligence" and "greenness"? According to the author (2005) conferences of the Executive Yuan, on December 3, 2009 and December 10, 2009 respectively, the government should accelerate the promotion of cloud computing, intelligent electric vehicles, the industrialisation of invention patents, and intelligent green architecture as the "four major intelligent industries."
Furthermore, the 38th Architecture Festival on December 12, 2009 made a forceful appeal for increased intelligent green architecture R&D, promotion of reform in the industry, and the improvement of human life. Nevertheless, we must ask how "intelligent green architecture" should be defined (Lisa & Chris, 2011).

Intelligent design of thermal buoyancy ventilation tower

What is the goal of employing intelligent green architecture? What methods can be used to achieve these goals? There has been a universal belief in architectural education that an intelligent building should be automatically controlled, and should apply active equipment to achieve a comfortable living environment; as a consequence, an intelligent building is energy consuming. In contrast, green architecture emphasises positive design, pursues the goal of environmentally sustainable development, and conserves energy and reduces carbon emissions (Kern, 2011).
2.29 Theory and Method

This study advocates the use of intelligence in intelligent green architecture to coordinate and manage the complex and contradictory needs among occupants and building environment or environmental factors, and thereby achieve the goal of "greenness." In other words, this study sees intelligence as a method, and greenness—environmental sustainable development—as a goal.

Traditional green architecture involves the use of passive design to achieve the goals of energy conservation and reduced carbon emissions. But while this is the ideal, a building is a container for living, and is the machinery of dwelling; there are many aspects of passive design that are impractical in the real world, or that cannot easily satisfy users' need for comfort (Jerry, 2009). As a consequence, intelligence is needed to remedy the deficiencies of passive design, and we can even consider intelligent and passive design models to be contradictory. In architecture, "passive design" implies that a building can maintain a comfortable environment by taking advantage of favourable natural climatic conditions without the use of any electronic or mechanical systems or devices. From another angle, buildings must employ passive methods (including built-configuration, use of architectural elements, and selection of materials) in order to achieve low energy consumption. However, when the built configuration is incorrect, electronic and mechanical facilities and systems must be used to compensate for errors in the passive design (Jacob & Ace, 2012).

Moreover, experts and scholars are still pondering the question of how a passive building can adapt to complex environmental changes while maintaining environmental comfort. For example, when natural lighting and ventilation depend on the same architectural opening conditions, lighting will be affected by the building's latitude and longitude, the sun's position at
different times, and the changes in the sun's trajectory due to the seasons; in addition, the weather and degree of cloudiness will also affect intensity, depth, and distribution of sunlight (Heather, 2010). For its part, ventilation will also depend on factors affecting the wind direction and wind speed, such as the area's climatic conditions and other buildings and landforms around the site. It is obvious that passive design provides an operating model that can only account for the most likely events and changes, but hard to respond to other environmental changes and exceptions.

Taking the command of "open the window" in a classroom as an example, on a sweltering day, in a hot classroom containing many students, should we still open the window if a noisy construction area lies outside? It will be extremely noisy if we open the window, but so hot that no one can stand it if we don't open the window. In these circumstances, passive design is wholly inadequate to deal with the contradictory needs to avoid heat and noise (Fiedler & Addie, 2008). In contrast, an intelligent window would be able to judge the situation, and in the face of this kind of contradiction could perhaps activate the air conditioning system, and then close the window; or could arrange for the construction unit to avoid class hours, and then open the window to maintain natural ventilation.

With regard to the development of "intelligent buildings," the evolution of sensing, computing, and communication technology has caused changes in the development of intelligent buildings and the intelligent building concept. According to the Taiwan Architecture & Building Centre, an intelligent building refers to the installation of a building automation system (BAS) in a building and on its site, where the BAS integrates ergonomic, physical environmental, operating format, and management format in conjunction with architectural space and building elements, and thereby automates operation, maintenance, and management of electrical,
telecommunications, water supply and drainage, air conditioning, fire prevention, theft prevention, and transportation equipment systems and spatial utilisation. This can improve building functionality in quality, achieving the goals of architectural safety, health, energy conservation, convenience, and comfort (Evans & Jones, 2008).

The basic constituent elements of a smart building include (1) building automation system equipment, (2) building use space, (3) and the building operating management system. Nevertheless, the government's 1990 building automation policy primarily favours automation of large buildings and facilities; this paradigm involves large central processing and control systems and various types of active electronic mechanical facilities. To date, the implementation of "smart living spaces" emphasising the application of personal mobile equipment employing computer networks and pervasive computing is evolving into a focus on "intelligent green buildings" promoting energy conservation and low carbon emissions; intelligent green buildings emphasise the application of environmental sensing and monitoring technology in order to enhance green design performance (Deakin & Allwinkle, 2007). The following section uses the example of the intelligent design of thermal buoyancy ventilation towers to explain how intelligent green architecture can use a building's intelligence to coordinate the complex and contradictory needs of the manager and environment or environmental factors, and thereby achieve the goal of "greenness."
Chapter 3: Methodology

3.1 Primary sources

Developed interview and questionnaire techniques with code for sustainable homes assessors and Passivhaus developers to understand the design, implementation and criteria which affects the performance of homes under the codes requirements. It is understood that there is a certification of accredited consultants, architects and designers under the Certified European Passivhaus Designer (CEPH) assessment. These members should be identified and interviewed to provide adequate feedback and evaluation on Passivhaus criteria in the UK and its relationship with the code for sustainable homes (Dale & Newman, 2009).

To develop knowledge and assessments of Passivhaus design strategies from case studies and visits to Passivhaus homes in the UK. These will provide an enlightening and first-hand assessment of a number of factors, including the advantages and disadvantages of living in a Passivhaus designed sustainable home. To develop a relationship with code for sustainable homes Assessors and critically appraise their approach to Passivhaus house projects in the UK (Crabtree, 2005).

To approach and contact people who own or use a Passivhaus designed home and ascertain from them, what a sustainable home is like to live/work with. What are the positives and negatives of living in this environment?

3.2 Secondary sources

To complete extensive background reading from the code for sustainable homes technical guidance and Passivhaus Planning Package (PHPP) to provide technical in-depth knowledge of the topic. Extended reading of books concerning climate change, energy use in buildings,
sustainable housing design, government policy and passive house will provide not only background knowledge but help provide a grounding to develop further questioning and development of ideas and strategies, when concerned with sustainable housing development and writing the dissertation (Bon & Hutchinson, 2000).

Qualitative researchers are particularly interested in understanding how things occur (. The research goal in this study was to uncover the nature of higher education administrators' experience and perspective on Passivhaus design and the code for sustainable homes criteria at three research sites; two colleges and one university. The knowledge and understanding generated was unique to the participants being studied, and cannot be generalised beyond the scope of the study (Adrian & Michael, 2011). Qualitative research was an emergent methodology with outcomes that were negotiated with the participants, as the researcher attempted to reconstruct the participants' realities. This research approach was subjective rather than positivistic, and not intended to establish rigid laws for Passivhaus design and the code for sustainable homes criteria or to compare data against established standards. The researcher subscribed to a subjective, interpretive worldview.

Qualitative researchers study phenomena in their natural settings, attempting to make sense of or interpret phenomena in terms of the meanings that people bring to them. Alison & Walter, (2011) stated that the process of qualitative research theory development was inductive, in that theory emerged from data. The data in this study were descriptive, and focused on participant perceptions and experiences, as well as the way participants made sense of their experiences. This is in contrast to quantitative, deductive research, where the researcher attempts to match data to a pre-formed hypothesis or theory. Through this process, qualitative researchers build abstractions, concepts, and hypotheses which enable more grounded theory to emerge from
the data. Choguill, (2007) add that qualitative researches more flexible than quantitative research since rigid adherence to initial guidelines throughout a study hinders discovery because it limits the amount and type of data that can be gathered. The research goal of obtaining rich and full descriptions from participants was a strong match for a qualitative research methodology. Qualitative research emphasised processes and meanings versus measures of quantity. Therefore, a qualitative research methodology was the method of choice for allowing the researcher to achieve a deeper understanding of **Passivhaus design and the code for sustainable homes criteria** in the research sites.

The researcher set out to interpret and understand the cultural experiences of a specific group (administrators at three Canadian research sites - one university and two colleges), and presented detailed information about the participants and the phenomenon of leadership succession planning (Adam, 2008). Qualitative research methodology was effective in producing rich, thick descriptions and stories from participant's experiences. A multi-site case study was the preferred qualitative methodology to understand the phenomenon of leadership **Passivhaus design and the code for sustainable homes criteria** in higher education. The following section presents rationales for qualitative case study methodology, higher education setting, research questions, research design strategy, data collection procedures, sampling design, a description of the setting, access and rapport issues, and data analysis procedures.

### 3.3 Research Design

In this research study, author will use the secondary research method. The proper formulation of the theoretical framework, real theoretical basis of the study focuses on how we can approach the study from the consultation of a history of how this type has been treated problem in other studies, what type of information collected, what designs were used, and so on.
Some types of secondary sources are textbooks, journal articles, literary criticism and comments, encyclopedias, biographies, investigations often start with secondary data, collecting internal and external sources.

3.4 An Overview of the Case Study Methodology

Therefore, the case study research methodology is widely used in the analysis of organisations by the various scientific disciplines, even though many scholars believe that the cases take us away from "normal" way in which to do science, because it tends to identify with the statistical analysis of large samples. The long presence and influence of case studies in the literature of the organisation is reflected in some of the most cited empirical work in texts and manuals, among them the May, Lawrence and Lorsch, Mintzberg and Hamel and Prahalad. Thus, we can go back to the considerations that Mintzberg was about scientific research, advocating more inductive than deductive approach (Deakin & Allwinkle, 2007). In fact, this is, first, to do some detective work in the search for patterns and consistencies in a second step, be able to describe something new beyond what is expected. The basic idea is that empirical research advances only when linked with logical thinking and not when it is treated as a mechanical stress.

However, the case studies have been considered traditionally as a research method weak and lacking in accuracy, objectivity and rigor, but it seems that there is a turning point in this conception, so that is increasingly being seen as a valuable research tool. Dedicate the following lines to highlight the causes that have supported this fundamental change in trend. So first, we must emphasise the growing complexity of organisational phenomena, which requires an exploratory research and understanding rather than seeking causal explanations, and for this case study may be the most appropriate research method. In this respect, Mintzberg argues that "No
matter what the state of the field, whether new or mature, all interesting research explores (Evans & Jones, 2008). In fact, it seems that the more deeply investigated in the field of organisations, we discovered that more complex, and more need to resort to methods of investigation of the so-called exploratory as opposed to those considered "rigorous". Second, this change of trend is based on the highest frequency of publications of studies that use this methodology, especially in the most important magazines and quality in the area of Business Organisation, indicating a higher level of support legitimacy and credibility.

Thirdly, the application of case study as a research tool has also intensified the efforts made to dispel the false premises about the same, which led to the consideration as a less desirable form of research than others. In fact, when the goal is to teach the material that is the case can be deliberately altered to illustrate a particular aspect and encourage discussion and debate, not even presenting a full and accurate account of actual events. However, the aim of using this strategy in research is precisely to present a complete and accurate to the reality and can not in any way alter the data, so the investigator must make an extra effort to present fairly all available evidence (Fiedler & Addie, 2008).

One of the main prejudices related to the case studies is that their conclusions are not statistically generalisable. However, the case studies do not represent a sample of a population or a particular universe, so it cannot be generalised statistically, but theoretical propositions, as the researcher's goal is to expand and generalise theories analytic generalisation and not to enumerate frequencies statistical generalisation. In this sense, the purpose of this research tool is to understand the interaction between different parts of a system and of the important features of it, so this analysis can be applied generically (Heather, 2010), even from of a single case, in that it achieves an understanding of the structure, processes and drivers, rather than an establishment
of correlation or cause and effect relationships. Now, you cannot generalise about the extent to which common-how, how often and how-these types of systems and patterns of interaction, and that this is necessary to undertake studies based on a large number of observations. There is the notion that case studies take too long to perform, and result in very long documents difficult to read. However, the wording of the cases do not have to always take the form of long narratives, no such studies must necessarily take too long, if not always data must be obtained through direct observation or ethnographic methods.

The case study methodology is not synonymous with qualitative research, as the case studies can be based on any combination of quantitative and qualitative evidence can even be based solely on quantitative evidence and need not always include direct observations and detailed source of information. Thus, the case study is a comprehensive methodology that uses techniques such as observation, interviews, questionnaires, document analysis, etc, can be both qualitative and quantitative data (Jacob & Ace, 2012). Therefore, a case study will not be defined by the techniques used but by their theoretical orientation and emphasis on understanding the processes within their contexts. However, it is true that the complexity of social phenomena requires different approaches and specific methods for their study and is more common that they focus on, preferably in their qualitative characteristics, especially when the purpose is to understand and interpret events as a whole, although nothing prevents applying statistical techniques or other quantitative methods.

Thus, we must avoid falling into the traditional view that the case studies are a form of research that cannot be used to describe or compare tenders. Moreover, we must stand, first, that the case studies, like other methodologies, can be used for purposes both exploratory and descriptive and explanatory and, secondly, that can contribute very positively to construction,
improvement or development of rigorous theoretical perspectives about organisations (Jerry, 2009). In this vein, Leonard and McAdam argue that the research methodologies that wish to develop richer theoretical frameworks must be supported by a combination of researchers and participants in the process, so that this theory is derived from models inductive grounded in different data sources, existing experience and the practical reality of the processes.

3.5 Justification of Secondary Research Method

The author will base this research on collection of secondary data. We will extract data from several different articles, journals, and books. Secondary research depicts information assembled by publications, literature, and other sources. This kind of research design does not involve call for involvement of humans.

The nature of the adopted research design is qualitative. Qualitative design of research is often more subjective in nature as compared to quantitative design of research and utilises very diverse techniques for collection of information that could be both primary and secondary in nature. The nature of this of this research design is open-ended and exploratory.

3.6 Rationale for Qualitative Case Study Methodology Research Design

Based on the exploratory nature of this research, the qualitative research strategy employed in this study was case study. John, (2009) stated that the goal of qualitative research is to produce a complex, dense, reflexive, collage like creation that represented the researcher's images, understandings, and interpretations of the phenomena under analysis. They suggested that qualitative researchers focus on the specifics of particular cases rather than probabilities derived from large numbers of randomly selected cases.
Case study methodology as described by author collects in-depth data specific to a single individual or group with the goal of increasing understanding of an unknown or poorly understood phenomenon. Case study is a qualitative research methodology that focuses on the collection and presentation of detailed information about individuals or groups. Cases can include anything that can be defined as a unique, bounded system; individuals, groups, or cultures can all be defined as a case. Katgerman & Frans, (2010) maintained that case study is a recommended research strategy when the researcher desires to understand an ongoing phenomenon within a real life context. The case study methodology was an appropriate choice as the goal was to understand phenomena from a participant's perspective and experience. Lisa & Chris, (2011) also suggested that the strength of case study approach was its ability to deal with multiple factors in understanding the unique character of the research subject. Case study has been described as useful for studying educational innovations, for evaluating programs, and for informing policy. Case study method perceives the world not as objective data, but as a function of personal interaction and interpretation. Unlike quantitative researchers who are primarily concerned with generalisable findings or cause and effect relationships, case study researchers focus on description and exploration. Author (2005) suggested that case study questions focus on how and why.

For this research study, case study allowed systematic and in-depth information gathering about each individual case. By revealing nuances and subtleties that other methodologies may miss, and by providing rich, thick, descriptive information that other strategies are not designed to produce, a case study was an effective method of gaining a holistic perspective of leadership Passivhaus design and the code for sustainable homes criteria in a higher education context. Utilising this methodology allowed participants to tell their stories and share the significance and
meaning that they attributed to the phenomenon of succession planning (Magali & Arnaud, 2011).

3.7 Focus of the Study

The focus of this multi-site case study was to understand how administrators at three Canadian research sites (i.e. two small colleges and one small university) ensured effective Passivhaus design and the code for sustainable homes criteria for their organizations. The research design employed an inductive approach, as this research was not intended to prove or test a theory (Creswell, 1998). Sixteen (16) full time employed and retired administrators were purposefully selected and invited to participate in the study. Informed consent was obtained from each participant. Participants were interviewed face to face at the campus sites, by telephone, and by email (Lisa & Chris, 2011).

Interviews were guided by a series of open ended questions specific to Passivhaus design and the code for sustainable homes criteria. Identification of the problem where passive house design does not meet sustainable homes ratings. The researcher was the main data collection and data analysis instrument. Research findings emerged from the analysed data, and were not generalisable to other settings, but specific to the research sites (Magwood, 2012). A record of the research process was kept to illustrate how the researcher developed his thinking and conclusions. The researcher described the specific phenomenon of higher education succession planning, what it included, underlying philosophies and structures that supported it, and its impact on the research sites. The units of analysis in this study were two small publicly funded colleges and one small university. The phenomenon was leadership succession planning. As suggested from the review of the literature, succession research in general, and Passivhaus design and the code for sustainable homes criteria research in particular, appeared to have
significant gaps as it pertained to the relationship between higher education administration and Passivhaus design and the code for sustainable homes criteria as studied through qualitative methodologies (Maliene & Malys, 2009). The existing literature relied heavily on quantitative methodologies, and focused primarily on succession in the context of business firms and sports teams. Researchers indicated that to augment Passivhaus design and the code for sustainable homes criteria research which relies heavily on quantitative, empirical research methodologies and archival data, future succession research could be given dimensionality by more qualitative research. Succession antecedents and consequences in past research (with some exceptions) appeared more closely tied to analysis of narrowly defined organisational performance and win-loss ratios.

Survey and interview methods did not seem to be well represented in most succession research methodologies. According to Kern, (2011), more qualitative methodologies offered potential for exploring the plethora of holes and gaps in our understanding of processes of the early stages of succession (i.e. planning). The opinions and observations of executives who have lived these events were useful in understanding the phenomenon itself. Author (2011) expressed caution against making erroneous interpretations of results and assumptions of causality. They suggested increasing the emphasis on qualitative investigation (through interviews, open ended surveys, etc.) to complement large sample quantitative analysis. Because causality is difficult to establish in complex processes, future succession researchers are encouraged to avail of more qualitative methodologies.

A qualitative case study approach allowed an in-depth analysis of a novel context with an underutilised methodology. Qualitative methodologies had potency when exploring complex processes, actual organisational constructs, and when some variables remained undefined. Case
study methods facilitated the exploration of the phenomenon of Passivhaus design and the code for sustainable homes criteria within educational and institutional contexts (Jerry, 2009).

3.8 Research Questions

The research questions attempted to uncover the core activities, perceptions, and requirements of Passivhaus design and the code for sustainable homes criteria. Identification of the problem where passive house design does not meet sustainable homes ratings. The central research question of this study was: How did mid to senior level Research Design Strategy and Data Collection Procedures As stated earlier, a case study methodology was used to address and explore the research questions. One to two hour, semi structured interviews were conducted with sixteen administrators in three higher education settings. The design of the interviews was influenced by current succession literature as well as the researcher's understanding of the post secondary context to assess both formal and informal Passivhaus design and the code for sustainable homes criteria processes. The interviews followed protocol for qualitative case study inquiry and narrative construction. Interviews were audio taped and field notes were written. The audio taped interviews were then transcribed verbatim by a designate in a closed environment. Each interview transcript was then coded and analysed by the researcher prior to beginning the subsequent interview to allow categories to emerge.

Data from each participant were compared to each other for similarities, differences, supporting themes, and models that emerged from responses. The researcher kept a running journal/log of emerging themes, notes, memos, codes, etc. Data were stored in a software application designed to facilitate qualitative research, NVIV08. Internal validity, or how research findings match individuals' interpretation, was dependant on the credibility and trustworthiness of both the researcher and informant. Triangulation helped improve internal validity.
Triangulation was the examination of the same phenomenon with several different sources of data so that converging lines of enquiry can develop. Jonathan & Ann, (2011) described triangulation as the use of multiple sources of data to confirm the emerging findings. In an effort to replicate the triangulation process for member checking recommended by participants.

3.9 Validity and Rigor of Qualitative Data

In qualitative studies, maintaining validity and conducting a rigorous study ensures the credibility of the researcher and the results of the study. For this study, the researcher took steps to comply with all required IRB and case study qualitative research methodologies.

Ireland, (2008) opined that the best way to approach reliability issue in research is to “make as many steps as operational as possible and to conduct research as if someone were always looking over your shoulder”. In qualitative research, the focus is to gather authentic data from the lived experiences of the participants. Author (2005) argued that though qualitative studies appear not to have endings, but more questions, and validations strategies are employed because, “We seek to have our accounts resonate with the participants, to be an accurate reflection of what they said”. However, results from qualitative studies cannot be generalised, and can only be transferable to similar contexts and settings. Fiedler & Addie, (2008) opined that the strength of any qualitative study that examines a problem, a setting, a process, a social group, or a style of interaction stands on the study’s validity.

Onwuegbuzie and Johnson further explained that researchers have identified areas that will be of great concern to the validity of any qualitative study. These areas include: the factual accuracy of the events (descriptive validity), the interpretation of the data that will be collected relative to group interpretations (interpretive validity), the connection of the data collected to the theories to be espoused (theoretical validity), the extent of applying critical findings to the cases,
and the extent to which the researcher can apply findings to a similar situation, context, or population.

This study met all the criteria and adhered to these validity steps in order to present the themes in an accurate manner. The researcher made sure to present descriptions and representations detailed in the study as accurately as possible (Elizabeth & Jake, 2010). Attention was given to the participants’ words and actions during the process. First hand observation data was also used in this study to validate some of the representations made by the participants. This study was conducted in such a realistic manner that will present similar findings if the same process is used to replicate this study and accurately reflects the voices of the participants.

3.9.1 Trustworthiness

Dale & Newman, (2009) pointed out that researchers should be aware that every component and stage of the research can be scrutinised for trustworthiness. In this study, trustworthiness relates to how the researcher persuaded the audience that the findings of the study deserve the respect and attention worthy of an academic endeavour.

The researcher set out to conduct a high level and quality study worthy of descriptive, interpretative, and theoretical strength. The researcher confirmed the trustworthiness of the study through transferability, triangulation, peer debriefing, and member checking.

3.9.2 Transferability

Transferability is a validation method that points to the fact that a qualitative research study will be able to be generalised in its usefulness, with similar questions, group, settings, and context. The results of this study will withstand academic scrutiny and replication. The
researcher included rich, thick descriptions of the participants’ voices and expressions during the interview and observation sessions (Crabtree, 2005). Rich data emanated not only from what the participants said, but also from the subtle non-verbal communications that they depict, such as gestures, their emotions, and the various ties they share with others in the same environment of study. Capturing these data ensured the strong points and focus of this study. During the interview process, I paid attention to the participants tone, their mannerisms or body language. I was able to detect when they were trying to avoid the question, or when they were holding back data. The researcher captured these data by focusing on the demeanour of the participants during the interview process and those behaviours were recorded as part of the data.

3.9.3 Triangulation

Triangulation involves the use of multiple data sources to arrive at valid themes. For this study, the researcher collected data that was used in triangulation during the various phases of interviews, observations, and collection of artefacts. These data were converted into valid themes on the topic of character education. Marshall and Rossman (1999) pointed out that triangulation is derived from navigational science and now applied to the social sciences where researchers bring “…more than one source of data to bear on a single point” (p. 194). Merriam (2002) added that triangulation continues to be a plan used to account for the validity and reliability of the qualitative research methodology. Using the various data sources, the researcher coded and analysed data from this study to check for possible relationships on the themes that emerged.
3.9.4 Dependability and Conformability

The qualitative research methodology is cognizant of the changes that could occur during a planned research activity. Therefore, to assure that this study could withstand validation scrutiny and replication, the researcher maintained accurate timelines of data collection and analysis steps. Patton (2002) maintained that inaccuracies and any form of bias are totally unacceptable in a case study (p. 93). This researcher maintained accurate documentation of activities dedicated to ensuring a rigorous, reliable, valid, and objective account of the process (Appendix B). Lincoln and Guba (as cited in Marshall & Rossman, 1999) stressed that conformability was to ensure that the question of whether the findings of the research can be replicated and confirmed by a different researcher. Themes that emerged from this study were coded, recoded, and presented to other cohort members for review. In addition, the researcher maintained a field note, observational notes, and listing and labelling of artefacts with times and dates of collection.

3.10 Ethical Considerations

Ethical considerations in conducting research studies have taken a serious tone as researchers in all phases of the research process are sensitive to ethical considerations (Creswell, 2007). This case study research involved spending time where people work and study, and most importantly in the midst of hundreds of middle school students.

Ethical issues in this study were of supreme consideration. A strong ethic was attained by assuring that appropriate conversations took place between the researcher and the site administrators. Appropriate permissions were received and the role of the researcher clearly clarified before research commenced. In addition, the proper documentations were sought
through University of Alabama at Birmingham’s (UAB) IRB, which had oversight powers and approval of the research study. Upon institutional approval of the study, the participants received consent forms that stressed their rights as participants.

Ethical consideration for this study called for assuring that the participant’s personal information and identity be respected throughout the study. In addition, the researcher took steps to ensure that the interview sessions were conducted in a room that does not easily reveal the participants during the study. Participants were respected as individuals and not stereotyped regardless of the data they offered during the study. Their rights not to continue in the study if they wished to do so remained intact, and no coercive methods were applied to the participants for any reason whatsoever. Many have argued that being aware and anticipating ethical conflicts that could arise in a study such as confidentiality issues, respecting the culture of the research site, even entering and exiting the research venues, and how we write the research itself ultimately presents the researcher with ethical issues that he/she must be aware of as the research steps are considered (Creswell, 2007; Marshall & Rossman, 1999).

To maintain confidentiality and safeguard data gathered from this research, all research materials stayed inside a secure metal filing cabinet with the researcher in sole possession of the keys. Electronic data were stored on a password protected computer.

During reporting, the participants’ names and actual sites were coded in pseudonyms.

3.11 Confidentiality & Anonymity

The privacy of participants was protected by giving participants a choice of being publicly named and cited or remaining anonymous by selecting a pseudonym. Any reported responses associated with a particular participant choosing to be publicly named and cited were identified by name. Any reported responses associated with a particular participant choosing to
use a pseudonym were identified by the pseudonym. Research interview notes, audio recordings, interview transcripts, and all related data documents and electronic files were stored in a locked cabinet, or password protected encrypted electronic files on the researcher's password protected home computer. These files were only accessible by the researcher and his supervisor. Data were reported in aggregate form where possible. Raw data were not accessible by the public in any form. Data will be stored for three years, at which time, they will be permanently destroyed. Participants were reminded that the information they provided during interviews may be identifiable as coming from the participant due to context. If any participant objected to their identity being revealed by the information they provided, those data were not used in the study. No other participant, member of the faculty or staff, or administrators of the research sites were informed if volunteers agreed or declined to participate in this study. Publicly available records and documents were used wherever possible.

3.12 Data Storage

Working copies of the recorded interviews remained password protected and encrypted on the researcher's computer during the study. After the completion of the study, all working copies were deleted, and the backup copies will be stored for a minimum of three years, at which time they will be destroyed. Field notes were created and will be kept for a period of three years following the study. These notes, primarily backup to the recorded interviews, are kept in a locked file cabinet at the researcher's home. Following this three year period, these notes will be permanently destroyed.
3.13 Data Analysis Procedures
Merriam (1998) suggested that data collection and analysis were simultaneous activities in qualitative research (p. 151). Using a constant comparative method of analysis, data were analysed as they were collected for themes, categories, and properties (Creswell, 1998). Subsequent data were then compared to the initial data set and tentative categories emerged. Stake (1995) suggested four forms of data analysis and interpretation specific to case studies. Each form informed the interpretation of the data from the research site.

Categorical aggregation of the data included the emergence of relevant meanings from a collection of instances from the data. Direct interpretation involved drawing meaning from single instances. Both forms of analysis led to the establishment of patterns and categories. Further levels of analysis led to naturalistic generalisations emerging from the data.

3.14 Role of the Researcher
Merriam (1998) suggested that in qualitative case study methodology, the researcher is a primary instrument of data collection and analysis. The researcher engages subjects to collect data, interprets the data, and reports on these interpretations. Throughout this process, the researcher should understand and address his or her own biases. One assumption in qualitative research is that the research will be influenced by the researcher's perspective. In an effort to provide transparency with regard to researcher bias, a running journal was kept of various streams of thought and reasoning to illuminate bias and assumptions.
Chapter 4: Result and Discussion

In European architecture and construction industry an increasingly greater attention is being paid to the energy efficiency issues. This is facilitated both by the effect of global processes on the design practice and by low efficiency of the traditional designing practice, which is no longer consistent with surging prices of energy resources. In Latvia the energy efficiency of the housing finds is very low ~ the specific energy consumption by the mass residential buildings for heating per annum makes up about 180 kWh/m (Blumberga 2006). Nevertheless, at present in Latvia a number of examples of implemented energy efficient construction projects is still very low, while the number of renovated multifamily houses is increasing, and thus being actively reported in the Latvian media. More and more various training workshops are organised for architecture and construction industry professionals on the principles of designing of energy-efficient buildings, also updating issues on the possibilities of implementation of the passive house concepts in Latvian climatic conditions.

Demand for the passive house design courses among professionals is high, because up to now the principles of passive house designing have not been included into the process of training of architecture specialists. Also the material and technical basis does not preclude from dissemination of the passive house concept in Latvia: the heating efficiency of structures can be ensured using traditional building materials, but more and more local companies offer to provide both a passive house quality control and production of windows and doors in accordance with the passive house standards. Thereby one can forecast that in years to come all the conditions will be misfiled for successful implementation of the passive house concept on a wider scale than before.
Besides, in the nearest ten years the designing of energy-efficient buildings will become a statutory provision, after enactment of the European Directive's requirements stating that after 2020 all newly erected buildings must be almost zero-energy buildings (Directive 2010/31/EU 2010).

A passive house is a type of an energy-efficient building is widely known in many European countries, particularly in Germany, Austria and Switzerland. In the Baltic States only the first implemented examples still exist. The passive house criteria under the conditions of Central Europe were defined at Passive House Institute in Darmstadt - the Research and Consulting Centre under the auspices of Dr Wolfgang Feist. The passive house concept is based on the idea, according to which comfortable to people indoor temperature can be provided without using any traditional heating system. This can be achieved by minimising the building heat loss thanks to the high performance of the structures and air-tightness of the building.

Therefore the heat emitted from the equipment available indoors, the people and the solar thermal energy received through windows shall be enough to ensure the indoor temperature. During cold winter months an additional necessary heat quantity can be provided with warmed air supplied by the ventilation system. Ventilation is necessary because of the air-tightness of the building in order to provide necessary air change, but, to reduce the heat loss through the ventilation system the application of a recuperation system is a must.

Not only the individual parameters of the structure play the most important role in achievement of the passive house standard, but also the building's architectonic spatial
organisation, and particularly, the cardinal orientation of window openings, because a lot of energy is lost through the windows. Usually it is recommended to position the largest glazing in a building facing the south, as in this case windows with high thermal parameters can ensure that solar heat obtained through windows will be greater than the quantity of lost energy (Feist et al. 2001). However, it is necessary to consider that in summer there might be a risk of overheating therefore it is necessary to construct the shading of windows.

4.1 Passive House Parameters Exposed to

4.1.1 Latvian Climatic Conditions

The passive house standard was originally developed and widely used in the area of Central Europe, but the climatic conditions in the Baltic Sea region are much harsher. Different calculations have been made in Latvia in order to make certain on feasibility of achievement of the passive house standard under such climatic conditions. The RTU specialists carried out a passive house simulation in TRNSYS software for the Latvian climatic conditions, taking as a basis a 160 m one-family two storey residential house. The paper describes two options of buildings with different building parameters. In both cases it was concluded that it is problematic to ensure the minimum heating load required by the passive house standard. This means that for such building a heating system is necessary, since warming by ventilation air would be insufficient (Kamenders 2007).
A bit more optimistic conclusions were made by a physicist Ainis Builevics, who made a passive house calculation for a 120 m two-storey residential house with an ideal orientation, giving a desired indoor temperature of about 20 °C. According to the calculation in order to achieve the passive house standard it is required 700 mm of rockwool for thermal insulation of the walls and roof, 700 mm of polystyrene foam for thermal insulation of the floor and the double glazed windows with heat penetration U = 0,6 W(mK), window frame heat penetration U = 0,7 W(mK), and the ventilation thermal efficiency 92% (Builevics 2007).

Since 2009, in Latvia, an association Passive House Latvia has been engaged in organisation of the energy-efficient building design training workshops and mainstreamification of the idea. Passive House Latvia recommends the minimum requirements to observe in order to achieve the passive house standard under Latvian climatic conditions.

The thermodynamic parameters of the house are very close to the passive house standards, however, they failed to achieve thereof, as the optimal orientation against the cardinal
direction was not provided (due to the underground stream network), as well as due to the window position (architectural and practical considerations). Thus, at present, Latvia has no building built fully in accordance with the passive house standards. In comparison to the passive house criteria for the Central European climate condition defined by the Passive House Institute in Darmstadt, much higher criteria are necessary in order to attain the passive house standards in the Baltic region, as evidenced by the recently finished buildings designed applying the passive house principles.

As evidenced by the listed theoretical and practical examples, the passive house criteria up to now have been considered mainly in architecture of single-family buildings located in the environment free from other spatial objects. Having studied the publicly accessible passive house database on the Internet, as well as various examples of passive houses constructed in Europe, one can conclude that the majority of passive houses have been designed in the environment free from other structures, and less frequently in an urban environment. Also, estimations performed in Latvia are mostly oriented to calculation of passive house parameters for free environment conditions, focusing on determination of technical parameters of a passive house. So far, less attention has been given to achievement of the passive house standard in a high-rise construction and the effect of the existing urban environment as an external factor on the building energy consumption.
The consideration of this issue is essential for several reasons. First, the building compactness ratio or volume-to-size ratio, expressed in the building envelope area against the building heated area, is essential for the energy-efficient building design and achievement of the passive house standard. The bigger is the external surface area, the greater is heat loss through the external surfaces. A multifamily building per se is a more compact solution than a single-family low-rise building. Therefore, in architecture of a multifamily house, it is potentially easier to achieve the passive house standard, because the energy loss through the external surfaces, in relation to the heated area, is less than in one-family buildings.

Secondly, insulation of a passive house in winter can provide an essential part of the building with necessary heat generation. Since in urban environment, other buildings cast additional shade to a projected building, a passive house placed in the real urban situation can receive a substantially smaller amount of solar heat radiation through windows, but this, as evidenced by the above referred practical example, can interfere with achieving the passive house standard. When designing a building in an undeveloped environment an architect is free to
operate with cardinal orientation of window openings, estimating the balance of the building energy. Amid dense urban development this is much more difficult, because orientation of a building is restricted by the plot position, as well as the surrounding development situation.

The character of the impact of the surrounding development in such a case plays both negative and positive role. The shading cast by the surrounding buildings reduces the quantity of energy received through windows, thereby resulting in a negative effect on the building energy consumption index in winter, but mitigating the building overheating risk in summer. However, it is possible to fight overheating by applying basic arrangements, ensuring the window darkening, but, if it is necessary to position the building windows against the north, which is often unavoidable, the quantity of energy lost through windows might become very significant in the total balance of the building energy.

The fact that in the structure of urban development it is impossible to vary freely the orientation of the building, is another obstacle that interferes with accurate following of all of the passive house designing provisions and thereby theoretically compromises the achievement of the passive house standards as well. This article attempts to clarify the significance of spatial orientation of a plot and impact of surrounding development on the passive house parameters.
The Project was implemented in several stages:

- Theoretical definition of the building's geometrical parameters based on the Riga construction regulations and fundamental requirements.

- Definition of thermodynamic parameters of the building structures, ensuring the achievement of the passive house standard in a spatially free environment without shading and with optimal orientation.

- Placing the obtained building simulation in a real urban environment and simulation of energy consumption, with due allowance for the effect of the defined external factor of real urban environment, i.e., shade and orientation against the cardinal direction. For the simulation of a passive house there was applied PHPP 2007 software, developed by the Darmstadt Passive House Institute for designing of a passive house. The software has a Table Excel file to enter
various building design thermodynamic and geometric parameters. PHPP software has been tested in practice and improved, while designing many passive houses and comparing real results with calculations.

4.2 Definition of Parameters of the Simulated House

Since the climatic conditions play an essential role in the passive house simulation, already at the initial stage it was necessary to choose a particular geographic location with known climatic data. Within the framework of the Project, the climatic data of city, were applied the initial house simulation was carried out, choosing the optimal orientation (orienting the front façade southwards) pursuant to the passive house designing principles and assuming that the building would be located in an environment completely free from other spatial objects. In this way, the building would receive the maximum quantity of solar thermal radiation, possible in the local climatic conditions.
The building spatial parameters were defined following the Riga construction regulations, which regulate construction in a perimeter development situation close to the historical centre of Riga. On this basis, the building height of 21.3 m to the eaves was selected, which accordingly meant that 6 stories could be located in the building. As the building prototype, one section of a high-rise residential house (an apartment block grouped with one staircase) was chosen assuming that in a perimeter development situation only two facades would be the most common, as the other two would be blocked by the adjacent buildings. For the purpose of insulation requirements the depth of the building was assumed 12 m, but the section length 20 m, which enabled to connect to one staircase three apartments - one, two and three-room apartments. So, in total 18 apartments were planned in the building.
Chapter 5: Conclusion and Recommendation

Conforming to the principle of passive design, the practical S House project uses staircases as thermal buoyancy ventilation towers. Under ideal circumstances, due to thermal buoyancy, hot air from inside the house enters the ventilation towers via the staircases, and escapes through vents at the top of the towers. However, in real world situations, the outdoor wind pressure may be greater than the indoor air flow pressure, causing air flow to reverse, and preventing air from escaping.

The application of air pressure difference sensors and computing technology can enable the ventilation towers to control the vents at the top of the towers. Accordingly, when the ventilation towers have negative pressure compared with the outside air, the system can open or close vents pointing in different directions, ensuring that the air flow in the towers maintains positive pressure and outside air has negative pressure, enabling hot air inside the house to easily escape. The intelligent design of thermal buoyancy ventilation towers employing sensors and computing technology allows the system to actively correct "exceptions" in the ventilation action of the passive thermal buoyancy ventilation towers.

Apart from this, the question of whether to open the vents of the thermal buoyancy ventilation towers often perplexes users. For instance, when the pressure difference is normal (i.e., there is positive pressure inside the towers), the vents should be opened, and if it is raining hard outside, or if there is an abnormal pressure differential (i.e., there is negative pressure in the towers) the vents should be closed; but if there is an excessively high, or even life threatening, CO2 concentration inside the house, the vents must certainly open. When more than one of these types of abnormal conditions occur at the same time, the decision to open or close the vents may be difficult.
In these circumstances, how should logic controller respond? When the CO2 concentration is excessively high, apart from opening the vents, the system should also activate a total heat exchanger, which will actively bring in fresh air from outside to improve indoor air quality. The control of the vents includes special mode and ordinary mode (pressure differential ventilation mode), and the control logic specifies that the special mode has greater priority than the ordinary mode. In the special mode, the order of priority is high wind > heavy rain > too cold/too hot. Apart from control based on window opening or closing conditions, release conditions, and changes in frequency parameter settings, the system can also accommodate home users' habits, and can make adjustments based on climate change experience values.

The intelligent green architecture advocated in this study can coordinate the complex and contradictory needs of the manager and environment or environmental factors, and thereby achieve the goal of "greenness." The following practical guidelines are recommended intelligent green architecture is based on passive architectural design, and employs supplementary intelligent functions. Greenness is the goal, and intelligence is the method. Intelligent functions are employed in a supplementary role to make up for deficiencies in a building's passive design.
References


Elizabeth Wilson, Jake Piper, (2010). Spatial Planning and Climate Change, The Natural and built environment series. Publisher. Taylor & Francis, 224-236


Rücker, Klaus, (2010). Development of standards, criteria, specifications. Publisher. Univerlagtuberlin, 149-159


