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EXAMINATION OF OVERHEATING IN PASSIVE SOLAR HOUSE IN SCOTLAND

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ABSTRACT

Passive solar heating is one of the many design tactics communally called passive solar design. When united appropriately it can supply both heating and cooling to the building [1]. The simplest passive solar design is the Direct Gain system. Direct Gain system works on a basic principle that sunlight passes through the windows and heats the thermal mass in the room. Passive solar cooling uses the natural breeze into the building, and the air exchange that takes place between the outdoor and indoor environment. This causes the necessary cooling to take place and hence fresh air is circulated into the building which helps to improve the indoor air quality as well [2].

This project examines the weakness of the existing passive house methods and to propose improved methods with regards to overheating in the building design methods. The major objective of the project is to investigate the effectiveness of a passive house building in Scotland during the summer with regards to overheating and to check the thermal comfort level of the occupants in a building. To make it a realistic approach, a dynamic model of craigrothie passive house is created using ESP-r design software and the results are compared with PHPP (PASSIVE HOUSE PLANNING PACKAGE) software.

Comparison of the two software falls on the important aspects of the project because passive house planning packages have several disadvantages. Though a building meets the PHPP standard, the buildings in UK experience a overheating because PHPP software assumes the whole house to be entire zones rather than assuming them as separate zones which would give an accurate result than the first. Also, the PHPP assumes a standard thermal comfort value of 25^{o}C which can vary with the different occupants in the building. In order to obtain a more realistic approach, ESP-r is utilized in the project to investigate the overheating of passive house in Scottish climate.

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1. INTRODUCTION

1.1. THE PASSIVE HOUSE APPROACH

A passive house is a building which is considered with certain strict set of standards to gain at most comfort level inside the building and as well obtain a minimal energy cost. The building fabric is designed in such a way that heat loss is minimized and internal heat gains are maximized. This approach leads to the removal of convectional heating system and give way to the space heating approach. Under the current building regulation this approach saves about 90 percent of the energy consumption when compared with the standard house [3].Watt committee working group defined passive house approach is to utilize the form and fabric of the building to permit, collect and deliver the solar power to the building for the purpose of heating and lighting. Moreover this approach saves fuels, improves the comfort of the building with no extra construction or maintenance costs. Passive solar approach with energy conservation measures when used closely, offers a reduction in usage of fossil fuels [4]. Only careful passive house design allows it to achieve the best thermal comfort level and reduces the energy cost .This is achieved by considering certain criteria's during construction such as super insulating walls, floor and roof, increasing the air tightness in order to minimize the hot air to escape from the building, introducing thermal mass to maintain the heat inside the building, Usage of MVHR(Mechanical ventilation heat recovery system) to increase the air quality and maintain internally the dispensed heat, using best quality windows such as triple glazing ,low-e etc to ensure maximum sun rays pass through it and avoid heat losses and improve heat gains[5].

1.2. THE PASSIVE HOUSE INSTITUTE

The concept of passive house and the first passive house was developed and built in Germany in 1990.Currently there are more than 30000 passive houses across EUROPE.

The passive house institute was established by Professor WOLFGANG FEIST in 1996.Passive house standard was developed in DARMSTADT ,GERMANY by research and monitoring thousands of passive house projects[3].

1.3. CERTIFICATION

The passive house building must always have a certification in order to claim itself to be a passive house. The certification is provided by the Passive House Institute itself or by a reputed organization which is a part of Passive House Institute. For a building to qualify as a passive house requires detailed planning. Retrofitting the building to be a passive house is a very difficult task. The passive house building to qualify for certification needs a blower door test, a signed statement from the builder stating that the construction has been to plan and finally establishing and agreeing upon the outset of the project[3],[6].

1.4. PASSIVE HOUSES IN SCOTLAND

The climatic change and UK government have encouraged many publications and legislative conditions in the last few years and requested the Scottish government to cut the CO2 emissions by 42 percent by end of 2020.One of the best solutions for reducing CO2 emission and energy costs is to develop more passive houses. The concept of a Passive house is new to Scotland and it is in a developing stage, hence it is difficult for the people to immediately adapt the new technology. The popularity of the passive house is increasing and the people have acknowledged that passive house construction could cost 20 % more than convectional building but the people have also noticed that there is about 80 to 90 % reduction in energy consumption and that they can obtain good comfort level and indoor air quality [7].

2. OBJECTIVES OF THE PROJECT

The primary objective of the project is to identify the weaknesses of the existing passive houses and to propose improved methods with regard to overheating in passive houses. The project deals with two software's –PHPP AND ESP-r .The secondary objective is to create a dynamic simulation model using ESP-r to check the performance of the passive house and compare it with PHPP and suggest which could give a realistic and accurate result.

2.1. AIM OF THE PROJECT

The aim of the project is to examine the performance of a passive house in SCOTLAND during summer period which particularly focuses on the overheating. Dynamic simulation tool, ESP-r is utilized to develop a building model of an existing house in SCOTLAND. This method is used to monitor the frequency of overheating in the model house there by applying some improved methods to avoid it and to ensure thermal comfort inside the developed model.

2.2. METHODS FOLLOWED IN THE RESEARCH

First the existing Passive House Design method, the Passive House Planning Package (PHPP) was investigated. Initially the PHPP overheating calculations were investigated for a standard example house and a sensitivity analysis carried out to illustrate the operation of the overheating calculations and develop skills for use later on in the project. (Chapter 3)

The use of open source dynamic simulation software ESP-r was then investigated, this was chosen as the both the Passive House Planning Package and the EU 13790 standard identify that the simplified methods have limitations and that dynamic simulation has the potential to address these limitations. (Chapter 3)

The Scottish Passive house to be used as a case study was identified as the Craigrothie Passive House and data gathered and connection made with the occupant and designers. The occupant's behaviour and experience of the house was investigated using a brief questionnaire. (Appendix 2)

A literature survey was carried out to understand the reported problems with overheating in Passive Houses. Studies were found which identified problems with passive houses and rooms within passive houses. In some of these studies dynamic simulation methods and PHPP were compared to actual measured performance providing a template for the analysis of this thesis to follow and apply to the Scottish context. (Chapter 5)

The literature then was extended to investigate and provide background knowledge of the factors affecting overheating in buildings, and criteria related to occupants experience (comfort and overheating) in domestic buildings. This review then formed the backdrop to the main analysis of the thesis. (Chapter 5)

The responses of the PHPP to the factors affecting overheating were investigated by carrying out a sensitivity analysis. This provided insight into the main factors and their effects as predicted by the PHPP method. While the PHPP provides an output in terms of annual %hours > 25C there is no detailed insight into internal conditions on a room by room or time of day basis – the conclusion then is that dynamic methods will be required to deliver this insight. (Chapter 6)

A dynamic simulation investigation was then carried out (Chapter 7) to provide this more detailed insight. A multi-zone model was constructed from available plans and used as the basis of this investigation to provide temporal and zonal insights.

The results from the simulation modelling and a preliminary sensitivity analysis provided insights not available through the PHPP simplified method. This preliminary investigation was sufficient to allow a conclusion to be made that either a dynamic simulation method or a dynamic simulation informed zonal simplified method would be required to address the limitations in the current methods. (Chapter 8)

A brief example of dynamic modelling of some options to improve performance is given. (Chapter 9).

The next stage of the investigation would be to carry out some monitoring of the Craigrothie house and use this as the basis for validating the simulation model.

Further to this an improved method could be developed. These future activities are described in the conclusion and future work (Chapter 10 and 11).

3. SOFTWARE EMPLOYED

3.1. PHPP (PASSIVE HOUSE PLANNING PACKAGE) SOFTWARE

Passive house planning package is improved energy modelling and design software. The data of the proposed building such as glazing, ventilation, shading, heat gains etc are entered in the excel software to create an accurate model of the building. The major advantage of the PHPP is once it has been entered correctly in the excel format as provided, all the data can then be varied to check the energy performance of the building[8], PHPP also takes into account exterior shading and local weather criteria's which is very helpful with respect to design of the building[9]. In order to create a good design and obtain certification, the Craigrothie passive house also has PHPP software. The PHPP software was utilized for obtaining certain important data so that it can be modelled in a dynamic simulating tool (ESP-r). PHPP of the Franchover house in Germany was also utilized for the sensitivity analysis to find out the important factors of overheating in passive houses.

3.2. ESP-r

ESP-r is modelling software which influences the energy and environmental behaviour of the building [10]. ESP-r supports UNIX operating system and windows and uses UNIX modulator [11]. The major advantage of the software is it brings realism and adheres exactly to the physical system, detailed design stage appraisal is supported early by ESP-r, and it always works on a holistic performance assessment. ESP-r allows the designer to play and explore the most complicated relationships between critical elements such as building form, fabric, airflow, and the plant and control [10]. The performance of the building is calculated by finite volume approach which solves the set of conservation equations and then integrates it with subsequent time steps in response to climate, occupant and control system influences [11]. ESP-r consists of a project manager which houses a simulator, various performance assessment tools and provides access to import and export with CAD and report generation [10].

4. CRAIGROTHIE PASSIVE HOUSE

Craigrothie passive house was led by passivhaus associates and this house is a 2-bed bungalow near cupar in fife. Craigrothie passive house has a total floor area of 81 m^2 and has been built according to the passive house standards. The passive house was built using timber frame construction and the house is designed in the way that it has a minimum heating load of 800W during the coldest of days. This house has an air-tightness of 0.28 and air exchange per hour of 0.36m^3/m^2h)@50 Pa. U-value for the walls, floor and roof is 0.08W/m^2K.The total budget of the craigrothie passive house is 165000 pounds. Regarding the windows, Optiwin Alu2wood windows from the green building were used in the house with a whole windows U-value of 0.77W/m^2K.The cork frame insulation and low maintenance aluminium cladding was also introduced to the outside of the windows. This house has ecopassive glazed doors which offer a whole window U-value of 0.75W/m^2K. Craigrothie passive house also has a mechanical ventilation heat recovery system for controlled exchange of air [12].

To have a realistic approach, the University of Strathclyde and the owner of the Craigrothie passive house had an agreement and agreed upon the dynamic modelling of the house in order to check the performance of the house.

5. LITERATURE SURVEY

Before starting the project a critical analysis was conducted based on the previous work done by researchers. This analysis helped in reviewing various ideas that could help me achieve my objective. One of the major problems was in determining the method which needs to be deployed in order to find out the frequency of overheating in a realistic way. Another major issue was to derive the significant factors responsible for overheating in passive houses. In order to overcome the problems, researchers conducted various modelling techniques to review different difficulties related to overheating and concluded with its positive aspects. Two important topics are listed below which have helped in choosing the dynamic model simulation and as well as helped in deploying solar shading that is overhang in the model. In addition factors which affect the overheating in passive house, thermal comfort, software employed and design standards have been explained in the literature survey which has helped in developing a model in ESP-r building simulation tool.

Tine Steen Larsen and Rasmus Lund Jensen wrote a paper that compared the indoor temperatures of a Danish passive house for two distinctive methods. Two different methods described in the following are a detailed dynamic simulation calculation based on hourly basis and a detailed 24 hrs average calculation and maximum temperature calculation during a warm summer day based on monthly dates. During modelling, the Danish house was simulated with mechanical ventilation and sensors were placed at two points for temperature, relative humidity and Co2 levels. The methods were time consuming because measurements were to be taken every 5 minutes during 24 hours case study. This method showed good results in prediction of average temperatures but when compared to maximum temperatures the difference went large .In case of dynamic simulation the average temperatures were also predicted along with maximum temperatures as this method was able to record the change in behavioural patterns during the 24 hours average period there by showing better and realistic results. As stated by above researchers, dynamic method shows better results with the experimental duration being longer than the simple method [13].

Paper presented at the conference of “PASSIVHUSNORDEN 2012” was basically focusing on the possible overheating problems in passive houses compared to the less insulated houses. In this case study, two different buildings with two different energy levels are modelled for three different locations in Norway. The above described houses insulation standards , air tightness, efficiency of heat exchangers , SFP factors , window solar factor ,orientation of building and shading were varied. The calculations made for the above modelled houses were for 5 subsequent days during summer to avoid short term effects. For both the houses the simulation was carried out with the help of SIMIEN software. This program can do yearly calculations based on Dynamic calculations in steps of 15 minutes. The basic focus of the whole work was concentrated on the indoor temperature during summer. This program helps to find the dimensioning summer day and the same day was repeated for the whole duration of 5 days. This program helped in concluding that houses using automatic solar shading were having lowering indoor temperatures compared to the houses without solar shading. Efforts were made after this paper to lower maximum temperatures during day and night in most of the effective passive houses. The effective methods to reduce overheating were free cooling, increased thermal mass and cross ventilation by using windows [14].

5.1. PHPP VS ESP-r

Passive house planning package is an excel software and as a result it needs a very little technical knowledge to use it. Major advantage is, it is very simple to use as all the pages are linked to each other and as result when the values are varied or changed the corresponding change is reflected immediately. When it comes to the overheating aspect in a passive house, an assumption is taken by the passive house institute with frequency over 25^{o}C exceeds 10 % then it is considered to be overheating and additional measures have to be taken to protect from the summer heat waves. This assumption with respect to overheating has caused several thermal comfort problems which are occurring due to it in a real time scenario. Craigrothie passive house is one of those houses which has thermal discomfort though the passive house planning package had a frequency of overheating at 2.2%. There arises a question in our mind that, standard internal temperature assumed by passive house institute is a reasonable temperature or not?

The purpose of the statement is made because according the ASHRAE standard the thermal comfort is defined as the combination of environmental factors and personal factors that will result a thermal comfort level of an occupant within space. When the standard definition of thermal comfort is defined in the manner above, assumption of a numerical value by passive house planning package for indoor temperatures is questionable. According to the environmental ergononomic definitions, thermal comfort is a condition of mind of an occupant so it is always a subjective perception because all the occupant is not the same and will not have the same feeling of comfort and assumption of a particular value for thermal comfort can create problem with respect to it. So this package is very simple and has a non realistic approach. Another major disadvantage of the PHPP is, it assumes the whole house has a single zone. Since the assumption is taken the package is not able to detect overheating in each room but this happens in a realistic scenario. Craigrothie passive house and other passive houses have several problems like thermal comfort in a single room especially which is south facing. The room seems to behave really hot and makes the occupant to have thermal discomfort though the PHPP predicts there is no overheating in the house. Discomfort during summer in passive house is a common problem but creates a major discomfort to the occupant as result in order to avoid this problem a more realistic approach - The Dynamic Simulation Model is chosen to model the craigrothie passive house and check whether for the presence of overheating during the summer. ESP-r is a dynamic simulation tool which can avoid the problem in PHPP but needs sound technical knowledge to model a passive house in it. But once modelled then it shows a realistic results than PHPP. The Major advantage of ESP-r is the internal temperature can be obtained to separates zones rather than assuming to be a single zone. The assumption of frequency of overheating over 25^{o}C is not considered in the ESP-r instead the occupant is surveyed about his thermal comfort and based on his acceptable levels a passive house is modelled.

5.2. OVERHEATING IN PASSIVE HOUSES

Passive house heating design is to overcome the frequent fluctuation of the air temperature, when it is not achieved then two major side effects will result in the building. First, the occupant will become uncomfortable during clear days which includes even in hot season, this will cause opening of windows frequently to get the natural ventilation and avoid discomfort. Secondly, the opening of windows during the Summer Seasons will result in loss of solar energy collected. Comfort in the building is the most important aspect not only with respect to the local environment but also with the efficiency of residents and resident's health. There are several factors which influences comfort such as temperature, humidity, noise level, dust level. Temperature is certainly the first to be addressed by the house regulation systems. According to ANSI/ASHREA standard a comfort zone is in balance with outdoor climate condition when it lies between 20 to 26 C and 30 to 60% of relative humidity. Higher temperatures are not uncommon in passive houses and in these cases passive house are loaded with large amounts of sunlight and a very high external temperature. Passive houses are highly insulated buildings and as result they are poorly linked with environment. The passive house building during afternoon can easily reach 500 W, when it has a single unshaded window with a specific loss up to 60W/K and it requires a 10K temperature gradient to discharge the energy. Considering the fact that such a temperature gradient is impossible, already a small energy input can have an adverse effect on internal temperature and with a low internal heat capacity especially in low weight construction has become popular in European conditions like Scotland. Another major problem can be reduction of internal energy sources which results in large ventilation in nights when the internal temperature is high. Protection towards overheating should be considered during the planning stage of the building which includes size of windows, shading, ventilation, building materials, solar protectors, solar gain, insulation, thermal gain, glazing etc [15]. Major factors towards overheating are

1. GLAZING
2. VENTILATION
3. ORIENTATION
4. INTERNAL HEAT GAINS
5. INFILTRATION

5.2.1. GLAZING

The problem of overheating do not arise with smaller windows but with the small windows the specific demand is below 15kWh/(m^2yr).Large windows are always recommended for daylight capturing. The internal temperature over 25^{o}C is reached when there is a increase in south facing windows with low e-triple glazing with glazing proportion of 30% of triple glazing with low-e coating and 25% with 3-magnetron. A good proportion of mix without sunshades can be achieved by mix of 42% of triple glazing with low e-coating and more than 35% with 3-magnetron. When glazing is a concern then overheating is due to high solar gain by windows which is a common issue and can be prevented by professional planning by utilizing some components such as blinds, curtains and overhangs [16].

5.2.2. VENTILATION

Passive houses generally have heat recovery ventilation in which the preheated air is channelled to rooms in the buildings. Air flow and efficiency of air exchange is influenced by the location of the inlet dampers. The inlet is often placed in the area of the separating doors. Many occupants have recorded health complaints in Netherlands due to heat recovery systems. The lack of good indoor air quality is the major reason and certain other reasons which added to it are the poor indoor environment where noise, draught, carbon dioxide, formaldehyde and also the high internal temperature in summer. Major complaints about HRV systems are that the air released is not fresh, ventilation capacity is low, noise by HRV is high, Ceilings and walls are dirty due to accumulation of particles and internal temperature is high when it is not functioning in 100% bypass. The volume of the air is reduced by 15 to 25% by using dirty filters and this also creates a lack of balance between exhaust and inlet. Cleaning at regular intervals can increase the capacity.

5.2.3. TEMPERATURE CONTROL

Passive houses tend to be well insulated and warm because of the influence of a heating load inside the building. Potential of overheating is created by indoor heat load and diffused sunlight. Heat recovery ventilation created by the Dutch with 100% bypass is the best solution to avoid overheating but it is not preferred by people due to its high cost. A surrogate solution is by switching off the inlet fan. Cool night can avoid overheating inside the building provided it should reach ACH=2.5 per room in early morning. In passive houses, climate in Western Europe as well as the internal temperature inside the building will be more than 16^{o}C for most of the year and the temperature will increase to 20^{o}C without heating as soon as the sun shines and hits the windows. Ventilation has become one of the most important aspects in insulated homes like passive houses. Ventilation is a control strategy for temperature inside the building commonly in bedrooms and living rooms during the summer season. In passive houses the internal temperature is cooled down by supplying it with the outdoor air which is commonly called as natural ventilation [17].

5.2.4. ORIENTATION

Design for orientation is an architectural skill in which the building is ensured to work along with the passage of the sun's path. Knowledge towards the path of sun is the basic in design of building windows to let the sunrays and obtain solar gains, reduce glare and as well as avoid overheating in the interiors of the building. It is very important to note that the position of sun is dynamic in nature and keeps varying its path in line with time of day, time of year and site latitude. Houses built in the temperature region can be benefitted by the sun rays .Openings should be oriented towards south taking into the account the conservatories and buffer spaces[18].Building orientation also takes into consideration of each rooms in the building to take maximum advantage of the sun light. For example, living spaces, dining hall should always face south because to have a good day light in a day, have maximum solar gain throughout the year, to have good passive solar gain during winter and it is always better to have a horizontal shading to avoid overheating in summer. Kitchen and dining hall is generally preferred to be east facing as they can be benefitted by early morning sunrays for the whole year and it is generally cool in the afternoon when the rooms face towards east .Bedrooms can also face towards east, since the late afternoon is cooler it makes it comfortable for the occupant during summer for sleeping. West facing rooms always get low angle sunlight, late afternoon sun and as a result it requires some shading aspects like overhangs to avoid overheating and glare especially during summer. Living room is generally preferred to be west facing as the occupants are not available during morning and their presence is more during evening. Kitchens facing towards west are a great problem as heat released by cooking coincides with low angled afternoon sunlight and causes overheating and glare. North facing rooms are more suitable for bathroom, laundry and garage as they have minimum level of sunlight during the day throughout the year and as a result they have very little heat gain [19].

5.2.5. INTERNAL HEAT GAINS

Internal heat gain is a process of converting chemical energy or electrical energy to thermal energy. The main sources of heat gains are from occupant, lighting and equipments. Internal heat gains are generally omitted in heat load calculation to make sure that the heating system does a fair job without heat gains but the internal heat gains is always taken into consideration in cooling load calculation because it contributes an important part of it [20]. A significant point about the internal heat gains is that they vary throughout the year and this variation will have repercussions on the balance point temperature of the building [21].

5.2.5.1.OCCUPANTS

Heat gains from the occupant vary by the level of work he/she does and it extends from 100 W for a resting person to 500 W for a physically active person. Heat dissipation by people consists of latent and sensible heat .Latent heat contributes one third of dissipation during resting but contributes about two third during heavy work. About 30 % of sensible heat is dissipated by convection and rest 70 % by radiation. The cooling load of the people is expressed in the form of latent and convective heat losses and on the other hand radiative sensible heat is ingested by neighbouring environment and then discharged with a delay. An average person during resting releases latent heat around 30 W. The water loss in a body due to evaporation is calculated by latent heat loss in the day due to vaporization. Heat dissipated by the occupant has a very important part in determining the sensible and latent heat of the building and also have a major part in cooling load in the highly occupied building but there is always an issue in judging the number of occupants in a building. Internal heat gains from the occupants in a building are listed in (Tab 1):

ACTIVITY	***APPLICATION***	***SENSIBLE HEAT (W)***	***LATENT HEAT (W)***
Seated at theatre	Theatre	65	30
Seated ,light work	Hotels, Apartments, Residential building	70	45
Moderate work	Hotels ,apartments, Residential building	75	55
Light bench work	Factory, Residential building	80	80
Heavy work	Factory, Residential building	170	255

TABLE 1 INTERNAL HEAT GAINS FROM THE OCCUPANTS IN A BUILDING [22]

5.2.5.2.LIGHTS

The energy usage of the lights is about 7 percent in residential building and 25 % in a commercial building as a result light is an important factor in heating and cooling load of a building. Primary types of lights are fluorescent lamps, incandescent lambs and gaseous discharge lambs. The heat dissipated per flux of lighting differs with the type of lighting so as a result it is must to know the type of lighting while predicting the lighting internal heat load. Poor efficiency of lighting sources is incandescent lights and therefore they lay the greatest load on cooling systems. Incandescent lights consume more electricity and make the cooling system to work hard to remove heat from the building. As a result florescent light is preferred by all office and residential buildings though they have a high initial cost. Consumption of energy by lights is released in the form of convection and radiation. The convection contributes around 40 percent for fluorescent lights and this component illustrates the cooling load by lighting. Remaining 60 % is contributed by radiation and this been absorbed by walls, ceilings and furniture etc and affects the cooling load. Lighting may also impose to the cooling load by re-radiating after the lights have been turned off. Comparison of different lighting systems is tabulated and shown in (Tab 2):

TYPES OF LIGHTING		***EFFICIENCY(lumens/W)***	***LIFE, h***	***COMMENTS***
Combustion Candle		0.2	10	Inefficient
Incandescent	Ordinary	5-20	1000	Low Efficiency
	Halogen	15-25	2000	Better Efficiency
Gaseous Discharge	Mercury Vapour	50-60	10000	Indoor and outdoor use
	High Pressure Sodium	100-150	15000	Good colour rendition
	Low Pressure Sodium	Up to 200		Outdoor use, Distinct yellow light
Fluorescent	Ordinary	40-60		
	High Output	70-90	10000	Used in offices, plants
	Metal Halide	55-125	10000	Very high efficiency

TABLE 2 DIFFERENT LIGHTING SYSTEMS

5.2.5.3.EQUIPTMENTS

Heat released in conditioned spaces by electric, steam and gas appliances such as refrigerator, television, washing machine, computer, printer etc have an important effect while predicting the cooling load of a building. Laser printer of 350 W consumes 175 W and a computer of 600 W consumers nearly 530W during standby mode. Equipments without hood have a 34 percent heat gain to be latent heat and 66 percent to be sensible heat. For equipments with hood, air which is heating by convection and the moisture released is removed by it as a result of heat gain from these applications is only radiation and it constitutes 32 percent of energy consumed by the appliance [20].

5.2.6. INFILTRATION

According to Hittmans report, infiltration accounts for 28% of the total heat losses in the majority of the buildings .A well insulated building will have infiltration losses for about 38% of the seasonal heat losses [21].When air enters a building from outside it is called infiltration. This is generally unavoidable flow of air into the building through cracks, gaps of windows and doors. The infiltration rate depends upon the pores in the building, wind from outside and external temperature [23]. Generally infiltration rate in a passive house should not exceed 0.6 AC/h and this unintentionally flowing air helps sometimes to reduce overheating as the external air flows inside the building and make the internal temperature to cool down a bit. Highly insulated building like passive house is benefitted by infiltration with respect to overheating and as a result unintentionally flowing air not exceeding 0.6 AC/h is considerable.

5.3. DESIGN STANDARDS

Passive house buildings have a certain standard to which the building has to be built so that it works properly and can avoid problems like overheating or overcooling etc and create a thermal comfort for the occupants in a building. Passive house institute standards for a passive house is tabulated and shown in (Tab 3) [24]:

BUILDING COMPONENTS	***VALUES***
WINDOW INSTALLATION	U value <= 0.85W/m^2K
THERMAL BRIDGE COEFFICIENT	Thermal bridge coefficient<=0.01W/m^2K
OPAQUE AREA	U value <=0.15 W/m^2K
DOORS	U value<=0.80 W/m^2 K
INFILTRATION	Infiltration<=0.6 AC/h
Glazing	<=0.8 W/m^2K

TABLE 3 DESIGN STANDARDS IN PASSIVE HOUSE

5.4. THERMAL COMFORT

Thermal comfort has a range of definitions and one definition among them by ASHRAE defines thermal comfort as the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHARAE Standard 55).The human body always tries to keep the body temperature in 37^{o}C and the body does it with number of mechanisms like increasing the flow of blood and sweating can lower the temperature of the body in warmer condition. When the blood flow is reduced and goose bumps are developed for making the body warm during the cold conditions. In order to sustain the body temperature at 37^{o}C, clothes also influence in regulate the insulation in skin. The main factors which affect the human heat balance are

1. AIR TEMPERATURE
2. MEAN RADIANT TEMEPERATURE
3. AIR VELOCITY
4. RELATIVE HUMIDITY

Air temperature and mean radiant temperature have direct effect on the heat balance of the human body but air velocity influence the convective losses from the skin and the relative humidity affect the proportion of sweat evaporates [25]. Since the air temperature and mean radiant temperature have direct effect they are considered to affect the rate of thermal comfort to a great extent as result these two factors are considered in the report. Air temperature and mean radiant temperature is collectively called zone resultant temperature in ESP-r. Air temperature or zone db temperature is the temperature of the air flowing inside the building. Mean radiant temperature is a measure of the cooling or warming by exchange of radiant heat to all the objects in the room [26]. In simple words the mean radiant temperature is the average temperature of all the objects around the occupant in the building. PHPP package by passive house institute assumes the thermal comfort criteria to be not more than 25^{o}C and is a fixed value but each human body behaves in a separate manner so this assumption is valid to be certain extent but cannot be accepted fully as a result ESP-r modelling is done for the craigrothie passive house and thermal comfort criteria is determined in ESP-r by conducting a survey to the occupant itself and according to that the improved model is achieved.

6. SENSITIVITY ANALYSIS

Literature survey was done in order to find out the significant factors of overheating in a passive house so that a careful design model can be developed in an ESP-r. The significant factors of overheating has been found out but in order to obtain a clear idea of how these factors affect the sensitivity of the building with regards to overheating. A sensitivity analysis was carried to a passive building in Germany (FREUNDORFER). This sensitivity analysis was carried out using the PHPP report of the FREUNDORFER passive house and the necessary results were obtained. Since this PHPP software is a excel software by changing the necessary values gives the corresponding output and to understand clearly, a Graphical Representation has been incorporated.

The first factor to be considered is the ventilation. Ventilation in simple words is defined as the exchange of air from one space to another. According to the passive house institute the ventilation rate should be minimum 0.4 1/h or 30 m^3/pers/h. So an analysis (Tab 4) was carried out for the ventilation rate below 0.4 1/h in order to visualize the effects of ventilation over frequency of overheating.

VENTILATION (1/h)	*FREQUENCY OF OVERHEATING*
0.13	1.50%
0.05	8.50%
0.04	13.90%
0.03	17%
0.02	22.30%
0.01	30.70%

TABLE 4 FREQUENCY OF OVERHEATING WITH RESPECT TO VENTILATION

The graph obtained for various ventilation rates below 0.4 1/h and their corresponding frequency of overheating is given in (Fig 1):

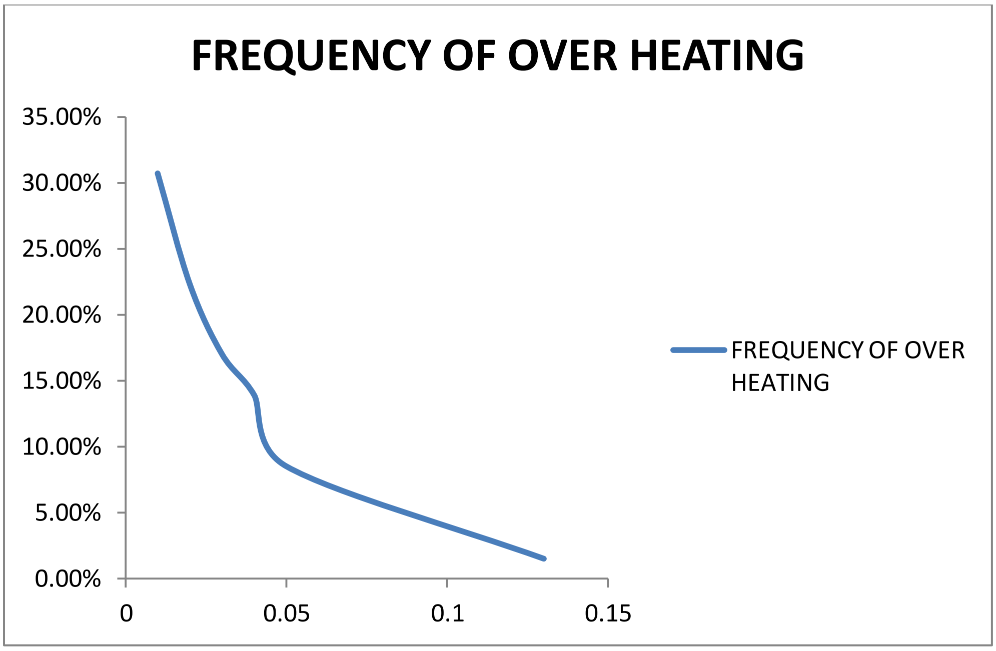

FIGURE 1 FREQUENCY OF OVERHEATING WITH RESPECT TO VENTILATION

Next factor considered is glazing of the windows in the building and the analysis was obtained with ventilation of 0.01 1/h, because it has the frequency of overheating at peak of 30% and this can help to obtain which type of glazing can reduce the frequency of overheating to maximum extent. Analysis is carried out only for 1 window in each room rather than considering all windows in the house to derive a solution for which window causes the problem of overheating. In other words orientation of windows is also considered in the analysis so considering one window at a time helps to derive which type of orientation of windows leads to frequency of overheating. A tabular column of frequency of overheating with respect to glazing is given in (Tab 5):

WINDOW IN EAST FACING BEDROOM	***FREQUENCY OF OVERHEATING***
DOUBLE LOW –e	30.50%
SINGLE GLAZING	25.30%
DOUBLE GLAZING	28.30%
TRIPLE GLAZING	29.90%
RX-WARM 0,58	30.50%
WINDOW IN WEST FACING BEDROOM	***FREQUENCY OF OVERHEATING***
DOUBLE LOW –e	30.40%
SINGLE GLAZING	25.10%
DOUBLE GLAZING	28.90%
TRIPLE GLAZING	29.90%
RX-WARM 0,58	30.60%
WINDOW IN EAST FACING OFFICE	***FREQUENCY OF OVERHEATING***
DOUBLE LOW-e	30.20%
SINGLE GLAZING	19.50%
DOUBLE GLAZING	27%
TRIPLE GLAZING	28.90%
RX-WARM 0,58	30.40%

TABLE 5 FREQUENCY OF OVERHEATING WITH RESPECT TO GLAZING

NOTE: Generally triple glazed glasses are preferred in location like Scotland so that the maximum heat is retained in the building and in the case of overheating these triple and double glazed windows especially in south facing rooms should have an additional shading like overhangs which helps to reduce the frequency of overheating.

A Graph is plotted (Fig 2) to the window in east facing office because it has produced the best result of 19.50% with respect to the frequency of overheating.

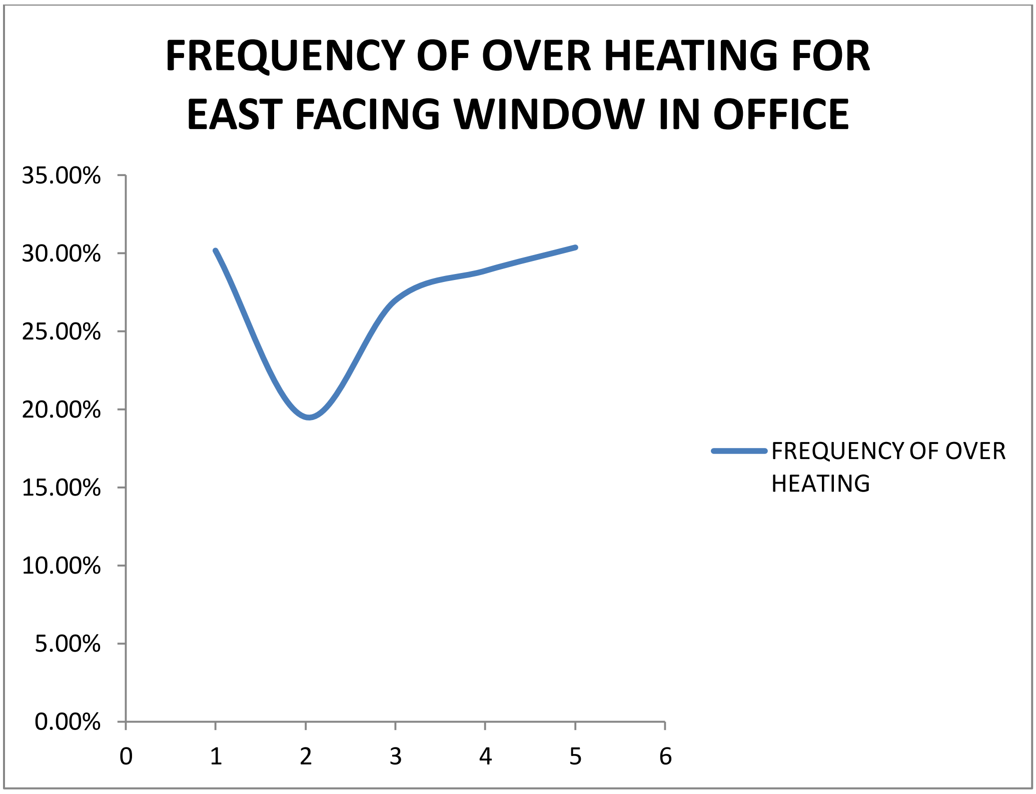

FIGURE 2 FREQUENCY OF OVERHEATING WITH RESPECT TO GLAZING

Now the temporary shading factor Z is varied in order to visualize the frequency of overheating. The analysis (Tab 6) for temporary shading factors is started with the frequency of overheating at 17.2 % so that it is easy to check at what percentage of Z can reduce the frequency of overheating in east facing office.

TEMPORARY SHADING FACTOR(Z)	*FREQUENCY OF OVERHEATING*
50%	17.30%
40%	16.70%
30%	16.20%
20%	15.60%
10%	14.90%

TABLE 6 FREQUENCY OF OVERHEATING WITH RESPECT TO TEMPORARY SHADING FACTOR

NOTE: The value of Z in percentage decrease then the temporary shading increases.

The graph is plotted with respect to temporary shading factor and frequency of overheating and is shown in (Fig 3):

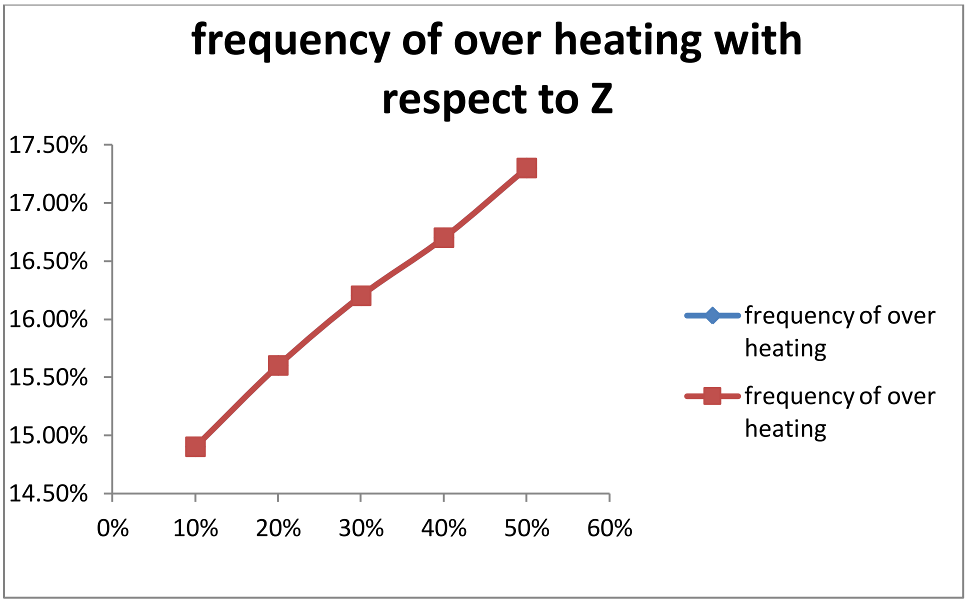

FIGURE 3 FREQUENCY OF OVERHEATING WITH RESPECT TO TEMPORARY SHADING FACTOR

A sensitivity analysis was carried out for internal heat gain with frequency of overheating at 19.8% in order to visualize the necessary effect of the internal heat gain to the building. Generally a passive house have an internal heat gain of 2 to 2.2 W/m^2. So an analysis is carried out with high internal heat gain that is more than the standard value to check the effect of high internal heat gains with the internal temperature inside the building. A tabular column of different internal heat gains and their frequency of overheating are listed in (Tab 7):

INTERNAL HEAT GAINS (W/m^2)	*FREQUENCY OF OVERHEATING*
2.5	24.70%
3	29.90%
3.5	33.40%
4	36.90%
4.5	41.10%
5	46.60%

TABLE 7 FREQUENCY OF OVERHEATING WITH RESPECT TO INTERNAL HEAT GAINS

A corresponding graph for the internal heat with frequency of overheating is obtained and shown in (Fig 4):

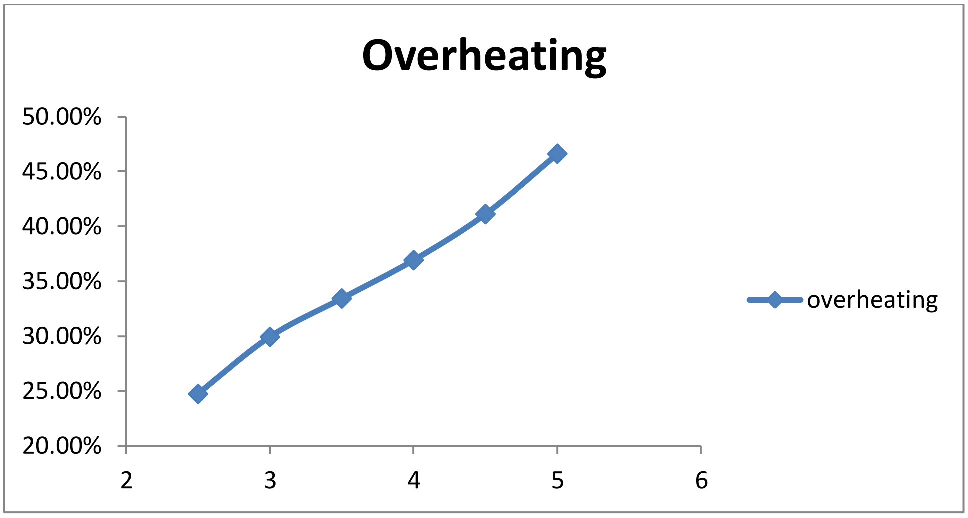

FIGURE 4 FREQUENCY OF OVERHEATING WITH RESPECT TO INTERNAL HEAT GAINS

A sensitivity analysis was carried out separately for the entire factors which can cause a thermal discomfort to the occupants in a building. But in the real time scenario all these factors have to be considered at the same time to avoid the problem. When the factors were considered separately the model has not avoided the frequency of overheating but the factors when varied, showed considerable decrease in the frequency of overheating. So a sensitivity analysis was again carried out for a realistic approach, also with an intention to avoid the frequency of overheating in the building.

This sensitivity analysis (Tab 8) was obtained when the frequency of overheating in the passive house is 35.6 % which is really high and the corresponding result of the overheating is directly assumed for the next one. For example when the ventilation, glazing, shading, and other factors are varied for first analysis and the result of frequency of overheating is at 35.6 % then the next analysis starts from 35.6%. So the procedure is followed in this manner in order to overcome overheating in a building.

Ventilation (1/h)	***Glazing In Office***	***Shading***	***Specific Capacity (Wh/K)***	***Internal Heat Load (W/M^2)***	***Frequency Of Overheating***
0.02	Single glazing	20% east office and 20% in west facing living room and bedroom	130	3.5	31%
0.04	Single glazing	15% in east office and 15% in west facing living room and bedroom	100	3	18.3%
0.08	Single glazing	10% in east office and 10 % in west facing living room and bedroom	80	2.5	8.6%

TABLE 8 SENSITIVITY ANALYSES OF VARIOUS FACTORS WITH RESPECT TO OVERHEATING

The tabular column (Tab 8) clearly illustrates the major factors of overheating in passive houses and it also clearly explains whenever the factors deviate from the design standards there is a problem of thermal discomfort inside the building. For example take the first case of the above tabular column where the ventilation rate of 0.02 1/h and internal heat gain of 3.5 W/m^2 has deviated to a large extent from the design standards framed by the passive house institute and this has resulted in 31 % of frequency of overheating in the passive house which is really high. In the same way, analysis did clearly explained for the third case, the factors when comes closer to the design standards then the frequency of overheating can be avoided. The frequency of overheating is 8.6% for the third case which is a reasonable result and has avoided overheating in the house but still the frequency of overheating can be reduced more by choosing the material, planning for ventilation, internal heat gains, specific capacity to be really close to the design standards so that frequency of overheating is still reduced and which increases the thermal comfort for the occupant inside the building.

6.1. CONCLUSION OF SENSTIVITY ANALYSIS

Sensitivity analysis has thus highlighted the major factors of overheating in a passive house and their effect on the building. This analysis explains that careful consideration have to be made when the craigrothie passive house is modelled in the dynamic simulation tool software or otherwise the frequency of overheating exceeds to the maximum extent and the precautionary measures employed also can't help to avoid it. The frequency of overheating when exceeds beyond 20 % then the internal temperature inside the building is really high and it is also very difficult to avoid it. So rigorous planning during the construction stage about the effect of these factors and analysis like above would help the passive house in a real time scenario to avoid the overheating to a maximum extent.

7. METHODOLOGY

7.1. OVERVIEW OF THE METHOD

Developing a model in ESP-r plays an important role because of the way it is going to behave with respect to the exterior and interior conditions will determine the factor of overheating. Keeping this in mind and great knowledge from the literature survey the craigrothie passive house model was developed. Approach and assumptions to develop a craigrothie passive house is explained in the next section. Next to consider was the climatic conditions, Craigrothie passive house is located near cupar in fife and has latitude of 56.287 degree and longitude -3.003 degrees. ESP-r has a facility of giving the latitude and longitude of the developed model and once given the climatic condition of the fife is assumed directly. ESP-r has separate realistic database of the climatic condition in United Kingdom and once the latitude and longitude is given, it picks the corresponding result from database. Construction details for the craigrothie passive house are one of the most important parts because the model to behave exactly like a real time scenario, the model needs to have the exact construction material which is utilized in the craigrothie passive house. Operational details are the next factor to be considered and this also plays an important role as they are the key factors for determining the internal heat gain inside the building. The great difficulty is that, it cannot be given directly or by assuming certain factors because the internal heat gain will vary according to it and a perfect result cannot be obtained. As a result a survey is conducted on the occupant of the building regarding certain important factors of operational details and then it is developed. Survey regarding the operational details is given in the appendix 2. Simulating and obtaining the result for thermal model is possible only when the geometry and attribution, construction details and operational details is given to the model. Simulating model to behave exactly like the real time scenario these details need to be accurate. But there might be some practical difficulties towards developing a model. Approach and assumption explains about the steps taken to make it a real time model.

7.2. APPROACH AND ASSUMPTIONS

Craigrothie model to be developed needs to have the geometry and attribution to be provided .ESP-r software have two facility to develop a model in it, so considering which method needs to be adapted is the first step. ESP-r can develop a model in 3D modelling or by separating the craigrothie passive house into zones and developing them. The architect of the craigrothie passive house provided with ground floor plan, section plan, and an elevation plan of the building which is given at the appendix-1. Since the details were provided about the building by the architect it was much simpler to develop a model by separating the craigrothie passive house into separate zones. The length, breadth, and height of the building are given clearly in the plan with which the vertex for the each separate zone is generated and the model was developed. The next step was to develop windows and doors in the house. Craigrothie passive house has nine windows and two doors. The position of these windows/doors in the wall, glazing and type of windows /door falls is an important part in modelling. ESP-r has an inbuilt facility of determining the position of windows and doors in the wall by giving the X offset and Z offset values. X offset is from lower left corner of the existing surface when looking from outside and Z offset is from lower bottom surface of the existing surface when looking from outside. This inbuilt facility makes it easy to insert the child surface in the position of the user's choice in the parental surface. Windows in the front of the house is display windows and totally there are five display windows, three in the kitchen and dining rooms and two in the bedroom 1. Three windows in the kitchen and dining rooms are assumed to be a one large window and out of two windows in the bedroom 1 are considered to be one large window. This assumption is taken to avoid some difficulties during the modelling and the effect of the separate windows and one large windows falls to be same when it is considered for the thermal simulation. The model of the separate zones in craigrothie passive house developed in ESP-r is given as below:

7.2.1. KITCHEN AND DINING HALL

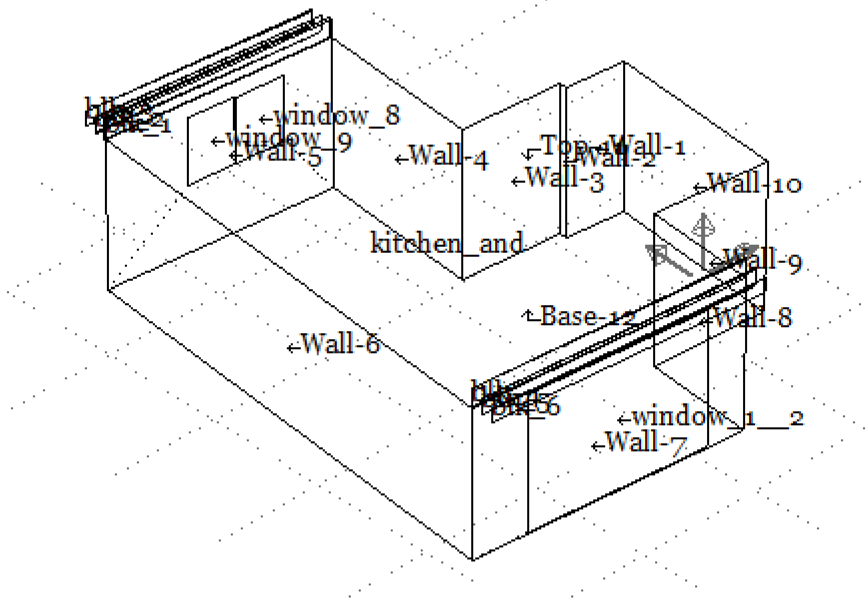

FIGURE 5 A ZONE IN CRAIGROTHIE PASSIVE HOUSE (KITCHEN AND DINING HALL)

A summary of the surfaces in kitchen_and(1) follows:

Sur	Area	Azim	Elev	surface	geometry			construction	environment
	m^2	deg	deg	name	optical	locat	use	name	other side
1	2.36	5.	0.	Wall-1	OPAQUE	VERT	-	intern_wall	< identical environment
2	0.302	95.	-0.	Wall-2	OPAQUE	VERT	-	intern_wall	< identical environment
3	4.04	5.	0.	Wall-3	OPAQUE	VERT	-	intern_wall	< identical environment
4	6.61	95.	-0.	Wall-4	OPAQUE	VERT	-	intern_wall	< Surf-4:utility_roo
5	7.42	5.	-0.	Wall-5	OPAQUE	VERT	-	external_wal	< external
6	18.5	275.	-0.	Wall-6	OPAQUE	VERT	-	external_wal	< external
7	4.45	185.	-0.	Wall-7	OPAQUE	VERT	-	external_wal	< external
8	4.48	95.	0.	Wall-8	OPAQUE	VERT	-	intern_wall	< identical environment
9	4.58	185.	0.	Wall-9	OPAQUE	VERT	-	intern_wall	< identical environment
10	7.09	95.	-0.	Wall-10	OPAQUE	VERT	-	intern_wall	< identical environment
11	38.3	0.	90.	Top-11	OPAQUE	CEIL	-	ceiling	< identical environment
12	38.3	0.	-90.	Base-12	OPAQUE	FLOR	-	ground_floor	< identical environment
13	0.841	5.	0.	window_8	DCF7671_	VERT	C-WIN	dbl_glz	< external
14	0.841	5.	0.	window_9	DCF7671_	VERT	C-WIN	dbl_glz	< external
15	6.48	185.	0.	window_1__2	DCF7671_	VERT	D-WIN	dbl_glz	< external

FIGURE 6 KITCHEN AND DINING HALL COMPOSITION

Shading and obstruction is also given to the windows of the kitchen and dining hall and the obstruction details is given in (Fig 7):

Block	X-	Y-	Z- coords	DX-	DY-	DZ- values	Orient	Opacity	Name	Material
1	-6.00	5.08	2.41	3.77	0.02	0.30	-5.00	1.00	blk_1	door
2	-5.99	5.28	2.41	3.77	0.02	0.25	-5.00	1.00	blk_2	door
3	-5.97	5.48	2.41	3.77	0.02	0.22	-5.00	1.00	blk_3	door
4	-6.67	-2.54	2.41	4.53	0.02	0.30	-5.00	1.00	blk_4	door
5	-6.69	-2.74	2.41	4.53	0.02	0.25	-5.00	1.00	blk_5	door
6	-6.70	-2.94	2.41	4.53	0.02	0.22	-5.00	1.00	blk_6	door

FIGURE 7 OVERHANG COMPOSITION

7.2.2. BEDROOM 2

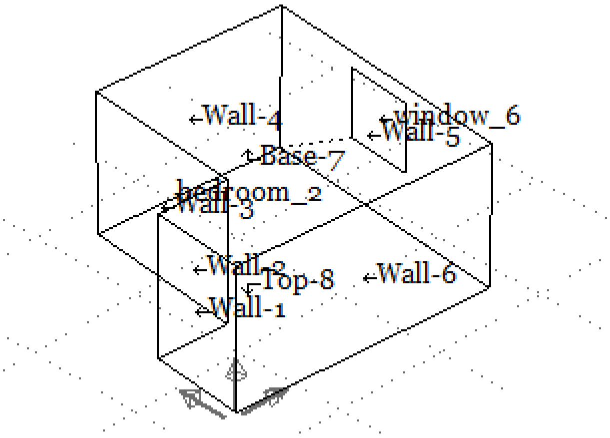

FIGURE 8 A ZONE IN CRAIGROTHIE PASSIVE HOUSE (BEDROOM 2)

A summary of the surfaces in bedroom_2(4) follows:

Sur	Area	Azim	Elev	surface	geometry			construction	environment
	m^2	deg	deg	name	optical	locat	use	name	other side
1	4.05	95.	0.	Wall-1	OPAQUE	VERT	-	intern_wall	||< identical environment
2	3.07	185.	-0.	Wall-2	OPAQUE	VERT	-	intern_wall	||< identical environment
3	6.91	95.	-0.	Wall-3	OPAQUE	VERT	-	OPAQUE	||< Surf-2:bathroom
4	8.14	185.	0.	Wall-4	OPAQUE	VERT	-	external_wal	||< external
5	9.57	275.	-0.	Wall-5	OPAQUE	VERT	-	external_wal	||< external
6	11.2	5.	0.	Wall-6	OPAQUE	VERT	-	intern_wall	||< Wall-3:bedroom_1
7	17.4	0.	-90.	Base-7	OPAQUE	FLOR	-	ceiling	||< identical environment
8	17.4	0.	90.	Top-8	OPAQUE	CEIL	-	ground_floor	||< identical environment
9	1.39	275.	0.	window_6	DCF7671_	VERT	C-WIN	dbl_glz	||< external

FIGURE 9 BEDROOM 2 COMPOSITION

7.2.3. BEDROOM 1

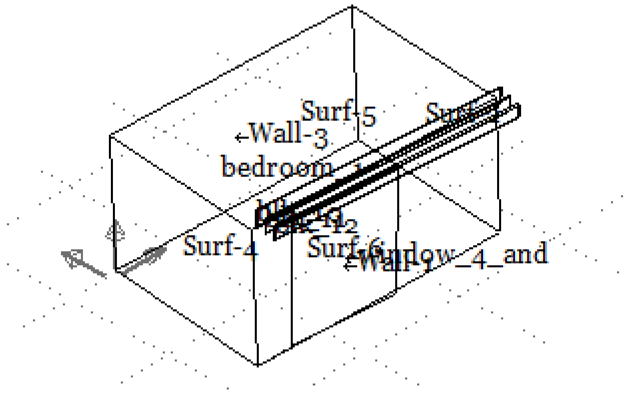

FIGURE 10 A ZONE IN CRAIGROTHIE PASSIVE HOUSE (BEDROOM 1)

A summary of the surfaces in bedroom_1(5) follows:

```
Sur| Area  |Azim|Elev| surface  |   geometry     | construction |environment
 | m^2  |deg |deg | name      |optical|locat| use | name        |other side
 1 6.91  185.  0. Wall-1     OPAQUE  VERT -   external_wal ||< external
 2 7.52   95.  2. Surf-2     OPAQUE  SLOP -   external_wal ||< external
 3 11.2    5.  0. Wall-3     OPAQUE  VERT -   OPAQUE      ||< Wall-6:bedroom_2
 4 7.52  275. -2. Surf-4     OPAQUE  SLOP -   intern_wall ||< Surf-2:hall
 5 14.5  275. 88. Surf-5     OPAQUE  SLOP -   ceiling     ||< identical environment
 6 14.5   95. -88. Surf-6    OPAQUE  SLOP -   ground_floor ||< identical environment
 7 4.31  185.  0. window_4_and DCF7671_ VERT C-WIN dbl_glz   ||< external
```

FIGURE 11 BEDROOM 1 COMPOSITION

Shading and obstruction is also given to the window of the bedroom 1 and the obstruction detail is given in (Fig 12):

Block	X-	Y-	Z- coords	DX-	DY-	DZ- values	Orient	Opacity	Name	Material
1	-0.27	-3.11	2.41	4.64	0.02	0.30	-5.00	1.00	blk_10	door
2	-0.29	-3.30	2.41	4.64	0.02	0.25	-5.00	1.00	blk_11	door
3	-0.31	-3.50	2.41	4.64	0.02	0.22	-5.00	1.00	blk_12	door

FIGURE 12 OVERHANG COMPOSITION

7.2.4. BATHROOM

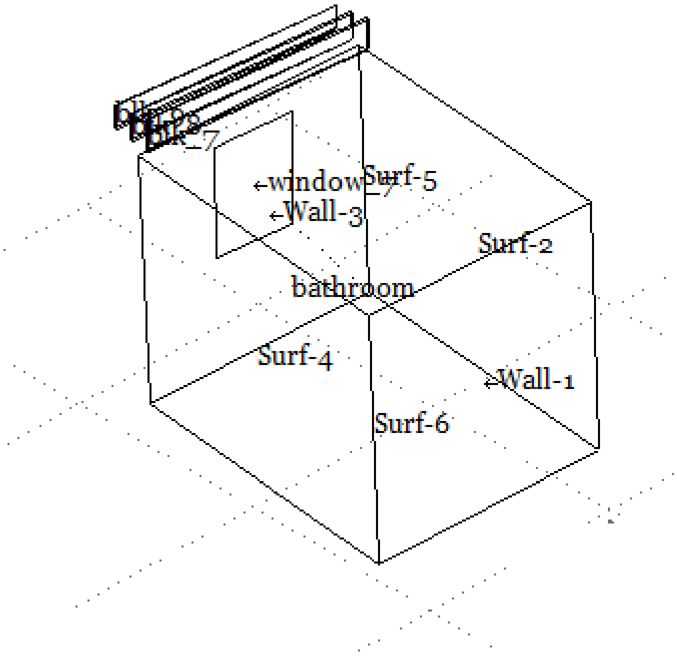

FIGURE 13 A ZONE IN CRAIGROTHIE PASSIVE HOUSE (BATHROOM)

A summary of the surfaces in bathroom(3) follows:

Sur	Area m^2	Azim deg	Elev deg	surface name	geometry optical	geometry locat	use	construction name	environment other side
1	5.43	185.	-0.	Wall-1	OPAQUE	VERT	-	intern_wall	||< identical environment
2	6.91	95.	2.	Surf-2	OPAQUE	SLOP	-	intern_wall	||< Wall-3:bedroom_2
3	4.60	5.	0.	Wall-3	OPAQUE	VERT	-	external_wal	||< external
4	6.91	275.	-2.	Surf-4	OPAQUE	SLOP	-	OPAQUE	||< Surf-2:utility_roo
5	6.44	275.	88.	Surf-5	OPAQUE	SLOP	-	ceiling	||< identical environment
6	6.44	95.	-88.	Surf-6	OPAQUE	SLOP	-	ground_floor	||< identical environment
7	0.831	5.	-0.	window_7	DCF7671_	VERT	C-WIN	dbl_glz	||< external

FIGURE 14 BATHROOM COMPOSITIONS

The craigrothie passive house building with full geometry and attribution is given in (Fig 15):

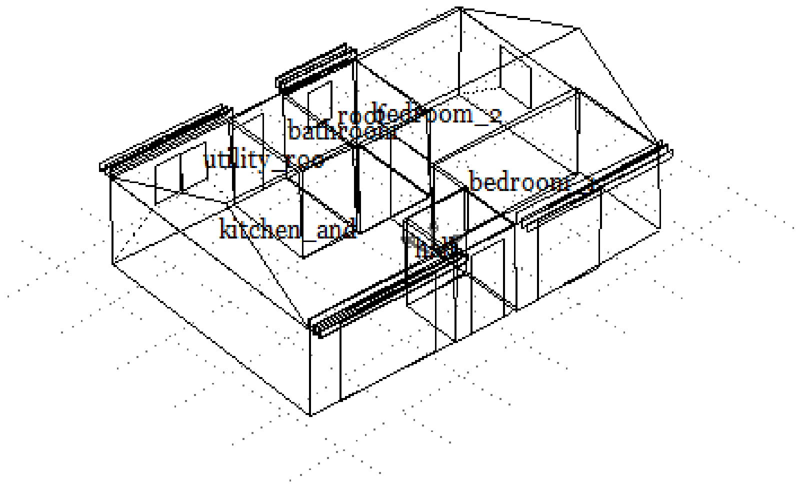

FIGURE 15 CRAIGROTHIE PASSIVE HOUSE

Once the geometry and attribution is given to the model then construction material have to be given to the model. ESP-r has a separate database for construction and it gives the user the opportunities to select from it. But the craigrothie is a passive house and there are certain design standards for the house to behave like a passive house. So, the selection from the database was not possible. An alternative method had to be found, ESP-r has the option for the user to create the own database for the construction so the method was utilized. Creating the own database for construction needed certain details such as thickness, U-value, the material used to model the passive house exactly like real house. The data was not provided separately but closely monitoring the passive house planning package given by the architect of the craigrothie passive house contained all values for the construction of a new database for the house. The construction database in PHPP of craigrothie passive house and ESP-r model is given below. Figure explains the construction material, thickness, U-value of the ground floor slab in PHPP (Fig 16) and ESP-r (Fig 17):

Assembly No.	Building Assembly Description
1	Ground Floor Slab

Heat Transfer Resistance [m²K/W] interior R_{si}: 0.17

exterior R_{se}: 0.00

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Plywood	0.130					20
2.	Insulation	0.036	45x50 battens	0.130			45
3.	Reinforced Concrete	2.100					200
4.	XPS Dow Floormate 3	0.036					400
5.							
6.							
7.							
8.							

Percentage of Sec. 2: 12.5%   Percentage of Sec. 3:   Total: 66.5 cm

U-Value: 0.080 W/(m²K)

FIGURE 16 CONSTRUCTION DETAILS OF GROUND FLOOR SLAB IN PHPP

Details of opaque construction: ground_floor and overall thickness 0.665

Layer|Matr|Thick |Conduc-|Density|Specif|IR |Solr|Diffu| R |Descr
|db |(mm) |tivity | |heat |emis|abs |resis|m^2K/W
Ext 78 20.0 0.130 500. 1500. 0.90 0.70 576. 0.15 Plywood deck : Plywood/felt (UK code)
2 283 45.0 0.036 100. 960. 0.93 0.93 30. 1.25 fiberglass batt : fiberglass batt insulation
3 38 200.0 1.930 2400. 1000. 0.90 0.70 13. 0.10 concrete 150mm : Concrete high density 150mm
Int 220 400.0 0.040 38. 1450. 0.90 0.30 350. 10.00 XPS CO2 foamed : XPS extruded polystyrene fo
ISO 6946 U values (horiz/upward/downward heat flow)= 0.086 0.086 0.085 (partition) 0.085

FIGURE 17 CONSTRUCTION DETAILS OF GROUND FLOOR SLAB IN PHPP

For the construction of the ground floor slab, the U-values in PHPP is 0.080 W/(m^2K) and in ESP-r is 0.085 W/ (m^2K) and it is almost close to the PHPP report. This small variation is due to the change in conductivity of the material used in ESP-r. Reinforced concrete with conductivity of 2.100 W/mK is utilized in PHPP report but in ESP-r, concrete with high density is used with has a conductivity of 2.400 W/mK and XPS dow floormate with conductivity of 0.036 W/mK is used in PHPP and in ESP-r, XPS extruded polystyrene is used with a conductivity of 0.040 W/mK. ESP-r has an inbuilt material database from which the construction materials have to be chosen and when the construction material in PHPP report of the craigrothie passive house was missing in ESP-r material database then material which has the nearest conductivity is chosen.

Construction material, thickness and u value for external wall in PHPP (Fig 18) and ESP-r (Fig19) is given below:

Assembly No.	Building Assembly Description
3	External Wall 2 25 service void + single layer internal battens

Heat Transfer Resistance [m²K/W] interior R_{si}: 0.13; exterior Rse: 0.04

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Plasterboard	0.250	Plasterboard	0.250	Plasterboard	0.250	13
2.	Still air gap	0.136	Batten 25 x 45	0.130	Batten 25 x 45	0.130	25
3.	Insulation	0.036	Batten 50 x 45	0.130	Insulation	0.036	50
4.	SmartPly Frame OSB	0.130	SmartPly Frame OSE	0.130	SmartPly Frame OSB	0.130	9
5.	Insulation	0.035	Timber stud 220x45	0.130	Insulation	0.035	220
6.	Timber sarking	0.130	Timber sarking	0.130	Timber sarking	0.130	25
7.	Thermosafe Homogen	0.037	Thermosafe Homogen	0.037	Thermosafe Homogen	0.037	140
8.	Thermowall	0.039	Thermowall	0.039	Thermowall	0.039	100
			Percentage of Sec. 2	20.0%	Percentage of Sec. 3	6.9%	Total 58.2 cm

U-Value: 0.080 W/(m²K)

FIGURE 18 CONSTRUCTIONAL DETAILS OF EXTERNAL WALL IN PHPP

```
Details of opaque construction: external_wal and overall thickness  0.582

Layer|Matr|Thick |Conduc-|Density|Specif|IR  |Solr|Diffu| R    |Descr
    |db  |(mm)  |tivity |       |heat  |emis|abs |resis|m^2K/W
Ext  110  13.0    0.210  900.  1000. 0.91 0.26   11.  0.06 Plasterboard (wallboard) : Internal finish (
  2   0  25.0    0.000    0.     0. 0.99 0.99    1.  0.50 air  0.50 0.50 0.50
  3 283  50.0    0.036  100.   960. 0.93 0.93   30.  1.39 fiberglass batt : fiberglass batt insulation
  4  79   9.0    0.130  650.  1700. 0.90 0.70 1200.  0.07 OSB : OSB wood based on the SBEM database
  5 283 220.0    0.036  100.   960. 0.93 0.93   30.  6.11 fiberglass batt : fiberglass batt insulation
  6 323  25.0    0.130  290.  1300. 0.90 0.90   10.  0.19 virtual_loft_space : for notional building l
  7 300 140.0    0.040   30.  1500. 0.90 0.70   10.  3.50 lambswool felt insulation : lambswool insula
Int  214 100.0    0.030   25.  1000. 0.90 0.30   67.  3.33 EPS : EPS (expanded polystyrene)
ISO 6946 U values (horiz/upward/downward heat flow)=  0.065  0.065  0.065 (partition)  0.065
```

FIGURE 19 CONSTRUCTIONAL DETAILS OF EXTERNAL WALL IN ESP-r

For the construction of the external wall, the U-values in PHPP is 0.080 W/ (m^2K) and in ESP-r is 0.065 W/ (m^2K).This variation is due to the change in conductivity of the material used in ESP-r. As explained earlier the available material database was utilized in the model and the material database lacked certain materials which were used in PHPP report so a closed match is chosen.

Construction material, thickness, and U-value for roof in PHPP (Fig 20) and ESP-r (Fig 21) are given below:

Assembly No.	Building Assembly Description
5	Roof 2 25 service void + single layer internal battens

Heat Transfer Resistance [m²K/W] interior R_{si}: 0.10; exterior R_{se}: 0.10

	Area Section 1	λ [W/(mK)]	Area Section 2 (optional)	λ [W/(mK)]	Area Section 3 (optional)	λ [W/(mK)]	Total Width Thickness [mm]
1.	Plasterboard	0.250	Plasterboard	0.250	Plasterboard	0.250	13
2.	Still air gap	0.153	Batten 25 x 45	0.130	Batten 25 x 45	0.130	25
3.	Insulation	0.036	Batten 50 x 45	0.130	Batten 50 x 45	0.130	50
4.	SmartPly Frame OSB	0.130	SmartPly Frame OSE	0.130	SmartPly Frame OSB	0.130	9
5.	Insulation	0.035	Flange 45 x 63	0.130	Flange 45 x 63	0.130	90
6.	Insulation	0.035	Insulation	0.035	Web 9mm OSB	0.130	210
7.	Timber sarking	0.130	Timber sarking	0.130	Timber sarking	0.130	25
8.	Ultratherm	0.043	Ultratherm	0.043	Ultratherm	0.043	120
			Percentage of Sec. 2	12.9%	Percentage of Sec. 3	2.1%	Total 54.2 cm

U-Value: 0.081 W/(m²K)

FIGURE 20 CONSTRUCTIONAL DETAILS OF ROOF IN PHPP

```
Details of opaque construction: roof_2 and overall thickness  0.542

Layer|Matr|Thick |Conduc-|Density|Specif|IR  |Solr|Diffu| R    |Descr
     |db  |(mm)  |tivity |       |heat  |emis|abs |resis|m^2K/W
Ext  110  13.0   0.210  900. 1000. 0.91 0.26  11.  0.06 Plasterboard (wallboard) : Internal finish (
  2    0  25.0   0.000   0.    0. 0.99 0.99   1.  0.50 air  0.50 0.50 0.50
  3  283  50.0   0.036  100.  960. 0.93 0.93  30.  1.39 fiberglass batt : fiberglass batt insulation
  4   79   9.0   0.130  650. 1700. 0.90 0.70 1200.  0.07 OSB : OSB wood based on the SBEM database
  5  286  90.0   0.034  133. 1200. 0.05 0.05  30.  2.65 KarnsTrussR19 : KarnsTrussR19 (Mfg specific
  6  283 210.0   0.036  100.  960. 0.93 0.93  30.  5.83 fiberglass batt : fiberglass batt insulation
  7  302  25.0   0.110  640. 1210. 0.90 0.90  10.  0.23 particle board underlay : Particle board und
Int  233 120.0   0.040   35. 1900. 0.90 0.30  10.  3.00 celulose fiber flakes : cellulose fibre insu
ISO 6946 U values (horiz/upward/downward heat flow)=  0.072  0.072  0.072 (partition)  0.071
```

FIGURE 21 CONSTRUCTIONAL DETAILS OF ROOF IN ESP-r

For the construction of the roof, the U-values in PHPP is 0.081 W/ (m^2K) and in ESP-r is 0.072 W/ (m^2K).This variation is due to the change in conductivity of the material used in ESP-r. This small change in U values does not cause a big variation in thermal simulation because it is within limits and as a result the assumption is being utilized. Model is supplied with the geometry and attribution, construction material then to make it more realistic, the number of occupants, type of lighting, and equipment usage can be supplied in ESP-r to determine how these will affect the internal heat gain of the building. The number of occupants, lighting, and equipment usage has to be given in sensible heat load and latent heat load .The number of occupant according to the survey is 1 (refer appendix 2) and sensible heat load and latent heat load of the occupant is given from literature survey of internal heat gain. The simulation is done for the summer period in Scotland and as a result the ambient light during summer stays till nine in the night and as a result lighting can be omitted as they contribute a very minimal variation towards internal heat gains since it is utilized very less in the summer months. Usage of equipments is also omitted because the occupant in the building works in office from seven in the morning to seven in the evening and utilizes the house only for sleeping and doing minor work, and as result the sensible and latent heat load from equipment is minimal and can be omitted. Occupancy is the only factor which is given in the operational details and determining the sensible and latent heat load is derived from the ASHRAE standard. The occupant according to the survey utilizes the house in weekdays from 19-24pm then 00 to 7 am and the sensible heat load and latent heat load is 100 W and 50 W for both the period separately. The occupant uses the house in weekends from 16-24 pm and 00-10 am and the sensible and latent heat load is 100 W and 50 W for both the period respectively. When the model is completed with the operational details then it is allowed for the thermal simulation. The simulation is done for the summer months in Scotland and according to the METEORALOGICAL OFFICE [27], UNITED KINGDOM the summer months in SCOTLAND is usually three months from June to August and May is also considered to be little warm and as a result simulation is done from May to August to determine the frequency of overheating in the craigrothie passive house.

8. RESULT

8.1. RESULTS FROM CRAIGROTHIE PASSIVE HOUSE

The craigrothie passive house is a two bedroom bungalow near cupar in fife, and there is a single occupant in the building .The occupant spends most of the time in office and utilizes the house for cooking and sleeping. Result is obtained for the zones which occupant uses in daily basis and the zones are kitchen and dining hall, bedroom two, the bathroom and bedroom one. Zones such as the hall and utility room is not used by the occupant regularly as a result they are excluded. According to the occupant in the survey, the internal temperature when exceeding 25^{o}C then thermal discomfort is been resulted and as a result frequency of overheating is set to start from 26^{o}C.

Frequency distribution of zone resultant temperature in kitchen and dining for summer month from May 2013 to August 2013 is given below (Tab 9):

PERIOD: 1ST MAY TO 30TH AUGUST 2013					
ZONE:KITCHEN AND DINING HALL					
RESULTANT TEMPERSTURE (DEG C)					
BIN	***DATA RANGE***	***DISTRIBUTION***	***FREQUENCY DISTRIBUTION (%)***	***CUMULATIVE FREQUENCY***	***CUMULATIVE (%)***
0	<10.8	0	0	0	0
1	10.8-12.87	30	1.02	30	1.02
2	12.87-14.94	94	3.21	124	4.23
3	14.94-17.01	186	6.35	310	10.59
4	17.01-19.08	309	10.55	619	21.14
5	19.08-21.15	492	16.8	1111	37.94
6	21.15-23.21	530	18.1	1641	56.05
7	23.21-25.28	499	17.04	2140	73.09
8	25.28-27.35	369	12.6	2509	85.69
9	27.35-29.42	207	7.07	2716	92.76
10	29.42-31.49	131	4.47	2847	97.23
11	31.49-33.56	62	2.12	2909	99.35
12	33.56-35.63	19	0.65	2928	100
13	>35.63	0	0	0	0

TABLE 9 FREQUENCY DISTRIBUTIONS WITH RESPECT TO TEMPERATURE IN KITCHEN AND DINING HALL

The zone resultant temperature obtained in (Tab 9) is relative to kitchen and dining hall during summer months varies from 10.8^{o}C to 35.6^{o}C. Frequency distribution of zone resultant temperature is obtained in order to check the frequency of the varying temperature in that particular zone during summer month. The occupant when surveyed (refer appendix 2) mentioned that the internal temperature should be within 25^{o}C in order to attain the thermal comfort level. So the thermal discomfort that is the overheating is the total frequency distribution of the temperatures above 25^{o}C from the figure above and it is 26.9% which is really high and the occupant inside the building faces severe thermal discomfort. Graph clearly explains the temperature variation in a particular zone that is kitchen and dining hall for summer period in Scotland and has been shown in (Fig 22):

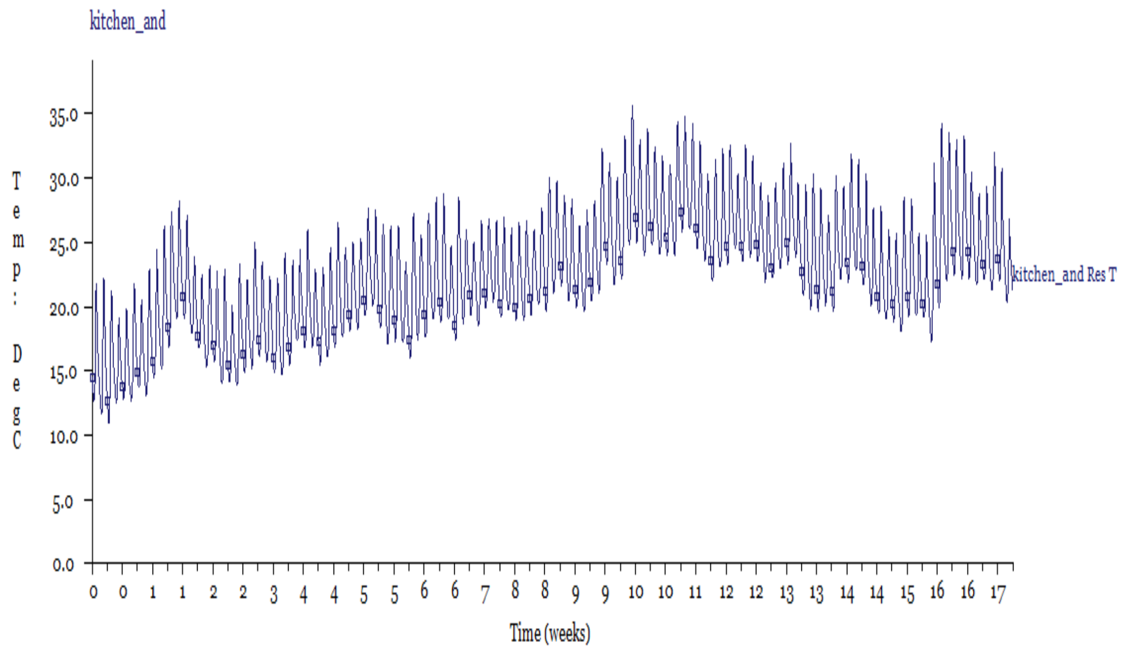

FIGURE 22 ZONE RESULTANT TEMPERATURES IN KITCHEN AND DINING HALL

The maximum temperature is recorded on 11th of July and the graph explaining the temperature variation in kitchen and dining hall on 11th of July is shown in (Fig 23):

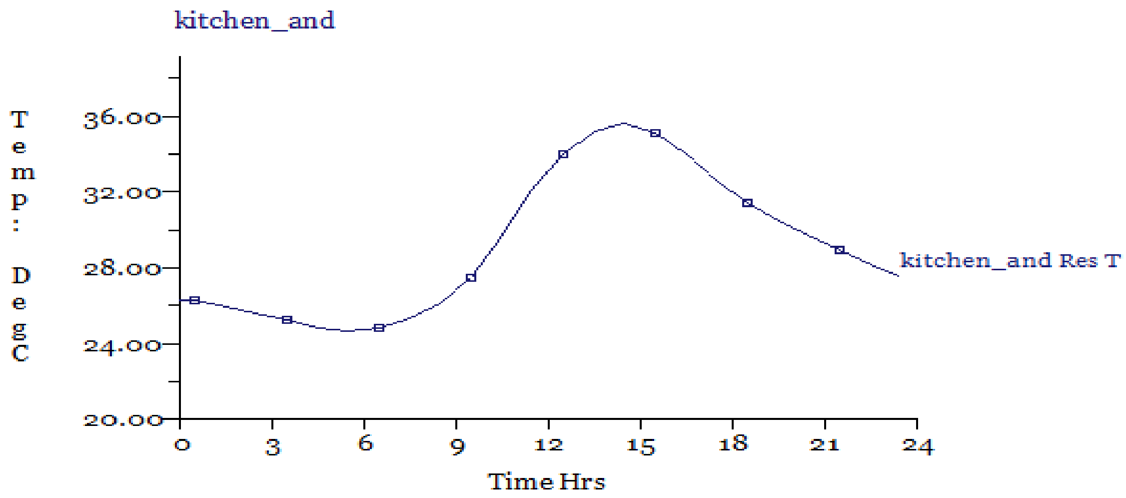

FIGURE 23 ZONE RESULTANT TEMPERATURES IN KITCHEN AND DINING HALL ON 11TH OF JULY

Shading analysis is done for kitchen and dining hall during the hottest month of the year in SCOTLAND that is July and the shading result is obtained for wall 5 on the seventeenth of July and shown in (Tab 10):

External surface shading for 17Jul.				
Surface 5 (Wall-5)				
HOURS	***DIRECT SHADING***	***DIFFUSE SHADING***	***SOLAR AZIMUTH***	***SOLAR ALTITUDE***
03:00:00 Before Sun-rise				
04:00	0.0%	12.40%	50.3	0.4
05:00	5.20%	12.40%	62.4	7.4
06:00	11.70%	12.40%	74.3	15.1
07:00	8.00%	12.40%	86.3	23.3
08:00	100.00%	12.40%	99	31.6
09:00	100.00%	12.40%	113.2	39.6
10:00	100.00%	12.40%	129.8	46.7
11:00	100.00%	12.40%	149.7	52.1
12:00	100.00%	12.40%	172.8	54.7
13:00	100.00%	12.40%	196.9	54
14:00	100.00%	12.40%	218.9	50.1
15:00	100.00%	12.40%	237.3	43.9
16:00	100.00%	12.40%	252.8	36.4
17:00	100.00%	12.40%	266.2	28.2
18:00	8.00%	12.40%	278.6	19.9
19:00	9.80%	12.40%	290.5	11.9
20:00	4.90%	12.40%	302.5	4.4
21:00:00 After sun-set				
Averages for sun-uphours Direct = 61.60%, Diffuse = 12.40%				

TABLE 10 SHADING ANALYSIS FOR WALL 5 IN KITCHEN AND DINING HALL

North facing windows that is window 8 and window 9 are deployed with sun shading /overhangs in the developed model. Shading analysis have been performed and the results (Tab 10) explains, since north facing windows gets a very little light that too only during the morning, a direct shading of 5 to 11% is attained from 5 o' clock to 7 o'clock due to the overhangs and have prevented the excess sun rays entering the kitchen and dining hall. The windows facing towards north does not contribute more towards the overheating.

Shading analysis is carried out for Wall 7 on 17 of July and the result obtained is shown in (Tab 11):

External surface shading for 17Jul.				
Surface 7 (Wall-7)				
HOURS	***DIRECT SHADING***	***DIFFUSE SHADING***	***SOLAR AZIMUTH***	***SOLAR ALTITUDE***
03:00:00 Before Sun-rise				
04:00	100%	17%	50.3	0.4
05:00	100%	17%	62.4	7.4
06:00	100%	17%	74.3	15.1
07:00	100%	17%	86.3	23.3
08:00	7.4%	17%	99	31.6
09:00	13.5%	17%	113.2	39.6
10:00	21.5%	17%	129.8	46.7
11:00	34.4%	17%	149.7	52.1
12:00	33.2%	17%	172.8	54.7
13:00	33.2%	17%	196.9	54
14:00	30.7%	17%	218.9	50.1
15:00	33.2%	17%	237.3	43.9
16:00	17.8%	17%	252.8	36.4
17:00	11.1%	17%	266.2	28.2
18:00	100%	17%	278.6	19.9
19:00	100%	17%	290.5	11.9
20:00	100%	17%	302.5	4.4
21:00:00 After sun-set				
Averages for sun-up hours Direct = 55.1%, Diffuse = 17.0%				

TABLE 11 SHADING ANALYSIS FOR WALL 7 IN KITCEN AND DINING HALL

A south facing window in kitchen and dining hall that is window 1_2_3 is also deployed with sun shading /overhangs in the developed model of kitchen and dining hall. Now when the shading analysis was performed for window 1_2_3 the south facing rooms gets enormous sunlight throughout the year (Tab 11) that too in afternoon and overhanging provides a direct shading of above 30 % from 11 o'clock to 3 o'clock and direct shading of 55.1 % is obtained during sun up hours that is from the sun rise to the sun set and has tried to avoid excess sunlight getting into the room.

Frequency distribution of zone resultant temperature in bedroom 2 for summer month from May 2013 to August 2013 is given in (Tab 12):

PERIOD: 1ST MAY TO 30TH AUGUST 2013					
ZONE:BEDROOM 2					
RESULTANT TEMPERSTURE (DEG C)					
BIN	***DATA RANGE***	***DISTRIBUTION***	***FREQUENCY DISTRIBUTION (%)***	***CUMULATIVE FREQUENCY***	***CUMULATIVE (%)***
0	<14.5	0	0	0	0
1	14.54-15.89	84	2.87	84	2.87
2	15.89-17.25	95	3.25	179	6.12
3	17.25-18.60	129	4.41	308	10.52
4	18.60-19.95	241	8.23	549	18.76
5	19.95-21.30	210	7.17	759	25.93
6	21.30-22.66	412	14.08	1171	40.01
7	22.66-24.01	506	17.29	1677	57.29
8	24.01-25.36	343	11.72	2020	69.01
9	25.36-26.71	400	13.67	2420	82.68
10	26.71-28.07	260	8.88	2680	91.56
11	28.07-29.42	192	6.56	2872	98.12
12	29.42-30.77	55	1.88	2927	100
13	>30.8	1	0	0	0

TABLE 12 FREQUENCY DISTRIBUTIONS WITH RESPECT TO TEMPERATURE IN BEDROOM 2

The zone resultant temperature obtained (Tab 12) for the bedroom2 during summer months are from 14.54°C to 30°C.The above shown figure demonstrates the frequency distribution of the zone resultant temperature and the frequency of temperature from 26°C to 30°C is roughly 16% which is lower than the kitchen and dining hall. Frequency of temperature around 15 % does not cause thermal discomfort severely to the occupant and this can be prevented by opening the windows and obtaining natural ventilation. Graph clearly explains the temperature variation in a particular zone that is bedroom 2 for summer period in Scotland and has been shown in (Fig 24):

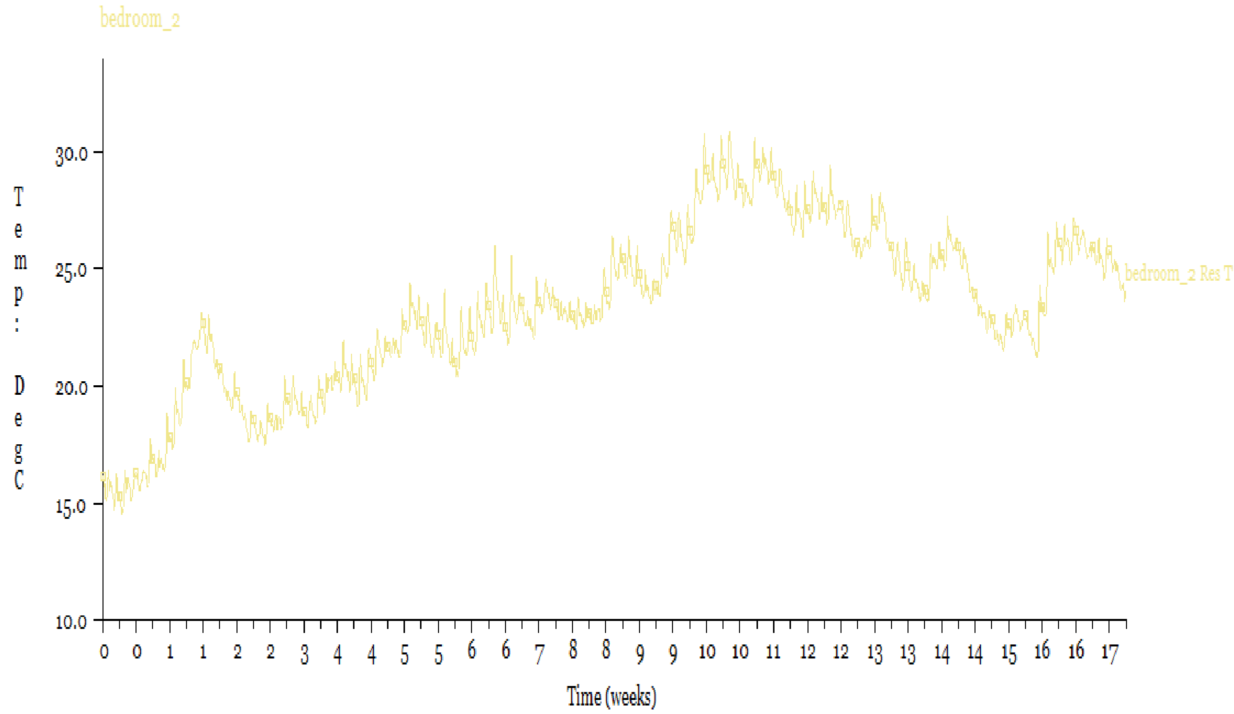

FIGURE 24 ZONE RESULTANT TEMPERATURES IN BEDROOM 2

The maximum temperature is recorded on 11th of July and the graph explaining the temperature variation in bedroom 2 on 11th of July is shown in (Fig 25):

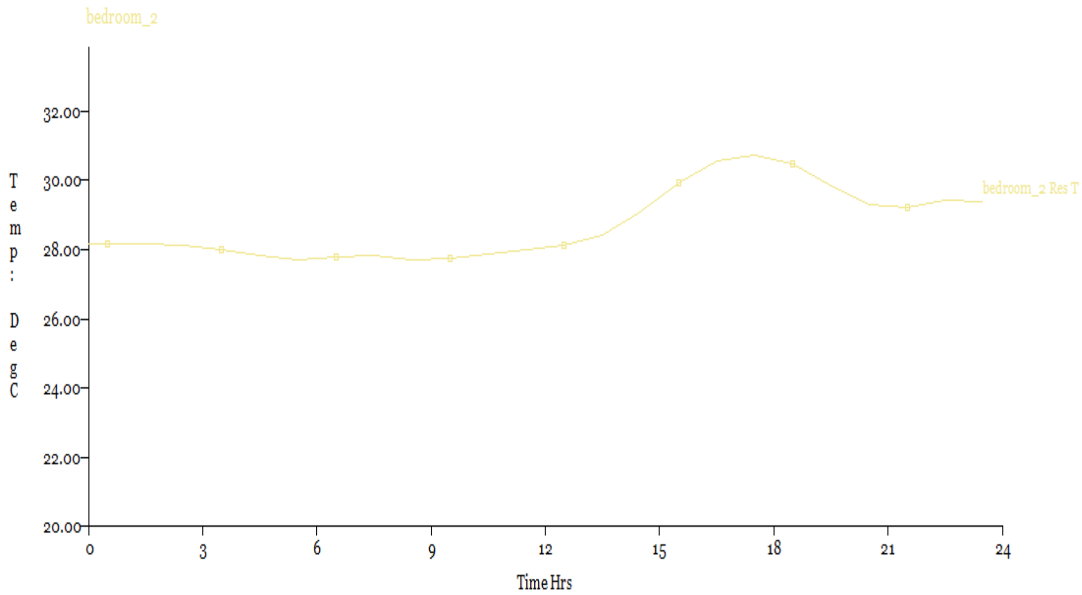

FIGURE 25 ZONE RESULTANT TEMPERATURES IN BEDROOM 2 ON 11TH OF JULY

Results of frequency distribution of zone resultant temperature in bathroom for summer months are shown in (Tab 13):

PERIOD: 1ST MAY TO 30TH AUGUST 2013					
ZONE:BATHROOM					
RESULTANT TEMPERSTURE (DEG C)					
BIN	***DATA RANGE***	***DISTRIBUTION***	***FREQUENCY DISTRIBUTION (%)***	***CUMULATIVE FREQUENCY***	***CUMULATIVE (%)***
0	<11.7	0	0	0	0
1	11.71-13.01	70	2.39	70	2.39
2	13.01-14.31	98	3.35	168	5.74
3	14.31-15.61	73	2.49	241	8.23
4	15.61-16.92	212	7.24	453	15.48
5	16.92-18.22	258	8.81	711	24.29
6	18.22-19.52	264	9.02	975	33.31
7	19.52-20.82	528	18.04	1503	51.35
8	20.82-22.12	373	12.74	1876	64.09
9	22.12-23.42	394	13.46	2270	77.55
10	23.42-24.73	265	9.05	2535	86.61
11	24.73-26.03	269	9.19	2804	95.80
12	26.03-27.33	123	4.20	2927	100
13	>27.33	1	0	0	0

TABLE 13 FREQUENCY DISTRIBUTIONS WITH RESPECT TO TEMPERATURE IN BATHROOM

The zone resultant temperature (Tab 13) obtained for the bathroom during summer months varies from 11.7^{o}C to 27.33^{o}C.The maximum temperature inside the bathroom is 27.3^{o}C and the frequency of overheating is 4.73% which is very less compared to the kitchen and dining hall and bedroom 2. The occupant inside this zone enjoys the thermal comfort as the frequency of overheating is within degree of limitation. Graph clearly explains the temperature variation in a particular zone that is bathroom for summer period in Scotland and has been shown in (Fig 26):

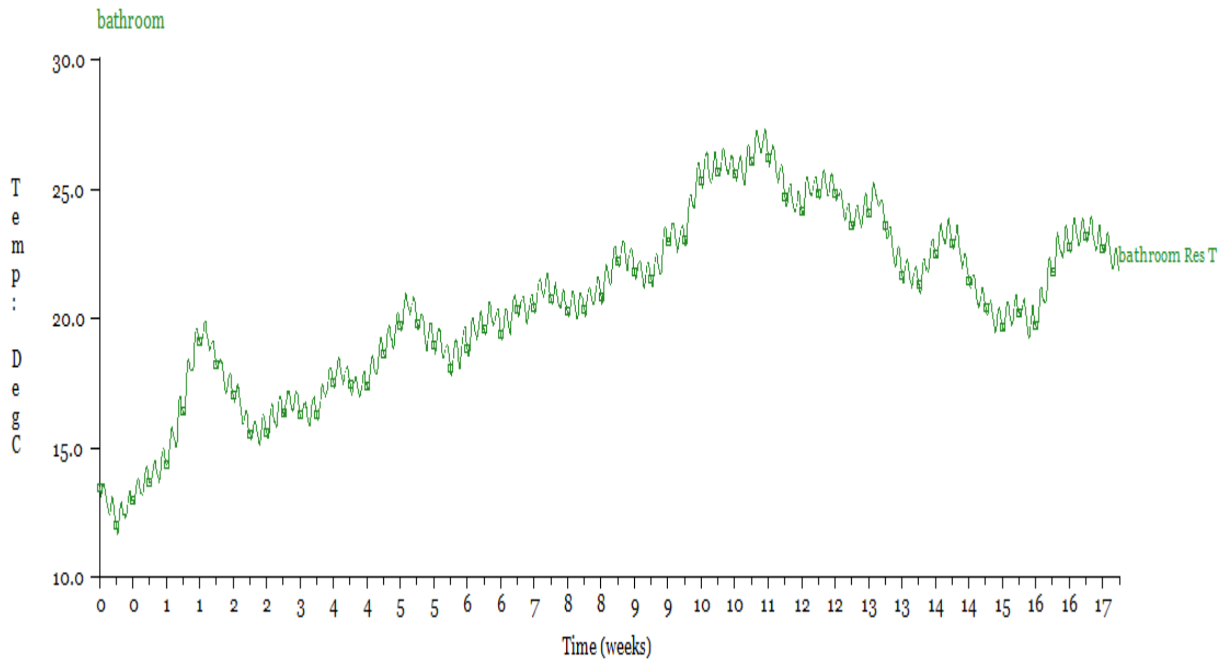

FIGURE 26 ZONE RESULTANT TEMPEARTURES IN BATHROOM

The maximum temperature is recorded on 11th of July and the graph explaining the temperature variation in bathroom on 11th of July is shown in (Fig 27):

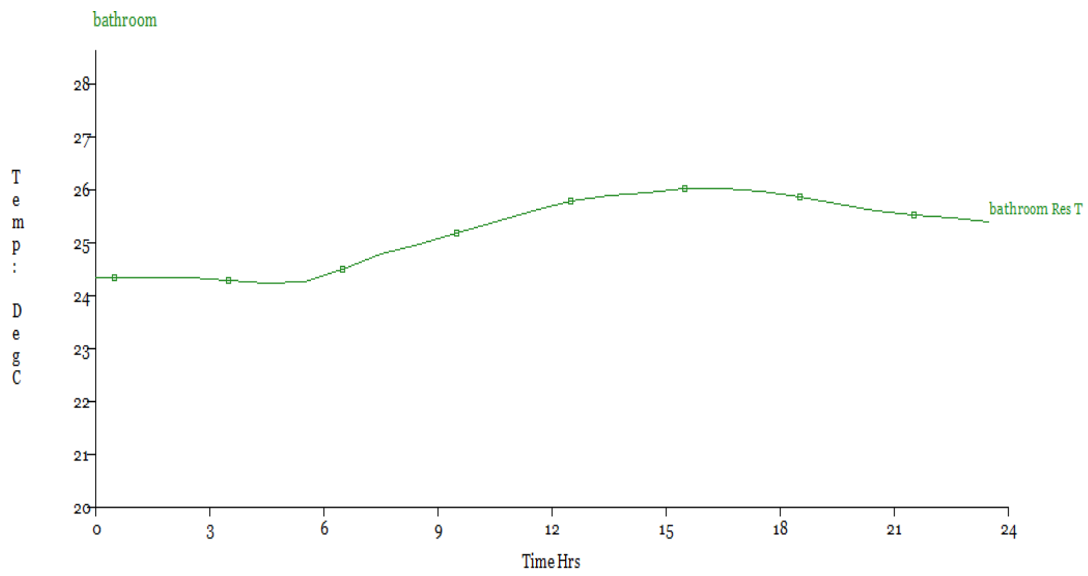

FIGURE 27 ZONE RESULTANT TEMPERATURES IN BATHROOM ON 11TH JULY

Frequency distribution of zone resultant temperature in bedroom 1 for summer month from May 2013 to August 2013 is given in (Tab 14):

PERIOD: 1ST MAY TO 30TH AUGUST 2013					
ZONE:BEDROOM 1					
RESULTANT TEMPERSTURE (DEG C)					
BIN	***DATA RANGE***	***DISTRIBUTION***	***FREQUENCY DISTRIBUTION (%)***	***CUMULATIVE FREQUENCY***	***CUMULATIVE (%)***
0	<13.9	1	0	0	0
1	13.95-16.09	55	1.88	55	1.88
2	16.09-18.23	126	4.30	181	6.18
3	18.23-20.38	214	7.31	395	13.50
4	20.38-22.52	401	13.70	796	27.20
5	22.52-24.66	486	16.60	1282	43.80
6	24.66-26.80	541	18.48	1823	62.28
7	26.80-28.95	438	14.96	2261	77.25
8	28.95-31.09	310	10.59	2571	87.84
9	31.09-33.23	172	5.88	2743	93.71
10	33.23-35.38	111	3.79	2854	97.51
11	35.38-37.52	52	1.78	2906	99.28
12	37.52-39.66	21	0.72	2927	100
13	>39.7	0	0	0	0

TABLE 14 FREQUENCY DISTRIBUTIONS WITH RESPECT TO TEMPERATURE IN BEDROOM 1

The zone resultant temperature (Tab 14) obtained for the bedroom1 during summer months are from 13.95^{o}C to 39.66^{o}C.The figure above explains clearly that the frequency of temperature exceeding 25^{o}C is 38% and is really high when compared to any zones in the building and causes severe thermal discomfort for the occupant inside the building .Temperature above 30^{o}C is reached more than 15% in this zone which makes the zone hot and makes the occupant uncomfortable inside the bedroom 1.A graph explaining the temperature variation in the particular zone that is bedroom 1 during summer months is given in (Fig 28):

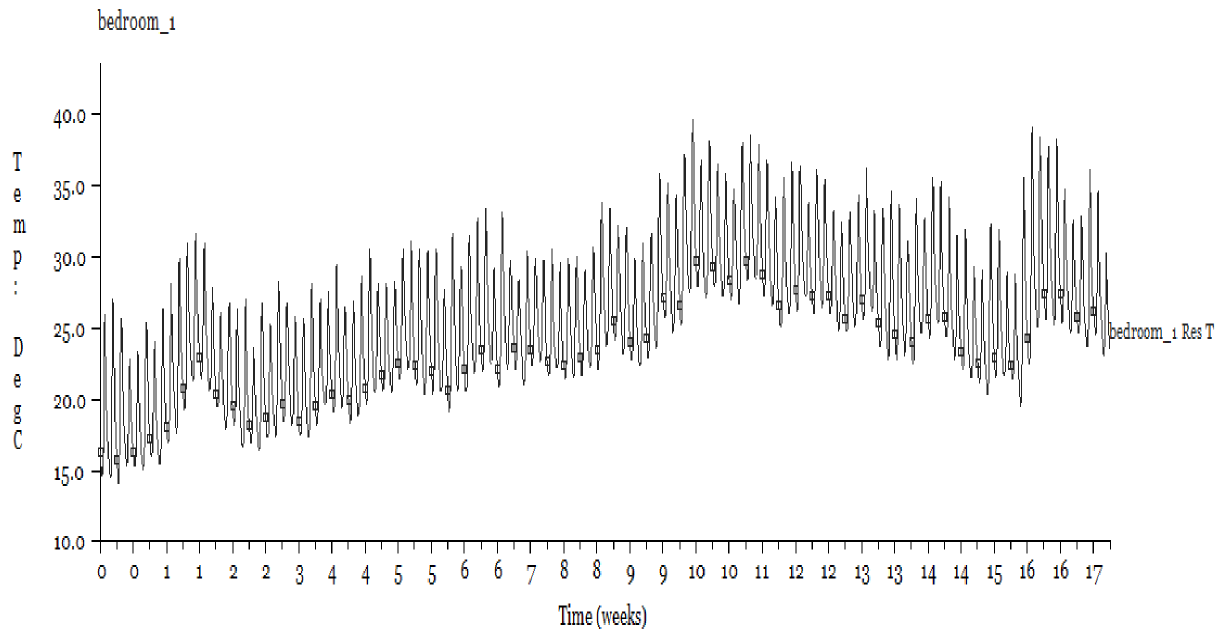

FIGURE 28 ZONE RESULTANT TEMPERATURES IN BEDROOM 1

The maximum temperature is recorded on 11th of July and the graph explaining the temperature variation in bedroom 1 on 11th of July is shown in (Fig 29):

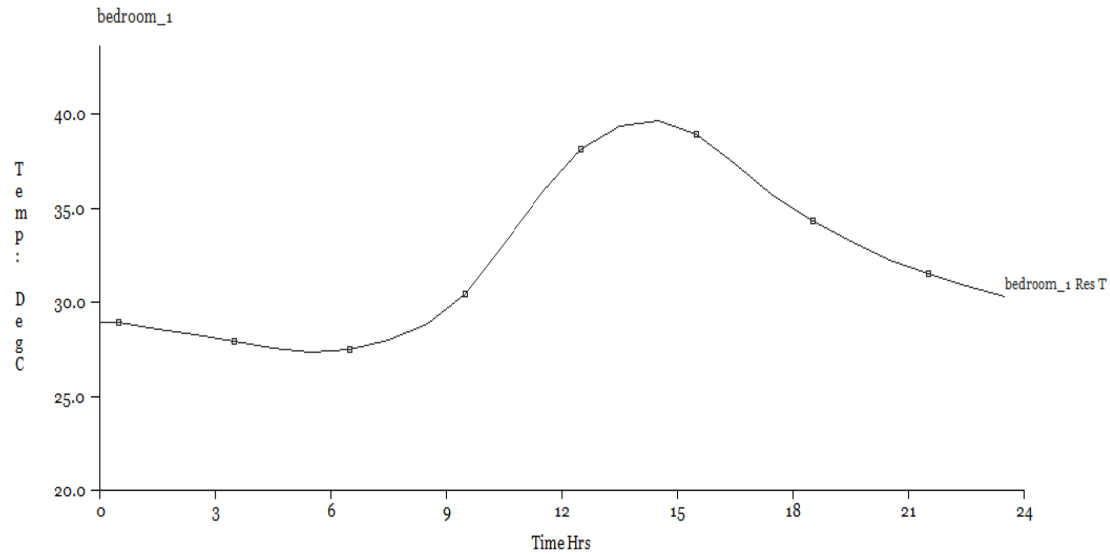

FIGURE 29 ZONE RESULTANT TEMPERATURES IN BEDROOM 1 ON 11TH OF JULY

Shading analysis is done for bedroom one during the hottest month of the year in SCOTLAND that is July. And, the shading result is obtained for wall 1 on the seventeenth of July and shown in (Tab 15):

External surface shading for 17Jul.				
Surface 1 (Wall-1)				
HOURS	***DIRECT SHADING***	***DIFFUSE SHADING***	***SOLAR AZIMUTH***	***SOLAR ALTITUDE***
03:00:00 Before Sun-rise				
04:00	100%	17.6%	50.3	0.4
05:00	100%	17.6%	62.4	7.4
06:00	100%	17.6%	74.3	15.1
07:00	100%	17.6%	86.3	23.3
08:00	9.7%	17.6%	99	31.6
09:00	16.9%	17.6%	113.2	39.6
10:00	25.3%	17.6%	129.8	46.7
11:00	28.7%	17.6%	149.7	52.1
12:00	29.5%	17.6%	172.8	54.7
13:00	27.8%	17.6%	196.9	54
14:00	27.8%	17.6%	218.9	50.1
15:00	27.0%	17.6%	237.3	43.9
16:00	22.3%	17.6%	252.8	36.4
17:00	19.8%	17.6%	266.2	28.2
18:00	100%	17.6%	278.6	19.9
19:00	100%	17.6%	290.5	11.9
20:00	100%	17.6%	302.5	4.4
21:00:00 After sun-set				
Averages for sun-up hours Direct = 55.0%, Diffuse = 17.6%				

TABLE 15 SHADING ANALYSES FOR WALL 1 IN BEDROOM 1

A south facing window in bedroom1 that is window 4_5 is also deployed with sun shading /overhangs in the developed model of bedroom 1. Window 4_5 is a display window and is large in size. Large size windows are generally prevented in south facing because the sun is high in the afternoon and large amount of heat is introduced inside the building .So in order to overcome it the overhang was introduced above it. When a shading analysis was performed to the window 4_5 (Tab 15) which gave a direct shading of 29% at 12 o' clock and direct shading of 55 % is obtained during sun up hours that is from the sun rise to the sun set which prevented excess heat radiated inside the building.

8.2. FREQUENCY OF OVERHEATING IN CRAIGROTHIE PASSIVE HOUSE

According to the passive house planning package of craigrothie passive house, the occupant in the building does not face the problem of overheating. The internal temperature inside the building is below 25^{o}C during summer month and the occupant has a thermal comfort. When the same model was developed in ESP-r and when results were obtained then frequency of overheating is above 25^{o}C in certain zones. Two zones which are really affected due to overheating are the kitchen and dining hall, and bedroom1. The maximum temperature (Fig 22) obtained in kitchen and dining hall during summer month is 35^{o}C and maximum temperature in bedroom 1(Fig 28) is 39^{o}C. The internal temperature in both of these zones is really high and the occupant will face severe thermal discomfort. Examination of two particular zones is necessary because the occupant faces thermal discomfort during summer month. According to the survey by the occupant (refer appendix 2) the internal temperature inside the building should not exceed 25^{o}C. Results obtained in kitchen and dining hall (Tab 9) during the period from May 2013 to August 2013 explains the frequency of overheating in the zone is 26% and this exceeds over 10 % of 25^{o}C. That is, out of 123 days of summer there is 33 days of thermal discomfort for the occupant inside the building. In the same way the results obtained in bedroom 1(Tab 14) explains, frequency of overheating in the zone is 38% and this also exceeds over 10% of 25^{o}C that is out of 123 days of summer there is 46 days of thermal discomfort for the occupant inside the building. Two zones which faces the problem of overheating is south facing and the building has a display windows on both the zones. Generally windows facing south are avoided because south facing sun is high in the sky during summer this cause more heat to enter the building through the windows and increases the internal temperature. The craigrothie passive house has two display windows in south facing and as a result overhangs/sun shading were installed in the developed model to avoid excess heat inside the building. Overhangs installation has reduced the heat to a certain extend but it was not able to bring it down to 25^{o}C. The shading analysis is done for the kitchen and dining hall(Tab 11) for wall 7 and when the sun is at peak from 12 to 3 the overhangs has given a direct shading of 33 % and diffuse shading of 17 % which prevented the internal temperature exceeding 40^{o}C which will cause furthermore thermal discomfort to the occupant. In the same way for bedroom 1(Tab 15), shading analysis is performed for wall 1 when sun is at peak from 12 to 3 the overhangs has given direct shading of 29 % and diffuse shading of 17 % which prevents further thermal discomfort. Climatic condition is another reason for the overheating, the ambient temperature can be high for two to three days in summer which is not expected and during the time the internal temperature can increase to the certain extent. According to the occupant in the survey (refer appendix 2) whenever there is a problem of overheating, the window is opened for natural ventilation. The occupant when surveyed felt 80 % of the time from June to August the window is been opened to avoid thermal discomfort. The ESP-r results shows results close to it that around 44 days in bedroom 1(Tab 14) and 33 days in kitchen and dining hall(Tab 9) there is thermal discomfort and the occupant inside the building is opening the windows to get natural ventilation and avoid overheating. Thermal discomfort is one of the main problem in passive houses but it can be avoided by planning properly for example installation of overhangs, sun shading can avoid overheating to certain extent .The major factors of overheating such as orientation, glazing, ventilation can be modified to avoid overheating. The choice of construction material is also a very key aspect in passive solar to avoid overheating inside the building. In a real time scenario, retrofitting the existing houses is really costly and as a result it is always better for rigorous planning during the construction of the passive house.

9. IMPROVED METHODS

Results obtained from passive house has clearly specified that there should be additional measures taken for two zones – bedroom 1 and kitchen and dining hall to avoid thermal discomfort. Improved method should be deployed to kitchen and dining hall and bedroom 1 to ensure thermal comfort inside these zones. Improved methods can be deployed in several ways but choosing which type of improved method to be implemented is the next step. Improvements on the basis of network flow, employing mechanical ventilation was an option but a more interesting method would be having found the important factors and their effects from the sensitivity analysis, modifying them and reducing the internal temperature is also possible. So improved method of craigrothie passive house deploys the modification of the significant factors derived from sensitivity analysis. Major factors considered in the improved methods are orientation, shading, glazing types and apart from it construction material itself is changed to check the performance of the modelled passive house. Consideration of glazing and orientation in the improved method was necessary because sensitivity analysis showed a huge variation when the glazing types and the window orientation was varied. Types of glazing for a building have to be chosen in accordance to the performance of the house and the orientation has to be planned during the construction period itself but the factors falls to be an important aspect with internal temperature inside the building so as a result these have been utilized in the improved methods. Shading is the next factor which is considered in improved methods because a sensitivity analysis was done for temporary shading factors which did show a great variation in frequency of overheating but the shading analysis done for the overhangs shown in the developed model showed positive results with reducing the overheating. The two models which are affected by thermal discomfort did not reach 40^{o}C because of the shading of the overhangs. The sun at the noon really influence a lot in determining the heat inside the building so an increase in overhang blocks to a developed model stops these sun rays even more than the previous model and thus produce a better results. Construction material used in the craigrothie passive house is modified. This factor is considered because the U-value, insulation level inside the building varies for each and every building and choosing these values and material which suits for a building is difficult. U-value of the material contributes in portion for reduction of the internal temperature inside the building and modifying the insulation level which has a greater impact in reducing the temperature because level of insulation of the material used decides upon the amount of heat radiated inside the building. So it is interesting to check when another set of construction material with different U-value and insulation level can be used to improve model and to check their effects on the performance of passive house. To improve the thermal comfort inside the building in both the zones, the modelling of both the zones separately in ESP-r was necessary in order to conduct a small modification with orientation, shading, glazing types, and construction material of the particular zones and check the modifications resulted in avoiding the overheating inside the building. The modelling is done for kitchen and dining hall with change in orientation of the zone by 40 degree anticlockwise direction towards east, increasing the shading from 3 blocks to 5 blocks to the windows in wall 7 and wall 5. The construction material is changed to view how these changes affect the internal temperature inside the building. Improved Model of the kitchen and dining hall is constructed in ESP-r and is shown in (Fig 30):

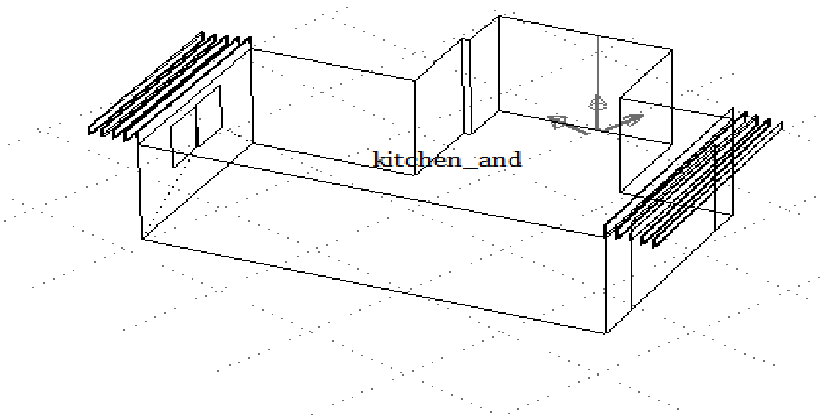

FIGURE 30 IMPROVED MODEL OF KITCHEN AND DINING HALL IN CRAIGROTHIE PASSIVE HOUSE

A summary of the surfaces in kitchen_and(1) follows:

Sur	Area m^2	Azim deg	Elev deg	surface name	geometry optical	locat	use	construction name	environment other side
1	4.05	70.	0.	Wall-1	OPAQUE	VERT	-	gyp_gyp_ptn	||< identical environment
2	2.36	340.	0.	Wall-2	OPAQUE	VERT	-	gyp_gyp_ptn	||< identical environment
3	0.302	70.	0.	Wall-3	OPAQUE	VERT	-	gyp_gyp_ptn	||< identical environment
4	4.04	340.	-0.	Wall-4	OPAQUE	VERT	-	gyp_gyp_ptn	||< identical environment
5	6.61	70.	-0.	Wall-5	OPAQUE	VERT	-	gyp_gyp_ptn	||< identical environment
6	7.42	340.	-0.	Wall-6	OPAQUE	VERT	-	extern_wall	||< external
7	18.5	250.	-0.	Wall-7	OPAQUE	VERT	-	extern_wall	||< external
8	4.45	160.	0.	Wall-8	OPAQUE	VERT	-	extern_wall	||< external
9	4.48	70.	-0.	Wall-9	OPAQUE	VERT	-	gyp_gyp_ptn	||< identical environment
10	4.58	160.	0.	Wall-10	OPAQUE	VERT	-	gyp_gyp_ptn	||< identical environment
11	3.04	70.	0.	Wall-11	OPAQUE	VERT	-	gyp_gyp_ptn	||< identical environment
12	38.3	0.	90.	Top-12	OPAQUE	CEIL	-	susp_ceil	||< identical environment
13	38.3	0.	-90.	Base-13	OPAQUE	FLOR	-	grnd_floor	||< identical environment
14	0.841	340.	-0.	window_9	DCF7671_	VERT	D-WIN	d_glz	||< external
15	0.841	340.	0.	window_8	DCF7671_	VERT	D-WIN	d_glz	||< external
16	6.48	160.	0.	window_1__2	DCF7671_	VERT	D-WIN	d_glz	||< external

FIGURE 31 IMPROVED MODEL-KITCHEN AND DINING HALL COMPOSITION

Construction material used for the improved model of the zone- kitchen and dining hall is shown below

Details of opaque construction: extern_wall and overall thickness 0.325

Layer	Matr db	Thick (mm)	Conduc- tivity	Density	Specif heat	IR emis	Solr abs	Diffu resis	R m^2K/W	Descr
Ext	6	100.0	0.960	2000.	650.	0.90	0.70	25.	0.10	Lt brown brick : Light brown brick
2	211	75.0	0.040	250.	840.	0.90	0.30	4.	1.88	glasswool : Glasswool (generic)
3	1	50.0	0.960	2000.	840.	0.93	0.70	12.	0.05	Paviour brick : Paviour brick
Int	2	100.0	0.440	1500.	650.	0.90	0.65	15.	0.23	breeze block : Breeze block

ISO 6946 U values (horiz/upward/downward heat flow)= 0.412 0.417 0.405 (partition) 0.397

FIGURE 32 CONSTRUCTIONAL DETAILS OF EXTERNAL WALL IN KITCHEN AND DINING HALL / BEDROOM 1

```
Details of opaque construction: gyp_gyp_ptn and overall thickness  0.074

Layer|Matr|Thick |Conduc-|Density|Specif|IR  |Solr|Diffu| R   |Descr
    |db  |(mm)  |tivity |       |heat  |emis|abs |resis|m^2K/W
Ext  108   12.0    0.190  950.  840. 0.91 0.22   11.  0.06 white gypboard : White paintedd Gypboard
  2   0  50.0    0.000    0.     0. 0.99 0.99    1.  0.17 air  0.17 0.17 0.17
Int  108   12.0    0.190  950.  840. 0.91 0.22   11.  0.06 white gypboard : White paintedd Gypboard
ISO 6946 U values (horiz/upward/downward heat flow)=  2.144  2.292  1.975 (partition)  1.798
```

FIGURE 33 CONSTRUCTIONAL DETAIL OF INTERNAL WALL IN KICHEN AND DINING HALL/ BEDROOM 1

```
Details of opaque construction: grnd_floor and overall thickness  0.975

Layer|Matr|Thick |Conduc-|Density|Specif|IR  |Solr|Diffu| R   |Descr
    |db  |(mm)  |tivity |       |heat  |emis|abs |resis|m^2K/W
Ext  263  200.0    1.280  1460.  879. 0.90 0.85    5.  0.16 earth std : Common_earth
  2  263  200.0    1.280  1460.  879. 0.90 0.85    5.  0.16 earth std : Common_earth
  3  263  200.0    1.280  1460.  879. 0.90 0.85    5.  0.16 earth std : Common_earth
  4  262  150.0    0.520  2050.  184. 0.90 0.85    2.  0.29 gravel based : Gravel based
  5   32  150.0    1.400  2100.  653. 0.90 0.65   19.  0.11 heavy mix concrete : Heavy mix concrete
  6    0   50.0    0.000     0.    0. 0.99 0.99    1.  0.17 air  0.17 0.17 0.17
  7   67   19.0    0.150   800. 2093. 0.91 0.65   96.  0.13 chipboard : Chipboard
Int  221    6.0    0.060   186. 1360. 0.90 0.60   10.  0.10 Wilton : Wilton weave wool carpet
ISO 6946 U values (horiz/upward/downward heat flow)=  0.699  0.714  0.680 (partition)  0.657
```

FIGURE 34 CONSTRUCTIONAL DETAIL OF GROUND FLOOR IN KITCHEN AND DINING HALL / BEDROOM 1

Construction of overhangs in wall 7 and wall5 is done in ESP-r model and this time to reduce the internal temperature the vertical fin overhang is increased to 5 blocks and the construction of the obstruction details is shown in (Fig 35):

```
Block X- Y- Z- coords DX- DY- DZ- values Orient Opacity Name Material
  1  -7.59   2.07   2.41   3.77   0.02   0.30  20.00  1.00 blk door
  2  -7.66   2.26   2.41   3.77   0.02   0.25  20.00  1.00 blk 2
  3  -7.73   2.44   2.41   3.77   0.02   0.22  20.00  1.00 blk door
  4  -7.80   2.63   2.41   3.77   0.02   0.20  20.00  1.00 blk door
  5  -7.86   2.82   2.41   3.77   0.02   0.19  20.00  1.00 new_blk door
  6  -4.97  -5.13   2.41   4.53   0.02   0.30  20.00  1.00 blk door
  7  -4.90  -5.31   2.41   4.53   0.02   0.25  20.00  1.00 blk door
  8  -4.83  -5.50   2.41   4.53   0.02   0.22  20.00  1.00 blk door
  9  -4.76  -5.69   2.41   4.53   0.02   0.20  20.00  1.00 blk door
 10  -4.70  -5.88   2.41   4.53   0.02   0.19  20.00  1.00 blk door
```

FIGURE 35 OVERHANG COMPOSITION IN KITCHEN AND DINING HALL

The modelling is done for the bedroom 1 with certain modification in order to make them an improved model with respect to thermal comfort. The modelling is performed for bedroom 1 with change in orientation of the zone by 40 degree anticlockwise direction towards east, increasing the shading to the window in wall 1 and the construction material is modified to view how these changes affect the internal temperature inside the building. The improved model of bedroom 1 is constructed using ESP-r and is shown below

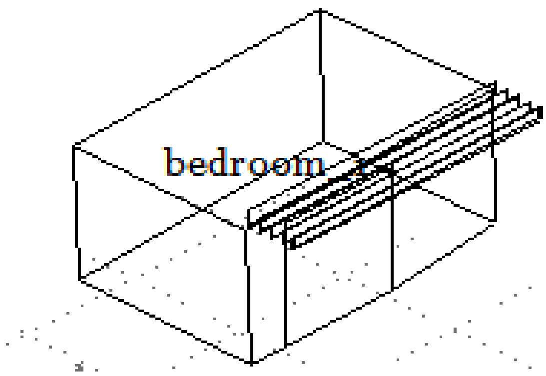

FIGURE 36 IMPROVED MODEL OF BEDROOM 1 IN CRAIGROTHIE PASSIVE HOUSE

A summary of the surfaces in bedroom_1(1) follows:

Sur	Area m^2	Azim deg	Elev deg	surface name	geometry optical	locat	use	construction name	environment other side
1	7.17	180.	-0.	Wall-1	OPAQUE	VERT	-	extern_wall	||< external
2	7.52	90.	2.	Surf-2	OPAQUE	SLOP	-	extern_wall	||< external
3	11.2	0.	0.	Wall-3	OPAQUE	VERT	-	gyp_gyp_ptn	||< identical environment
4	7.52	270.	-2.	Surf-4	OPAQUE	SLOP	-	gyp_gyp_ptn	||< identical environment
5	14.5	270.	88.	Surf-5	OPAQUE	SLOP	-	ceiling	||< identical environment
6	14.5	67.	-87.	Surf-6	OPAQUE	SLOP	-	grnd_floor	||< identical environment
7	4.31	180.	0.	window_4_and	DCF7671_	VERT	D-WIN	d_glz	||< external

FIGURE 37 IMPROVED MODEL OF BEDROOM 1 COMPOSITION

Construction material used in kitchen and dining hall is used for the bedroom 1 as well and the simulation is performed. Construction of the overhangs were performed in ESP-r for bedroom 1 and the improved model consists of 5 blocks to avoid excess heat inside and the building and the obstruction details are given in (Fig 38):

Block	X-	Y-	Z- coords	DX-	DY-	DZ- values	Orient	Opacity	Name Material
1	0.00	-3.11	4.83	4.64	0.02	0.30	0.00	1.00	blk door
2	0.00	-3.30	4.83	4.64	0.02	0.25	0.00	1.00	blk door
3	0.00	-3.50	4.83	4.64	0.02	0.22	0.00	1.00	blk door
4	0.00	-3.70	4.83	4.64	0.02	0.20	0.00	1.00	blk door
5	0.00	-3.90	4.83	4.64	0.02	0.19	0.00	1.00	blk door

FIGURE 38 OVERHANG COMPOSITION IN BEDROOM 1

9.1. RESULTS FOR THE IMPROVED MODEL

9.1.1. KITCHEN AND DINING HALL

Frequency distribution of zone resultant temperature in improved model – kitchen and dining hall for summer months starting May 2013 – and ending AUGUST 2013 is shown in (Tab 16):

PERIOD: 1ST MAY TO 30TH AUGUST 2013					
ZONE:KITCHEN AND DINING HALL					
RESULTANT TEMPERSTURE (DEG C)					
BIN	***DATA RANGE***	***DISTRIBUTION***	***FREQUENCY DISTRIBUTION (%)***	***CUMULATIVE FREQUENCY***	***CUMULATIVE (%)***
0	<7.1	1	0	0	0
1	7.07-8.30	49	1.66	49	1.66
2	8.30-9.53	108	3.66	157	5.32
3	9.53-10.75	56	1.90	213	7.22
4	10.75-11.98	234	7.93	447	15.15
5	11.98-13.21	315	10.67	762	25.82
6	13.21-14.43	273	9.25	1035	35.07
7	14.43-15.66	258	8.74	1293	43.82
8	15.66-16.88	443	15.01	1736	58.83
9	16.88-18.11	439	14.88	2175	73.70
10	18.11-19.34	279	9.45	2454	83.16
11	19.34-20.56	363	12.30	2817	95.46
12	20.56-21.79	134	4.54	2951	100
13	>21.8	0	0	0	0

TABLE 16 FREQUENCY DISTRIBUTIONS WITH RESPECT TO TEMPERATURE IN KITCHEN AND DINING HALL

The zone resultant temperature obtained from the (Tab 16) relative to kitchen and dining hall during summer months are from 7.07^{o}C to 21.79^{o}C.The occupant when surveyed (refer appendix 2) set the limit of discomfort when the internal temperature exceeds 25^{o}C.From (Tab 16) it is clearly seen that the overheating is been avoided in the particular zone by adopting improved methods and the occupant inside the zone has thermal comfort as the maximum temperature attained in summer months is 22^{o}C.A graph representing the temperature variation for the summer months in the improved model of kitchen and dining hall is shown in (Fig 39):

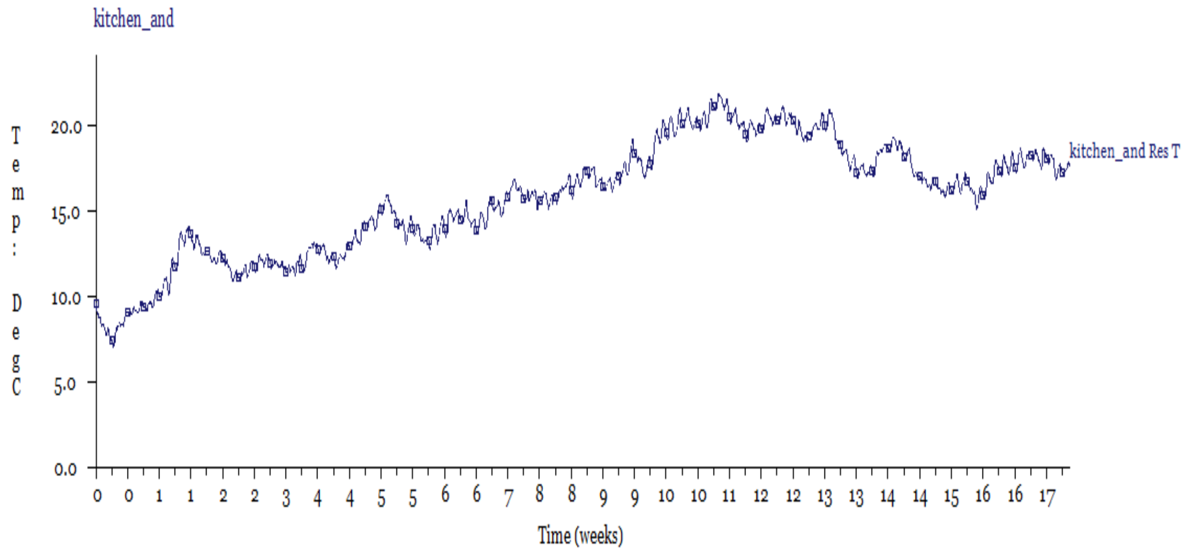

FIGURE 39 ZONE RESULTENT TEMPERATURES IN KITCHEN AND DINING HALL

The maximum temperature is recorded on 18th of July and the graph explaining the temperature variation in kitchen and dining hall on 18th of July is shown in (Fig 40):

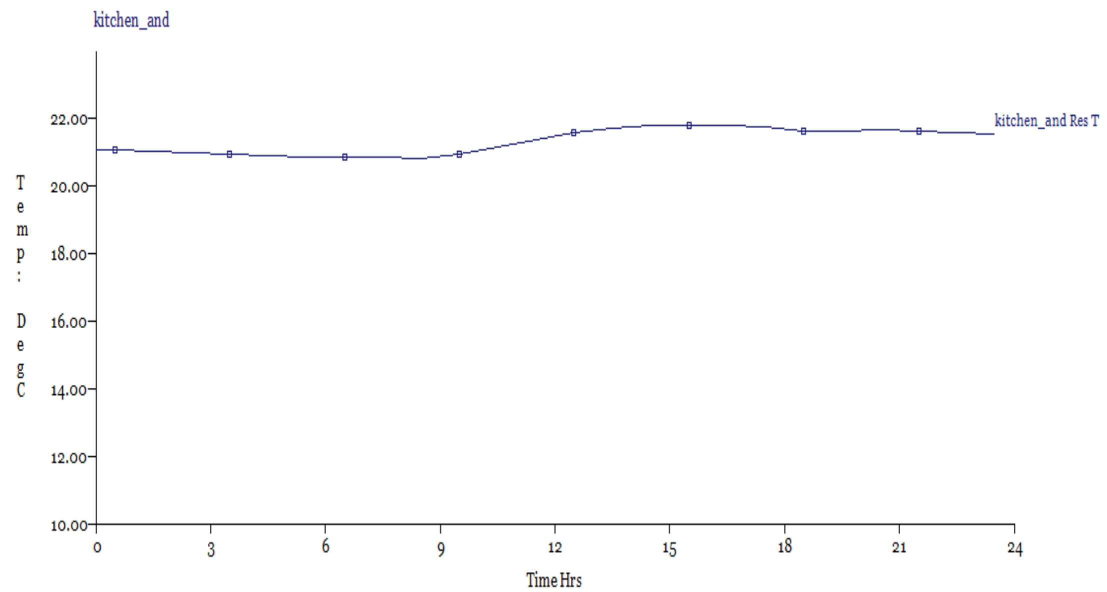

FIGURE 40 ZONE RESULTANT TEMPERATURES IN KITCHEN AND DINING HALL ON 18TH OF JULY

Shading analysis is carried out for overhang placed above window 8 and window 9 on 17 of July and the result obtained is shown in (Tab 17):

External surface shading for 17Jul.				
Surface 6 (Wall-6)				
HOURS	***DIRECT SHADING***	***DIFFUSE SHADING***	***SOLAR AZIMUTH***	***SOLAR ALTITUDE***
03:00:00 Before Sun-rise				
04:00	0.0%	18.5%	50.3	0.4
05:00	8.6%	18.5%	62.4	7.4
06:00	100%	18.5%	74.3	15.1
07:00	100%	18.5%	86.3	23.3
08:00	100%	18.5%	99	31.6
09:00	100%	18.5%	113.2	39.6
10:00	100%	18.5%	129.8	46.7
11:00	100%	18.5%	149.7	52.1
12:00	100%	18.5%	172.8	54.7
13:00	100%	18.5%	196.9	54
14:00	100%	18.5%	218.9	50.1
15:00	100%	18.5%	237.3	43.9
16:00	15.0%	18.5%	252.8	36.4
17:00	20.2%	18.5%	266.2	28.2
18:00	16.6%	18.5%	278.6	19.9
19:00	10.7%	18.5%	290.5	11.9
20:00	5.5%	18.5%	302.5	4.4
21:00:00 After sun-set				
Averages for sun-up hours Direct = 63.3%, Diffuse = 18.5%				

TABLE 17 SHADING ANALYSIS FOR WALL 6 IN KITCHEN AND DINING HALL

The improved model having oriented 40 degree towards east, window 8 and window 9 have moved to the North West direction. Above these windows, overhangs have been deployed in the developed model. Overhang blocks have been increased from 3 to 5 blocks. Shading analysis have been performed for the windows 8 and 9 and from the (Tab 17) which clearly explains; since the windows have oriented towards north west, the improved model of kitchen gets more sunlight than the first model but only during the sun set as the window has moved towards west and as a result increased direct shading of 5% to 20% is attained from evening 6 o'clock to 8 o' clock. This shading prevents the extra heat rays entering into the zone.

Shading analysis is carried out for overhang placed above window 1_2_3 on 17 of July and the result obtained is shown in (Tab 18):

External surface shading for 17Jul.				
Surface 8 (Wall-8)				
HOURS	***DIRECT SHADING***	***DIFFUSE SHADING***	***SOLAR AZIMUTH***	***SOLAR ALTITUDE***
03:00:00 Before Sun-rise				
04:00	100%	24.3%	50.3	0.4
05:00	100%	24.3%	62.4	7.4
06:00	7.4%	24.3%	74.3	15.1
07:00	38.1%	24.3%	86.3	23.3
08:00	35.6%	24.3%	99	31.6
09:00	39.3%	24.3%	113.2	39.6
10:00	45.5%	24.3%	129.8	46.7
11:00	49.2%	24.3%	149.7	52.1
12:00	47.9%	24.3%	172.8	54.7
13:00	31.3%	24.3%	196.9	54
14:00	33.8%	24.3%	218.9	50.1
15:00	12.9%	24.3%	237.3	43.9
16:00	100%	24.3%	252.8	36.4
17:00	100%	24.3%	266.2	28.2
18:00	100%	24.3%	278.6	19.9
19:00	100%	24.3%	290.5	11.9
20:00	100%	24.3%	302.5	4.4
21:00:00 After sun-set				
Averages for sun-up hours Direct = 61.2%, Diffuse = 24.3%				

TABLE 18 SHADING ANALYSIS FOR WALL 8 IN KITCHEN AND DINING HALL

The improved model having oriented 40 degree towards east, window 1_2_3 has moved to the south east direction. Above these windows, overhangs have been deployed in the developed model. Overhang blocks have been increased from 3 to 5 blocks. Since the windows have oriented towards south east direction, the amount of sunlight entering the building is decreased than the previous model and adding to it overhang have been increased to 5 blocks so from (Tab 18) these modifications resulted in direct shading of more than 40 % from morning 10 o'clock to noon 12 o' clock and has prevented excess sunlight entering into zone.

9.1.2. BEDROOM 1

Frequency distribution of zone resultant temperature in improved model- Bedroom 1 during the summer months from May 2013 to August 2013 is in (Tab 19):

PERIOD: 1ST MAY TO 30TH AUGUST 2013					
ZONE:BEDROOM 1					
RESULTANT TEMPERSTURE (DEG C)					
BIN	***DATA RANGE***	***DISTRIBUTION***	***FREQUENCY DISTRIBUTION (%)***	***CUMULATIVE FREQUENCY***	***CUMULATIVE (%)***
0	<8.4	1	0	0	0
1	8.36-9.58	57	1.93	57	1.93
2	9.58-10.79	105	3.56	162	5.49
3	10.79-12.00	64	2.17	226	7.66
4	12.00-13.22	275	9.32	501	16.98
5	13.22-14.43	276	9.36	777	26.34
6	14.43-15.64	319	10.81	1096	37.15
7	15.64-16.86	235	7.97	1331	45.12
8	16.86-18.07	452	15.32	1783	60.44
9	18.07-19.28	463	15.69	2246	76.14
10	19.28-20.49	205	6.95	2451	83.08
11	20.49-21.71	395	13.39	2846	96.47
12	21.71-22.92	104	3.53	2950	100
13	>22.9	1	0	0	0

TABLE 19 FREQUECY DISTRIBUTIONS WITH RESPECT TO TEMPERATURE IN BEDROOM 1

The zone resultant temperature obtained from the (Tab 19) relative to bedroom 1 during summer months are from 8.36^{o}C to 22.9^{o}C.From (Fig 19) it is clearly seen that the overheating is been avoided in the particular zone by adopting improved methods and the occupant inside the zone has thermal comfort as the maximum temperature attained in summer months is 22.92^{o}C and has not exceeded the set limit of 25^{o}C.A graph representing the temperature variation for the summer months in the improved model of bedroom 1 is shown in (Fig 41):

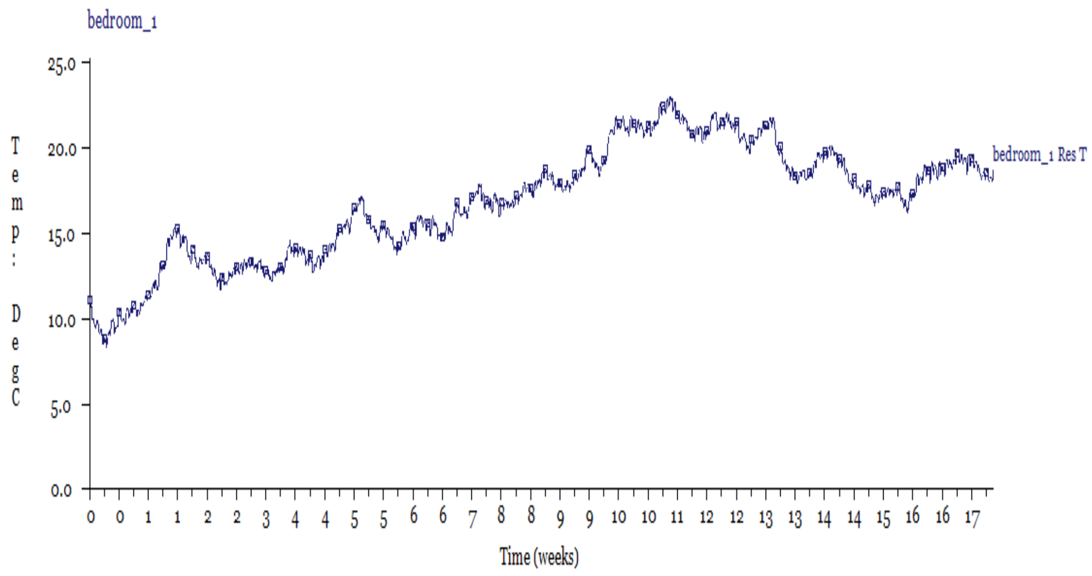

FIGURE 41 ZONE RESULTENT TEMPERATURES IN BEDROOM 1

The maximum temperature is recorded on 18th of July and the graph explaining the temperature variation in bedroom 1 on 18th of July is shown in (Fig 42):

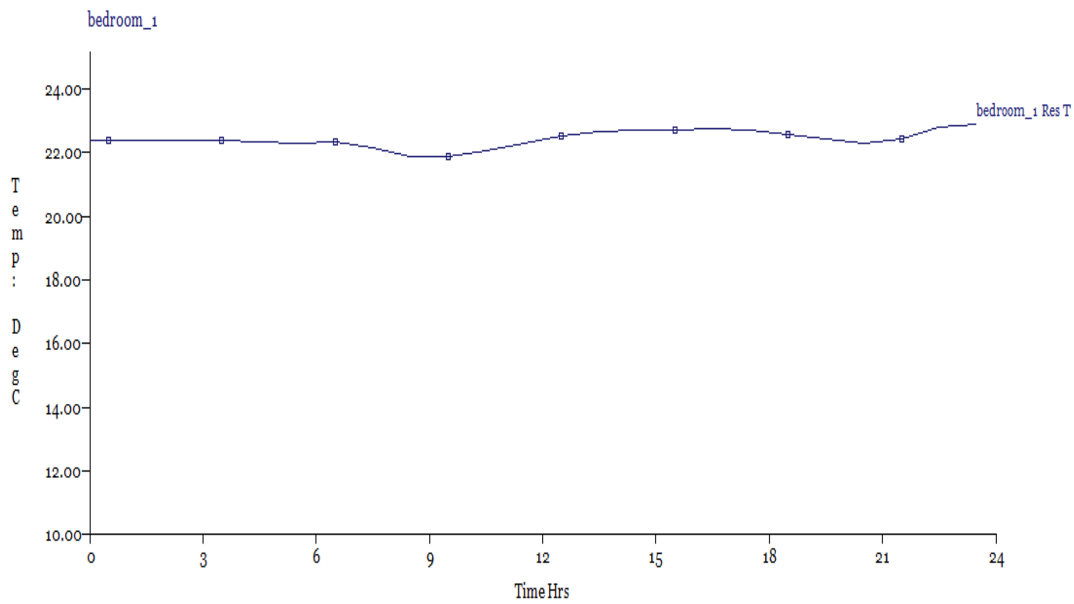

FIGURE 42 ZONE RESULTANT TEMPERATURES IN BEDROOM 1 ON 18TH OF JULY

Shading analysis is carried out for wall 1 on 17 of July and the result obtained is shown in (Tab 20):

External surface shading for 17Jul.				
Surface 1 (Wall-1)				
HOURS	***DIRECT SHADING***	***DIFFUSE SHADING***	***SOLAR AZIMUTH***	***SOLAR ALTITUDE***
03:00:00 Before Sun-rise				
04:00	100%	24.2%	50.3	0.4
05:00	100%	24.2%	62.4	7.4
06:00	100%	24.2%	74.3	15.1
07:00	100%	24.2%	86.3	23.3
08:00	14.2%	24.2%	99	31.6
09:00	27.6%	24.2%	113.2	39.6
10:00	32.8%	24.2%	129.8	46.7
11:00	43.6%	24.2%	149.7	52.1
12:00	44.9%	24.2%	172.8	54.7
13:00	47.9%	24.2%	196.9	54
14:00	39.3%	24.2%	218.9	50.1
15:00	30.2%	24.2%	237.3	43.9
16:00	25.5%	24.2%	252.8	36.4
17:00	10.4%	24.2%	266.2	28.2
18:00	100%	24.2%	278.6	19.9
19:00	100%	24.2%	290.5	11.9
20:00	100%	24.2%	302.5	4.4
21:00:00 After sun-set				
Averages for sun-up hours Direct = 59.8%, Diffuse = 24.2%				

TABLE 20 SHADING ANALYSES FOR WALL 1 IN BEDROOM 1

The improved model of bedroom 1 is oriented 40 degree towards east, window 4_5 has moved to the south east direction. To protect from the excess sunlight overhangs have been deployed above the window. The improved model has been deployed with increased blocks of overhangs so that excess sunlight is prevented. From the (Tab 20) it clearly states that the direct shading above 42 % is attained from morning 11 o' clock to 1 o' clock and has prevented excess sunlight entering the zones.

9.2. DISCUSSION

The simulation was performed for the improved model of kitchen and dining hall (Fig 39) and bedroom 1(Fig 41) and has the maximum temperature of 22°C and 23° C, when the important factors of overheating are modified. Initially when the orientation was shifted to 40 degree anticlockwise to east from south then the internal temperature reduced to certain extent this is because sun's position in south is high during summer so that increased the internal temperature so having modified to east then the angle of sun is low compared to south and as a result temperature inside the building is reduced and east facing rooms always be cooler during the afternoons so this way orientation has helped to increase the thermal comfort for the occupant. The next factor considered was to increase the overhangs from 3 blocks to 5 blocks to avoid the excess heat to enter into the building. When the shading analysis (Tab 18) was performed the direct shading increased from 33% to 47 % when the overhang blocks were increased above window 1_2_3 of kitchen and dining hall and in bedroom 1(Tab 20) the direct shading increased from 29.5% to 47% when the overhang blocks were increased above window 4 _ 5 so the shading factors does reduce the internal temperature and increase the thermal comfort inside the building. Choice of the construction material used in the building will also determine the internal temperature inside the building. In-built database is utilized for the improved model to check how these will have an effect on the model with respect to internal temperature inside the building and as a result when the external wall (Fig 32) of U-value of 0.142W/m^2K and internal wall of gypsum board (gyp_part) (Fig 33) with U-value of 2.14W/m^2K is used for the building then the internal temperature decreased to a certain extent and made it comfortable for the occupant with respect to thermal comfort. The construction material used in the improved model has a higher U-value than the design standards but still the analysis is performed in order to visualize, how these influence the temperature inside the building. The sensitivity analysis performed in the PHPP clearly stated when all the factors were combined and then modified with certain planning then the overheating in the building can be avoided so in this way an analysis with modification of orientation, shading, and construction material has benefited the craigrothie passive house to avoid excess heat inside the building and thus increase the thermal comfort for the occupant. Specific values from the sensitivity analysis and the analysis performed in dynamic simulation tool have to be treated with appropriate level of caution. The thesis have thus tried to focus in demonstrating the potential of dynamic analysis and in order to obtain more specific values the simulation has to be performed with more accurate modelling. Modelling when performed in the dynamic simulation tool with accurate values shall be much closer to the real time scenario. A similar analysis like above can be performed during the construction stage of a building in a real time scenario so that it draws the potential effect like overheating. Careful considerations while constructing such a house can mitigate these problems.

10. CONCLUSION

The result from the project has clearly highlighted the frequency of overheating in a Craigrothie Passive House in fife and an improved method is adopted for the two zones which had been affected more by internal temperature. Passive house planning package of craigrothie passive house has not able to detect the overheating in specific zones, so ESP-r modelling was necessary to craigrothie passive house and the results were obtained. But ESP-r modelling has certain disadvantages such as a certain technical knowledge is needed to obtain a model and simulation in ESP-r. The software behaves bit complicated but PHPP instead is in Excel so it is very easy to use but it is lacking in realistic approach. Passive house institute can develop passive house planning package to be more realistic like ESP-r so that it can help the occupant to improve the thermal comfort inside the building. PHPP should definitely have separate zone access for the building rather than having it as a single zone so this can help them out to find the overheating in particular zones. Passive house institute should give greater importance to the occupant in the building and survey must be conducted about his/her thermal comfort and other factors and according to it the PHPP should be designed this can help the occupant to live peacefully without any discomfort inside the building. The up gradation of PHPP should focus on some of the points like above which can result in significant impact on the occupant's comfort level and automatically the popularity of the passive house building are increased. Passive house building is in a developing stage in countries such as Scotland and upon careful consideration of small problems like thermal discomfort by the Passive House Institute, the popularity will only increase.

11. FUTURE WORK

This project is the initial point of investigation of summer overheating in passive house in SCOTLAND. The future work should concentrate more in other factors which affects the passive house thermal comfort and also can try developing accurate values for the internal heat gains inside the building and coming out with more realistic approach.

The project can also focus on mechanical ventilation heat recovery system in summer climate and analyse the thermal comfort of the occupant in the building.

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APPENDIX

APPENDIX-1

FOR DETAILS ABOUT GROUND FLOOR PLAN, SECTION PLAN, ELEVATION PLAN AND WINDOW DIMENSION OF CRAIGROTHIE PASSIVE HOUSE, PLEASE CONTACT THIS EMAIL ADDRESS:chachan126@gmail.com

APPENDIX-2

1. During summer month when will you open the windows and i would like to know which month?

Windows are opened most of the summer months when occupant feels too warm (see question 5). Depends on the weather conditions eg if overcast & rains for a week then windows will be closed.

2. Have you ever had an estimate how many times did you open it in a week?

Say 80% of the time generally in June, July, and August unless it gets too cold.

3. In a summer month period what are the hours of occupation in the building?

1900 to 0700 Monday to Friday; on Saturday & Sunday out of house for 4 to 6 hours per day

4. What type of flooring is used in the house?

Vinyl tile (Amtico Spacia) on plywood

5. What is the comfort zone (Internal temperature of the house) of the occupant?

20 – 24 degC is OK; 25 degC or warmer is uncomfortable

6. Did u ever face overheating in this month?if yes what will you do?

Sometimes too hot overnight when in bed (under duvet!); Open more windows.

7. What is the occupation in your house?

One person (male)

8. What type of mode will you keep the mechanical ventilation during summer?

Switched off as Paul Focus unit not fitted with summer bypass

9. If it is a manual ventilation system under what circumstances do u off it?

Switch off when weather gets warmer outside