Developing Affordable Vertical Greening Systems and its Impact on indoor comfort for Low Income Groups in Lagos, Nigeria.

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Abstract

This thesis examines the detailed process of developing affordable Vertical Greening System prototypes, through participatory development with low income communities in Lagos, Nigeria. Sequel to the development of the prototypes, an experimental analysis in an uninterrupted setting of the low-income house is undertaken to analyse the impact of the prototypes on indoor comfort.

The ability of Vertical Greening Systems to impact internal temperature has been well documented in literature, most importantly in similar climatic conditions of the location of study. However, there is a dearth in attempts to simplify construction methods and financial costings often associated with these forms of prototypes. Pertaining to participatory development with communities, while the Community based participatory research principles seem applicable to this study, experiences and unanticipated challenges encountered during the field work reveals its limitations for application in its entirety.

Hence, the original contribution to knowledge of this thesis stems from developing a series of unique methodological approaches in various aspects of the study. These include recruiting low income communities for participatory development of the prototypes and borrowing applicable aspects from CBPR to develop solutions (either solitarily or through input with the community) to unanticipated challenges encountered when physically developing the prototypes. A series of methodological steps specific to overcoming the challenges in the research environment were undertaken to prove the reliability of using two rooms: Experimental room 1 and Control room 10; and to evaluate the performance of the developed prototypes

The results revealed the steps, meetings, challenges and decisions first in identifying a co-operative community within Lagos and then developing the prototypes albeit through predefined physical criteria influencing the performance of VGS from relevant literature. Also, the experimental analysis of the developed prototypes reveals the detailed steps and considerations undertaken to analyse the system in an untainted, unorthodox and live setting of the study context.

The impact of the fully-grown HDPE prototype on the measured Average Hourly Internal Air temperature in the month of August was a maximum of 2.6°C within the Experimental room. Further analysis also revealed that the average hourly internal air temperature was consistently within the adaptive thermal comfort range 90%-100% of the time. The perception survey within the community also revealed opinions and attitudes towards the prototypes. Recommendations were also suggested by the community members, that, combined with the principles developed in this study could be applicable in other low-income communities in developing other more affordable prototypes.

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Chapter 1: Introduction and Background to Study

We are never going to scare people into living more sustainably! We have to be able to demonstrate just how dynamic and aspirational such a world could be - Jonathon Porritt ('The World We Made', 2013).

Although Vertical Greening Systems (VGS) have been in existence for centuries, since the Hanging Gardens of Babylon (605BC): the beginning of the 20th century has witnessed renewed interest in them (Kohler, 2008), particularly as tools to improve buildings and cities sustainability (Sheweka, 2011:2012).

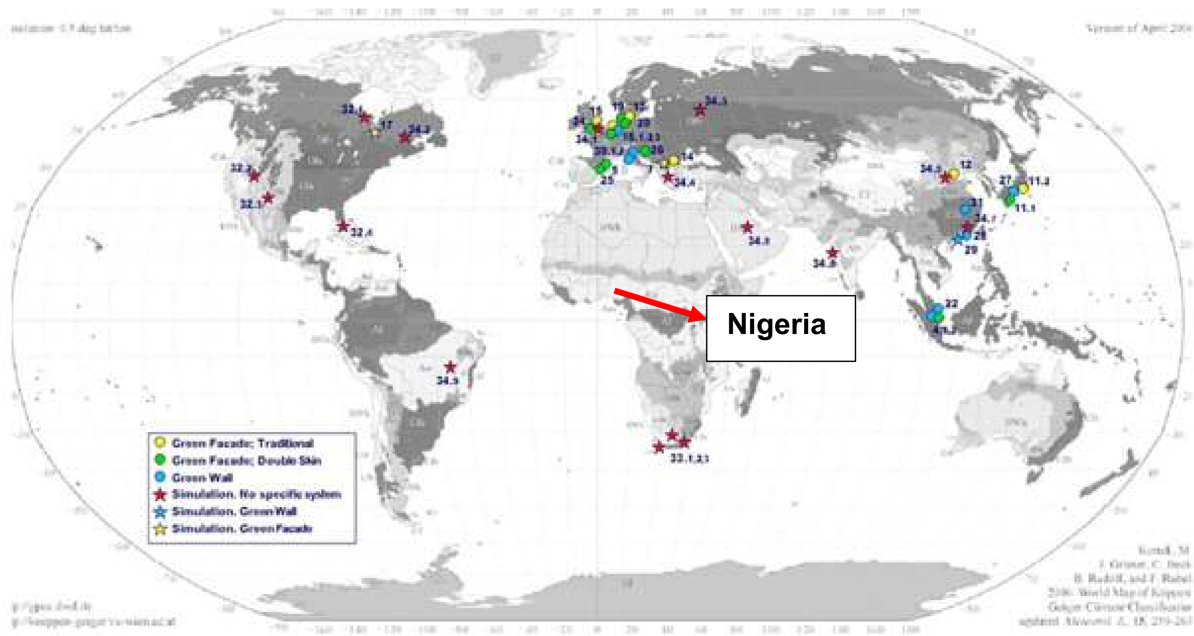

Figure 1-1; Documented VGS studies and Classifications around the world: Source Perez, 2011, Accessed January 2015

The highlighted areas in the figure 1-1 reveal the documentation of research on the Type, Classification and Study methods of Vertical Greening Systems from around the world, highlighting the absence in tropical Africa, particularly Lagos, Nigeria, located in West Africa. The aim and objectives of this study are presented and the arguments behind these are subsequently discussed.

1.1 Aim and Objectives

The aim of the study is:

- To develop and test an appropriate VGS that improves indoor thermal comfort in low income residencies in Lagos, Nigeria, which is both economically viable and socially acceptable.

To achieve the aim listed above, the objectives of the study were defined as follows:

I. To investigate the variety of Vertical Greening Systems (VGS) available and to establish the most appropriate solutions for adaptation for use in low income houses in Lagos, including the essential elements important for the systems to be effective in reducing indoor air temperature and influencing occupants' indoor comfort.

II. To design, develop and assemble a VGS system prototype, based on the views and inputs of the Low-income groups, that appropriately balances the 4 parameters of:

- Financial affordability
- Practicality in terms of assembling
- Maintenance
- Impact on Occupant's Thermal Comfort.

III. To establish the potential limitations of application of VGS in the context of low income groups in Lagos, Nigeria, including investigation of user awareness and acceptability levels.

1.2 Location and Climate of Lagos, Nigeria

To further understand the general context of the study, a brief overview of the location and climatic context of the city is presented and the target population, which are the Low-income groups are overviewed. Electricity supply challenges are then discussed as a case to highlight the relevance of this study.

Lagos is a megacity in South-West Nigeria. It lies on the Atlantic Coast in the Gulf of Guinea (West Africa), located on latitude 6° 27′ 11″ N and Longitude 3° 23′ 45″ E, on the narrow coastal plain of the Bight of Benin and bounded on the south by the Atlantic Ocean.

Plate 1.1: Location of Lagos, Nigeria: Source; Google images

It is comprised of a land area of approximately 356,861 Hectares (3568.6km^2) representing only 0.4% of Nigeria's land area. With 17% of the total land area consisting of lagoons, creeks and waterways (Balogun, Odumosi and Ojo ,1999, cited in Ilesanmi, 2009).

Plate 1.2: Aerial view illustrating the Geography of Lagos, Nigeria, Source; Nairaland.com

It is also characterized by low lying areas, most of which are below 41m. Residential land use accounts for over 60% (2141km^2). Commercial 5.5% (178km^2), industrial 7.8% (278km^2), Institutional and special areas 14% (499km^2), Transportation 18% (642km^2).

Lagos is classified under the AM climate (Equatorial Monsoonal) of the Koppen-Geiger climate classification. The location, close to the equator leads to intense solar radiation all year round Also, there is little difference in solar heating between summer and winter (McMullan, 2007).

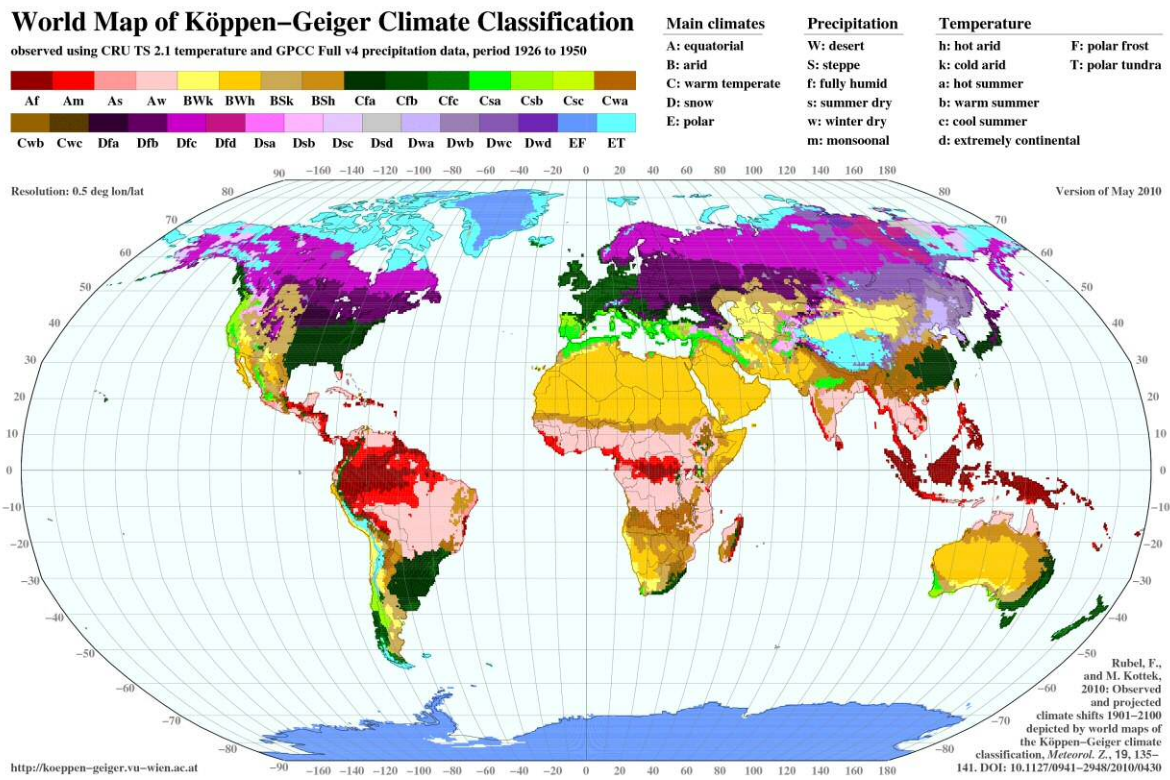

Figure 1-2; Koppen-Geiger classification of Lagos, Nigeria climate, Source; Koppen-Geiger, 2012

This climate (AM) is characterized by high temperature and high humidity, with small annual temperature ranges, a significant amount of precipitation between 2000 to 5000 mm annually and that can exceed 500 mm in a single month, during peak periods (Koenigsberger et al, 1975; Akinmoladun and Oluwoye, 2007; Koppen-Geiger,2012) as well as limited wind movement.

In summary, Nigeria experiences two seasons:

- A wet season from April through October
- A dry season from November through March.

In the wet season, moisture-laden south westerly wind from the Atlantic brings cloudy and rainy weather, whereas in the dry season, the dry north easterly wind from the Sahara (Harmattan) brings dusty and fair weather. The influence that these alternating winds have over the country is linked to the movement of the Inter-Tropical Convergence Zone (ITCZ) north and south of the equator (McSweeney et al, 2010). This climatic characteristic reveals the potential that the VGS presents for exploration in this region.

1.3 Low income groups in Lagos, Nigeria

Low Income groups in Lagos, Nigeria, have emerged as a result of urbanization and uncontrolled population growth (Ojo, 1988; Olotuah, 2009). The scenario of urbanization in Lagos is aptly described by Olayiwola (2005, pp2) in the statement below;

> *"Owing to the marked imbalance between the few developing areas (Urban) and the many vast underdeveloped regions, specifically due to the acute withering away of the latter, considerable groups of rural dwellers have been swept away in recent decades through the continuous process of direct migration to the few and weakly developing regional metropolises of greater economic and production concentrations. This massive flow of population with the existing poor level of city development and state of unpreparedness creates profound disruptions and imbalances. Simultaneously the inability of the city to integrate or absorb the new population socio-economically and infrastructural provision became apparent and almost 'unavoidable'" (Olayiwola, 2005, pp2)*

Aduwo (2011) corroborated that Urbanization is an unavoidable phenomenon in Lagos and as a result, the population of Lagos is estimated to reach 23 million in 2025 (UN 2000). Consequently, almost 75% of the urban dwellers live in slums in Lagos (Onibokun, 1972; Olotuah, 2005; Afolayan, 2007; Ademiluyi, 2008; Aluko, 2012). These groups are also referred to as the urban poor.

Definition by Income

The average earning for a single adult is 72 pounds per month (N18, 000) (Lawanson et al, 2012) who is surviving on less than a dollar a day (UNDP, 2008). This comprises of approximately 70% of the 22 million people residing in Lagos (Asojo,2010), which is a significant proportion of the population, thus informing the focus and potential impact of this study.

Economic importance and Employment

Lagos State Government (2004) estimates that 50% - 75% of the population are either unemployed, or employed within the informal sector. These includes; hawking, artisans, selling: cooked food, raw farm produces and other minor household items; usually operated as home-based enterprises or micro-enterprises. Only an estimated 20% of them are employed in the formal sector, being generally low paid junior staff employments such as janitors and office assistants. (Akom, 1984; Lawanson et al,2012). Therefore, the potential of VGS systems to offer financial savings could be of interest to them.

Plate 1-3; Common economic activities among low income groups, Source, Naija.com, 2012

Low Income Houses

A typical low-income residence in Lagos is characterized by overcrowding, poor building orientation and building materials with high conductivity, usually concrete blocks and un-insulated corrugated roofing sheet. Coupled with the ever-increasing temperature, due to global warming, overheating is the norm in these houses (Akom, 1984; Ahianba et al ,2008). Consequently, this often leads to high demand for electricity to cool indoor spaces (Bluyssen ,2009).

Plate 1-4; Typical low-income residences, source; Tony Irribor and Emmanuel Oshodi on google images.,2014

As Thermal comfort is a major litmus test for housing quality and is one of the most important parameters that has a direct impact on the satisfaction level of occupants (Adebamowo, 2010; Humphrey's, Nicol and Roaf, 1996).The achievement of a comfortable indoor climate is important to the success of a building, not only because it impacts on occupants, but also because it influences building energy consumption, consequently influencing its sustainability (Nicol and Humphreys', 2002). Therefore, in the hot and humid climate of Lagos, the use of mechanical cooling to attain a desired level of thermal comfort is often considered to be unavoidable. However, air conditioning and operation of mechanical cooling devices uses electricity, which is largely either unavailable or inconsistent in its availability due to an unreliable grid supply. Also, this costs money to operate (Sangowawa and Adebamowo, 2008:2013), usually imposing a financial burden on the target group in this study.

Hence, the need for innovative means of enhancing thermal comfort through shading buildings from solar radiation also informs this research. Although the study of Green roofs might have a larger impact, due to the exposure of roofs to solar radiation, which is a major source of heat gain in this climate, factors pertaining to pitched roof and extreme storm water runoff during the rainy season were considered and thus could not be pursued for further research at this time. Also, implementing them on existing buildings without prior consideration of their structural integrity was not considered achievable in this context.

1.4 Electricity Supply Challenges

In 2010, the Central bank of Nigeria stated that residential consumption of electricity accounted for 56.3% of the total electrical energy consumption: where 64% of Nigeria's electricity is generated from fossil fuel and 34% from hydro plants (Energy Commission of Nigeria, cited in Oyedepo, 2012).

Consequently, electrical power generation from fossil fuel combustion is accompanied by escalating fuel prices and adverse environmental consequences of large scale combustion of carbon rich fuels. Also, due to the poor electricity supply in the country, a huge number of people resort to the use of back up electricity in the form of generators. The African review of business and technology in its April 2006 edition revealed that Nigeria topped the list of countries importing generators for the 4^{th} year in a row, having surpassed others since 2002. According to the report, Nigeria accounted for 35% or US$125million dollars of the total US$432.2million dollars spent by African countries on imports in 2005. These generators require petrol or diesel to run, thus significant amounts of money is spent running these devices and proportionally higher quantities of CO_2 are emitted into the atmosphere due to their relatively low efficiencies (Ibitoye, 2007).

1.5 The need for this Study

The need for this research is discussed from three vantage points;

- Existing strategies for improving indoor comfort and their limitations
- Electricity Supply Challenges
- Financial implications of Vertical Greening Systems

Existing strategies for improving indoor comfort and their limitations

Over time, the impact of climate change in Lagos has been documented by Ojo (1988) and McSweeney et al(2010) as:

- A temperature increase of 0.04 °C per year from now until the 2046-2065 period, with areas near the coast expected to warm up at a slower rate than elsewhere
- A wetter climate, with the annual rainfall increasing by about 15cm and a rainy season that will be longer by up to two weeks by 2046-2065
- An increase in the frequency and magnitude of extreme weather events, such as extreme heat days (with the temperature exceeding 38 °C) and more violent tropical storms

The effect has been documented through intense heatwave, increasing solar radiation, rainfall and sea level rise (Mcsweeney et al; UNDP 2010).Thereupon, compromising timeless passive cooling principles in buildings, which include: preventing solar radiation from hitting building surfaces directly, especially the east and west facing walls, through shading and roof overhangs as well as utilizing cross-ventilation to encourage evaporative cooling. Also, the densely populated city and uncontrolled growth over time has led to an Urban Heat Island Effect leading to higher temperatures than experienced in rural areas while, the effect of cross ventilation has been compromised through haphazard and poorly planned neighbourhoods and buildings (Abiodun, 1993;Amao, 2012), thus informing the need for alternative approaches to promote passive cooling.

Electricity supply challenges

The cost of powering generators, coupled with the rising cost of electricity as well as the intermittent and unstable power supply has been felt the hardest by low-income groups in Lagos (Agbola,2007). In addition, the impact is felt at a larger scale through its contribution to climate change due to burning of fossils to generate the electricity required for cooling systems. Although there have been previous attempts to ameliorate this situation, primarily driven by the need to combat the challenges of electricity generation, such as harnessing solar energy: factors including, lack of information, lack of Government support, poverty, lack of technical knowledge, expenses and particularly non-involvement with the low-income groups who comprise a substantial part of the population; have limited the widespread implementation (Ikejemba et al, 2016). To this point, the need to develop affordable and viable sustainable ideas specifically with the challenges listed above informs this study.

Financial implications of Vertical Greening Systems

In view of a financial perspective, which is of great significance in this study, VGS, particularly living wall systems are known to be expensive to assemble and maintain (Perini and Rosaco, 2013: Oosterlee 2013: Cheng and Chu, 2013), and often incorporate relatively complex irrigation systems (Cheng et al, 2010: Wong et al, 2010: Chen et al, 2013). This is in contrast to the target group in this study who are financially constrained and limited educationally, hence informing the need to develop affordable and less complicated, context appropriate alternatives.

1.6 Scope and limitations of Study

- The research is limited to certain groups within the city and a specific form of housing morphology, thus, the researcher acknowledges the forms of houses available among this group and does not claim representativeness of all the housing types available within the city.
- The development of the cheaper prototypes was through participation with certain groups with limited financial capabilities within the city, thus the relevance of this study is limited within this criterion and findings from this research are specific to these prototypes. Building on this, the research was conducted in a live environmental context, thus, certain variables were uncontrollable, as opposed to conducting such a study in a laboratory setting. Hence, while controls were ensured through maximum co-operation from the occupants and detailed steps for undertaking the experimental analysis as discussed in Chapter 7, the researcher acknowledges that human and instrumental error might have occurred.
- Studying all aspect of Vertical Greening Systems would not have been feasible in this research. Thus, only relevant studies specific to achieving the objectives outlined are analyzed.
- The research and monitoring period took place from April to September 2014, which ideally should have taken place throughout the year, which the researcher acknowledges. However, the justification behind the selection of months has been discussed, which includes the relative homogeneity and minimum diurnal range of the climate all year round, as well as the limitations of the research environment. The period of the study is characterized by high ambient temperature and the rainy season, which is a suitable period to plant the VGS, allowing the plantings to thrive quickly. Although the dryer season has less rainfall, the ambient temperature is still very high, thus the effect of VGS systems could be felt all year round.

Chapter 2 details the research design and overall thesis structure.

Chapter 2: Research Design

This Chapter presents the research design and summarizes the combined methodological approaches to be adopted to fulfil the aim and objectives of this thesis.

To reiterate the aim of this study is *'To Develop and Test a Vertical Greening System for improving indoor comfort in low income residencies, Lagos, Nigeria which is both economically viable and socially acceptable'.* Given this, there is no individual comprehensive method which would enable an appropriate response to this multifaceted research, a combined approach is therefore proposed. Figure 2-1 illustrates the overall thesis design.

Figure 2-1; Chapter distribution for aspects of Thesis

Further explanation of the rationale behind this structure is discussed below:

2.1 Part 1: Literature review

The first part of the thesis presents a critcial review of relevant literature across four themes.These include:

- ***Vertical Greening Systems***

This theme discusses what a Vertical Greening System is, its components, typologies and likely performance in a tropical context as informed by current literature. It also determines the essential elements that constitute VGS and their specific roles in order to inform the necessary design and development of affordable alternatives during the field work.

- ***Occupants Thermal Comfort***

This second theme discusses literature pertaining to the potential impact of the proposed VGS prototypes on occupant's thermal comfort. Studies on thermal comfort are analyzed to present variables that it is appropriate to measure during this study.

- ***Low-Income Groups in Lagos; income and Housing Overview***

This third theme reviews low income groups in Lagos, including the emergence of their communities, their commonly associated housing characteristics and their average individual / household income and expenses. Consumption habits of low income groups are analyzed to understand the percentage of income spent on housing and other expendables. This is to forecast where the VGS might enhance their household budgets, especially in estimating how affordable the prototypes could be per individual / household.

- ***Participatory Action Research Approach.***

This fourth theme provides a critical review of Participatory Action Research (PAR), in which Community Based Participatory Research (CBPR) is an aspect. This leads to comparison with conventional research approaches as well as an outline of the limitations associated with applying CBPR in its entirety. In other words, CBPR's principles and guidelines are presented, as discussed across literature and these are critically analyzed highlighting both its limitations and potentials in this research context. The aspects that are identified as being appropriate to be adopted in this work are then outlined accordingly.

2.2 Part 2: Field work

The second part of this thesis pertains to the aim of the study in physically developing the prototypes within the community and testing the impact of the developed VGS prototype on occupant's thermal comfort. This involves developing the field study methodology as informed by relevant literature discussed in Chapter 3.

2.2.1 Aspect 1: Participatory development of Vertical Greening Systems.

This aspect is presented in Chapters 4, 5 and 6 as follows:

Chapter 4: Recruiting Communities for Participation (documentation through researcher's experience)

This describes the lessons learned during attempts to locate a community with which to engage with, in order to jointly develop the VGS prototypes. This includes the description of the process and challenges encountered during the three unsuccessful attempts, to recruit communities, prior to the 4th community that self-selected. This process culminated in the identification of four steps, which emerged during the process, that are required to gain trust and collaboration in this context, namely:

1. Penetrating the community
2. Building trust
3. Overcoming cultural issues and barriers
4. Presenting the research as an independent body from the government

<u>Chapter 5:</u> Field work: Case Study House selection within Agege community

This Chapter describes the process and criteria for selecting Case Study Houses within the community as well as the subsequent selection of the experimental and control rooms in each of the houses. This includes a description of the important physical criteria necessary to build the prototypes (through reference to relevant literature) such as the need for unobstructed bare walls with maximum exposure to solar radiation, the location and proximity of the two rooms and other unanticipated social criteria as were encountered during the field study, such as obtaining permission from the landlord as well as the need for cooperative occupants within the rooms selected. Further description of the 4 unsuccessful attempts to locate houses matching the predefined criteria is also outlined, culminating in the final selection of the two Case Study Houses.

<u>Chapter 6:</u> Participatory development and Construction of Affordable Vertical Greening Systems

This Chapter describes in detail the processes by which the VGS prototypes were adapted and built within the affordability criteria and through participatory efforts with the community. It details the process, steps, decisions and approaches undertaken to design and develop the prototypes on the Case Study Houses with participants within the community. This was informed by the literature review presented in Chapter 3 that provided fundamental information on the essential elements that comprise a VGS and a critical analysis of the principles of CBPR to be applied in developing affordable prototypes with a community. The process as applied here described under the following sub headings:

- Approaching and recruiting community members with specific skillsets;
- Engagement with recruited specific skillset and community members;
- Design of prototypes and costing;
- Construction phase; physically assembling the prototypes.

2.2.2 Aspect 2: Testing the developed prototypes

This aspect of the thesis documents the series of decisions undertaken to design an experimental process of testing the impact of the developed prototype on indoor comfort. This includes the challenges faced in the live project setting of the Case Study House and the process of overcoming them. The purpose that each Chapter plays towards achieving this aspect are briefly outlined.

<u>Chapter 7:</u> Methodological Development for Testing Environmental Performance of Prototype in Case Study House A

This Chapter describes the detailed process and steps taken to conduct the experimental analysis of the developed prototype in Case Study House A. This begins with the steps/ methodology undertaken to prove that the two rooms selected within the Case Study House were comparable, thus improving the reliability of the results. They include:

- <u>Step 1:</u> Field study instrumentation, as informed by relevant literature
- <u>Step 2:</u> Comparing occupant's lifestyle, activities and equipment usage
- <u>Step 3:</u> Solar radiation study (comparison of western wall surface)
- <u>Step 4:</u> Integrated analysis (based on the result of steps 1,2,3 impact on the measured average hourly internal air temperature for comparison in the two rooms, first for the month of June (prior to the installation of the prototypes) and the month of August (after the full growth of the prototype)

<u>Chapter 8:</u> Result of environmental performance of prototype in Case Study House A

This Chapter analyzes the results of the experiment by establishing the comparability of the two rooms through the results of the steps 1, 2 and 3 detailed in Chapter 8. The integrated analysis described in step 4 summarizes the results in the previous steps and presents its impact on the measured average hourly internal air temperature. First for the month of June and then August. Further comparison with adaptive thermal comfort range and occupants comfort vote/ adaptive action is presented across the two months.

2.2.3 Aspect 3: Perception survey

This aspect of the thesis documents the perception survey of community members attitudes towards the developed prototypes, whilst integrating relevant information from previous Chapters.

<u>Chapter 9:</u> Perception Survey and general discussion

This Chapter presents the analysis of the survey of community perception of the developed prototype. The surveys were undertaken in the form of interviews within the immediate community and those in its environs. These results are presented in the context of a synthesized discussion of relevant findings from previous chapters and is presented within three themes relating to:

- Acceptability/ attitudes of the community towards the developed prototypes.
- Costing/ affordability of the developed prototypes
- Impact on occupant's comfort

<u>Chapter 10:</u> Conclusions and recommendations for future work

This Chapter provides conclusions to the objectives and the main aim, to assess how achievable they were. Recommendations for future work are also discussed.

Chapter 3: Literature review

This Chapter discusses literature pertaining to the various themes that comprises the multifaceted aspect of this thesis, as outlined in Chapter 2.

3.1: Vertical Greening Systems: Performance Overview and Essential Elements for Design and Construction

This Chapter critically analyses literature on Vertical Greening Systems (VGS), pertaining to the aim of the thesis, which is '*To Develop and Test a Vertical Greening System for improving indoor comfort in low income residencies, Lagos, Nigeria which is both economically viable and socially acceptable'*. Thus, relevant aspects in literature to be discussed include:

- Critical overview of existing classification of Vertical Greening Systems.
- Benefits of VGS in relation to research context/ climate.
- Critical overview of VGS essential elements and their roles.
- Summary and Selection of VGS to be adapted during Participatory development with the final selected community.

3.1.1 Critical Overview of Existing Classification of Vertical Greening Systems

In VGS literature, there is no established standardization that determines its design and variations. Thus, different researchers and enterprises have attempted to solve this challenge by simply covering large vertical building surfaces with plants, using a variety of systems, substrates and structures, among other factors. However, different designs are likely to translate into variations in their thermal behaviours (Perez, 2011). This fact subsequently hinders the comparison between research results. This makes it necessary to consider the types of greening systems when discussing these results. There have to date been various attempts to provide classifications of VGS as postulated by previous researchers (Dunnet and Kingsbury, 2008; Wong et al, 2010; Ashraf, 2011; Perini et al, 2011; Perez et al, 2011; Sheweka, 2011; Chen et al, 2013; Manso, 2015) where their findings suggest that VGS can be classified under two major umbrellas: Green façade and Living wall (Blanc, 2008; Ottelle, 2011; Perini and Rosasco, 2013) as illustrated in figure 3-1.

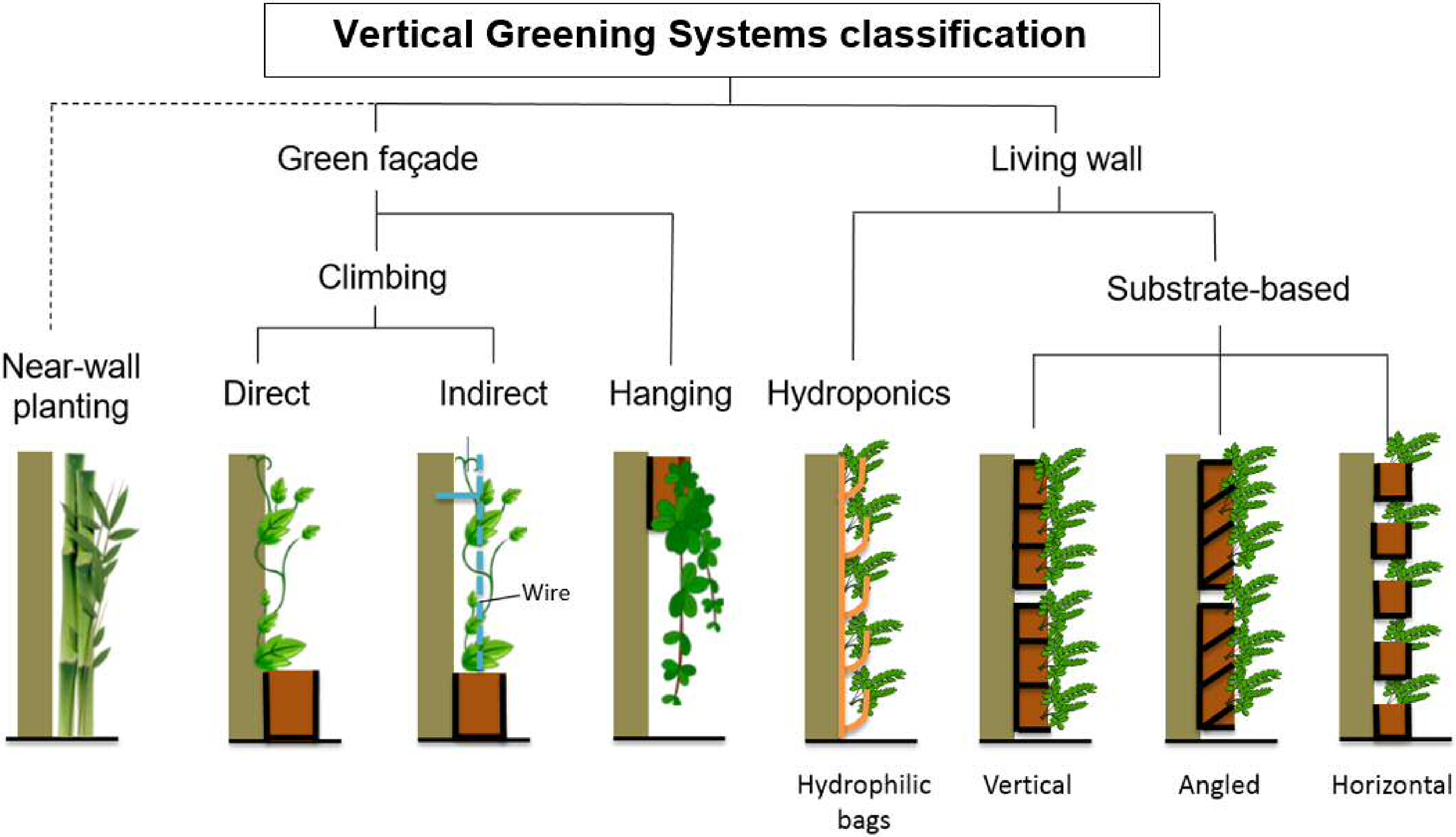

Figure 3-1; Classification of Vertical Greening Systems by Ottelle, 2011

Detailed description of these classifications is discussed:

Green facades

Green facades are a type of VGS in which climbing plants or cascading groundcover is trained to cover specially designed supporting structures. Further described by Wong (2010) as typically covered with woody or herbaceous climbers either planted into the ground or in planter boxes, to cover buildings with vegetation. They are mainly rooted at the base of these structures, in the ground, in intermediate planters or even on rooftops.

Kontoleon and Eumorfopoulou (2009:2010) stated that they can also be anchored to existing walls or built as free-standing structures, such as fences or columns. These self-clinging climbing plants have commonly been used to create green walls, since their sucker root structure enables them to attach themselves directly to a wall, covering entire surfaces. These can also be referred to as direct greening facades, as illustrated in plate 3-1.

To prevent these plants from entering cracks in walls, the building wall is usually covered by a rigid lightweight three-dimensional panel or even wires, which provides a captive growing environment for plants. When this is provided, it is referred to as indirect greening facades (Blanc, 2008; Perini and Rosasco, 2013), as illustrated in plate 3-2. Other forms of this classification by Sheweka (2011) includes hanging down and modules (which are made up of frames in which plants for VGS systems grow from).

Despite their relative affordability and simplicity in development, with the average costs of direct greening systems between £32-72 / m² and indirect greening systems between £37-222 / m² (Perini et al, 2011; Perini and Rosaco,2011; Ottelle et al, 2011; Manso et al, 2015; Peng et al, 2015), the major challenge associated with these systems is a potential compromise to the structural integrity of walls.

Plate 3-1: Direct greening façade, Source Designrulz.com, 2015

Plate 3-2; indirect greening façade, Source: greenroofs.com, 2015

Living wall systems

These systems are based on artificial substrates/ hydroponics or potting soil / compost (Perini et al, 2011). They are usually composed of pre-vegetated panels, vertical modules or planted blankets that are fixed vertically to a structural wall or frames (Kontoleon and Eumorfopoulou, 2009; 2010)

Dunnett and Kingsbury (2008) explained that they are often constructed from modular panels, which could be made of plastic, expanded polystyrene, synthetic fabric, clay, metal and concrete, each of which contains its own soil or other artificial growing mediums. Ottelle (2011) further explained that they are typically dependent on irrigation systems and/or the addition of nutrients to substrates such as is the case with hydroponics, as illustrated in figure 3-2.

1. Planter boxes
2. Foams
3. Laminar layers of felt sheets
4. Mineral wool

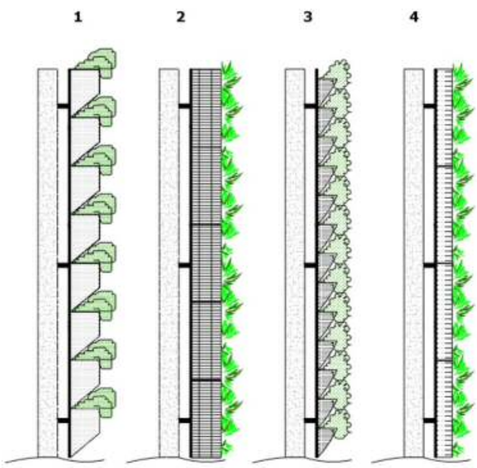

Figure 3-2; Further classification of Living wall systems by substrate, Ottelle, 2011

Although living wall systems which involve the use of substrates is the most effective in terms of cooling, as a result of the additional materials delaying heat flux transfer, due to the combination of plants and substrates (Cheng et al, 2010; Perez, 2011), they are typically expensive to assemble and maintain (Perini and Rosasco, 2013; Oosterlee, 2013). Also, the materials used in these prototypes has environmental impacts, that in turn influence their sustainability (Ottelle, 2011).

3.1.2 Potential Environmental benefits of Vertical Greening Systems in the research context

This section provides an analysis of literature relating to the potential benefits of VGS in similar climatic context. The resulting environmental performance factors of relevance discussed in literature and considered here include:

- Provision of additional insulation to reduce heat flow into buildings
- Absorption of excess solar radiation

- Improvement of the durability of building facades
- Overall improvement of sustainability in the built environment
- Reduction of Urban heat island effect

3.1.2.1 Insulation to reduce heat flow into buildings

Studies demonstrate that a VGS can contribute to the building envelope performance by creating an extra stagnant air layer, through providing additional barriers between the building interior and the hot (or cold) external environment, which have an insulating effect (Kohler,2006; Wong et al,2009; Perini et al, 2011; Jim and He, 2011) and has the potential to reduce energy demand for air-conditioning by up to 40-60% in Mediterranean climate (Jones and Alexandri; 2008; Perini, 2013). As further explained by Sheweka (2011; 2012), the fluctuation of wall surface temperatures could be reduced by as much as 50% by having vegetation cover, through the green plant protection mechanism which helps to maintain the temperature differential between the interior and exterior of the building. Krushe et al (1982) further illustrated in table 3-1, the percentage improvement of U-values provided by VGS compared with bare facades in the Mediterranean climate.

Other studies in similar climatic contexts such as Chen et al (2013) and Susorova at al (2013) revealed its insulation potential and impact on indoor temperatures.

While there are evidences on the insulation potential of VGS, the potential of an affordable soil based living wall system in enhancing indoor comfort, remains unexplored in literature. Particularly in the live setting of a typical low-income house in Nigeria.

U-value of bare façade without VGS	U-value of same façade with VGS	Improvement
1.5	1.0	33%
1.0	0.75	25%
0.6	0.5	16%
0.3	0.27	10%

Table 3-1; improvement of the insulating value of a greened façade, Krushe et al, 1982

3.1.2.2 Absorption of solar radiation

The effectiveness of living wall systems in absorbing excessive solar radiation preventing their direct penetration through wall surfaces has been discussed widely in the literature (Kontoleon and Eumorfopoulou, 2009; Wong et al, 2010; Perez et al, 2011; Chen et al, 2013; Susorova et al,2013;2014). Since incident solar radiation is a primary source of heat gain in buildings in the tropics (Koenigsberger et al, 1975), the potential of VGS in reducing solar heat gain is clear, and as explained by Ottelle (2011):

> *‘’…vegetation prevents solar radiation from reaching the buildings’ envelope, through shading effect of leaves, with extra thermal insulation provided by vegetation and substrates in living wall systems. Therefore, a reduced amount of incident solar radiation penetrates beyond the green foliage and thus influences the interior environment of buildings…” (Ottelle 2001 pp21).*

Also, Eumorfopoulou and Kontoleon (2009) and Jafaar et al, (2011; 2013) theorized that the plant-covered wall restricts air movement and controls humidity, resulting in significant reductions in temperature variations. With this potential discussed, this research focusses on developing an affordable soil based living wall system and evaluating its potential impact on indoor temperature through absorption of excess solar radiation.

3.1.2.3 Durability of building facades

The use of VGS can reduce the climatic stress on building facades. The application of such systems can delay the decay of some underlying wall constructions caused by UV rays, temperature changes, acid rain and air pollution. This effect is evident particularly in the case of living wall systems, where an additional protective action is provided by the continuous supporting layers. UV light deteriorates materials as well as the mechanical properties of coatings, paints and plastics. Therefore, plants therefore have positive effects on durability aspects and on maintenance costs. (Wong et al, 2009; Johnson and Newton 1996, cited in Sheweka, 2011; Ottelle, 2011).

In the context of the Low-income groups in Lagos, whose houses are often characterized by decayed facades due to poor quality of building materials (Aduwo, 2011: Amao, 2012: Lawanson et al, 2012), the benefit of the VGS could therefore transcend beyond improvement of indoor comfort, which is the key aim of this work, to improving aesthetic value.

3.1.2.4 Overall Improvement of sustainability in the Urban environment

VGS has potential to positively affect the urban environment, primarily because in most instances, there are four walls to every roof (Price, 2010). VGS can also be an active contributor to the increase of the ecological value of our urban environment (Birkeland 2007, cited in Loh, 2008).

The adoption of plant-covered surfaces is aesthetically and ecologically appropriate as an adequate architectural feature that promotes passive building design. Their use leads to an energy conscious design approach that prevents heavily populated urban areas from changing into a deteriorated natural environment (Kontoleon and Eumorfopoulou, 2010). VGS could also be an active contributor to the increase of the ecological value of our urban environment (Birkeland 2007, cited in Loh, 2008). Hence, the characteristics of building façade deterioration common to low income housing in Lagos could benefit from the covering effect of the VGS.

3.1.2.5 Reduction in Urban Heat Island effect

Throughout the years, replacement of vegetated surfaces with paved and impervious surface in the urban area have caused the temperatures in the areas to increase compared to surrounding rural areas this is known as the Urban Heat island effect (UHI). The UHI is characterized by significantly higher air temperature in densely built environment as compared with rural environment's temperatures. Among the causes of UHI are:

- Canyon Geometry
- Building materials
- Green house effects
- Anthropogenic heat source

UHI phenomenon can cause air temperature in the cities to be 2-5ºC higher than those in the surrounding rural areas mainly caused by the number of artificial surfaces (high albedo) compared with natural land cover (Taha, 1997 cited in Perini, 2011). By constructing green facades/ roofs great quantities of solar radiation could be absorbed for the growth of plants and their biological functions, significant amounts of radiation are used for photosynthesis, transpiration, evaporation and respiration Krushe (2011), as vegetation plays a fundamental role on the mitigation of the urban heat island (Sailor, 2008).

In the urban area, the impact of evapo-transpiration and shading of plants can significantly reduce the amount of heat that would be re-radiated by facades and other hard surfaces. The reduction of the heat island effect with regard the lower amount of heat re-radiated by greened facades and the humidity is affected by the evapotranspiration caused by plants (Ottelle, 2011). A research conducted by (Akabari et al, 2001, cited in Perini, 2011), showed that the mitigation of the urban heat island effect with trees, green roofs and green façades could reduce the U.S. national energy consumption for air conditioning up to 20%, saving of more than $10billion in energy use.

Although this is not the focus on this study, this looks at the wider scale influence of VGS, if the developed prototypes were to be found to be feasible and acceptable in Lagos, the potentials that these systems offer to curb the UHI effect on a larger urban scale may also be beneficial in the long run.

3.1.3 Vertical Greening Systems: Essential design elements overview and their impact on heat transfer

To design a Vertical Greening System, it is imperative to understand the essential elements in a VGS system and their impact on the various mechanisms of heat transfer. The purpose is to transfer the knowledge of these elements and their roles in heat transfer, while devising a functional Affordable Soil Based Vertical Greening System, howbeit through participation with the selected community as discussed later in this study. For instance, Living Wall System(LWS) are known for their ability to reduce indoor temperature substantially than when compared to Direct Greening Systems(DGS) (Alexandri and Jones, 2008: Ottelle, 2011). This is attributed to the substrates contained in LWS, which act as additional insulation that is usually absent in DGS. The essential elements are:

- Plants/ leaf area index
- Soil/substrates
- Support materials/construction
- Drainage/irrigation

The plants/leaf area index and soil/substrates are the primary elements directly involved with the passive cooling potentials of the prototypes, while the choice of the secondary elements which are support materials/ construction and drainage/ irrigation provides support and influences the moisture content in the soil/ substrates which in turn impacts the growth rates of the plants, as illustrated in figure 3-3

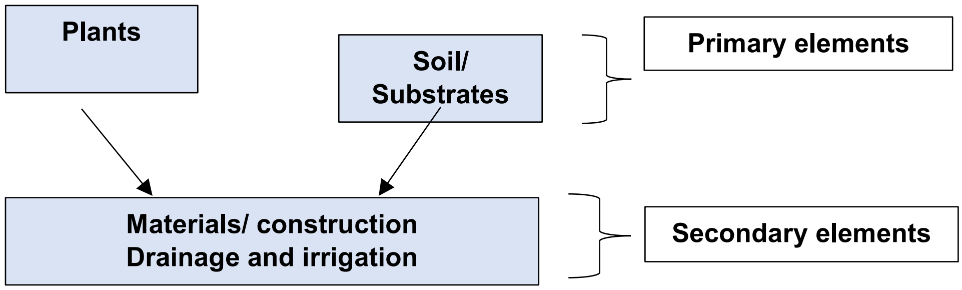

Figure 3-3; Primary and secondary essential elements in VGS

3.1.3.1 Plants/ Leaf area index

Reiterating, excessive incident solar radiation is a primary source of heat gain in buildings in the tropics (Koenigsberger, 1975). Thus, one of the specific roles of plants/leaves in VGS is in absorbing solar radiation and therefore this will be an important element within the prototypes. Plants absorb a vital amount of solar radiation for their growth and their biological functions, such as photosynthesis, respiration, transpiration and evaporation. Consequently, their function is similar to a solar barrier, through absorption and conversion of solar radiation into photochemical energy and latent heat which otherwise would be absorbed elsewhere (Wong et al, 2010; Hoelscher, 2015). By covering the building with vegetation, solar radiation is prevented from reaching the building skin, through the shading effect of plants. This is because the evaporation of water inside the leaves coverts sensible heat into latent heat through incoming solar radiation. The temperature of water inside leaves then rises (Krushe, 1982; Sailor, 2008; Oosterlee, 2014). Pertaining to convection, a plant layer acts as a buffer that keeps wind from moving along a building surface.

Oosterlee (2014) further explained that the process of heat loss then plays a major role in holding the leaf at an acceptable temperature. These processes are: radiation, through long wave infrared radiation; convection, through transfer of molecules in the direction of the temperature gradient through air movement and transpiration, as illustrated in figure 3-4.

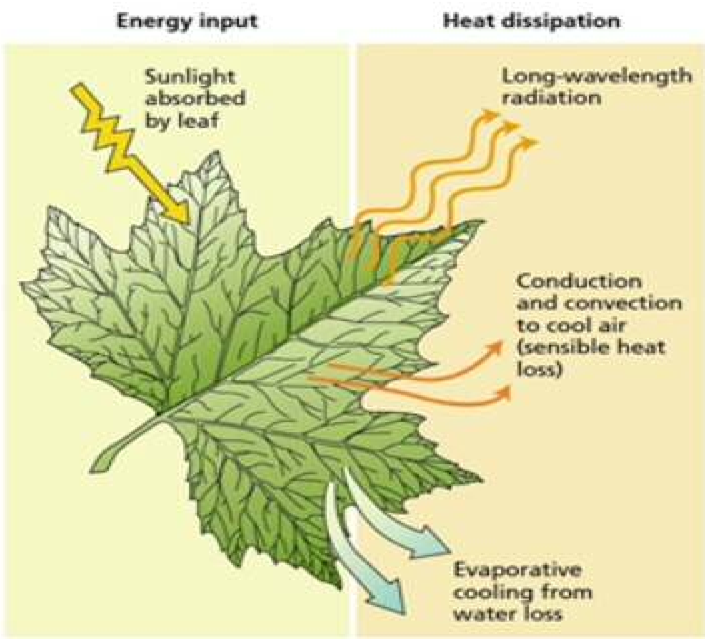

Figure 3-4; The absorption and dissipation of energy from sunlight by the leaf (source: Taiz L, 2010)

Krushe et al (1982) and Perez et al (2011) further explained the process of absorption of excessive solar radiation by foliage as 50% being absorbed, 30% reflected and approximately 20% passing through the foliage and reaching the surface of the façade, thus preventing further heat loss from the wall surface through the foliage acting as a buffer against wind movement as illustrated by Krushe et al (1982) in figure 3-5.

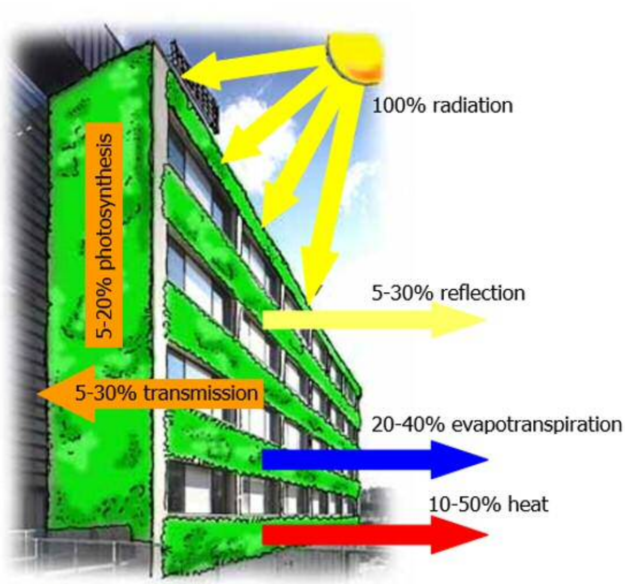

Figure 3-5; schematisation of the energy balance of vegetation by Krushe et al (1982)

Leaf Area Index(LAI)

Leaf Area Index was first defined in Watson (1947) as the total one-sided area of photosynthetic tissue per unit ground surface area. This is also defined as the projected leaf area per unit area of soil surface (Sailor, 2008). Although it is mostly related to plant canopies in the biological /ecological fields, the importance of LAI to Vertical Greening Systems is that impacts the percentage of wall covering[1], also explained as 'spatial extent' (percentage cover). This is one of the important parameters that determines the cooling potential of VGS as it impacts the shading potential from solar radiation on wall surfaces (Papadikas 2001: Sailor 2008: Kontoleon and Eumorfopolou,2009). LAI(m^2/m^2) is a dimensionless quantity and Oosterlee (2014) also observed that determining an absolute value for the LAI will be time consuming, sophisticated and only gives a temporary result, as foliage shifting is likely to happen over time. LAI ranges from 0 (bare ground) to over 10 (dense conifer forests).

Pertaining to its impact within VGS (Schumann, 2007, cited in Ottelle, 2011) estimated that a LAI of 1 corresponded to a solar radiation transmittance of 40% and a LAI of 5 corresponded to 5% transmittance. Price et al (2010) during an experimental analysis observed that the amount of temperature reduction provided by the green facades was directly related to the amount of LAI present. It was however argued by Umberto (2013) that a high LAI could cause heat loss through the leaves through convective heat transfer. Oosterlee (2014) also noted that the property of foliage cover (LAI) is the reduction of wind speed through convective heat transfer along the wall, causing the heat resistance of the external air film to reduce indoor air temperature. This might not be applicable to the warm-humid climate of Lagos where air movement is limited, although, this aspect will be explored through the hands-on approach of the proposed field work.

Figure 3-6 reveals the approximate values of LAI of various foliage coverage. The ivy (Hedera helix) plant was used in many studies likely due to its relatively high LAI, as illustrated in the third image in figure 3-6 (Di and Wang, 1999: Stec et al, 2005; Susorova et al, 2013). Other plants with high LAI include Virginia creepers (Parthenocissus quinquefolia), as documented in studies by (Kenneth et al, 2010; Ottele et al, 2011; Perez et al, 2011).

Figure 3-6: Estimation of Leaf Area Index, source: Susorova, 2013

[1] Extent of plants covering a wall surface

With the importance of LAI and their implication on percentage of wall covering discussed, it is imperative that the proposed prototype achieves as much LAI and percentage covering as possible to increase its potential in absorbing excess solar radiation.

3.1.3.2 Soil and substrate

Cheng et al (2010); Wong et, al (2010); Ottelle (2011), Susorova et al (2013:2014) observed that the insulating effect of the substrates/soil in VGS at high temperatures may also translate into lower wall surface temperature, due to the substrate/soil itself having the characteristics to retain high amounts of heat at high temperatures, especially during periods of intense solar radiation. The Importance of moisture in substrate was also discussed by Cheng et al (2013) during a thermal performance of a vegetated cladding on façade walls. When the top part of a living wall system was more irrigated than the lower parts, temperature differences observed had significant association with green coverage and moisture, suggesting that maintaining a healthy plant cover and providing adequate water was crucial for optimizing the cooing effect.

The role of substrate as extra insulating properties for VGS has also been discussed by Metselaar (2012), who estimated that the soil heat flux[2] can be increased by roughly 25–30 W m^{-2} for a 5-cm substrate layer. Another estimate was proposed by Oosterlee (2013) as an increase in the R-value being between 0.1 and 0.2 m^2 K W^{-1} dependent on the wetness of the growing medium. Pertaining to hydroponics, there are 6 basic types of these systems; Wick, Water Culture, Ebb and Flow (Flood & Drain), Drip (recovery or non-recovery) as used by Jim and He(2011), Nutrient Film Technique (N.F.T.) for example foam, felt, perlite and mineral wool as used by (Cheng et al, 2010; Dunnet and Kingsbury 2008 cited in Perini and Rosasco, 2011) light growth media by Chen et al (2013) and Aeroponics. There are hundreds of variations on these basic types of systems.

However, these substrates are relatively complex to set up and expensive, which is a dichotomy from the research focus and target group. Hence the other consideration is the use of soil. Many soil parameters, such as thermal conductivity, texture, specific heat capacity, short wave reflectivity and albedo, vary as a function of the moisture content (Sailor 2008), as illustrated for thermal conductivity in figure 3-7.

[2] Rate of heat transfer through soil

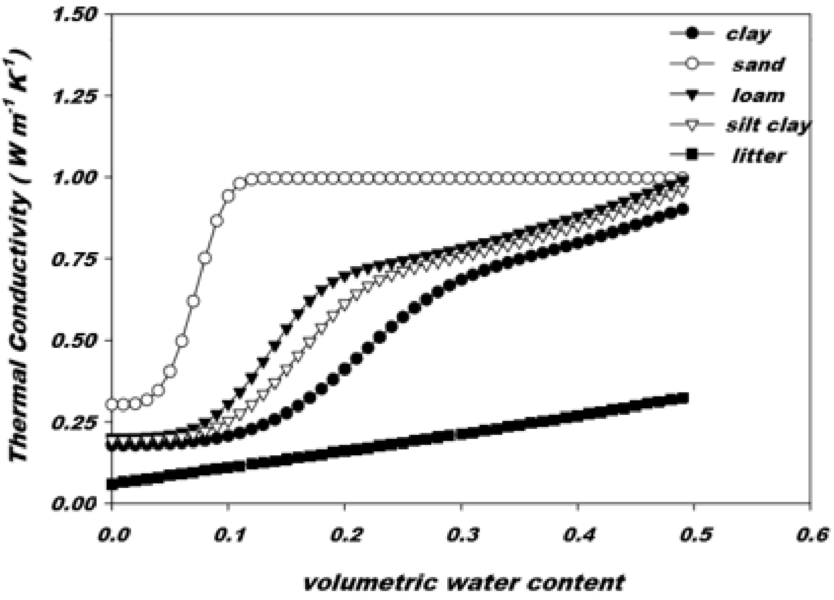

Figure 3-7; Thermal conductivity is a function of soil texture and moisture, source: Abu-Hamdeh, 2003

However, one of the major challenges relating to volumetric water content in soil in Lagos, Nigeria is its increase during rainy season. This leads to excessive water and if the subsoil content is impermeable, water logging or ponding might occur, resulting to a reduction in gas exchange between the soil and atmosphere. This causes oxygen deficiency leading to a reduction in root respiration and subsequently plant growth, as soil texture significantly influences the time that critical levels of soil oxygen reach the roots of plants. Thus, the importance of incorporating effective soil drainage in the proposed prototypes is paramount. The selected community empirical expertise will be used to find out what would be the most appropriate soil type and drainage in this context.

3.1.3.3 Materials and construction

Predominant materials used in relevant VGS literature include steel structures by (Perez et al, 2011 and Ottelle et al,2011), vegetation boxes and modular systems by Chen et al (2013), while a plastic variation made with recycled polypropylene by Jim and He (2011) and Jafaar et al (2013). The use of prefabricated external cladding composed of an aluminum module was documented by Cheng et al (2010), with a PVC panel and three felt layers added by Mazalli et al (2013) and geotextile felt systems by Blanc (2008). As illustrated in figure 3-8, Ottelle et al, (2011) undertook a life cycle analysis of VGS to calculate the environmental impact of the production, use, maintenance and waste for four common VGS which included;

- Direct façade greening system + bare wall
- Indirect façade greening + bare wall
- Living wall system (LWS) based on planter boxes filled with soil + bare wall,
- Living wall system (LWS) based on felt layers + bare wall.

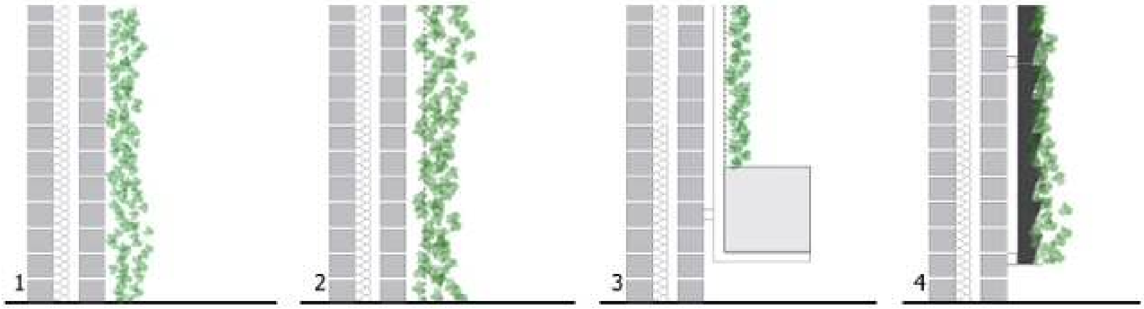

Figure 3-8; Life cycle analysis by Ottelle et al, 2011

The factors considered in the analysis were: raw material depletion, fabrication, transportation, Installation, operation, maintenance, waste for the facade(s) area.

The complete set of environmental impact categories was known as the "environmental profile", which included ten categories:

1. Abiotic depletion (kg Sb equivalents)
2. Global warming (kg CO2 equivalents)
3. Ozone layer depletion (kg CFC-11 equivalents)
4. Human toxicity (kg 1.4-DB equivalents)
5. Fresh water aquatic Eco toxicity (kg 1.4-DB equivalents)
6. Marine water aquatic Eco toxicity (kg 1.4-DB equivalents)
7. Terrestrial Eco toxicity (kg 1.4-DB equivalents)
8. Photochemical oxidation (kg C2H4)
9. Acidification (kg SO2 equivalents)
10. Eutrophication (kg PO4 equivalents).

The result from the conducted life cycle analysis provided insight into the environmental impact of the materials used in the different greening systems.

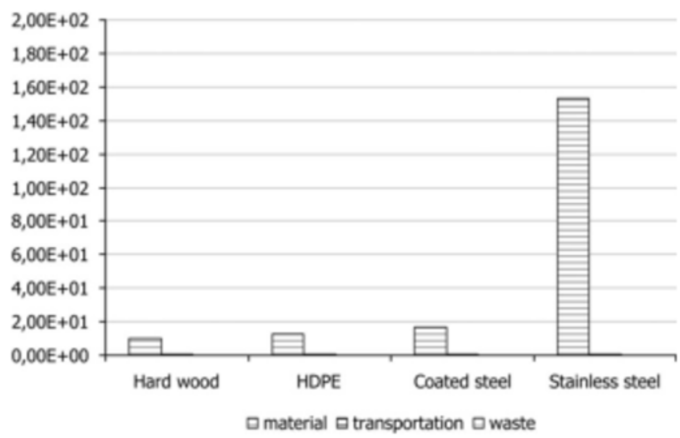

Figure 3-9; Environmental burden profile for different supporting materials, Ottelle, 2011

Figure 3-9 reveals that the stainless steel had the highest impact on the environment, as it was least sustainable. The two materials hardwood and HDPE (High-density polyethylene), both recyclable materials were observed to have the least environmental impact, thus, during in the development of the VGS in Lagos, Nigeria, the use of wood and HDPE (High-density polyethylene) will be explored when designing and erecting the prototype. With this information, this will be the first criteria discussed during participatory development of the prototypes with the community.

3.1.3.3 Drainage and irrigation

The most commonly used categories for drainage and irrigation are either designed to be closed or open systems integrated as electrically controlled irrigation system as documented in studies by Chen et al (2013) and Mazalli et al (2014) or manually watered as documented in studies by Cheng et al (2010); Price (2010) and Hoelscher et al (2016). Other documented forms of irrigation are the drip irrigation as documented in studies by Olivieri et al (2014).

However, these systems are relatively complex and expensive, which is a dichotomy from the research focus and target group. Thus, the possibility of adapting these irrigation techniques into simpler and cheaper alternatives, appropriate for this context is an important aspect that will be explored during the field work.

3.1.4 Overview of Vertical Greening System performance in tropical context

The effectiveness of these systems on thermal performance, i.e. indoor temperature reduction translating into energy demand reduction has been evaluated and proven in similar climates to that found in Lagos, Nigeria, through experimental set-up (Wong et al ,2010;Price,2010and Sheweka,2014), Field experiments (Kontoleon and Eumorfopoulou, 2010; Susorova,2014; Olivieri, 2014)who used mechanical cooling to manipulate indoor variables and simulations were carried out and confirmed by (Holm ,1989; Alexandri and Jones,2008; Kontoleon and Eumorfopoulou, 2009; Wong et al ,2009).

Its ability to provide extra insulation on a building façade has also been documented (Minke et al, 1982; Krushe et al, 1982; Ottelle, 2011). However, the documentation of the capacity of VGS to deliver a reduction in indoor air temperature and occupants thermal comfort remains unexplored in this region, thus providing a basis for theory exploration through the development and testing of a prototype within this study.

The essential elements in a VGS and the roles they play in reducing indoor temperature have been established as:

- Plants
- Soil/substrates
- Materials and construction
- Drainage and irrigation

All of which will be adapted to the criteria of affordability and simplicity in development through participatory development with the would-be community.

3.1.5 Discussion: Context Appropriate Vertical Greening Systems Typology

As mentioned before, of all the VGS typologies mentioned above, while the direct greening façade is likely to be the cheapest to install (Ottelle, 2011: Perini and Rosasco, 2013) especially in relation to the research context where low income groups are surviving on less than a dollar a day. Its potential to absorb excess solar radiation might be compromised due to the absence of substrate on the wall surface. Thus, the final decision to adapt living wall system primarily stems from the extra insulation the substrates provide. Building on this, the prototypes to be developed should therefore represent an optimal balance between the following attributes:

- **Affordability**

  The financial limitation of the target group has been discussed, hence it is imperative that the prototypes to be developed are as financially affordable as possible for the low-Income groups without becoming overwhelming to them. This is discussed in detail under section 3.3
- **Simplicity and ease of construction**

  This attribute is essential to suit the unrefined context of the study settings, using appropriate technological methods. In other words, the VGS should be able to be erected by the low-Income groups themselves.
- **Ease of maintenance**

  There is typically significant effort required in the maintenance of Vertical Greening Systems (Perini and Rosasco, 2011). Therefore, a simply erected VGS in this context should be one that requires minimal effort to be maintained.
- **Thermal function in providing passive cooling.**

  This is the hypothesis to be tested in this research and the aim of the developed prototype. Reiterating this attribute is dependent on the essential elements that influence the performance of the prototypes. These will offer guidance during the physical design and construction during the field study, which will be jointly decided with the community members. A summary of these elements is presented below:

- **Plants**

Ideal plants type selected should have large leaf area index, quick growth rate (due to the time frame of the study) to enable maximum percentage of wall covering.

- **Soil/substrate**

The decision on the soil/substrate will also be jointly decided with participating community members which might be driven by the most ideal of the available soil type

- **Materials**

The guiding material choices previously discussed is HDPE or wood. The final selection of the materials under this category will be jointly decided during the field work.

- **Construction**

Construction method should be simplistic, relatively easy to assemble without compromising on its function.

- **Drainage and irrigation**

Drainage and irrigation method should be uncomplicated enough to be easily incorporated within the prototype yet functional enough to support the plant growth.

Thus, the classification of interest to this study is the '*Affordable soil based living wall systems*' for low-income groups. With this discussion on VGS and the essential elements, the next theme discusses occupants thermal comfort, as this is the conspicuous means of measuring the impact of the prototypes.

3.2 Occupants Thermal comfort

This section briefly discusses occupants thermal comfort and the relevance in this study, especially as it relates to testing the impact of the developed prototype(s).

3.2.1 Thermal comfort conditions

Thermal comfort is regulated by standards, which in turn are important in determining ideal indoor conditions to be maintained in buildings. There are two most popular and widely used international standards that relate specifically to thermal comfort; ISO standard 7730(2005) and ASHRAE Standard 55. Both are based on the Fanger model, which solves the heat balance equations between human body and its surroundings represented as a uniform environment. However, (MacIntyre ,1980, cited in Fahad, 2005) noted that there was no absolute value for comfort, rather, it is generally relative to personal experience and expectation. Following this, Nicol and Humphreys (2002) observed that the experiments underlying the rational approach in determining these standards were conducted in climate chambers of the developed world, thus cultural inclination and acclimatization in hot and humid environment are often not considered when setting these standards.

Hence, in relation to the climate of Lagos in this study, attainment of such standards is often unrealistic, as issues like overcrowding and overpopulation in this climate are not considered when these standards are being set. Thus, field-based researchers recognize the person-environment system as an integral unit in which sensation and perception are influenced by the thermal environment, which in turn is modified by behaviour in a self-regulating manner (Nicol, 2004). In this study, the purpose of documenting thermal comfort conditions is to gauge the current satisfaction level of the occupants in both rooms. Thus, the underlying research question for this section was: ‘Will the effect of the VGS influence their current perception of the thermal conditions in the rooms’?

Adaptive approach

The adaptive approach to thermal comfort is based on field surveys of thermal comfort that demonstrated that people are more tolerant of temperature changes than laboratory studies suggest (Humphreys, 1994). The principle codifies the behaviour of building occupants which takes two basic forms:

- Adjustments to the optimal comfort temperature through making changes such as: in clothing, activity, posture; such that the occupants are comfortable in the prevailing conditions.
- Adjustments of indoor conditions using controls such as: opening or closing windows, blinds or turning on / off fans. Occupants may also migrate around the room to find improved conditions.

Comfort may therefore be achieved in a wider range of temperatures than predicted by international standards, typically design for application in serviced environments. Studies by (deDear et al 1990; Nicol et al, 1996; Wong et al ,2002; Ogbonna and Harris, 2007; Adebamowo and Akande, 2010; Rajasekar and Ramachandraiah, 2010), provide evidence that people's comfort vote, in free running buildings, is at higher temperatures than suggested by such international standards. Table 3-2 summarizes prominent adaptive comfort models in literature;

Nos	Source	Equation	Outdoor temperature limitation
1	ASHRAE-55	$0.31*T_O+17.8$	10°C-33°C
2	Humphreys and Nicol, 2002	$0.534*To+12.9$	10°C-34°C

Table 3-2; Adaptive approach in literature, ASHRAE-55 and Humphreys and Nicol, 2002

The ASHRAE standard was the first international standard to include an adaptive component applicable to naturally conditioned buildings, through extensive field studies undertaken by deDear (1998)

Subsequently, the adaptive approach postulated by Nicol and Humphreys (2002) allows for an estimation of the indoor temperature which building occupants are likely to find comfortable, particularly in free running buildings, the context which is of primary interest in this research. This model is essentially a regression equation that relates the desired temperature indoors to the monthly average temperature outdoors. Also, documentation of adaptive actions carried out by occupants is critical to this principle. Hence, the interest in this study. However, the criticism of this model lies in the only input variable used, which is the average outdoor temperature (due to its indirect impact upon the human heat balance) and its non-inclusion of the six classical thermal parameters that have an impact upon the human heat balance and, therefore, upon thermal sensation (Elaiab 2014), these are: air temperature˙ temperature of the surrounding surfaces (radiant heat)˙, relative humidity˙, air velocity, clo values and metabolic rate. It has also been described as a black-box' based on empirical observations in which the nature of the adaptive mechanisms is hidden and not quantified or related to measurements. It is also criticized as overlooking the effect of humidity and air movement. However, humidity will be considered during analysis in this thesis. Thus, the argument is that while the VGS prototypes may not act as mechanical cooling devices through significantly altering indoor variables, its impact on indoor comfort might be significant enough to fall within the occupant's adaptive thermal comfort temperature proposed by Nicol and Humphreys (2002). With this discussed, the variables to be measured to document this is presented in Chapter 7.

The next theme discusses low-income groups in Lagos, Nigeria.

3.3 Low income groups; housing characteristics and income overview

This section begins by presenting the common morphological housing characteristics associated with low-income groups in Lagos, Nigeria. Household sizes, income and consumption habits of these groups are discussed to project on how affordable the prototypes should be.

3.3.1 Housing

As a unit of the environment, housing has a profound influence on the health, efficiency, social behaviour, satisfaction and general welfare of the community (Onibokun, 1990). It reflects the cultural, social and economic stance of any given society (Olukayode, 2003 et al cited in Gambo, 2012). With the UN-habitat's agenda's (2003) definition of quality housing as…... *"being more than a roof over one's head, provision of adequate privacy; adequate space; physical accessibility; adequate security; security of tenure; structural stability and reliability; adequate lighting, heating and ventilation; adequate basic infrastructure, such as water supply, sanitation and waste-management facilities; suitable environmental quality and health-related factors; and adequate and accessible location with regard to work and basic facilities: all of which should be available at an affordable cost"*. (UNHabitat, 2003).

It is evident that availability of quality housing, which is one of the litmus tests of a developed society is still a challenge in many parts of the world, particularly among low income groups in developing nations like Nigeria (Dogan, 2009, cited in Aduwo, 2011).

According to the Centre for Affordable Housing finance in Africa, (2017), more than half of Nigeria's estimated population of 186 million live on less than £1 a day. With the unemployment rate increasing from 10.4% in 2016 to 14.2% in 2017 and minimum wage remaining at N18 000 (£72) per month, home purchase and rent prices have also been seen to have grown ahead of general inflation. Consequently, almost half of Nigeria's population lives in cities and housing continues to witness a disconnect in supply and demand between socio-economic brackets. This has resulted in high cost of housing, with 51% of the population living in rented accommodation, especially the low-income groups.

Hence, with their limited financial resources, many of these groups are forced to rent houses. However, there are limited regulatory bodies monitoring issues regarding rentals, landlords and estate agents, which results in these stakeholders dictating the market, further alienating the low-Income groups and limiting them to poor quality houses described by Olotuah (2005) as "…*housing* [that] *does not ensure dry shelter, safe water supply, drainage, sewerage and refuse disposal, as well as access roads. These houses constitute a health risk to its occupants".* Common morphological characteristics of this housing will now be reviewed.

3.3.2 Morphological characteristics of houses among Low income groups in Lagos.

The common morphological characteristics of houses associated with these groups can be divided into three main categories: shanty houses (Awotana, 1988), government provided housing estates (Onyekachi, 2015) and Brazilian Multihabitation houses, locally known as 'face me I face you' (Aina, 1989: Tipple, 2002).

3.3.2.1 Shanty houses

According to Gandy (2006,) there \\\are as many as 200 different slums inhabited by low income groups in Lagos. Plate 3-3 illustrates one of the largest shanty towns in Lagos, informally known as dustbin city. They consist of rooming units, usually built with either zinc or corrugated iron sheet walls, wooden board or plank walls such houses are also common in swampy areas (Aina, 1989: Gambo, 2012: Akinmoladun, 2012: Aluko, 2012).

Plate 3-3; Dustbin city, Ajegunle, Lagos, source, BBC.com

Plate 3-4 illustrates shanty houses in Makoko, another low-income settlement in Lagos. The squalid conditions are evident in the form of poor environmental conditions, hazardous location, insecure tenure and vulnerability to serious health risks (Lawanson, 2012). The precise number of these houses remains undocumented and officially unrecognized as dwellings by the Lagos State Government. This makes them prone to demolition, which was initially undertaken in 2012. Hence, it is unlikely that the final selected low-income communities will comprise of these forms of housing.

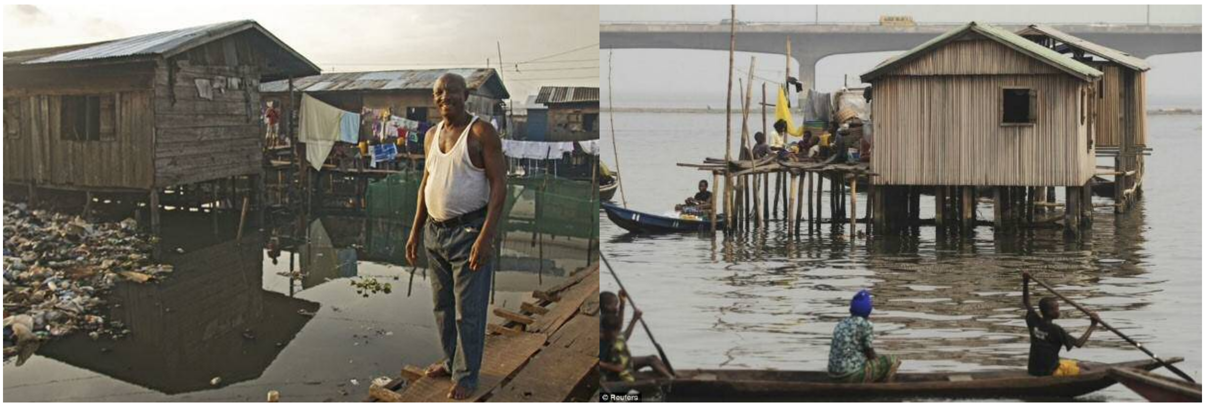

Plate 3-4;shanty housimg in Makoko, Lagos; source Bellnaija.com,

3.3.2.2 Low income housing estates provided by Lagos State Government

Other forms of housing among the low-income groups include low income housing estates initially built by the housing department of the Lagos State Government. Initially established in 1928 as the Lagos Executive Development Board (L.E.D.B.), it was charged primarily with the task of getting rid of the filth and unhealthy living conditions which existed within the city (Olotuah, 2005). The Board was also set-up to transform the slum areas and ghettos into a planned and habitable environment. (LSDPC Official Website, 2014). An example was the slum clearance in 1955 in which 1,300 low income one or two-bedroom units were provided for low income families in Surulere, however, many slum dwellers refused to move to the apartments due to exorbitant prices placed on the housing (Olotuah,2005:2009;Aduwo, 2011).

Another board was established separately in 1956 (The Ikeja Area Planning Authority (IAPA)) to control development in the part of the metropolis. In 1958, the Western Nigeria Housing Corporation was created by the then Western Region government with the responsibility of providing housing finance.

In 1972, the LEDB, the IAPA, and the Epe Town Planning Authority (ETPA), were merged to form the Lagos State Development and Property Corporation (LSDPC) to stimulate greater efficiency, eliminate delay, waste and distribute responsibilities in the housing sector, primarily for the provision of public housing (Ilesanmi,2009; LSDPC official website, 2013). It was the implementation agency of the mass-housing program of the first civilian administration (1979-1983) by embarking on massive construction of low-cost housing estates. Between 1981-1990 about 20,000 housing units compromising of 20 low income, 9 middle income and 5 upper-medium income housing estates. (Oduwaye, 2009; Ilesanmi,2009). Table 3-3 summarizes the activties of the LSDPC.

Housing Agency	Scheme	Remarks
Lagos Executive Development Board, 1928-1972	Slum clearance of Central Lagos Other housing schemes in Surulere	1347 families housed in Surulere 1337 families resettled in low-income rented houses, subsidized by Lagos State Government
Lagos State Development and Property Corporation (LSDPC) 1972-Date	Low -income housing Middle-income housing	16,878 housing units 1790 housing units

Table 3-3; LSDPC housing estate

The housing units provided were not only insufficient. They were unaffordable for the low-income groups. Also, over time, poor maintenance of these estates has resulted in dilapidation of infrastructures as corroborated in studies on low income housing by Akinmoladun (2007); Ilesanmi, (2010); Aduwo (2011); Oguejiofo (2014) and Olajide (2010) further described low income housing estates as characterized by untarred roads, poor drainages, lack of street light and absence of pedestrian walkway/ street parking. Plates 3-5 illustrates the evident decay and poor maintenance in Gowon and Ogba low income housing estates.

Plate 3-5 Gowon and Ogba low income estates(clockwise), Source, Naija.com

3.3.3.3 Brazilian housing morphology and Multihabitation among low income groups

Multi-habitation can be described in terms of sharing facilities in a dwelling with extended / multi-family occupancy or friends/ acquaintances which is common in many parts of the third world (Tipple et al, 2011). Variations in the form of multi-storeys are not uncommon. They may or may not be free-running, in other words, they may/ may not consume energy for the purpose either of heating or cooling (Nicol et al, 1999). Like most urban cities in West Africa, Multihabitation among low income groups is a common characteristic (Tipple et al, 2002).

The most popular form of the multi-habitation dwelling in Lagos is Brazilian housing, known locally as face me I face you (Aina, 1989; Akinmoladun, 2007; Lawanson, 2012). Vlach (1984) stated that they emerged from the Yoruba bungalow which has its origins in Brazil. He described the structures as the last phase of prolonged cultural exchanges and transformations with Brazilians that began in the 19th century when Lagos was an important port for the colonial masters. The city faced cultural alterations with the three strongest influences being Brazillian, Saro (returnee slaves from sierra-leone) and British colonial, with the Brazillian becoming the most popular and influential[3]. Thus, overtime, the Yoruba changed their houses, through inclusion of the Afro-Brazilian ideas, which they adapted in a way that made an imported design profoundly their own (Oliver, 1971, cited in Vlach, 1984). The Yoruba traditional compound was consequently transformed with the evolution of the Afro-Brazillian house, which today is the most visible form of housing among these groups in Western Africa. They are often built with cement/sandcrete blocks and asbestos roofing sheets. (Aluko, 2012: Tipple et al, 2000). A typical example is presented in plate 3-6.

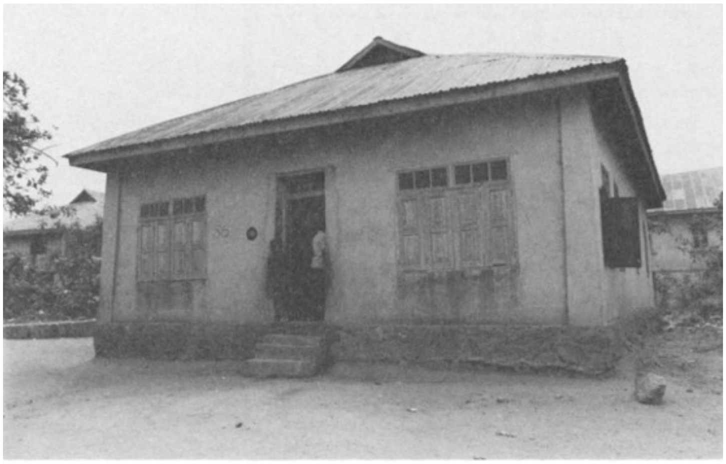

Plate 3-6: A typical Yoruba bungalow, Source Vlach, 1984

Adeokun et al, (2013) and Okeyinka and Odetoye, (2015) observed that the houses were not usually orientated in any particular direction, as they were usually built on collectively owned land. The main entrance into the house was usually directly into the courtyard or a small lobby (veranda). The toilet and shower areas were always separate from the main building within the compound or family land. In other words, the buildings were initially designed and built to occupy large families with many wives and children.

[3] Worthy to note is that by the late 1880's, they constituted about 9% of the population in Lagos Vlach,1984,.

In more recent times, (Schlyter ,2003; Korboe et al 1992, cited in Oyeyinka, 2014) explained that while multi-habitation was initially significantly influenced in West Africa by central issues such as kinship and inheritance[4], it has evolved in the urban areas. This was predominantly through the family members (as a result of seeking greener pastures in other places) moving out of the residences and renting the spare rooms to outsiders, thus, in order to avoid loneliness and to make extra income, the landlord (father of the house) often decided to bring in other people who needed homes, in exchange for a (rent) which is paid monthly (Agbola, 1988; Aina, 1989), further explained by Peace (1979) as petty-landlordism, which is renting out part of one's house to other tenants. Landlords often live in one or more rooms and let out the rest to tenants. Sometimes they employed Care takers (representative of the Landlord who resides within the houses) to oversee rent collection and house maintenance. Consequently, it is not unusual to find an average of 6 people in an $18m^2$ space or 4-6 people in a $12m^2$ space. This is partly due to the greed of the landlords but also due to squatting with friends and relatives (Awotana, 1988; Aina, 1989).

Over time, people with similar levels of income, social status and cultural inclination lived together, forming a microcosm within a community, since each house was composed of unrelated individuals from many ethnic communities who live together in a confined area (Schildkront, 1978). These houses tend to be overcrowded and classified as informal due to them often being built without local authority control. Consequently, there is no official documentation on the exact number of these housing types within the city. This challenge was also acknowledged by Aina (1988:1989); Aduwo (2011) and Lawanson (2012) when undertaking a survey of low income groups/housing during their research, thus, most of these housing morphologies sampled in prior studies by Akom, (1984); Aina (1989); Awotana (1989); Abiodun (1993); Olajide (2010); Aduwo (2011) and most recently Lawanson et al (2012) ; Aluko (2012) were through personal surveys and physical visits.Typical variations of this housing floor plans is illustrated in figure 3-10.

[4] through encouraging their sons to marry and bring their wives into the family compound to perpetuate the family traditions

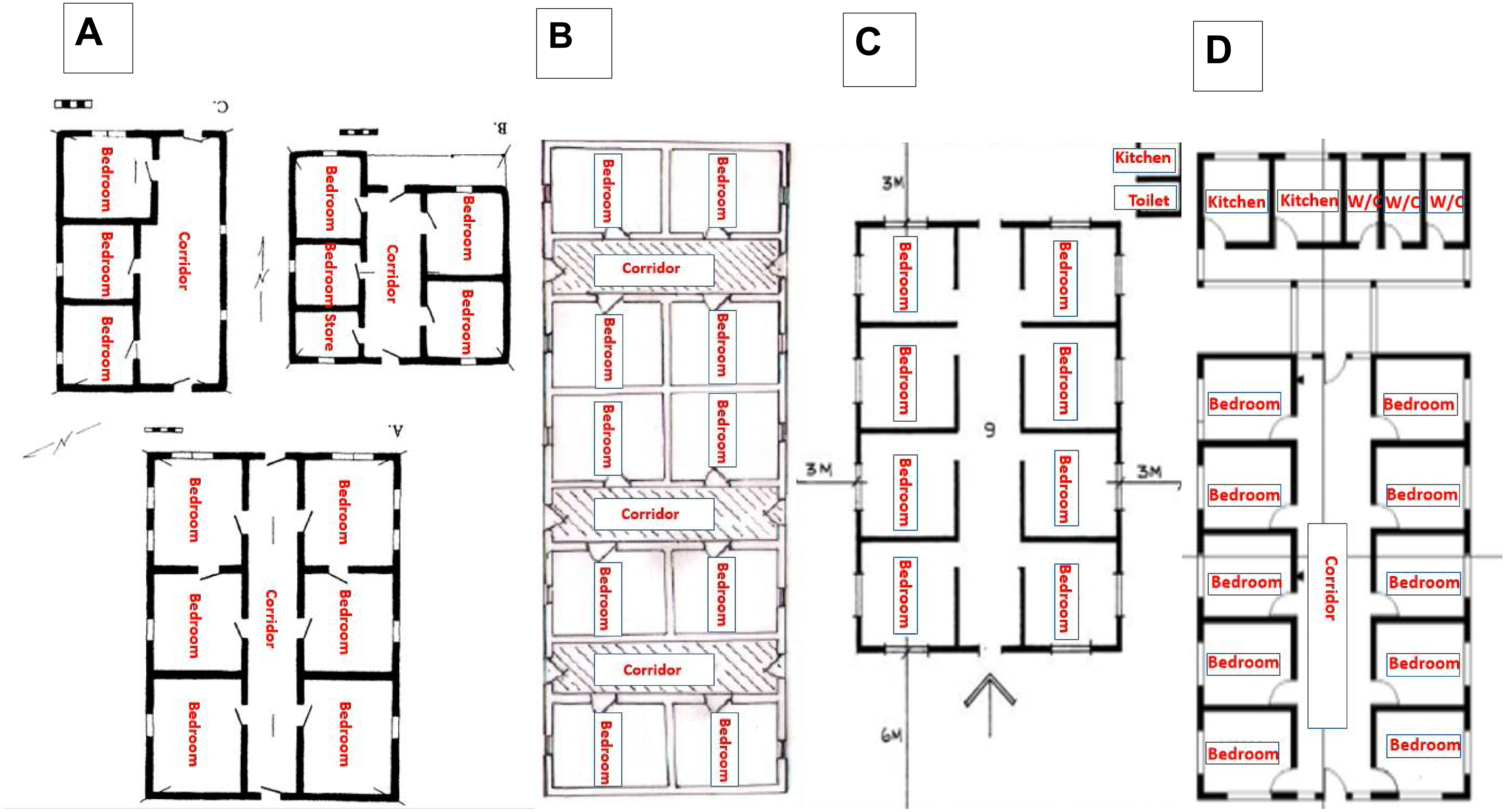

Figure 3-10; Typical variations of Brazilian housing morphology floor plans by Vlach, 1984(A), Igwe,2002(B), Akinmoladun,2007(C), Oyeyinka,2002(D

As illustrated, the common feature in the floor plans is the shared corridor and communal areas (kitchen and bathroom). Due to the immense popularity of this housing within the city, it is likely that the final recruited low-income communities to engage with in developing the prototypes will have this form of housing.

3.3.4 Average household size of low income groups

Household sizes refers to the number of occupants residing within a room/house, who may or may not be related. The National Bureau of Statistics, Nigeria (2009) presented the National average household size as 5 members, closely followed by households with 7 people or more (40%). Households with two persons has 5% while single occupied household were 3%. Noteworthy is 60% of these households live within single rooms.

Average household sizes were also confirmed in studies by Lawanson (2012). The most common number of occupants was documented as 4-6 by 57% of respondents. 7-9 people was documented by 16% of respondents. Larger households of more than 10 people comprised of 4% of all the respondents and were particularly evident in neighbourhoods like Ajegunle (the largest slum area in Lagos) and Mushin.

Another study by Lawanson (2010) involved an assessment of three low-income residential settlements of Ketu, Mushin and Ebutte Metta in Lagos. Household sizes were documented as average of 4-6 (55%) in Ketu, (67%) in Mushin, (59%) in Ebutte metta, all residing in a single room.

3.3.5 Income generation among low income groups

Aluko (2012) stated that historically in Nigeria, income generation, especially among the low-income groups was an intricate part of the domestic realm, through using their domestic spaces for full time occupations. The low-income groups in Lagos, Nigeria survive through the informal sector employment, especially in Home Based Enterprises, also called Household enterprises or unincorporated enterprises owned by households / individuals are distinguished from corporations and quasi-corporations based on their legal status and the type of accounts they hold. They are usually run from their homes or within the vicinity. This reduces costs associated with transportation and payment of rents (Lawanson, 2012).

The reason being that financial limitations prevented low income groups from obtaining loans to finance their intended businesses, leading to the use of their houses to offset additional costs of renting spaces for businesses. Overtime, this led to the necessity to include additional spaces, usually in the layout of their houses. The implication of this was activities/occupations being integrated side-by-side with domestic life, consequently, engaging with trading activities within the domestic setting (Tipple et al, 2002: Lawanson et al, 2012; Aluko,2012)

This is also corroborated in studies across low income communities in Lagos by Aluko, (2012), and Lawanson et al (2004; 2012), where approximately 83% of the working population were engaged in some form of Home Based Enterprise (HBE). Noteworthy is that over time, this has influenced the morphological characteristics of the Brazilian houses by inclusion of shops within these houses. This provides an opportunity to confirm this during the field study.

Pertaining to household consumption/ income distribution, the World bank (2017) estimates the total household consumption for low-income groups in Nigeria in figure 3-11.

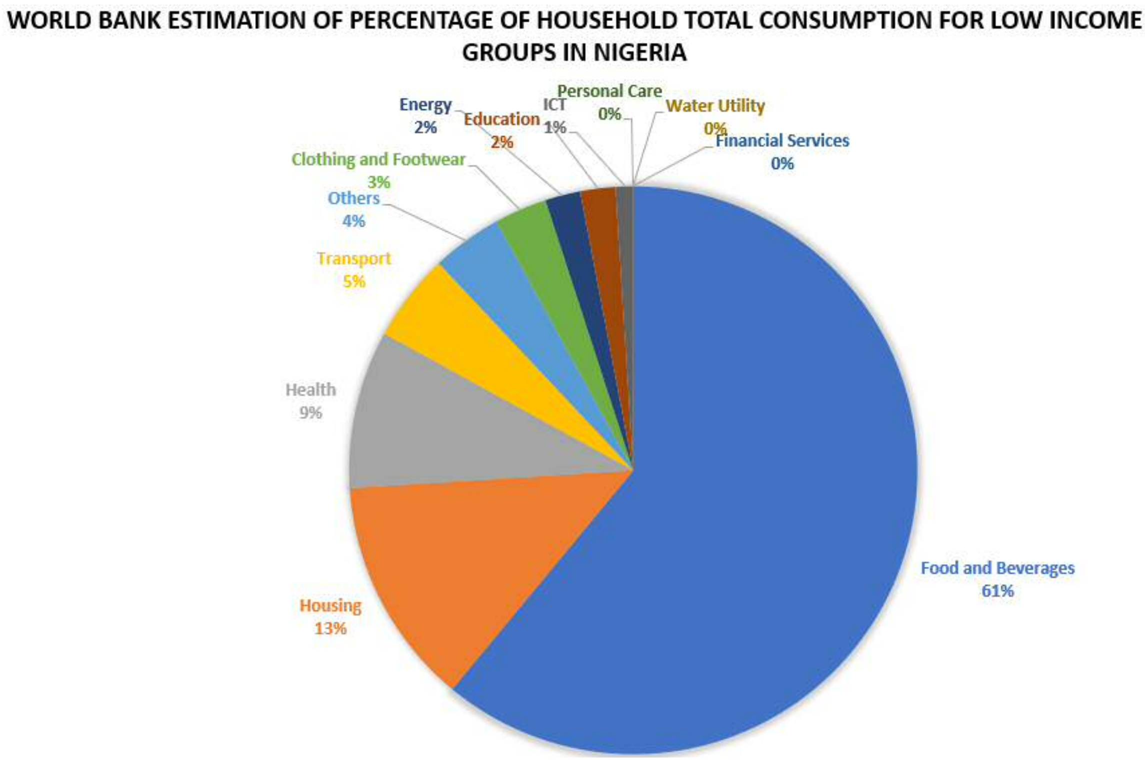

Figure 3-11; World bank estimation of % of household consumption for low income groups in Lagos, Nigeria

As illustrated, 61% (which is the highest consumption expenditure) of their income is spent on food and beverages, followed by housing (13%), health (9%) transportation is 5% and others (4%), clothing and footwear (3%) with energy, education being (2%), ICT (1%). Water utility, personal care and financial services is estimated at 0%.

Further details on the amount of money spent on expenditures by the National Bureau of Statistics (2009) reveals that 63% spends N1000(£4)-N4999(£19.99) on house rent/ expenses, which is approximately 5-25% of the average income of N20,000(£80).

With the average income and consumption habits of the low-income groups discussed, the area where the VGS is likely to fit is either improving affordability of food, through provision of fresh vegetables and physical comfort for free-running houses and reducing energy costs for houses with mechanical cooling.

Household consumption/ income distribution

Figure 3-12, illustrates income classification of Nigerian adult population and challenges of housing supply and finance by KPMG industry overview.

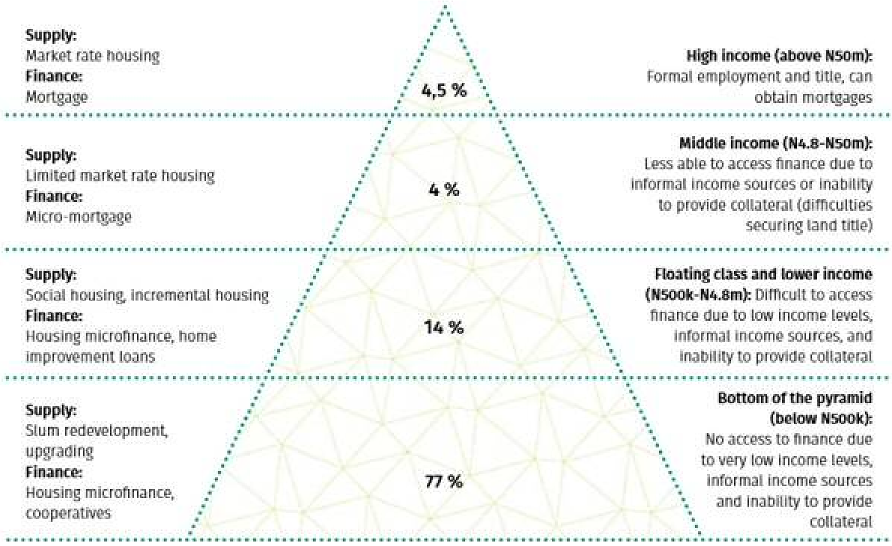

Figure 3-12; income classification of Nigerian adults, source, KPMG.

As evident, 77% of the population have no access to housing finance due to very low-income levels. Further details on income of these groups by the Nigerian National Bureau of Statistics (2009) reveals that at the National level, 80% of the occupants within the households earns income and allowances ranging between N1,000 (£4) and N20,000 (£80) per month. 14% earns approximately N21,000 (£84) and N40,000 (£160), while only 0.9% earned income and allowances of N61,000 (£244)-N100,000 (£400) per month. As corroborated in surveys of low income groups by Lawanson et al (2012) and Gambo et al (2012), where approximately 54% of respondents earned monthly incomes of less than N20,000 (£80) monthly and 25% earned below the national minimum monthly wage of N7,500 (£30), this category of people automatically fell under the absolute poor category. To generate additional income, these groups typically engage in Home Based Enterprises as discussed below.

Hence, the pertinent question pertaining to the affordability of Vertical Greening Systems is 'how affordable is ''affordable''? In other words, how much will these groups be willing to spend in developing/purchasing the prototypes? especially as the perception of what is affordable varies significantly across income groups. Although the estimated monthly average income is N20,000 per occupant i.e N100,000(£400) per household (based on the national average of 5 occupant per household), the amount of money each individual and household might be willing to spend can only be ascertained during the field work. Also, the initial amount of money they might be willing to spend in developing the prototypes could be inspired by the willingness to sacrifice financially for its future gain or indeed they may not be interested in the prototypes at all. Again, these will be addressed during the study.

With the low-income groups and discussions of affordability addressed, the next theme addresses Participatory Action Research and its applicable aspect in this study.

3.4 Critical overview of Participatory Action Research

As previously discussed, there is no individual comprehensive method which encompasses a single response to the multifacted aspect of this research. Thus, while section 3.1 discussed the criteria and components for installing/ developing Vertical Greening Systems, this chapter critically analyses the participatory approach as well as ideologies and principles that could be applied in developing the prototypes within the final selected community.

This overaching approach is that the closest fit in achieving the research aim of developing affordable prototype is the Community Based Participatory Research (CBPR) approach. The term closest fit is used because of the emphasis on equal participation by researchers and local people (community). However, there are challenges and considerations, specific to this research context, that limit the application of the CBPR approach in its entrirety.

This section begins with a general overview of Participatory Action Research(PAR), of which CBPR is categorized under. A comparison with conventional research is undertaken including a discusion and critical analysis of various principles and guidelines proposed across literature to highlight their limitations, advantages and relevance in this research context. The principles to be adopted in the research are then outlined accordingly

3.4.1 Overview of Participatory Action research

There have been discussions in literature on procedures for conducting research with a community, with frequent references to 'Action research, Participatory research, Participatory action research, Community-based research, Community driven development, Community Engagement, Action science, Action inquiry and Cooperative inquiry' (Kemmis and Mc Taggart, 2000; Jones and Wells, 2009). The first emerged from Kurt Lewin (1946) who rejected the positivist belief that researchers study in an objective world, separately from the meanings understood by participants and how they act in their world. His 1946 paper: *"Action Research and Minority Problems,"* described the action research approach as "a spiral of steps, each of which is composed of a circle of planning, action and fact-finding about the result of the action" (Lewin, 1946, pp. 34-35).

The roots of Participatory Action Research can also be traced to the work of Paulo Freire (1970), who believed that critical reflection was crucial for personal and social change. Particularly influential was his 1972 publication, *Pedagogy of the Oppressed*, a critique of colonial oppression, that challenged the positivist tradition that dominated universities and educational systems by arguing that objectivity was a social construct and reality was always subjective (a matter of people's perception often based on their political power) rather than something that could be isolated as an objective truth. Friere (1972) advocated Conscientization, a process through which poor or marginalized groups would first develop an awareness of the social and political forces influencing their lives and then use this awareness to guide their political actions. He advocated that communities were no longer to be passive objects of study, but rather active and equal partners in the research process. His work affirmed that peoples' own knowledge was valuable to community development and the research process.

With the two primary influencers of participatory research advocating the importance of participants in research, it could be said that they emanate from the same ontological paradigm of embracing a participative reality and rely on an epistemology of experiential and participative knowing, informed by critical subjectivity and participatory transaction (Reason, 1994 and Lincoln ,2001).

Building on this, various perceptions on PAR have since been discussed in literature. In terms of its perception of 'collaborations', Kindon, Pain and Kesby (2008: 9-10) defined Participatory Action Research (PAR) as "*a collaborative process of research, education and action explicitly orientated towards social transformation, it involves people who are concerned about or affected by an issue taking a leading role in producing and using knowledge about it*''. Another perspective on collaboration was explained by (Walter, 2009) in terms of Participation and Action. The former being expressed as more than just finding out, but involving an action component that seeks to engender positive change, while the latter being a participatory process that requires the equal and collaborative involvement of the community in the research interest. Further explaining equal partnership, Lucock et al (2007), cited in Farmer (2015) observed that when participants and researchers are equal partners, the research focus and results could be more relevant to the specific community. However, what constitutes and indicates equal partnership remains tenebrous. As further clarity is needed pertaining to questions like: does the research entail equality in making pertinent decisions between researchers and community members? If it does, how does the process maintain a form of order, which is an important aspect of this research context?

Another perspective on PAR which pertains to respecting local people and their knowledge was postulated by Cornwall and Jewkes (1995, pp1) who observed that '*participatory research is about respecting and understanding the people with whom the researcher works, developing a realization that local people are knowledgeable and can work towards analyses and solutions*. *It involves recognizing the rights of those whom research concerns, enabling people to set their own agendas for research and development and giving them ownership over the process…'*

Although these definitions stem from various perspectives of the PAR approach, its specific definition in relation to adapting expensive VGS prototypes to affordable alternatives remains vague. However, what can be learned from their underlying approaches and philosophies are how they differ from conventional methods (as summarized in table 3-3) as this understanding could be used to develop unique methodological approaches as the research unfolds.

Parameters	Participatory research approach	Conventional research approach
What is the research for?	Action	Understanding with perhaps action later
Who is the research for?	Local people	Institutional, personal and professional interests
Whose knowledge counts?	Local people's and scientists	Scientists
Topic choice influenced by?	Local priorities	Funding priorities, institutional agendas, professional interests
Methodology chosen for?	Empowerment, mutual learning	Disciplinary conventions, objectivity and 'truth'
Problem identification	Local people	Researcher
Data Collection	Local people	Researcher, enumerator
Interpretation	Local concepts and frameworks	Disciplinary concepts and frameworks
Analysis	Local people and scientists	Researcher
Presentation of findings	Locally accessible and useful	By researcher to other academics or funding body
Action on findings	Integral to the process	Separate and may not happen
Who takes action?	Local people, with/ without external support	External agencies
Who owns the results?	Shared	The researcher

Table 3-4; Participatory and conventional research, a comparison of processes in terms of their purposes: Cornwall and Jewkes, 1995

As observed, the importance of local people/ community is paramount in the process of PAR. The target, topic selection, problem identification, methodology, data collection and even results are all heavily influenced by the participants (local people), which can be seen to differ significantly from conventional research. Tagum (2012) further explained that the PAR approach enables research participants to increase their knowledge and ideas through valid analysis of social reality leading to more relevant solutions being achieved, with both researchers and subjects of the study gaining more from the research process. Walter (2009) observed PAR as a form of research with practical outcomes that are feasible through community understanding, knowledge and collective activities. Lennie (2006) observed that rather than involving research on' people, it involved research with people, in other words, it generates knowledge through the lived experience of participants. Wadsworth (2008) also stated that PAR involves all relevant parties in actively examining, together, current action (which they may experience as problematic) to change and improve it.

The common themes in the arguments above are that the PAR approach heavily relies on participants and the research problem emanating from them. However, in this study, although the central role of the participants is absolute in this work, the problem identification emanated from the researcher, thus highlighting variation from pure PAR within this thesis. Nevertheless, wider aspects of the research approach are found to be applicable and are discussed during this Chapter.

3.4.2 Community Based Participatory Research method: A critical analysis of its principles and applicability to this study

The difference between PAR and CBPR (Community Based Participatory Research) is that the former may or may not involve a community during research, while the fundamental aspect of the latter relies explicitly on community participation.

Israel et al (1998) defined CBPR as a collaborative process that equitably involves all partners in the research process and recognizes the unique strengths that each brings. It begins with a research topic of importance to the community with the aim of combining knowledge and action for social change. More pointedly, CBPR has been framed as an orientation to research that focuses on relationships between research partners and goals of societal transformation (Minkler & Wallerstein, 2003), rather than a specific set of research methods or techniques. Also, it is often adopted by researchers and practitioners to address health disparities and knowledge exchange/ dissemination among specific groups in rural communities (Simmons et al, 2003: Minkler,2004: Farmer,2015). Although its emphasis on 'community' and views of local participants initially seemed ideal to be adopted in this study, as the research was grounded in the views of the participants, the limitations of this approach are discussed as the chapter progresses

The difference between CBPR and traditional approach as proposed by Horowitz et al (2009) and the relevant applicable characteristics in relation to this thesis is summarized in table 3-4.

Research Phase	Traditional Approach	CBPR Approach	Applicability to thesis
Formative stage	Researchers plan project and form team, including researchers, staff, clinicians	Community and Academic partners plan, project, form team and develop shared mission and decision-making structure	This research did not originate from the target group in this study i.e. the low-income groups, thus, the initial design phase of the thesis did not involve planning with a community.
Study selection/design	Researchers choose topic and design based on scientific theory, academic interest, evidence, data and methodological feasibility	Community and Academic partners also incorporate community priorities, insights and assets, emphasizing rigor and community feasibility, acceptability, context, cultural factors and local knowledge	This was incorporated during the field work as opposed to jointly designing with the L.I.G before undergoing the study. Details of this are presented in Chapter 5, 6 and 7.
Funding	Grant written by researchers, funds go to researcher	Community and Academic partners co-develop grant and equitable division of funds based on contributions to project	Funding was not discussed, since the research problem was not co-developed with the community and the financial capacity of the target group was limited.
Implement study, analyze and interpret data	Researchers solely responsible for study conduct and analyses	Community and Academic partners collaborates on all efforts; traditional analysis supplemented with community driven questions and local relevance of findings	The aim of the study heavily relies on collaboration and local relevance of findings
Disseminate findings	Disseminate to academic audience	Community and Academic partners are coauthors and co-presenters, disseminating to academics, research participants, involved communities and policy makers	Due to the practical nature of the research, the dissemination of findings is expected to be at the community and academic levels.
Sustain team benefits and resources	When grant ends, researchers often move into new project	Sustainability built into work from inception; partners honor initial commitment to continue partnership and work beyond funding cycle	Opportunity for further study and future collaboration

Table 3-5; Traditional and CBPR approaches a comparison in terms of their development (Horowitz et al 2009)

Minkler (2003; 2004) stated that to apply the CBPR, it was imperative to underscore the key elements of approaches it characterizes and explore the ethical challenges such work may entail. A brief overview of these principles, steps and procedures across relevant literature are summarized and their potential level of applicability to this study are outlined below. The four principles to be addressed are:

- Principle 1: The definition of community
- Principle 2: CBPR is participatory
- Principle 3: CBPR is a co-operative and co-learning process
- Principle 4: CBPR is an empowering process

A brief overview of these principles, steps and procedures across relevant literature are summarized and their potential level of applicability to this study are outlined below:

3.4.2.1 Principle 1: The definition of community

(Green et al 1995; Selenger 1997; Kemmis and McTaggert 2000 and Krishnaswamy 2004) postulated that the research problem or study emanates from the community itself. The first part of the criticism relates to the definition of community. However, in terms of community definition, MacQueen et al (2001) argued that the absence of a commonly accepted definition of community could lead to different researchers developing contradictory assumptions about community, thus undermining the effectiveness of this approach.

Cooke and Kothari (2001) criticized the definition of community in the CPBR approach by stating that *''community is often condensed to a homogenous, harmonious, competent entity, characterized by solidarity relations, often believing that they are capable of everything which is unrealistic as they will always be certain limitations''*. Minkler (2004) argued that there could be a confusion between *'community placed'* or *'community based'* as this may not always be definitive or straightforward. Further corroborated by Walter (2009), who observed that categorizing a group with shared interest or problem as a *'community'* does not automatically result in a consensus on the specific problem and the ideal means of addressing it. Implications of this were described by Horowitz et al (2009) as representatives in communities being relegated to passive participants in studies or reacting to researchers as part of community advisory boards, merely assisting with recruitment. Cornwall and Jewkes (1995) also argued that communities constitute groupings of diverse individuals who might for example, be differentiated by wealth, religion, sexual orientation, and education, to name just a few. With these inconclusive arguments on what constitutes a community, it can be inferred that the definition of 'community' is debatable. However, in this research context, community is defined primarily by income and within a definable geographical area/space.

Thus, in relation to this study, the definition of community is *''a group of people with diverse characteristics who are linked by social ties, share common perspectives, and engage in joint action in geographical locations or settings*'' Macqueen et al (2001).

In this context, it refers to the low-Income groups in Lagos, Nigeria as defined by their income, surviving on less than a dollar a day and living within the same vicinity.

3.4.2.2 Principle 2: CBPR is participatory

Reason, (1994); Israel et al (1998); Green et al, (1995); (Atack 1999, cited in Minkler 2004) and Stoecker (2008) described it as a participatory methodology which entailed people being actively involved at all levels of decision making. It is to be an end in itself because of its crucial contributions to the empowerment of local communities and not merely a means for completing projects more efficiently.

Although this principle might appear agreeable on paper, it could be vague when implemented during the field study. This is because it doesn't take into account unanticipated but pertinent criteria that might influence the successful implementation of the approach. For instance, describing it as *participatory* raises pertinent questions: *'what entails participation in a community research'?* For whom are we participating? Are communities homogenous enough for general principles and approaches to be effective? If not, how can true participatory research be achieved? What are the criteria to determine true participation with the community?

Cornwall and Jewkes (1995) questioned the authencity of the process suggesting that what researchers term as participatory might be the use of rapid rural appraisal to engage community members as informants. A provocative argument was postulated by Cooke and Kothari (2001) by stating that the inclusion of '*participation'* into projects is often a political and strategic tool by development organizations to market their projects to donors. They further explained that project agencies always 'own' the process and it is therefore not always fully participatory. While this is debatable, it evolves a thought-provoking process on how this aspect can be clarified and explicitly defined within this research.

Another school of thought from (Aimes 2001, cited in Minkler 2004) observed that there is disagreement on the definition of participation among scholars and practitioners. Some use the term to mean active participation in political decision making, for others, it has no meaning unless the people involved have significant control over the decisions concerning the organizations to which they belong. Others argue that participation could be an end in itself. More flexible approaches were postulated by Cornell and Jewkes (2005) who stated that the terms 'participatory', 'participation' and 'participant' create spaces for a range of applications and confusion. They further advocated that participatory methodologies should be reflexive, flexible and iterative. Further, Wallerstein et al (2008) argued that the central issue of participation is where power lies. With no singular outlook on what entails participation in CBPR literature, this automatically questions the application of the aspect to this study.

As mentioned before, the second critique of this principle relates to the source of the research topic, as CBPR typically involves this being derived or emanating from the community itself, which was not the case in this study. This might be considered to have an influence on the scale and scope of participation of the selected community, either negatively or positively.

3.4.2.3 Principle 3: CBPR is a co-operative and co-learning process

Israel et al (1998) stated that CBPR is co-operative, engaging community members and researchers in a joint process to which each contributes equally. It was explained as a co-learning process by (Hatch et al 1993, cited in Minkler 2003) as "*researchers transferring tools for community members to analyse conditions and make informed decisions on actions to improve their lives and community members transferring their expert content and meaning to researchers in the pursuit of mutual knowledge and its application to their communities" (Minkler 2003)*.

It is a process that facilitates a more accurate and authentic analysis of social reality, with the researcher being a participant, facilitator and learner. This is especially important considering the live and realistic context of the study. The critique of this principle lies in the non-description of the process for this to be achieved under different contexts and communities. It also doesn't consider factors such as the role of culture and the possible impact it might have in trying to achieve this.

Pertaining to the description of the CBPR as a co-learning process, this is only possible with the full and unhindered co-operation of both the researchers and community, which might not always be realised. Also, the achievement of this principle might be unstraightforward and challenging. If this is encountered during the field work, should the research process be abandoned due to lack of co-operation from the community? Or should other means of achieving this be explored, despite not having been previously considered prior to the field work? These questions reveal that the process of achieving the research aim is just as important as the pre-set principles.

3.4.2.4 Principle 4: CBPR is an empowering process

CBPR was described by Selenger (1997) as an empowering process through which participants can increase control of their lives: often encompassing those marginalized from society, including the poor (which is the target group in this study); and creating greater awareness in individuals own resources that can mobilize them for self-reliant development (which is part of the objectives of this study). This involves building trust and achieving a balance between research and action (Krishnaswamy, 2004). However, its description as a balance between research and action is not definitive.

Hence, the underlying question to this principle is *'Is all research that involves community members always beneficial to them? If the research is successfully undertaken, does it guarantee that it will always empower them?'.* Especially if the research problem does not necessarily emanate from the community as in the scenario of this study. While the hypothesis of this thesis postulates that the VGS will empower and benefit the low-income groups, the result may not necessarily be empowering for all involved.

Summary

Despite the various arguments and proposals on approaches to community research, in which some were identified to be relatively applicable to this study, it has been observed that it does not constitute a homogenous, single, clear-cut development strategy, rather it is characterized by the presence of diverse approaches and empirical implementations (Leeuwis,2000; Dahl-Ostergaard et al, 2003; Hickey and Mohan, 2005; Manzo and Brightbill, 2007). Also, given its relatively new focus in general, the principles of CBPR have not been applied exhaustively in all contexts, nor have they been fully documented. Hence, it is appropriate that they inform, while not being completely adhered to, within this study. Also, the unpredictability of human nature and behaviour is often ignored as observed by Cooke and Kothari (2001), who stated that actions of humans should be seen as a process, in which not every activity is reasoned or motivated. Thus, defining principles or methods of engaging with a community might not always apply.

As further explained by Minkler (2008), the emancipatory approach of CBPR is difficult because the actual research practice may vary with the local context, history and ideology of the stakeholders. In relation to this research context, there were unanticipated challenges pertaining to literacy, deeply engrained cultural perceptions and general mistrust towards researchers, that are not considered in the principles and approaches of CPBR, nor were these identifiable prior to this work, but these emerged during the research process itself[5].

Cooke and Kothari (2001) also observed that the *'tensions within cultures being rarely debated and often by-passed with focus on 'social glue' and 'solidarity"*. It is also observed that since CBPR mostly involves work with low income communities, there is a tendency for the researcher not to have common ground with the participants, thus, opportunities for cultural misunderstandings are more pronounced, consequently compromising the effectiveness of the approach.

The criticisms and limitations of the CBPR approach to this study have been highlighted, with the conclusions being that 'community' and 'participation' are debatable constructs and that the approach to CBPR is not fully defined, rather postulated as various proposals in literature. Also, it is important to note that human nature is unpredictable and cannot be guided by defined principles, rules or approaches. Leading to a key question: If unanticipated circumstances are encountered, should the research be abandoned? With the critical discussion of participation and community above as well as the challenge of fitting the research within definable principles and approaches, the next sections glean and define what might be applicable from this approach within this research context

3.4.3 The closest fit of Community Based Participatory Research approach in this Study

Although the role of CBPR in developing a Vertical Greening Systems has not been documented in literature, relating it to this research, it could be defined as an active process by which beneficiary/client groups influence the direction and execution of a development project with a view to enhancing their wellbeing in terms of income, personal growth, self-reliance or other cherished values. While the important essential elements that influence the performance of VGS have been gleaned from relevant literature, the participatory aspect involves important in-put from the community on adapting this complex technology. In other words, involvement with the community will heavily influence the outcome of the prototypes, especially in terms of their affordability. The detailed process of how this will be achieved relies

[5] This is discussed in Chapter 6

on the outcome of participation during the field work. However, in terms of physically fostering participation within communities, Cooke and Kothari (2001) observed that that '*willingness for individual action was often reduced to economic incentive'*. They argued that literature was often vague about specific incentives to encourage participation and other reasons to encourage participation were not highlighted which could include their desire for respect. Thus, selection of a community for participation depends solely on their interest and co-operation, which will inform the final selected community or location to conduct the research. This is discussed in detail in Chapter 4: Recruiting Communities for Participation (Documentation through Researcher's experience) and Chapter 5: Housing Selection within Agege Community. The strengths of CBPR, most cited by Webb (1990) and Israel (2001) that could be incorporated during the study include:

- ✓ **Allowing innovative adaptation of existing resources**, which in this research context is the adaptation of Complex VGS into simple prototypes by the community.
- ✓ **Exploring local knowledge and perceptions**, which is part of the objective, to develop ideas grounded in the views of the participants.
- ✓ **Empowering people by considering them as agents who can investigate their own situations**, which entails shifting power and decisions to the community.
- ✓ **Encouraging the community input to enhance project credibility**, which involves attempts at ensuring maximum participation and valuing inputs.
- ✓ **Joining research participants who have varied skills, knowledge and expertise to address complex problems in complex situations**, which is part of the range of skills needed to physically develop and assemble these prototypes.
- ✓ **Providing resources for communities involved, through its collaborative nature**, this entails sourcing of materials and development of indigenous ideas that could be incorporated into the prototypes.
- ✓ **Providing a forum that can bridge across cultural differences among participants and helping to dismantle lack of trust communities may exhibit in relation to research**. However, this might not be straightforward and was encountered as a barrier which will be discussed in the next chapter.

With the points listed above, the importance of community leaders as gatekeepers in facilitating the study is presented in section 3.4.4. However, the final details and methods of implementation will emerge during the field study, details of which are discussed in Chapter

6: Participatory development of Vertical Greening Systems. The next section discusses the need for identification of gatekeepers[6] prior to engaging with communities

3.4.4 Emergence of low-income communities and the influence of Community Leaders as potential gatekeepers for proposed field study

This section briefly reviews the emergence of low income communities, the roles of Community Leaders/ Chiefs (known in the local Yoruba language as Baales) and the power / influence they have over the community members. This is to postulate their roles as potential gatekeepers for the researcher to engage with the final selected low-income community. This is particularly important because as explained by Cornelius,1973

> *"anyone who does extended fieldwork in squatter settlements or related types of low-income zones cannot fail to be impressed by the importance of leadership differences in accounting for the developmental trajectories of each settlement. ….…" Cornelius, 1973, pp 136*

The Yoruba's are one of the largest African ethnic groups south of the Sahara Desert (Johnson, 1921: Moore, 2010). Lagos was originally inhabited by the Awori subgroup of the Yoruba people who migrated to the area from surrounding towns such as Isheri, around the 15th century (Lagos state official website, 2012). Along with immigration came existing traditions, customs and traditional leadership hierarchy. For this thesis, only the traditional leadership hierarchy and its importance is overviewed. Historic emergence of communities and community leaders was also explained by Johnson (1921) as ''*migration emerged through individuals attracting others to a spot he/she newly discovered. These areas usually evolved into sites for public activities such as markets or farmsteads, eventually leading to the development of villages or hamlets. Once these developed, the necessity for order and control became apparent, leading to a decision that the individual who first discovered the area was considered as the Oba (King) of the village. This becomes hereditary with either the son or brother succeeding in perpetuity. Once elected, he appoints chiefs and other officers of the town.*

Ológundúdú (2008) further explained that the hierarchal leadership was more complicated than the basic political unit as the town/ village (ilu). He explained that a typical Yoruba kingdom was made up of many towns, villages, markets and farmsteads, one of which served as the capital town where the King (Oba) lived, who claimed descendancy from Oduduwa[7] . Eades (1980) further explained that the leading Oba, was the wearer of a beaded crown, either bestowed on by his ancestor or selected according to local custom. Johnson (1921) stated that each settlement was then organized in a hierarchical form and the component lineages were headed by male adults called Baale (Chief), who oversaw the administration of the town.

[6] individuals who have the power or influence to grant or refuse access to a field or research setting
[7] Traditionally believed to be the ancestor of all kings.

Power and influence of Community Leaders

Although Johnson (1921) documented that the traditional government of the Yoruba people as an absolute monarchy, where the King was dreaded and revered more than local deity or gods, (Smith, 1988 and Onadeko,2008) argued that the sacred aspect of Yoruba kingship did not lead to the Oba becoming an autocrat but rather the reverse. Not only was he bound by rules and precedents in his personal life, but these also required him to submit all business to councils of Chiefs (Baale) and officers, and only after consultation and deliberation by these bodies could a policy be decided upon and proclaimed in the Oba's name (Ayittey,2012). Also, the Yoruba culture of reverence, respect and regard for the elderly and those in authority further solidified their power (Ajala, 2006).Subsequent colonization by the British in the 19th and 20th century did not jettison this traditional leadership structure, rather, it was incorporated under the indirect rule which was a system of colonial administration, in which colonial powers ruled through local chiefs as introduced by Frederick Lugard (1922), published in *'The Dual Mandate in British Tropical Africa'* .

Today, although the Lagos State system of governance is the tripartite separation of powers system consisting of the Executive (Office of the Governor) , the legislature (House of representatives and Local Government Chairman) and the Judiciary (High court). The traditional structure which holds no official political power still exists and is still influential due to the perception and deep respect by the communities. Such is their influence that today, they are often sought for counsel and sponsorship by politicians (Ojo ,1988; Akintoye, 2010). According to the Lagos State Official website (2013)

> *''They exist as the Lagos State Council of Oba's and Chiefs as a body, which has the capacity to enhance good governance in the state by constantly availing government of its wisdom and sound advice: using its tremendous influence to mobilize popular support for public policy as well as being an important source of communication and feedback between the government and the grassroots. The Institution of the Council of Oba's and Chiefs is a critical building block that the government engage with for development and orderly societal growth''….*

Further explained by Olukoju (2005), in a paper titled '*Actors and institutions in urban politics in Nigeria: Agege (Lagos) since the 1950's'*, who highlighted the roles and relevance of Community Leaders (Baale's) and their importance as middle men to the Lagos state Government. He noted that regardless of the prevailing government (military or civilian), traditional authorities were always consulted on issues of crime, law and order, mobilization for development, land and chieftaincy disputes etc. Other responsibilities by the traditional authorities was harnessing and coordinating the efforts of the people with those of the government to effect improvements in the social and economic conditions to enable them to participate meaningfully in national development. Thus, their roles are still important today.

Worthy to note are slight variations in hierarchical structures across communities often adopting a decentralized approach in which the Baale appoints other community heads on each of the streets (Lawanson et al, 2011).

Community Leaders as potential gatekeepers for field study

Typically, gatekeepers are influential members of the community and may or may not be Community Leaders. To conduct field studies within low income communities, the researcher must identify relevant gatekeeper(s) and focus attention on gaining their support and cooperation (UNCHS, 1988). With the roles and power of Community Leaders outlined, it is apparent that they are the obvious choice as gatekeepers within the final selected community in this study, due to their power, influence, relevance and recognition by the Lagos State Government. Also, as this study is a dichotomy from community development projects they might have been accustomed with such as borehole projects etc., the need for an influential community member such as the community leader is important as it involves active participation and exchange of ideas, which might not be what they have been accustomed.

However, identifying key leaders is not without challenges UNCHS/HABITAT (1988) observed that to successfully undertake community engagement, spending sufficient time to identify key leaders in the community is vitally important. Yet it is also difficult to achieve since researchers/ agencies usually have limited time and finance. Short-cuts at this stage may result in alienation from leaders, a subsequent lack of cooperation and major obstacles to project implementation. Also, community members may be reluctant to identify their leaders to outsiders, probably due to mistrust. Furthermore, leaders may resent the fact that preliminary enquiries have been made without their approval or permission. Another challenge is that in some settlements there is more than one leader and the researcher may miss the most influential one.

Once they are identified, it is important that trust is built with them and be culturally aware of actions that might be perceived offensive. For instance, the left hand could not be used to hand out objects or be extended for handshakes due to its belief that it is reserved for personal toiletries and thus considered dirty and offensive, which could discourage participation (Ológundúdú, 2008; Akintoye, 2010; Olajide, 2010) . Also, pertaining to incentives, monetary incentives could be considered inappropriate and disrespectful. Hence, the detailed process of identifying and engaging with the community leaders is likely to be a unique experience and is relayed in Chapter 4: Recruiting Communities for Participation (Documentation through researcher's experience)

3.4.5 Establishing the Role of the Researcher

The role of the researcher has been debated in PAR as an applied research approach in which participants, those with a stake in the outcomes of the research, take on active co-researcher roles (Carr and Kemmis, 1986; Greenwood and Levin, 1998; McAllister and

Vernooy, 1999); where researchers enter into a collaborative partnership with participants to facilitate improved practice through the direct application of research findings in a practical context. Walter (2009) emphasized the need for equal and open collaboration between the researcher and research community, which is central to PAR. She advocated that the subject group are the owners and instigators of the research rather than the researcher, however this does not always apply, especially in this context, as the researcher is the initiator of the research idea. Further, explaining the role of the initiator, Stoecker (2008), observed that while the role can be useful in community research, the critical need for skills in community organizing and groups dynamics was important in helping to shift control to the community.

Other recommendations on the need for clarity regarding the position of the researcher including Webb (1990); Adler and Adler (1991) observed that the researcher should be either emic-insider[8] or etic [9]. However, Minkler (2004) noted that the notions of participation should be flexible enough to consider the culture and social environment of the community members with whom we work, to reflect critically on our own role as outside researchers in relation to them. It was observed that although PAR requires sensitivity to the relationship between insiders (the participants or community) and the 'outsiders' (the research team), it should recognize that what constitutes 'success' in the conduct of a project is likely to differ between these two roles.

Thus, while the researcher could be classified as an active participant, being the instigator of the research, care will be taken to ensure that those who participate feel equally important, in other words, no opinion will be ignored, as people perceive when their views are not respected which could compromise effective participation.

Also, there may be no definitive role that the researcher might assume during the field work, hence, the classification as an active observer with guidance notes jointly decided with the community is ideal. The specific roles adopted by the researcher are listed as:

- Identification of Community Leaders to facilitate community participation
- Locating ideal Case Study Houses within the community and obtaining necessary permissions to conduct research.
- Locating, identifying and engaging Participants with specific skill set to design and physically assemble prototypes.
- Bearing all financial and logistics cost
- General co-ordination of activities including data collection and managing conflicts

Worthy to note is that not these roles are pre-defined, but where appropriate, these will arise during the research process and will be documented accordingly.

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[8] defined as a full participant in activity, program or phenomenon

[9] from an outside view.

3.4.6 Ethical considerations in CBPR

Various proposals in CBPR literature on ethical considerations are usually listed as:

- **Community collaboration** (involvement, mutuality, reciprocity, credit, shared leadership, trust, transparency, authencity),
- **Community significance and joint ownership of data** (Brugge and Kole, 2003; Manzo et al, 2007; Jacklin and Kinoshameg, 2008).

Another school of thought from Holkup et al (2004) observed that it might be difficult to anticipate all the ethical dilemmas that may arise during a CBPR project, but it is important to be sensitive to the people involved in research.

Noteworthy is that the primary ethical considerations for this study is borne from the general mistrust towards researchers by the members of low income group in Lagos[10]. This culminated in the need for focus on: respect of their privacy request; as well as honesty, openness and transparency on the purpose of the research as presented by the researcher. Also, every aspect of participatory development that the community was involved with was duly acknowledged, documented and referenced. The details are outlined below:

- **Benefits to the participants:**

The research is perceived to be potentially beneficial to the participants both on short and long-term basis. This informs the motivation to conduct the research within the selected community.

- **Privacy:**

This entails guaranteeing anonymity to all participants where requested: this included photographing and naming of participants.

- **Referencing/ credit**

This entails giving credit to anyone involved and accurately documenting all contributions made by members of the community.

- **Openness and Trust**

This entails being open about the intention of the study and expected roles that the community members are expected to play. This includes showing them the necessary form of identification should the need arise.

- **Division of Labour**

Since the study will involve members of the community, it is expected that the roles and labour is fairly assigned without any person(s) taking more roles than expected.

- **Respect**

The desire for participation stems from respect of the community's skills, knowledge and contributions. Also, the community perception of respect on the part of the researcher might

[10] Details of this is discussed in Chapter 4

influence the degree of active participation, subsequently influencing the achievement of the overall aim of the study

- **Rigor of research and fidelity to findings**

This involves documenting the process of the research in detail, duly acknowledging the contributions made by the community members and the researcher.

3.4.7 Overview of projected methods and means of engaging with the community

Although all methods of engaging/ communicating with the final selected community may not be anticipated prior to the field work, the primary projected means may include;

- **Observations**

Observation is a technique of data collection in which the situation or the behavior of research subjects is watched and recorded without any direct contact or intervention (Bryman 2005). This is expected to be undertaken prior to engaging with the final community.

- **Meetings**

This will involve assemblies of community members first for the purpose of acquaintance with the researcher and intent of study and then joint decisions pertaining to the design/ construction of the prototypes.

- **Cues and Visualizations**

This was informed in prior participatory studies by Cornwall and Jenkins (1995) who suggested the use of visualizations to provide opportunities for local people to explore, analyse and represent their perspectives in their own terms. This will be incorporated when needed.

- **Sketches**

Idea generation techniques, like brainstorming are commonly applied by designers to come up with design ideas. Idea generations during design meetings, such as expected during the prototype designs are usually communicated through drawings/ sketching. Lugt (2005) stated that the relevant functions of sketching are:

- To support a re-interpretive cycle in the individual thinking process, which includes access to earlier ideas. In this study, especially during design meetings, it is likely that more than one individual might communicate ideas at the same time. Hence the need to sketch.
- To support re-interpretation of each other's ideas in group activity. This is especially important to ensure order during the design meetings

This means of idea compilation with the final selected community is expected to be spear-headed by the researcher.

Conclusion

With the analysis of the multifaceted themes in this study, which are: Vertical Greening Systems, Occupants thermal comfort, Participatory action research and low-income groups, the relevance of these themes are incorporated within the field studies undertaken (in Chapters 4, 5, 6, 7).

Chapter 4; Field work: Recruiting Communities for Participation (Documentation through researcher's experience)

Research can be considered as a process rather than a single event, it is often likened to a journey by the researcher than a task”
(Roberts, 2004)

The previous Chapter discussed applicable aspect of CBPR (Community Based Participatory Research) to be undertaken in this study, while developing various/unique methodological approaches to the participatory aspect of this study. In other words, unanticipated factors that simply did not fit the mainstream research, but was however been inclined to (CBPR) needed to be accounted differently, thus informing this Chapter.

It describes how informally organized heterogeneous communities within Lagos, were approached to be recruited to take part in this research. The practicalities and peculiar experience[11] encountered by the researcher, including the approaches, limitations and challenges specific to this context are classified under subsections and discussed accordingly. This culminated in specific actions undertaken in selecting the communities within which the study was conducted. This is documented as the four- steps undertaken to approach them, which evolved during the field work as illustrated in the figure 4-1. Other important aspects discussed include the historical emergence of community/ traditional leaders and their relevance while undertaking this research.

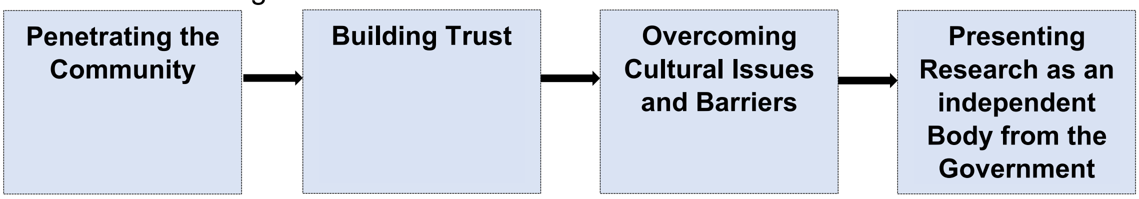

Figure 4-1; Four-steps undertaken to approach selected communities, source, Author, 2014

These steps are discussed briefly to describe the experience of the researcher in various attempts to select community case studies. For instance, the 2nd step was reached in certain communities but could not progress due to some unanticipated challenges which are discussed accordingly. Table 4-1 summarizes the communities approached and the stages reached in each of them. The experiences in each community are detailed later in this chapter.

[11] Such as factors pertaining to cultural inclination and the impact they had are documented.

Four steps undertaken, and stage reached in each Community	Areas/Communities Approached			
	Mushin	Ajegunle	Ipaja	Agege
Penetrating the Community	●	●	●	●
Building Trust				●
Overcoming Cultural issues and Barriers		●	●	●
Presenting the Research as an independent body from the Government				●

Table 4-1; Stages reached in approached community

4.1 Location of potential Case Studies

The influx of migrants from Rural areas into Lagos has been discussed briefly in Chapter 1. The major reason being the perception of the city as a centre of opportunities and perceived better quality of Life (Abiodun,1993; Agbola,2007; Aduwo, 2011; Aworemi et al, 2011). The implication of this is uncontrolled and unplanned immigration leading to increase in Low Income Groups. This led to a common phenomenon where undeveloped land was taken over by these groups to satisfy their urban land needs (Agbola ,2007 and Jiboye,2011). Overtime, such invasions usually led to uncontrolled and unorganized developments of sub-standard and overcrowded houses that characterize typical low-income communities in Lagos, Nigeria. Thus, the key general criteria for the community to be selected for this research was the need for it to be densely-populated to capture the common characteristic of overcrowding as documented in relevant literature (Akom 1984; Aina, 1988; Lawanson et al,2012) and the predominant housing morphology (which is the Brazilian housing morphology described in Chapter 5) for the sites to develop the prototypes being located within such communities.

To achieve this, the 15 officially recognized Local Government areas within Lagos state was identified. Sequel to this, the most populated areas within these areas (highlighted in red) were selected to be approached (as shown in table 4-2)

	Local Government	Male	Female	Total
1	**Agege**	**564,239**	**468,825**	**1,033,064**
2	**Ajeromi-Ifelodun**	**723,644**	**711,651**	**1,435,295**
3	**Alimosho**	**1,099,656**	**947,370**	**2,047,026**
4	Amuwo-Odofin	301,012	223,959	524,971
5	Apapa	264,728	257,656	522,384
6	Eti-Osa	460,124	523,391	983,515
7	Ifako-Ijaiye	380,112	364,211	744,323
8	Ikeja	328,778	319,942	648,720
9	Kosofe	527,539	407,075	934,614
10	Lagos-Mainland	326,433	303,036	629,469
11	**Mushin**	**684,176**	**637,341**	**1,321,517**
12	Ojo	507,693	433,830	941,523
13	**Oshodi-Isoko**	**514,857**	**619,691**	**1,134,548**
14	**Shomolu**	**517,210**	**507,913**	**1,025,123**
15	**Surulere**	**698,403**	**575,959**	**1,274,362**
	Total	7,898,304	7,301,850	15,200,154

Table 4-2; Population breakdown of Local government in Lagos, Nigeria, source; Lagos state official website, 2012

2002 survey of the megacity by Nubi and Omirin (2006) revealed that over 70% of the built up area of the metropolis was blighted and are scattered though out the city. However, for easier identification of these areas, a total of 42 areas, officially classified as blighted areas within these Local Governments were identified. Within these areas, the precise locations of the low-income groups were identified based on official classification of these areas as urban poor communities by the Lagos state official website (2015) and UNDP (2000), as adapted in previous studies on low-income groups (Akinmoladun, 2007; Ahianba, 2008; Agbola, 2007; Asojo, 2010; Aduwo, 2011; Aluko, 2012; Opoko, 2011; Lawanson, 2012; Lagos state official website 2014). The precise location of these local government areas within the city are shown in Figure 4-2:

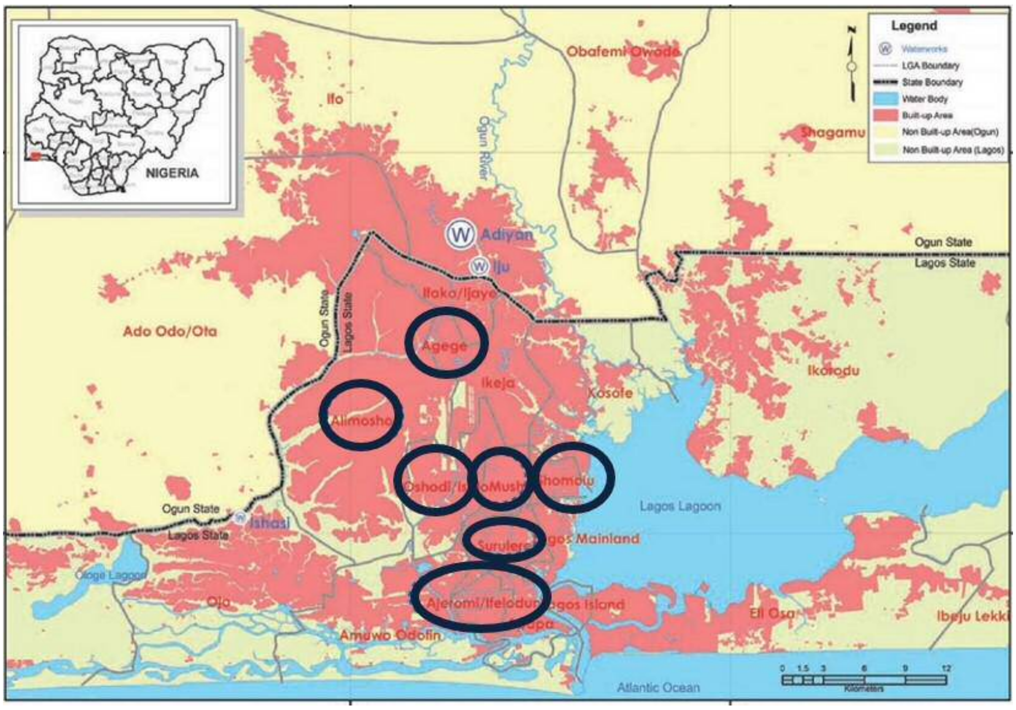

Figure 4-2; Locations of the 7 most populated local government areas by the low-income groups in Lagos, Nigeria, source: Lagos state official website, 2014

The officially classified blighted communities within these local government areas are illustrated in figure 4-3.

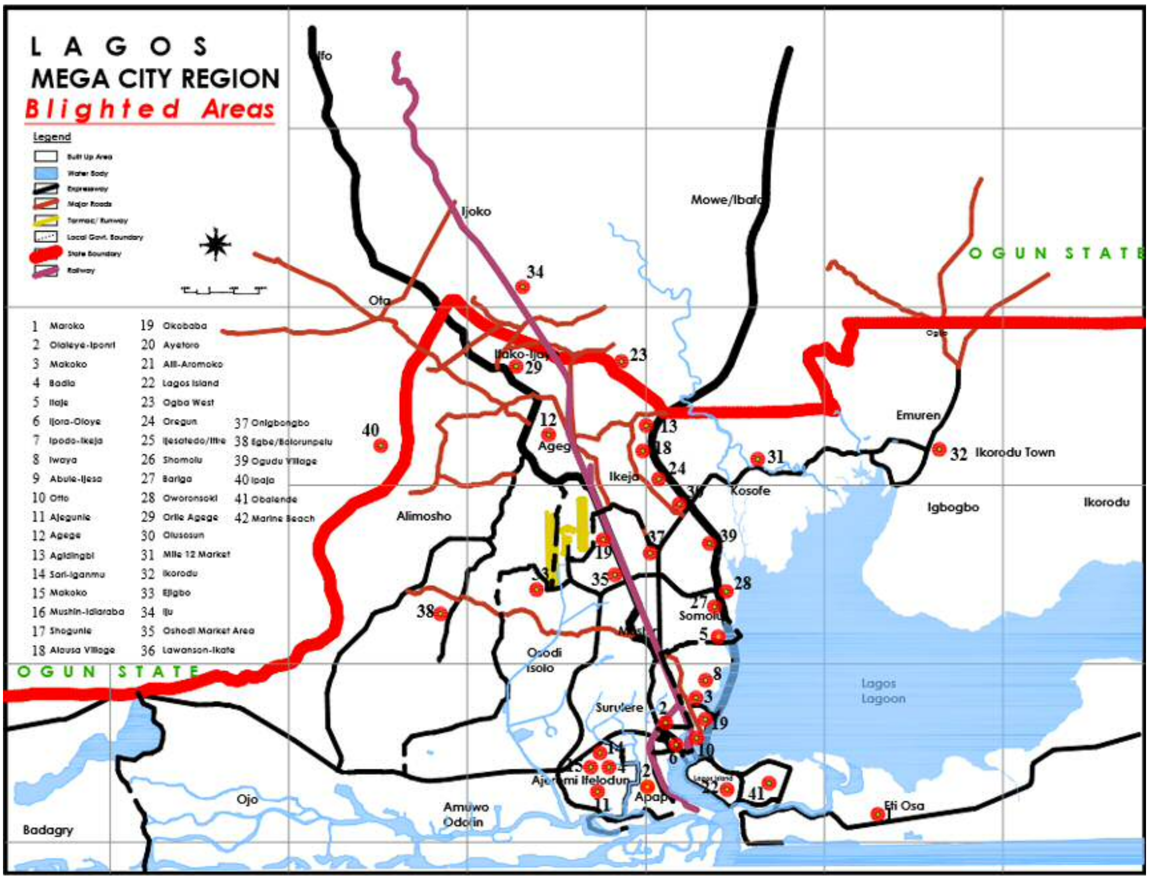

Figure 4-3; Locations of low income groups in Lagos, Nigeria, Source, Lagos State Official Website, 2013

With the identification of the officially classified blighted communities within the local government areas, the final 7 most populated areas within these communities were selected as illustrated in table 4-3. This number was selected due to the time required to approach these areas and the limited timeframe of the research.

Local Government	Most populated blighted area within the Local Government
Agege	Agege
Ajeromi-Ifelodun	Ajegunle
Alimosho	Ipaja
Mushin	Mushin
Oshodi-isolo	Oshodi (Market area)
Shomolu	Shomolu
Surulere	Olaleye Iponri

Table 4-3; Locations of selected blighted areas within the Local Government areas

However, due to failed attempts in recruiting the communities and the limited timeframe available for this survey, a total of 4 areas were randomly selected from these, namely Agege, Ajegunle, Ipaja and Mushin. The location and dates of approach for each area are presented according to the dates the communities were approached.

4.1.1 Mushin (Mushin Local Government)

Mushin Local Government is located right in the heart of Lagos State. It is predominantly a commercial hub with almost every street engaging in trading activities. It shares boundaries in the North with Oshodi -Isolo Local Government, in the East with Shomolu and the south with Surulere. (Mushin Local Government Official Website, 2014) This was the first area approached, on the 10th of April 2014

Figure 4-4; Location of Mushin in Lagos, Nigeria, Source, google maps 2014

Plate 4-1; Street view in Mushin, Lagos, Source: jao, 2014

Plate 4-2; Commercial Hub in Mushin, Lagos, Source: jao, 2014

Plate 4-3; Residential neighbourhood in Mushin, Lagos, source, jao, 2014

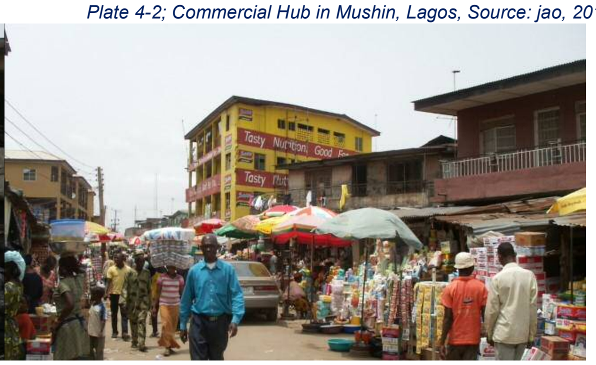

Plate 4-4; Typical Street in Mushin, Lagos, Source, jao, 2014

4.1.2 Ajegunle (Ajeromi-Ifelodun Local Government)

Ajegunle is located in Ajeromi-Ifelodun Local Government, the south of Lagos and is a major slum, unofficially referred to as 'the jungle city' (Agbola, 2007). It is comprised of 335 streets. It is bordered on the west by Apapa Wharf and Tincan, two of Nigeria's biggest sea ports. This area was approached on the 14th of April 2014.

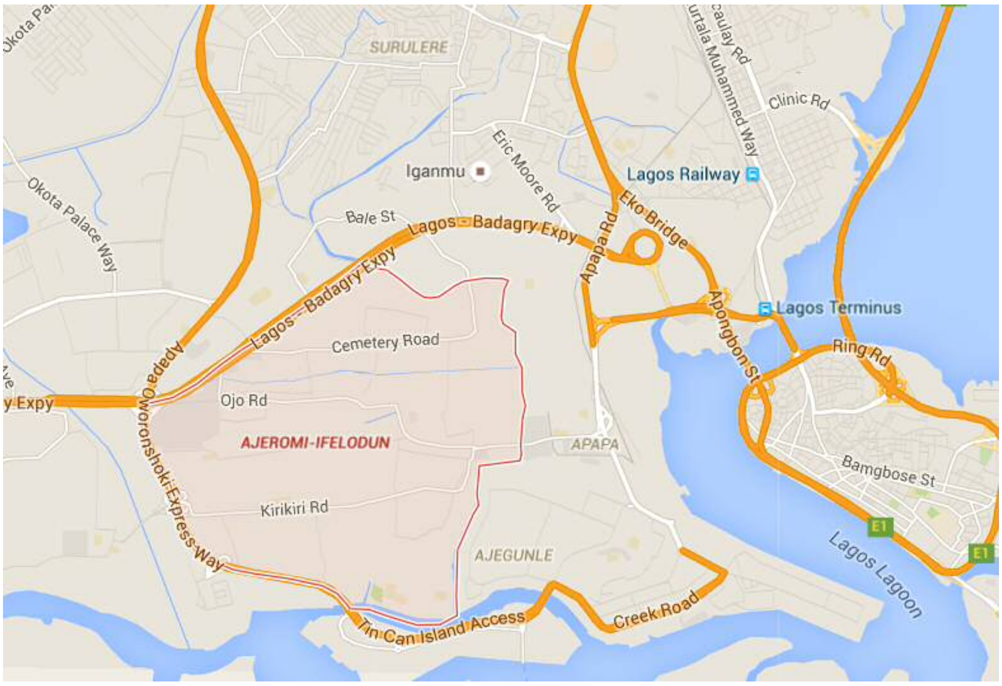

Figure 4-5; Location of Ajegunle in Lagos, Nigeria, Source: google maps, 2014

Plate 4-5; Street view in Ajegunle, Lagos, Source: jao, 2014

Plate 4-6; Aerial view in Ajegunle, Lagos, Source: jao, 2014

Plate 4-7; Street view in Ajegunle, Lagos, Source: jao, 2013

Plate 4-8; Another Street view in Ajegunle, Lagos, Source: jao, 2013

4.1.3 Ipaja (Alimosho Local Government)

Ipaja is located within the Alimosho Local Government, at the western part of the city, which is the most populated area within the city (Lagos state official website, 2014). This area was approached on the 17th of April 2014.

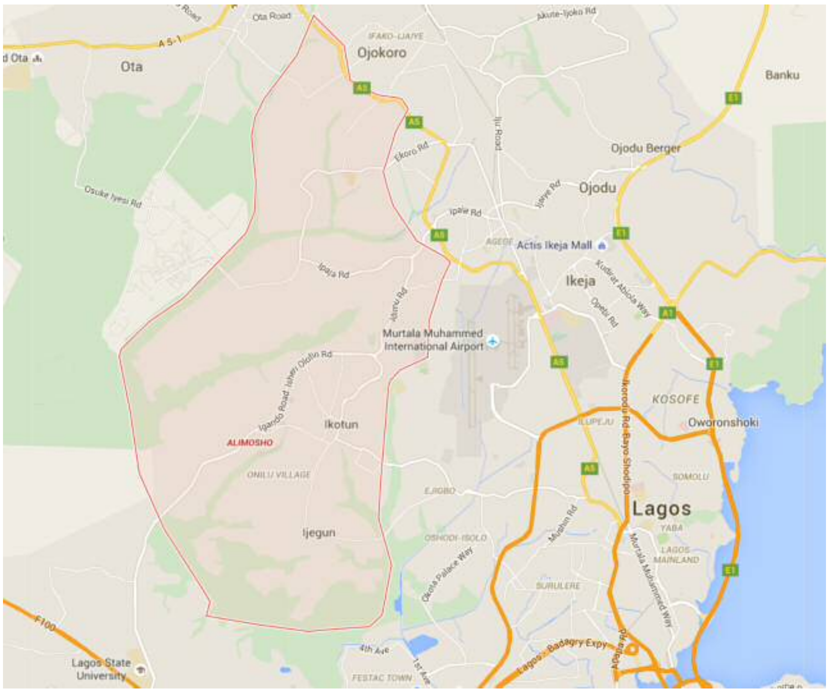

Figure 4-6 Location of Ipaja in Alimosho Local government, Source: google maps, 2014

Plate 4-9 Aerial view in Ipaja, Source, jao, 2013

Plate 4-10; Street view in Ipaja, Source, jao, 2013

4.1.4 Agege (Agege Local Government)

Agege is located towards the northern part of the city. It accommodates a football stadium and one of the largest markets within the city (Agege Market). This was approached on the 22nd of April 2014.

Figure 4-7; Location of Agege in Agege Local Government, Source: google maps, 2014

Although selecting these areas seemed relatively straightforward, the physical act of personal visit, penetration within the communities and building trust was not without challenges, culminating in 3 failed attempts, with success at the 4th attempt by the researcher. The researcher was presented with two options in the process of recruiting communities for participation;

- Approaching the Local Government Office and introducing the purpose of the research, while requesting for direct information on the Community Leaders (also known as Baale's' or chiefs informally), which might lead to their endorsement of the researcher in these communities.

- Directly approaching and interacting with the community members for relevant information on the location of their leaders, which might present an opportunity to directly meet the people and introduce the research.

The first approach, seemed direct and ideal, however, there was the risk of the community perceiving the researcher as a government official which could compromise their interest and participation. This was due to their previous experiences with government officials, who in the past have disguised themselves as researchers, only to return to demolish dilapidated houses. Thus, a lack of trust and hostility remains towards researchers that has been bred over time. An instance of this is documented in the excerpt below:

Researcher: Hello, I am a researcher, I will like to know where the Baale lives
Participant 1: (Walks away) You are not a researcher that is what all you 'government people' always say….
Participant 2: That is what they said, they destroyed some houses last month after claiming to be researchers

Although this challenge had not been discussed in detail in relevant literature, it was encountered as a barrier by the author, thus, eliminating the option of approaching the local government directly. This also presented the need to present the research as an independent body from the government. Also, with the role and importance of community leaders previously discussed in Chapter 3, the ideal option was to approach community leaders, culminating in the four steps undertaken[12] in recruiting communities for participation as discussed below.

4.3 Four Steps Undertaken by the Researcher

Recently, Oluwole (2011) proposed that African philosophy should be inculcated within the phenomenological methodology, to address research problems specific to developing countries. This is to enable studies to ascribe practical solutions and applications, grounded in the 'A*frican way of life*'. However, while this was a laudable attempt, the challenges of generalizing a single community's case as an 'African way of life' is impractical, due to different contexts, challenges, perceptions and the unpredictability of human behaviours and scenarios. Thus, in relation to the context of developing prototypes, actions, ideas and cooperation was imperative, culminating in a necessity to continually develop the methodology at every stage of the research, as encountered through challenges encountered during the field survey, again informing this chapter. A brief explanation is outlined and the detailed experience in each community is relayed, through inclusion of interview excerpts where necessary.

4.3.1 Penetrating the Community

Plate 4-11 below is a typical view within the city of Lagos. It is described as the economic capital of Nigeria (Olotuah,2005: Olusanya, 2012: Omojola,2015). Thus, the bustling and endless stream of activities made approaching potential participants for inquiry

[12] As encountered during the field work

within the identified communities impractical and ineffective. This presented itself metaphorically as an invisible wall cloaked around the community, thus the term *penetrating the community*.

Plate 4-11; Typical view in Lagos, Nigeria, Source: howng.com, 2012

Other challenges encountered by the researcher included illiteracy, disinterestedness and wariness towards strangers amongst others. Scenarios encountered in Mushin are described below;

Researcher: (Approaching a stranger sitting in a kiosk), Hello, I am a researcher and I am interested in conducting a study here, this is my ID card….
Stranger 1: (Stares dismissively) …. i am not interested, please leave….

Another scenario is illustrated below:

Researcher: (Approaching a stranger on the road), Hello, I am a researcher and I will like some information……
Stranger 2: (Cuts in) …. What is this? I am busy…….

These scenarios reveal that attempting to approach people to locate community leaders was neither straightforward nor direct.

4.3.1.1 Approaching Traders wares as a means of identifying Community Leaders

Approaching a stranger and beginning conversations is often discouraged either due to wariness towards unfamiliar faces, fear of being hypnotized and kidnapped for ritual purposes, with reasons ranging from superstitious beliefs to traditional worship (Smith, 1988; Falola and Adebayo, 2000; Igwe 2004), thus leading to the researcher being rebuffed by people when initially approaching members of the public. A typical conversation is illustrated below:

Researcher: (Approaching a stranger on the road), Hello, I am a researcher and I will like some information……
Stranger 3: (Speaks in Yoruba Language) …. i don't speak English and I don't believe you are genuine…

However, a study by Omoegun (2013) which involved approaching potential participants in Low income communities overcame this challenge through targeting traders and purchasing significant amounts of their wares, subsequently leading to conversations and the acquisition of relevant information. Examples of such traders is illustrated in plate 4-12

Plate 4-12; Traders in Mushin, Lagos, Nigeria, Source: heraldng.com,2012

This approach was undertaken in all four communities, but wasn't always met with positive response. The experiences in each community is detailed below:

- **Mushin**

Random approach to the first four traders and purchasing of goods (within the range of £10(N2500) to £20(N5000)) yielded no information on the location of the Community Leader. However, the 5th trader referred us to a larger store, in which the relevant information was obtained from the trader located there, yielding positive results. The address of the Community Leader was obtained, however, due to concern for security and cultural perception on women not allowed to visit alone, the researcher was escorted by a male colleague.

- **Ipaja and Ajegunle**

In both communities, conversations with traders revealed a lack of information on the whereabouts of the Community Leader, yielding to unfruitful results. This continued for two days in Ajegunle and 3 days in Ipaja. Due to the reputation of these areas as generally unsafe, the researcher was once again escorted by a male colleague. Once it was observed that approaching traders did not yield the desired information, bus stations and workshops became the next places that were accessed for information. One of such visit to a mechanic's workshop yielded the address of the Local Community Leader in the area (Ajegunle), while a visit to the local bus station in Ipaja also yielded positive information. Thus, approaching traders and buying their wares was not always an efficient strategy in identifying Community Leaders, as presented in Chapter 3, where it was discussed that identifying them may not always be straightforward or easy.

- **Agege**

The researcher noticed a street sign within the community called Lagos street and decided to locate a trader there. A Woman in her 50's who sold hair products was approached by the researcher, where products worth £10 (2500Naira) was purchased, leading to an exchange of pleasantries and discussion on hair products. After engaging for a few minutes, the request on the location of the community leader was documented as follows:

Researcher: I will like to know where the Community Leader lives, do you have any idea please?
Trader: He doesn't stay too far away, in fact, I can show you the place directly, but I will advise you go with my son, as he has worked for him a couple of times'

Although, this aspect could be perceived as relatively straightforward in this instance, time and money was the sacrifice which proved effective in this scenario. This could also be attributed to luck as the decision to approach this specific trader was spontaneous. This suggests that the success of participatory research could be influenced by chance encounters.

The next relatively challenging phase was building trust with the community leader.

4.3.2 Building Trust

A broad definition of trust by Hall et al (2002) is the optimistic acceptance of a vulnerable situation in which the trustor believes the trustee will care for the trustor's interest. There has been discussion in literature on the stages of building trust in a community, such as Goudge and Gilson (2005) who recommended that researchers establish trust with indigenous community members by acknowledging personal and group histories, understanding the historical context of previously conducted research, being present and listening to community members, acknowledging their expertise while being honest and clear about intentions. Another perspective on building trust was proposed by Ezezika (2008) who through participatory research with small scale farmers in Nigeria, who suggested that trust could be built in the following stages:

- Listening and Learning,
- Knowing your participants,
- The use of the right communication methods,
- Informed consents and continuous communication after research.

While these postulations, methods and theories might seem ideal, the researcher quickly discovered that this aspect was not always achievable through defined by rules or methods as experienced when the Community Leader was approached in Mushin, the conversation is illustrated below;

Researcher: Good Afternoon sir (offered a bottled of wine)[13,]
Community Leader(Mushin): How can I help you?
Researcher: I am a student from Cardiff University (Showed id card and Letter) and I am here to talk to you about conducting a research sir, I do hope you can give me some time to explain the details to you. You can always confirm my identity if needed.
Community Leader (cuts in): You are only wasting your time, no one here will give you any audience, everyone is busy, trying to make a living, I will advise you go somewhere else (Leaves the compound)

The research could not progress beyond this stage due to the lack of cooperation from the Community Leader, who believed that the community members were too busy to indulge in any form of research. Looking at the hub of activities taking place, including hassling for potential customers, one could objectively examine his argument, as he probably knew more about his community than a stranger.

Subsequently, the researcher discovered that building trust was in two phases:

- The first phase was with the Community Leader
- The second was with the Community members

  This latter phase culminated in the location of the Case Study Houses (to build and install the prototypes). This phase involved the personal nature of the research which included accessing the bedrooms in the Case Study Houses and working side-by side with the community for a period. Thus, the trust required in allowing a stranger within their vicinity and their place of abode had to be earned. It is suggested that this couldn't be achieved through strict adherence to pre-defined rules, as is discussed later in this Chapter.

4.3.2.1 Building Trust with the Community Leader (Baale /Chiefs/ Community Leader):

On identifying the Community Leader, an incentive was used to foster communication or break the ice. This was particularly sensitive as it was discussed in Chapter 3 that culturally, monetary incentives could be considered inappropriate and disrespectful. However, it is often used to facilitate survey recruitment and motivate participation among individuals who might otherwise not respond (Singer et al, 1999). Dunn and Gordon (2005) also suggested that, since economic forces operate in any case, investigators and researchers must explicitly take them into account while motivating participation. Individuals will participate in research if they think the benefits[14] are greater than the cost. Thus, in this instance, the incentives were presented in the form of bottles of wines, a culturally accepted form of gift when visiting the Community Leaders (Johnson, 1921; Ajisafe, 1924; Moore, 2010). The researcher then introduced herself, providing evidence with the Cardiff university identity card and official letter

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[13] The significance and importance of offering a bottle of wine to community leaders is discussed later under section 4.3.2.1.

[14] including, but not limited to, monetary compensation

of introduction[15]. This action was not always met with positive results, with responses ranging from indifference to hostility[16] . The experience in approaching the Baales in different areas are discussed below:

Approaching Community Leaders in Ipaja and Ajegunle

Unlike the experience in Mushin, the lesson learned was to display more enthusiasm and adapt another method of approaching the Community Leader. Thus, the results in these communities were straightforward and positive. The conversation with the Community Leader in Ajegunle went thus:

Researcher: Its finally great to meet you, Good Morning Sir (Offers bottle of wine)
Community Leader(Ajegunle): Hello, I understand it is difficult to locate me, not everyone is aware of my whereabouts
Researcher: (introduces self, purpose of visit and relevant identification)
Community Leader (Ajegunle): It sounds interesting, do come back tomorrow so I can personally take you around the area, hopefully, we can find some places for you to conduct your research (with the agreement of the people of course)

The conversation with the Baale in Ipaja went thus:

Researcher: I hope you have a few minutes to spare please
Community Leader (Ipaja): Not really, I am in a hurry
Researcher: (introduces self, purpose of visit and relevant identification and offers bottle of wine)
Community Leader (Ipaja): That's fine, if you can wait till 2:00pm, when I return, I can take you to some areas and introduce you to them

Approaching the Baale in Agege

Approaching the Baale, the conversation was as follows:

Researcher: Good Morning Sir (Offers bottle of wine)
Community Leader (Agege): Good Morning, how can I Help you?
Researcher: (Explains purpose of Research and Provides necessary identification)
Community Leader (Agege): I think it is a brilliant idea, I am concerned about the funding, Is it the Government? Why are you doing this? The people here are trying to make ends meet…...
Researcher: It is a University Research, they will not contribute to it financially, but I will need their input on conserving money when developing the systems
Community Leader (Agege): o, I see…. I remember watching the news and seeing the efforts by the Lagos state Government in Planting Flowers within the state…. i think it Is a good idea, I hope the people co-operate, I will talk to them, I know a few places you can do this, do come back tomorrow morning, so I can explain it briefly before you come?
Researcher: Thank you

[15] approved by the ethics committee of the Welsh School of Architecture
[16] as documented under the experience in Mushin above.

In this scenario, the researcher succeeded in meeting a Community Leader that was supportive and interested in the study. This influenced the facilitation within the community.

4.3.2.2 Building trust with the community

Once the trust was established with the Community Leader, this usually culminated in the leader taking the researcher to the busiest and most likely co-operative streets within the community. An impromptu meeting was usually announced leading to an introduction and endorsement of the researcher. Although the use of incentives within the community was discouraged as it was believed to compromise their honest opinions, however, at certain stages during the research, they were incorporated on the initiative of the researcher. This further enhanced rapport with the community members, albeit not in all cases as factors relating to cultural perception arose in a few areas which is discussed under the next section 4.3.3 as ‘Overcoming Cultural issues and Barriers’.

4.3.3 Overcoming Cultural issues and Barriers

This phase was the first time in which the researcher encountered cultural perception and its impact. It is important to recognize, respect and work within the major components of culture when introducing new ideas and implementing new inventions. However, cultural perceptions might not always be easily identifiable. These are often deeply ingrained in the subconscious that might not have a chance to manifest itself.

In this context, Nigeria is known to have over 250 unofficial languages with various ethnic groups with deeply ingrained cultural values. While this was not initially anticipated to pose challenges, the researcher quickly learned that the while the issues of culture might not always be apparent, its influence and power should not be underestimated as discussed in Chapter 3.

In Ajegunle, the Community Leader escorted the researcher to a popular street within the area, called out the occupants of the houses and introduced the researcher and intentions to them. Further description and details of the work was explained in the Yoruba Language. During one of these conversations and meetings, the cultural perception of snakes as causes of ill luck and thus abominable was elicited from the belief that plants in the prototypes will attract them. This bred suspicion and prevented co-operation within a few communities. No methods were found to convince them that the use of snake-repelling plants in the prototypes could reorient their pre-conception. Excerpts of these conversations are detailed below:

- **Cultural challenges in Ajegunle**

Respondent 1: ‘My culture believes that snakes bring ill luck. Since this will involve plants, it will attract them. I cannot participate in this….
Respondent 2: ‘Yes…...the snakes…. if they live anywhere near you, it attracts evil occurrences…. i can’t take the risk…
Respondent 3: ‘Snakes will be bred; you cannot convince us otherwise…

This led to fear and disinterestedness. Eventually, their cultural perception was too strong to be overcome. Thus, the lesson learned was that building trust alone did not always guarantee participation, terminating the possibility of working with this community.

- **Disinterestedness in Ipaja**

In Ipaja, the Community Leader escorted the researcher to a street within the area which happened to be engaged in a town meeting during arrival. An introduction was made, and the researcher explained through images, the intention of the research. Again, the belief in the unnecessary nature of the research led to a lack of cooperation by the community members. Some responses were documented as:

Respondent 1: 'I think it is a waste of time, this is Africa, this is more of a 'western thing'
Respondent 2: 'Plants on walls? Not for me'
Respondent 3: 'Who will look after it when you are away? Goats will eat all the leaves when you are not there'
Respondent 4: 'All this 'Educated' people who like flowers think we have time for such'
Respondent 5: 'What is this nonsense'?
Respondent 6: 'May be another time, it looks like a lot of work to me'
Respondent 7: 'I don't understand, why this'?
Respondent 8: 'It looks like a nice research, but to be honest, people here just don't care about such, they want jobs…...
Respondent 9: I see attempts by the Government on TV, I just feel they should concentrate more on providing of sources income for people

The disinterestedness displayed naturally ended the recruitment process in this community.

- **Overcoming Cultural perceptions in Agege.**

Within the Agege community, similar pre-conceptions on plants attracting snakes, were encountered, however, in this community the researcher could dissuade the fears effectively. However, when data loggers were to be installed in the Case rooms and wall surfaces of the developed prototypes, there was a further misconception, this time of the loggers themselves being harmful, as it was believed to bear a resemblance to a traditional object also known as 'juju', a form of Black magic practiced within Nigeria (Igwe, 2004). Thus, the prototypes in various stages of development were threatened with vandalism. The scenario is illustrated below:

Participant 1: 'Hello researcher…. i heard you put this 'juju' in this prototype yesterday……
Researcher: Hi….it is not 'juju', it is for recording temperature, I thought the Case worker[17] explained this to you….
Participant 2: I tried to explain it to them, they almost vandalized this prototype last night……

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[17] A Caseworker is a representative of the landlord, who usually resides with fellow tenants. Details of this is discussed in Chapter 5

Researcher: Hold on please, let me get the Baale to assure you of the intent….

This was assuaged by the Community Leader who convinced the community members on their safety.

4.3.4 Presenting the research as an independent body from the Government

The perception of Government officials by these communities has already been raised, however, in some instances, the researcher was still assumed to be a representative of the state government, thus, this aspect had to be reinforced through the official form of identification which was the Cardiff university identity card and the verbatim assurance of their privacy.

The need to present the research as an independent body from the government emerged for the first time in the Agege community. The perception of the researcher as a government official resulted in wariness and reluctance in participating both by occupants in the Case Study Houses and the rest of the Community. However, over time, their perception shifted to viewing the researcher as a part of the community. Typical scenarios are illustrated below:

Researcher: 'Hi everyone, I will appreciate your input and perception. No opinion is negative. Please feel free to share your views…….

Participant 1: We can't be comfortable. What if you are a government official just pretending?

Participant 2: Yes, why are you recording us? How can we be free to express ourselves?

Participant 3: Please don't take our pictures or record us, we are not free to participate …………

Participant 4: Don't take it personal…but this is the way you can get maximum co-operation from us….

The implications being no pictures could be taken of the participants and a refusal to be recorded on camera. Although challenging, the researcher was willing to assuage such perceptions by compromising through acquiescing to their requests. The researcher took the initiative to bring little gifts for the children, wear simple clothes and communicated in the local Yoruba language. By the first week, participation increased, and suggestions began to emerge during meetings and conversations with the participants.

The 4 steps undertaken by the researcher culminated in selecting a community within Agege, Lagos, the final Case Study Houses and potential participants within an approximate 1000m radius (For easy movement to the main site of the research) is shown in the figure 4-9;

Figure 4-8; Vicinity of Case Houses Source: Author, 2014

4.4 Timelines and lessons learned

The four steps took time and effort as approaching a community for research was by no means a clear-cut approach which often tended towards frustrations in some areas.

Date (April 2014)	Community approached, and lessons learned
10th April	**Mushin (Mushin local government)** Unco-operative community leader truncated recruitment process
14th April	**Ajegunle (Ajeromi-Ifelodun local government)** Refined approach yielded positive results with the Baales, however cultural perception inhibited the process of building trust with the community, truncating the progress of the research
17th April	**Ipaja (Alimosho local government)** Refined approach yielded positive results with the Baales, however disinterestedness inhibited the process of building trust with the community, truncating the progress of the research
22nd April	**Agege (Agege local government)** Refined approach yielded positive results with the Baale, leading to significant progress within the community.

Table 4-4; Lessons learned in Communities approached, Source, Author, 2014

The experience in the 3 communities that yielded no positive response is discussed and the general lessons learned are discussed as illustrated in table 4-4:

- Penetrating such communities is neither clear-cut nor straightforward, it cannot be defined by principles and rules as unanticipated factors might occur, which might lead to stagnating the research process, if flexible but appropriate actions are not employed.
- Random approach of people often leads to being rebuffed, rather, engaging with their trade, buying their wares and friendly conversations might lead to relevant information.
- Suggestions on the process of building trust might have been discussed in relevant literature, but attaining it is difficult, requiring extreme patience, openness and creativity, which may still not always yield the desired results.

- Participatory research is not definitive, rather it evolves, leading to change in tactics, trial and error and most importantly it requires time and flexibility.

Lessons learned in each community are;

- In the Mushin area, Community Leaders, although important, may not always influence decisions by the community members, however, they are still important to be consulted in approaching community members.
- In Ajegunle, cultural perception is often difficult to observe at face value, especially as an outsider and using logic to overcome cultural perception is difficult, but not impossible.
- In Ipaja, true participation and input from the community is dependent on interest, co-operation and valuing inputs/ opinions. However, this is entirely voluntarily, and disinterestedness ultimately truncates the research process.

4.5 Limitations and Conclusions

As previously stated, recruiting communities for research is a subjective experience that should be approached with an open mind, informed by (but not necessarily dictated by) predefined rules and methods, in other words, the selection of the community comes down to what is possible, rather than a set of ideal formal research procedures.

In this context, the selection of the communities was by no means a direct approach, which led to learning on the field and adapting creative solutions to unanticipated challenges. This resulted in the emergence of a bespoke method of selecting communities especially for participatory research.

However, the different responses experienced by the researcher in various communities proves the subjectivity of this approach, with the most challenging steps identified as building trust and overcoming cultural perception. This suggests that overcoming these could increase its viability and could be replicated in varying research aims and contexts. Although the unpredictability of human nature might develop new challenges, these could serve as lessons learned before approaching other communities.

Figure 4-9; Cyclical research approach in recruiting communities for participation

As illustrated in the figure 4-9 above, a cyclical approach culminating in embracing challenges and overcoming them could yield to a refined methodology, as it was not by chance that the last community approached was successful, rather combinations of lessons learned from attempts in previous communities. The next chapter discusses the criteria and process of identifying the Case Study Houses within Agege Community.

Chapter 5: Field Work: Case Study House Selection within Agege Community

Chapter 4 discussed the process of recruiting communities for participatory research describing how the Agege community eventually selected itself to be part of this study. Predominant housing morphologies commonly associated with low-income groups was previously discussed in Chapter 3. It was concluded that the most likely form of housing to be encountered within low-income communities was the Brazilian housing morphology, known locally as 'face me I face you'. This Chapter explains how the 2 Case Study Houses[18] selected themselves to be part of this study. This includes discussing the role of the community participants in locating the houses.

The physical characteristics of the houses required for the development of the prototypes are discussed. These include important considerations required in the Case Study Houses for the development of the prototypes and testing its impact on indoor comfort, such as similarity in solar insolation of the walls of rooms selected within the Case Study Houses, similarities in construction materials including U-values and similarities in room occupancy and other characteristics of the two rooms.

5.1 Identifying Case Study Houses for development of prototypes

A few residences were initially recommended by the Community leaders and Community members. However, certain criteria led to disqualification of potential residences (4 in total) prior to the final two houses selected as illustrated in table 5-1. A typical conversation below illustrates the initiation process of selecting the houses.

Researcher: Please what occupants/ houses will you recommend? Which occupants do you think will be co-operative?
Community Leader(Agege): Not everyone will be co-operative, I will take you to a few streets today, let's see how it goes. If it goes accordingly, I will hand you over to the Landlord or Care takers
Researcher: Thank you Sir, I might not be able to use the first house recommended because of some criteria…...
Community Leader (Agege): Once I introduce you to a Caretaker, he will oversee all that, I will just break the ice by introducing you to the community, so that they recognize you and stop viewing you as a stranger….

[18] Sites for developing, assembling and testing the impact of the prototypes on indoor comfort

Houses approached/ images and location		Criteria for Case House selection				
		Permission from Landlord/ Caretakers	Bare wall/ façade exposed to Maximum and unobstructed solar radiation to set up the prototypes	Two rooms located behind bare walls to develop and test the effect of the prototypes	Appropriate and Uniform morphological characteristics of the Case Houses	Safety of occupants and similarity in occupancy, schedule and activities
House 1, located on Shobowale street	 	■				
House 2, located on Kosoko street	 	■				
House 3, located on Bankole street, Agege	 	■	■	■		
House 5, located on Lagos street, Agege	 	■	■	■	■	■
House 6, located on Suru street, Agege	 	■	■	■	■	■

Table 5-1: Criteria for selection of Case Study Houses within Agege Community, source: Author, 2014

The criteria leading to the disqualification on the use of the first four houses are discussed below:

House 1, Location Shobowale street, Agege

Building orientation influences the quantity of solar radiation falling on its different faces at different times of the day. Both radiation and temperature eventually affect heat gain through surfaces, which is a requirement to develop the prototype and test its impact on indoor comfort. This formed the basis for the location of the proposed development of the prototypes in this study, as undertaken in similar studies on Vertical Greening Systems development by Cheng and Chu (2013) and Wong et al (2010). This house was recommended by the Baale, based on his rapport with the landlord. However, the researcher on closer inspection to the house discovered that shading from surrounding structures resulted in no bare wall exposed to maximum solar radiation. This resulted in the disqualification on the use of this house.

House 2, Kosoko street, Agege

The second house was recommended by a community member as illustrated below:

Researcher: This house is ok, but because there is no sun reaching the wall, we won't be able to use it….
Participant 1: There could be a few other places, will try to find where there is sunlight
Participant 2: There might be another one on the next street, let me ask the caretaker first
Researcher: Please do, thank you….

While the second house received solar radiation, it was still obscured by a fence, which again led to its disqualification.

House 3, Bankole street, Agege

The third house was recommended by chance, while the researcher and some participants were walking past it. However, it was a double story Brazilian house which would have had cost implications when developing the prototypes. Single story buildings are generally between 2.5m-3.5 m in height especially among these housing morphologies (Vlach, 1984: Akom, 1984: Awotana, 1988: Akinmoladun, 2007: Aluko, 2012), developing a prototype of 6m in height would have significantly increased its cost due to increase in materials and other technical requirements, such as irrigation, thus eliminating this option.

House 4, Oshidehin street, Agege

This house was recommended through a participant whose relative was a landlord at this property as illustrated below:

Participant 1: At this rate, are you sure you can use any house? Why don't you use what is available…?
Participant 2: No, she cannot, she has requirements….
Participant 3: Let us try my aunt's house, about 5 minutes away
Researcher: That will be great, thank you….

Although the requirements pertaining to solar radiation exposure was met, pertinent issues relating to safety (due to large number of children under the age of 5 residents in this house) arose. The possibility of the prototypes being tampered with was discussed, leading to a refusal by the landlady. The 5th and 6th houses approached was recommended as illustrated below:

Researcher to 4 Community members present: Please do you know any other places we can use?
Participant 1: I think we should try Mr Olabiyi's place at number 20. The Caretaker lives in the same building; it might be easier to facilitate the study.
Participant 2: That's if it suits your criteria……
Participant 3: We could also try my aunt's house on Suru Street. She is the Landlady

The 5th and 6th houses were approached on the 30th of April 2014. All the requirements were met, and their location is illustrated below:

Figure 5-1; Location of Case Houses within Community, Source; Author, 2014

5.2.1 Selected Case Study House A, Lagos Street, Agege and Case Study House B, Suru street, Agege

The final selected Case Study Houses were:

- House A: Located on Lagos Street, Agege
- House B: Located on Suru street, Agege

The conversation on approaching the Care taker in Case Study House A on Lagos Street is illustrated below:

Researcher: (introduces self and purpose of research)
Participant: Yes, she has been around for a while, she is familiar with the rest of the community….
Caretaker: I heard about it from the Baale…. i think you can use this house; I will introduce you to each occupant as well….
Researcher: Thank you.

With the permission of the Care taker obtained and the researcher introduced to the occupants, the research progressed. The conversation on approaching the landlady in Case Study House B on Suru Street is illustrated below:

Researcher: (introduces self and purpose of research)
Landlady: So far, it's not dangerous…. also, must it be mounted on the wall?
Researcher: Yes, it will be mounted on the wall, but the weight will be transferred into the ground, so you don't have to worry about structural damage.
Landlady: Alright then, here is my room number if you need help…
Researcher: Thank you……

The researcher then assessed the house against the criteria listed, briefed the occupants of the house (along with the landlady) and answered questions pertaining to safety and practicalities. Once this was established, the research progressed. The overall physical appearance of both houses is illustrated below:

Layout of Case Study House A

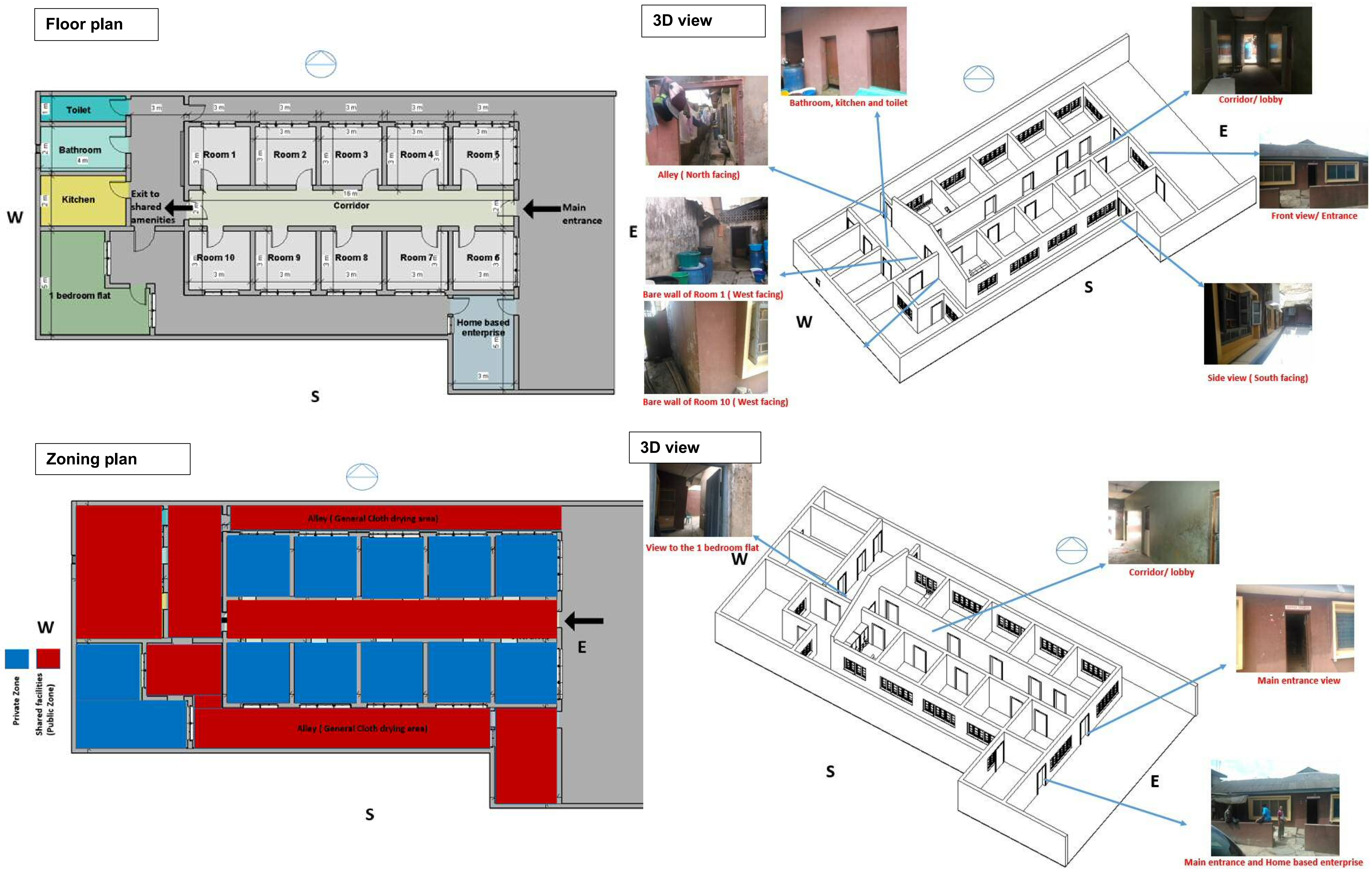


Figure 5-2; Layout of Case Study House A, source: Author, 2014

Layout of Case Study House B

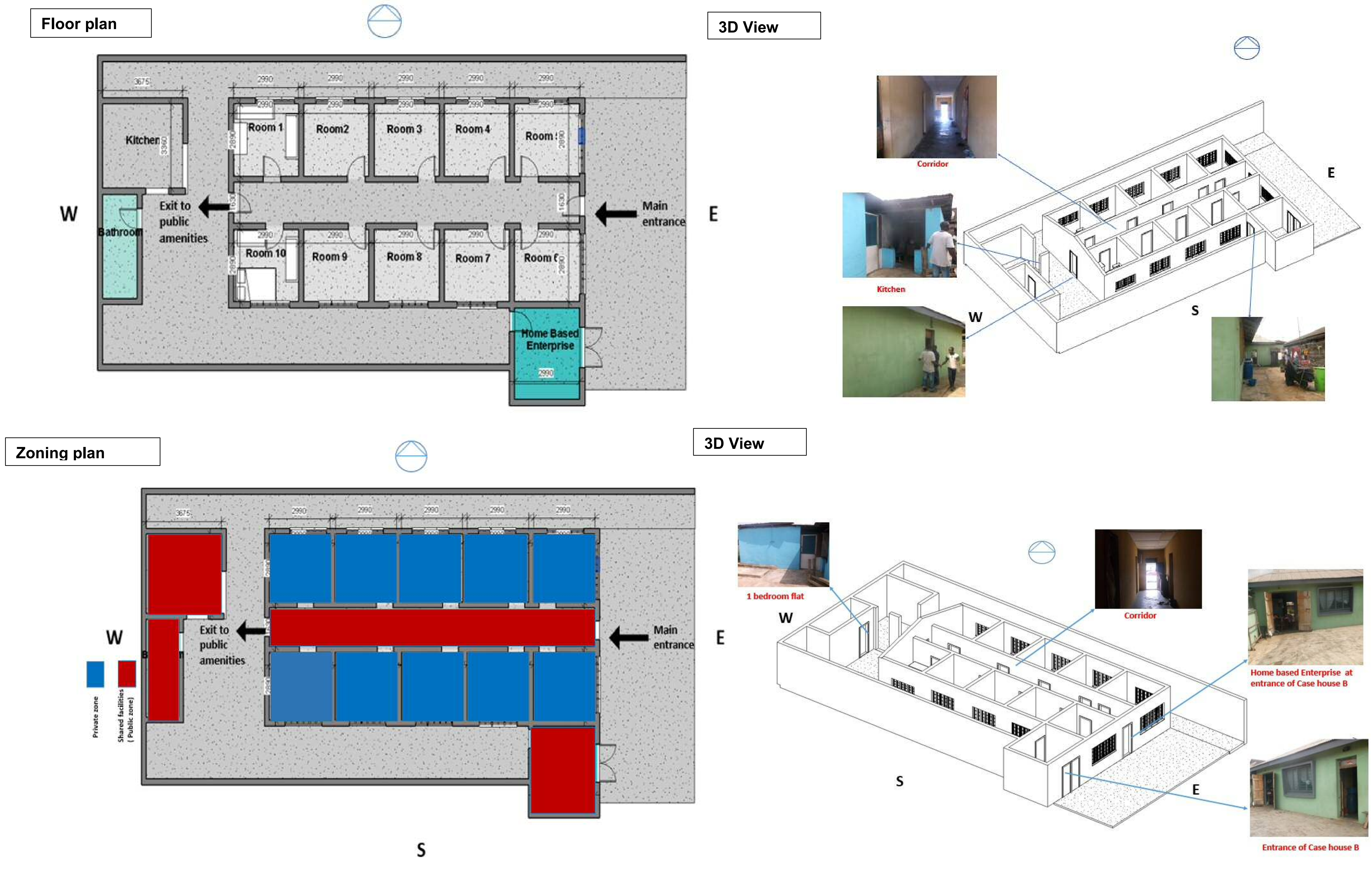


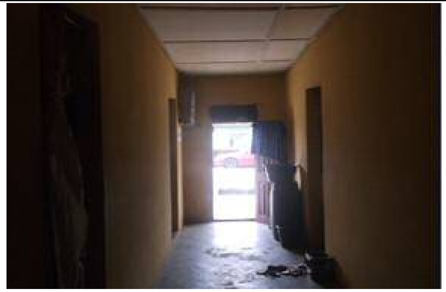
Figure 5-3: Layout of Case Study House B, source: Author, 2014

Description of the public/ shared zones are detailed below:

Public spaces in Case Study House A and Case Study House B

Kitchen in Case Study House A **Kitchen in Case Study House B**

The kitchen is used by all 42 occupants in House A and 38 occupants in House B. Kerosene stove and gas cylinders are used in cooking their meals. The location is 3-3.5m away from the main building.



Corridor in Case Study House A **Corridor in Case Study House B**

Used for ironing of clothes by residents' due to cramped conditions in the room and its propensity to generate more heat.

Bathroom in Case Study House A **Bathroom in Case Study House B**

The bathroom and toilet are without running water, which is a common scenario within this housing typology

Water storage in Case Study House A **Water storage in Case Study House B**

Water is purchased in the community centre and stored in plastic buckets/ storage

Figure 5-4: Shared public amenities in both houses: source, author, 2014

- **Kitchen**

The kitchen, bathroom and toilet[19] (This was due to limited land spaces while being built as discussed earlier in the chapter) is used by all the occupants in the Case Study Houses. Kerosene stoves and gas cylinder are used in cooking their meals.

- **Corridor**

Another heat generating activity that took place outside the rooms was ironing of clothes on the corridor. Further inquiry on this is illustrated in the excerpt below:

Researcher: Does everyone in the house iron on the corridor?
Occupant 1: Yes, we all do that, because there is no space in the room and if we try to iron, it gets really hot indoors
Researcher: How often do people iron?
Occupant 2: Usually in the afternoon, if there is electricity supply…

As discussed, the reason was both a combination of limited spaces and noticeable increase in heat gain in the rooms when ironing.

- **Bathroom and Toilet**

The bathroom and toilet are without running water, which is a common scenario within this housing typology, as reported in previous studies on low income housing by (Akom, 1984: Aina, 1989; Awotana 1989; Abiodun, 1993; Olajide, 2010; Aduwo,2011; Lawanson et al, 2012; Aluko, 2012). Thus, water was purchased in the community centre and stored in buckets/ plastic storage in front of the bare walls (where the HDPE prototype was assembled). However, over time and with discussion/ agreement with the occupants, the plastic buckets had to be relocated about 1.2m away from the wall in order not to compromise the variables being measured (especially the external air and wall surface temperature). Worthy to note is that this did not interfere with the community living as it was agreed to be relocated after the time frame of the research. The storage in Case Study House B was located at the side of the building which did not interfere with the site of the study.

[19] Detached away from the main building, with Its location about 3m away from the main building.

Plate 5-1; Temporary relocation of water storage containers, source; author, 2014

5.2.1.1 Room 1 and 10 (location for development of and testing of prototype within Case Study House A and Case Study House B)

The two rooms selected for the site of the research within the Case Study houses are illustrated below:

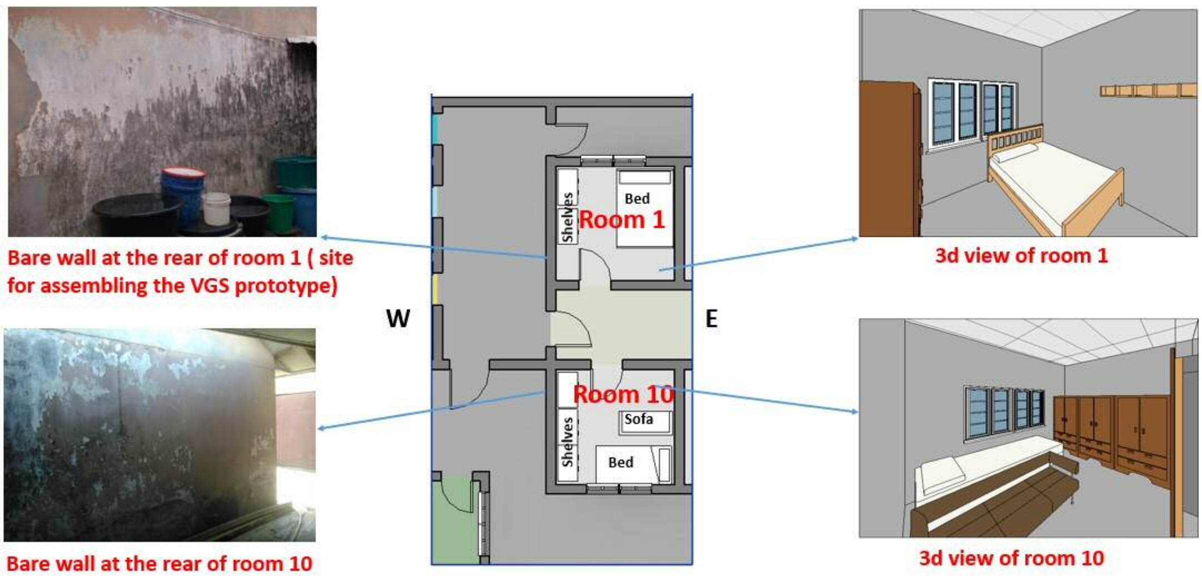


Figure 5-5; Details of rooms within Case Study House A (used for evaluating performance of VGS prototype), source; author, 2014

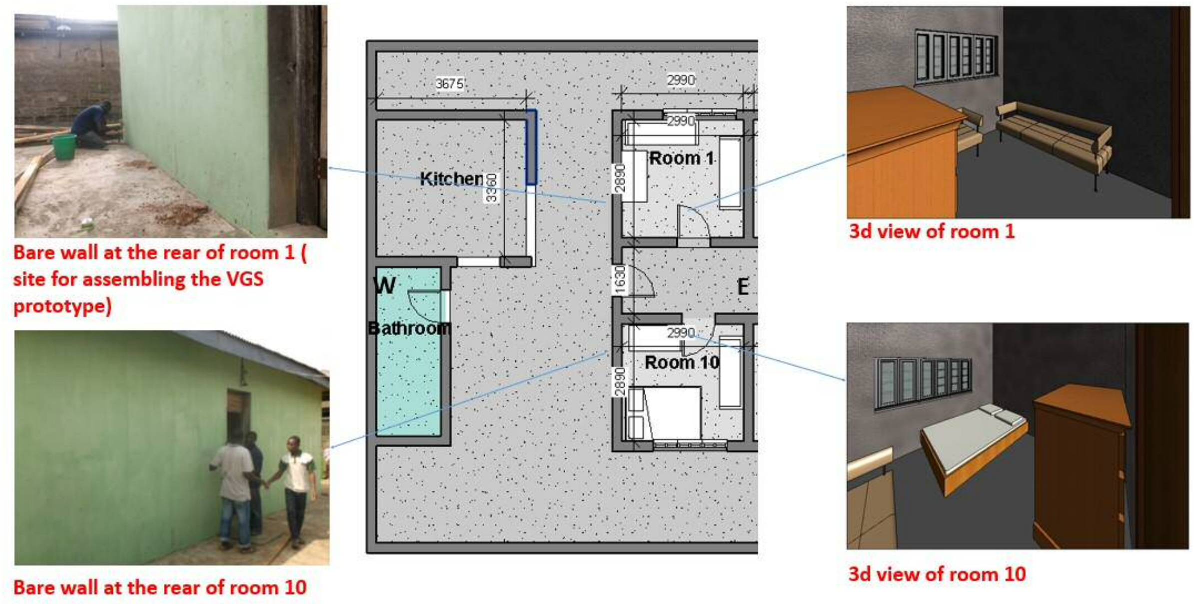


Figure 5-6; Details of rooms within Case Study House B (used for evaluating performance of VGS prototype), source; author, 2014

Due to privacy concerns by the occupants, taking photographs of the rooms was forbidden, thus informing the drawings above. Room 1 in Case Study House A had a double bed, two cabinets and an overhanging shelf, while room 10 had a single bed, sofa and three shelves, while that of Case Study House B had two sofas and a wardrobe in room 1 and a double bed with a single sofa in room 10. Equipment used in both houses were listed as television, refrigerators, low quality incandescent bulbs, standing fans and computers.

The construction materials for both houses, were identified through careful visual inspection by the researcher during the field work; the U-values were calculated manually based on McMullan (2007). As summarized in table 5-2, the fabric elements used in both rooms were the same, as observed during the field work.

Room 1			Room 10		
Fabric element	**Description**	**Estimated U-value**	**Fabric element**	**Description**	**Estimated U-value**
External and internal walls	Walls (225mm hollow concrete block, plastered with 20mm thick cement	3.048W/m²K	External and internal walls	Walls (225mm hollow concrete block, plastered with 20mm thick cement	3.048W/m²K
External and internal floors	External ground floor(150mm) concrete slab and 10mm floor cement screed)	2.490W/m²K	External and internal floors	External ground floor(150mm) concrete slab and 10mm floor cement screed)	2.490W/m²K
External roof and ceiling	Aluminum roofing sheet (5mm thick) supported by 20mm thick hardwood. Ceiling 5mm thick asbestos	3.682W/m²K	External roof and ceiling	Aluminum roofing sheet (5mm thick) supported by 20mm thick hardwood. Ceiling 5mm thick asbestos	3.682W/m²K
Windows	Windows (700mmX1800mm, 5mm (90%)single glazed louvres, wooden window frame	3.560W/m²K	Windows	Windows (700mmX1800mm ,5mm (90%)single glazed louvres, wooden window frame	3.560W/m²K
Doors	Doors (from treated hardwood 2100mmX900mm	2.251W/m²K	Doors	Doors (from treated hardwood 2100mmX900mm	2.251W/m²K

Table 5-2; Fabric element description in room 1 and room 10 (both Case Houses) and U-value, source: manual calculation based on McMullan, 2007

5.2.1.2 Bare wall/ façade exposed to maximum unobstructed solar radiation to set up the prototypes in both Case Houses

Reiterating, a criterion considered for the location to develop and test the prototype is a bare wall exposed to maximum solar radiation. Figure 5-9, shows that with locations close to the equator, solar angles are mostly close to 90° with the lowest being 66.5°.

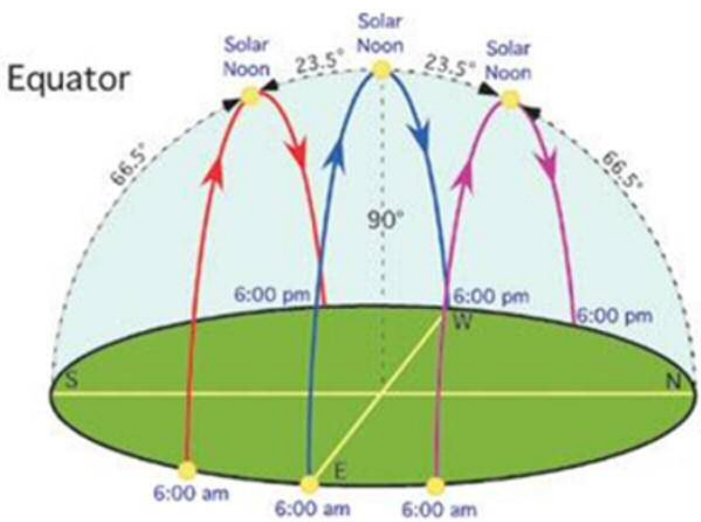


Figure 5-7; Sun path movement in locations near the equator, source, Muazu,2015

Lagos is located in the Atlantic Coast in the Gulf of Guinea (West Africa), latitude 6° 27′ 11″ N and Longitude 3° 23′ 45″ E, near the narrow coastal plain of the Bight of Benin. The implication of this is that maximum exposure of solar radiation (apart from the roof) is to the eastern (sunrise) and western walls (sunset) with its peak overhead during midday (Koesinberger,1975). Thus, either the east or west orientations (bare walls) were ideal to evaluate the VGS (depending on over shading from surrounding buildings), as it entailed that the wall enables conduction of maximum solar heat gain into the interior space (Koesinberger, 1975; Godwin, 1988; Price, 2010).

Simulation illustrating incident solar radiation on western walls

To establish that both rooms can be used for the testing of the prototypes, it is imperative that they are as similar as possible[20], especially regarding incident solar radiation. Thus, simulation in Design Builder for a peripheral comparison is illustrated in figure 5-10 and 5-11 reveals the time effect of shading from the western sunset.

[20] Detailed methodological approach to establish this is presented in Chapter 7

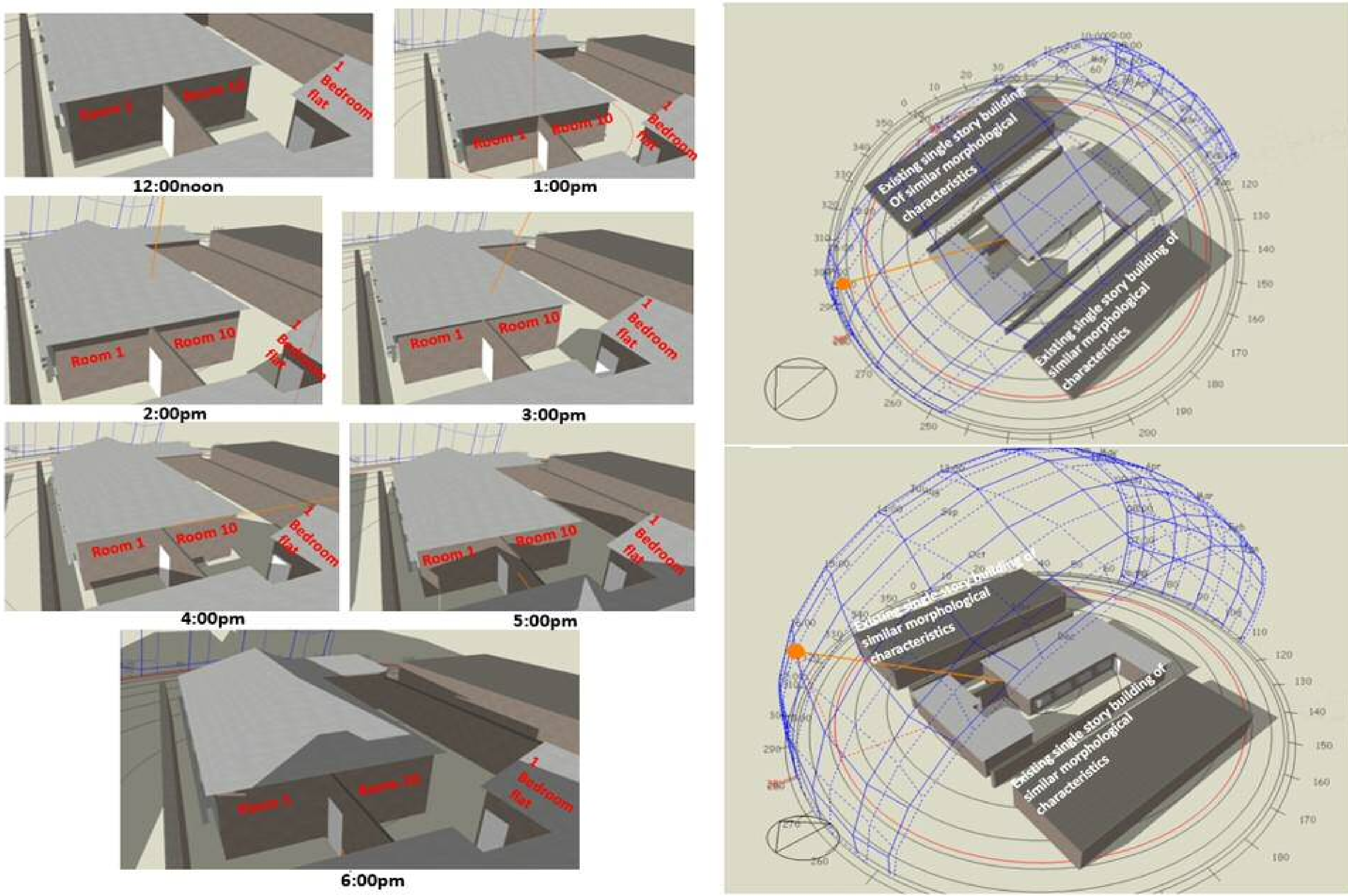


Figure 5-8; Time effect of shading on western facing wall of room 1 and room 10 in Case House A, source; design builder, 2014

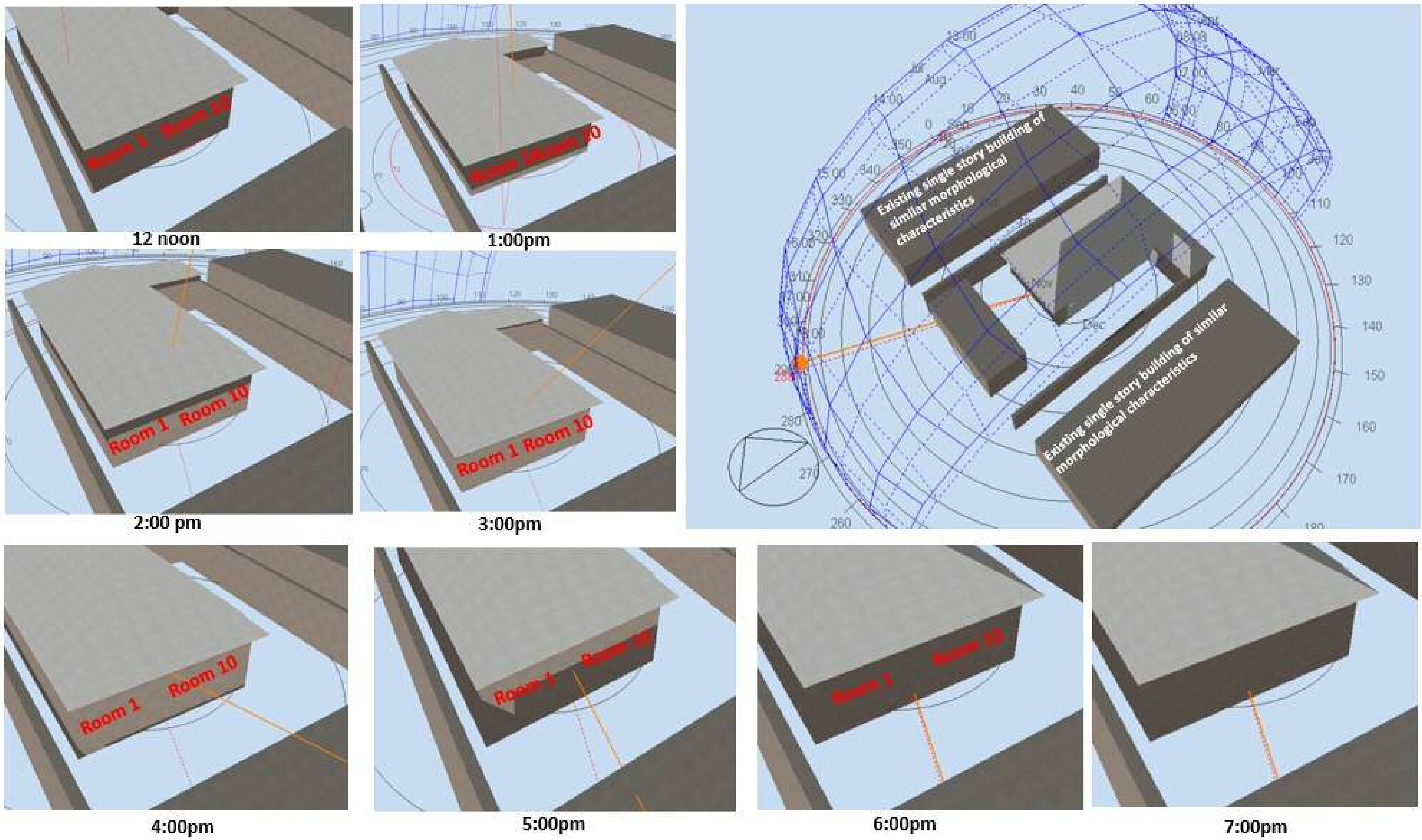


Figure 5-9; Time effect of shading on western facing wall of room 1 and room 10 in Case House B, source; design builder, It can be observed that the behaviour of incident solar radiation is similar at face value. However, a more detailed analysis of the solar radiation is discussed in Chapter 9. A brief overview of the occupants is discussed below:

5.2.1.3 Brief overview of occupants in Case Study House A and Case Study House B

Table 5-3 and 5-4 below summarizes the gender, occupations, number of occupants in each room within the Case Study House.

Case Study House A, Lagos street			
Room(9m²)	Number of Occupants	Gender	Occupations
1	4	3 men, 1 woman	Artisans and Seamstress
2 and 3	6	1 man, 1 woman 4 children	Housewife, cleaner and students
4	4	2 men, 2 women	Traders
5	2	1 man, 1 woman	House Caretaker
6,7,8	16	10 women, 6 men	Unemployed, traders and businessmen
9	6	4 men, 2 women	House Caretaker
10	4	4 men	Carpenters
	Total 42	21 men, 17 women, 4 children	

Table 5-3; Room and occupant's details in Case Study House A, source: author, 2014

Case Study House B, Lagos street			
Room(9m²)	Number of Occupants	Gender	Occupations
1	5	3 men, 2 women	Bricklayers, Caterers, Unemployed
2	4	4 women	Students
3 and 4	7	1 man,1 woman,5 children	Caterer and Banker
5	3	2 men, 1 woman	Landlady and Caretaker
6	4	4 men	Traders and Tailors
7 and 8	6	6 women	Unemployed, Teacher and Businesswoman
9	4	4 men	Carpenters and Plumbers
10	5	3 women, 2 men	Tailor, Traders and Student
	Total 38	16 men, 17 women,5 children	

Table 5-4; Details and Occupants in Case Study House B, Source; Author,2014

As discussed in Chapter 3, due to limited literacy/educational skills, their occupations are usually low skilled or self-employed (Onibokun,1972: 1990; Lawanson, 2012). Thus, this limits their financial capacity and the quality of the houses they can afford. All occupants had spent more than 5 years in the residence, with two of them recently relocating to room 1 from room 6 in Case Study House A. Noteworthy is that the case rooms in both houses had equal number of occupants, however, while this information is relevant, the activities, occupancy schedules and equipment usages are important criteria's in determining how comparable both rooms are.

Summary

To successfully achieve the overall aim of the study, the location of the co-operative community had to be undertaken (as discussed in Chapter 4). After this, the process of identifying and locating the ideal house that met the set of criteria needed for the research to proceed was discussed. This included the necessary physical attributes pertaining to bare walls with maximum exposure to solar insolation and other factors pertaining to co-operation with occupants.

With these in place, the final two houses selected were the sites for all meetings and development and experimental testing for the prototypes, the detailed process of developing and constructing the prototypes within the two houses are discussed in Chapter 6.

Chapter 6: Participatory Development and Construction of Affordable Vertical Greening Systems

Chapter 3 critically analyzed Community Based Participatory Research and outlined the strengths in relation to this research context. This Chapter describes the inculcation of the most cited strengths of CBPR by Webb (1990) and Israel et al (1998) in the participatory development of affordable vertical greening systems within the Agege community:

- Allowing innovative adaptation of existing resources, which in this research context is the adaptation of Complex Vertical Greening systems into simple prototypes by the community.
- Exploring local knowledge and perceptions, which is part of the objective, to develop ideas grounded in the views of the participants.
- Empowering people by considering them as agents who can investigate their own situations, which entails 'shifting power and decisions' to the community.
- Encouraging the community input to enhance project credibility, which involves attempts at ensuring maximum participation and valuing inputs.
- Joining research participants who have varied skills, knowledge and expertise to address complex problems in complex situations, which is part of the range of skills needed to physically develop and assemble these prototypes.
- Providing resources for the involved communities, through its collaborative nature, this entails sourcing for materials and development of indigenous ideas that could be incorporated in the prototypes.
- Providing a forum that can bridge across cultural differences among participants
- Helping to dismantle lack of trust communities may exhibit in relation to research.

However, this was combined with a set of criteria and essential elements to build VGS Systems[21] as a guidance while engaging with the community in developing the prototypes. table 6-1 illustrates the three major forms of VGS classification and their essential elements and cost range as discussed in Chapter 3, which the final two materials of HDPE (high density polyethylene) plastic and wood were selected for their minimum environmental impact and recyclable properties.

[21] support materials/construction, soil/substrates, plants/ leaf area index and drainage/irrigation

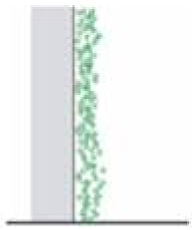
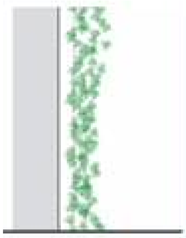
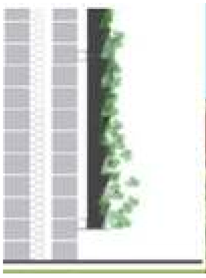
Vertical Greening System classification	Essential elements	Images	Cost in (£/m^2)	References
Direct Greening Systems	- Plants - Adhesive disc - Climber plants	 	30-75	Perini et al, 2011; Perini and Rosasco, 2011; Ottelle et al, 2011; Manso et al, 2015; Peng et al, 2015
Indirect Greening Systems	- Potted plants - Support materials	 	40-241	Perini et al, 2011; Perini and Rosasco, 2011; Manso et al, 2015; Peng et al, 2015
Living wall Systems	- Support materials - Growing media - Vegetation - Drainage and irrigation	 	100-1200	Perini et al, 2011; Perini and Rosasco, 2011; Oosterlee, 2013; Olivieri et al, 2014; Manso et al, 2015; Peng et al, 2015

Table 6-1; VGS classification and average costs

The role of each element has been discussed in Chapter 3, leading to the decision to the living wall system being adapted to the researcher's classification of '*affordable soil based living wall system'*. These relevant criteria and essential elements were used as a starting point to develop affordable VGS sketches in a participatory way, i.e. in discussion with the community and are relayed accordingly.

Ethics approval and privacy concerns

Due to the participatory nature of the study, involving several participants over a period, ethical considerations were important to be considered. This was sought and obtained from the Research Ethics Committee at the Welsh School of Architecture under the reference number 33233. Thus, everyone who participated was briefed and a signature on every interview schedule was obtained from all the participants under anonymity[22] as evidence of their consent. For those who refused to sign, especially during informal discussions, their consent was obtained verbatim and no one was forced to participate against their will. Also, the participants only attended the meeting based on not being filmed, recorded or photographed

[22] for privacy purposes as requested

for privacy issues, which the researcher duly complied with. However, the recruited skillsets that were involved in the physical assembling of the prototypes acquiesced to being photographed verbatim.

Other relevant information

Extracts of verbatim Interviews/ conversations as documented by the researcher are included in some part of the texts to relay relevant information accordingly.

6.1 Timeline of Activities and Meetings

Figure 6-1 illustrates the timeline of activities and meetings involved in the development of the prototypes, from the 3rd to the 12th of May 2014 which are discussed accordingly:

I. **Approaching and recruiting community members with specific skillsets** (3rd to 7th of May,2014)

II. **Engagement with recruited specific skillset and community members** (7th of May,2014-8th of May, 2014) .

III. **Design of prototypes and costing** (8th -9th of May,2014) .

IV. **Construction phase;** physically assembling the prototypes (9th – 12th of May,2014).

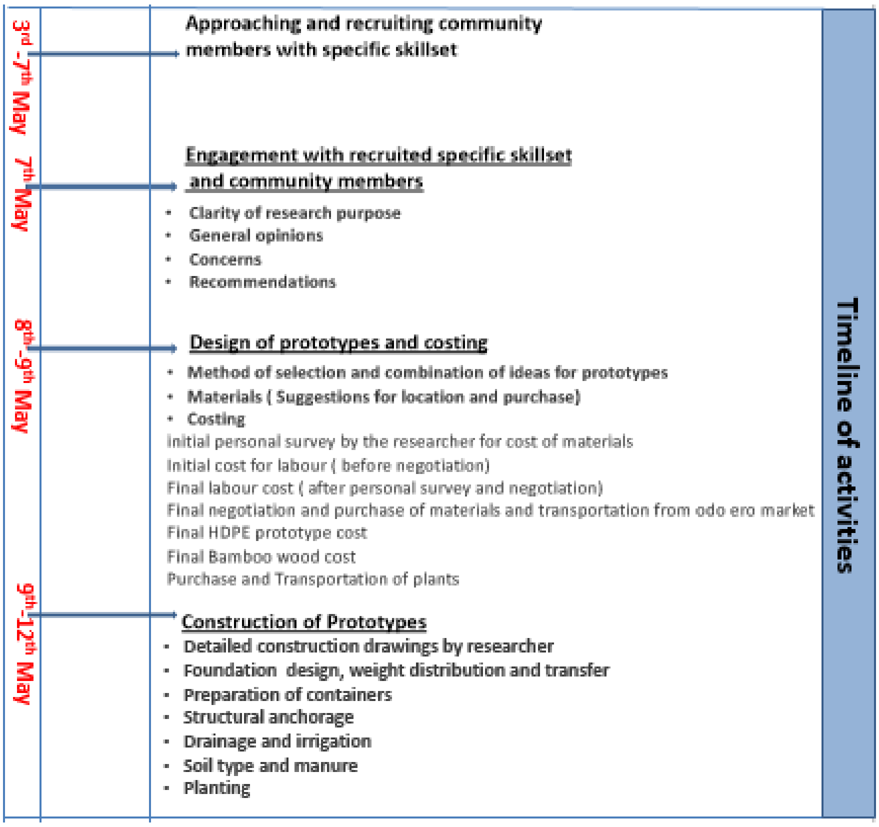


Figure 6-1; Timeline of activities in developing affordable Vertical greening systems prototypes in Agege community, source: Author, 2014

6.1.1 Approaching and recruiting Community members with Specific Skillset (3rd to 7th of May)

Locating community members with specific skillsets relating to carpentry, horticulturists, plumbing and welding was through direct recommendations by the community members and the Baale. This was confined within 800-1000m vicinity of the Case Study Houses by the researcher, as illustrated in figure 6-2. This was to facilitate easier movement of the recruited skillset to the houses, as further distances may have discouraged on-site participation.

Figure 6-2; Vicinity of area approached for recruiting specific skillsets, google images, 2014

Typical conversations that led to recommendation of the specific skillset are illustrated in the excerpt below:

Researcher: 'Can you recommend a good carpenter, plumber and horticulturist around here'?
Participant 1: 'There are so many of them on this street and they all do good jobs'
Participant 2: 'Yes, I would recommend 'Alfa', Mr Adekunle and Mr Tunde, they have worked with me a couple of times'
Participant 3: (Cuts in) 'I think they are too expensive'….
Participant 4:' True…. Mr Bolanle is better and cheaper, also Mr 'Calabar' is very good with gardening I can take you to their shops'…
Baale(Agege): 'Yes, he stays at the end of this street, I know a few others I can introduce you to'…...
Researcher: 'Ok, please give me all their numbers, I will like to discuss with them together'…………

The conversation illustrated above reveals how the researcher allowed uninterrupted discussions among participants to identify those with the relevant skillsets. Conversations often involved 12 to 15 participants (directly approached by the researcher) at the same time, often yielding varied but helpful recommendations. A list of the names, addresses and location of all recommended was documented in the researcher's field note on the 3rd of May 2014, while a visit to each of them took place from the 4th to the 6th of May 2014, usually escorted each time by a community member for introduction. This was a necessity, due to safety reasons on the part of the researcher[23] and familiarity/ trust reasons on the part of those approached [24]. Initially, those interested were:15 Carpenters,12 Welders, 12 Plumbers,8 Horticulturists, However, only 3 carpenters, 2 welders, 2 plumbers, 1 ironmonger and 3 horticulturists were physically involved in the assembling of the prototypes. This was predominantly due to interest in participating and negotiations pertaining to time and money. Although, the rest of them offered valuable expertise advice and suggestions.

The knowledge/expertise of the recruited skillset are outlined in table 6-2:

Recruited skillset	Expertise
Carpentry	Woodwork and assembling
Horticulturist	Local plants and conditions for maximizing growth
Welding/ ironmongery	Assembling metal parts
Plumbing	Drainage

Table 6-2: Recruited skillset and expertise, source: author, 2014

With the final selection of community members with the desired skillset selected in place, the next phase was the first design meeting with the recruited skillsets and community members.

6.1.2 Engagement with recruited Specific Skillset and Community Members (7th May, 2014)

This section discusses the meeting set-up[25] and the results.

6.1.2.1 Aim of meeting

Due to the participatory approach in this research context, the aim of this meeting was to foster a sense of project ownership and familiarity with the researcher, whilst re-emphasizing the purpose of the study. The purpose was to enable a sense of familiarity, relaxation and consequently unhindered participation. This was as suggested by Cornwall and Jewkes (1995), who postulated that maximizing co-operation among the community members in participatory research was through organizing meetings, as opposed to relying only on interviews. Creswell (2009) provided another perspective on the role of meetings as '*An opportunity to commit time in the field, including collecting extensive data and* an 'insider' perspective to build access and rapport (among community members) which could be in form of *general discussions and meetings/dialogues and observations, field notes and visualizations*, as discussed in Chapter 3. A set of topics/ prompts were indicated in a field note to guide the discussions, should they detour from the original intent, as illustrated in figure 6-3:

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[23] Venturing alone into unknown part of the community was risky and discouraged especially for women.

[24] As being approached by strangers for 'research purposes was often met with disdain and unco-operation, as discussed in Chapter 4

[25] Including the aims, location and method

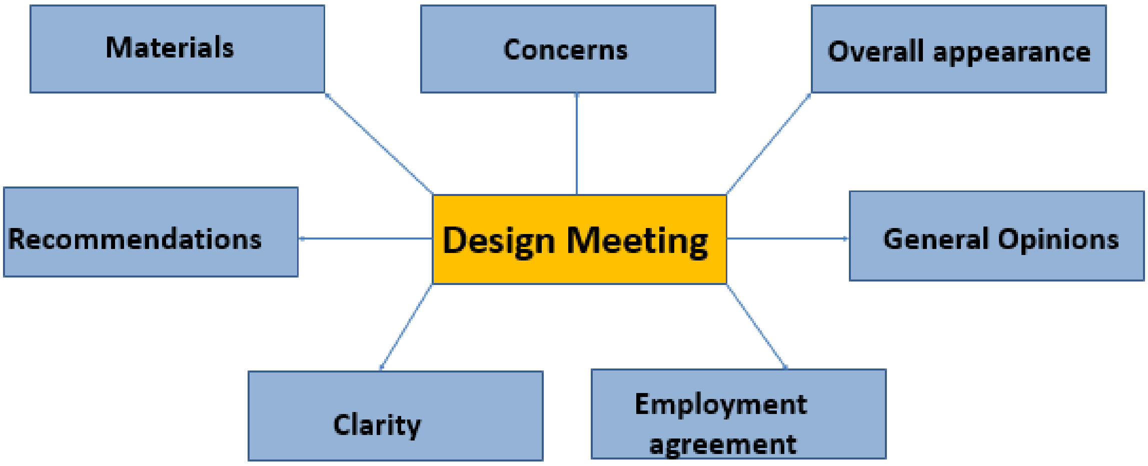


Figure 6-3; Topics/prompts in meeting

These were transformed into cue cards and visualizations which was an important prop while engaging with the community, as previously discussed in Chapter 3. The method of conveying a new topic for discussion was through cue cards with the topics (and its interpretation verbally in the local Yoruba language) as illustrated below;

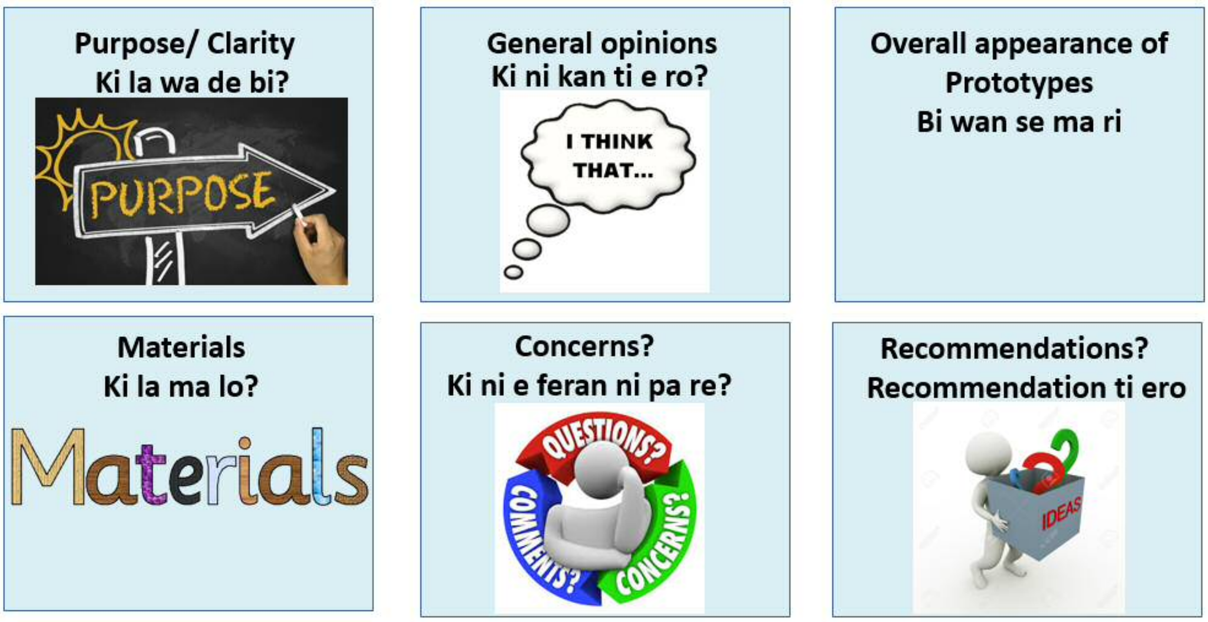


Figure 6-4; Cue cards for facilitation of meeting, Source google images (2014) adapted for field work by Author, 2014

Observations

The importance of observations during participatory field studies was presented in Chapter 3. This took place whenever conversations, suggestions and arguments arose during the meeting as the aim was to avoid as little interruption by the researcher as possible. This was to encourage brainstorming indigenous solutions to perceived challenges, subsequently increasing a sense of ownership during the research (Mosavel et al, 2005).

6.1.2.2 Meeting Location and set-up (decided on the 6th of May 2014)

Plate 6-1; Meeting location (Case Study House A, Lagos street)

Plate 6-1 illustrates the location of the meeting. This decision was due to the Case worker in Case Study House A[26] volunteering to assist the researcher in coordinating the meeting and the location of the Study.

The role of the researcher was defined as:

- Introducing the purpose of the research.
- Inculcating the use of cue cards (for those with limited understanding of English language) while the case worker explained in the local language (Yoruba).
- Ensuring discussions during meeting is not diverged from its original purpose.
- Ensuring a person or group of people do not suppress responses from the rest of the attendees.

The role of the Case worker was defined as:

- Standing outside the property to signal the location of the meeting for those unaware.
- Interpret essential information in the local language (Yoruba) to ensure no one present is excluded.
- Assist in holding cue-cards when the need arises.

An estimate of an hour (about 10 minutes per topic) in total for the meeting was advised by the Community Leader, who attended this preliminary meeting to officially endorse/introduce the researcher to the community and ensure that the attention of the participants was maintained throughout the meeting by encouraging their participation.

6.1.2.3 Methods of invitation (disseminated on the 6th-7th of May 2014)

With the location, topics for discussion and format of the meeting decided, the date, time and location of the meeting was disseminated across the community through door-to-door method by the researcher, case worker and 2 community members who volunteered to

[26] Is a representative of the landlord who usually resides in the Case Study Houses

knock directly on doors. Interested participants also recruited friends, colleagues and neighbors as undertaken in similar participatory studies by (Cooke and Kothari 2001; Minkler,2004: Holkup et al,2004; Farmer,2015). The list of streets to be approached was selected by the researcher[27] , after advice by the community members on the most populated streets within the vincinity. The summary is illustrated in table 6-3.

Streets approached	**Number of houses approached**
Suru street	14
Lagos street	22
Shobowale street	19
Bankole street	4
Kosoko street	3
Adedosu street	5
Total	**67**

Table 6-3; streets approached and number of houses

Thus, a systematic approach[28] of each house on the 9 different streets was employed to ensure that no single house was visited more than once. A total of 67 houses were approached[29] and invitation was extended to the occupants available at the time.The houses approached are highlighted in figure 6-5:

Figure 6-5; All houses approached within the mapped vicinity, source: google map, 2013

[27] within the 800-1000m radius from the location of the meeting,
[28] Through noting house numbers visited on cue cards
[29] Each house with an average of 30 occupants

Plate 6-2; Some houses approached(Clockwise) on Suru Street, Shobowale street, Bankole street and Adedosu street, author, 2014

Noteworthy was the use of the image of an existing prototype to facilitate easier understanding of the purpose for the meeting during invitation of the community members as illustrated below:

Figure 6-6; Image of VGS used as basis for explaining the purpose of research during invitations and meetings, source: google images, 2013

Examples of conversations involving invitations include:

Community member 1 (speaking Yoruba language): Good day here, there is a meeting coming up on the 7th of May at 'Alfa's' house, on Lagos street it involves us developing something like this (holds up an image of a Vertical Greening System on an A2 sheet)
Researcher: it will not look exactly like this; we will develop our own version….
Resident 1 in house approached: How exactly will our ideas help? We do not know about this
Researcher: That is what we plan to explain in the meeting, every single idea, opinion or concern will be encouraged to be voiced, your opinions matter
Resident 2 in house approached: Sounds good…I hope it won't take long?
Researcher: it shouldn't last more than an hour….
Community member 2: Baale will be attending as well
Resident 3 in house approached: ok, we will let the other occupants (in this house) know when they get back

A total of 85 (70 men, 15 women) community members (Incuding the carpenters, plumbers etc earlier recruited) attended the preliminary meeting.

6.1.2.4 Meeting Results and discussions

- **Clarity of research (10 minutes)**

A large cue card (A2 size) with an image of a VGS was erected on a makeshift board and the researcher introduced the purpose of the research, discussed the role of community participation and re-established the importance of their opinions (as there were no right or wrong answers). Clarity on the identity of the researcher was established by circulating the Welsh School of Architecture ID card throughout the meeting. Field notes were also used by the researcher to physically document the discussions arising during this meeting. The Case Worker further explained the purpose of the study in Yoruba language and assured that they were not being photographed or filmed to enable a free environment to express their opinions. At this point, benches were provided for people sit and be comfortable. As discussed in Chapter 3, the final material choices to be used is the HDPE and wood, due to the minimum environmental impact and recyclable properties of the materials. This was re-emphasized again during the meeting. Typical conversations include:

Researcher; …. 'Hello everyone, thank you very much for coming to this meeting, I know Baale has explained why I am here. I will love for you to please be free to contribute your ideas and opinions, nothing you say is wrong or inferior. I value every single input. And I believe we can develop the prototypes together. The two major materials we will use to develop the prototypes are Plastic pipes and Wood'…
Community Members: ...No problem. So far, they don't bring snakes and insects, also, can we plant our seeds?...
Researcher; ….'We won't use bright flowers and we will use anti snake plants, yes, please feel free to plant vegetables'…...
Horticulturists: 'Just let me know the seeds so I can place them properly….
Participant 1....It sounds interesting; I have a few ideas….

Participant 2: …. ok, I will be contributing in my spare time…

- **General opinions (15 minutes)**

At this point, the researcher allowed people to express their opinions, however, maintaining orderliness proved challenging, they were encouraged to raise a piece of wood above their head if they wanted to express a thought or opinion. The use of wood was recommended by the Community Leader as a lively means of identifying those who wanted to express themselves as involuntary movements might be wrongly perceived as raising hands. This was effective and participation facilitation greatly improved. The frequent themes that emerged under this prompt/topic [30]was related to skeptism, finances and pests. Skeptism and finance was frequently as expressed as:

'That looks complicated and very expensive, what way can we contribute exactly'?

While that of pests was expressed as:

'I am still in doubt that this will not bring insects and rodents….it looks like a magnet for snakes'!

The researcher again reiterated that the image of the prototypes was a guidance, and not an exact replication. In other words, the methods, ideas and means of adapting the image within an affordable budget was the aim of the research and the assurance on the use of snake/ insect repelling plant was relayed by one of the horticulturist present. Once this was established, the next topic emerged.

- **Concerns (25 minutes)**

This topic elicited a large response from those previously uninvolved in the previous topics, especially relating to:

- Safety of prototypes for inquisitive children
- Plant types
- Maintenance
- Expenses
- Aesthetic quality

leading to a debate during the meeting. A group of people suggested that the prototypes should be mobile as against being erected directly on the wall surface, while the other group suggested otherwise. However, the women in the meeting questioned the mobile prototypes structural integrity and raised the issue of safety pertaining to children and their propensity for curiosity. The conversation pertaining to this is illustrated below:

[30] Based on the field note documented and observation by the researcher

Female participant: What if the mobile prototypes falls on a child's head? You know how curious they can be…
Participant: You can warn them not to go near it?
Female participant 2: You don't know children. They will keep fidgeting with the prototype when no one is watching……
Female participant 3: True…my 4-year-old wont rest until he climbs it.
Researcher: Being that we have a few children living here, I suggest we suspend the development of mobile prototypes?
Participants: ok, lets suspend that…...

This eliminated the possibility of developing mobile prototypes. The plant type was open to the community offering them an opportunity to plant seeds of their choice[31] within the prototypes. This context involved cultural considerations as discussed in Chapter 4, thus, plant selection was constrained not necessarily by its role in passive cooling, but by meeting the community member's criteria and that of relevant literature on leaf area index/ percentage of wall covering as shown below:

- No insects, bees or snakes, due to cultural perception as abhorrent
- No bright flowers in order not to attract unsupervised children/ toddlers, due to the possibility of either eating them or plucking them before they achieve their full growth
- Quick growing plants to ensure maximum percentage of wall covering, due to limited time frame to conduct the research
- Edible plants for ease of maintenance requirements, through simply harvesting the plants for consumption whenever wild growth was observed.

Thus, Leaf area index and percentage of wall covering was dependant on these criterias .

Plant selection

Table 6-4 summarizes the details of the plants used as suggested by the horticuturists and community members. Popular delicacies such as Ugu (pumpkin leaves) were also encouraged to be planted which generated excitement and a list of plants emerged at the end of this session.

[31] howbeit to the horticulturist knowledge, as certain plants were not ideal to be planted in a confined space as the prototypes

Plant types selection				
Local name	**Image**	**Scientific name**	**Local use**	**Classification**
Pumpkin leaves/ Ugu		Telfairia Occidentalis	Edible plant	Vines
Ewedu		Corchurus Olitorius	Edible plant	Herbs
Aloe Vera		Aloe Vera	Medicinal	Succulent plant species
Flowerless antisnake plants		Lantana Camara	Snake repellant	Perennial shrub
Tropical nettle		Laporte aestuans	Aesthetics	Perennial shrub

Table 6-4; Plant selection and characteristics, source, MedicinalplantsfromNigeria, 2013

Pertaining to maintenance, the caseworker volunteered to water the prototypes as often as needed and encouraged everyone to provide seeds during visit to the site, during and after the prototypes were assembled. The researcher reminded the participants that the cost and aesthetical quality of the prototypes was dependent on their ideas.

- **Recommendations (16 minutes)**

With the basics of the prototype design agreed and a sense of community partnership fostered, recommendations on further development of the prototypes in a more public space like the community hall emerged as it was believed to be an interesting idea which was new.

The researcher thanked all present for their contribution and invited anyone interested in a shorter meeting (the next day) strictly to sketch the design of the prototypes. The community members were also reminded on a shorter survey (at the end of the August) on their attitudes and perception of the developed prototypes.

6.1.3 Design of Prototypes and Costing (8th -9th May 2014)

Due to the practicality involved relating to sketching, description and creativity that only people with vested interest could participate in, this meeting was voluntarily attended[32] by 45 people in total, including the recruited skillset who were genuinely interested in the research project.

6.1.3.1 Aim of meeting

The aim of this meeting was:

- To develop sketches through individual proposals (through verbal suggestions by participants) by the recruited skillset and interested community members based on the discussions in the first meeting. These sketches through recommendations was then combined into single proposals by the researcher.
- To prepare a list of materials for each prototype.
- To finalize payment negotiations with the recruited skillset based on final sketches/proposals.
- To negotiate, purchase and transport materials and plants to the Case houses[33].

6.1.3.2 Meeting location and Set-up

Case Study House A remained the location of the meeting. Also, there were supplies of pencils and paper for sketching purposes to those who might be interested.

The role of the researcher was defined as:

- Translating verbal suggestions into physical sketches.

The role of the Case worker was defined as:

- Interpret essential information in the local language (Yoruba) to ensure no one present is excluded.

An estimate of 3.5 hours in total for the meeting was anticipated due to the sketches and feedbacks expected. Although the meeting took place over two days, each day the meeting ended, it culminated in purchasing of materials (Construction materials on the 8th of May and plants on the 9th of May 2014).

6.1.3.3 Meeting results and discussion

Clarity of meeting (15 minutes)

The purpose of the meeting was explained and its emphasis on participation was re-established as illustrated below:

---

[32] Without the researcher approaching them as undertaken in the previous meeting

[33] This took place after the meeting at the Odo-ero construction market, a nearby construction market with different traders selling various construction materials in a large open area.

Researcher (offering everyone a paper and pencil): The two materials to be used are plastic pipes and wood, and based on our discussion yesterday, can you sketch an idea on how the design might turn out? Do feel free as no one is criticizing your idea. Thank you, Also, by the end of this meeting, you can volunteer with us to purchase materials …if you are interested.

Although no one physically sketched their ideas, rather, they preferred to express their ideas verbatim, thus, the researcher assumed the role of translating their ideas into sketches. A few proposals (sketches) emerged at the end of the meeting. Then the researcher and recruited members with specific skillset combined the ideas received.

Method of selection/ combination of ideas for prototypes (1hr 30minutes)

The final selection of ideas to be combined, after a vote carried out during the meeting were based on the following criteria:

- Simplicity in understanding
- Easy comprehension and agreement by the recruited skillsets involved in the physical assembling process

The researcher coordinated a popularity vote during the meeting to decide on the final selection of ideas to be developed. This was through asking the participants to raise their hand if they approved of the sketch(s) presented during the meeting.

Three sketches emerged during this meeting as physically sketched by the researcher and are discussed below:

Sketch 1:

This sketch emerged through a discussion on the use of hardwood to support the bamboo/ HDPE pipes as illustrated below:

Community member 1: How about using the thick hardwood to support the HDPE pipes?

Carpenter 1: The problem might be drainage; it might not be so easy to create a functional irrigation system

Researcher to community member 1(Sketching the proposal and holding it up for everyone to see): let me physically sketch the idea, we might be able to work out the perceived challenges…. Do you mean something like this?

Community member 1: Yes…. what do you think?

Researcher (Showing the sketch to everyone else present at the meeting): What do you think of this? How can we solve the problem of drainage?

Horticulturist: We might need pipes to drain the water directly into the ground, but that will cost more money…

Community member 2: Perhaps we should eliminate using the hardwood underneath the HDPE then….

Community member 3: I think so too…we can support the HDPE or Bamboo wood in a less complicated way….

Community member 3: Like using smaller material as a support…...

Researcher: ok.let's think of alternative ways then….

The sketch (as drawn by the researcher based on the discussions in the meeting) in figure 6-7, based on discussions with the participants revealed the potential problem of drainage. This led to alternatives ideas for this aspect of development.

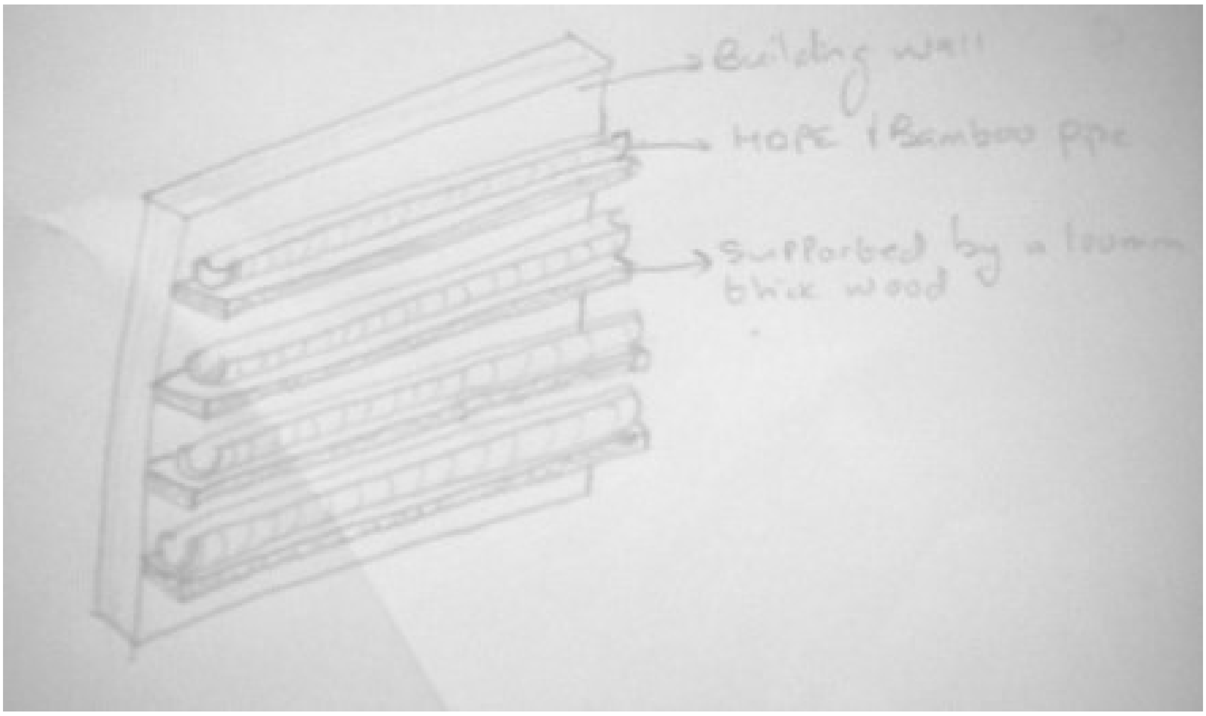


Figure 6-7; Sketch 1 as co-developed with the community members, source, author, 2014

Sketch 2

This emerged while brainstorming alternative ways of providing support for the HDPE pipes an excerpt of the discussion is illustrated below:

Carpenter 1: We can think of a way to connect the pipes directly to a vertical wooden support as opposed to the horizontal one sketched earlier?
Carpenter 2: Yeah…that will support the pipes and we can figure out how to irrigate the system …….
Researcher: ok…just express what you have in mind, I'll do the sketching
Community member 1: we can use materials to support the pipes like ropes? Some kind of anchor?
Horticulturist: Yes, a form of anchor to the vertical support….
Community member 2: We could even use metal as the pipes are heavy?
Carpenter 3: Yes…I think metal will do….
Community member 4: How will it work?
Community member 5: By spacing the anchor support evenly….
Researcher (sketching suggestions): You mean something like this?......
All present: Yes, like that….

The ideas proposed culminated in the sketch below,

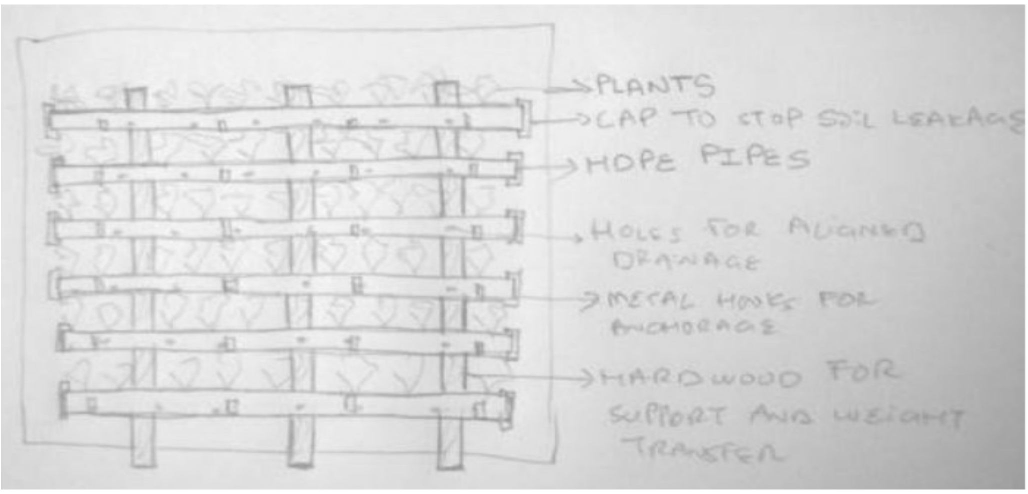


Figure 6-8; Preliminary sketch (on site) of HDPE prototypes, Source, author, as co-developed with participants,2014

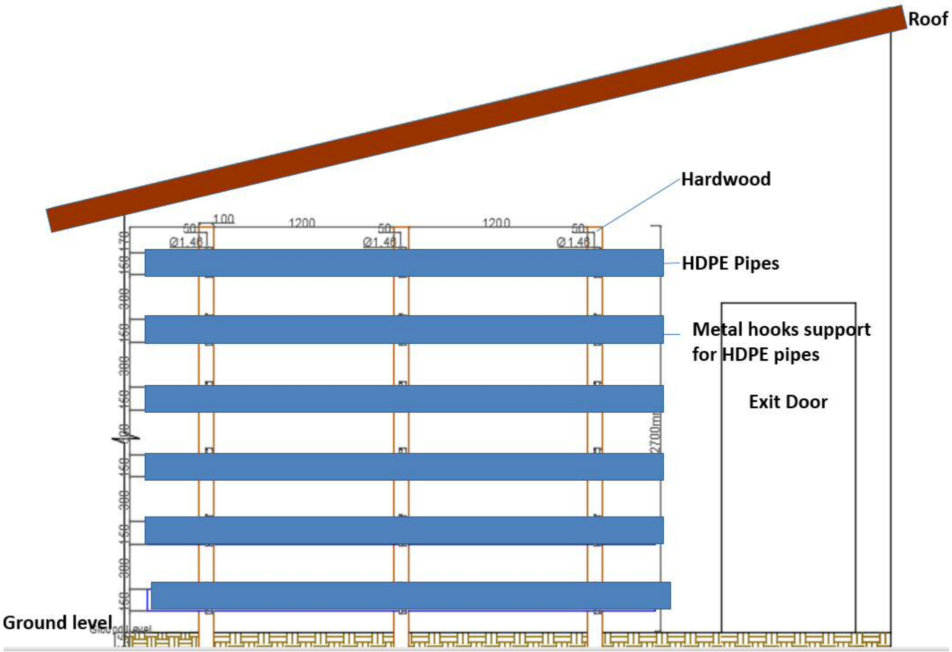


Figure 6-9; Sketch of HDPE prototype, source, author, 2014

Ideas on developing support materials also emerged while sketching as illustrated below:

Researcher: We need a strong material to support the heavy pipes, and link the weight to the hardwood
Community member; How about using support made from wood?
Welder 1: Let's use scrap metals, then we employ an iron monger to bend it in shape? There are lots of scrap metals on construction sites
Welder 2: I think that's the safest material to offer the support as well…………
Carpenter 1: We make sure we drill holes in the metallic support as we will need to anchor it directly to the wood
Carpenter 2: I can go to the iron monger, so they do it right?
Researcher: That's ok, I will join you in selecting scrap metals from construction sites and 'odo ero'

Sketch 3

The HDPE pipe was replaced with the bamboo wood in the proposed sketches by the researcher. It was initially assumed that the metal hooks used in the HDPE prototypes will be used to support the bamboo wood, however, the conversation below illustrates how the use of binding wires was suggested during a conversation:

Welder 1: We only decided to use metal hooks due to weight of the prototype, this one is much lighter…we can save money by using ropes?
Carpenter 1: Not too sure about ropes, it is still a bit heavy…
Community member 1: What about binding wires? they are like ropes but much stronger
Carpenter 2: That is much better than ordinary rope…and it is very cheap.
Researcher: ok, we use the binding wires and if there Is time for a third prototype, we try another option. Thank you very much for this idea…...

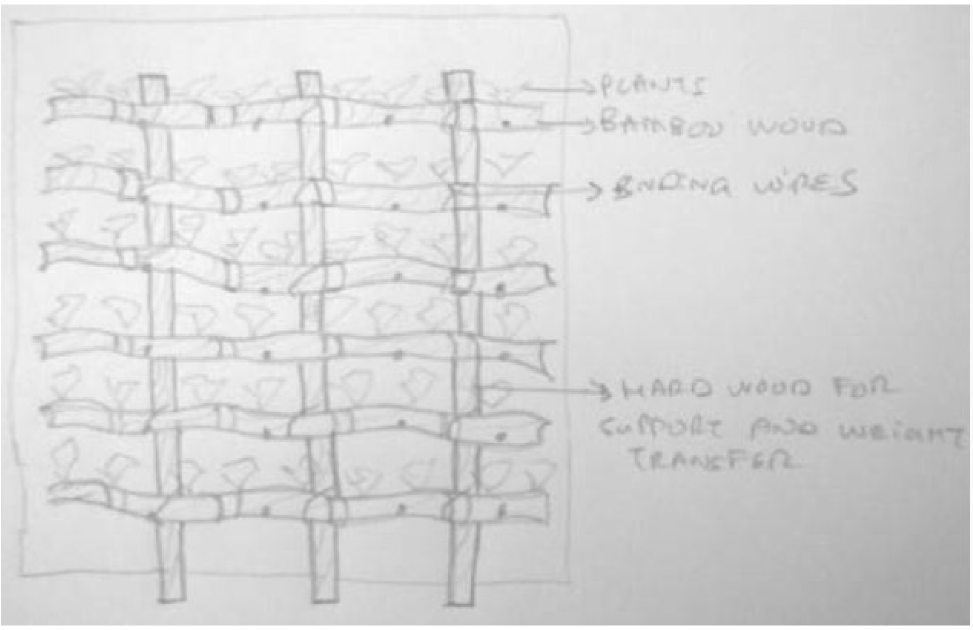


Figure 6-10; Preliminary sketch (on site) of Bamboo prototypes, Source, Author, as Co-developed with participants,2014

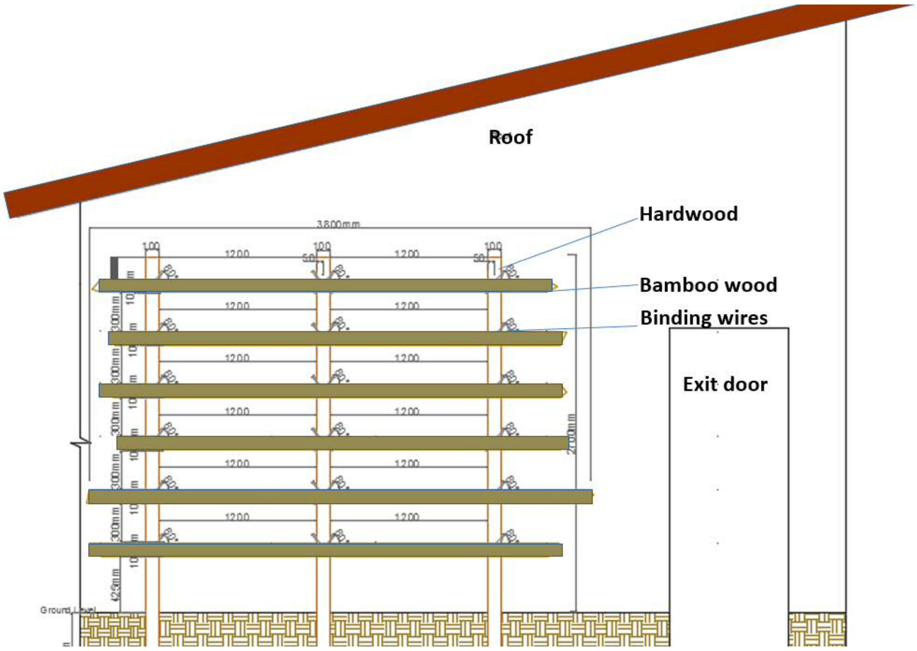


Figure 6-11; Sketch of Bamboo wood prototype, source, author, 2014

Materials (Suggestions for location and purchase) (1hr 30minutes)

Suggestions on ideal places for the best deals on prices, proximity to the site for less transportation costs and even possibility of obtaining the materials for free arose and a few places were recommended, as documented in the conversation below:

Researcher: Please where can we get the pipes and bamboo wood?
Community member 1: There are a few shops nearby, but they might be more expensive
Carpenter 1: There is a place called 'odo ero', it's a big market for pipes, wood etc.
Plumber: Yea but you need us to buy the items for you…you might be cheated price wise…
Carpenter 2: Yes, we all buy the items, once we have a list
Community member 2: Can't we get the wood for free in construction sites? Makes more sense….
Carpenter 3: We must ensure the woods are usable and termite free….
Carpenter 1: We can check the construction site across the road for wood they want to dispose of…
Researcher: Ok…I will follow you to 'odo ero' but I won't be part of the negotiation, if we don't find wood at the construction site, then we could negotiate at 'odo ero'
Community member 2: We could use large wheel barrow to transport them to site as well, as it is a short distance away…
Researcher: I will pay for that, anyone interested in doing this, do let me know so we can negotiate price?

The final list of materials [34] are illustrated below:

[34] listed by the researcher in the field note

Final list of materials	
HDPE prototype	Bamboo wood prototype
HDPE pipes	Bamboo wood
Metal hooks	Binding wires
Nails	Nails
Hardwood	Hardwood
Wood treatment	Wood treatment

Table 6-5; Final list of materials, Source; Author,2014

These were purchased through a total of 12 participants (who volunteered), with the researcher being a silent participant in this aspect, were involved in the process of negotiating prices and transporting purchased materials to the site at the end of the meeting and transported to Case Study House A at the end of the meeting.

6.1.3.4 Costing

The costing for the prototypes comprised of 3 aspects: Materials, transportation of materials to site and labour. To ensure that the prices were not exorbitantly charged, certain actions had to be undertaken by the researcher as discussed below:

Initial personal survey by the researcher for cost of materials (7th May 2014)

The initial budget for the cost of materials was compiled after the researcher's personal visits[35] and brief discussions with horticulturists in the community. This was to have a general overview on prices of materials and transportation prior to engaging with the community and recruited skillset, to offer basic knowledge for negotiating prices.

[35] On the 7th of May 2014, to another construction market, near the Agege community called Okeira construction market

Plate 6-3; Okeira construction market, source, author, 2014

Typical conversations relating to inquiry of prices for materials and transportation are illustrated below:

Researcher (after approaching a construction stall selling hardwood): Hello, what is the average price for these construction wood?
Trader: It is usually N10000-N10,500(£36-£42) per bundle (3-5), depending on the quality
Researcher: Is that your best price?
Trader: Bring N10,000, we also transport to the site at an extra charge

The initial estimated cost of the HDPE and Bamboo prototype by the researcher based on personal enquiry at the Okeira construction market is summarized in table 6-6 and 6-7 respectively. Worthy to note was that the prices listed above were for guidance for further negotiations only[36].

Initial cost for Labour (before negotiation, 8th May, 2014) (10 minutes)

After the community members left the meeting, the recruited skillset discussed their fee, time of work and general requirement. The person hired, skills and business name and task to be undertaken is summarized in table 6-6, 6-7, while the initial cost of labour is summarized in the detailed tables 6-8, 6-9. Extracts of these conversations are illustrated below:

[36] To offer a basic knowledge of the pricelist of materials for the researcher

Researcher: ok…we are the only ones left, let us discuss about fees and other logistics…please name your best prices for both prototypes…
Mr Balogun (carpenter): we the carpenters will charge you (N20,000 , £80) in total…….
Mr Tubosun (Welder): we will charge you (N8000, £32) in total…
Mr Calabar (Horticulturist): bring (N20,000, £80) in total…
Mr Steve (Ironmonger): I will charge (8000, £32) per day……….
Mr Adetoro (Plumber): I will charge you N10,000, £40) in total.
Researcher: (noting down prices in field note), of course you know we will negotiate these prices. Which will be more concrete later today…. the time frame of the project should be within 3 to 4 days, all things being equal and the requirement is just a neat job, I will be here along with a few of your colleagues (volunteering to input ideas) and some interested community members
All: ok, later then.
The possibility of being charged exorbitantly prompted the researcher to undertake a personal survey on the general payment rates[37] of the recruited skillsets by randomly approaching carpentry, welding, plumbing stalls and engaging in conversations about wages. Typical conversation is illustrated below:
Researcher (after approaching a carpentry workshop): Hello, hope work is going on well today?
Carpenter 1: Its going ok…are you looking to hire a carpenter today?......
Researcher: Yes, I am. If I want to hire you to assemble a group of bamboo and hardwood about 9m^2 in total, not likely to exceed a day's job, how much will you charge?
Carpenter 2: It depends, but based on your description, we could charge you N2000-N3,000 (£8-£12)
Researcher: Is that your best price?
Carpenter 3: That's the standard rate…

Final labour cost, 8th May,2014, (after 1 hour of discussing the initial costing for labour and personal survey)

The final labour cost[38] with the recruited skillset was re-negotiated as illustrated in the extract below:

[37] Through enquiry from other carpenters, welders and plumbers within the community on average daily wages, by directly approaching workshops/ stalls and asking what they charge daily .
[38] As summarized in table 6-6, 6-7

Researcher to recruited skillset: Hi everyone, as you know we haven't concluded on pay rate, I am offering N4000 to the carpenters as against the normal rate of N3000, the welders, ironmonger and horticulturist N3000 and the plumber N1000

Mr Alfa (carpenter): That's ok……

Mr Femi (Welder): Yea that's fine…………

Mr Calabar (Horticulturist): ok….

Mr Steve (Ironmonger): ok….

Mr Adetoro (Plumber): ok…

Researcher: (noting down prices in field note), Ok, I know I have been fair in these prices as the work required is not overly demanding. We begin work tomorrow, thank you.

Skills and business name	Task undertaken	Time taken to complete the task
Carpentry	Woodwork/physical assembling	2 days
Carpentry	Woodwork/physical assembling	2 days
Carpentry	Woodwork/physical assembling	2 days
Welding	Anchoring metal hooks to hardwood supports	1 day
Welding	Advice	1 day
Ironmongery	Transforming scrap metals into metal hooks (support for HDPE pipes)	1 day
Plumbing	Drainage system for excess water in prototypes	1 day
Plumbing		
Horticulturist	Planting of plants/ flowers	3 day's intermittent work - payed for 1 full day
Horticulturist	Advice	3 days
Horticulturist	Advice	3 days

Table 6-6; Skillset, task to be under taken and time completion proposed for labour (both prototypes)

It can be inferred that personal survey on payment rate enabled the researcher negotiate wages to a lower rate as compared to the initial exorbitant prices offered by the recruited skillset.

Final negotiation, purchase of materials and transportation from odo ero market, 8th May 2014, (3.5 hours, 3:30pm-7:00pm)

The negotiation for prices and purchase of materials with traders took place with 3 carpenters and a welder (who volunteered) on the morning of the 9th of May in Odo ero construction market, which is a large market with various stalls/ locations selling different construction materials, as illustrated in plate 6-4. The stalls (stations) are over 100 in total. The market was selected due to familiarity with the recruited skillsets. The researcher played the role of a silent participant. This entailed following the recruited skillsets to the market, but not partaking in the negotiations, rather, standing by as an observer and taking notes when needed, due to concerns of being charged exorbitantly when perceived to be an outsider.

Plate 6-4; Odo ero construction market, source, Author, 2014

The extract below reveals how prices were discounted by allowing the carpenters lead and close negotiations effectively.

Carpenter 1 (approaching trader he purchases materials): We would like the following items…hardwood, price to 'bend' metal hooks and hard nails….
Trader 1; You will pay N7500(£30) per hardwood…….
Carpenter 2: You are not serious o… do we look like idiots?
Trader; Ok, bring N5000?
Carpenter 3: we are not paying more than N3500, of which we are even being generous, don't you know us again?
Trader: ok, how many should I bring?
Carpenter 1; we will select the wood ourselves, so you don't give us substandard wood….

The materials were transported through trucks and additional means provided by the traders as a means of augmenting income. Inquiry on the use of a single truck to transport all the materials at once yielded more expenses due to the amount of materials purchased. A comparison of the initial and final cost of the materials, transportation to the Case Study Houses is outlined in table 6-8 and 6-9.

Plant purchase 9th May, 2014 (1:00pm-2:30pm)

The horticulturist escorted the researcher to purchase some plants agreed to be used in the prototypes from the popular garden in Ikeja, Lagos (G.R.A also called Government Residential areas) off Oba Akinjobi street as located in figure 6-12.These included: Tropical nettle, flowerless anti-snake plants and Pumpkin leaves.

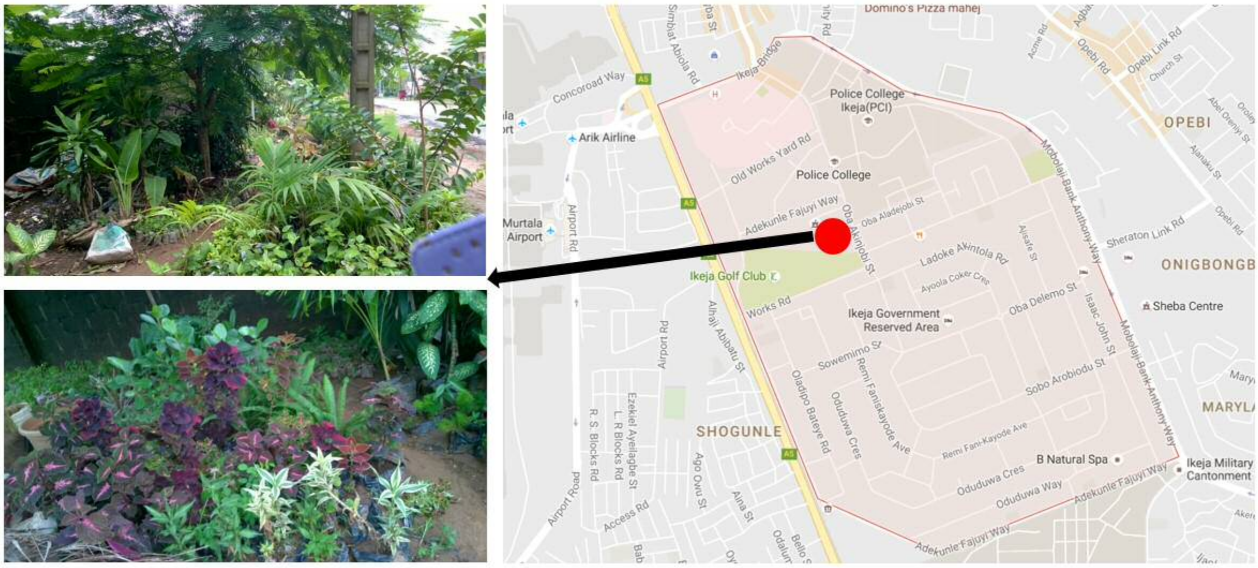


Figure 6-12; Location of gardens for purchasing plants in G.R.A, Lagos, source; Author and googlemap, 2014

While some seeds (Aloe vera and Corchurus) were provided by some community members. Multiple recommendations to dig up soil from the backyard and a nearby park arose, however, skeptism on the quality of the soil and its potential to maximize plant growth was displayed by the horticulturists as detailed in the excerpt below:

Community member; Let's just dig for soil in the park down the road
Horticulturist 1: We need to physically check the quality of the soil, as I know people urinate in that park
Researcher: We can check it first and if you are satisfied with the quality, we could go for it? Or will you suggest we buy the soil?
Horticulturist 2: let's check it first, we would use manure boost its quality if needed….

The quality of the soil was approved by the horticulturists, through their local knowledge and experiences of identifying fertile soil types and manure was used to improve its growth potential. Details of the quantity, places of purchase and transportation is illustrated in table 6-7.

Plant type	Plant quantity	Place of purchase	Transportation cost (singularly transported)
Soil	4 bags (2 per prototype)	Free from the back of the Case Houses	
Aloe Vera	50 (25 per prototype)	Provided by community members	
Corchurus plants (locally called Ewedu)	100 (65 in HDPE due to bigger size and 25 in Bamboo)	Provided by community members	
Pumpkin leaves (locally called Ugu)	48 (24 per prototype)	G.R.A(Government Residential Area, Ikeja)	Transportation cost for all goods purchased at G.R.A. N2000 (£8) added to the total
Tropical nettle	88 (44 per prototype)	G.R.A(Government Residential Area, Ikeja)	
Flowerless anti snake plants	88 (44 per prototype)	G.R.A(Government Residential Area, Ikeja)	
Manure	4 bags (2 per prototype)	G.R.A(Government Residential Area, Ikeja)	

Table 6-7; plants costing for both prototypes, source; Author, 2014

Initial and Final HDPE prototype costing (material , transport and plants)

The initial researcher's estimate of the HDPE prototype, without including the cost for plants was N110,250 (£441). Through community participation and their involvement in negotiating cost of materials/ transportation and the researcher's negotiation of initial labour costs , the final cost of the HDPE inclusive of plants was N67,928 (£ 271.7). An approximate 50% decrease in the initial estimate by the researcher as summarized in table 6-8.

Initial and final cost of High density polyethylene prototype													
Material type	Initial estimated material quantity	Final material quantity	Place of purchase	Initial estimated material cost	Final unitary material cost	Final total material cost	Initial transportation cost	Final transportation cost	Hired skill and task to be undertaken	Initial labour cost	Final labour cost	Plant type	Final cost of plants
HDPE Pipe	6	6	Odo ero market (HDPE trading section)	N7000 (£28) each, N42,000 (£168) in total	N4000 (£16) each	N24000 (£96) in total	N3500 (£14)	N2000 (£8)	Mr Balogun Carpentry Woodwork/physical assembling	N6000 (£24) per day	N2000(£8) per N4000(£16) total	Pumpkin leaves (locally called Ugu)	N30 (£0.12), each, 24 for HDPE prototype N720(£2.88)
Hard wood	3-5	3	Odo ero market (wood trading section)	N2100 (£8.40), each, N10,500 (£42) in total	N1500 (£6), each	N4500 (£18)	N2500 (£10)	N1000 (£4)	Mr Tubosun Welding Anchoring metal hooks to hardwood supports	N4000 (£16) per day	N3000(£12) total	Tropical nettle	N22(£0.09), each, 44 for HDPE prototype N968(£3.87)
Hard nails	0.5kg	0.5kg	Odo ero market (nail trading section)	N800(£3.2) per Kg	N800(£3.2) per Kg	N400 (£1.6)	N450(£1.80)	N150(£0.6)	Mr Steve Ironmongery Transforming scrap metals into metal hooks (support for HDPE pipes)	N8000 (£32) per day	N3000 (£12) total	Flowerless anti snake plants	N50 (£0.20) 44 for HDPE prototype N2200(£8.80)
Metal hooks	20	15	Odo ero market (Welders section)	N1900(£7.60) each, N10,500 (£42) in total	N666(£2.7) each	N9990 (£40)	N7000 (£28)	N5000 (£20)	Mr Adetoro Plumbing Drainage system for excess water in prototypes	N5000 (£20) per day	N1000 (£4) total	Manure	N500 (£2) per bag N1000(£4)
									Mr Calabar Horticulturist Planting of plants/ flowers	N10,000(£40) per day	N3000 (£12) total		
Sub total				N63,800 (£255.20)		N38,890 (£155.56)	N13,450 (£53.80)	N8150 (£32.60)		N33,000 (£132)	N14,000 (£56)		N4,888 (£19.50)

Initial Material + transport cost= N77,250(£309)

Initial labour cost= N33,000 (£132)

Total initial cost of Material+transport+labour cost=N110,250 (£441)

Final Material + transportation cost= N49,040(£196.16)

Final labour cost= N14,000(£56)

Final plant cost= N4,888(£19.50)

Total final cost of Material + transport+ labour+plants= N67,928 (£ 271.7)

Table 6-8: Initial and final HDPE prototype costing ,2014

Final Bamboo wood prototype costing(material , transport and plant)

As illustrated in table 6-9, the initial researcher's estimate of the Bamboo wood prototype without including costing for plants was N38,800 (£ 155.20). Through community participation culminating in decisions pertaining to accessing free materials (Bamboo wood and binding wires) as illustrated in the excerpt below;

Community member present: Instead of buying bamboo wood, we can get it for free from construction sites willing to dispose of them
Researcher: Really? Are you sure it is for free?
Carpenter 1: Yes, that's true, I should have thought of that initially, they will give you for free or at very low prices, but you must transport it to site yourself…
Researcher: Ok…please let me know of any nearby construction site we can approach for bamboo wood.
Carpenter 1: Ok. Also, don't buy binding wires, I have a free roll I can give for free…yourself…
Researcher: Thank you both for the bamboo wood idea and binding wires

Also, an indigenious approach to anchoring bamboo wood to foundation support through binding wires as oppossed to the metal hooks used in the HDPE prototypes was suggested as discussed previously, leading to another reduction in cost. The final cost of the bamboo wood prototype inclusive of plants was N17,788 (£71.1),a,55% decrease in the initial estimate by the researcher. At the suggestion of another community member, bamboo woods were obtained at a nearby construction site for free, it however, had to be transported using a hired minivan, which was fixed in price.

Initial and final cost of Bamboo wood prototype													
Material type	Initial estimated material quantity	Final material quantity	Place of purchase	Initial estimated material cost	Final unitary material cost	Final total material cost	Initial transportation cost	Final transportation cost	Hired skill and task to be undertaken	Initial labour cost	Final labour cost	Plant type	Final cost of plants
Bamboo wood	6	6	Free from nearby construction site (after agreement with the site engineer)	N800 (£3.2) each, N4,800(£19.20) in total	Free	Free	N2000 (£8)	N3000 (£12)	Mr Balogun Carpentry Woodwork/physical assembling	N6000 (£24) per day	N2000(£8) a day, N4000 in total	Pumpkin leaves (locally called Ugu)	N30 (£0.12), each, 24 for Bamboo prototype N720(£2.88)
Hard wood	3	3	Odo ero market (wood trading section)	N2100 (£8.40), each, N6,300 (£25.20) in total	N1500 (£6), each	N4500 (£18)	N1000 (£4)	N1000 (£4)	Mr Adetoro Plumbing Drainage system for excess water in prototypes	N5000 (£20) per day	N1000 (£4)	Tropical nettle	N22(£0.09), each, 44 for Bamboo prototype N968(£3.87)
Hard nails	0.5kg	0.5kg	Odo ero market (nail trading section)	N800(£3.2) per Kg	N800(£3.2) per Kg	N400 (£1.6)	N450(£1.80)	N150(£0.6)	Mr Calabar Horticulturist Planting of plants/ flowers	N10,000(£40) per day	N3000 (£12) total	Flowerless anti snake plants	N50 (£0.20) 44 Bamboo prototype N2200(£8.80)
Binding wires	1m length	Free as offered by a volunteer carpenter	Free from volunteer carpenter	N2000(£8), per roll	Free	Free	N450(£1.80)	Free				Manure	N500 (£2) per bag N1000(£4)
Sub total				N13,900 (£55.60)		N4900 (£19.6)	N3,900 (£15.60)	N4150 (£16.6)		N21,000 (£84)	N8000 (£32)		N4,888 (£19.50)

Initial Material + transport cost= N17,800(£71.20)

Initial labour cost= N21,000 (£84)

Total initial cost of Material+transport+labour cost=N38,800 (£155.20)

Final Material + transportation cost= N4,900(£19.60)

Final labour cost= N8,000(£32)

Final plant cost= N4,888(£19.50)

Total final cost of Material + transport+ labour+plants= N17,788 (£ 71.1)

Table 6-9: Initial and; final Bamboo wood prototype costing ,2014

Although the decision to use available bamboo wood eventually compromised the growth rate of the plants in the prototypes[39].This raises the question of affordability and functionality, does ensuring the affordability of VGS ultimately compromise its quality? Could there have been alternative means of purchasing bamboo wood with larger diameters which may have improved the growth of the plants?. These questions provide an opportunity for further research on balancing affordability with functionality when developing VGS with low income groups.

6.1.4 Construction of Prototypes (9th -12th of May, 2014, 12 noon-4:00pm daily)

This section details the physical process of assembling the prototypes. Decisions taken during this phase is also reported.

6.1.4.1 Aim of meeting

This was the final meeting for physically assembling the proposed prototypes. Invitation to community members had been extended in the two prior meetings. However, the recruited skillsets were personally reminded by the researcher on the dates, location and time of the meeting. This section is illustrated through hand sketches as developed on site, with detailed construction drawings by the researcher (although not detailed during the fieldwork). However certain decisions were decided on site, as the sketches developed in previous meetings only offered a general picture of the prototypes. The purpose for the inclusion of the detailed drawings is for easier comprehension, especially on intricate decisions, not easily explained through the initial sketches. Thus, storyboards are inculcated to explain actions and decisions undertaken during the field work[40]. Each prototype is discussed accordingly, beginning from the HDPE.

This meeting was attended by 38 people[41] in total (including the recruited members with specific skillset).

6.1.4.2 Meeting location and Set-up

Case Study House A and Case Study House B were the sites for developing the prototypes and thus the meeting locations. Timeline for developing the prototype in the former, which was the site for all the prior meetings was on the 9th and 10th of May, while the latter was on the 11th and 12th of May.

[39] This is discussed in detail under 'construction of prototypes'

[40]Field notes and memos documented the stages of the design and assembling of the prototypes, the relevant ideas and information suggested during discussions and incidents that unfolded were also recorded, this is incorporated accordingly

[41] Who volunteered to attend

Plate 6-5, Locations of site for assembling prototypes in Case House A and Case House B, source: author, 2014

The role of the researcher was defined as:

- Co-ordination of all activities pertaining to physical assembling of the prototypes

The role of the Case worker was defined as:

- Interpreting essential information in the local language (Yoruba) to ensure no one present is excluded.

An estimate of 4 hours in total for the meeting was anticipated due to the physical process of assembling the prototypes.

6.1.4.3 Construction process

Figures 6-13 and 6-14 illustrates the construction drawings developed by the researcher based on the initial sketches. This section outlines the processes, decisions, challenges encountered, and final implementations involved during the physical assembling of the prototypes. Details of the construction process is discussed concurrently (both the HDPE and Bamboo prototype) in 5 sections as outlined below:

- Foundation design, weight distribution and transfer of HDPE and Bamboo wood prototypes
- Preparation of containers (for both HDPE and Bamboo prototypes)
- Anchoring HDPE pipes and Bamboo wood to foundation support
- Drainage and irrigation method for both HDPE and Bamboo wood prototypes
- Plant distribution in both prototypes

Notable is that some unanticipated actions and decisions were decided in-situ during the assembling process. These are discussed accordingly.

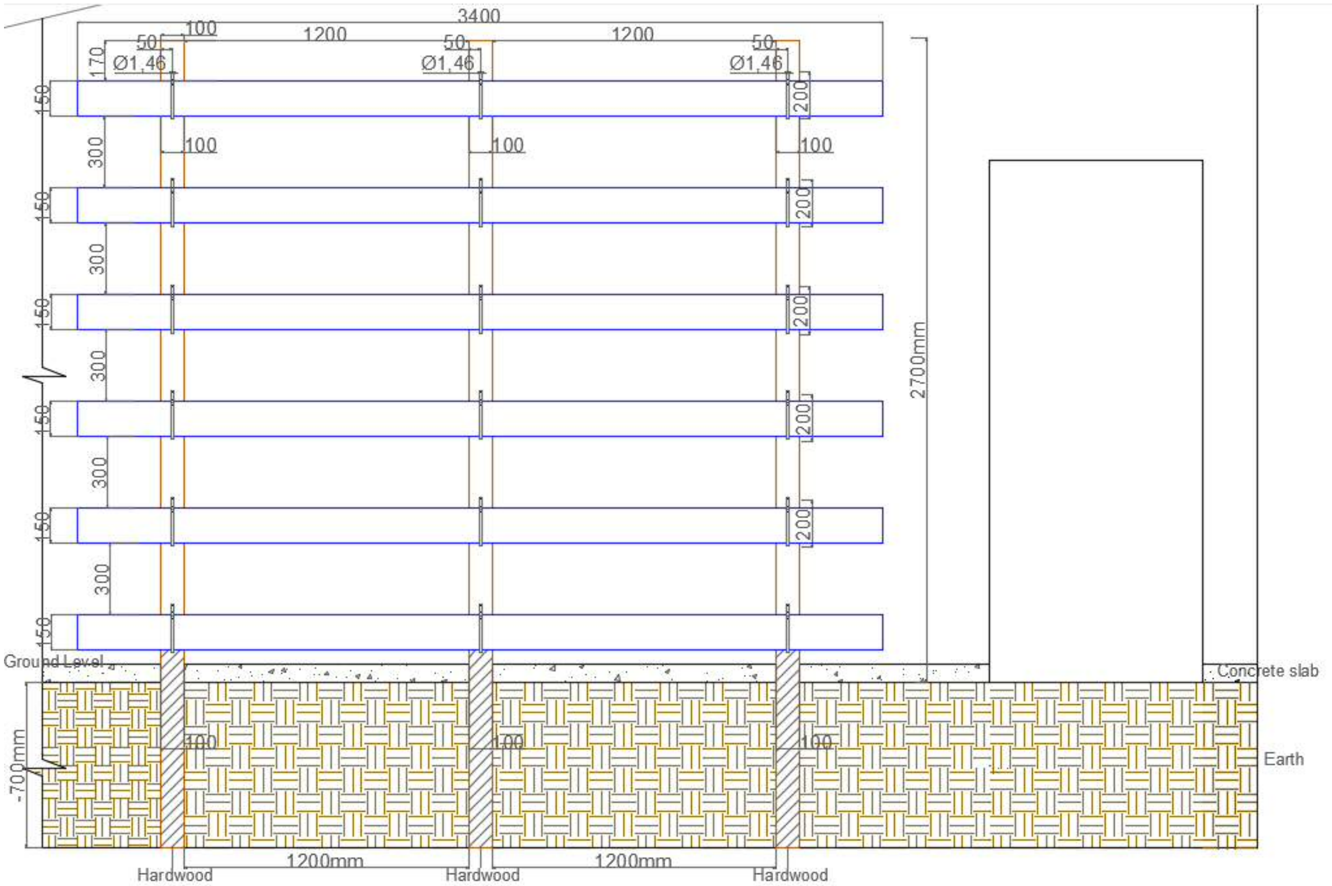


Figure 6-13; Construction drawing of HDPE prototypes, source, Author, 2014

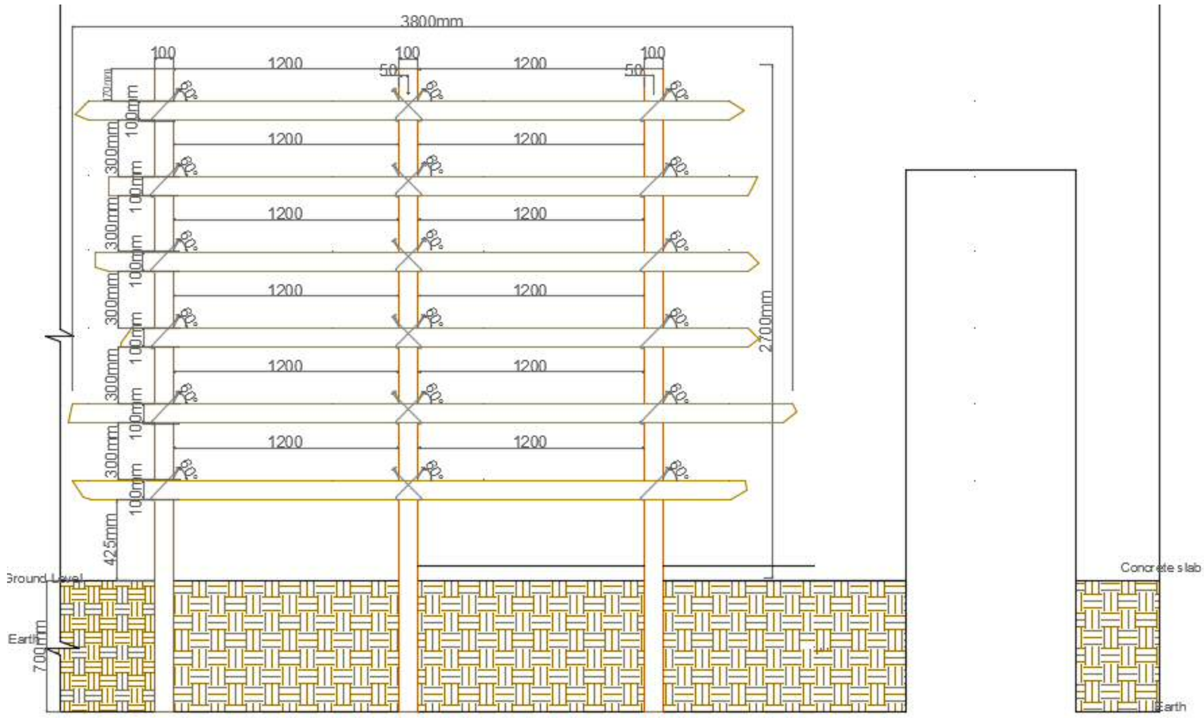


Figure 6-14; Construction drawing of Bamboo wood prototypes, source, Author, 2014

6.1.4.3.1 Foundation design, weight distribution and transfer of HDPE and Bamboo wood prototypes

The HDPE pipes were heavy and anticipated extra weight from the soil and plant was expected (between 10kg-20kg per pipe[42]), thus,while the initial suggestions[43] recomended the use of hardwood as a 'barrier' between the proposed prototype and building wall, transferring the weight of the prototype directly into the ground, the final decision was discussed during this process as illustrated below:

Case worker in House A: I hope the heaviness of the material will not affect the structure of the wall?......
Carpenter 1: I suggest we find a way to transfer the weight away from the wall into the ground
Researcher: Ok, what do you suggest?......
Carpenter 3: We use hardwood as a barrier between the pipes and the wall,….
Community member: Yes, and we dig into the ground to transfer the weight directly
Researcher (sketching the suggestion) I think that is a great Idea, thanks for that……

The culminated in creating a 'mini foundation' , dug 700mm into the ground, with the hardwood, placed inside the foundations and nailed diectly into the wall, subsequently transferring the weight of the prototypes directly into the foundation away from the wall. The same method was applied to the bamboo wood prototype, although the bamboo wood weight was not as heavy as that of the HDPE pipes (with an estimated weight of 5kg-10kg). These are illustrated in figures 6-15 and 6-16.

[42] After weighing soil and each HDPE prototype on site
[43] Based on the sketches developed in previous meetings by the carpenters and researcher

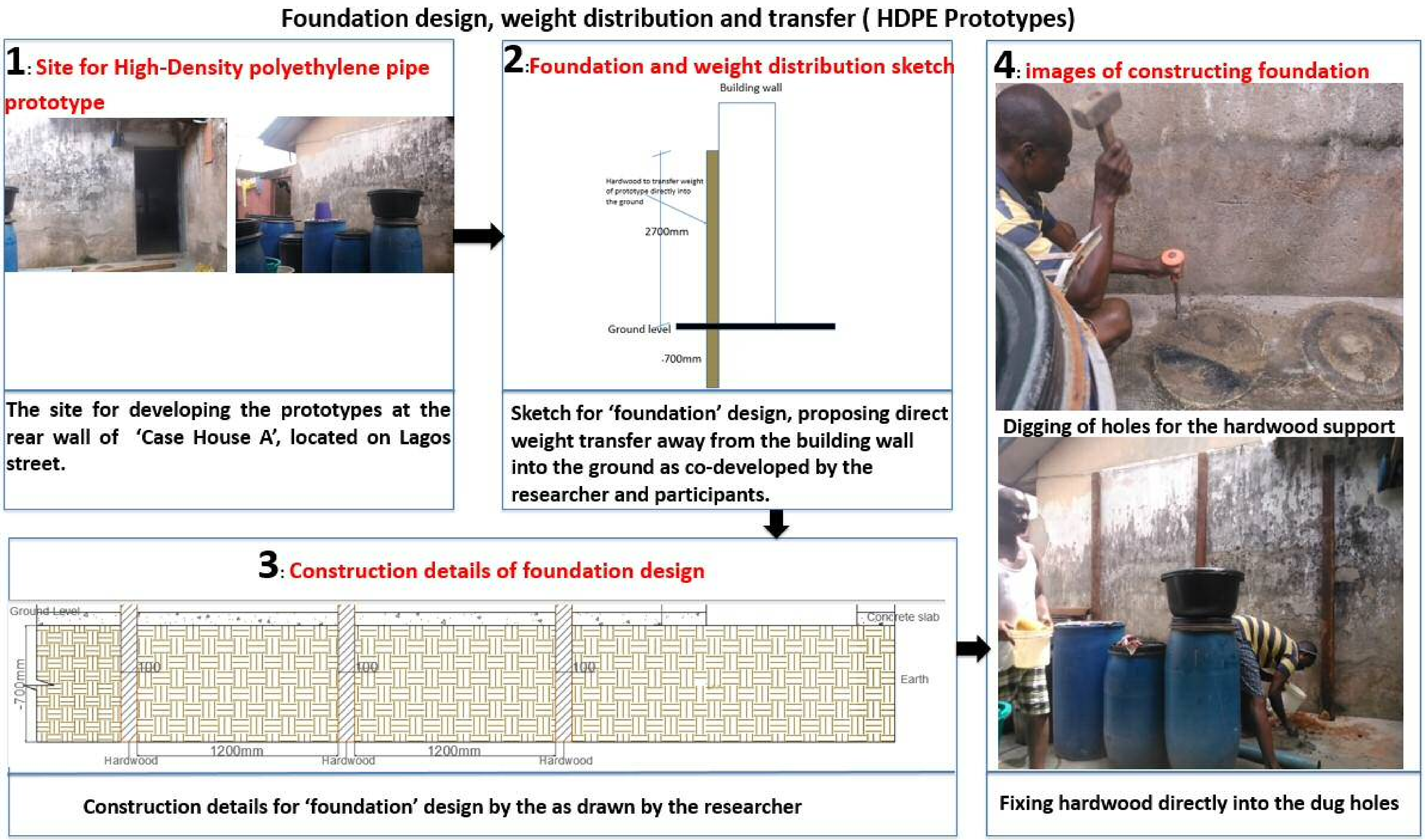


Figure 6-15; Simple mechanism of weight transfer, source; author, 2014, as developed with community members in Agege, Lagos

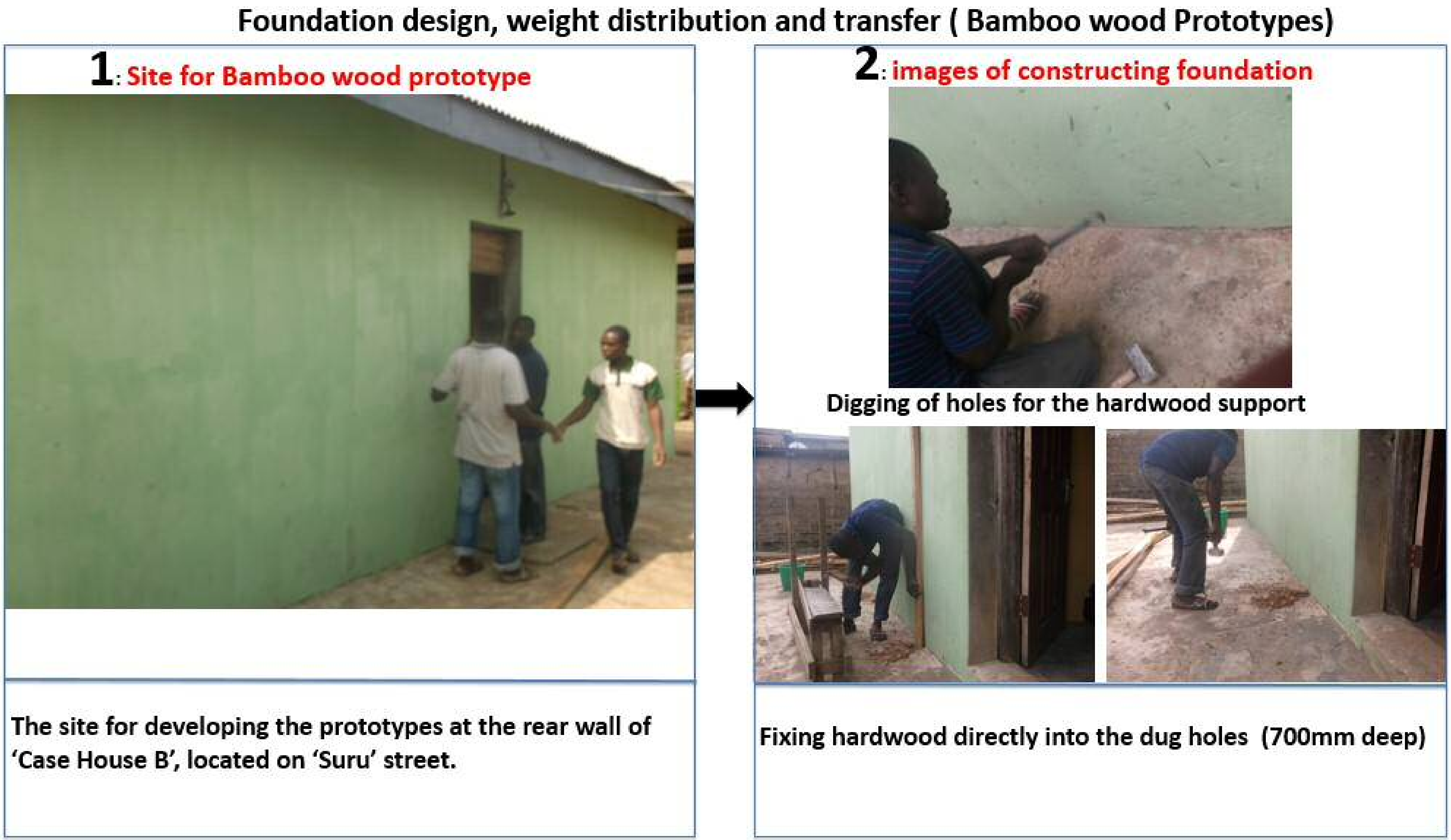


Figure 6-16; Simple mechanism of weight transfer, source; author, 2014, as developed with community members in Agege, Lagos

The first site (Case Study House A) was prepared through relocating the water drums originally in front of the walls[44]. The debris in front of the wall was then disposed by the Carpenter who also dug the holes with the use of a metal hammer and stake.

Plate 6-6; Holes dug for mini foundation, source, Author, 2014

In the second site (Case Study House B), the foundation was prepared by the Carpenter, using the same process of a metal hammer and stake to dig through the concrete flooring.

Plate 6-7; Digging foundation and placing 'hardwood barriers', source, Author, 2014

6.1.4.3.2 Preparation of containers

The exact process of transforming the HDPE pipes and Bamboo woods into containers was not discussed until the challenge presented itself. This was raised by the horticulturists pertaining to the amount of moisture/ water content the container might hold effectively as it was believed to influence the growth rate of the plants. Excerpt of the conversation and decision is illustrated below:

[44] As agreed with the occupants

Horticulturist 1; For the soil capacity, we need to ensure that the HDPE pipes are not cut in half……

Horticulturist 2; Yes, otherwise the amount of soil it holds is reduced. We need as much soil as possible since we are not planting directly into the ground.

Researcher; What do you reckon?...............

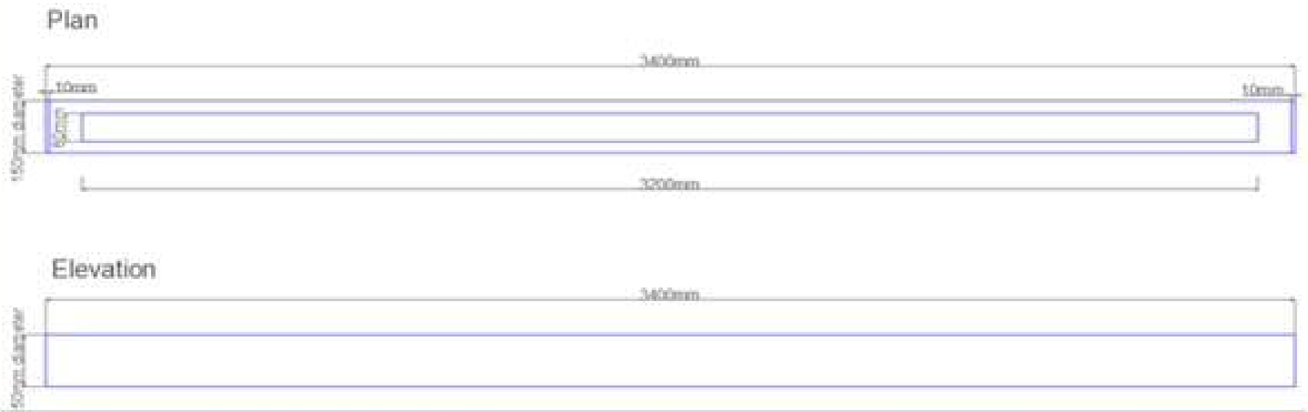
Horticulturist 1; We cut just a small part from the top of the pipes, as opposed to removing the entire diameter…….

Researcher; Alright then……

The welder created the container from the pipes, through the use of a specialist saw (due to the thickness of the pipe) after the dimensions was illustrated by drawing the lines to be cut directly

Plate 6-8: Marking HDPE pipes for area to be cut out, source: Author, 2014

1 Construction details for the High density polyethylene pipe prototype



Detailed construction drawing as developed by the researcher, based on discussions with the horticulturist

2 On-site construction

Cutting open the HDPE pipes with the use of Saw

Clearing debris from HDPE pipe

Figure 6-17; Preparation of HDPE 'containers' source; author, 2014, as developed with community members in Agege, Lagos

Although the agreement during the design meeting was to adopt an open form of container for planting as opposed to drilling tiny holes in the Bamboo wood. However, certain challenges pertaining to the choice of this material presented itself in the form of its propensity to degradation and being attacked by termites, thus each bamboo wood was 'cured' (treated with solignum wood preservative) for a few hours before they were prepared as containers, as suggested by the carpenters. The tools used were a saw to cut along the wood and a small metal wrench to remove excess wood from the area opened. While the carpenter was selected to create the container from the bamboo wood, due to his desirable skill for woodwork, as it required cutting carefulness when cutting around the joints of the bamboo wood[45].

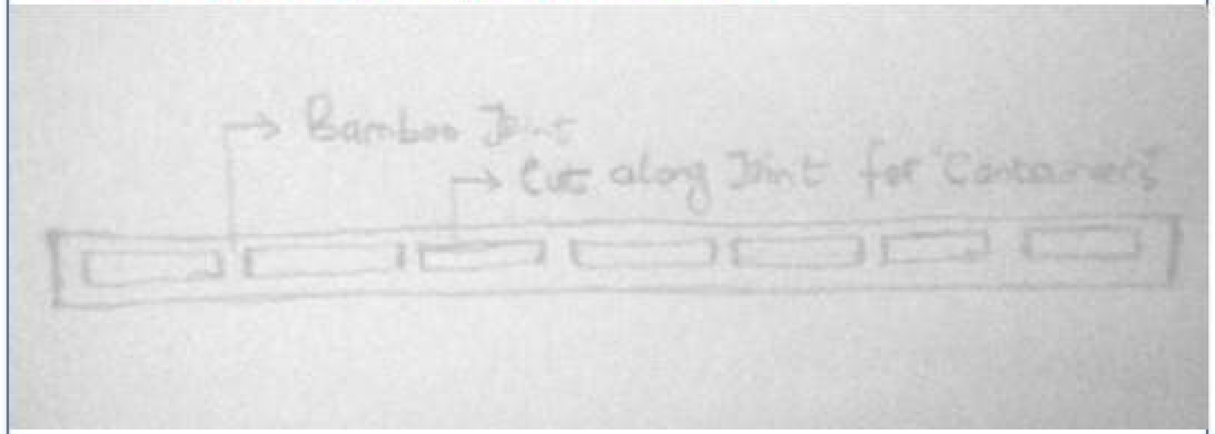
Plate 6-9; Marking Bamboo wood and cutting along joints, source: Author, 2014

The process is illustrated below:

[45] The bamboo wood was cut along the natural joints creating the container for the soil and plants

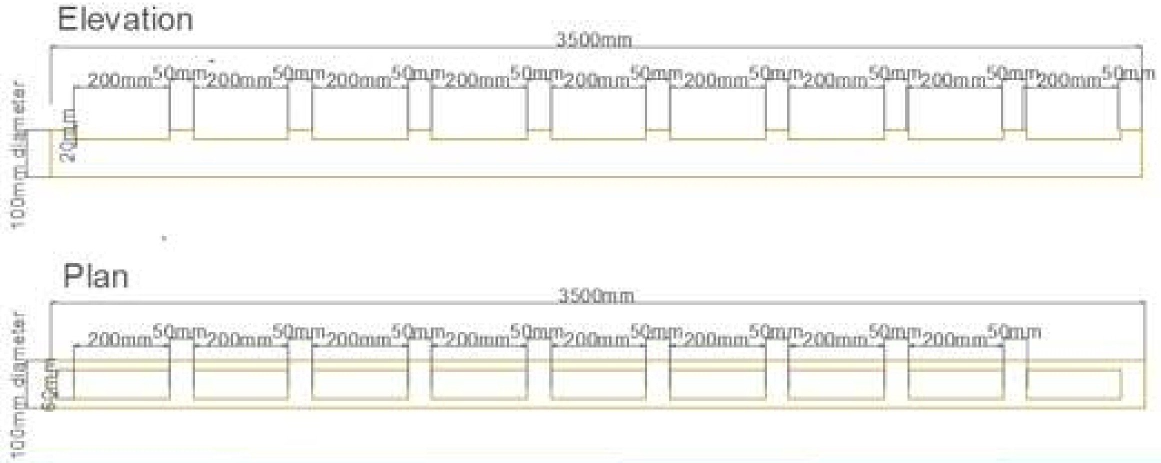
Preparation of containers (Bamboo Prototype)

1. Bamboo wood prototype on-site sketch



On-site sketch for the use of HDPE pipes as 'containers' as co-developed by the researcher and participants

2: Construction details



Detailed drawing by the researcher

3: Preparation on site

Leaving the treated bamboo wood under the sun to 'cure for a few hours

4: Preparation on site

Cutting along the bamboo wood joinery to create the 'containers' for the soil and plant

Figure 6-18; Preparation of 'containers' bamboo wood prototype, source, Author as developed with community members in Agege, Lagos

6.1.4.3.3 Anchoring containers to foundation support

The process of deciding and developing the ‘anchors’ for both prototypes has been discussed briefly in previous meetings.

With the anchors for the HDPE fitted within the specification required by the ironmonger and transported to the site, the Carpenter nailed each ‘anchor’ to the hardwood based on specific dimensions and spacing[46]. There was also the need to ensure that they were aligned in a straight line to prevent the prototypes from appearing skewed. This was done through the use of measuring tapes.

Plate 6-10; Measuring space between anchors in prototypes, source; author, 2014

Details on the process of anchoring the HDPE containers to the support is illustrated below:

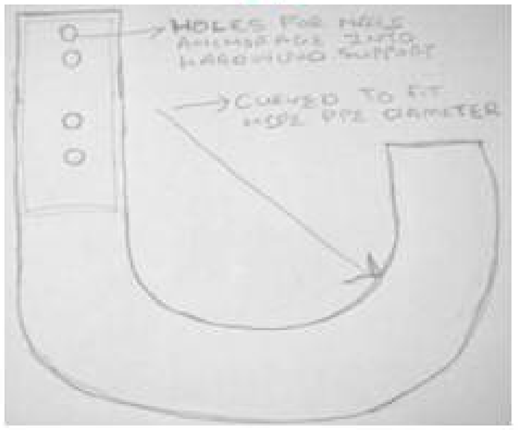
[46] 300mm spacing as recommended by the horticulturist to ensure plants are not ‘suffocated’ during growth.

Anchoring HDPE pipes to foundation support

1: Weight transfer finalization (with hardwood)

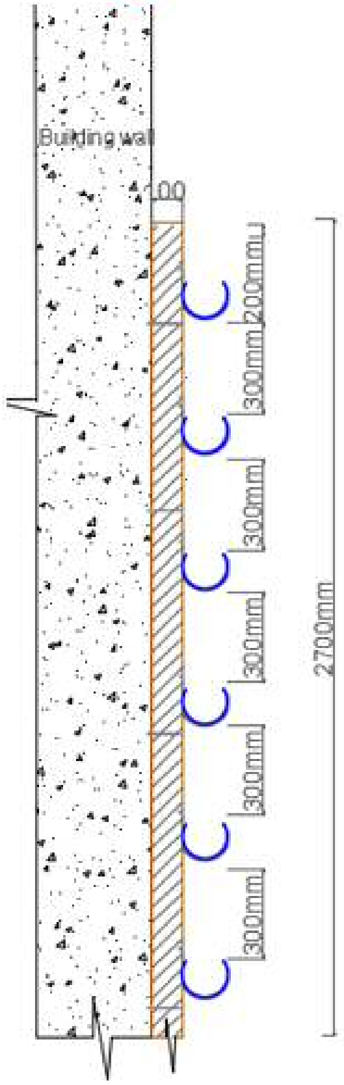
The site for developing the prototypes at the rear wall of 'Case House A', located on Lagos street.

2: On-site proposal for anchoring HDPE pipes to hardwood support



On-site proposals and sketches for HDPE Vertical Greening systems prototypes, as co-developed by the researcher and participants.

3: Detailed drawing of metal hook support



The metal hooks were arranged at 300mm spacing, at the recommendation of the horticulturist to allow space for plant growth formed with 150mm diameter to accommodate the HDPE pipes

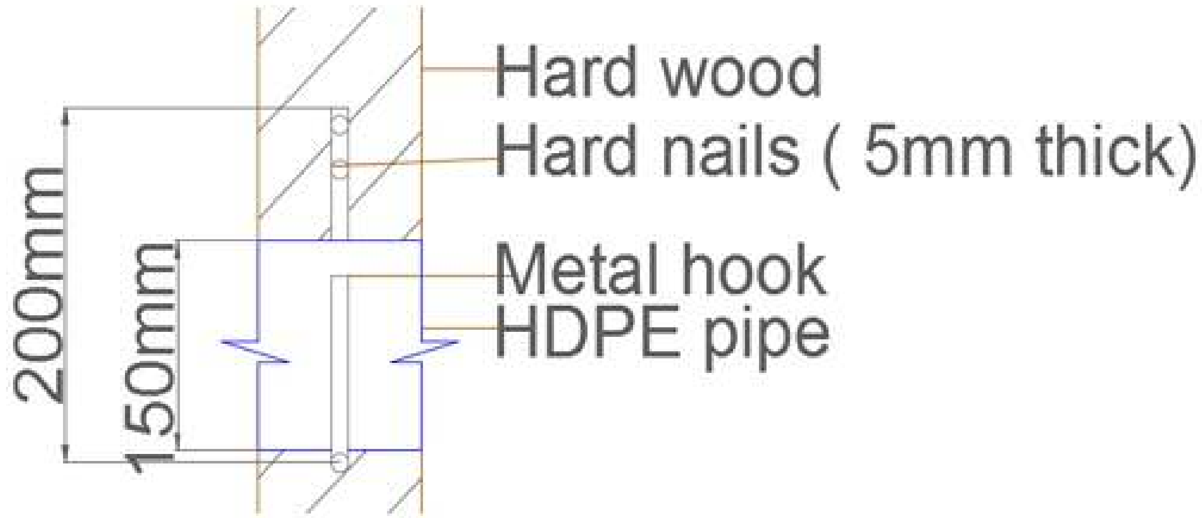
4: Detailed drawing of metal hook support 2

A detailed view of a single metal hook support (with an HDPE pipe). Hard nails were hammered directly into the hardwood (into the building wall) for support, while smaller nails were used to anchor the metal hook into the hardwood.

Figure 6-19; Anchoring HDPE pipes to foundation support, source, author as developed with community members in Agege, Lagos (1)

Anchoring HDPE pipes to foundation support 2

5: Detailed drawing of metal hook support 3



Elevation view of HDPE pipe in metal hook support

6: Images on Site 1

Hammering nails into metal hooks into hardwood supports

7: Images on Site 2

Measuring distances between anchors

8: Images on Site 3

HDPE Pipes fixed in metal hooks and anchored into hardwood supports

Figure 6-20; Anchoring HDPE pipes to foundation support, source, author as developed with community members in Agege, Lagos (2)

The anchor for the bamboo wood was developed through altering binding wires to fit around each wood and then fastened to the hardwood support through nails.This was done by the plumber.

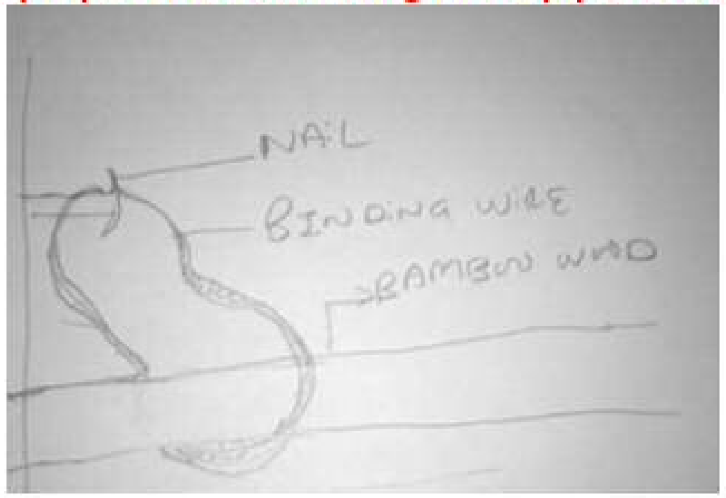
 

Plate 6-11; Anchoring binding wires to hardwood support, source: Author, 2014

Details on the process of anchoring the Bamboo wood containers to the support is illustrated below:

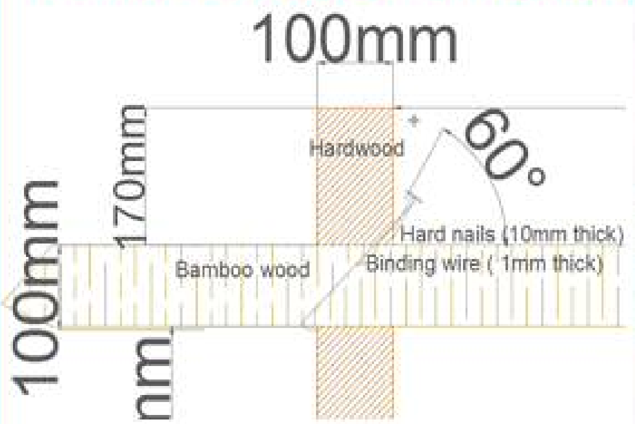
Anchoring Bamboo wood to foundation support

1: **On-site proposal for anchoring HDPE pipe hardwood support**



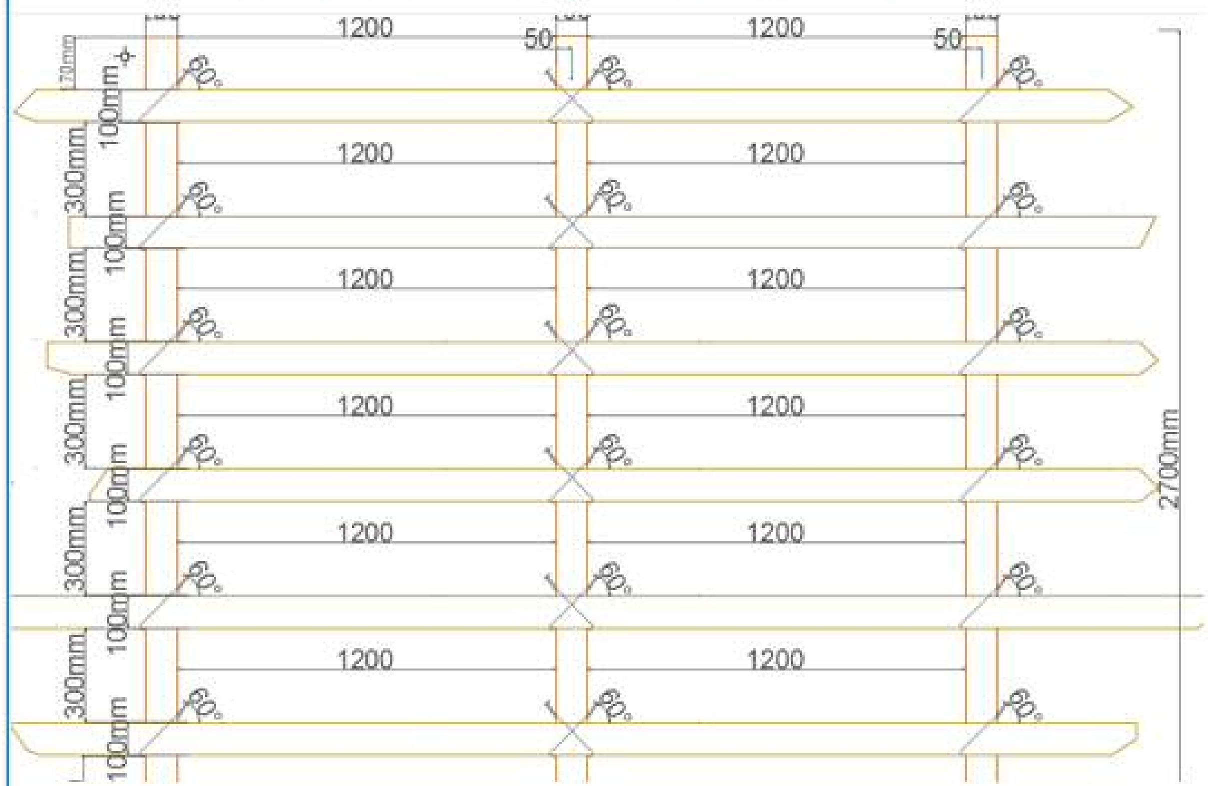
On-site proposals and sketches for Bamboo wood Vertical Greening systems prototypes, as co-developed by the researcher and participants.

2: **Detailed drawing of Bamboo wood (1) support**



A detailed view of a single binding wire support (with a bamboo wood pipe). Hard nails were hammered directly into the hardwood (at an angle) and the binding wires were wrapped round each wood while anchored to the nail

3: **Detailed drawing of Bamboo wood support (2)**



The Bamboo woods were arranged at 300mm spacing, with 100mm diameter. Due to the uneven length of each wood, the overall appearance was not as symmetrical as that of the HDPE prototype

Figure 6-21; Anchoring bamboo wood to foundation support, source, author, as developed with community members in Agege, Lagos

6.1.4.3.4 *Drainage and irrigation method for both HDPE and Bamboo wood prototypes*

Worthy to note is that due to absence of running water in both properties[47], water had to be purchased daily either from community boreholes or water vendors and stored in plastic containers by the occupants. Thus, purchasing the amount of water proposed by the horticulturist (two, 50 litre keg of water every 2 days) was financed by the researcher. A keg of water was N50, 0.20p.

The responsibility of watering the plants in both prototypes was taken up by the Case worker in House A. The drainage and irrigation method to be adapted for the prototypes was unanimously decided by all participants that drilling holes at specific distances was the easiest way to encourage excess water being drained. Extract from the meeting is illustrated below:

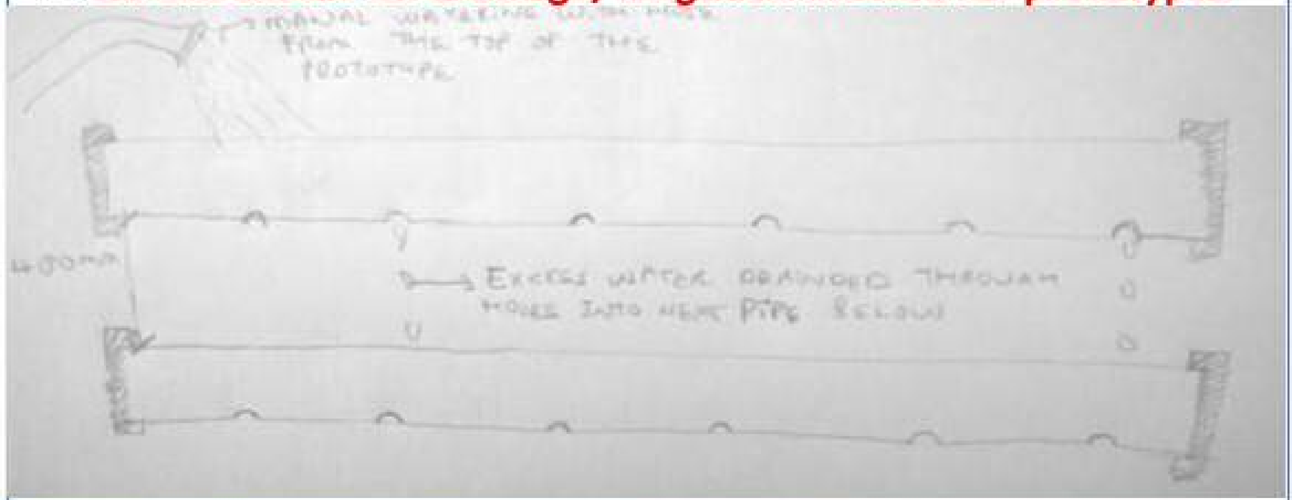
Researcher to Community members present: The VGS will have to get rid of excess water, what do you suggest?
Carpenter 1; Easy, we drill holes at specific distances on the HDPE and Bamboo, before we plant?
Horticulturist 1: The water will drip from the top to the bottom….
Researcher: Do you think it will have adverse effect on the growth of the plants?
Horticulturist 2: Plants don't need to be watered every day, a spray hose or even the use of bottles is fine
Community member 1: Won't it stain the wall?
Community member 2: That's a concern, dirty water staining the wall….
Carpenter 2; It can be minimized, water it carefully…...
Researcher: So, I guess we will adapt the simple solution to irrigation, drill holes…. It might be difficult in the HDPE as it is quite thick….
Carpenter 3; I can do it with my tools, shouldn't take too long.

Community engagement resulted in the simplest adaptation of irrigating the prototypes. The details of the development are illustrated below;

[47] Typical low-income houses in Lagos do not have running water. Water is usually purchased and stored in drums within these houses (Akinmoladun, 2007; Lawanson et al, 2012)

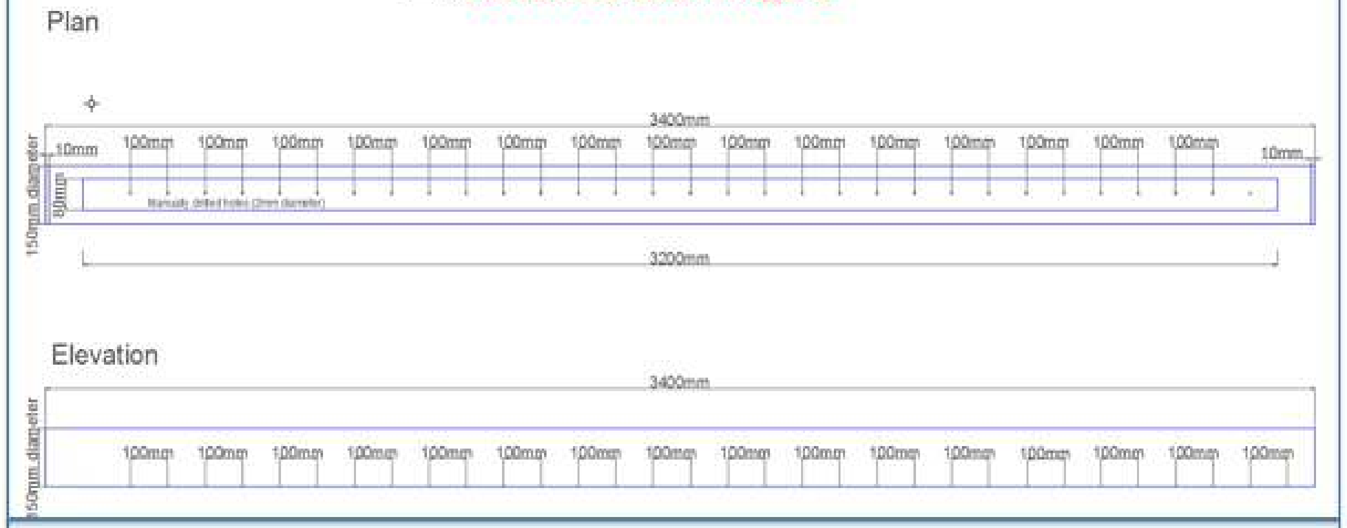
Drainage and Irrigation of HDPE prototypes

1: **On-site sketch for drainage/ irrigation method for prototypes**



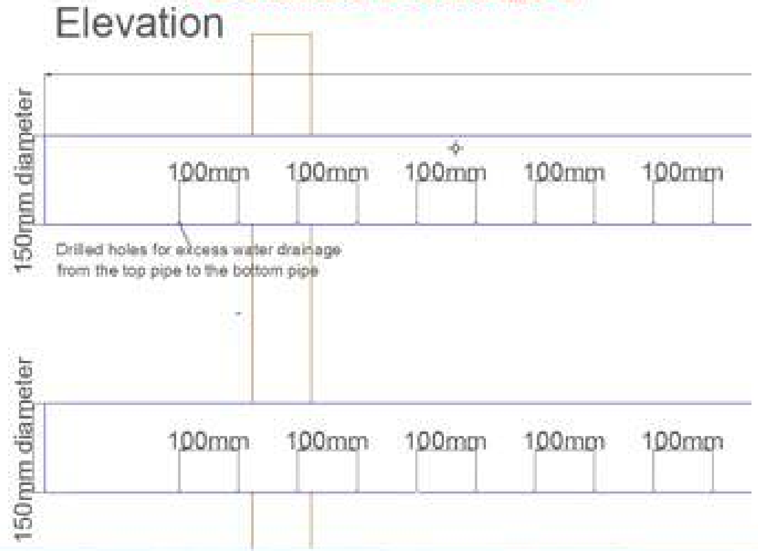
Idea emerged through discussion with participants. Manual watering with either a water can or hose pipe from the top of the pipe, with excess water drained into the pipes below.

2: **Detailed drawings 1**



Excess water drained through holes drilled in pipes manually, at 100mm spacing

3. **Detailed drawings 2**



Simple drip irrigation method

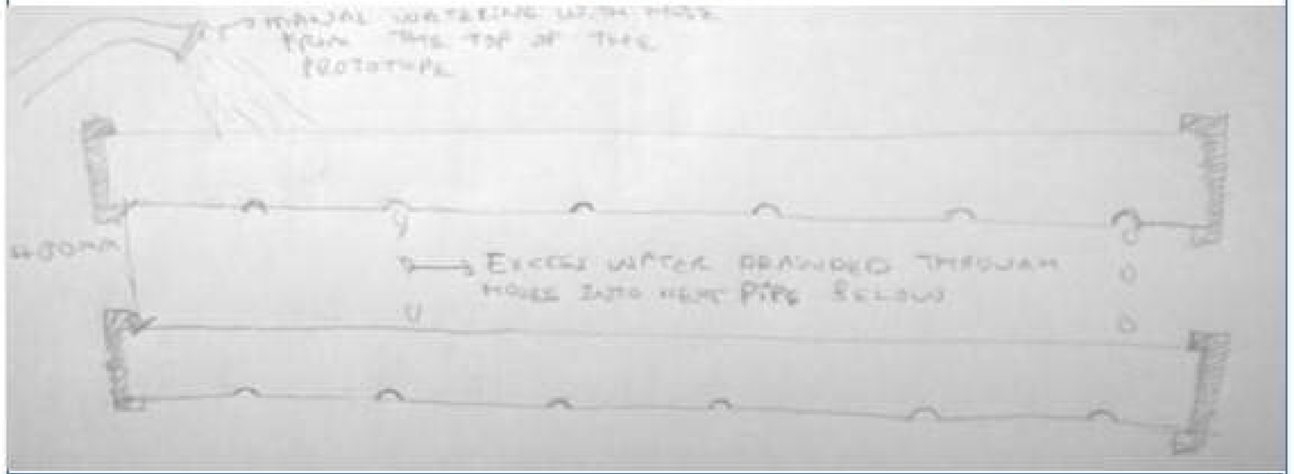
4: **Images on Site**

Process of manually drilling holes in pipes through a hand drilled machine, at 100mm spacing recommended by the horticulturist to prevent excessive water drainage

Figure 6-22; Drainage and irrigation of HDPE prototype, source: Author as developed with community members in Agege, Lagos

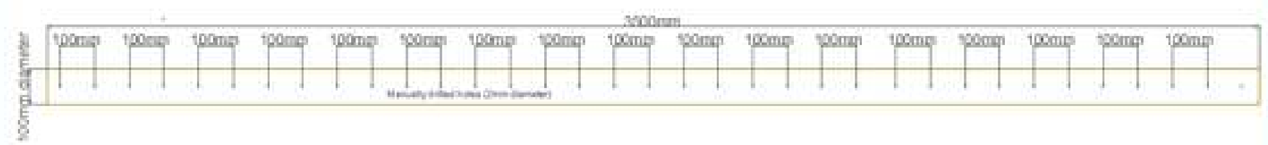
Drainage and Irrigation of Bamboo wood prototypes

1: **On-site sketch for drainage/ irrigation method for prototypes**



Idea emerged through discussion with participants. Manual watering with either a water can or hose pipe from the top of the pipe, with excess water drained into the pipes below

2: **Detailed drawing**



Excess water drained through holes drilled in pipes manually, at 100mm spacing(refer to HDPE prototype simple drip irrigation method)

3: **Images on Site**

Process of manually drilling holes in pipes through a hand drilled machine, at 100mm spacing

Figure 6-23; Drainage and irrigation of Bamboo wood prototype, source; Author as developed with community members in Agege, Lagos

This was done by the welder by using a specialist tool (a hand drilled machine of 1mm diameter) to create holes in the HDPE pipes for the drainage of excess water.

Plate 6-12; manual drilling of holes in HDPE pipes, source: Author, 2014

For the bamboo wood, the same procedure of using hand drilled machines was used as undertaken by the carpenter involved in assembling the prototype.

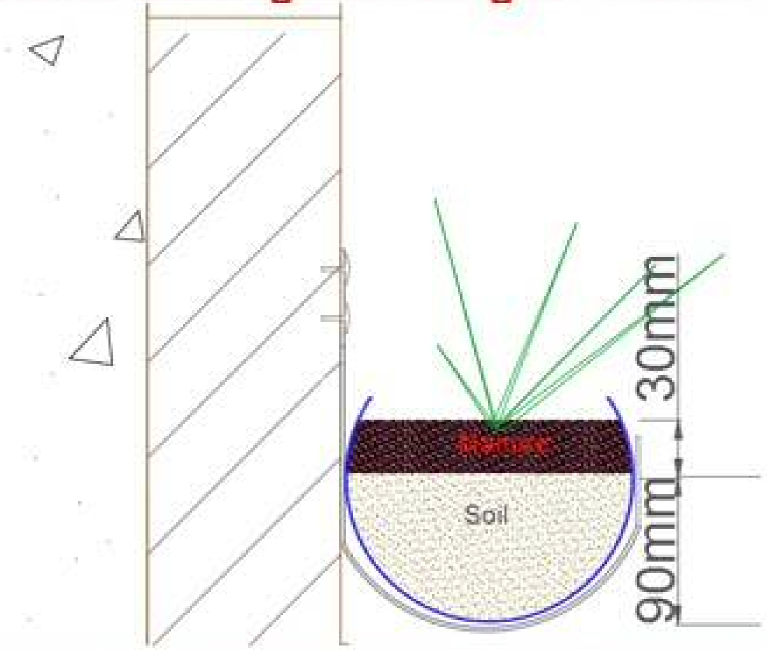
6.1.4.3.5 Plant and Soil type

With the quality of the soil approved by the horticulturists[48], the prepared containers were first mounted up and filled with the soil/ manure (90mm of soil and 30mm of manure for the HDPE protototype and 50mm of soil/ 20 mm of manure for the Bamboo prototype) as recommended by the horticulturist to allow more soil for the base for plant. Details of this is illustrated below;

[48] manure was used to improve its growth potential

Plant and Soil type in HDPE prototype

1: **Detailed drawing illustrating soil-manure ratio**



Details showing the ratio of soil-manure in each HDPE as recommended by the horticulturist

2: **Images on Site (1)**

Transporting soil and plants to site in sacks and buckets

3: **Images on Site (2)**

Planting soil and manure in HDPE pipes

4: **Images on Site (3)**

Physically planting selected plants in HDPE pipes

Figure 6-24; Soil preparation and planting in HDPE prototype, source: Author as developed with community members in Agege, Lagos

The plants were distributed in the prototypes primarily to increase/improve the percentage covering of the walls and to allow a variety of plants per container[49] as illustrated below:

Plate 6-13; arrangement of plants within HDPE prototype

The growth rate of the plants from May till August is illustrated below:

[49] There were at least 3 different plants per container

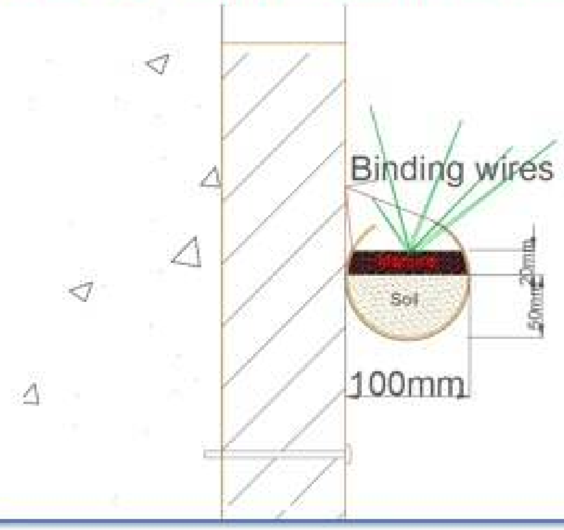
Figure 6-25; Growth rate of plants in HDPE prototypes from May to August 2014, source: Author as developed with community members in Agege, Lagos

Figure 6-25 illustrates the growth rate of the plants in the HDPE prototypes, from May 2014 till August,2014. With the recommendation by the horticulturist on watering the plants twice a week, the growth rate in the HDPE was satisfactory. However, between June 10th to June 16th, 2014, the growth rate of some of the plants (Aloe Vera and the flowerless anti snake plant) significantly decreased. Consultation with the horticulturist attributed this to excessive moisture content in the soil, leading to a waterlogged base for the plant and suggested the frequency of the watering be decreased to once a week. This improved the plant growth significantly.

Due to the smaller diameter of the bamboo wood, which was what was available to the researcher during this research, the volumetric capacity of soil/ manure (50mm of soil, 20mm of manure) was not as considerable as that of the HDPE prototype. Although larger bamboo woods could have been obtained, they were however located outside the city, resulting in both time and cost implications, thus, with the limited timeframe of the research, the researcher made use of the smaller and easily available bamboo woods. The implication of this was the limited growth rate of the plants within the bamboo wood prototypes.

Plant and Soil type in Bamboo wood prototype

1: **Detailed drawing showing soil-manure ratio**



Details showing the ratio of soil-manure in a single bamboo wood as recommended by the horticulturist

2: **Images on Site 1**

Planting soil and manure

3: **Images on Site 3**

Physically planting selected plants in bamboo wood pipes

Figure 6-26; Soil type and planting in Bamboo wood prototype, source, Author, as developed with community members in Agege, Lagos

Again, plants were distributed to ensure maximum percentage of wall covering. Each container had a variety of plants.

Plate 6-14; Arrangement of plants within Bamboo wood prototype

The growth rate of the plants from May till August is illustrated below:

Growth rate of plants in Bamboo wood prototypes (May to August, 2014)

Figure 6-27; Growth rate of plants in Bamboo wood prototypes from May to August 2014, source, author, as developed with community members in Agege, Lagos

6.2 Summary of Main findings

The importance of participatory engagement with communities in achieving affordable soil based living wall system yielded the results as discussed below:

1. **Simply adapted irrigation system**

With irrigation systems described as being complex and expensive in literature (Oosterlee, 2013; Olivieri et al, 2014), The simply adapted form was left majorly to the community participants, resulting in the simplest form of drip irrigation method. This involved no use of pumping machines, pipes or computerized watering systems, rather, a manual watering of the prototypes from the top to the bottom, with excess water drained from the holes in each pipe was incorporated resulting in a effective form of irrigation system, especially evident in the growth rate of plants in the HDPE protototypes. Noteworthy is that the input of the horticulturalist was required to ensure that watering levels were appropriate. Despite this input, over watering still occurred which stalled the growth rates of the plants.

2. **Recyclable materials**

Although the impact of materials on life cycle analysis was undertaken in Chapter 3, purchasing of some materials such as the bamboo wood provided alternative options of salvaging from construction sites, resulting in significant reduction in costs, 55% reduction from the researcher's initial estimted cost for the HDPE prototype and 50% for the bamboo wood prototype. While this suited the research context of financial affordability for low income groups, this may not suit the purpose of producing it in a larger scale. However, the process and procedures of producing the VGS could be adopted by other members of the low income groups culminating in its replicability across communities.

3. **Innovative structural anchorage**

Two innovative forms of anchorage/ support for the 'containers' emerged during the field work- the metal hooks and binding wires, which again resulted in significant cost reduction in assembling the prototypes. The detailed process has been discussed.

4. **Simple maintenance method**

The maintenance method was borne out of the desire for minimum efforts by the community participants, thus, the encouragement on the use of edible plants to double as food was greatly encouraged as it was believed that 'eating the plants' was a simple maintenance method as revealed in the discussion below:

Community member 1: Researcher, how can we maintain this? This might take time….
Community member 2: The plants are edible, we can always pluck them to eat if they are getting too bushy
Researcher: Remember the major influence in the choice of plants was medicinal and for food
Horticulturist 1: Maintenance is just a function of eating fresh vegetables then…but please let them grow before you eat them…...
Community member 3: That sounds ideal, what about watering it?
Horticulturist 2: Please don't water everyday as it will kill the plants, every two days is fine and during rainy periods, no need.
Researcher: That sounds straightforward……

6.3. Lessons learned during the participatory development of the prototypes.

- Maximizing participatory development with community members begins by acknowledging every suggestion and enabling the final decisions to be mutually decided upon as much as possible[50], as illustrated in the extracts of the conversations that took place during this study. However, maintaining a form of control on the final decisions is important so as not to lose focus on the overall aim of the research. This can only be learned 'on the field'
- Care should be taken that the researcher is not excessively charged (money) for labour by undergoing independent and personal research in this aspect.
- The community members are resourceful and intelligent but will only offer technique and expertise when they feel respected.
- Negotiations for materials should be left entirely to the recruited skillset with the researcher playing the role of the 'silent participant'[51]. This is to ensure that material prices are not overcharged.
- Bamboo wood is prone to degradation and requires pre-treatment (with wood preservatives called Solignum) before being used.
- Due to technological and substrate limitations, the prototypes developed did not have 100% maximum percentage of wall covering, especially when compared to other studies with more sophisticated VGS in literature. Although, this may have imparted the results documented in Chapter 8[52], the findings of this study relate more with the

[50] Through less interruption by the researcher when such conversations were taking place
[51] The role as a silent participant' has been discussed-being present at all negotiations but not participating
[52] Presented as Result of environmental performance of prototype in Case Study House A

process and procedures with engaging a low-income community in producing cheaper alternatives to these otherwise expensive systems.

- As illustrated above, the growth rate of the plants in the bamboo wood was not as prominent as that of the HDPE. This could be attributed to the minimum space for plant root growth provided by the bamboo wood container [53]subsequently resulting in minimum percentage of wall coverage. Discussing this in relation to relevant literature, studies by Kontoleon and Eumorfopoulou (2010) in the Greek region during summer revealed that the thermal performance (indoor temperature reduction) of the building envelopes was dependent on as the wall covering percentage of the plant foliage (from 0-100%), with the influence of a green layer on the wall surface is more pronounced for east- or west-oriented surfaces. This phenomenon was further explained by (Krushe,1982), that vegetation protects wall surfaces from the thermal loads of long wave radiation through the reflective properties of plants, the convection of the energy absorbed by plants for their growth and biological functions and the evaporation from the foliage. Consequently, the foliage that covers up wall surfaces significantly restricts the influence of outdoor environmental conditions such as ambient-air temperature, solar radiation, relative humidity and wind speed direction. Thus, with the poor growth recorded in the bamboo prototype, its environmental impact will be unexplored in the next chapter.

6.4 Community Based Participatory Research and its role in the result

The detailed discussion on the pariticipatory development of both prototypes reveals how the process of engaging the most cited strengths of CBPR by Webb (1990) and Israel et al (1998:2001), enabled the development of affordable prototypes, which are briefly outlined below:

- **Allowing innovative adaptation of existing resources**; which was through shifting power of decisions to the community and viewing it as a symbiotic process of knowledge exchange. This required a conscious effort of suppressing initial prejudices pertaining to essential design elements of Vertical Greening Systems in literature on the part of the researcher and being open with ideas emanating from the community participants.
- **Exploring local knowledge and perceptions**; which was through meetings, discussions and allowing uninterrupted conversations among the participants. The aim was to ensure that they had a sense of ownership of the prototypes and their opinions and contributions mattered.

[53] As discussed by the horticulturist during the meetings.

- **Empowering people by considering them as agents who can investigate their own situations**, which was again allowing the process of uninterrupted conversations and the researcher only stepping in when it diverged from the original topic. They were encouraged to brainstorm, to be creative in their solutions and no idea was discarded.
- **Encouraging the community input to enhance project credibility**, which involved a detailed process of recruiting the community, Case Study Houses, familiarizing oneself with the baale and community leaders and generally ensuring the right foundation of trust and mutual respect was built. Only then did they fully participate and help in achieving the objectives of this research.
- **Joining research participants who have varied skills, knowledge and expertise to address complex problems in complex situations**, which involved a detailed process of identifying those with the right skillset and encouraging participation regardless of them being physically involved in the assembling process.
- **Providing resources for the involved communities, through its collaborative nature**, which entailed discussions and mutual decisions on processes, location of materials and innovative approaches to complex challenges
- **Providing a forum that can bridge across cultural differences among participant;** which involved numerous meetings, door-to-door inquiries and being immersed within the community in general. The recruitment of the case worker in Case Study House A to interpret in the Yoruba (local language) also helped to bridge such gaps over time.
- **Helping to dismantle lack of trust communities may exhibit in relation to research**; which was through time and working with the community in developing solutions to challenges which arose during the research process

Reiterating, the entire process of participatory development did not follow pre-conceived processes and ideologies, rather, it emerged on its own during the field work, as argued in Chapter 3.

Chapter 7: Methodological Design for Testing Environmental Performance of prototype

The decisions and criteria culminating in the selection of the Case Study Houses for the site of the development, assembling and testing of the prototypes has been discussed in Chapter 5, while the participatory process of physically constructing the prototypes has been discussed in Chapter 7, which has concluded that due to the poor growth of plants leading to minimal wall coverage over summer months in Case Study House B (Bamboo wood prototype), the effect of this prototype on indoor temperature/ occupant comfort is not analyzed. Thus, the focus for the remainder of the thesis will be on the performance of the HDPE prototype in Case Study House A. This Chapter begins by discussing the challenges associated with field experiments i.e the use of room 10 as a control proxy for room 1. The arguments for undertaking the field experiment is then outlined, culminating in the series of steps to be taken to ascertain the comparability of both rooms.

7.1 Experimental design overview

` As discussed in previous Chapters, the particularity of the Case Study Houses relates to its free-running mode and overcrowded rooms. Thus, documenting the effect of the HDPE prototype in this setting on energy use is irrelevant as no energy is used to condition the space and further there is poor electricity supply to the Case Study Houses. Rather, the VGS impact on occupants' comfort is of primary interest to this study, where this impact is to be evaluated through the direct benefits this system could bring to variables relating to thermal comfort i.e. in the reduction of internal air temperatures by comparing a control and experimental room within the Case Study House. Establishing experimental and control rooms as opposed to the use of the same room for evaluating the performance of the prototype was based on two primary factors:

1. Time constraints in conducting the experiment
2. Relevant literature

In relation to literature, Price (2010); Chen et al (2013); Safikhani et al (2014); Olivieri et al (2014) documented the impact of the VGS by comparing two (control and experimental) specially constructed thermal laboratories, controlled settings, which is a departure from the context of this thesis. Other experiments conducted within live settings that involved the comparison of experimental and control rooms include Cheng et al (2010) and Susorova et al (2013; 2014). However, the indoor variables were controlled mechanically, which is again a dichotomy from the free running context of the Case Study House in this study. More recently, Chu (2014) documented the impact of VGS in naturally ventilated flats in London, during summer. This also involved the use of two flats (experimental and control) as well as interviews with occupants. However, details on the extent of the comparability of the two flats were not documented thus questioning the reliability of the results.

The study conducted in this thesis is the first to evaluate the effect of the VGS by comparing two rooms in a low-income residence without any attempt to manipulate variables.

Therefore, it is the intention of the author to ensure that a careful and systematic evaluation of the comparability of both rooms be undertaken to ensure reliability of results. However, this is not without challenges. As discussed in Chapter 5, rooms within low income houses are often characterized by differences in activities/ lifestyle of occupants (Abiodun, 1993; Agbola, 2007; Akinmoladun,2007; Lawanson et al, 2012) as well as increased possibility of variations in physical characteristics e.g. overshading from surrounding buildings. This raises pertinent questions relating to reliability in the use of room 10 as a control proxy for room 1. Thus, informing a series of methodological steps undertaken to ascertain this as described below:

- **Step 1: Field study instrumentation**
  A detailed description of the variables measured, and their purpose, tools and methods of measurement is outlined.
- **Step 2: Comparing occupant's lifestyle, activities and equipment usage**
  The first step in comparing both rooms was to document the rooms' usage and activities, as it was imperative to calculate internal gains, which could in turn influence indoor thermal comfort.
- **Step 3: Solar radiation study (comparison of western wall surface)**
  Although both rooms share a common west facing wall, it might have different incident solar radiation due to overshadowing. Thus, it was imperative to establish the amount of solar radiation received on the wall surface of each room as these affect heat flux through the walls, which could in turn influence the comparability of the rooms, subsequently influencing the result.
- **Step 4: Integrated analysis**
  The integrated analysis is undertaken both for comparison between the two rooms and then finding relationships between variables to ultimately determine if the impact of the prototype (if any) is due to the VGS and not any other criterion.
  It involves bringing together the studies of total internal gains undertaken in step 2, total solar incident radiation on the west facing walls as undertaken in step 3, measured average hourly wall surface temperature and average hourly internal air temperature (AHIA) as undertaken during the field work described in step 1.

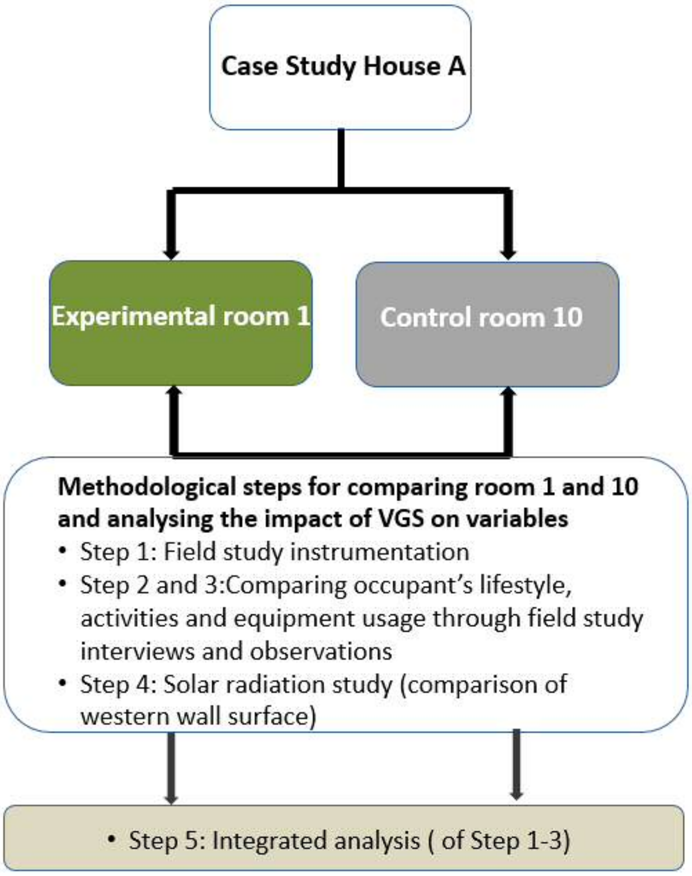


Figure 7-1; General methodological steps for comparison of Experimental room 1 and Control room 10

However, field experiments are not without challenges, which is discussed below:

As previously asserted, the purpose of the experimental field study is to physically measure the impact of the developed prototype on indoor air temperature within Case Study House A. Similar studies that tested the impact of VGS on thermal comfort variables in physical experiments include; Wong et al (2010); Perez et al (2011); Sunakorn and Yimprayoon (2011); Chen et al (2013) and Susorova et al (2013; 2014). However, no study in the literature (to the authors knowledge) has involved the development of affordable prototypes in tropical Africa and subsequently physical measurement of its impact on indoor comfort. Thus, the arguments for undertaking the field study as postulated by Oppenheim (2008) include:

- Field methodology provides a view of performance in practice. Unlike the laboratory methods that often involves control and isolation and might divorce the research from reality, in this case is explicitly context specific.
- The environment is as found. The use of laboratory methods might have involved artificial conditions which may, in this context make the results challenging to interpret appropriately.

- Unknown processes or unanticipated factors can occur; as the behaviour is closer to reality. This includes challenges encountered whilst undertaking the field work which accurately points to realistic scenarios in the study.
- The use of laboratory methods may have resulted in subjects involved not being representative of real-life occupant's activities/ lifestyle. Thus, the aim of this field study is to capture the behaviour of VGS in as realistic as possible context, to allow for successful implementation should the need arise.

7.2 Field study instrumentation

Although field studies on the impact of VGS on variables (particularly interior air temperature and energy consumption) has been documented by Wong et al 2010; Oosterlee,2013, no studies on the impact of VGS on occupant's thermal comfort within a live setting (such as the Case Study Houses described in Chapter 5) has been documented. Thus, the purpose of section 7.2.1 is to review relatively comparable studies to inform final decisions on variables to be measured and methods of measurements.

7.2.1 Experimental description , variables measured and tools/error bands

As discussed, the primary interest in testing the developed prototypes primarily relates to its impact on indoor comfort, thus informing the variables measured. This section describes the purpose of the variables selected for measurement.

- **<u>Indoor air temperature</u>**

The aim of measuring indoor air temperature was to gauge the effect of the VGS on indoor air temperature in room 1 (experimental room) by comparing it with room 10 (control room), to determine if, and by how much it reduces indoor temperature in the experimental room. Although studies by Safikhani et al (2014); Chen et al (2012) measured indoor air temperature and relative humidity using experimental and control rooms/ thermal laboratories, they were usually mechanically controlled. However, Price (2010) documented the impact of this variable within a free running uncontrolled thermal laboratory, which although is similar to this research context, the live context, which is paramount to this thesis was missing. More recently, Chu (2014) documented the impact of VGS on indoor air temperature and indoor relative humidity in a naturally ventilated flat in London, which like the interest of this study, was free running and involved in documenting its direct impact on the occupants. However, the peculiarity of this thesis lies in observing the impact of the developed prototypes on the variables, particularly within the adaptive thermal comfort temperature range, as discussed previously in Chapter 3 .

- **<u>External wall surface temperature</u>**

The purpose of measuring external wall surface temperature was to gauge the effect of the VGS on external wall surface temperature of room 1 by comparing it with external wall surface temperature of room 10. This is to determine if the VGS reduces wall surface temperature, subsequently reducing heat flux (and possibly heat gain indoors) through walls. Although the impact of VGS on these variables were documented in studies by Wong et al (2010), it was conducted on 'stand-alone' external surfaces and not in live settings. Studies by Kontoleon and Eumorfopoulou (2009); Price (2010); Perez et al (2011); Chen et al (2013) documented the effect of VGS on external wall surface through comparison between the bare and plant-covered surface sections of walls. However, the results were focused on the developed temperature variations and dynamic thermal characteristics of wall surfaces, without consideration of its impact on indoor and occupants.

- **External air temperature**

The purpose of measuring external air temperature was to gauge the effect of the VGS in the outdoor area adjacent to it by comparing temperatures approximately 1m (as undertaken in relevant studies from literature by Wong et al,2010; Price, 2010; Chen et al, 2013) away from external walls in rooms 1 and 10 to determine its potential on surrounding air temperature which could be beneficial socially to the occupants in the Case Study House, in that the area around the installed prototypes was used often used for social activities.

- **Indoor relative humidity**

In general, an occupant's ability to modify any uncomfortable indoor thermal conditions in tropical naturally ventilated building is limited (Feriadi and Wong, 2004). More so, relative humidity is always constantly high throughout the year in the climate of Lagos. This impact of this variable can only be reduced either through mechanical means i.e. air conditioners (which is a departure from the free running context of the study), or increasing air velocity within the buildings (Koenigsberger, et al, 1975). Also, studies in similar climate by reveals that the impact of RH on indoor comfort is generally small (Nicol, 2004; deDear et al, 1990; Nicol et al, 1999). However, the purpose of documenting relative humidity in this study is to see if there's any impact of VGS on this variable.

Variables not recorded

- Internal wall surface temperature

Studies by (Eumorfopoulou and Kontoleon, 2009; Chen et al 2013; Nori et al, 2013: Safikhani et al, 2014) measured indoor air temperature while documenting the effect of VGS on heat flux through the walls indoors in their studies. Although Indoor surface temperature could have an impact in indoor comfort as it would affect the Mean Radiant Temperature and consequently the environmental temperature, indoor surface wall temperature was not measured due to the focus of the research being strictly on reduction of indoor air temperature and its consequent impact on human comfort.

- Total solar incident radiation on wall surface

This variable was not physically measured as the only equipment available to do this would record solar radiation on horizontal surfaces (roof). Total incident solar radiation was however estimated through modelling and findings are incorporated into the result (Chapter 8)

Tools for measurement

The selection of appropriate tools for this study has been influenced both by literature and context. Although more sophisticated tools have been used for measurement of variables in literature as documented in studies by Wong et al (2010) and Jim and He (2011), the research environment (pertaining to cultural perception and safety issues) in which the study was conducted did not enable the use of such expensive and relatively complex tools. Thus, it was imperative that the tools used were as simple, inexpensive and as effective (with provision of back-up and replacements) should they be tampered with to:

- Avoid unnecessary attention from the occupants which might lead to tampering with the loggers, theft or even vandalism.
- Avoid confusion about the loggers and their uses, such as being mistaken as a form of black magic called juju which might breed mistrust hindering cooperation, thereby affecting the progress of the study.

This led to the decision to use simple instruments, as detailed in table 7-1 including;

- 4 Tiny Tag Ultra Range H/ Relative Humidity TGU-4500 data loggers (Temp sensor: 10K NTC thermistor, RH sensor: capacitive)
- 6 thermistors with 6 Tiny tag talk 2-TK4023 sensors (Temp sensor: 10K NTC thermistor external probe)
- Two radiation shields (Stevenson Screens) were used to protect the Tiny tag talk 2-TK4023 sensor and thermistors from inclement weather during measurement of ambient air temperature.

Variable measured	Measurement description	Type of measurement and sensor type	Sensor (photo, name/brand)	Range & Error band	Reference from literature
Temperatures (°C)	**<u>Indoor air temperature</u>:** 2 sensors, 1 in room 1 and the other in room 10 **<u>External wall surface temperature:</u>** 2 sensors, 1 in external wall surface from room 1 and the other in external wall surface from room 10 **<u>External air temperature:</u>** 2 sensors, 1m away from external wall surfaces in rooms 1 and 10 (Figure 7-2)	Indoor air temperature (Temp sensor: 10K NTC thermistor external probe)	 Tiny tag Talk 2TK4023	Range: From -40°C to +125°C Error: ± 0.01°C	Kontoleon and Eumorfopoulou, 2010; Price, 2010; Wong et al, 2010; Chen et al, 2013; Safikhani et al, 2014
Temperatures (°C) and Relative humidity (%)	**Indoor air temperature and relative humidity**: 2 sensors, 1 in room 1 and the other in room 10 **External wall surface temperature and outdoor relative humidity:** 2 sensors, 1 in external wall surface from room 1 and the other in external wall surface from room 10 (Figure 7-3).	Indoor air temperature and relative humidity data logger with built in sensor (Temp sensor: 10K NTC thermistor, RH sensor: capacitive)	 Tiny tag Ultra range H/Relative Humidity (Ultra 2)	Range: From -25°C to +85°C (Temp) and 0% to 95% (RH) Error: ± 0.02°C (Temp) and ±3% (RH)	Cheng and Chu, 2010; Price, 2010; Wong et al, 2010; Chen et al,2013; Safikhani et al, 2014

Table 7-1; Variables measured. Measurement description and sensors/error bands, source: Author, 2014

From table 7-1, it can be observed that air temperature and relative humidity measurements were duplicated inside room 1 and 10 as well as for the external walls of rooms 1 and 10. This was to cross check both measurements, to minimize error, as temperature (especially indoor temperature) is the most important variable to be influenced by the VGS, as documented in field studies by Price (2010) Chen et al (2013) and Susorova et al (2014).

7.2.2 Validity, Calibration and Reliability of instruments

All instruments used have been validated in previous research. The most recent being of a field experiment involving measurement of variables at the Sherman theatre in Cardiff by students of the Welsh School of Architecture. In addition to that, all the instruments were continuously tested by the department (in a laboratory) over a 30-day period prior to the field work.

Also, all the data loggers are professionally calibrated[54] by the tinytag company annually and issued with a calibration certificate[55]. This provides verification that the data logger has been checked and has been found to be reading within the specification quoted on the unit's data sheet. The data loggers are compared to reference meters that have been calibrated in a UKAS (United Kingdom Accreditation Service) approved laboratory. As described on the website: ….

> *The certificate lists the value recorded by the reference meter (the temperature or humidity at which the data logger was tested), the value recorded by the data logger and the error between the two readings (the certificate will also show readings before and after any adjustment made to the unit where appropriate). In addition to the reading information, calibration certificates also list the test method and the details of the equipment used to provide traceability back to national standards……. (Tiny tag official website, accessed January 2014)*

As above, before and after adjustment readings are quoted on the calibration certificate. Calibration certificates do not have a period of validity, they are simply a statement of what the unit was reading when it was tested. The standard calibration points were within the following ranges:

- Temperature: -20 to +150 °C

<u>Measurement reliability</u>

The measurements and tools were informed by 3 criteria:

- Overview of relevant literature
- Use of calibrated loggers by the tiny tag company
- Multiple loggers to provide backup and enable comparison of readings.

Readings were recorded continuously every 10 minutes and downloaded weekly through the tiny tag explorer software installed onto the researcher's computer [56] for a total of

[54] Before the field work
[55] Attached in appendix
[56] Installed with the Tiny tag Explorer Data Logging Software

approximately 4 months from May 3rd, 2014-31st August 2014. It should be noted that a factor which could influence results was the use of waterproof materials, which in this context were black cling films, to protect the loggers from torrential rainfall and suspicious occupants, as illustrated in plate 7-1.

Plate 7-1; data logger wrapped in black cling film

While this is unlikely to have any major effect on the readings, direct exposure to sunlight might increase the temperature of the material, leading to inaccurate readings. This was minimized by using additional loggers with built-in sensors, which did not require the use of cling films to compare readings from the loggers. The impact (if any) on the readings is assessed during the analysis of results in Chapter 8.

Illustration of logger placements

Hunter et al (2014) observed that in relevant studies that documented the impact of VGS, there was a dearth in illustration of logger placements making replication of the experiments relatively difficult. Figure 7-2, 7-3, 7-4,7-5 and 7-6 illustrates the location of the loggers on the floor plan layout. The location of each logger was the same in both rooms to ensure variables are measured similarly.

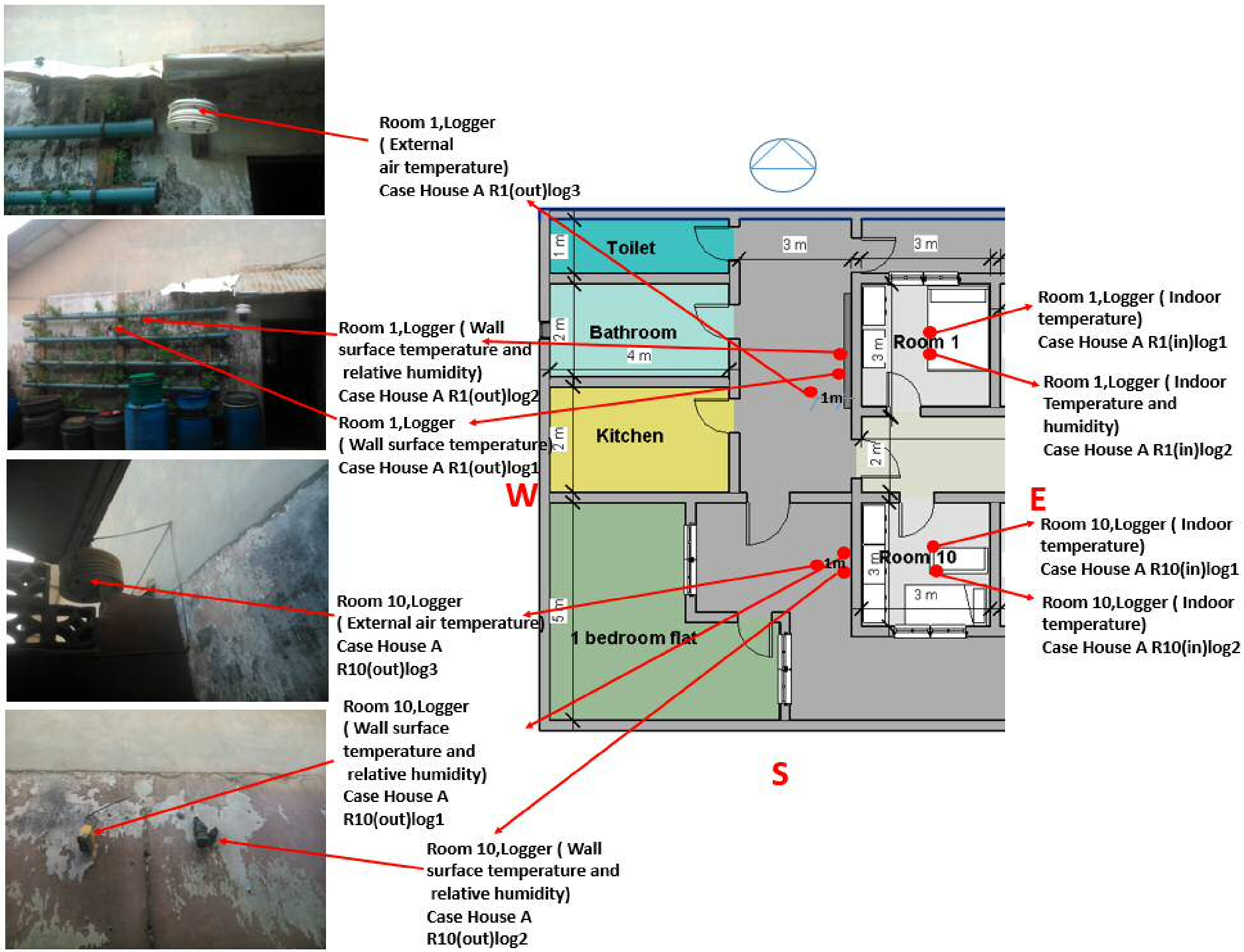


Figure 7-2; Location of loggers in floor plan, Case Study House A, source; Author, 2014

View of loggers on wall surfaces

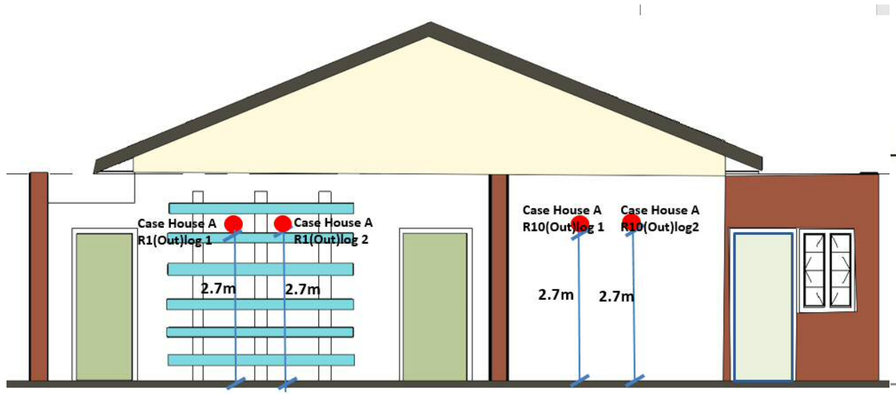


Figure 7-3; Approach view illustrating location of loggers in Case House A, source; Author, 2014

Cross-section of location of loggers in Room 1

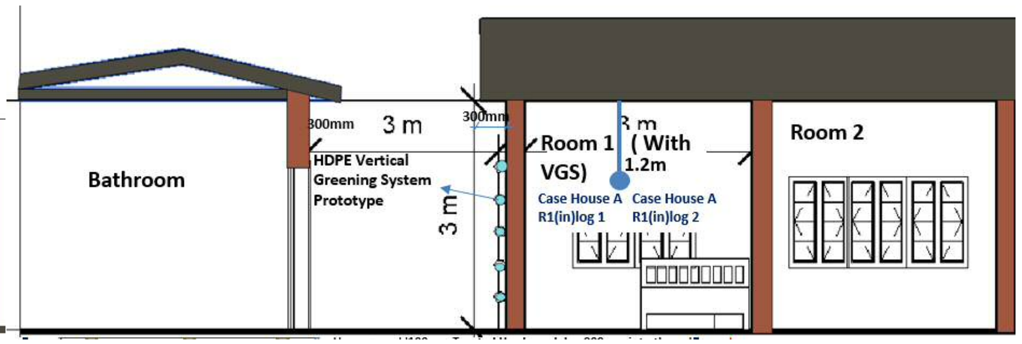


Figure 7-4; Location of loggers in Room 1 in Case House A, source: Author, 2014

Cross-section of location of loggers in Room 1 and 10

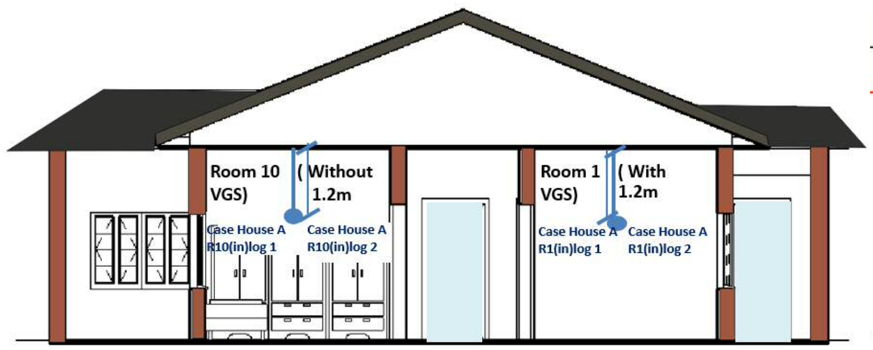


Figure 7-5; Location of loggers in Room 10, in Case House A, source: Author, 2014

Cross-section of location of loggers in Room 10

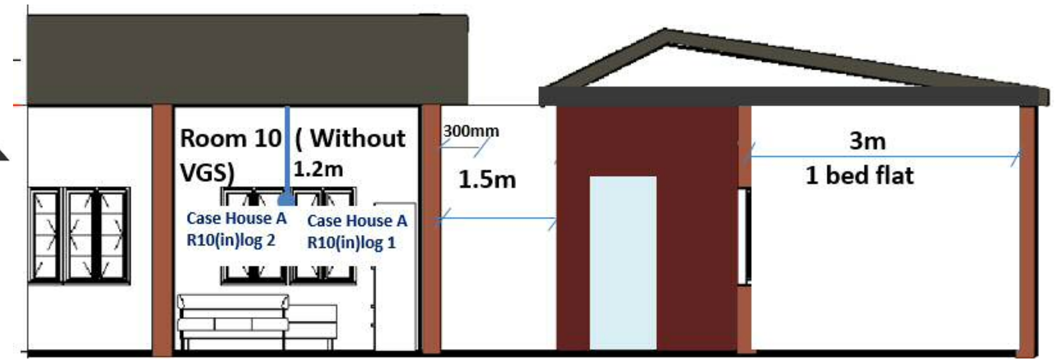


Figure 7-6; Cross-section of Rooms 1 and 10 showing location of data loggers in Case House A, source: Author, 2014

7.3 Field study interviews and observations

This step was designed to document occupant's activities, schedules, equipment usages and behaviours in both rooms, in order to enable a comparison of the daily average total energy gain in each room. The method of data collection included pre-coded semi structured interviews, which were conducted three times daily[57] with all 8 occupants in both rooms for 10 consecutive days from May 3rd to May 12th 2014. The purpose of this multiple number of interviews was to compare the consistency of the occupants responses, in order to identify and clarify any discrepancies in responses. Ideally, another set of interviews would have been conducted in August, after the full development of the prototypes, however, this was not undertaken because of the similarity in weather conditions and regularity in room usage/ occupants schedule (during the month of June), as observed by the researcher and further confirmed by the occupants during the field study.

Semi-structured interview schedule design

Typically, this type of data collection could ideally have been documented through questionnaires, however, all occupants had a secondary school qualification, with challenges relating to literacy which limited their ability to comprehend written English language. Thus the researcher personally documented their responses during the interviews. Sometimes for easier understanding, interviews were conducted in the local languages (Yoruba). The interview schedule comprehended the sections described below:

- **Personal information**

This included basic information relating to age, gender, occupation, number of years lived in rooms, house ownership status and qualification as illustrated below:

Information to be collected	Aims and Purpose
Age and gender	To provide a context to life style and activities to be unfolded.
Occupation	To confirm their means of survival, as discussed in relevant literature pertaining to low income groups, and provide a reference for prototype affordability
Number of years lived in rooms	To gauge their level of familiarity with the living conditions of their rooms and room usage patterns
House ownership status	To infer and gauge how much residents would be prepared to invest in improving their living conditions
Qualification	To gauge their education level in order to determine how the researcher will relate with them in terms of language and vocabulary

Table 7-2; Personal information-aims and purpose

Thermal comfort conditions

The relevance of occupant's thermal comfort to this study has been discussed in Chapter 3. Thus, it was included in the interview schedule as the question: *How do you enhance the thermal conditions? (Morning, afternoon, evening and night?)*, to document the predominant

[57] Morning at 9:00am, afternoon at 2:00pm and evening at 7:00pm (based on availability of the occupants)

adaptive behaviours of the occupants in both rooms, across different time periods, in order to observe the possible impact of adaptive actions of occupants on internal gains or temperature/ relative humidity variables within the same time period.

- **Occupants schedule and Metabolic rate/activity**

As the lifestyle and occupancy period in both rooms was relatively different to European standard occupancy schedules, it was imperative to document the detailed lifestyle of each occupant to extract relevant information to calculate/ compare internal gains in both rooms. This included the timeline of activities for each occupant, their time frame in each room and predominant activities during such times as well as equipment/appliance usage during such times. Worthy to note is that the responses of the occupants were based on predominant activities that occurred on average during the morning, afternoon and evening periods and not just while the interview was conducted. These were asked as **'***Which electrical gadget at home do you use frequently? How many people are typically in your house (morning, afternoon, evening and night? and Please what are the major activities that take place during these times?*

- **Clo-values**

The insulation properties of clothing are a result of the small air pockets separated from each other to prevent air from migrating through the material in general, all clothing makes use of this principle of trapped air within the layers of cloth fabric. The Clo value is a numerical representation of a clothing ensemble thermal resistance, with 1 Clo = 0.155 °C/W. Clo values were documented based on observing how occupants in both rooms dressed. This data was collected to see if it influences the comfort vote of the occupants.

- **Observations**

It was important to document any vital information initially not included or anticipated in the interview schedule that was however more obvious from a third person perspective than the occupants. For example, it was observed that certain activities (such as ironing of clothing) were deliberately undertaken outside of the rooms due to heat gain when in use. Also, it was observed that the spaces directly in front of the VGS prototype was used for social activities such as house meetings and washing of clothes. Thus, a section was created as 'other information' within the interview schedule.

7.4 Complementary Simulation of solar radiation

Solar radiation is an important factor influencing heat gain in buildings in the tropics. (Koesinberger, 1975). Since Lagos is in the Atlantic Coast in the Gulf of Guinea (West Africa), latitude 6° 27′ 11″ N and Longitude 3° 23′ 45″ E, near the narrow coastal plain of the Bight of Benin, its location near the equator, reveals there is very little variation in sun path movement and therefore in seasons throughout the year as illustrated in figure 7-7:

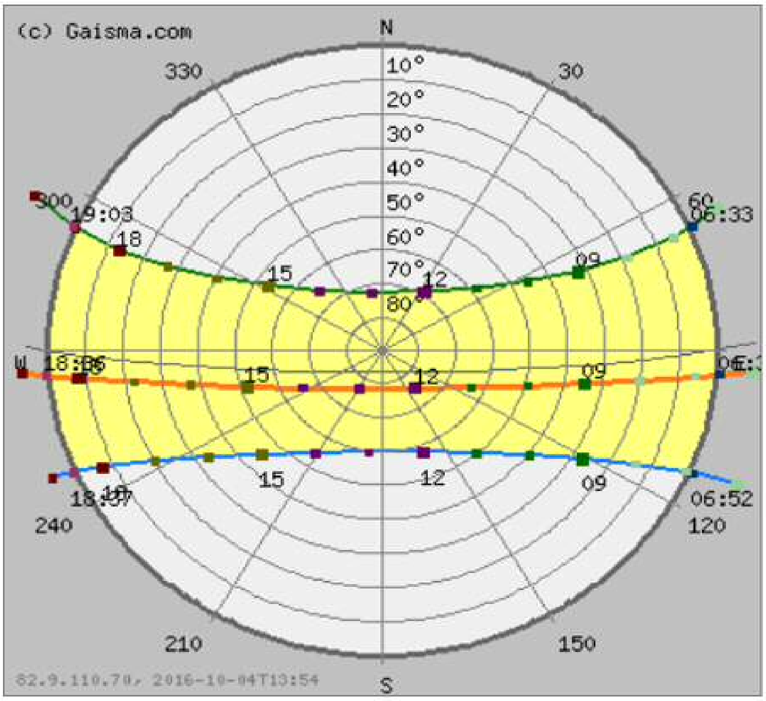


Figure 7-7; Sun path movement throughout the year for Lagos, Nigeria, source: gaisma.com, 2014

The implication of this is that maximum exposure of solar radiation (apart from the roof) is to the eastern (sunrise) and western walls (sunset) with its peak overhead during midday (Koenigsberger,1975). The estimated intensity of incident solar radiation on an East and West façade without any shading is an average of 600W/m^2 (eastern walls) and 450 W/m^2 (western facing walls) (NIMET, 2014). Thus, either the east or west orientations (bare walls) were ideal to install the VGS (depending on over shadowing from surrounding buildings), as it entailed that the wall enables conduction of maximum solar heat gain into the interior space (Price, 2010). This was also a criterion for the experimental set up in studies on VGS and its impact on indoor temperature by (Eumorfopoulou and Kontoleon ,2009; Price, 2010; Susorova et al ,2013 and Chen et al ,2013).

As the primary purpose of the analysis is to determine the impact of the fully developed HDPE plastic prototype on indoor air temperature, the solar radiation study was undertaken first in the month of June (prior to the growth of the plants within the prototypes) and the month of August, also called 'august break' was when the HDPE prototype was fully developed i.e. the plants in the VGS were fully grown and percentage of wall covering had increased from previous months. Also, this month was usually uninterrupted by rainfall, with high ambient temperature and consistent clear sky days as considered in prior studies by (Price ,2010; Wong et al, 2010 and Susorova,2013;2014).

As the solar radiation was not physically measured on site, simulation was run in design builder[58] to answer the following questions:

[58] Assumptions are attached in the appendix

- How comparable is the solar radiation value received on the external wall of both rooms? In June and then August?
- Are there consistent patterns observed in the month of June and August?
- Does overshading influence the amount of solar radiation received on the external wall of each room for June and August?
    - If so, by how much?

The primary purpose was to find out if values or patterns differed, so as to improve reliability of the results and ascertain that the impact of the prototype (if any) is due to the installed VGS and not any other factors.

Design builder (DB) 4.2.0.054 was selected due to the reliability of data exchange and straightforward, user-friendly interfaces (Maile et al, 2007). Building energy software tools formerly hosted by the U.S department of energy list DB as its top 10 tools. It is also accredited both by the U.S department of Energy and CIBSE as a reliable interfaceto Energy Plus which is the U.S. DOE building energy simulation program for modelling building heating, cooling, lighting, ventilation and other energy flows.

Noteworthy is for the simulation of solar incident radiation with design builder, the climatic assumptions for Lagos, Nigeria was absent in the energy plus weather data, hence, the decision to use of Ghana's weather data. While this might raise questions on the reliability of the weather data to the location of study, the similarities lie of the location of both cities (6.5244° N, 3.3792° E for Lagos, Nigeria and 5.6037° N, 0.1870° W for Accra, Ghana), near the equator with the same seasons (wet and dry), minimum variation in temperature all year round and similar daily solar insolation (between 4.2-5.9 KWh/m^2/day)

7.5. Data analysis integration

This section describes the purpose and process of first documenting and then integrating the analysis of total internal gains, total solar incident radiation and measured average hourly wall surface/ internal air temperature of the experimental and control rooms as illustrated in in figure 7-8.

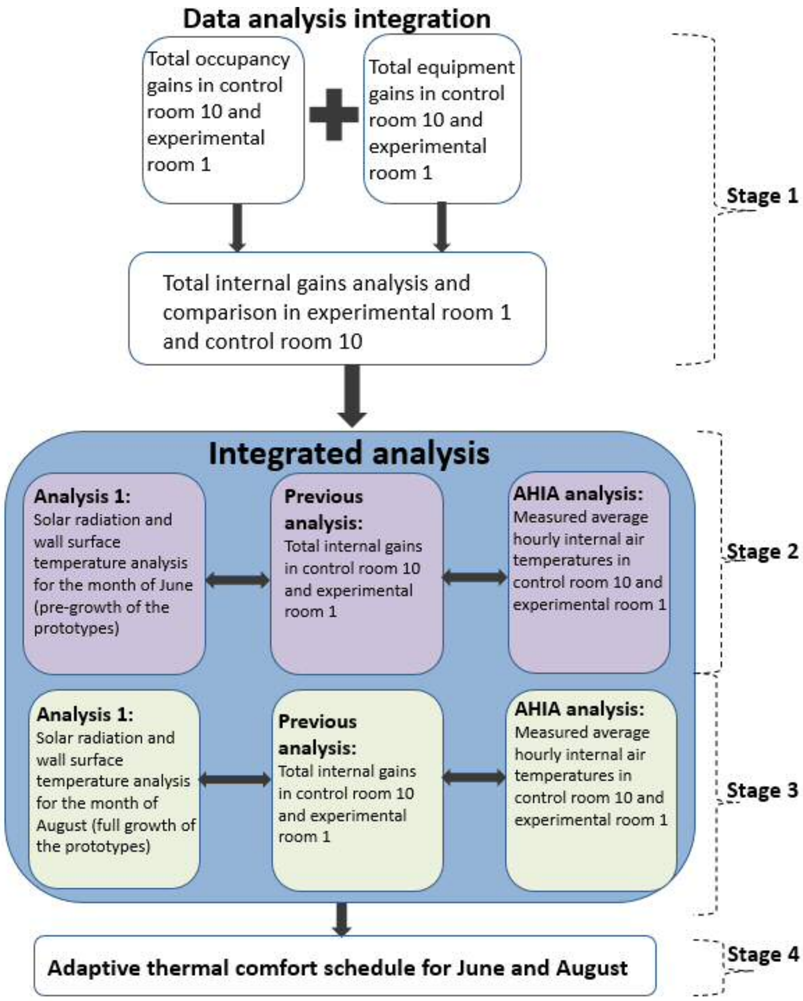


Figure 7-8; Data analysis integration

7.5.1 Stage 1: Individual and total occupancy gains

Reiterating, due to the unconventional lifestyle of the occupants, an idiosyncratic approach that suits this context needs to be adapted, hence the use of personal profiles, which is a summary and illustration of their daily activities and movements within the case study house. Through these information, metabolic activities/ rates against time periods are presented in the form of graphs to facilitate analysis. A total occupancy gain graph is analyzed first for each room and then both rooms, with the measured average hourly internal air temperature and external air temperature. This is to observe patterns of behaviour and document which periods the gains are equal or higher than the other.

Total internal gains in control room 10 and experimental room 1

To complete the analysis of the total internal gains in rooms 1 and 10, lighting and equipment usages are examined to determine how comparable the rooms are, albeit based on electricity supply schedule. However, due to the unorthodox electricity supply experienced, the typically reoccurring schedule is used to calculate periods of lighting and equipment usage. This is then added to the initially calculated total occupancy gains, thereby comparing the total internal gains for both rooms in its entirety, with the measured average hourly internal air temperature and external air temperature,

7.5.2 Stage 2 :Integrated analysis for the month of June

The purpose of the integrated analysis is to observe relationships between the total internal gains, total solar incident radiation and measured average hourly wall surface and internal air temperatures to establish how comparable the two rooms are, therefore establishing reliability in using control room 10 as a reference in the experiment.

This begins by analyzing the total incident solar radiation and measured average hourly wall surface temperature on the common exposed western wall surfaces. As previously discussed, a comparison of the simulated total incident solar radiation and measured wall surface temperature (for the western walls of both rooms) is undertaken, first in the month of June (prior to the plants growth in the installed VGS). This is imperative as it was revealed in

Chapter 5 that the Control room 10 is slightly overshadowed, hence, the need to establish the comparability of both rooms in relation to this criterion, to properly ascertain the impact of the prototype in the month of August (after plants are fully grown). Subsequently, an integrated table containing a summary of the internal gains, solar radiation and hourly average internal air temperature analysis is presented and discussed. Hourly average internal air temperatures are compared in terms of how much they differ as well as their standard deviations to gauge the extent to which internal gains and solar radiation would influence internal air temperatures in each room.

7.5.3 Stage 3 : Integrated analysis for the month of August

The purpose of the integrated analysis for this month is to observe if there is a similarity in the relationships between the total internal gains, total solar incident radiation and measured average hourly wall surface/ internal air temperature in control room 10, as documented in June to therefore gauge the effect of the VGS in experimental room 1. This begins by analyzing the total incident solar radiation and measured average hourly wall surface temperature on the common exposed western wall surfaces. As previously discussed, a comparison of the simulated total incident solar radiation and measured wall surface temperature (for the western walls of both rooms) is undertaken in the month of August to establish if patterns of variations in solar radiation between both rooms were similar to the ones observed in June. Similar variations to June if observed in August would aid in the establishment of control room 10 as a reference in the experiment. Subsequently an integrated table containing a summary of the internal gains, solar radiation and hourly average internal air temperature analysis is presented and discussed. Hourly average internal air temperatures are compared in terms of how much they differ as well as their standard deviations to gauge the effect of the VGS in this important comfort variable therefore quantifying the effect of the VGS in the experiment.

7.5.4 Stage 4:Adaptive thermal comfort schedule for the month of June and August

The percentage of time internal air temperatures fall within the comfort zone are then calculated for each room in the months of June and August to further quantify the full benefits of the VGS in this environment. This also includes the comfort rating by the occupants in the morning, afternoon and evening periods of each occupant and their corresponding adaptive actions.

Summary and limitations

The purpose of conducting the experiment within the two rooms in the Case Study House was to test the effect of the VGS prototype on indoor air temperature within an untampered and unconventional environment as the low-income house. This is however not without a range of challenges, pertaining to reliability of the results, especially in proving that any reduction in indoor temperature (within the experimental room) is as a result of the prototype and not any other factor(s). Thus, the arguments for undertaking the field study has been outlined while the detailed decisions (in relation to relevant literature) and methodological steps has been discussed to ascertain the reliability of using both rooms to conduct the experiment. The results of these methodological steps described are presented in the next Chapter.

Chapter 8: Results of Environmental Performance of prototype in Case Study House A

This Chapter begins by establishing the comparability of the experimental and control rooms, as detailed in the process presented in Chapter 8. Reiterating, comparability will be established by studying the lifestyle of the occupants in both rooms through the results of the semi-structured interviews and physical observations undertaken by the researcher. This is in the form of personal profiles for each occupant which include detailed daily activities and the metabolic rates in both rooms as well as their equipment usage. These are converted to internal gains and analyzed against measured average internal and external air temperatures.

A comparison of the simulated total incident solar radiation and measured wall surface temperatures (for the western walls of both rooms) is undertaken, first in the month of June (prior to the plants growth in the installed VGS). This is imperative as it was revealed in Chapter 6 that the Control room 10 is slightly overshadowed, hence, the need to establish the comparability of both rooms in relation to this criterion, to ascertain the impact of the prototypes (if any) in the month of August.

An integrated analysis which involves bringing together the previously discussed analysis for both June and August is undertaken to find relationships between internal gains, incident solar radiation and measured average hourly wall surface temperatures and average hourly internal air temperatures (AHIA)

The end of the chapter presents the AHIA and percentage within the calculated adaptive thermal comfort range for June and August concluding what are the full benefits of the VGS in this type of environment

8.1 Establishing the comparability of the Control and Experimental room

The comparisons across both rooms are described below. Detailed data on interview and schedules are presented in Appendix C

- **<u>Personal information</u>**

Personal information from the interview schedule included details on the occupation, age, qualification, house ownership status and number of years lived in residence as illustrated in table 8-1.

Room	Occupants	Gender	Age	Occupation	Number of years lived in residence	House ownership status	Qualification
Experimental Room 1	Occupant 1 Occupant 2 Occupant 3 Occupant 4	M M M F	32 44 39 30	Artisan Artisan Artisan Seamstress	5 years 3 years 2 years 3 years	Renting Renting Renting Renting	Secondary school Secondary school Secondary school Secondary school
Control Room 10	Occupant 1 Occupant 2 Occupant 3 Occupant 4	M M M M	48 42 38 40	Carpenter Carpenter Carpenter Carpenter	4 years 4 years 4 years 1 year	Renting Renting Renting Renting	Primary school Secondary school Secondary school Secondary school

Table 8-1; Personal information of occupants

The maximum educational qualification of all the occupants was secondary school, with limited literacy skills. With the competitive job market (limited range of jobs for millions unemployed within the city) this has resulted in limited employment options to jobs that were either low skilled or on temporary basis, thus limiting their earnings as corroborated in studies of low income groups by Akinmoladun and Oluwoye (2007) and Lawanson et al (2012). All occupants were renting the house and they were not related. Carpenter 1 and 2 in control room 10 who worked together in a nearby carpentry workshop, and they were married, however, their wives and children resided outside Lagos. The rest of the occupants were single. Clo values were observed by the researcher and were approximately 0.2-0.5 clo (very light weight clothing)

- **Occupant lifestyle**

Reiterating, due to their limited educational level, the occupants predominantly work in what is called the informal sector employment: A necessity survival strategy especially in many countries like Nigeria that lack social safety nets such as unemployment insurance and effective pension schemes (Yasmeen 2001). It is often characterized by irregular low paid jobs, which may include; hawking, selling of cooked food, raw farm produce and other minor household items, janitorial jobs and vocational jobs, which includes tailoring, carpentry and artisans (Abiodun 1993). -In this study, artisans worked in construction sites either as bricklayers, cement mixers or diggers. Carpenters are engaged in furniture making or general repairs of woodworks, which include doors, window sills etc. in existing buildings. The seamstress sews clothing's as designed by the fashion designer she works for.

8.1.1 Personal profile of Occupants

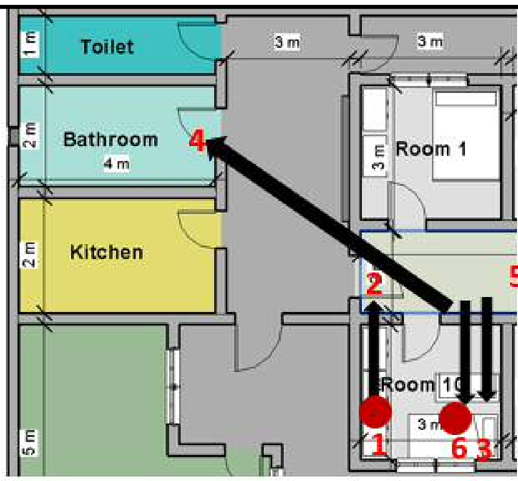
The purpose of documenting the timeline of activities for each occupant during a typical day is to extract a definable occupancy schedule and equipment/ appliance usage to calculate and compare the average internal gains in each room. These have been informed by the interview schedule (see appendix C for the detailed interview schedule). Noteworthy is that weekly and weekend schedules were usually the same, likely due to their extremely flexible work periods. Thus, the detailed personal profile of each occupant and the summary in graphical forms are illustrated in the figures below;

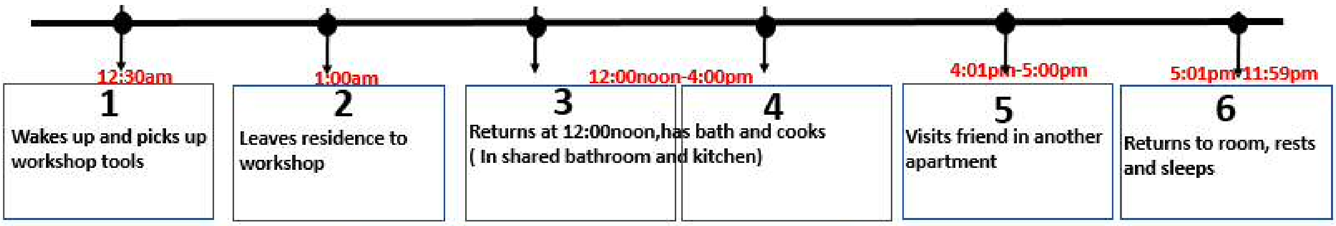
8.1.1.1 Personal profile of occupants in Case House A-Control room 10

The daily movement of the 4 Carpenters living in Control room 10 is described below. A summary of the timeline of activities in each space is presented. These include the predominant activity undertaken by the occupant across different times and the corresponding metabolic rate (as in McMullan, 2007).

Personal profile of Carpenter 1 in Case Study House A, Control Room 10

The first carpenter is aged 48, he prefers to work very early in the morning and spend the rest of the day resting/ sleeping. He owns his private workshop on the same street. His wife and children live in the village, outside the city and he visits them monthly.





Summary of time resident in spaces

12:00am-12:30am (occupancy period in room 10)
1:00am-12:00noon (At work)
12:00noon-4:00pm (Bathroom and Kitchen)
4:01pm-5:00pm (At friend's apartment)
5:01pm-11:59pm (occupancy period in room 10)

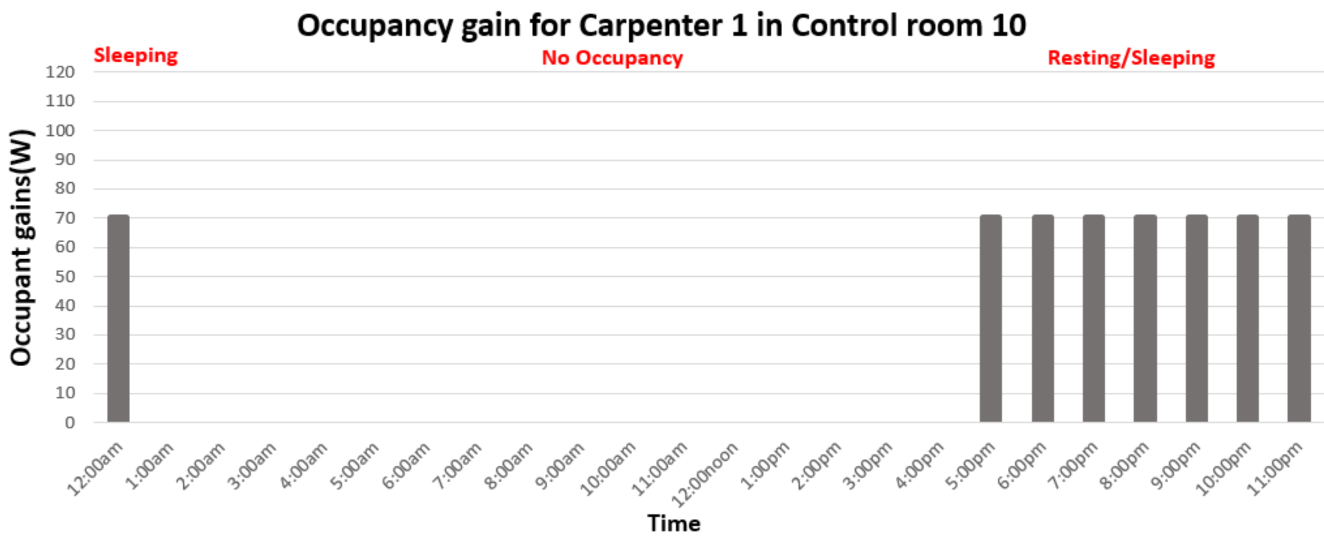
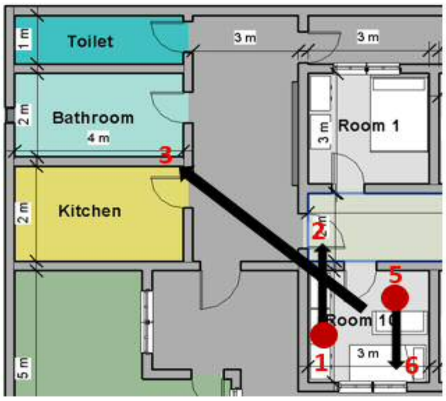
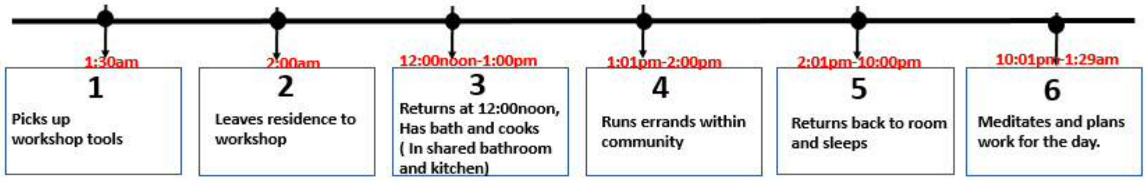


Figure 8-1; Occupancy gain for Carpenter 1

Personal profile of Carpenter 2 in Case House A, Control Room 10

The second carpenter is aged 42. He works with carpenter 1 and prefers to work very early in the morning as well. When he returns at midday, he usually cooks and does his laundry before spending the rest of the day sleeping





Summary of time resident in spaces:

12:00am-1:30am (occupancy period in room 10)

2:00am-12:00noon (At work)

1:00pm-2:00pm (Running errands)

2:01pm-10:00pm (occupancy period in room 10)

10:01pm-1:29am (occupancy period in room 10)

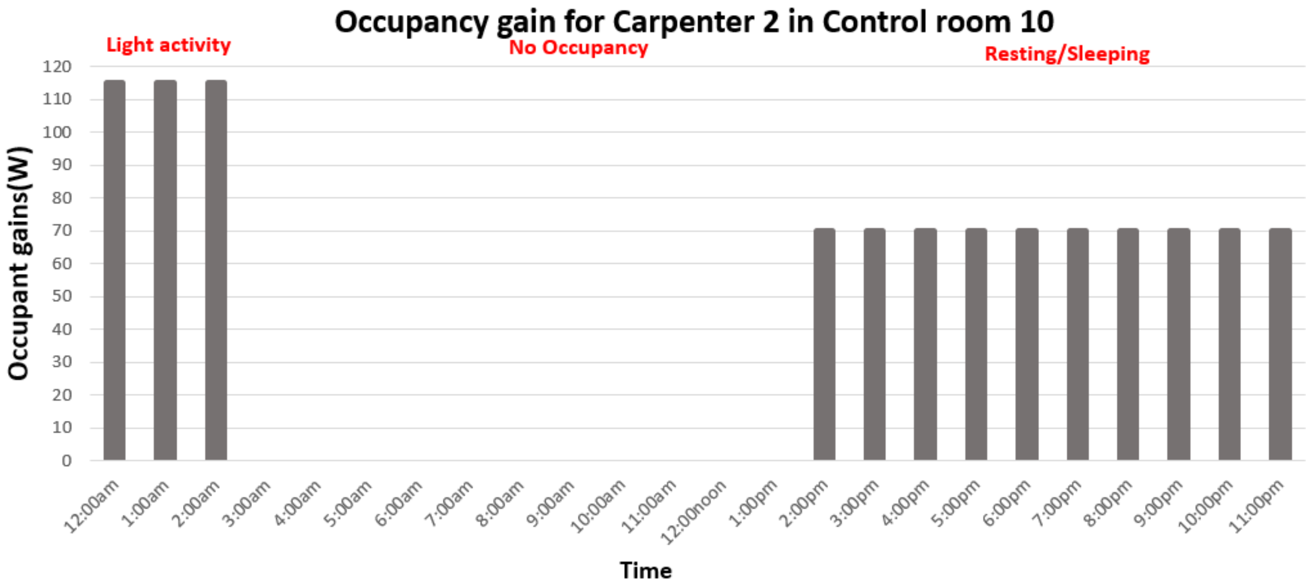
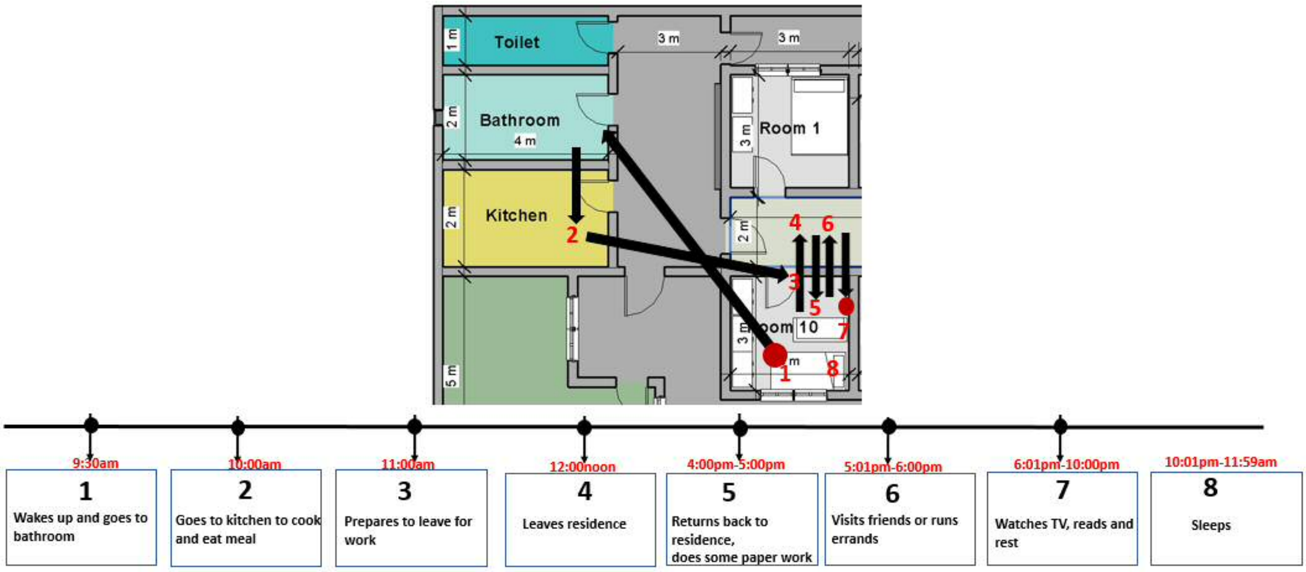


Figure 8-2; Occupancy gain for Carpenter 2

Personal profile of Carpenter 3 in Case House A, Control Room 10

The third carpenter is aged 38, He is usually in the room from 12:00am to 9:30am before going to work from 12noon to 4:00pm daily in a carpentry workshop dealing with furniture manufacturing within the community



Summary of time resident in spaces
12:00am-9:30am(occupancy period in room 10)
9:31am-11:00am(Kitchen)
11:00am-12noon (occupancy period in room 10)
12:00noon-4:00pm (At work)
4:01pm-5:00pm (occupancy period in room 10)
5:01pm-6:00pm(Errands)
6:00pm-10:00pm(occupancy period in room 10)
10:01pm-11:59am(occupancy period in room 10)

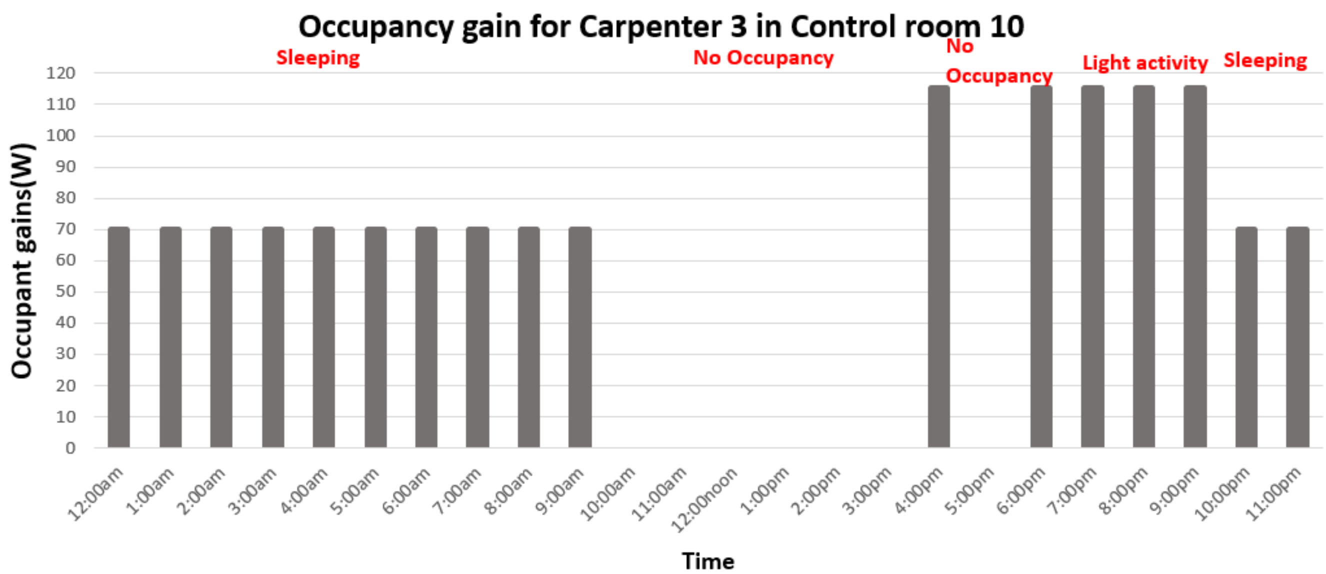
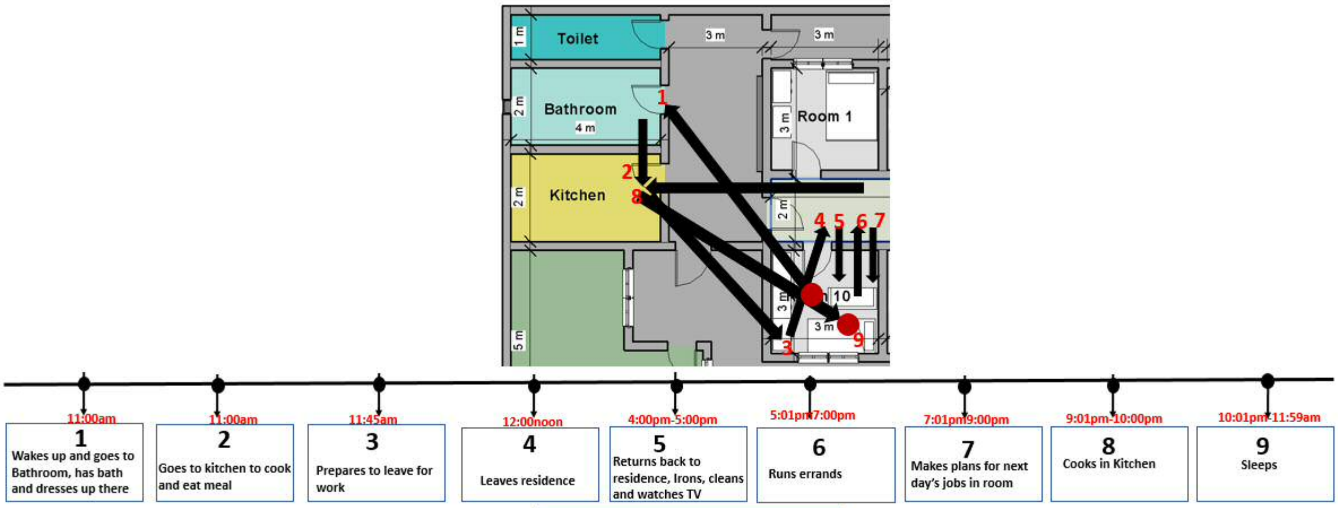


Figure 8-3; Occupancy gain for Carpenter 3

Personal profile of Carpenter 4 in Case House A, Control Room 10

The fourth carpenter is aged 40. He is usually in the room from 12:00am to 10:00am before going to work from 12noon to 4:00pm daily in a carpentry workshop dealing with provision of scaffoldings for construction sites. At 6:00pm-7:00pm, he goes to run personal errands



Summary of time resident in spaces
12:00am-11:00am (occupancy period in room 10)
11:01am-11:45am (in bathroom and kitchen)
11:45am-12:00noon(occupancy period in room 10)
12:01pm-4:00pm (At work)
4:01pm-5:00pm (occupancy period in room 10)
5:01pm-7:00pm (Runs errands)
7:01pm-9:00pm (occupancy period in room 10)
9:01pm-10:00pm (Kitchen)
10:01pm-11:59am (occupancy period in room 10)

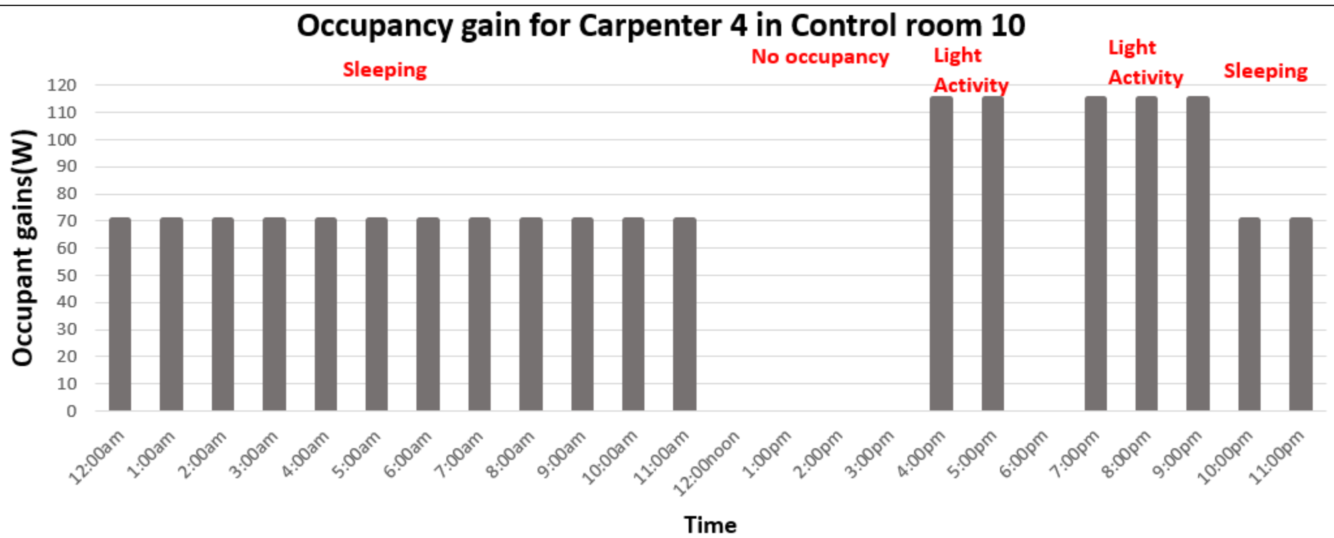


Figure 8-4; Occupancy gain for Carpenter 4

Combined occupancy gain: Control room 10`

The combined occupancy of all the occupants in the control room is discussed below:

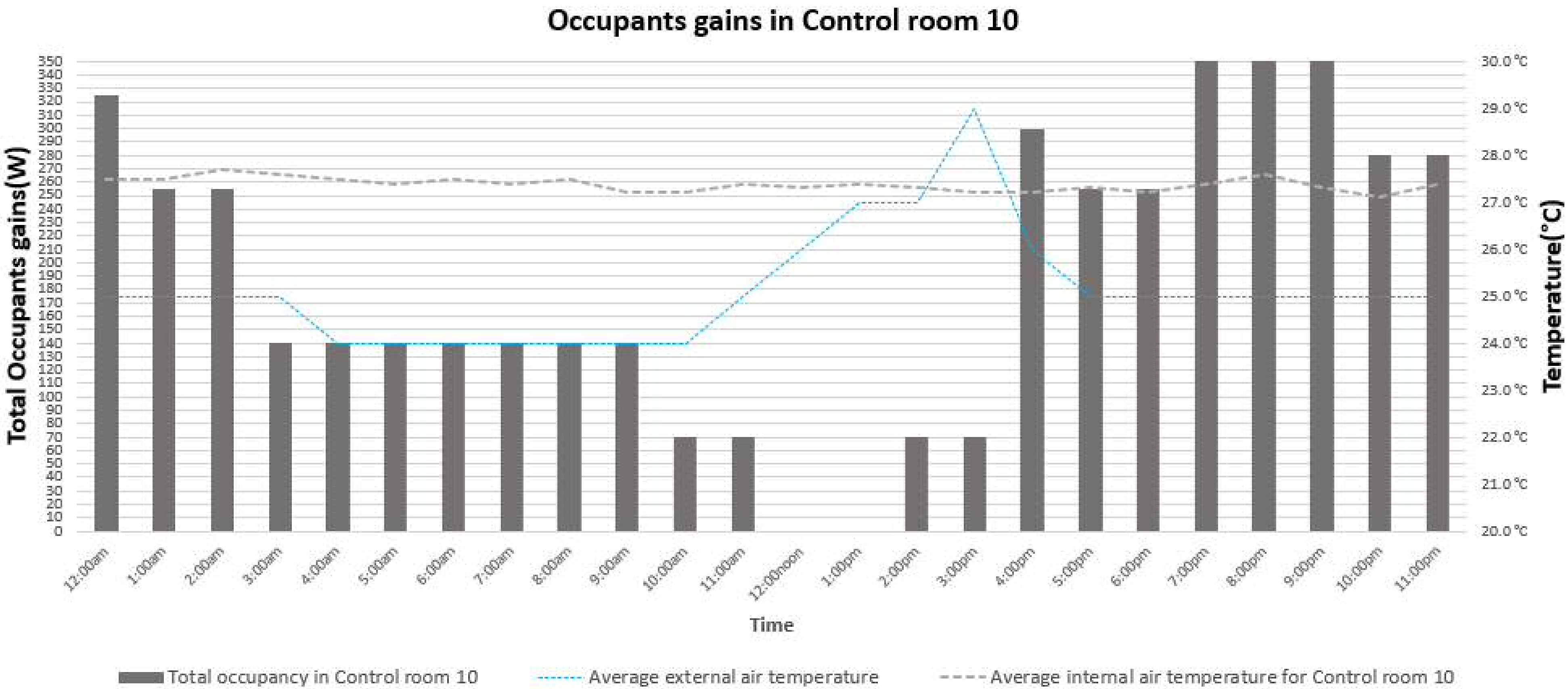


Figure 8-5; Occupancy gains in Control room 10

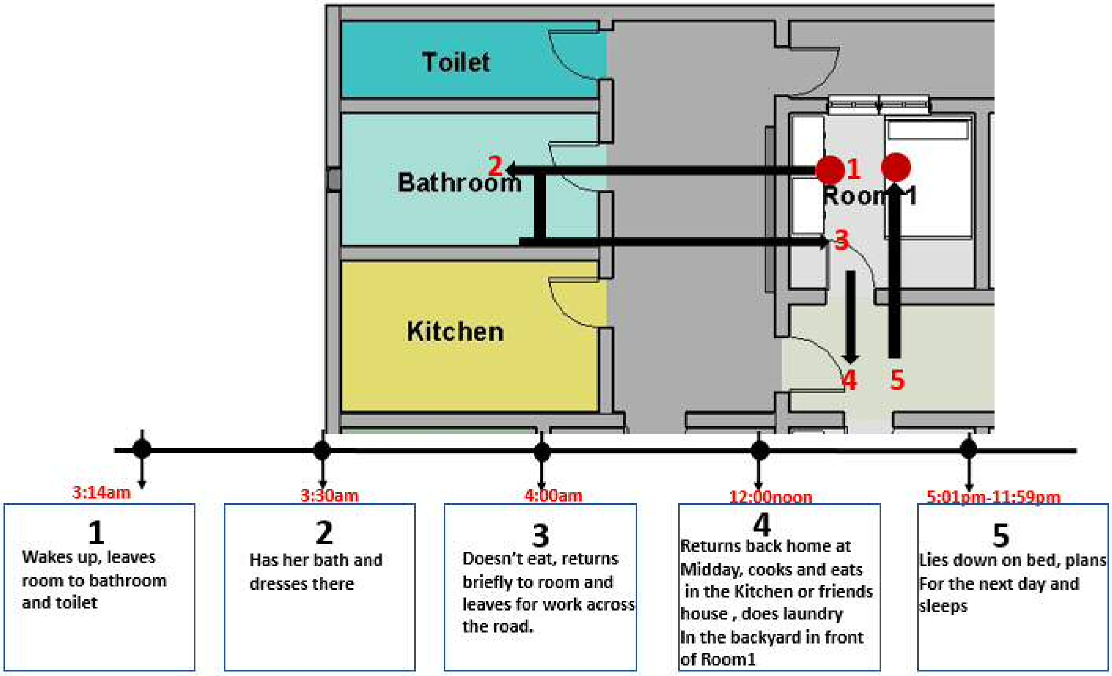
As observed, the daily average external air temperature for a typical day (from the Nigerian meteorological Agency) and the hourly average of indoor air temperature for the month of June was plotted to compare relationships between occupancy and temperature. The daily sum of occupant's internal gains over the 24-hour period is 4575Wh. Inside activity is lowest from 10:00am, to 12:00pm and from 2:00pm to 4:00pm which is when either of the carpenters are sleeping. From 12noon till 2:00pm, there are no residents in the room. This is due to Carpenters being either at work or engaging in activities outside the room. Inside activity peaks between 7:00pm-10:00pm(350W), which is when the room is fully occupied with each occupant either sleeping/resting (Carpenter 1 and 2) or engaging in light activities (Carpenter 3 and 4). As observed, external air temperature is almost always lower than indoor air temperature apart from 3:00pm, in which people come home right after this peak. Also, there is minimal oscillation of the measured indoor air temperature, during periods of occupancy or non-occupancy as evident during the unoccupied period from 12noon till 2:00pm. From 3am to 10am, two people are in the room sleeping, while the other two are at work. From 10am to 12pm and from 2pm to 4pm there is only 1 person asleep in the room. Sleeping period happens from 5:00pm to 12:00am for Carpenter 1, 2:00pm to 11:00pm for Carpenter 2, 10:00pm-9:00am with Carpenter 3 and 10:00pm to 11:00am with Carpenter 4. Thus, the only time when everyone is asleep at the same time is from 10pm to 12am.

8.1.1.2 Personal profile of occupants in Case House A-Experimental room 1

The daily movement of the 3 artisans and the seamstress living in Experimental room 1 is described below. A summary of the timeline of activities in each space is presented. These include the predominant activity undertaken by the occupant across different times and the corresponding metabolic rate (as in McMullan 2007).

Personal profile of Seamstress in Case House A, Experimental Room 1

The seamstress is aged 30 and single, her occupation is sewing clothing's for a nearby tailor. Her place of work is three buildings away, on the same street. The flexible nature of her job allows her to choose unorthodox working hours, which she preferred to be in the early hours of the morning and return at midday to rest and undertake household activities.



Summary of time resident in spaces
12:00am-3:14am (occupancy period in room 1)
3:15am-3:55am (in bathroom and toilet)
4:00am(**occupancy period in room 1**)
4:01am-11:59am (at work)
12:00noon-5:00pm (in kitchen and laundry area)
5:01pm-11:59pm (occupancy period in room 1)

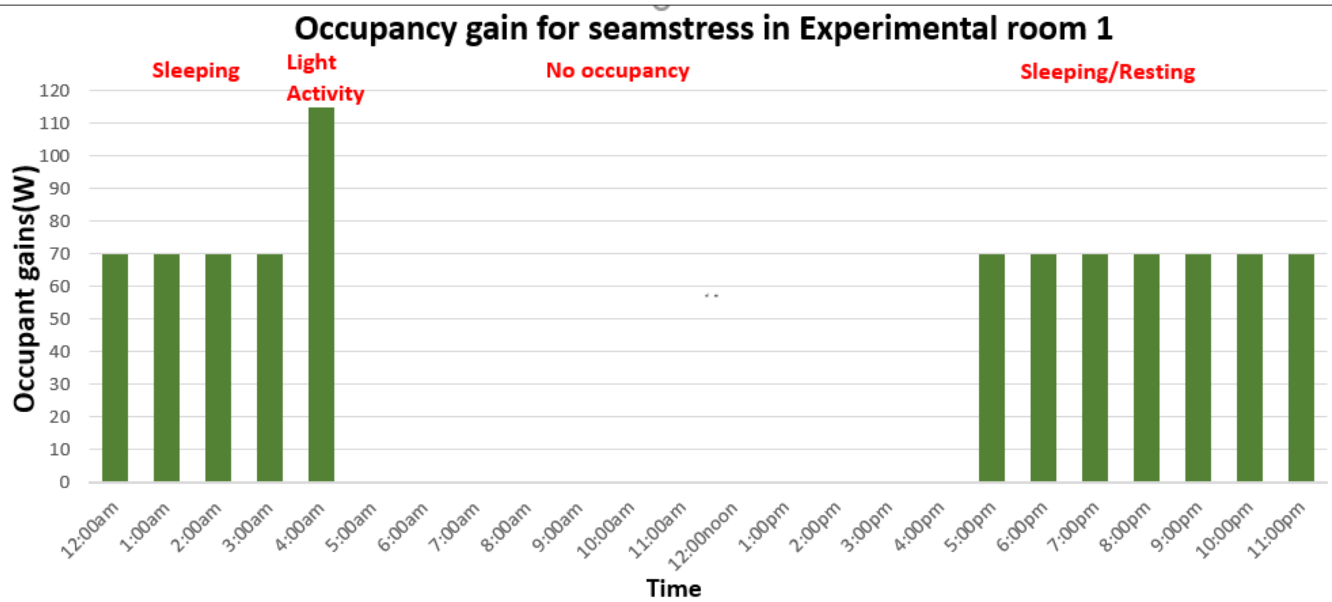
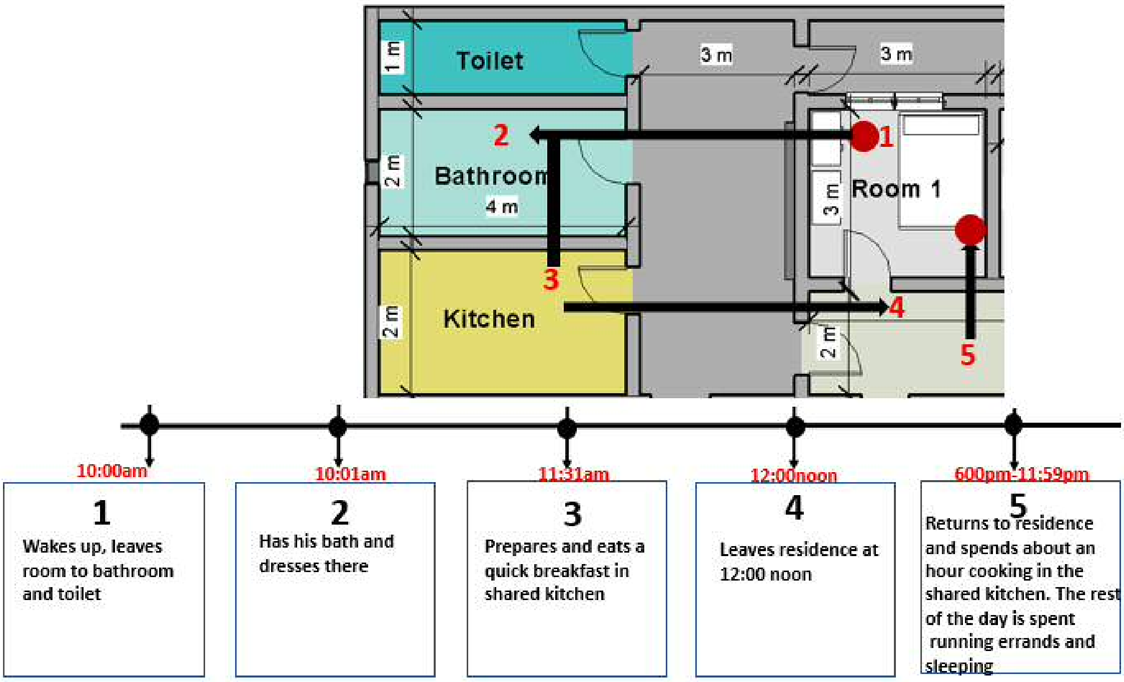


Figure 8-6; Occupancy gain for seamstress

Personal profile of Artisan 1 in Case House A, Experimental Room 1

The first artisan is aged 32. His occupation is working on building sites as a carpenter. This job is not always regular but on demand basis. During periods of work, he works from midday to 4:00pm. From 4:01pm, either he goes out of the house briefly for about 2 hours, or he runs errands. From 6pm-11:59pm, he usually rests or sleeps



Summary of time resident in spaces

12:00am-10:00am (occupancy period in room 1)
10:01am-11:30am (in bathroom and toilet)
11:31am-11:50am (in kitchen)
11:51am-12:00noon (preparing for work in room 1)
12:01pm-4:00pm (At work)
4:01pm-6:00pm (Errands)
6:01pm-11:59pm (occupancy period in room 1)

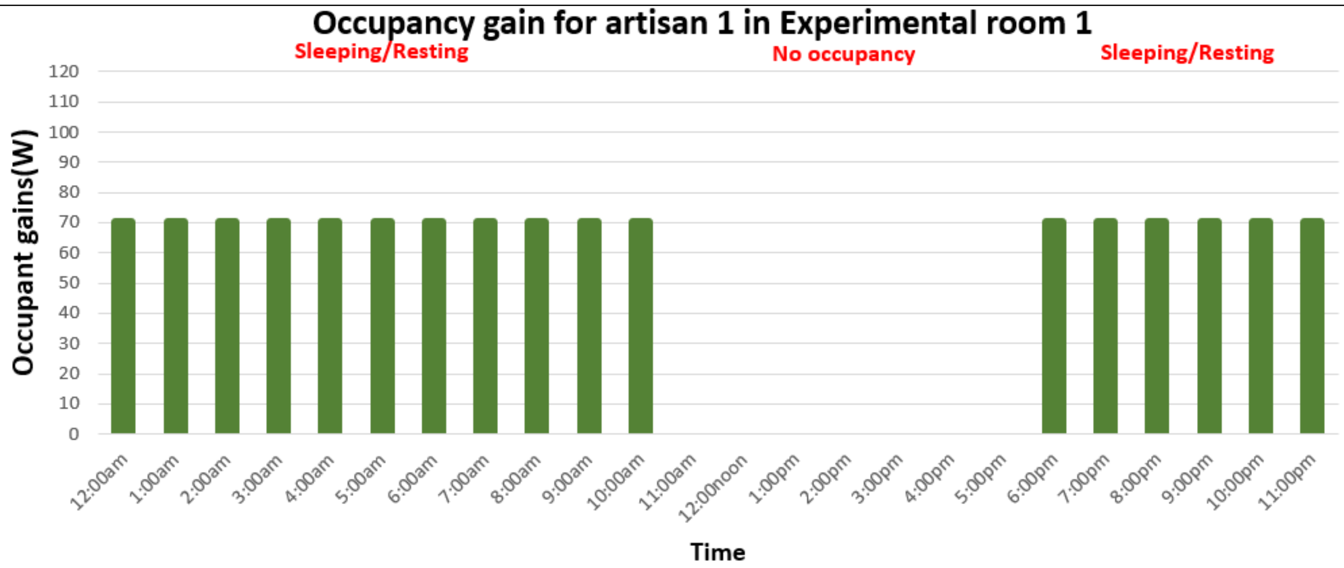
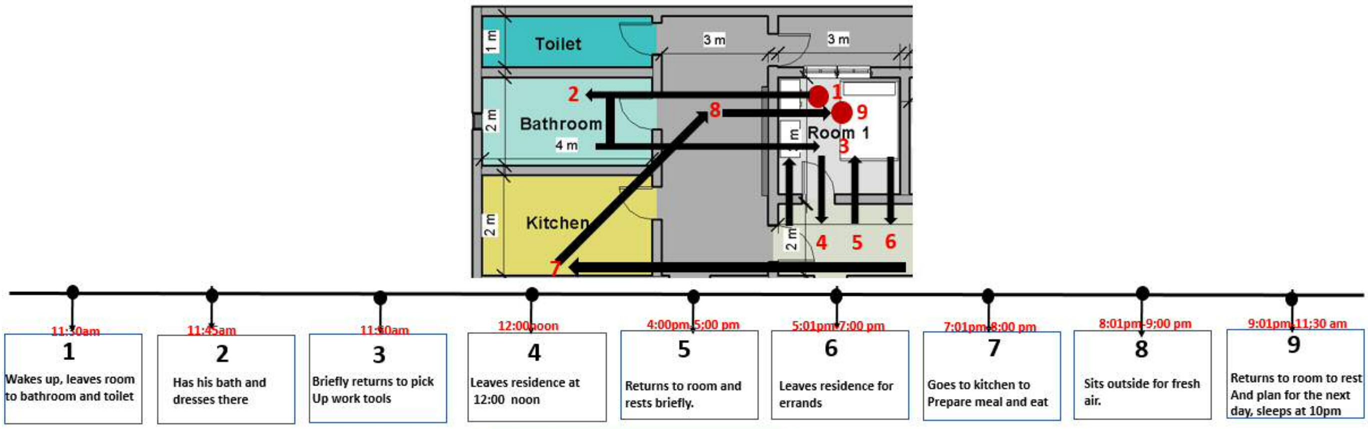


Figure 8-7; Occupancy gain for Artisan 1

Personal profile of Artisan 2 in Case House A, Experimental Room 1

The second artisan is aged 44, his occupation is working on a building site as a bricklayer. His job is fairly regular and he works daily from midday till 4:00pm. He returns home and rests till 5:00pm, he then leaves to run errands till 7:00pm. He goes to the kitchen from 7:00pm-8:00pm to cook and from 8:00pm-9:00pm he sits outside for the fresh air, returning to the room at 9:00pm, before retiring to bed at10:00pm.



Summary of time resident in spaces

12:00am-11:29am (occupancy period in room 1)
11:30am-11:45am (in bathroom and toilet)
11:46am-12:00noon (preparing for work in room 1)
12:01pm-4:00pm (At work)
4:01pm-5:00pm (occupancy period in room 1)
5:01pm-7:00pm (Outside residence)
7:01pm-8:00pm (Kitchen)
8:01pm-9:00pm (Backyard)
9:01pm-11:59pm (occupancy period in room 1)

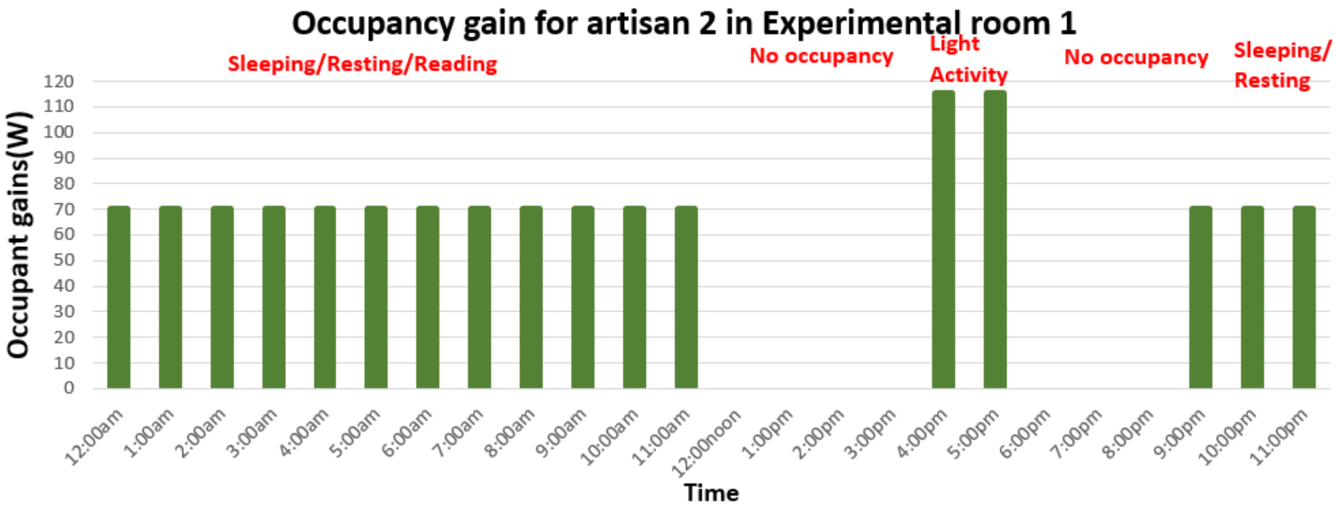
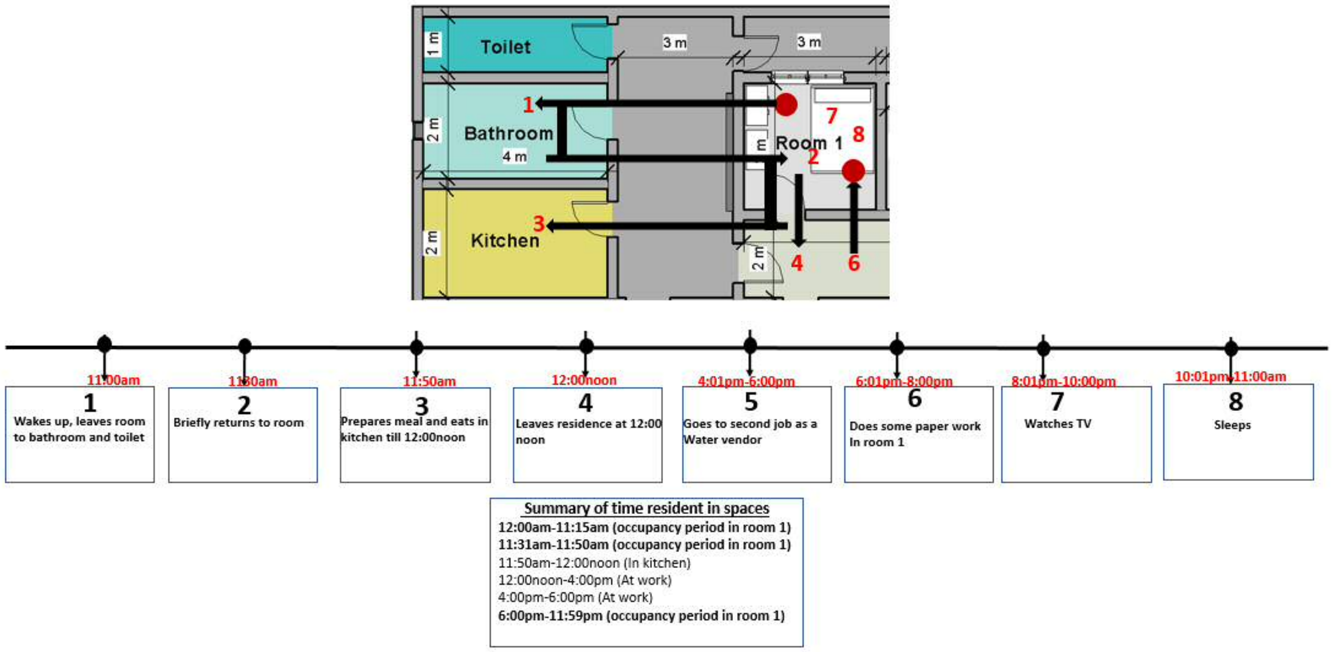


Figure 8-8; Occupancy gain for Artisan 2

Personal profile of Artisan 3 in Case House A, Experimental Room 1

The third artisan is aged 39. His occupation is working on a building site as an iron bender. This job is irregular. He works from 12noon-4:00pm daily and he supplements his income by working as a vendor, supplying drinking water within the community from 4:00pm-6:00pm



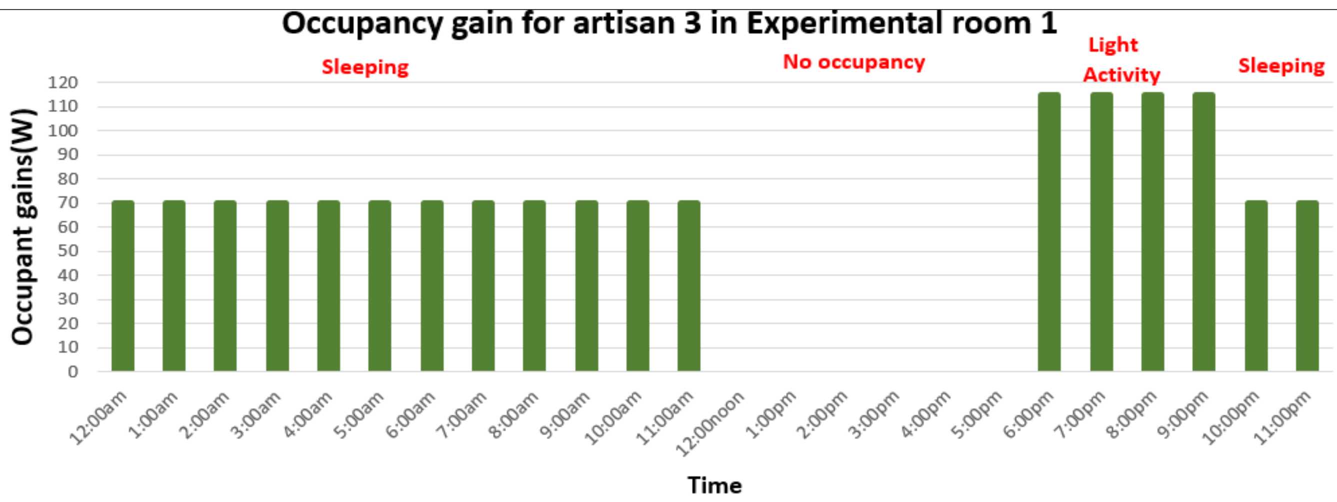


Figure 8-9; Occupancy gain for Artisan 3

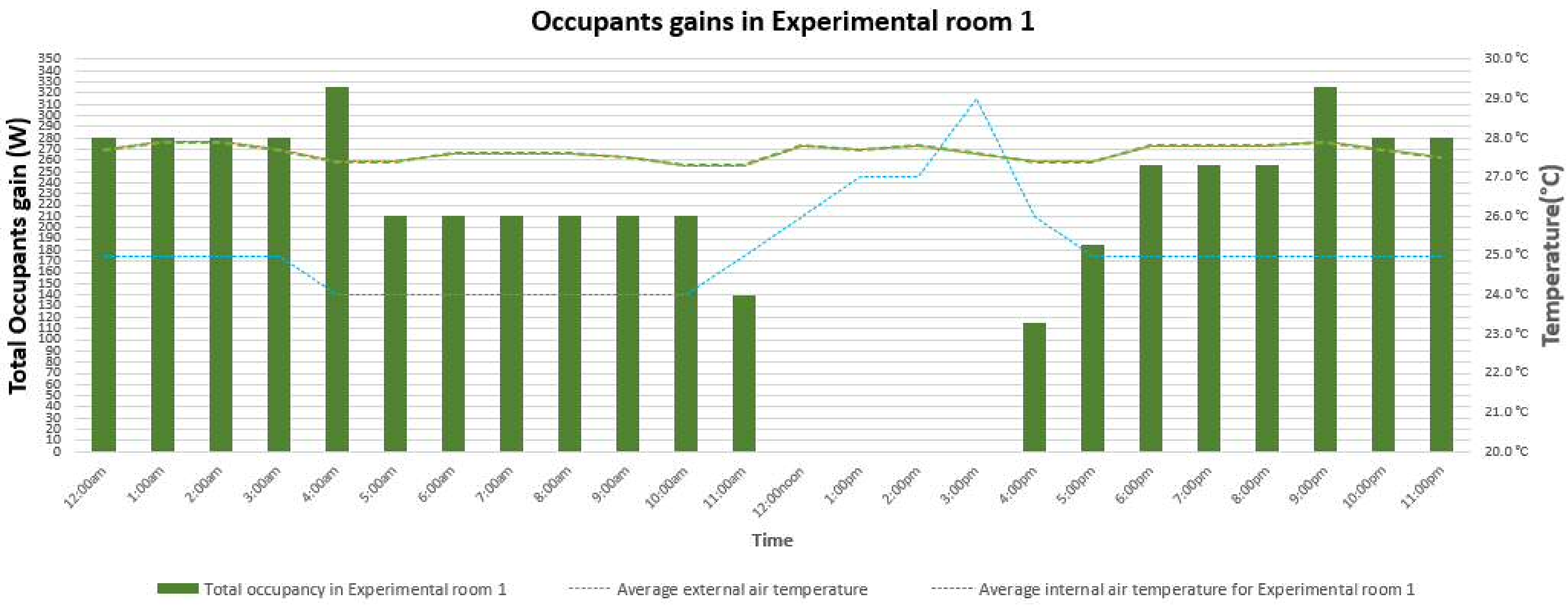


Figure 8-10; Occupancy gains in Experimental room 1

Again, the daily average external air temperature for a typical day and the hourly average of indoor air temperature for the month of June were plotted to compare relationships between occupancy and temperature. The daily sum of occupant's internal gains over the 24-hour period is 4795Wh. Inside activity is lowest at 4:00pm, which is when the artisan 2 is the only one in the room after returning from work. From 12noon till 4:00pm, there are no residents in the room. This is due to the three artisans being at work and the seamstress engaging in activities outside the room. Inside activity peaks at 4:00am (325 W), which is when the seamstress prepares to leave for work and everyone else is asleep and 9:00pm (325W), when every person has returned to the room and is either sleeping or resting. There are also periods of 'flat occupancy', when internal gains are constant, from 10:00pm to 4:00am (280W), when all occupants are asleep; from 5:00am to 11:00am (210W), after seamstress leaves for work and the rest of the occupants are asleep; and from 6:00pm to 9:00pm (210W) when three occupants are either sleeping or engaging in light activities. As observed, the external air temperature is almost always lower than indoor air temperature apart from 3:00pm, around 1h before people start coming back from work. Also, there is minimal oscillation of the measured indoor air temperature, during periods of occupancy and non-occupancy as evident during the empty period from 12noon till 4: 00pm.Sleeping period is from 5:00pm-4:00am with the seamstress, artisan 1 is from around 6:00pm-11:00am, artisans 2 is asleep from 9:00pm until 12:00noon and artisans 3 is asleep from 10:00pm until 12:00noon. Thus, the period when everyone is asleep at the same time is from 10:00pm to around 4am.

8.1.1.3 Comparing occupancy gains in Experimental room 1 and Control room 10

The overall comparison of occupancy gains is discussed below;

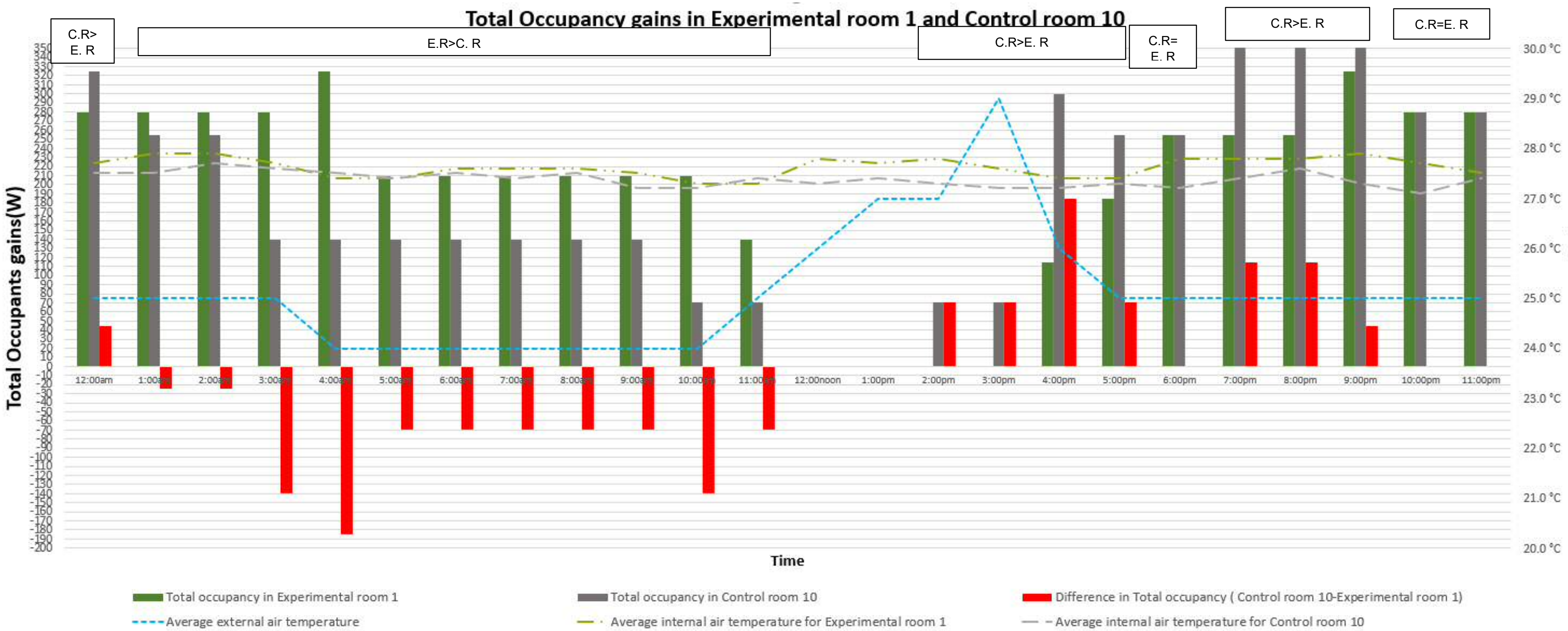


Figure 8-11; Total occupancy gains in Experimental room 1 and Control room 10

From figure 8-11, it is observed that from 1:00am to 12:00pm, the occupancy gains are higher in the experimental room than in the control room. The same is valid for the indoor temperature. Minimum difference on internal gains between the two rooms during this period occurs at 1:00am and 2:00am (25W), which translates to 3 occupants (1 engaged in light activities, 2 asleep) in the control room as opposed to full occupancy (all asleep) in the experimental room.

Maximum difference occurs at 4:00am (185W), when the seamstress is engaged in lightweight activities and the remaining occupants in the experimental room are asleep and there are only 2 people are in the control room, both asleep. The ‘flat occupancy’ period from 5:00am to 10:00am has a difference of 70W, which translates into three sleeping occupants in the experimental room and two sleeping occupants in the control room. Interestingly, the average external air temperature is also ‘flat’ during this period. There is no occupancy from 12:00noon to 2:00pm.

From 2:00pm to 12:00am, internal gains in the control room are either equal to or higher than the experimental room. The periods of exact occupancy gains are: at 6:00pm and from 10:00pm to 12:00am. Minimum difference between the two rooms during this period occurs at 9:00pm (45W) when both rooms are occupied by 4 people. During this period, two occupants are engaged in light activities and the other two are sleeping in the control room and 3 occupants are sleeping while the 4th engages in light activity within the experimental room. Maximum difference occurs at 4:00pm (185W), when there are 3 occupants in the control room and only 1 occupant in the experimental room. From 7:00pm - 9:00pm, the difference is 115W, due to full occupancy in the control room (two engaged in light activities, two sleeping) and 3 occupants in experimental room (two sleeping, 1 light activity).

Noteworthy is that despite the fact internal gains in the control room are higher than the ones in the experimental room from 4pm, internal air temperatures in the experimental room are still higher than the ones in the control room.

In general, it can be inferred that the two rooms are not exactly comparable in terms of occupancy. This is because, out of the daily 24-hour period, there are only three periods in which occupancy in both rooms are the same: At 6pm, from 10pm to 12am and from 12pm to 4pm. Other periods with howbeit smaller differences ranging from 25W to 45W (differences mainly down to the type of activities being undertaken in each room rather than the number of people in them) include 12:00am-2:00am and 9:00pm. Equipment and lighting usage should be added to this analysis to check the comparability of internal gains in its entirety.

8.2 Comparison of Equipment usages in experimental room 1 and control room 10

To complete the analysis of internal gains in rooms 1 and 10, lighting and equipment usages will be examined to determine how comparable the rooms are. However, equipment usages are dependent on the electricity supply, which, as discussed in previous chapters, is unstable and inconsistent in Nigeria. It is not unusual for blackouts to be experienced often for days at a time, thus leading to the need for backup electricity in the form of generators to be operated intermittently. These complexities make the process of analyzing equipment usages unstraightforward. This being the case, equipment usage will be analyzed in a range of minimum, maximum and typical hours of operation.

Figure 8-12 estimates the number of hours of electricity from the Power Holding Company of Nigeria (PHCN) and the generator on a typical day, as observed by the researcher. A single generator was usually operated by the Case Worker to provide back-up electricity for all the rooms within the house. The timeline for its operation was approximately 6 hours daily from 9:00pm-11:00pm and 4:00am-6:00am, although these times might vary should the need arise.

Hence, the typical estimated hours of electricity supply from both the PHCN and generator is 8 hours (6 from the generator, 2 from the PHCN, as confirmed by the occupants through interviews), minimum estimated hours of electricity supply from the generator alone is 6 hours, and maximum estimated hours from PHCN is 24 hours.

Minimum, maximum and typical estimated periods of electricity supply schedule for Case Study House A																								
Minimum estimated period of electricity supply					●	●	●															●	●	●
Maximum estimated period of electricity supply	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Typical estimated period of electricity supply					●	●	●					●	●									●	●	●
Hours	**12:00am**	**1:00am**	**2:00am**	**3:00am**	**4:00am**	**5:00am**	**6:00am**	**7:00am**	**8:00am**	**9:00am**	**10:00am**	**11:00am**	**12:00 noon**	**1:00pm**	**2:00pm**	**3:00pm**	**4:00pm**	**5:00pm**	**6:00pm**	**7:00pm**	**8:00pm**	**9:00pm**	**10:00 pm**	**11:00 pm**

Figure 8-12; Typical electricity supply schedule for Case Study House A

Equipment loads were gotten from the power holding company of Nigeria and are illustrated in Table 8-2.

Equipment	Load(W)
Refrigerator	150
Low quality incandescent light bulb (1 per room)	100
Television	100
Standing fan	100

Table 8-2; Equipments and corresponding load, source: PHCN, 2015

- **Minimum period of electricity supplied (6 hours)**

As observed, from 4:00am-6:00am in Experimental room 1, equipment in operation include; 1 incandescent light bulb per room likely to be operated due to the absence of daylight and preparation by the seamstress to leave for work, 1 refrigerator and 1 standing fan per room. The standing fan and refrigerator operate at the same time in both rooms. From 9:00pm-11:00pm, all equipments are in operation as both rooms are fully occupied.

- **Maximum period of electricity supplied (24 hours)**

With the 24-hour electricity supply, the refrigerators are in constant operation in both rooms. In the Control room, between 12:00am and 2:00am is when Carpenter 1 and 2 prepare to leave for work. Since there is electricity available, the incandescent light bulb is continuously in operation during this time. The standing fans are in operation only when the rooms are occupied. From 4:00pm, the televisions are in operation in both rooms, which is when both rooms have at least one occupant engaging in light activities. At 7:00pm, the incandescent light bulbs are switched on in both rooms till 9:00pm. At 10:00pm, which is when everyone is asleep, only the refrigerators and standing fans are in operation.

- **Typical period of electricity supplied (8 hours)**

With the 9-hour electricity supply, the low quality incandescent light bulb is the extra equipment in operation in Experimental room 1 at 4:00am (the time the seamstress prepares for work). At 5:00am, 6:00am and 11:00am, the refrigerators and standing fans are in operation in both rooms. At 12:00 noon, during periods of no occupancy, only the refrigerators are in use. All equipments which coincides with occupancy are in use from 8:00pm-9:00pm. At 10:00pm, when all occupants are asleep only the standing fans and refrigerators are in use.

Due to the most commonly occurring scenario of electricity supply being the typical period of electricity supply as confirmed during interviews, this is the focus for the calculation of the total internal gains for equipment gains/ load.

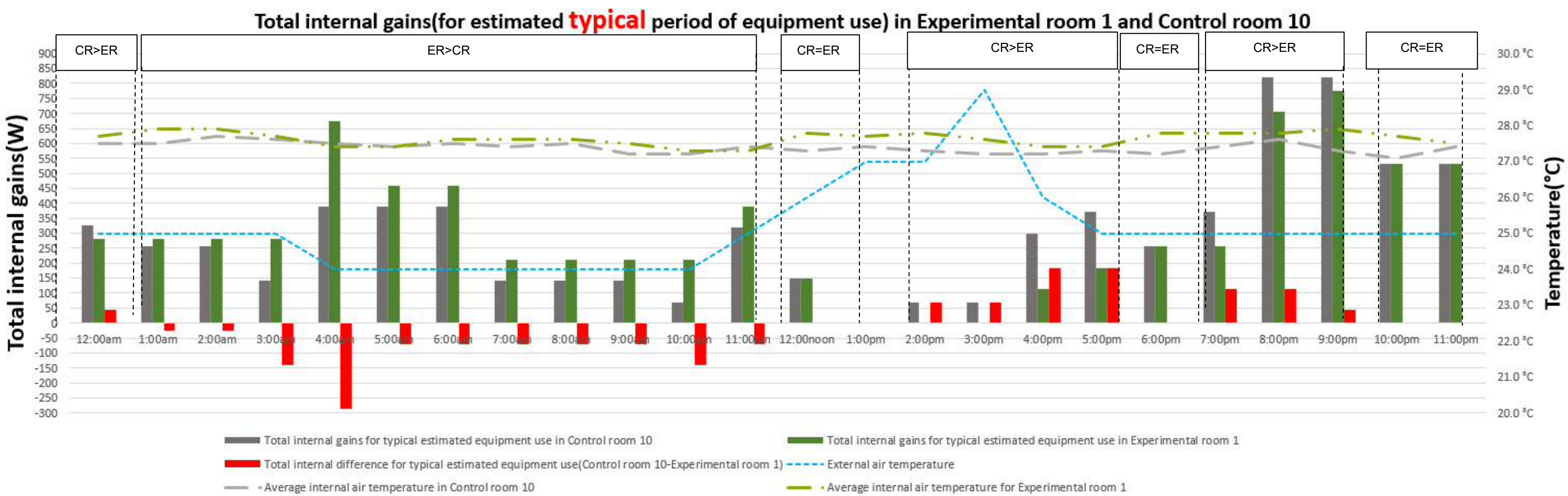


Figure 8-13-; Total internal gains for estimated typical period of equipment use

For the typical period of equipment usage, the refrigerator is in operation for 8 hours in both rooms. While other equipments are in operation at various times in both rooms. The total daily load generated by the equipment adds to 2650Wh to the internal gains in the experimental room (over 24 hours), and to 2550Wh to the control room, only 10Whs difference.

As observed, the total internal gains in the experimental room are higher than that of the control room from 1:00am to 12pm, with the maximum difference occurring at 4:00am (285W), which is when the low quality incandescent bulb is the extra appliance in operation during this time. The least difference occurs at 1:00am - 2:00am (25W), when no extra load due to lighting or equipment is added to internal gains in either room. Internal gains in the control room are higher than the ones in the experimental room from 2pm to 6pm and from 7pm to 10pm, when the television and standing fan are in operation in the control room.

Equal amounts of internal gains which translates into equal occupancy and use of television, light bulbs and standing fans are recorded at 6:00pm, 10:00pm - 11:00pm. At midday, neither rooms are occupied but the refrigerators are in operation for approximately 1hour. The flat occupancy difference observed from 7:00am to 11:00am is due to occupancy only as there are no equipment in operation during this period. Noteworthy is that indoor air temperature is almost always higher in the experimental room despite the differences in internal gains. Indoor air temperatures vary within a range of around 1° C in a period of 24hs and no observed thermal lag seems to be present when comparing it with external air temperatures.

In conclusion, the internal gains are not exactly comparable. However, it is important to notice that equal gains are estimated at noon, 1pm, 6pm and from 10pm to 12am.

8.3 Integrated analysis for the month of June (prior to installation of prototypes)

With the total internal gain in both rooms having been analyzed, the next sections integrate the total solar incident radiation study of the western wall surfaces, wall surface and indoor air temperature, first for the month of June (prior to the installation of the prototypes) and then for the month of August (after the full growth of the plants). This is to ascertain the level of similarity /dissimilarity on the amount of solar radiation received on both walls to establish how comparable the rooms are, thus increasing the reliability of the impact of the prototype on indoor temperature (if any). Finally, the percentage range the average indoor air temperature is within the adaptive thermal comfort range for the month of June and August is compared[59].

[59] Details of this has been discussed in Chapter 7

8.3.1 Solar radiation and wall surface analysis for the month of June (pre-growth of the prototypes)

Figure 8-14 reveals that the only wall directly exposed to incident solar radiation is the western wall surface, which informed the interest of this wall for the set-up of the prototypes in this study. However, it receives direct solar radiation at a particular time frame from approximately 2:00pm to 7:00pm.

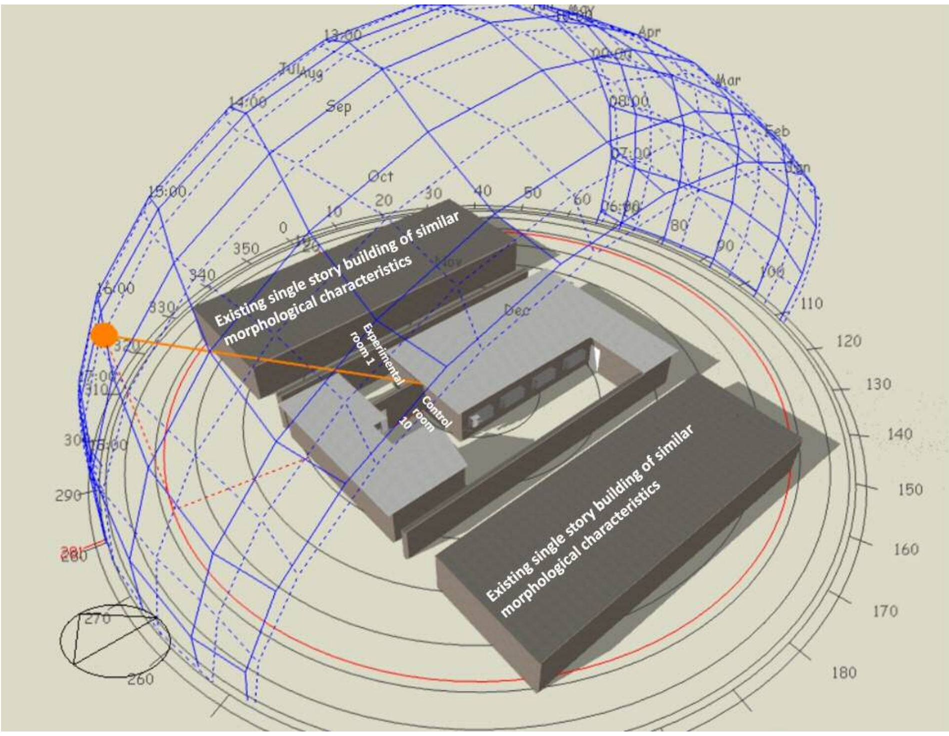


Figure 8-14; incident solar radiation on western wall surface as modelled in design builder

A comparison of the total incident solar radiation for the month of June is presented below:

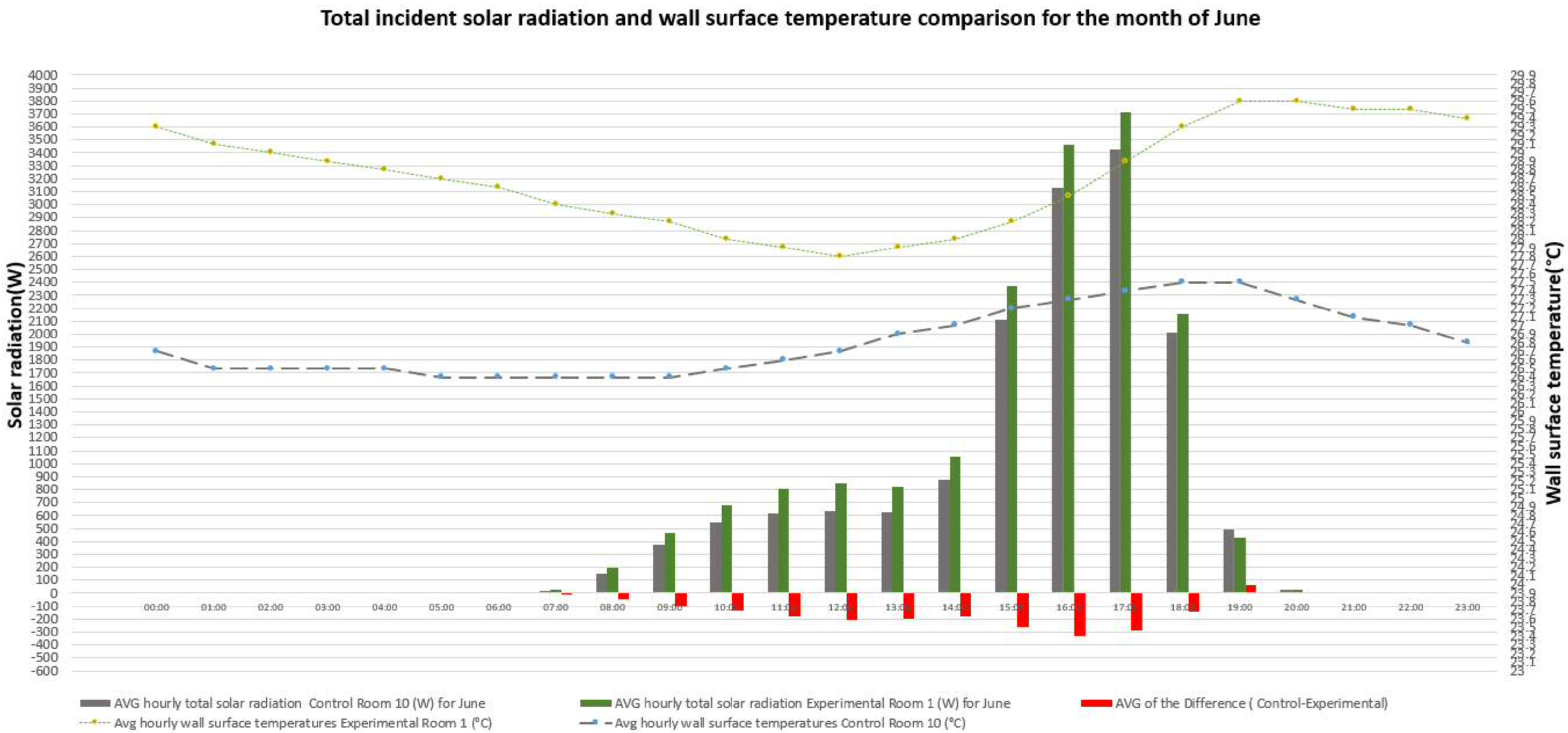


Figure 8-15; Total incident solar radiation and wall surface comparison for the month of June

As observed, the incident solar radiation received on the experimental room is always slightly higher than the one of the control room (except for 7pm) possibly due to overshadowing from neighbouring walls. It is also evident that the corresponding wall surface temperature values are always higher in the experimental room wall. However, at 7:00pm, while the control room incident radiation is slightly higher, this doesn't seem to impact the surface temperature.

The minimum exposure to solar incident radiation occurs at 7:00am-8:00am (difference of 4.5W-44.3W) and 7:00pm-8:00pm (difference 60.1W-1W).

Maximum exposure to solar incident radiation occurs at 5:00pm (3427.7W for the control room and 3712.7W for the experimental room), the corresponding wall surface temperatures are 27.4°C and 28.5°C. Noteworthy is that the wall surface temperature for both rooms, peaks after this time, which is 7:00pm (27.5°C and 29.3°C).

From 10:00am to 3:00pm, the differences range between 134.8W to 200W, which is when there is a slight decline on the wall surface temperature in the experimental room, but the wall surface temperature increases on the control room.

8.3.2 Combined discussion for the month of June

This section brings together the internal gains and solar radiation analysis for both rooms.

Integrated analysis for the month of June

Time	12:00am	1:00am	2:00am	3:00am	4:00am	5:00am	6:00am	7:00am	8:00am	9:00am	10:00am	11:00am
Internal gains (W)	**C.R >E.R**	**E.R>C.R**										
Total Solar incident(W)	No solar radiation								**E.R>C.R**			
AVG hourly internal air temperatures Experimental Room 1 (°C)	**27.7°C**	**27.9 °C**	**27.9 °C**	**27.7 °C**	**27.4 °C**	**27.4 °C**	**27.6 °C**	**27.6 °C**	**27.6 °C**	**27.5 °C**	**27.3 °C**	**27.3 °C**
AVG hourly internal air temperatures Control Room 10 (°C)	**27.4 °C**	**27.5 °C**	**27.5 °C**	**27.7 °C**	**27.6 °C**	**27.5 °C**	**27.4 °C**	**27.5 °C**	**27.4 °C**	**27.5 °C**	**27.2 °C**	**27.2 °C**
AVG of the Difference (Experimental - Control)	**0.3 °C**	**0.4 °C**	**0.4 °C**	**0.1 °C**	**-0.1 °C**	**-0.2 °C**	**0.1 °C**	**0.1 °C**	**0.2 °C**	**0.0 °C**	**0.1 °C**	**0.1 °C**
STD DEV of the Difference (Experimental - Control)	1.2 °C	1.2 °C	1.2 °C	1.3 °C	1.1 °C	1.1 °C	1.0 °C	1.0 °C	0.9 °C	1.3 °C	0.9 °C	1.0 °C

Time	12:00noon	1:00pm	2:00pm	3:00pm	4:00pm	5:00pm	6:00pm	7:00pm	8:00pm	9:00pm	10:00pm	11:00pm
Internal gains (W)	**No Occupancy**			**C.R >E.R**			**Equal gains**	**C.R >E.R**			**Equal gains**	
Total Solar incident(W)								**C.R >E.R**	No solar radiation			
AVG hourly internal air temperatures Experimental Room 1 (°C)	**27.8 °C**	**27.7 °C**	**27.8 °C**	**27.6 °C**	**27.4 °C**	**27.4 °C**	**27.8 °C**	**27.8 °C**	**27.8 °C**	**27.9 °C**	**27.7 °C**	**27.5 °C**
AVG hourly internal air temperatures Control Room 10 (°C)	**27.4 °C**	**27.3 °C**	**27.4 °C**	**27.3 °C**	**27.2 °C**	**27.2 °C**	**27.3 °C**	**27.2 °C**	**27.4 °C**	**27.6 °C**	**27.3 °C**	**27.1 °C**
AVG of the Difference (Experimental - Control)	**0.4 °C**	**0.4 °C**	**0.4 °C**	**0.3 °C**	**0.2 °C**	**0.3 °C**	**0.4 °C**	**0.6 °C**	**0.4 °C**	**0.3 °C**	**0.3 °C**	**0.4 °C**
STD DEV of the Difference (Experimental - Control)	0.9 °C	1.1 °C	1.1 °C	1.2 °C	1.2 °C	1.3 °C	1.1 °C	1.3 °C	1.3 °C	1.3 °C	1.2 °C	1.5 °C

Figure 8-16; Integrated analysis for the month of June

In general, it can be observed that AHIA are mostly slightly higher in the experimental room, with or without occupants. Minimum difference is at 9:00am (0°C) and maximum difference at 7:00pm (0.6 °C). Typical differences range between 0.1°C and 0.4 °C and standard deviation varies between 0.9°C-1.5°C. This means that there are no large variations among the internal air temperature values as they are closely clustered around the mean.

At 12:00am, the internal gains in the control room are higher than that of the experimental room, there are no solar radiation at this time. The AHIA temperature difference is 0.3°C, while standard deviation from the average is 1.2°C.

From 1:00am to 12:00noon, the internal gains are higher in the experimental room as well as the solar radiation (when available from 8am). The highest internal air temperature recorded in the experimental room is at 1:00am - 2:00am (average difference of 0.4°C in relation to the control room, standard deviation of 1.2°C). The highest internal air temperature in the control room is recorded at 3am (average difference of 0.1°C and standard deviation of 1.3°C). The lowest internal air temperatures recorded in both rooms are from 10am-11am (average difference of 0.1°C in relation to the control room and standard deviation around 1.0°C).

From 12:00noon till 3:00pm, there are no occupants or internal gains, however, the total solar incident radiation is higher in the experimental room and corresponding internal temperatures are consistently higher in the experimental room, with average differences of 0.3°C-0.4°C and corresponding standard deviation from 0.9°C-1.2°C.

From 3:00pm to 6:00pm, the internal gains in the control room are higher than the ones in the experimental room, whereas the incident solar radiation is higher in the experimental room. Higher internal air temperatures are still recorded in the experimental room, with average differences ranging from 0.2°C-0.3°C and standard deviation between 1.2°C to 1.3°C.

Further observation at 6:00pm reveals that despite higher solar radiation in the experimental room and equal amounts of internal gains calculated, higher internal air temperature is recorded in the experimental room, with average difference of 0.4°C and standard deviation of 1.1°C

From 7:00pm to10:00pm, internal gains are higher in the control room as well as the little amounts of solar radiation still available at 7:00pm. During this period, higher internal air temperatures are recorded in the experimental room with average differences in relation to the control room varying between 0.3°C-0.6°C and standard deviation is 1.3°C.

At 10:00pm and 11:00pm, there are equal amounts of internal gains and no solar radiation. Higher internal air temperatures in the experimental room have an average difference between 0.3°C-0.4°C in relation to the control room and standard deviation varying between 1.2°C-1.5°C.

In conclusion, the difference between both rooms in terms of total incident solar radiation and internal gains do not appear to significantly influence the average hourly indoor air temperature, meaning the rooms can potentially be comparable.

8.3.3 Solar radiation and wall surface analysis for the month of August (full growth of the prototypes)

A comparison of the total incident solar radiation for the month of August is first presented and the difference across the two months are analyzed.

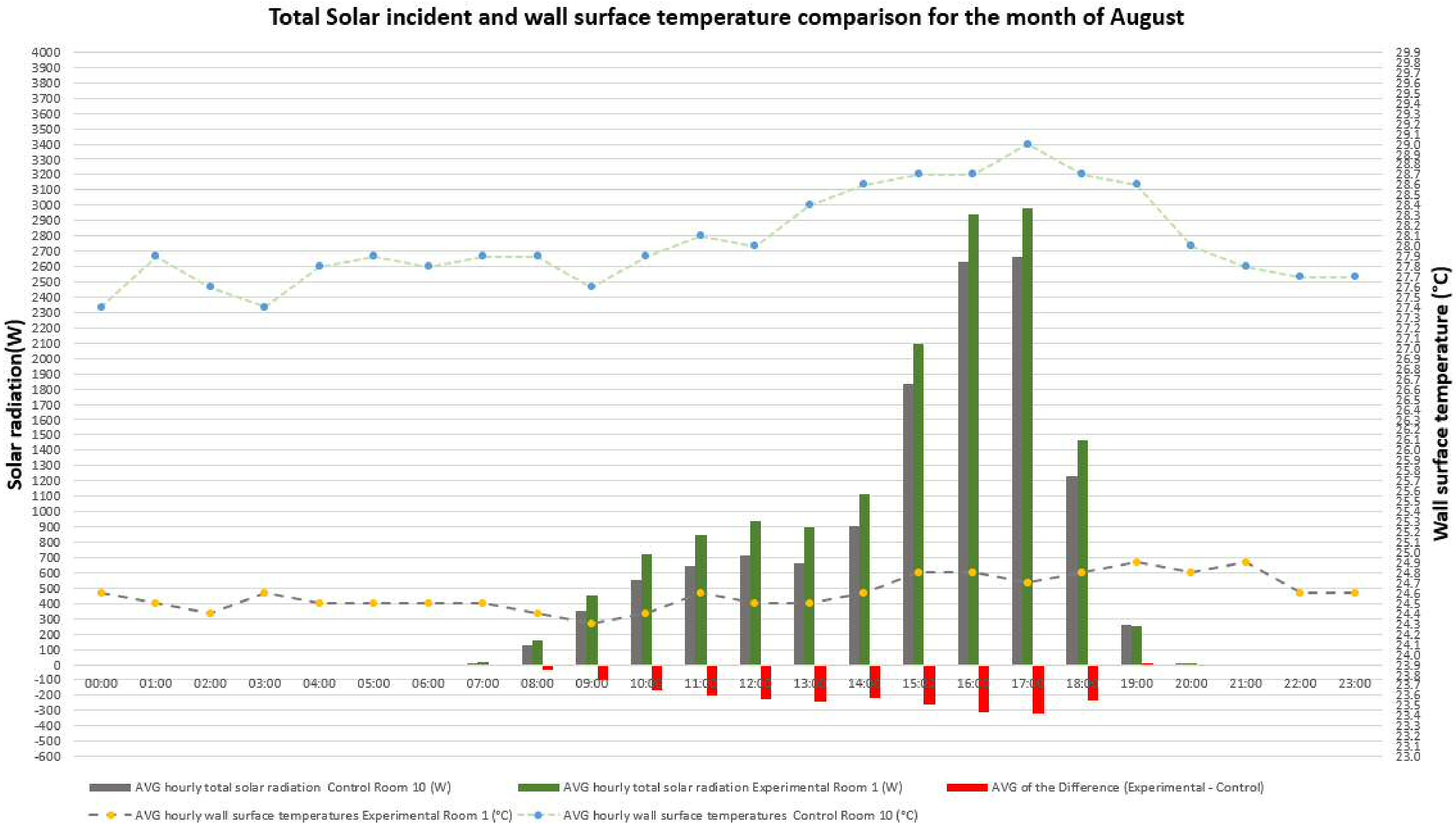


Figure 8-17; Total solar incident and wall surface temperature comparison for the month of August

It is observed that the total incident solar radiation received in June (total average daily solar incident radiation of 32083.8Wh) is consistently higher than that of August (total average daily solar incident radiation of 27467.9Wh) This is likely due to the sun-path movement that varies slightly across the different months as illustrated in figure 9-18.

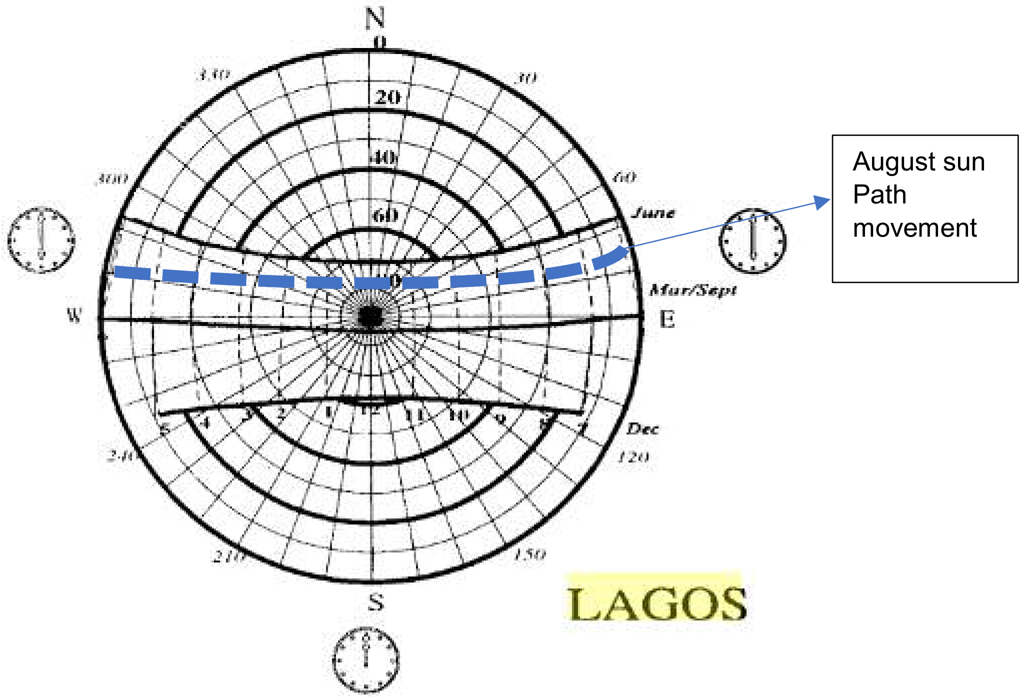


Figure 8-18 August sun path movement in Lagos, Nigeria, Hawkes et al, 2002

Like observed in June, the incident solar radiation received on the experimental room is always slightly higher than the one of the control room (except for 7pm) possibly due to overshadowing from neighbouring walls. However, in this month, surface temperatures in the control room are significantly higher than the ones from the experimental room, a first indication of the beneficial effects of the VGS to be discussed later on in this section.

As in June, minimum exposure to solar incident radiation occurs at 7:00am-8:00am (difference 2.3W-30.5W) and 7:00pm-8:00pm (difference 7.6W-0.8W).

Closer to what was observed in June, maximum exposure to solar incident radiation occurs at 5:00pm (2665.3W for the control room and 2985W for the experimental room), the corresponding wall surface temperatures are 29°C peak temperature for the control room, and 24.7°C for the experimental room. The peak temperature recorded in the experimental room is at 9:00pm (24.9°C), later than the one recorded in June which happened between 7:00-8:00pm, whereas the peak temperature in the control room is recorded at 5:00pm, slightly earlier than the one in June recorded at 6:00-7:00pm.

Like what was observed in June, from 10:00am to 3:00pm, the difference in solar radiation ranges from 166.1W to 238.9W but this time with corresponding wall surface temperature difference is much higher ranging from 3.4°C-3.9°C.

8.3.4 Combined discussion for the month of August.

This section brings together the internal gains and solar radiation analysis for both rooms.

Integrated analysis for the month of August

Time	12:00am	1:00am	2:00am	3:00am	4:00am	5:00am	6:00am	7:00am	8:00am	9:00am	10:00am	11:00am	12:00noon	1:00pm	2:00pm	3:00pm	4:00pm	5:00pm	6:00pm	7:00pm	8:00pm	9:00pm	10:00pm	11:00pm
Internal gains (W)	**C.R >E.R**	**E.R>C.R**											**No Occupancy**			**C.R >E.R**			**Equal gains**	**C.R >E.R**			**Equal gains**	
Total Solar incident(W)	No solar radiation								**E.R>C.R**											**C.R >E.R**	No solar radiation			
AVG hourly internal air temperatures Experimental Room 1 (°C)	**27.2 °C**	**27.2 °C**	**27.2 °C**	**27.1 °C**	**27.1 °C**	**27.0 °C**	**26.9 °C**	**26.9 °C**	**26.9 °C**	**26.8 °C**	**26.8 °C**	**26.9 °C**	**27.1 °C**	**27.2 °C**	**27.3 °C**	**27.4 °C**	**27.4 °C**	**27.5 °C**	**27.5 °C**	**27.5 °C**	**27.5 °C**	**27.4 °C**	**27.4 °C**	**27.4 °C**
AVG hourly internal air temperatures Control Room 10 (°C)	29.6 °C	29.6 °C	29.6 °C	29.6 °C	29.6 °C	29.3 °C	29.5 °C	29.6 °C	29.5 °C	29.4 °C	29.2 °C	29.3 °C	29.2 °C	29.3 °C	29.4 °C	29.5 °C	29.5 °C	29.9 °C	29.9 °C	29.6 °C	29.6 °C	29.5 °C	29.5 °C	29.4 °C
AVG of the Difference (Experimental - Control)	**-2.4 °C**	**-2.4 °C**	**-2.4 °C**	**-2.4 °C**	**-2.6 °C**	**-2.4 °C**	**-2.6 °C**	**-2.7 °C**	**-2.6 °C**	**-2.6 °C**	**-2.4 °C**	**-2.3 °C**	**-2.1 °C**	**-2.1 °C**	**-2.1 °C**	**-2.1 °C**	**-2.1 °C**	**-2.4 °C**	**-2.4 °C**	**-2.2 °C**	**-2.1 °C**	**-2.1 °C**	**-2.1 °C**	**-2.1 °C**
STD DEV of the Difference (Experimental - Control)	**1.1 °C**	**1.1 °C**	**0.9 °C**	**1.0 °C**	**0.9 °C**	**1.0 °C**	**0.9 °C**	**0.7 °C**	**0.9 °C**	**0.9 °C**	**1.1 °C**	**1.1 °C**	**1.0 °C**	**0.7 °C**	**0.8 °C**	**0.8 °C**	**1.0 °C**	**1.0 °C**	**1.4 °C**	**0.8 °C**	**0.8 °C**	**0.8 °C**	**0.8 °C**	**0.9 °C**

Figure 8-19; Integrated analysis for the month of August

In the previously analyzed month of June, the average hourly internal air temperature across both rooms differed only by a maximum of 0.6 °C, and the experimental room had almost always higher internal air temperatures than the control room. From figure 8-20, despite lower incident solar radiation in the month of August and the same internal gains, the average hourly internal air temperature across both rooms differ by a maximum of -2.7°C, and the experimental room has consistently lower internal air temperatures than the control room. This indicates the VGS is having an effect in lowering internal air temperatures in the experimental room. As June at 2:00am, the internal gains in the control room are higher than that of the experimental room. However, the AHIA temperature difference is now -2.4°C (with a standard deviation of 1.1°C), i.e. the control room has higher temperatures in relation to the experimental room.

Again, as in June, from 1:00am to 12:00noon, the internal gains are higher in the experimental room as well as the solar radiation (when available from 8am). However, throughout this period, internal air temperatures in the control room are consistently higher than the ones in the experimental room. Highest internal temperatures in the control room are around 29.6°C, whereas in the experimental room they are 27.2°C. Maximum difference at this period occurs at 7:00am (2.7°Cwith standard deviation of 0.7°C. The lowest internal air temperatures recorded in both rooms happen at 5am (average difference of -2.4°C in relation to the control room and standard deviation around 1.0°C).

From 12:00noon till 3:00pm, there are no occupants or internal gains, and the total solar incident radiation is higher in the experimental room. However, corresponding internal temperatures are consistently higher in the control room, with average differences of -2.1°C and standard deviation varying from 0.7°C-1.0°C.

From 3:00pm to 6:00pm, the internal gains in the control room are higher than the ones in the experimental room, whereas the incident solar radiation is higher in the experimental room. However, again higher internal air temperatures are still recorded in the control room, with average differences ranging from -2.1°C to -2.4°C and standard deviation between 0.8°C to 1.0°C.

Further observation at 6:00pm reveals that despite higher solar radiation in the experimental room and equal amounts of internal gains calculated, higher internal air temperature is recorded in the control room, with average difference of -2.4°C and standard deviation of 1.4°C

From 7:00pm to10:00pm, internal gains are higher in the control room as well as the little amounts of solar radiation still available at 7pm. During this period, higher internal air temperatures are recorded in the Control room with an average difference of -2.1°C and standard deviation of 0.8°C.

At 10:00pm and 11:00pm, there are equal amounts of internal gains and no solar radiation. Higher internal air temperatures in the Control room have an average difference of -2.1°C and standard deviation varying between 0.8°C-0.9°C

8.4 Adaptive thermal comfort range

With the establishment of the impact of the prototypes on AHIA, this section observes the amount of time it is within the adaptive thermal comfort range in both rooms to gauge the full benefits of this system. The purpose of this as discussed in Chapter 7 is to determine the amount of time the occupants might be comfortable within this model, as indoor temperatures with the prototypes are still rather high, especially in comparison to ASHRAE standards.

The analysis focuses on periods of occupancy within adaptive thermal comfort range, which is $\pm$ of the adaptive thermal comfort temperature proposed as $0.534*T_o+12.9$ by Nicol and Humphrey's (2002), with the range from ± 3, where T_o is the mean monthly outdoor temperature, which was gotten from NIMET, 2016. This is divided into 'sleeping' period (passive period) and 'awake' period (active period) for each occupant. The comfort rating (using the Bedford scale) and adaptive actions for morning, afternoon and evening period are also documented.

Adaptive thermal comfort schedule for Control room 10

	MORNING												AFTERNOON						EVENING					
	12:00am	1:00am	2:00am	3:00am	4:00am	5:00am	6:00am	7:00am	8:00am	9:00am	10:00am	11:00am	12:00noon	1:00pm	2:00pm	3:00pm	4:00pm	5:00pm	6:00pm	7:00pm	8:00pm	9:00pm	10:00pm	11:00pm
Carpenter 1	Sleeping	Awake								No occupancy											Sleeping			
Carpenter 2		Awake							No occupancy										Sleeping					
Carpenter 3					Sleeping								No occupancy				Awake	No occupa		Awake			Sleeping	
Carpenter 4						Sleeping								No occupancy			Awake		No occupa		Awake		Sleeping	
June																								
Percentage of average indoor air temperature within ATC range	97%	97%	93%	93%	97%	97%	100%	93%	100%	97%	100%	100%				97%	100%	100%	100%	100%	100%	90%	97%	97%
August																								
Percentage of average indoor air temperature within ATC range	29%	26%	26%	26%	23%	39%	35%	29%	26%	26%	39%	35%	45%	35%	32%	29%	39%	23%	23%	29%	29%	26%	29%	29%

Adaptive thermal comfort schedule for Experimental room 1

	12:00am	1:00am	2:00am	3:00am	4:00am	5:00am	6:00am	7:00am	8:00am	9:00am	10:00am	11:00am	12:00noon	1:00pm	2:00pm	3:00pm	4:00pm	5:00pm	6:00pm	7:00pm	8:00pm	9:00pm	10:00pm	11:00pm
Seamstress			Sleeping								No occupancy										Sleeping			
Artisan 1						Sleeping										No occupancy					Sleeping			
Artisan 2							Sleeping								No occupancy		Awake			No occupancy			Sleeping	
Artisan 3							Sleeping									No occupancy				Awake			Sleeping	
June																								
Percentage of average indoor air temperature within ATC range	93%	90%	93%	93%	100%	100%	100%	100%	97%	100%	100%	100%					97%	97%	97%	93%	93%	90%	87%	93%
August																								
Percentage of average indoor air temperature within ATC range	100%	100%	97%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	97%	90%	97%	90%	94%	94%	100%

Figure 8-20; Adaptive thermal comfort schedule for Control room 10 and Experimental room 1

8.4.1 Adaptive thermal comfort schedule for the month of June (pre-installation of prototype)

The sleeping period for Carpenter 1 is from 5pm to 1:00am. During this time, the AHIA falls within the ATC range 90%-100% of the time. The period when he is awake, briefly, before leaving the residence for work, is at approximately 1:00am, the AHIA falls within the ATC range 97% of the time. For carpenter 2, sleeping period is from 2:00pm to 11:00pm, which is also within the ATC range 90% to 100% of the time. The period when he is awake (from 12:00am to 2:00am), the average indoor air temperature falls within the ATC range 93%-97% of the time.

Carpenter 3's sleeping period from 10:00pm to 10:00am reveals that the AHIA range is between 93%-100% of the time. The awake period between 4:00pm-5:00pm and 6:00pm to 10:00pm shows that the ATC range is 100%.

The sleeping period for Carpenter 4 from 10:00pm-12:00pm reveals that the AHIA is within the ATC range 93%-100% of the time. From 4:00pm to 6:00pm, when he is awake, the ATC range is 100%. From 7:00pm-10:00pm, the ATC range is 90%-100%.

The experimental room reveals that the sleeping period for the seamstress from 5:00pm to 4:00am is within the ATC range 87%-93% of the time, while the awake period from 4:00am is at 100%

For Artisan 1, sleeping period from 6:00pm to 11:00am is 87%-100% of the time. Artisan 2's sleeping period form 9:00pm to 12:00pm AHIA is within the ATC range 87%-100% of the time. The period when he is awake from 4:00pm-6:00pm, the AHIA is within the ATC range 97% of the time.

Artisan 3's sleeping period from 10:00pm to 11:00am AHIA is within the ATC range 87% to 100% of the time. At 6:00pm-9:00pm, when he is awake, the AHIA is within the ATC range 90%-97% of the time.

In general, it is observed that the AHIA for the month of June for both rooms is within the ATC range (23.3°C to 29.3°C) between 87%-100%.

When asked to rate the thermal comfort conditions, in the morning, afternoon and evening, their response is based on the Bedford scale in table 8-3.

Comfort rating	-3	-2	-1	0	+1	+2	+3
Description	much too cool	too cool	comfortably cool	comfortable	comfortably warm	too warm	much too warm

Table 8-3; Bedford scale thermal comfort rating

Comfort rating				
Morning period (Experimental room 1)	+2	+2	+2	+1
Morning period (Control room 10)	+2	+2	+2	+2
Afternoon period (Experimental room 1)	+3	+3	+2	+2
Afternoon period (Control room 10)	+3	+3	+3	+3
Evening period (Experimental room 1)	+1	+2	+2	+1
Evening period (Control room 10)	+2	+3	+2	+1

Table 8-4; Comfort rating by occupants in Case Study House A

In the morning period, 75% of the occupants in Room 1 were uncomfortable and stated that they found the housing conditions in the morning '**too warm'**, while all the occupant's in Room 10 were dissatisfied with all of them stating that the room was **'too warm'.** This reveals that the thermal conditions in the houses during this period was uncomfortable for the occupants, despite AHIA being within the ATC range 93%-100% of the time in the control room and AHIA being within the ATC range 90%-100% of the time in the experimental room.

In the afternoon period, if they were in the houses, 100% of the occupants in both rooms were uncomfortable. Whereas 100% of occupants in control room 10 stated they felt 'much too warm' only 50% of occupants in the experimental room 1 felt 'much too warm' Despite AHIA being within the ATC range 97%-100% of the time in the control room and AHIA being within the ATC range 97% of the time in the experimental room.

In the evening period, control room 10 was notably more uncomfortable than the experimental room 1. In the former, 50% of the occupants were uncomfortable while the rest of the occupants stated that the house was '**comfortably warm'** , whereas in the latter 75% of the occupants' stated their room as **'too warm'** or '**much too warm'** and 25% stated their room as **'comfortably warm'**, despite AHIA being within the ATC range 90%-100% of the time in room 10 and being within the ATC range 87%-97% in room 1.

When asked on how they enhance indoor comfort, table 8-5 summarizes the actions undertaken in both rooms, during the three different periods;

Occupant	Morning		Afternoon		Evening	
	Experimental room 1	**Control room 10**	**Experimental room 1**	**Control room 10**	**Experimental room 1**	**Control room 10**
1	Bathing	Leave residence	Leave residence	Leave residence	Adjust window	Adjust window
2	Bathing	Adjust window	Leave residence	Leave residence	Cope	Adjust window
3	Bathing	Bathing	Cope	Drink cold water	Bathing	Adjust window
4	Adjust window	Bathing	Drink cold water	Drink cold water	Leave residence	Adjust window

Table;8-5; Adaptive actions for enhancing indoor comfort

In the morning period, bathing and adjusting window are the two adaptive actions undertaken by the occupants in room 1, while bathing, adjusting window and leaving residence was documented in room 10.

In the afternoon period, which includes periods of no occupancy in both rooms, the predominant adaptive actions were documented as 'leave residence', 'cope' (ignore discomfort) and drink cold water.

In the evening period, which is when everyone was usually indoors, the predominant adaptive actions were documented as 'adjust window', 'cope', 'bathing' and 'leave residence' in room 1, while 'adjust window' was undertaken by all occupants in room 10.

8.4.2 Adaptive thermal comfort schedule for the month of August (full installation of prototype)

The sleeping period for carpenter 1 is from 5pm to 12:00am. During this time, due to the higher AHIA recorded, they fall within the ATC range 23%-29% of the time. For carpenter 2, sleeping period is from 2:00pm to 11:00pm, which is also within the ATC range 23% to 32% of the time. The period when he is awake (from 12:00am to 2:00am), the average indoor air temperature falls within the ATC range 26%-29% of the time.

Carpenter 3's sleeping period from 10:00pm to 9:00am reveals that the AHIA range is between 26%-39% of the time. The awake period between 4:00pm-5:00pm and 6:00pm to 9:00pm shows that the ATC range is 23%-29%.

The sleeping period for Carpenter 4 from 10:00pm-11:00am reveals that the AHIA is within the ATC range 23%-39% of the time. from 4:00pm to 5:00pm, when he is awake, the ATC range is 23%-39%. From 7:00pm-9:00pm, the ATC range is 26%-29%.

The experimental room reveals that the sleeping period for the seamstress from 5:00pm to 3:00am is within the ATC range 90%-100% of the time, while the awake period at 4:00am is at 100%

For Artisan 1, sleeping period from 6pm to 10am is 90%-100% of the time. Artisan 2's sleeping period form 9:00pm to 11:00am AHIA is within the ATC range 90%-100% of the time. The period when he is awake from 4:00pm-5:00pm, the AHIA is within the ATC range 97%-100% of the time.

Artisan 3's sleeping period from 10:00pm to 11:00am AHIA is within the ATC range 94% to 100% of the time. At 6:00pm -9:00pm, when he is awake, the AHIA is within the ATC range 90%-97% of the time.

In conclusion, it is observed that the AHIA for the month of August for the Control room is less within the ATC range (23.3°C to 29.3°C) between 23%-45%. The experimental room is within the ATC range 90%-100%.

When asked to rate the thermal comfort conditions, in the morning, afternoon and evening, their responses were

Comfort rating				
Morning period (Experimental room 1)	+2	+2	+1	+1
Morning period (Control room 10)	+2	+1	+2	+2
Afternoon period (Experimental room 1)	+3	+2	+2	+2
Afternoon period (Control room 10)	+3	+2	+2	+3
Evening period (Experimental room 1)	+1	+1	+2	+1
Evening period (Control room 10)	+2	+1	+2	+1

Table 8-6; Comfort rating by occupants in Case Study House A

In the morning period, 50% (an improvement of the 75% documented in June) of the occupants in Room 1 were uncomfortable and stated that they found the housing conditions in the morning '**too warm'**, while 75% (an improvement of 100% documented in June) of the occupant's in Room 10 were dissatisfied with all of them stating that the room was **'too warm'.** This reveals that the thermal conditions in the houses during this period was still uncomfortable for the occupants, although not as much as perceived in June. However, the AHIA was within the ATC range 23%-39% of the time in the control room 10 and AHIA was within the ATC range 97%-100% of the time in the experimental room 1.

In the afternoon period, if they were in the houses, 100% (as documented in the month of June) of the occupants in both rooms were uncomfortable. Whereas 50% of occupants in control room 10 stated they felt 'much too warm' only 25% of occupants in the experimental room 1 felt 'much too warm', again showing an improvement in relation to what happened in June. The AHIA was within the ATC range 23%-45% of the time in the control room and AHIA being within the ATC range 97%-100% of the time in the experimental room.

In the evening period, control room 10 was still notably more uncomfortable than the experimental room 1. In the former, 50% of the occupants (an improvement from the data documented in June) were uncomfortable, whereas in the latter only 25% were feeling uncomfortable (an improvement from the 50% documented in June). The AHIA was within the ATC range 23%-29% of the time in room 10 and 90%-100% in room 1.

When asked on how they enhance indoor comfort, figure 8-25 summarizes the actions undertaken in both rooms, during the three different periods;

Occupant	Morning		Afternoon		Evening	
	Experimental room 1	**Control room 10**	**Experimental room 1**	**Control room 10**	**Experimental room 1**	**Control room 10**
1	Bathing	Leave residence	Leave residence	Leave residence	Adjust window	Adjust window
2	Bathing	Adjust window	Leave residence	Leave residence	Cope	Adjust window
3	Bathing	Bathing	Cope	Drink cold water	Bathing	Adjust window
4	Adjust window	Bathing	Drink cold water	Drink cold water	Leave residence	Adjust window

Table;8-7; Adaptive actions for enhancing indoor comfort

In the morning period, bathing and adjusting window were the two adaptive actions undertaken by the occupants in room 1, while bathing, adjusting window and leaving residence was documented in room 10.

In the afternoon period, which includes periods of no occupancy in both rooms, the predominant adaptive actions were documented as 'leave residence', 'cope' (ignore discomfort) and drink cold water.

In the evening period, which is when everyone was usually indoors, the predominant adaptive actions were documented as 'adjust window', 'cope', 'bathing' and 'leave residence' in room 1, while 'adjust window' was undertaken by all occupants in room 10.

Comparing tables 8-5 and 8-6 shows that in June, conditions in the experimental room were slightly better than in the control room in the morning, marginally better in the afternoon and much better in the evening. In August, conditions in the experimental room were slightly better than in the control room in the morning and afternoon but only much better in the evening. This is an interesting finding which does not correspond directly with the improvements in indoor air temperatures, i.e. indoor air temperatures indicate internal comfortable conditions in experimental room 1 should be significantly better than the ones in control room 10, whereas the survey does not state the same rate of improvement. Thus, the next section compares internal relative humidity analysis for both months to see if there are any changes due to the prototype in this metric, prior to presenting the overall conclusions.

8.5 Average hourly internal relative humidity analysis

This section compares the average hourly internal relative humidity(AHIRH) in both rooms (experimental and control), firstly for the month of June and then August, to establish whether there are patterns that are similar or different between the two spaces and across both months.

Month of June

Table 8-8, compares the AHIRH in both rooms for the month of June.

Time	Average hourly internal relative humidity Experimental Room 1 (°C)	Average hourly internal relative humidity Control Room 10 (°C)	Average of the Difference (Experimental - Control)	% Average of the difference in relation to Control room	STD DEV of the Difference (Experimental - Control)
00:00	82	85	-3.9	-4.6	3.0
01:00	82	86	-3.9	-4.6	3.0
02:00	82	86	-4.1	-4.8	2.9
03:00	82	86	-4.0	-4.6	2.8
04:00	82	86	-4.0	-4.6	2.7
05:00	82	86	-3.9	-4.6	2.6
06:00	82	86	-3.9	-4.6	2.7
07:00	82	86	-3.9	-4.5	2.8
08:00	82	86	-3.9	-4.5	2.7
09:00	82	86	-3.9	-4.6	2.6
10:00	82	85	-3.9	-4.6	2.7
11:00	82	85	-3.8	-4.4	2.8
12:00	82	85	-3.9	-4.6	2.7
13:00	82	85	-4.0	-4.7	2.8
14:00	82	85	-4.1	-4.8	2.9
15:00	82	85	-4.0	-4.7	2.9
16:00	82	85	-3.9	-4.5	2.8
17:00	82	85	-3.9	-4.6	2.9
18:00	82	85	-4.0	-4.7	2.8
19:00	82	85	-3.9	-4.5	2.9
20:00	82	85	-3.9	-4.6	2.8
21:00	82	86	-4.0	-4.7	3.0
22:00	82	86	-3.9	-4.6	3.0
23:00	82	86	-4.0	-4.7	3.1

Table 8-8; Average hourly internal relative humidity comparison for the month of June

It can be observed that the AHIRH is consistently higher in the control room, with maximum difference of 4.1% at 2:00pm, while minimum difference is 3.9%. As the temperature was consistently higher in the experimental room this is to be expected. Also, the standard deviation of these values ranges from 2.6% to 3.1%, which suggests these values are not broadly distributed from the mean. It can be inferred that the AHIRH are not significantly different across the control and experimental rooms for this month.

Month of August

Table 8-9, compares the Average hourly internal relative humidity(AHIRH) in both rooms for the month of August.

Time	Average hourly internal relative humidity Experimental Room 1 (°C)	Average hourly internal relative humidity Control Room 10 (°C)	Average of the Difference (Experimental - Control)	% Average of the difference in relation to Control room	STD DEV of the Difference (Experimental - Control)
00:00	82	86	-3.8	-4.4	-3.0
01:00	82	86	-3.7	-4.4	3.1
02:00	82	86	-3.9	-4.6	3.0
03:00	82	86	-3.8	-4.4	2.9
04:00	82	86	-3.8	-4.4	2.9
05:00	82	86	-3.7	-4.4	2.8
06:00	82	86	-3.7	-4.4	2.8
07:00	82	86	-3.7	-4.3	2.8
08:00	82	86	-3.8	-4.4	2.7
09:00	82	86	-3.8	-4.5	2.6
10:00	82	85	-3.4	-4.0	3.7
11:00	82	85	-3.3	-3.9	3.8
12:00	82	85	-3.4	-4.0	3.9
13:00	82	85	-3.5	-4.1	4.0
14:00	82	85	-3.5	-4.1	4.1
15:00	82	85	-3.4	-4.0	4.1
16:00	82	85	-3.3	-3.9	4.0
17:00	82	85	-3.4	-4.0	4.0
18:00	82	85	-3.4	-4.0	4.0
19:00	82	85	-3.3	-3.9	4.0
20:00	82	85	-3.4	-3.9	4.0
21:00	82	86	-3.8	-4.5	3.2
22:00	82	86	-3.7	-4.4	3.2
23:00	82	86	-3.8	-4.4	3.2

Table 8-9; Average hourly internal relative humidity comparison for the month of August

As was found in the month of June, it can be observed that the AHIRH is consistently higher in the Control room, with maximum difference being slightly lower value of 3.9% at 2:00am, while minimum difference is slightly higher 3.3%. The standard deviation these values range from 2.6%-4.1%, presenting a slightly wider distribution than for June. It can be inferred that the AHIRH are again not significantly different across the control and experimental rooms for this month. Hence, it can be said that the prototype did not have any effect on internal relative humidity.

Conclusion

In conclusion, it was observed that in the month of June, prior to the growth of the plants, the maximum difference in total internal gains in both rooms was 285W, maximum difference in the total solar incident radiation was also 285W. The average hourly internal air temperatures were very similar in both rooms, with maximum difference of only 0.6°C and almost always slightly higher in the experimental room than in the control room.

However, in the month of August (after the full growth of the prototypes) it was observed that internal gains remained the same, there was a general reduction in total incident solar radiation, with maximum difference of 319.7W. Despite these similar conditions in gains, the internal air temperatures were less similar between the two rooms, with average differences increasing to around -2.6°C with temperatures always higher in the control room than those found in the experimental room. Hence, it can be concluded that the fully-grown plants in the VGS does have an effect in the reduction of the inside air temperature in this climate by a maximum of 2.6°C.

Pertaining to its impact on the AHIA within the adaptive thermal comfort range, for the month of June, it was observed that the AHIA in both rooms were within the Adaptive Thermal Comfort (ATC) range of 23.3°C to 29.3°C for 87%-100% of the time, while the AHIA for the month of August for the Control room is less within the ATC range of 23.3°C to 29.3°C between 23%-45% and that of the experimental room within the ATC range 90%-100%.

Pertaining to its impact on the thermal comfort vote within the experimental room, it can also be concluded that the impact of the VGS on AHIA influenced the percentage of occupants' comfort vote the most in the morning where 75% of occupants were uncomfortable in June reducing to 50% being uncomfortable in August; while in the evening period the 50% of the occupants in the experimental room were uncomfortable in June reducing to 25% being uncomfortable in August.

Chapter 9: Perception survey and general discussion

The purpose of this Chapter is to synthesize the main findings within a coherent context whilst highlighting the unique contributions especially of Chapter 4, 5, 6, 7 and 8, towards the fulfilment of the overall objectives of the study. Worthy to note is that, the attitudes and perception of the occupants and community members within the vicinity of the Case Study houses towards the developed prototypes are central to this discussion. This is in response to achievement of objective IV, '*To establish the potential limitations of application of VGS, including investigation of user awareness and acceptability level among low income groups*', as the impact on indoor air temperature was established in Chapter 8. The evaluation of communities' perception and attitudes took place between August 1st and August 30th, 2014.

9.1 Community perception interview schedule

The interview schedule was designed to be very short and direct[60], due to the literacy and sampling challenges associated with approaching the low-income groups as described in Chapter 4[61]. Their responses were transcribed by the researcher during the interviews. This included interpreting the responses that were translated from the local Yoruba language (in which the researcher was fluent) into English.

Importantly, apart from focus groups, which did not exceed 4 participants at any given time, interviews with the participants were conducted independently from each other. Although, it was encouraged that each participant within the focus groups expressed their opinion independently, the probability of them being influenced in response by each other may not have been eliminated (Fontana and Frey,1991).

9.1.1 Method description

The method of data collection was the semi-structured interview, including questions pertaining to the following demographic factors:

- Age
- Gender
- Income levels
- Educational qualifications

[60] Detailed interview schedule is attached in the appendix C
[61] Particularly wariness towards strangers

While the three major themes addressed by the interview schedule includes:

- **'Awareness'** of the existence of VGS prior to interview, asked in the form of:
    - *Have you heard about wall gardens?*
      In order to document the level of their knowledge they might have of these systems prior to this project.
    - *Please tell me your opinion of this wall garden*?
      To document their perception of this prototype.
    - *If I told you they offer cooling, will your opinion remain the same?*
      To ascertain whether prior negative perceptions towards the prototypes might change.
    - *Would you be interested in producing vegetables with them?*
      To establish if there is further opportunity for research work pertaining to developing vertical farming and to determine if the VGS will be more successful as a Vertical farm than a passive cooling prototype.
- **'Acceptability', 'opinions' and 'concerns'** about the prototypes, asked in the form of:
    - *Are you comfortable with them mounted on the wall of your house if they can offer cooling?*
      To determine whether there were any objections towards erecting the systems in their own residences
    - *Please, what are your concerns about these prototypes?*
      To document all negative concerns towards the prototypes
- **'Recommendations'** and any other information

Location and Sampling method

Reiterating, data collection was through surveys undertaken in the form of semi-structured interviews, first with the occupants in the Case Study Houses themselves and then with other available / co-operative community members within the vicinity (approximately 1000m). A total of 135 people was interviewed within the area illustrated in figure 9.1.

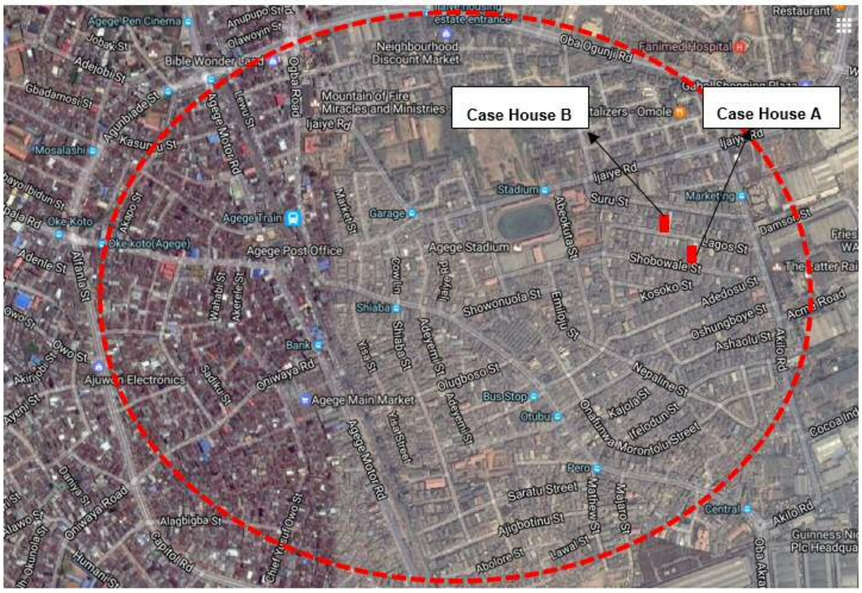


Figure 9-1; Vicinity of Case Houses for conducting attitudes survey

As observed, the Case Study Houses are not at the centre of the vicinity plotted above. This is because the other locations at the other side are social centres, a stadium and churches. Hence, probability of approaching community members in these locations was less likely.

Apart from the other occupants in the Case Study Houses, the selection of participants for interviews was through a combination of random and snowball sampling, approaching people, with the aid of a well-known community member, who helped identify the most likely areas to be co-operative within the community. Those who cooperated were then interviewed. Due to the impracticality of relocating all respondents to the sites of the prototypes, images of the successful HDPE prototypes (as photographed by the researcher) formed the basis of the interviews for those who could not visit the sites of the prototypes.

Locations	Interview type	Location of participants	Interview location	Number of participants
Site of prototypes	Individual	Occupants of Case Study Houses	Site of prototypes	**85**
Site of prototypes	Focus Groups (4 people in each)	Living on the same street of the project site	24 at Site of prototypes	**24**
Total number of respondents interviewed on site, 109				
Agege market			Through images	**8**
Agege school of carpentry /carpentry workshop			Through images	**7**
Ajuwon electronics workshop		Residing within 1000m radius of the Case Study Houses	Through images	**5**
Neighborhood discount market	Individual (Using Images)		Through images	**3**
Mama put catering services			Through images	**3**
Total number of respondents interviewed by images, 26				
				Total: 135

Table 9-1; interview and interviewee details

9.1.2 Result presentation

Certain response types were seen to be recurrent when analyzing the interviews, thus, recurrent responses were classified under appropriate 'types of responses', (verbatim responses are documented and presented in Appendix C). These findings are presented either through pie charts, tables and figures to illustrate the percentage and total number of participants under each response type. Where appropriate, tables detailing the percentage of participants who were either interviewed at the site of the prototypes or by the images are further analyzed.

Theme 1: Attitudes of the community towards the developed prototypes	Theme 2: Costing and affordability of the developed prototypes	Theme 3: Impact on occupant's comfort
• Subtheme 1: Previous awareness of prototypes • Subtheme 2: Attitude to prototypes being installed in residences • Subtheme 3: General appearance and aesthetic perception • Subtheme 4: Concerns by community participants • Subtheme 5: Initial opinion shift towards prototypes	• Subtheme 1: Perception of prototypes cost • Subtheme 2: Perception of prototypes maintenance • Subtheme 3: Perception of prototypes as a potential for vertical farming and income augmentation.	• Subtheme 1: Perception of Prototype's cooling potential

Figure 9-2; Themes and Subthemes

9.2 Demographic details

The demographic details of participants interviewed (which includes the occupants in the Case Study Houses, vicinity and selected areas) are discussed below;

- **Age-group of respondents**

The age-group of respondents interviewed is illustrated below:

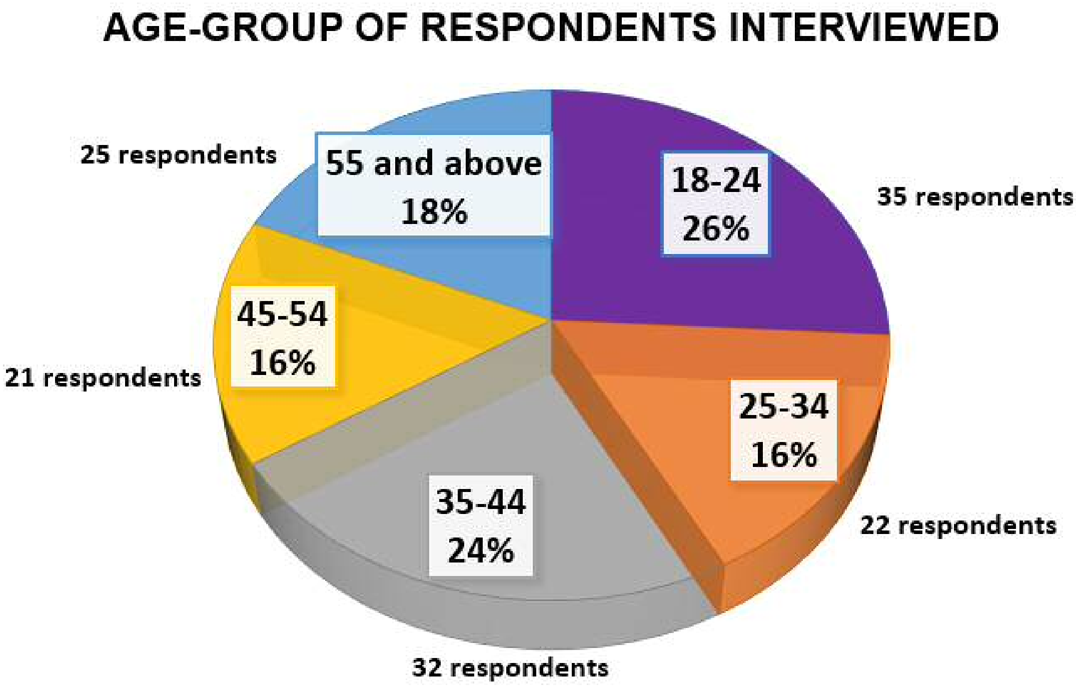


Figure 9-3; Age-group of respondents interviewed

As observed, the highest number of people interviewed was within the 18-24 age bracket (35 respondents), which was due to their willingness and availability, while the least number of people interviewed was within the 45-54 age bracket. However, at every opportunity, conscious effort was taken to ensure that every age-group was included in the sample.

- **Gender**

44% (60) of the respondents were female, while 56% (75) were men.

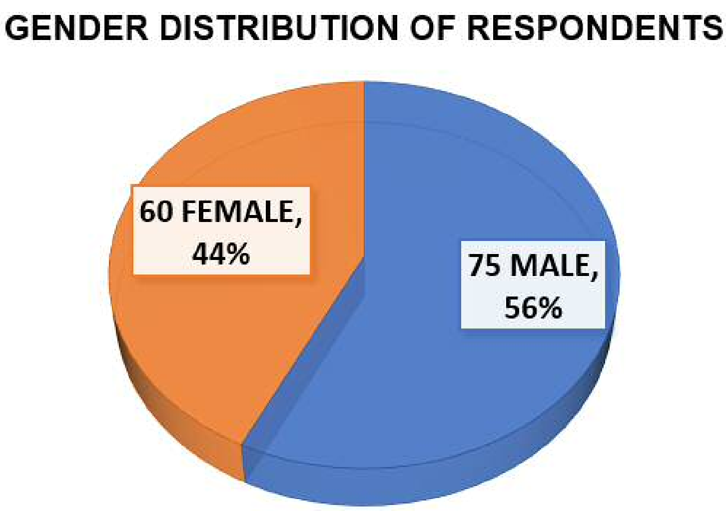


Figure 9-4; Gender distribution of Participants

There were attempts to ensure that both genders were interviewed in equal numbers, however, the male gender was seen to be more willing to express their opinions than the women, leading to a slightly higher proportion of male respondents. This was affected by the fact that the interpreter that escorted the researcher while approaching community members, was well known by men in this community.

- **Education level/ Qualification**

This information was important to document to compare the attitudes towards VGS against educational levels. This was to gauge literacy / qualification levels to confirm / refute prior studies on the literacy levels of low-income groups.

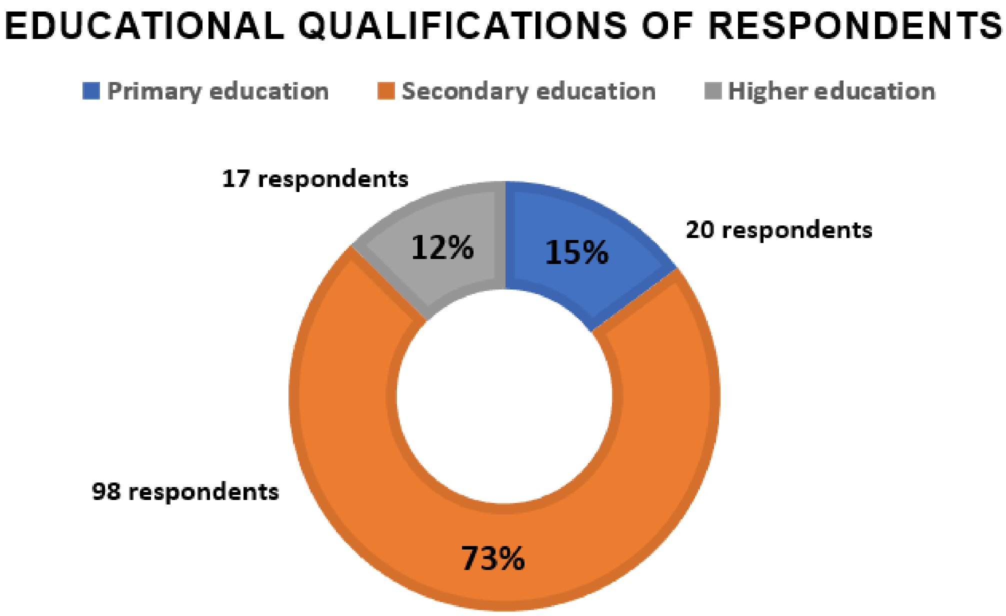


Figure 9-5; Educational Qualification of Participants

73% (98) of them had a secondary school education, which were the highest number of respondents. Further confirming prior studies of low income groups by Akinmoladun and Oluwoye (2007); Aluko (2012) and Lawanson (2012) as well as the UNCHS (2014) that the majority of low income groups in Lagos, Nigeria were qualified with a secondary school education. 15 % (20) of them had a primary school education with only 12%(17) respondents had a higher education (which on further questioning was confirmed as Ordinary National Diploma, which is usually awarded in technical institutes).

- **Occupations**

The occupations of the respondents are presented below;

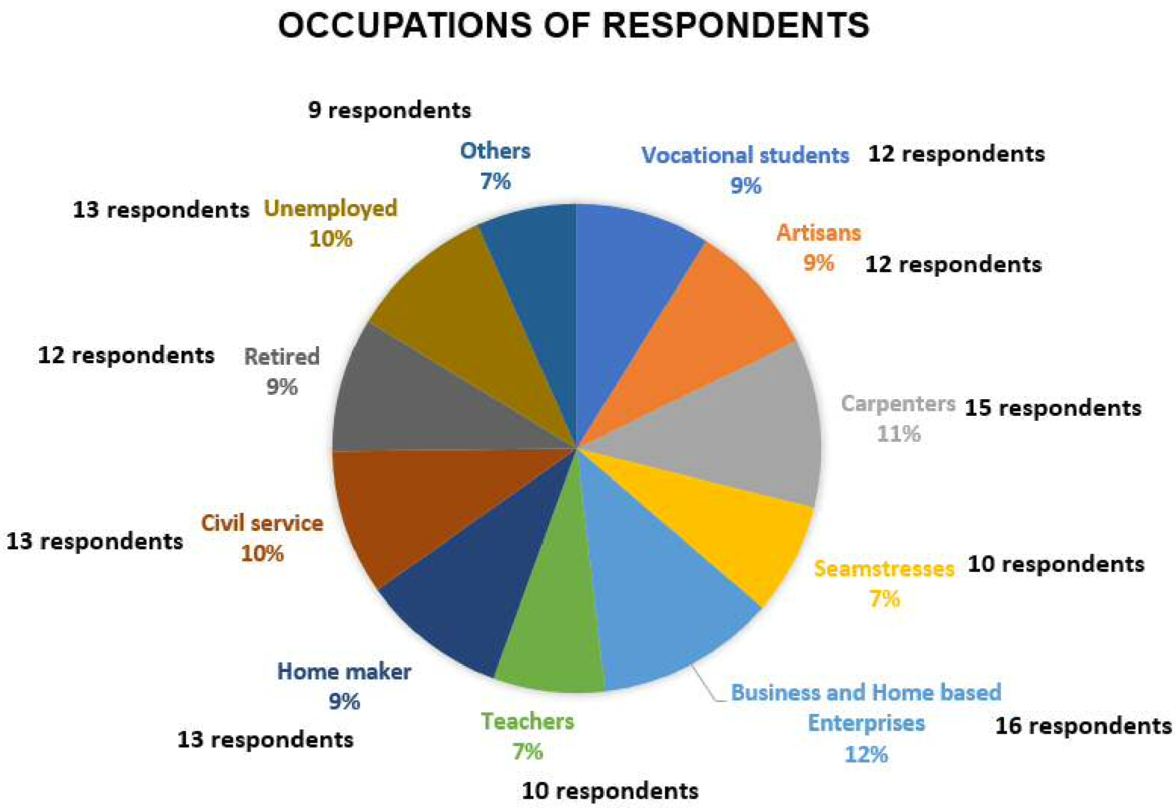


Figure 9-6; Occupations of Participants

The most frequent occupation was stated as Business and Home-based enterprise by 12% (16) of the respondents. This corroborates the study by Lawanson et al (2012) on Home based enterprises and its frequency among low income groups in Lagos. Further questioning revealed that income was usually inconsistent and limited to an average of £70 (N17,500) a month as indicated in the typical responses below:

'I don't have a choice than to do business (sell drinking water) as there are no jobs. Luckily, I don't need to pay for a shop, although I make only N2000 (£5) a day', (Participant 24, Business owner)

'The money is very small, but it is better than nothing', (Participant 55, Home based Enterprise)

The next frequent occupation was listed as carpenters by 11% (15) of the respondents. 13 respondents (10%) were listed as unemployed, civil service and home makers. 9% (12) respondents were listed as vocational students, artisans and retired. 7%(10) respondents were listed as seamstresses and 7% (9) respondents were listed as "other", which might suggest a desire for anonymity, perhaps due to either being unemployed or employed in jobs they preferred to remain undisclosed.

The next sections discuss the themes addressed during the interviews

9.3 Theme 1: Attitudes of the community towards the developed prototypes

Under this theme, which relates to their general perceptions and feelings towards the prototypes, the sub themes discussed include;

- Previous awareness of prototypes
- Attitude to prototypes being installed in residences
- General appearance and aesthetic perception
- Concerns by community participants
- Opinion shift by undecided/disinterested respondents towards prototypes being installed in residences

9.3.1 Previous awareness of prototypes

In Chapter 1, it was revealed that academic studies of Vertical Greening Systems as a means of thermal enhancement had not been previously documented in western Africa. This presented an opportunity to ascertain whether the community in which the study took place had any prior knowledge. Noteworthy is that during the process of recruiting the Agege community, the purpose of the study was communicated. However, the official documentation on previous awareness of VGS took place after the prototypes were developed. It was especially important to document this among community members who did not participate in the construction of the prototypes. The responses are discussed below.

30% (41) of the total 135 respondents questioned had heard about VGS, while, 70% (95) of had never heard of VGS. Further analysis based on the 41 respondents who had previously heard of these systems, as garnered through supplementary questions during the interviews is presented in table 9-2.

Type of responses	All Respondents	Interviewed on Site	Interviewed with Images
Yes, in rural areas	12	8	4
Yes - on the internet	18	13	5
Yes, in reality - on a fence	11	6	5
Total	**41**	**27**	**14**

Table 9-2; Number of respondents previously aware of VGS and method of interview

As observed, 27 of the respondents were interviewed on site while 14 were interviewed through images. Figure 9-7 analyzes this based on percentage of response in relation to the method of interview (which is the total number of respondent’s type of response divided by the total number of respondents under the method of interview)

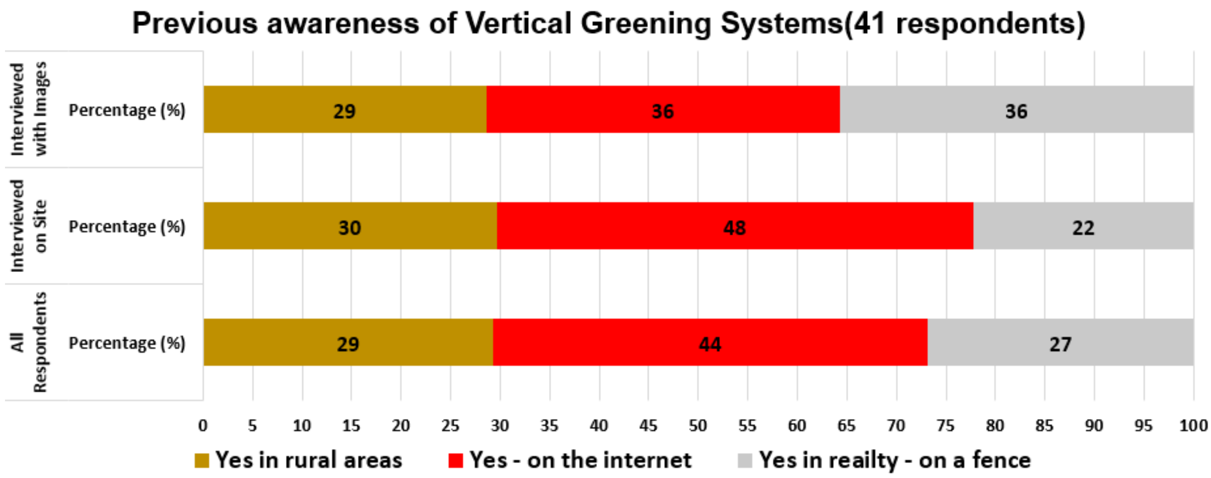


Figure 9-7; Details of respondent's awareness of VGS

It was revealed that a higher percentage of respondents interviewed at the site of the prototypes (30%, 8) affirmed that they had seen a few in rural areas albeit in passing and had seen similar images on the internet (48%, 13). A higher percentage of respondents (36%, 5) interviewed by images confirmed that they had seen some on fences incorporated for aesthetics (in reality). Thus, based on the answers they provided one could infer they had not heard about VGS as a system that is integrated into the building environment with the intention of modifying the internal or external thermal environment. Hence, previous knowledge on VGS as a means of enhancing thermal comfort was not confirmed.

9.3.2 Attitude to prototypes being installed in residences

This was asked in the form of *'Are you comfortable with them being mounted on your house?'*. All respondents (135) answered this question with (60%, 81 respondents) of them stating that they were comfortable with them being assembled on their houses, (24%, 32 respondents) said no, while (16%, 22 respondents) were undecided.

Type of responses	All Respondents	Interviewed on Site	Interviewed with Images
Yes	81	50	31
No	22	10	12
Undecided	32	16	16
Total	**135**	**76**	**59**

Table 9-3; Number of respondent's attitude to prototypes installation and method of interview

As observed, 76 of these respondents were interviewed on site while 59 were interviewed through images. Figure 9-8 analyzes this based on percentage of response in relation to the method of interview

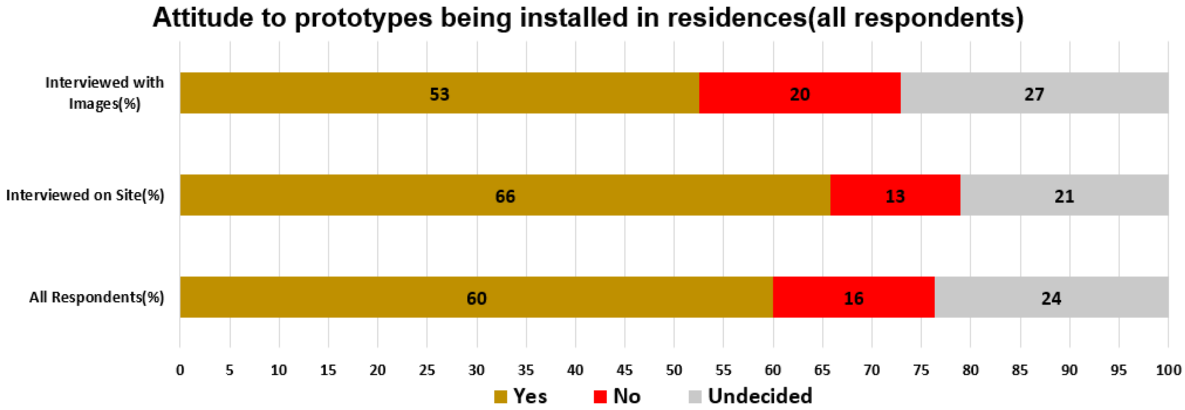


Figure 9-8; Details of respondent's comfortability with prototypes assembled on residences

For those interviewed at the site of the prototypes (66%, 50) were comfortable with the prototypes being installed on their residences, as opposed to (53%, 31) interviewed by images. This suggests that a visual perception of the assembled prototypes might have influenced their responses. More respondents interviewed via images (47%, 28) were inclined to responses of 'No' and 'Undecided'. Again, this suggests that the images alone may not have presented a realistic/ convincing picture of the prototypes being installed in their residences, as opposed to those who could physically view the prototypes in the Case Study Houses.

9.3.3 General appearance and aesthetic perception

A brief overview of the most visible essential elements (plant and simply adapted irrigation systems) that contributed to the overall appearance of the prototypes is undertaken, reiterating the decisions culminating in the final layout of the prototypes.

- **Plants**

As discussed previously in Chapter 6, the choice of plants was made primarily for meeting cultural and pest concerns – and not necessarily to respond to aesthetic or wider horticultural objectives

- **Simply adapted irrigation systems**

Another predominant decision that influenced the overall appearance of the prototypes was the simple irrigation systems, this system seemed to be a key factor in the overall aesthetic quality of the prototypes because it involved arranging the containers of plants vertically (as detailed in section 6.1.4.3.2).

Thus, in terms of how they were perceived in the overall innovation, especially pertaining to plant choices and irrigation method, 123 (91%) of respondents thought it was a creative/innovative project. The remaining 9%(12) respondents did not express any opinion pertaining to this aspect.

Type of responses	All Respondents	Interviewed on Site	Interviewed with Images
Positive perception of its irrigation method	61	42	19
Overall positive perception of prototypes	20	15	5
Retainment of prototypes after study	42	28	14
Total	**123**	**85**	**38**

Table 9-4; Number of respondent's attitude to prototypes innovation / creativity and method of interview

As observed, 85 of the respondents were interviewed on site while 38 were interviewed through images. Figure 9-9 analyzes this based on percentage of response in relation to the method of interview

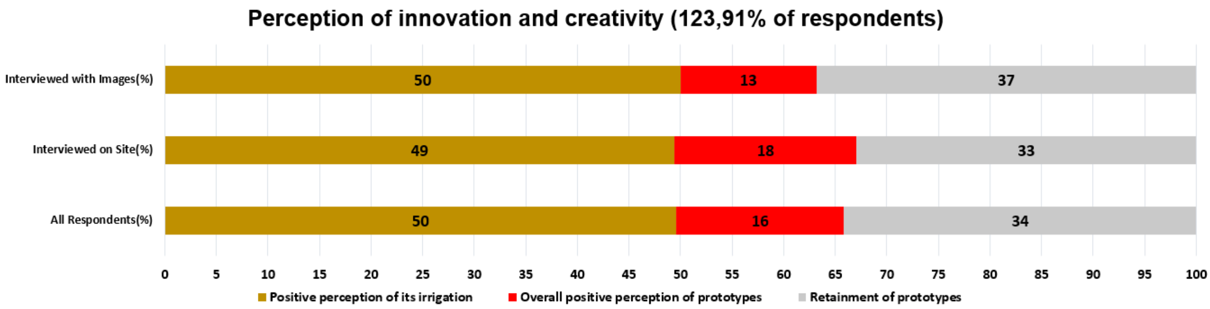


Figure 9-9; Details of typical responses pertaining to prototype's innovation and creativity

Similar percentage of respondents, regardless of the method of interview, thought it was a good idea, especially the irrigation (50%,19, for those interviewed by images and 49%,42, for those interviewed on site). Pertaining to the prototype being left on the wall after the study was completed, (retainment of prototypes after research was completed, due to its perceived creativity) surprisingly, a higher percentage of respondents interviewed with images (37%,14) were inclined to this suggestion. Their curiosity to physically examine the prototypes within the Case Study Houses may have elicited such response.

Aesthetic perception

Pertaining to aesthetic perception, all participants referred to its aesthetic quality when their opinions towards the prototypes was asked. This factor was prominent in their responses due to belief that it could improve or diminish the aesthetic quality of their residences . Table 9-5 presents the categories of typical responses created from the verbatim responses documented.

Type of responses	All Respondents	Interviewed on Site	Interviewed with Images
Dissatisfaction with overall aesthetic quality	31	22	9
Positive perception of prototypes aesthetic quality	104	66	38
Total	**135**	**88**	**47**

Table 9-5; Number of respondent's aesthetic perception of prototypes and method of interview

As observed, 104 (77%) of the respondents expressed their opinions pertaining to its positive aesthetic quality, while 31 (23%) perceived the aesthetic quality to be negative. 88 respondents were interviewed on site and 47 were interviewed by images. Figure 9-10 analyzes this based on percentage of response in relation to the method of interview

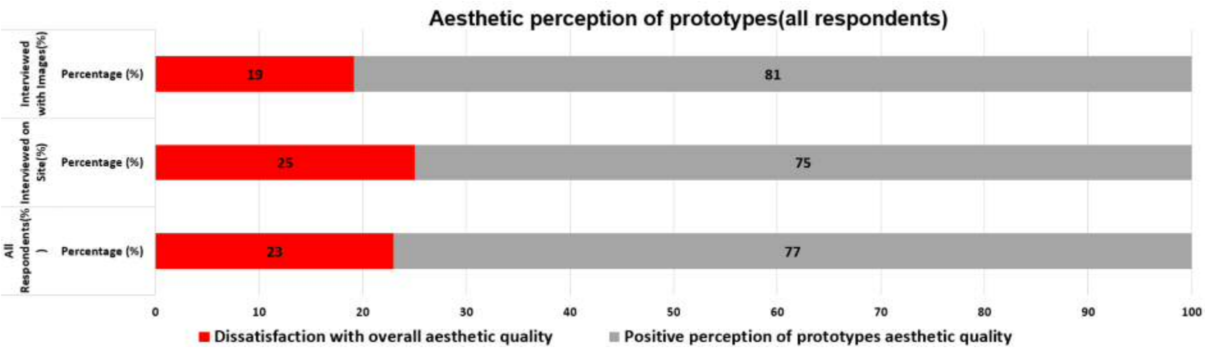


Figure 9-10; Details of typical responses pertaining to perceived aesthetic quality of prototype

A higher percentage of respondents interviewed on site (25%,22), compared to those interviewed with images (19%, 9), were dissatisfied with the overall aesthetic quality of the prototypes. This perception was likely due to the soil that stained the wall during the assembly of the prototypes, which was more noticeable on site than through the images.

However, a much higher proportion of respondents, in relation to the total number of respondents (by images: 81%, 38 & on site: 75%, 66) had a positive perception of the prototype's aesthetic quality.

More specifically, of all the occupants (8 in total) who resided in the two rooms of the Case Study House, 6(75%) of them believed that it beautified the house, while the remaining 2 (25%) believed it had no effect in enhancing the aesthetic quality of the house.

Thus it could be inferred that a majority of the low income group interviewed in this study believed the systems had the potenital to enhance the aesthetic quality of their houses.

9.3.4 Concerns of community participants

As briefly discussed under 9.3.2, pertaining to attitudes to prototypes being installed in houses, it was revealed that some respondents (total of 54, 30%)) were either uninterested or undecided due to certain concerns. These are discussed below:

9.3.4.1 Propensity of prototypes to attract pests

The need to avoid pests was a major factor in the choice of plants, however, despite the careful considerations by the researcher and recruited skillsets in ensuring that plants selected were insect / pest repellant, this did little to assuage their perceptions of the prototypes as a magnet for pests, as it was brought up by 90% (122) of the respondents. The remaining 10% (13) respondents didn't mention this. Table 9-6 presents the categories of typical responses created from the verbatim responses documented.

Type of responses	All Respondents	Interviewed on Site	Interviewed with Images
Concerns about reptiles	90	49	41
Concerns about insects	32	23	9
Total	122	72	50

Table 9-6; Number of respondent's Concern of prototypes and method of interview

Figure 9-11 presents the analysis of this factor in terms of percentage of response in relation to the method of interview.

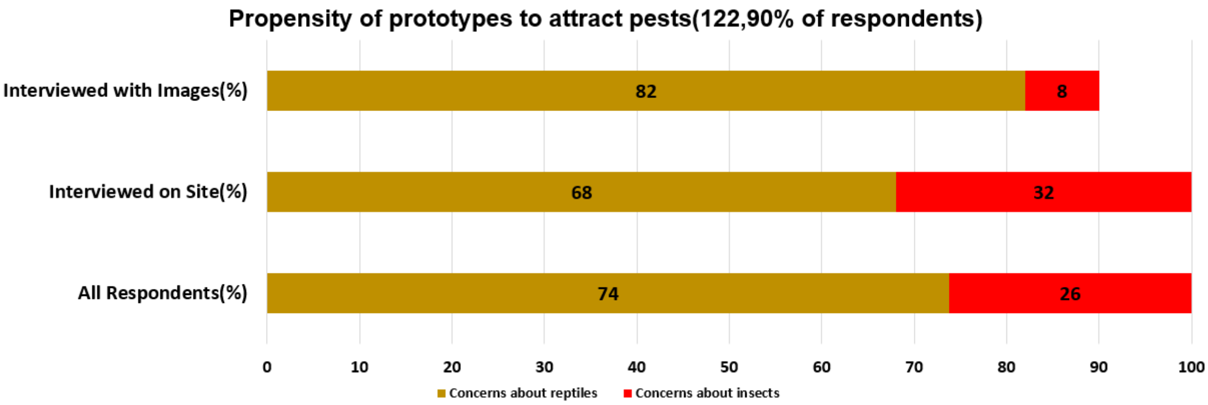


Figure 9-11; Details of typical responses pertaining to Concerns about pests

A higher percentage of respondents interviewed by images (82%,41 compared to 68%, 49 on site) associated the prototypes with its propensity to attract reptiles. This was likely due to their unawareness that the plants selected within the prototypes were snake repelling, unlike those who were opportuned to physically observe the plants selected at the site.

Pertaining to the prototypes attracting insects such as bees, a higher percentage of respondents interviewed at the site of the prototypes(32%,23 compared to 8%,9 via images), believed it will attract unwanted or even dangerous insects, especially in the future.

More specifically, all the 8 occupants residing in the Case Study House (the rooms used for the experiments), confirmed that there were no sightings of pests/ insects throughout the research period.

9.3.4.2 Likelihood of landlord approval

Another major concern was the issue of house ownership. Reiterating, the financial characteristics of low income groups discussed in Chapter 3, it was confirmed that, the majority of low-income groups could only afford to rent their houses. This was also confirmed by the researcher during the field work. Consequently, this influenced their responses as it was believed that accepting the idea of prototypes being installed in their residences would be dependent on the approval of the landlords. Hence, 95 (70%) of all the respondents (64%,61 respondents on site compared with 36%, 34 respondents interviewed via images) stated this as a concern, while the remaining 30%(40) didn't express this as a concern. Table 9-7 presents the category of typical response created from the verbatim responses documented.

Type of responses	All Respondents	Interviewed on Site	Interviewed with Images
Concern with landlord approval	95	61	34

Table 9-7; Number of respondent's Concern of landlord approval and method of interview

As documented in Chapter 5, all occupants within the two Case Study Houses rented the rooms, thus, permission had to be obtained from both landlords. This obviously facilitated the use of both houses for the study. Hence It can be inferred that landlords/ Case workers could influence low-income groups attitude towards the prototypes.

9.3.5 Opinion shift by undecided/uninterested respondents towards prototypes being installed in residences

As discussed in section 9.3.2, 55(41%) of all respondents interviewed respondents were either uninterested or undecided in being comfortable with the prototypes being installed in their residences. Hence, further questioning on their opinions, was undertaken to ascertain whether these would change, when they were informed that the systems could reduce indoor temperature in their houses and reduce electricity demands, revealed that their opinions remained unchanged by 55% (30), of the respondents (replied as 'No'). While 27%(15) respondents revealed that the initial negative perceptions towards the VGS will change if it reduces indoor temperature (replied as 'Yes'). 18% (10) respondents were still 'undecided'. Worthy to note is that (55%, 30) of the respondents whose perceptions did not change were those who were interviewed with the image of the VGS as its basis. All the respondents whose opinions changed were those who resided in either of the Case Study Houses and experienced its effects. In other words, physically experiencing the effect of the system could be a basis of its acceptability among the low-income groups.

9.4 Theme 2: Costing/ affordability of the developed prototypes

In Chapter 3, the income and consumption characteristics of low-income groups was discussed, leading to a conclusion on how affordable the prototypes might be either per household or for an individual.

With the two prototypes developed, when participants were interviewed, three aspects pertaining to costing emerged. The first one being associated with the overall cost of assembling the prototypes (capital cost), the second aspect being the general maintenance effort and cost (Revenue cost) and the third being associated with the potential to double as a Vertical farm (Potential to augment income). Details of these are presented below:

9.4.1 Perception of prototype's cost

Table 9-8 presents the categories of typical response created from the verbatim responses documented.

Type of responses	All Respondents	Interviewed on Site	Interviewed with images
Perception of prototypes as expensive	135	65(48%)	70(51%)

Table 9-8; Number of respondent's perception of prototype cost and method of interview

A relatively equal percentage of respondents (48%,65 interviewed on site, compared with 51%,70 interviewed by images), regardless of the interview method believed it was still expensive and unaffordable.

Reiterating, the average monthly income of these group is approximately £72 (N18,000). Bearing this in mind, the final cost of the HDPE prototype was N67,928 (£271.70), which is £201.70 (50,425) more than their monthly income. For the final cost of the bamboo wood prototype which was N17,788 (£71.1), this is approximately the average income of the low income group, thus the perception of the prototypes as unaffordable.

Alternatively, dividing the total cost of the prototypes per household (4 in each room) might be reasonably realistic as oppossed to a single individual. This will equate to N17,490(£68) per person for the HDPE prototype and approximately N4,500(£18) per person for the bamboo wood prototype. However, this is still relatively expensive.

Another alternative scenario is if they are utilized as a vertical farm by all occupants within the house, then the overall cost of the prototypes could be divided by all 42 occupants in the Case Study House, this goes down to N1,617(£6) per person for the HDPE prototype and N423 (£1.69) per person for the bamboo wood prototype. Thus, a shared cost among the occupants could improve its affordability.

9.4.2 Perception of maintenance

The issue of maintenance of the prototypes both in terms of effort and revenue costing was brought up by all respondents during the interviews. Table 9-9 presents the categories of typical response created from the verbatim responses documented.

Type of responses	All Respondents	Interviewed on Site	Interviewed with Images
Perception of significant amount of efforts to maintain prototypes	135	86	49
Total	**135**	**86**	**49**

Table 9-9; Number of respondent's perception of maintenance and method of interview

A higher percentage of respondents interviewed on site (64%,86), compared with those interviewed by images (36%,49) interviewed via images believed it would require significant financial and physical effort to maintain the prototypes.

As discussed in Chapter 6, water was not readily available to sprinkle the plants, hence it needed to be purchased. Also, the amount of water estimated by the horticulturist to water each prototype was two, 50 litre keg of water every 2 days, with each keg of water costing N50(0.20p). Hence the average monthly cost was estimated as £6 (N1500). This might be perceived as expensive by the average low-income earner, depending on the interest in the prototypes. Other perceptions relating to maintenance were the effort and time required, however, within the Case Study House, the Case worker volunteered to maintain the prototypes and watering was financed by the researcher. Hence, the typical response of occupants within the two rooms responses pertaining to maintenance was:

'It doesn't cost a lot to maintain them, I only need reminder to water them as I could easily forget'.

9.4.3 Perception of prototypes as providing potential for Vertical farming and income augmentation

The potential cost implication of the prototype as a vertical farm for each occupant within the Case Study House was briefly discussed in section 9.4.1. Participants were asked if they would be interested in producing vegetables with the prototypes. Although, this question does not assess the impact of VGS on occupant's thermal comfort, this was included in the interview schedule to determine whether the VGS could also be successful as a vertical farm. 75% (101) respondents were interested in producing vegetables with the prototype, 25% (34) were undecided. This suggests an opportunity for further research on affordable prototypes solely for farming purposes. Table 9-10 presents the categories of typical response created from the verbatim responses documented.

Type of responses	All Respondents	Interviewed on Site	Interviewed with Images
Interest in using prototypes to produce fresh vegetables	101	56	45

Table 9-10; Number of respondent's perception of prototypes vertical farming potential and method of interview

A higher percentage of respondents interviewed on site (55%,56), compared with (45%,45) interviewed via images generally believed that the prototypes were important for provision of fresh vegetables. More specifically, all occupants in the Case Study House were interested in its ability to provide fresh vegetables, which they witnessed firsthand.

This provides opportunity for further study on potential turn over and growth rates of each edible/ medicinal plants in affordable VGS.[62]

[62] An Engineering and Physical Sciences Research Council grant has since been awarded to develop affordable Vertical Farms.

9.5 Theme 3: The Impact of the prototypes on indoor comfort

The Impact of VGS on occupant's comfort was established in Chapter 8. This theme discusses its impact on respondent's perception pertaining to its cooling potential (especially the occupants within the Case Study House). Its impact on external air temperature and its social implications among the occupants of the Case Study House is presented in this section.

9.5.1 Perception of Prototypes cooling potential

It was concluded that the fully-grown plants in the VGS had an effect in the reduction of the average hourly internal air temperature by a maximum of 2.6°C. Reiterating its impact on the comfort vote within the experimental room, it was concluded that the impact of the VGS on Average Hourly Internal Air temperature increased the percentage of occupants' comfort vote mostly in the morning and evening by around 25%.

When asked about their opinions on the cooling potential of the prototypes, 74 (55%) of respondents provided positive responses, while skeptical reactions were documented by the remaining 61(45%) respondents. Table 9-11 presents the categories of typical responses created from the verbatim responses documented.

Type of responses	All Respondents	Interviewed on Site	Interviewed with Images
Skepticism on prototype's cooling potential	61	37	24
Interest in prototypes due to its cooling potential	74	32	42
Total	**135**	**69**	**66**

Table 9-11; Number of respondent's perception of prototypes cooling potential and method of interview

Details based on the respondent's method of interviews are illustrated below;

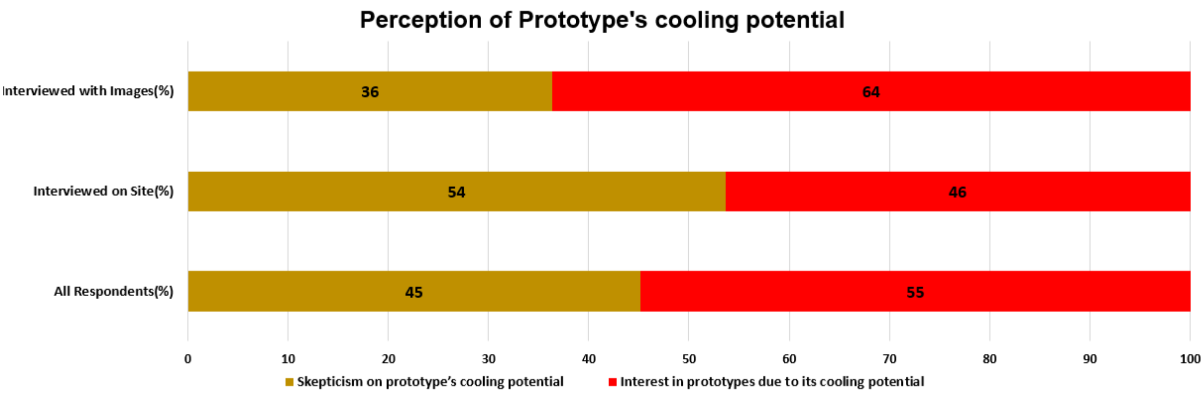


Figure 9-12; Details of typical responses on prototypes cooling potential

A higher percentage of respondents interviewed on site (54%, 37 compared with those interviewed by images, 36%,24) believed the prototypes cooling potential was irrelevant.

Higher percentage of respondents interviewed via images (64%,42) were interested in the prototypes due to its cooling potential, versus those interviewed on the site (46%,32).

More specifically, for the occupants within the experimental room of the Case Study House, who experienced the effect of the prototypes, 3(75%) respondents affirmed its impact as summarized below

'I definitely felt a bit of improvement'

The 4th respondent however felt he needed more time to gauge its effect in its entirety.

9.5.2 External air temperature and social impact

Although this aspect was not included in the interview schedule, during the interviews, all occupants in the Case Study House affirmed that the location of VGS gradually became a place for social gatherings and relaxation especially during periods when the indoor temperature was too high. The improvement of the microclimate encouraged people to migrate to its location, subsequently improving social activities within the case house. Verbatim responses included:

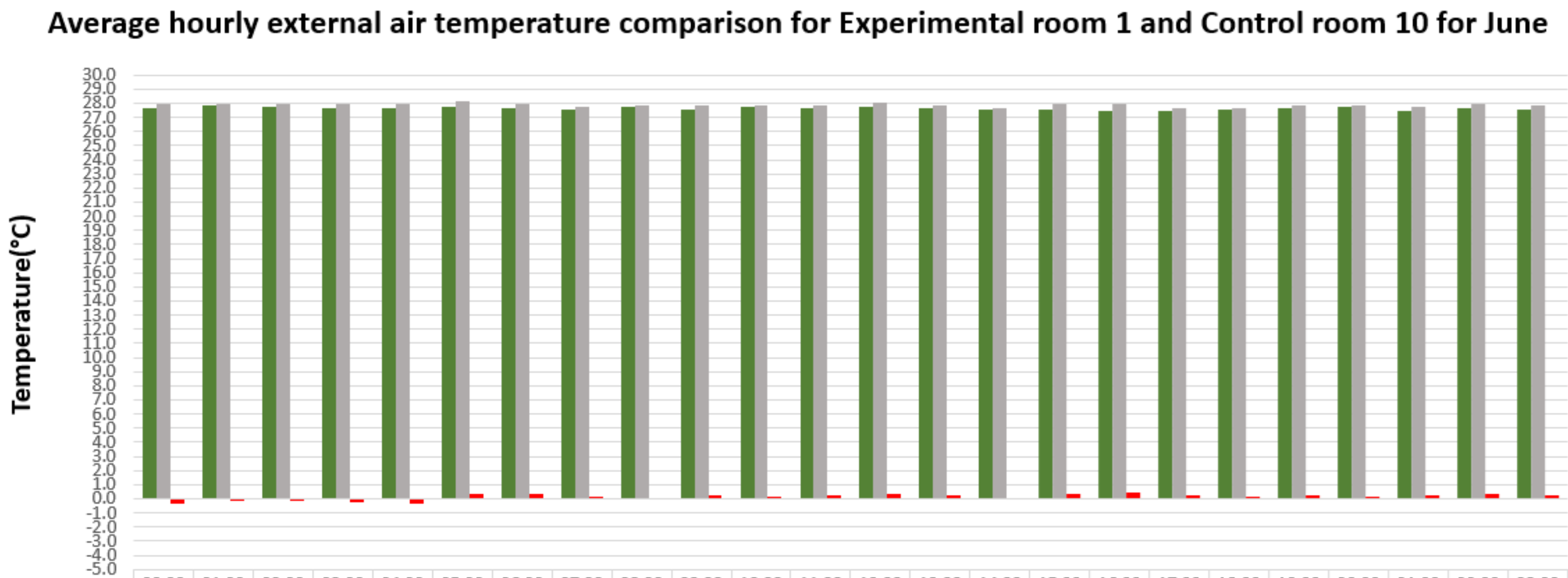
Verbatim reponses by all occupants in Case Study House A	Total number of participants	
	Number	Percentage (%)
'I come here to cope with the heat indoors, it is very relaxing for me'	12	29
'We gather here on weekends to relax'	12	29
'I think if colorful flowers were planted it will be attractive to host small gatherings'	16	38
'We used the place to celebrate my Son's birthday, the pictures came out beautifully	2	4
	Total 42	100%

Table 9-12; Details of responses by Case Study House occupants on impact on social activities

Thus, this informs the analysis to ascertain the impact of the prototypes on external air temperature. This was measured at 1m away from the control room wall and approximately 700mm (when considering the width of the HDPE prototype) from the experimental room.

Average hourly external air temperature for the month of June

Prior to establishing the impact of the prototypes on indoor air temperature, maximum exposure to solar incident radiation for the month of June occurred at 5:00pm (3427.7W for the control room and 3712.7W for the experimental room, otherwise, there were no significant differences in the total solar incident radiation received on both walls.



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AVG hourly external air temperatures Experimental Room 1 (°C)	27.7	27.8	27.7	27.7	27.6	27.8	27.6	27.6	27.8	27.6	27.7	27.6	27.8	27.6	27.5	27.6	27.5	27.4	27.6	27.7	27.7	27.5	27.6	27.5
AVG hourly external air temperatures Control Room 10 (°C)	28.0	28.0	27.9	27.9	27.9	28.2	28.0	27.7	27.8	27.9	27.9	27.9	28.1	27.9	27.6	27.9	27.9	27.7	27.7	27.9	27.8	27.8	28.0	27.8
AVG of the Difference (Experimental - Control)	-0.3 °C	-0.1 °C	-0.2 °C	-0.3 °C	-0.3 °C	0.4 °C	0.3 °C	0.1 °C	0.1 °C	0.3 °C	0.2 °C	0.2 °C	0.3 °C	0.3 °C	0.1 °C	0.3 °C	0.4 °C	0.2 °C	0.1 °C	0.2 °C	0.1 °C	0.3 °C	0.3 °C	0.3 °C

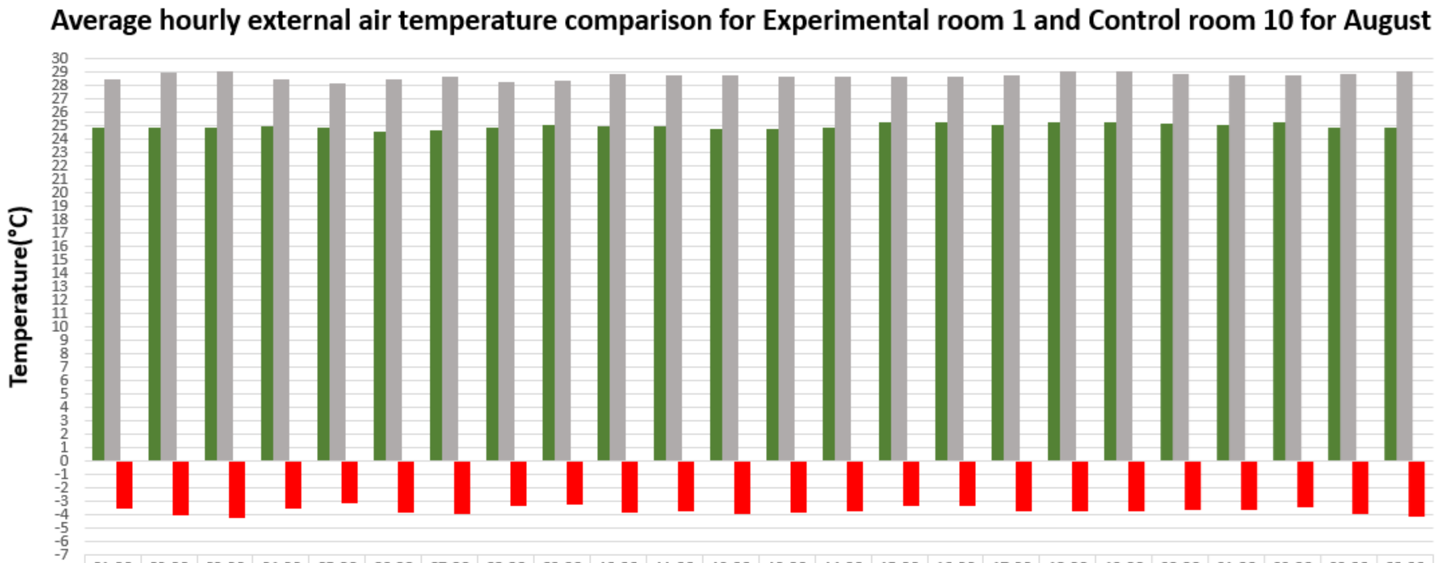
AVG hourly external air temperatures Experimental Room 1 (°C) AVG hourly external air temperatures Control Room 10 (°C) AVG of the Difference (Experimental - Control)

Figure 9-13; Average hourly external air temperature comparison for the month of June

As observed, the AEHA values in the control room were slightly higher than that of the experimental room, with maximum difference occurring at 5:00am, 0.4°C (standard deviation 1.0°C and minimum difference of 0.1°C.

Average hourly external air temperature for the month of August

This was the period when the plants within the prototypes were fully developed in front of the experimental wall. The impact on AHEA is illustrated in figure 9-16



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AVG hourly external air temperatures Experimental Room 1 (°C)	24.8	24.8	24.8	24.9	24.8	24.5	24.6	24.8	25	24.9	24.9	24.7	24.7	24.8	25.2	25.2	25	25.2	25.2	25.1	25	25.2	24.8	24.8
AVG hourly external air temperatures Control Room 10 (°C)	28.4	28.9	29	28.4	28.1	28.4	28.6	28.2	28.3	28.8	28.7	28.7	28.6	28.6	28.6	28.6	28.7	29	29	28.8	28.7	28.7	28.8	29
AVG of the Difference (Experimental - Control)	-3.6 °C	-4.1 °C	-4.3 °C	-3.6 °C	-3.2 °C	-3.9 °C	-4.0 °C	-3.4 °C	-3.3 °C	-3.9 °C	-3.8 °C	-4.0 °C	-3.9 °C	-3.8 °C	-3.4 °C	-3.4 °C	-3.8 °C	-3.8 °C	-3.8 °C	-3.7 °C	-3.7 °C	-3.5 °C	-4.0 °C	-4.2 °C

Figure 9-14; Average hourly external air temperature comparison for the month of August

Reiterating that the total solar incident radiation patterns were similar in the month of August, the impact of this observation on the AHEA in front of the experimental wall reveals that it is consistently lower than the Control room, with maximum difference occurring at 3:00am (4.3°C, standard deviation 1.3°C), minimum difference occurring at 5:00am (3.2°C, standard deviation 1.1°C) and average difference of (3.8°C, standard deviation 1.1°C)

Thus, while it could be inferred that the VGS has had some impact on external air temperature, other factors such as overshading or wind movement may have influenced these results, Consequently, this provides an opportunity for further detailed study on the likely mechanisms for impact on air temperature. This result presented here is therefore not definitive: meaning that a correlation between a reduction in external air temperature and the presence of the VGS has been found, while causation cannot yet be claimed.

9.6 Resulting Recommendations

The recommendations for future work as proposed by the sampled low-income groups are presented under category of responses as presented below:

- **Aesthetics (81% (109) respondents)**

Although brightly coloured flowers were not used in the systems due to its propensity to attract bees for pollination, which was another major concern by the respondents, this provides a route for further research on brightly coloured flowers that repels insects and bees to provide a balance between aesthetics and pest control. Also, the recommendations on the need to develop a modern VGS provides another route for further research on the use of affordable materials to develop such prototypes.

- **Workshops and Seminars (33% (45) respondents)**

Another recommendation was the need to organize mini seminars educating the community on the system and its benefits, with many of them ready to recommend other members of the community for this purpose. This offers a potential means of disseminating information about these prototypes especially with the involvement of community leaders.

- **Structural integrity (45% (61) respondents)**

The issue of the effect of the weight of the system on the wall of buildings in the long run was raised during the interviews, with respondents recommending indigenous techniques for such a scenario. This included the use of hardwood for extra support for the system, to transfer the weight of the prototype away from the building. In the end, a third prototype was in the process of development which could not be completed due to time constraints during the research, thus providing an opportunity for further research on this developing prototype.

- **Affordability (100%(135) respondents)**

The recommendation on the successful implementation of this system was the need to be extremely affordable. Thus, further research on this aspect is needed.

- **Easy Maintenance (78% (105) respondents)**

The need for maintenance and the danger of uncontrollable growth of plants were recurrent concerns. However, during the observation of the prototypes in Case Study Houses, it was seen that the possibility of the system doubling as a vegetable garden might reduce the propensity for uncontrollable growth. Perhaps with the frequent consumption of the edible plants, such tendency could be reduced.

- **Mobile(movable) Vertical Greening Systems (42% (57) respondents)**

The idea of developing mobile prototypes was also raised, as opposed to assembling them directly on building walls. It was recommended based on concerns that it might affect the building structure on which it is assembled, thus providing another avenue to conduct further research.

- **Wide-spread Implementation (61% 82 respondents)**

Recommendations on the wide spread implementations beginning from community centres was also suggested as a means of reaching a wider audience across the low-income communities.

With the analysis of the attitudes and opinions of low-income groups towards the prototype, the next Chapter presents the Conclusions and recommendations for future work.

Chapter 10: Conclusions and Recommendations for future work

In response to the overarching aim of the study, *to develop and test an appropriate Vertical Greening System that improves indoor thermal comfort in low income residencies in Lagos, Nigeria, which is both economically viable and socially acceptable*, this Chapter discusses how achievable it was, as well as discussing responses to the research objectives.

Pertaining to the developing context, appropriate prototypes for low-income groups, the processes, steps and methods employed in overcoming unanticipated challenges in identifying and engaging in participatory development with the selected Agege community in developing two context appropriate functioning Vertical Greening Systems was presented in Chapter 4, 5 and 6, while the process of testing the prototypes was presented in Chapter 7 and 8. In relation to social acceptability among low-income groups, Chapter 9 presented the major findings. Thus, the purpose of this Chapter is to present the conclusions of this thesis, which includes the fulfilment of the objectives in this study under three themes,

- Context appropriate Vertical Greening Systems alternatives for low-income groups in Lagos
- Context appropriate experimental analysis of prototypes
- Community participation, project ownership and longevity

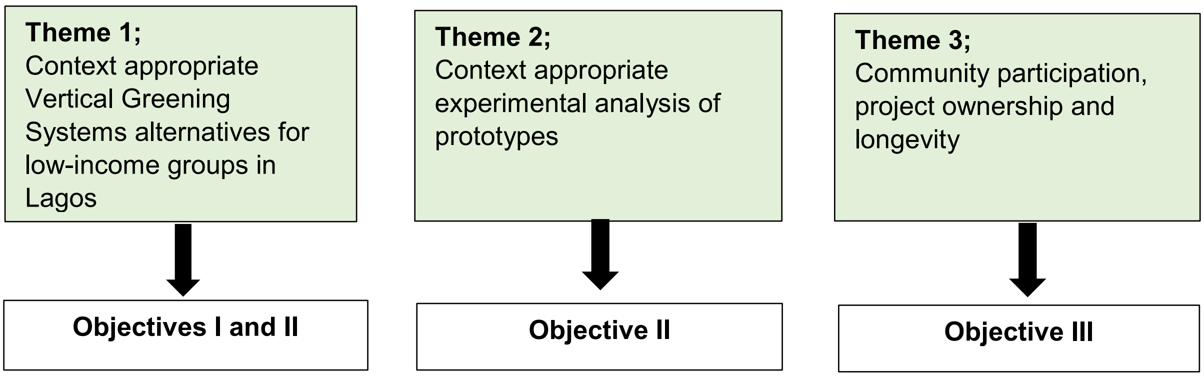

Figure 10-1; Themes and relationship with objectives

Figure 10-1 illustrates the relationship between the resulting themes and the initial objectives of the study. Further discussion includes an overview of how achievable the objectives were towards achieving the overall aim of the study. These include a discussion on the methodological approaches undertaken to achieve the multifaceted aspects of the research. Recommendations for future work is also discussed.

10.1 Context appropriate Vertical Greening Systems alternatives for low-income groups in Lagos

The VGS prototypes that were developed here responded directly to objectives I and II, which were:

I. ***To investigate the variety of Vertical Greening Systems (VGS) available and to establish the most appropriate solutions for their adaptation for use in low income houses in Lagos: including the essential elements important for the***

systems to be effective in reducing indoor air temperature and influencing occupants' indoor comfort.

II. ***To Design, Develop and Assemble a VGS system prototype, based on the views and inputs of the Low-income groups, that appropriately balance the four parameters of:***
   - ***Financial affordability***
   - ***Practicality in terms of assembly***
   - ***Maintenance***
   - ***Impact on Occupant's Thermal Comfort – Discussed under 10.2***

Prior to undertaking the participatory development with the Agege Community, as presented in Chapter 6, Chapter 3 presented an overview of VGS typologies, their components, average cost and likely performance in a tropical context. This revealed the necessary parameters and specific roles each part plays in influencing the performance of these systems; subsequently imparting indoor comfort. This literature review concluded that there was no precedent for VGS specifically designed for very low-income groups and that the living wall system was likely to be most suited for adaptation, in relation to cost, specifically due to the extra insulation provided by substrates/ growing medium. It was also established that each of the parameters identified: plants, soil/substrate, materials and construction, drainage and irrigation; must be adapted to suit the research context.

Financially affordability

Discussion on income and the consumption habit of low-income groups in this context was presented in Chapter 3. This was in response to objective II which was to develop prototypes that were financially affordable. Reiterating, the findings here, the average monthly income of these group is approximately £72 (N18,000). Bearing this in mind, the final cost of the HDPE prototype was N67,928 (£271.70), which is £201.70(50,425) more than their monthly income. For the final cost of the bamboo wood prototype which was N17,788 (£71.1), this is approximately the average income of the low income group. Noteworthy is that all respondents interviewed as documented in Chapter 9 believed the prototypes were expensive (relatively equal percentage of respondents interviewed on site of the prototypes or through images). Also, all respondents believed it required effort and financial implications to maintain the prototypes. 75% of respondents believed it had a potential for vertical farming and income augmentation.

To improve its affordability, an alternative perspective was presented, whereby the total cost might be divided across the household (typically 4 occupants in total). This might be reasonably realistic as oposed to a single individual as this equated to £68 (N16,981) per person for the HDPE prototype and approximately N4,443 (£18) per person for the bamboo wood prototype. Based on the findings in Chapter 3, where the average income of low income households was estimated at N20,000 (£80) per occupant, this study presented the total income per household as N80,000 (£177). However, this would represent 38% of their income for the HDPE prototype and 10% of their income for the bamboo wood prototypes. Again, this might still be deemed expensive.

Another alternative approach to improve its affordability is if utilized as a Vertical farm by all occupants within the house, then the overall cost of the prototypes could be divided by all 42 occupants in the Case Study House, this will be estimated as a cost of N1,617(£6) per person for the HDPE prototype and N423 (£1.69) per person for the bamboo wood prototype. Thus, a shared cost among all the occupants with the Case Study House could improve overall affordability.

However, despite signficant effort to reduce costs signficantly, affordability for the average individual low income earner, remained low, thus providing an opportunity for further research on improving its affordability.

Practicality in terms of assembling

In designing, developing and constructing the prototypes, participation and provision of ideas was encouraged by the community members through identification of relevant skillsets and negotiating labour costs, sharing power and pertinent decisions with community members without relinquishing control over the research process and adopting the role of a silent participant, particularly when negotiating prices of materials as detailed in Chapter 6.This was presented under the framework of a timeline of activities and meetings as;

- Approaching and recruiting community members with specific skillsets
- Engagement with recruited specific skillset and community members.
- Design of prototypes and costing.

Construction phase; physically assembling the prototypes

This also included a discussion on the detailed process and challenges of engaging the community. This culminated in the development of a VGS that was both in terms of materials and assemblage, contextually appropriate.

Maintenance

The maintenance of the prototypes was from two aspects:

1. Plant growth
2. Drainage and irrigation

The final plants to be used in the prototypes were selected jointly with the community which represented a departure from literature, where their selection was primarily driven by selecting those with high leaf area index, so as to ensure maximum percentage of wall covering, which in turn influences absorption of solar radiation. In this study, selection was driven by a combination of cultural fears of snakes/ pest, ability to grow quickly due to time constraints and edibility for provision of food/ fresh vegetables for the occupants. Thus, overgrown plants simply doubled as fresh vegetables simplifying maintenance.

Pertaining to drainage and irrigation, the use of timers to control irrigation in VGS was widely documented in Chapter 3. However, within the research environment, limited by poor electricity supply and limited literacy skills, the alternative developed was a simple drip irrigation from the top to the bottom, in which excess water could drip through the successive levels to the bottom. With the instruction of the local horticulturist to water 3 times daily, the plants thrived without the use of timers and other complicated approaches to irrigation.

Summary

Although the prototypes were not necessarily sophisticated nor high tech in appearance especially, compared to those briefly presented in literature (Chapter 3); the process of their design was predominantly about the engagement of the community to transform relatively complex Vertical Greening Systems into simpler, more context appropriate alternatives.

10.2 Context appropriate experimental analysis of prototypes

In relation to the fulfilment of part of objective II:

III To Design, Develop and Assemble a VGS system prototype, based on the views and inputs of the Low-income groups, that appropriately balances the parameter of Impact on Occupant's Thermal Comfort.

The challenge of developing a field experiment in an unorthodox environment of the low-income houses with specific challenges relating to house ownership, conflicting occupancy schedules and electricity/energy supply was presented. With these challenges and unusual research environment considered, a series of methodological steps in ascertaining the reliability of using the two rooms was developed and presented in Chapter 7. These included:

- <u>Step 1:</u> Field study instrumentation
- <u>Step 2:</u> Comparison of occupant's lifestyle, activities and equipment usage
- <u>Step 3:</u> Solar radiation study (comparison of western wall surface)
- <u>Step 4:</u> Integrated analysis

With these methodological steps, the major findings based on the results of the experiment were presented in Chapter 9:

- Despite internal gains remaining the same in both rooms and a reduced total solar incident radiation for the month of August, the measured average hourly indoor air temperature for the month of August in the experimental room 1 was lower than that of the Control room by a maximum of 2.6°C.
- When examining the Average Hourly Internal Air temperature (AHIA) in relation to the adaptive thermal comfort (ATC) range, for the month of June, it was observed that the AHIA in both rooms were within the ATC range (23.3°C to 29.3°C) 87%-100% of the

time, while the AHIA for the month of August for the Control room is less frequently within the ATC range (23.3°C to 29.3°C) between 23%-45% and that of the experimental room within the ATC range 90%-100%, this shows the positive impact effect of the VGS in improving internal thermal comfort conditions

Thus, the prototype was proven to be effective, when its impact was assessed through the measure of achieving adaptive thermal comfort and to a certain degree in reducing internal air temperature. The major benefit was to shift the temperatures to lie within the comfort zone.

10.3 Community participation, project ownership and longevity

This section presents conclusions in relation to the fulfilment of objective IV:

IV To establish the potential limitations of application of VGS in the context of low income groups in Lagos, Nigeria, including investigation of user awareness and acceptability levels.

Pertaining to the perception of the prototypes by the community members, Chapter 9 revealed the results of attitude surveys of 135 community members, interviewed within 1000m of the Case Study Houses. Responses to open questions were recurrent and these were coded into response types and presented thematically according to frequency. The responses pertaining to acceptability and concerns were grouped under aesthetics, effectiveness in cooling, innovation and creativity, pests, cost/ maintenance, likelihood of landlord approval and potential for vertical farming. It was found that 60% of respondents were comfortable with prototypes being installed in residences, 91% thought that they were innovative and creative, with 77% having a positive aesthetic perception of the prototype and 23% had a negative perception. Further, 90% had concerns about the prototypes, with 70% having concerns relating to landlord approval, 55% had positive perceptions pertaining to its cooling potential, while 45% expressed scepticism relating to this. All occupants in the Case House confirmed its positive impact on their social activities.

Project longevity

Pertaining to project longevity, community participatory development of the prototypes stemmed from genuine interest in the project, based on the belief that their views/ perception was respected and ultimately implemented. This created a sense of project ownership, which has resulted in its longevity, even after the research ended. Thus, as of 26th August 2016, the prototype is still being maintained within the Case Study Houses approximately two years after it was installed, albeit now, as a vertical farm.

With this result, it is apparent that the key to increasing the success and widespread implementation of otherwise complicated devices or prototypes in low income communities is to engage with them, seek their opinions on alternative approaches to design and development. While these may not always yield sophisticated alternatives, this may not significantly compromise its functionality as documented in this study.

10.4 Recommendations for future work

Based on the findings of this study, recommendations pertaining to developing better alternatives to the prototypes which evolved during this study and applicability of the methodological approaches that emerged during the research to similar context is presented.

Pertaining to the four-steps undertaken to engage with low-income communities, this presents opportunities for further study to replicate / refine the steps in various research contexts that might involve participation with low income communities.

Pertaining to affordability, although the prototypes developed were cheaper alternatives, affordability remained a major issue, as found during the survey method, with all respondents calling for even cheaper prototypes. Hence, with a consideration of the concerns documented in Chapter 9, this provides opportunity for further research on developing even more effective alternatives that could be affordable per low-income individual. This might include further studies on material sourcing, further investigation on the impact of mass-production of prototypes on costing towards possible widespread implementation across low income communities. Further, the possibility of equipping low-income groups with the relevant skills to assemble the prototypes themselves, leading to savings in cost of labour.

Pertaining to vertical farms, an opportunity for further study affordable vertical farms, specifically mobile alternatives, that are easier to erect and inexpensive to assemble and maintain, was expressed by respondents during interviews. Thus, further research on easier ways to construct prototypes as vertical farms as well as possible ways of equipping the low-income groups is suggested.

Regarding the peripheral impact of the prototype on external air temperature documented in Chapter 9, this provides an opportunity for further study on the impact of the developed prototypes on surrounding microclimate and its possible application in more public spaces within the community such as schools and community centre.

Finally, further study on developing prototypes for predominantly aesthetic purposes could be undertaken and possibly included in slum up-grading schemes.

Postscript

In July 2016, the Engineering and Physical Sciences Research Council awarded a research grant for developing Affordable Vertical Farms for low income groups surviving on less than a dollar a day, within the same community in Agege, Lagos. As mentioned before, it was revealed that the initially developed prototypes were still being maintained by the occupants within the Case Study Houses, albeit as vertical farms due to the provision of fresh vegetables. Also, due to the success of the initially design prototypes, the local community hall (which houses the water supply tank for the community) was offered for use in developing affordable vertical farms. Over 300 community members were involved with developing and providing feedback on the AVF (affordable vertical farms)

This proves that context appropriate approach to complex technologies could be more successful both in function and durability especially in low-income communities.

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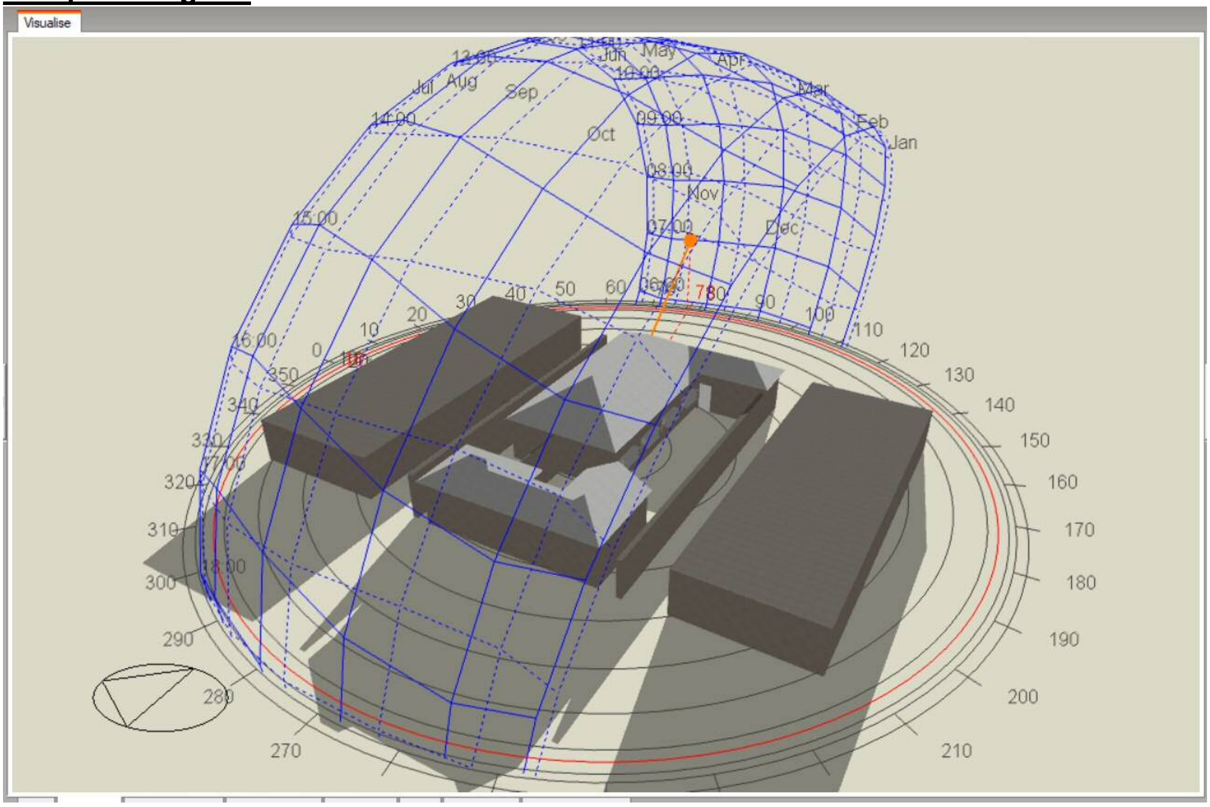
APPENDICES

Appendix A: Assumptions for modelling Case Study House A

Element	Description	Images
Weather file	Ghana weather file	
Location	Nigeria, uninsulated building	
Walls	Walls (225mm hollow concrete block, plastered with 20mm thick cement	
Roofs	Aluminum roofing sheet (5mm thick) supported by 20mm thick hardwood. Ceiling 5mm thick asbestos	
Floors	External ground floor(150mm) concrete slab and 10mm floor cement screed)	

Openings	Windows (700mmX1800mm,5mm (90%)single glazed louvres, wooden window frame	
Activity	4 occupants per room	
Lighting	Low standard suspended incandescent light bulb	
HVAC	No heating or cooling	

Sun path diagram



Appendix B: Data loggers' description and Calibration

The calibration certificate provides verification that the data logger has been checked and has been found to be reading within the specification quoted on the unit's data sheet.

Data loggers are compared to a reference meter that has been calibrated in a UKAS (United Kingdom Accreditation Service) approved laboratory.

The certificate lists the value recorded by the reference meter (the temperature or humidity at which the data logger was tested), the value recorded by the data logger and the error between the two readings (the certificate will also show readings before and after any adjustment made to the unit where appropriate). In addition to the reading information, calibration certificates also list the test method and the details of the equipment used to provide traceability back to national standards.

In the case of humidity data loggers we always adjust this channel to reduce any reading errors as far as possible. This adjustment is performed at 20, 50 and 80%RH to give good overall accuracy across a logger's reading range. Loggers are not adjusted at customer specified points as this can give poor performance at other humidity levels. As above, before and after adjustment readings are quoted on the calibration certificate.

Calibration certificates do not have a period of validity, they are simply a statement of what the unit was reading when it was tested.

Our standard calibration points are:

• Temperature: 0 and 30°C
• Humidity: 20 and 80 % RH (at 25°C)

These points have been chosen to give good coverage for general purpose use, but should other points be required we can calibrate units within the following ranges:

• Temperature: -20 to +150 °C
• Humidity: 20 to 90 % RH (at 25°C)

For CO_2 loggers, our calibration points are:

• 0 to 2000ppm units: 250, 500 and 1750ppm
• 0 to 5000ppm units: 500, 2500 and 4000ppm

For Energy Loggers, our calibration points cover a range of currents from 10 to 1000A per-phase in both the single and three phase modes of operation. Voltage, power and power factor readings are also tested.

We do not have standard calibration points for voltage and current loggers.

Gemini Data Sheet

Tinytag Ultra Range H/ Relative Humidity
TGU-1500

Issue 6: 27th February 2003
E&OE

Features

Memory Size : 16k (Non-volatile)
No. of Readings : 7900 per channel
Resolution : 8 bit
Delayed Start : Relative / Actual up to 45 days
Stop Options : When Full / After n Readings / Never (Wrap around)
Reading Types : Actual, Min, Max.
Logging Interval : 1 sec to 10 days
Offload : While stopped or when logging in minute multiples
Alarms : Two, fully Programmable
Functional Range : -20°C → +85°C / -4°F → +185°F
IP Rating : IP53 splashproof
Battery Life : Up to 4 years

Notes:
Battery replacement is recommended every 2 years. It may be replaced with Saft 3.6V 1/2AA Lithium cells. Stop the unit logging before replacing the battery.

Functional Range describes the limits to which the datalogger may be subjected, **not** the range over which it will record.

Sensor Details

Sensor 1: Temperature Range H
Range : -30°C → +50°C / -22°F → +122°F
Sensor Type : 10k NTC Thermistor (Encapsulated)
Sensor location : Internally mounted
Response Time : 3 min to 90% Apprx.
Sensor accuracy : ± 0.2°C / ± 0.36°F From 0°C → 50°C / 32°F → 122°F
Resolution : 0.25°C at 0°C / 0.45°F at 32°F

Sensor 2: Relative Humidity
Range : 0 → 95% RH
Sensor Type : Capacitive
Sensor Accuracy : ±3% at 25°C / 77°F
Sensor Location : In base of unit
Temp. Dependency : Low
Response Time : 10 sec to 90% (Non-condensing)
Resolution : Better than 0.5%RH

Mechanical Data

Case Style : IP53 Plastic shell

Case Dimensions
Height : 72mm / 2.83"
Width : 60mm / 2.36"
Depth : 33mm / 1.3"
Weight : 50g / 1.8 oz.

Special Notes

When using the units at low temperatures, condensation may form. Before opening the case, allow the units to reach room temperature. The IP53 rating is only valid when the rubber connector cap is fitted and the unit is oriented with the hanging tab uppermost.

The RH sensor has excellent long-term performance and can be wetted without damage, however the accuracy will be temporarily impaired and it should be allowed up to 30 minutes to recover. It can be cleaned in de-ionised water or pure isopropanol, but **not abrasive detergents.** The sensor will resist small amounts of the following chemicals: Formaldehyde, Ammonia, Carbon Monoxide, Sulfur Dioxide, Ethylene Oxide, Hydrogen Chloride, Hydrogen Fluoride, Hydrogen Peroxide, Nitrogen Dioxide, Methyl Chloride, Chlorine, Freon, Methanol, Ethanol, Isopropanol and ozone. It also offers resistance to ultraviolet rays.
Surface scratches or residue will compromise the accuracy. Salt solutions may also cause permanent damage as crystals forming within the porous layers affect moisture levels there.

Approvals

This equipment complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause any harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

This product is manufactured by Gemini Data Loggers (UK) Ltd to BS EN ISO 9001:2000 (Certificate No. 6134), and is CE approved to EN50081 part 1:1992 and EN50082 part 1 and 2:1992/95 with any standard leads or probes supplied.

NAMAS traceable calibration certificates are available on individual units.

Interface Information and Related Products

To use your Tiny Data Logger you will require:
Tinytag interface cable (CAB-0007), PC with GLM for Windows™ (SW-0009) or Easyview for Windows 95™ (SW-0500).

Further Related Products:

SER-9520	Tinytag Ultra Service Kit including battery and seal
DWG-ULTRA	Drawing with detailed dimensions of Tinytag Ultra casing

Gemini Data Loggers Pty
Australia

Gemini Data Loggers UK Ltd
UK

Gemini Data Loggers Inc
USA

http://www.geminidataloggers.com **e-mail: sales@geminidataloggers.com**

Certificate of Registration

nqa

This is to certify that the Environmental Management System of:

Gemini Data Loggers (UK) Limited
Scientific House, Terminus Road, Chichester, West Sussex, PO19 8UJ, United Kingdom

applicable to:

The design, manufacture, calibration and service of data logging and associated equipment including software

has been assessed and registered by NQA against the provisions of:

ISO 14001:2015

This registration is subject to the company maintaining an environmental management system, to the above standard, which will be monitored by NQA

Managing Director

Certificate No.	3933
ISO Approval Date	28 September 2010
Reissued:	18 July 2016
Valid Until:	18 July 2019
EAC Code:	19

UKAS MANAGEMENT SYSTEMS

Certificate of Registration

nqa

This is to certify that the Quality Management System of:

Gemini Data Loggers (UK) Limited
Scientific House, Terminus Road, Chichester, West Sussex, PO19 8UJ, United Kingdom

applicable to:

The design, manufacture, calibration and service of data logging and associated equipment including software

has been assessed and registered by NQA against the provisions of:

BS EN ISO 9001:2015

This registration is subject to the company maintaining a quality management system, to the above standard, which will be monitored by NQA

Managing Director

Certificate No.	6134
ISO Approval Date	20 February 1995
Reissued	18 July 2016
Valid Until:	18 July 2019
EAC Code:	19

UKAS MANAGEMENT SYSTEMS

Appendix C: Interview Schedule and Raw data

Case Study House Occupants interview schedule

Case Study House Occupants

I am Akinwolemiwa Feyikemi, a second year PhD Student of the Welsh School of Architecture.

I am conducting a research titled **'AN EVALUATION OF THE IMPACT OF VERTICAL GREENING SYSTEMS ON OCCUPANTS' THERMAL COMFORT AND INVESTIGATION OF USER ACCEPTABILITY IN LOW COST RESIDENTIAL BUILDINGS, LAGOS, NIGERIA.'.**

The research is to investigate on the awareness level that you have of VGS. In the coming weeks, I will be interviewing selected occupants within the city of Lagos on their level of awareness they have of Vertical Greening Systems.
Interest in this research includes UNHABITAT and the Lagos State Government.

- I would like to record this interview:
- Your participation is entirely voluntary.

If you are interested in being interviewed and agree to being recorded, please sign here.

……………………………………………………………………………………

However, I would appreciate your time (approximately half an hour) for an interview.
The data will be published in the thesis, however anonymity will be ensured .Please choose a date and a convenient time for the interview.
If you need further information about the project, please feel free to contact me with this email addresses
hanfeyie@yahoo.com
Thank you,
Feyikemi Akinwolemiwa, Welsh School of Architecture

INTRODUCTION/ BACKGROUND

Please confirm your Age group (lease select age group below) (Use of Cue card with age range on it)	18-24	1	25-34, 3		Gender (confirmed on sight)	Male[1]	
	35-44,	2	45-54, 4			Female 2	
	55and above 5		N/A 6				

- Are you currently renting this house? Is it your family's house? Do you own this house?
- How many people live in this house? Are they Family members or strangers?
- How many people are in the house in:
  1. Morning (12am-11.30am)
  2. Afternoon(12.00noon-4pm
  3. Night(5pm-11.30pm)

  i) Please are the major activities that take place during these times? (cue cards; 'cooking', TV/relaxing?, others)

  ii) How do you improve comfort during busy times?
- Please point out your Qualification level? (A prompt card will be used to ease discomfort) primary school, secondary school, Higher education? None of the above
- Please what is your Occupation?
- Do you use your home for home based enterprises (trading)? If yes, please what is the nature of your business?
- What proportion of your income do you spend on housing? (Prompt card)

How many months/ years have you lived in this residence?

Greater than 5 people……………………….[1]
Less than 5 people…………………………….[2]
F ([1]family members) S ([2]Strangers)
…………………………………………………………
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…………………………………………………………
…………………………………………………………
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…………………………………………………………
…………………………………………………………
……………………………………………………
primary school [1] secondary school [2] Higher education[3]

Y[1]	N[2]

30-40%[1]	40-50%[2]	50-60%[3]

THERMAL COMFORT/ SUSTAINABILITY

Are you satisfied with the thermal comfort conditions in your house : Show card:	Thermal Comfort Scale :Bedford 1: much too cool / 2:Too cool 3: Comfortably cool 4:Comfortable neither warm nor cool 5: Comfortably warm 6:Too warm 7:Much too warm

Morning		Afternoon	Evening		Night		

- How do you enhance the thermal conditions? (Morning, afternoon, evening and night?)
- How many people are typically n your house (morning, afternoon, evening and night?)

Morning……………………………………………………………………………
……..
Afternoon………………………………………………………………………………
……
Evening……………………………………………………………………………
………
Night……………………………………………………………………………………
……..

• Please estimate how much you spend weekly (including fuelling generators) when trying to achieve thermal comfort • Which electrical gadget at home do you use frequently?	Greater than 5 people……………………..[1] Less than 5 people…………………………..[2] Less than 5000naira(18pounds)………..[1] Greater than 5000naira…………………..[2]
AWARENESS/ OPINION	……………………………………………………………………………………………… .
• Have you heard about green walls/ wall gardens? • Please tell me your opinion of that wall garden mounted there? • If I told you they offer cooling, would your opinion still remain the same? • Would you be interested in producing vegetables with them?	[ ] [N] [U] [ ] [N] [U]
ACCEPTABILITY • Are you comfortable with them being mounted on your house if they can offer cooling?	[ ] [N] [U]
CONCERNS/ DRAWBACKS • Please what are your concerns about these systems?	
RECOMMENDATIONS • Is there any other thing you will like to add?	
EXTRAS	

Vertical Greening Systems attitude/ perception interview schedule

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

Public – Interview Schedule

I am Akinwolemiwa Feyikemi, a second year PhD Student of the Welsh School of Architecture.

I am conducting a research titled **‘AN EVALUATION OF THE IMPACT OF VERTICAL GREENING SYSTEMS ON OCCUPANTS’ THERMAL COMFORT AND INVESTIGATION OF USER ACCEPTABILITY IN LOW COST RESIDENTIAL BUILDINGS, LAGOS, NIGERIA.’.**

The research is to investigate on the awareness level that you have of VGS. In the coming weeks, I will be interviewing selected occupants within the city of Lagos on their level of awareness they have of Vertical Greening Systems.
Interest in this research includes UNHABITAT and the Lagos State Government.

- I would like to record this interview:
- Your participation is entirely voluntary.

If you are interested in being interviewed and agree to being recorded, please sign here.

………………………………………………………………… ……………………

However, I would appreciate your time (approximately half an hour) for an interview.
The data will be published in the thesis, however anonymity will be ensured .Please choose a date and a convenient time for the interview.
If you need further information about the project, please feel free to contact me with this email addresses
hanfeyie@yahoo.com
Thank you,
Feyikemi Akinwolemiwa, Welsh School of Architecture

INTRODUCTION/ BACKGROUND							
Please confirm your Age group (lease select age group below)	18-24	[1]	25-34, [3]			Male[1]	

<table>
<tr><td rowspan="2">(Use of Cue card with age range on it)</td><td>35-44,</td><td>2</td><td>45-54,
4</td><td></td><td rowspan="2">Gender (confirmed on sight)</td><td rowspan="2">Female
2</td><td rowspan="2"></td></tr>
<tr><td colspan="2">55and above
5</td><td>N/A
6</td><td></td></tr>
<tr><td colspan="5">• Are you currently renting this house? Is it your family’s house? Do you own this house?
• Please point out your Qualification level? (A prompt card will be used to ease discomfort) primary school, secondary school, Higher education? None of the above
• Please what is your Occupation?</td><td colspan="3">……………………………………………………..
……………………………………………………….
……………………………………………………….
……………………………………………………….
……………………………………………………….
……………………………………………………….
………………………………………………………..</td></tr>
<tr><td colspan="2">• Have you heard about green walls/ wall gardens?
• Please tell me your opinion of that wall garden mounted there?
• If I told you they offer cooling, would your opinion still remain the same?
• Would you be interested in producing vegetables with them?</td><td colspan="6"></td></tr>
<tr><td colspan="2">ACCEPTABILITY
• Are you comfortable with them being mounted on your house if they can offer cooling?</td><td colspan="6"></td></tr>
<tr><td colspan="2">CONCERNS/ DRAWBACKS
• Please what are your concerns about these systems?</td><td colspan="6"></td></tr>
<tr><td colspan="2">RECOMMENDATIONS
• Is there any other thing you will like to add?</td><td colspan="6"></td></tr>
<tr><td colspan="2">EXTRAS</td><td colspan="6"></td></tr>
</table>

Ethics approval document

WELSH SCHOOL OF ARCHITECTURE
ETHICS APPROVAL FORM FOR STAFF AND PHD/MPHIL PROJECTS WS

Tick one box:	☐ STAFF ☑ PHD/MPHIL
Title of project	An evaluation of the impact of vertical greening systems on occupants thermal comfort and investigation of users' acceptability
Name of researcher(s)	in low cost residential buildings, Lagos, Nigeria
Name of principal investigator	Akinwolemiwa Oluwafeyikemi
Contact e-mail address	[illegible]@yahoo.com
Date	29th Jan 2014

Participants		YES	NO	N/A
Does the research involve participants from any of the following groups?	• Children (under 16 years of age)		✓	
	• People with learning difficulties		✓	
	• Patients (NHS approval is required)		✓	
	• People in custody		✓	
	• People engaged in illegal activities		✓	
	• Vulnerable elderly people		✓	
	• Any other vulnerable group not listed here		✓	
• When working with children I have read the Interim Guidance for Researchers Working with Children and Young People (http://www.cardiff.ac.uk/archi/ethics_committee.php)				

Consent Procedure	YES	NO	N/A
• Will you describe the research process to participants in advance, so that they are informed about what to expect?	✓		
• Will you tell participants that their participation is voluntary?	✓		
• Will you tell participants that they may withdraw from the research at any time and for any reason?	✓		
• Will you obtain valid consent from participants? (specify how consent will be obtained in Box A)[1]	✓		
• Will you give participants the option of omitting questions they do not want to answer?	✓		
• If the research is observational, will you ask participants for their consent to being observed?	✓		
• If the research involves photography or other audio-visual recording, will you ask participants for their consent to being photographed / recorded and for its use/publication?	✓		

Possible Harm to Participants	YES	NO	N/A
• Is there any realistic risk of any participants experiencing either physical or psychological distress or discomfort?		✓	
• Is there any realistic risk of any participants experience a detriment to their interests as a result of participation?		✓	

Data Protection		YES	NO	N/A
• Will any non-anonymous and/or personalised data be generated or stored?		✓		
• If the research involves non-anonymous and/or personalised data, will you:	• gain written consent from the participants	✓		
	• allow the participants the option of anonymity for all or part of the information they provide	✓		

Health and Safety	YES
Does the research meet the requirements of the University's Health & Safety policies? (http://www.cf.ac.uk/oshou/index.html)	✓

Research Governance	YES	NO	N/A
Does your study include the use of a drug? You need to contact Research Governance before submission (resgov@cf.ac.uk)		✓	
Does the study involve the collection or use of human tissue? You need to contact the Human Tissue Act team before submission (hta@cf.ac.uk)		✓	

[1] If any non-anonymous and/or personalised data be generated or stored, *written consent* is required.

If any of the shaded boxes have been ticked, you must explain in Box A how the ethical issues are addressed. The list of ethical issues on this form is not exhaustive; if you are aware of any other ethical issues you need to make the SREC aware of them.

Box A — The Project (provide all the information listed below in a separate attachment)

1. Title of Project
2. Purpose of the project and its academic rationale
3. Brief description of methods and measurements
4. Participants: recruitment methods, number, age, gender, exclusion/inclusion criteria
5. Consent and participation information arrangements - please attached consent forms if they are to be used
6. A clear and concise statement of the ethical considerations raised by the project and how is dealt with them
7. Estimated start date and duration of project

All information must be submitted along with this form to the School Research Ethics Committee for consideration

Researcher's declaration (tick as appropriate)

• I consider this project to have negligible **ethical implications** (*can only be used if none of the grey areas of the checklist have been ticked*)	✓
• I consider this project research to have **some ethical implications**.	
• I consider this project to have **significant ethical implications**	

Signature [signature] **Name** Akinwolemiwa Feyikemi **Date** 29/01/14
Researcher or MPhil/PhD student

Signature [signature] **Name** [illegible] **Date** 27.01.14
Lead investigator or supervisor

Advice from the School Research Ethics Committee

STATEMENT OF ETHICAL APPROVAL

This project had been considered using agreed Departmental procedures and is now approved

Signature [signature] Name Wouter Poortinga **Date** 31/01/14
Chair, School Research Ethics Committee

Verbatim responses of participants (as presented in Chapter 9)			
Theme	**Verbatim responses**	**Nos**	**Category/ Classification of prototypes**
General appearance	I think it is a good idea, especially the draining aspect'	15	**Perception of innovation and creativity**
	The way it is watered is quite interesting'	15	
	Very good way to water it'	12	
	The way it is drained is very nice'	10	
	So we only need to hose it? Quite interesting'	9	
	Actually, great idea'	5	**Overall positive perception of prototypes**
	Sounds good to me'	3	
	Wow, what a good project'	4	
	Good idea'	4	
	Very Very interesting'	4	
	I think it is a very good idea, I will like the system to remain on the wall after the research is over, it looks nice on it'	8	**Retainment of prototypes after study**
	I think you should continue with the project, it has a nice feel'	7	
	Wow, don't remove it, nice look'	9	
	leave it there'	7	
	Make some more in the community after study is over	6	
	It should be here for a long time	5	
Aesthetic perception	'It will dirty my wall/ it disfigures the wall'	4	**Dissatisfaction with overall aesthetic quality**

	‘It will make the wall look rough’	7	
	‘I don’t like it because it doesn’t beautify the house or make it look good or attractive’	8	
	It looks funny’	7	
	‘I think it is ugly and not presentable enough’	5	
	It beautifies the house'	12	**Positive perception of prototype's aesthetic quality**
	It is quite beautiful and lovely'	16	
	It looks nice'	13	
	Quite nice to look at'	10	
	Realy pretty, especially the leaves	10	
	lovely to see'	10	
	Its very fine'	10	
	Brightens the place '	10	
	Nice looking'	13	
Concerns	To be honest, when I look at this VGS all I see are snakes’	8	**Concerns about reptiles**
	‘It may not be nice because it might attract reptiles’	13	
	Looks like reptiles will be hiding there	18	
	Looks like bats will make that place a home	8	
	Reptiles will come to this compound	14	
	Animals will come here	16	

	Reptile haven	5	
	I like it if it does not breed animals’	8	
	It looks like there might be insects hiding inside’	5	**Concerns about insects**
	Bees, insects will be everywhere	4	
	Looks like insects will make this place their home	5	
	I see insects coming soon	3	
	Maybe scorpions will come here	8	
	Insects, all dangerous will be here	7	
	‘I will be interested in it, but only if it was my house, I rent this property and it all depends on my caretaker’	33	**Concern with landlord approval**
	I like it but I am not sure my landlord will allow me assemble it as it is not my house’	35	
	Might want one but only if I own the house’	27	
Prototype's Costing	‘I still think it is very expensive, it has to be very cheap’	31	**Perception of prototypes as expensive**
	‘I still can’t afford it’	17	
	Looks expensive to me	16	
	Don’t have extra income for this	14	
	I hope it is extremely cheap	13	

	Expensive right?	13	
	You know people are struggling,hope it is cheap	20	
		11	
Maintenance	‘It looks high maintenance and expensive to maintain’	28	**Perception of significant amount of efforts to maintain prototypes**
	Too much maintenance	17	
	No time to maintain	15	
	‘It looks like a lot of stress to me’	21	
	‘It looks like the plants will grow uncontrollably’	31	
	I am not a plant person, I might abandon it’	23	
Vertical farming potential	I think they are important for provision of fresh vegetables’	12	**Interest in using prototypes to produce fresh vegetables**
	‘I like the idea of growing my own food as there are no spaces where I live to plant vegetables’	9	
	‘I am solely interested in having it, but just for planting food’	13	
	will just use it as a garden	21	
	Will use it for my medicinal plants	13	
	Will use it to plant my ugu and soko	13	
	Looks like a nice place to plant fresh vegetables	20	
Prototypes cooling potential	‘I think it is a waste of time’	12	**Skepticism on prototypes's coooling potential**
	What in the world is this nonsense?’	8	

		'Disinterested'							10	
		'It cannot work'							16	
		Interesting but I need to experience it before my final say'							15	
		It is ok, in order to control the hot weather in Nigeria'							15	**Interest in prototypes due to its cooling potential**
		It has potential, I am interested							8	
		Why not? If it works I want one							5	
		Wont mind having one if it works							13	
		'I welcome the idea if it will reduce the heat in my house'							15	
		'Only interested if it brings cooling is it effective?'							15	
		If it is effective then I want one							3	

Appendix D: Average of readings from data loggers

Simulated total Incident Solar radiation for the Month of June

day of the month	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)
	07:00			08:00			09:00			10:00			11:00	
1	26.97	32.76	-5.80	178.50	226.60	-48.10	417.6	515.3	-97.7	638.0	783.0	-145.0	776.7	959.6
2	20.3	24.6	-4.28	142.1	178.0	-35.88	383.7	477.6	-93.9	615.2	758.4	-143.3	750.2	940.1
3	27.0	32.8	-5.80	159.7	220.4	-60.75	376.2	491.7	-115.5	519.6	658.1	-138.5	0.0	0.0
4	26.7	32.4	-5.72	167.8	218.9	-51.12	391.3	494.1	-102.9	556.8	697.7	-140.8	577.9	764.8
5	27.0	32.8	-5.79	158.6	217.4	-58.81	364.9	475.5	-110.6	516.2	652.9	-136.7	530.0	718.8
6	25.1	30.4	-5.36	163.0	210.1	-47.08	383.3	489.3	-105.9	525.6	663.9	-138.3	540.1	734.0
7	26.3	32.0	-5.64	165.8	217.8	-51.96	392.1	500.0	-108.0	548.1	687.7	-139.6	601.8	798.7
8	19.3	23.3	-4.06	136.9	167.9	-30.98	355.0	435.3	-80.3	552.7	682.3	-129.5	607.9	794.2
9	26.0	31.5	-5.56	162.8	215.9	-53.12	381.0	490.0	-109.1	528.3	666.6	-138.3	548.1	740.6
10	26.6	32.3	-5.71	158.5	217.9	-59.40	372.8	486.9	-114.1	515.8	653.1	-137.4	535.0	728.4
11	19.3	23.3	-4.06	136.5	167.3	-30.84	353.0	432.8	-79.8	571.5	699.4	-127.9	725.6	895.1
12	24.8	30.1	-5.32	162.8	198.1	-35.36	373.1	456.0	-82.9	562.2	703.3	-141.1	596.6	780.3
13	25.5	31.0	-5.47	156.2	210.2	-53.95	381.1	494.0	-112.9	542.2	680.8	-138.6	596.6	784.3
14	18.8	22.8	-3.97	134.5	164.9	-30.41	355.0	435.6	-80.6	580.7	718.1	-137.4	666.8	857.1
15	26.0	31.7	-5.61	156.0	215.2	-59.18	370.8	484.1	-113.4	514.9	651.7	-136.8	536.3	729.1
16	18.8	22.8	-3.96	134.1	164.4	-30.27	348.7	427.5	-78.7	566.2	692.8	-126.6	704.9	881.2
17	23.6	28.7	-5.06	158.1	192.2	-34.14	370.7	451.6	-80.9	544.8	672.3	-127.5	611.6	791.0
18	25.6	31.1	-5.52	154.9	213.3	-58.43	368.4	480.9	-112.5	513.1	649.2	-136.1	537.7	730.0
19	25.2	30.7	-5.44	152.4	210.8	-58.32	368.1	480.9	-112.8	513.6	650.0	-136.4	533.4	725.7
20	24.9	30.2	-5.36	157.6	210.5	-52.88	373.3	481.6	-108.3	523.1	658.2	-135.1	567.3	753.0
21	16.6	20.1	-3.54	156.2	204.2	-47.95	376.7	473.9	-97.3	534.9	668.3	-133.4	596.8	778.8
22	12.2	14.7	-2.55	131.3	161.1	-29.76	357.8	438.4	-80.6	567.3	697.3	-130.0	704.9	882.1
23	11.6	14.1	-2.44	128.5	156.9	-28.47	351.9	430.1	-78.2	575.8	708.7	-133.0	662.4	840.9
24	15.8	19.2	-3.38	148.8	193.1	-44.25	363.6	459.4	-95.8	533.1	665.9	-132.8	588.2	770.5
25	13.5	16.3	-2.82	142.8	182.9	-40.05	383.8	473.2	-89.4	568.8	707.9	-139.0	585.0	771.5
26	15.8	19.1	-3.37	162.5	204.7	-42.18	386.9	475.1	-88.2	559.2	687.3	-128.1	668.7	856.0
27	14.0	17.0	-2.98	146.9	181.0	-34.07	377.6	464.2	-86.6	593.0	726.0	-133.0	726.4	894.9
28	11.3	13.7	-2.38	126.0	153.9	-27.94	341.2	417.0	-75.8	559.7	684.5	-124.8	723.9	891.7
29	15.4	18.7	-3.31	152.2	198.2	-46.00	371.3	467.1	-95.9	530.3	662.4	-132.1	592.0	770.1
30	15.4	18.7	-3.30	146.0	194.5	-48.50	359.1	458.0	-98.9	500.3	628.2	-127.9	574.5	756.9
AVG of the difference (°C)			-4.5			-44.3			-96.2			-134.8		
STD DEV of the difference (°C)			1.2			10.9			13.3			5.2		

Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)
		12:00			13:00			14:00			15:00:00			16:00
-182.9	833.0	1036.2	-203.2	762.8	972.4	-209.6	913.7	1103.7	-189.9	2344.6	2627.3	-282.7	3190.5	3534.1
-189.9	697.6	896.3	-198.6	696.9	895.5	-198.6	888.5	1082.9	-194.4	1962.1	2228.4	-266.3	3508.1	3870.9
0.0	523.1	741.2	-218.0	534.1	737.3	-203.2	900.2	1066.2	-166.1	2689.3	2968.7	-279.4	4269.3	4663.0
-186.9	569.7	775.8	-206.1	597.8	794.8	-197.0	898.7	1094.6	-196.0	1799.8	2060.2	-260.4	2251.2	2549.6
-188.8	522.2	731.9	-209.7	528.7	728.6	-199.9	897.9	1066.1	-168.2	2686.5	2965.9	-279.4	4270.3	4660.7
-193.9	532.2	751.7	-219.5	530.6	732.8	-202.3	898.4	1064.0	-165.6	2691.2	2969.7	-278.5	4248.4	4637.3
-197.0	542.7	757.7	-215.0	563.0	766.9	-203.9	895.2	1082.5	-187.3	2156.4	2429.4	-272.9	3017.9	3352.2
-186.3	621.0	825.1	-204.2	607.1	807.3	-200.3	868.8	1054.2	-185.4	1948.9	2219.9	-271.0	3505.0	3867.8
-192.5	538.0	752.1	-214.1	593.0	798.6	-205.6	863.2	1050.1	-186.9	1771.9	2036.0	-264.1	2237.1	2534.7
-193.4	523.8	740.8	-217.0	537.2	740.2	-202.9	900.2	1067.2	-167.1	2680.1	2958.5	-278.5	4248.0	4637.3
-169.6	741.7	926.2	-184.4	744.5	932.5	-188.0	836.1	1021.8	-185.8	910.9	1082.8	-171.9	931.1	1088.4
-183.7	729.4	938.7	-209.2	624.1	829.1	-204.9	868.9	1055.0	-186.1	1879.6	2146.9	-267.3	3060.5	3400.1
-187.7	695.3	876.4	-181.1	743.2	931.0	-187.8	856.3	1045.3	-189.0	1357.0	1582.0	-225.0	1558.6	1792.4
-190.3	634.7	850.8	-216.0	553.1	755.5	-202.3	884.2	1052.3	-168.1	2673.3	2952.7	-279.5	4238.9	4628.1
-192.8	523.4	739.8	-216.4	537.2	739.9	-202.7	898.3	1065.1	-166.7	2676.5	2954.8	-278.3	4250.7	4640.1
-176.2	700.7	932.2	-231.5	618.7	824.3	-205.6	883.1	1067.7	-184.6	2193.4	2467.6	-274.2	3529.4	3891.7
-179.4	725.7	919.1	-193.4	688.8	904.0	-215.2	841.3	1024.0	-182.7	1394.6	1615.6	-221.0	1554.5	1787.6
-192.3	524.8	740.8	-216.0	538.9	741.7	-202.8	898.8	1066.2	-167.4	2667.6	2946.0	-278.4	4238.7	4627.7
-192.3	511.1	725.1	-214.0	515.3	712.8	-197.5	895.5	1084.0	-188.5	2142.2	2415.8	-273.6	3012.2	3346.4
-185.7	616.5	830.1	-213.6	598.9	806.0	-207.2	878.8	1051.3	-172.6	2650.7	2930.2	-279.6	4254.9	4645.1
-182.0	662.9	870.4	-207.5	618.3	820.8	-202.5	843.7	1026.6	-182.9	1897.4	2152.2	-254.8	1697.4	1932.7
-177.2	722.8	921.7	-199.0	699.5	896.5	-197.0	853.2	1044.8	-191.5	1704.9	1955.1	-250.1	2063.1	2331.5
-178.5	678.7	887.1	-208.4	619.5	823.0	-203.5	857.7	1038.9	-181.2	2540.8	2819.7	-278.9	4159.8	4537.7
-182.2	617.0	825.1	-208.1	607.5	808.4	-200.9	852.8	1034.9	-182.1	2277.1	2551.3	-274.2	3389.1	3736.6
-186.5	552.8	763.4	-210.6	537.7	737.1	-199.3	836.3	1001.1	-164.8	2556.2	2828.6	-272.4	4145.5	4522.3
-187.3	661.2	872.1	-210.8	711.2	895.7	-184.5	834.8	1021.8	-186.9	1325.5	1548.2	-222.8	1544.3	1776.9
-168.5	823.8	1019.0	-195.2	767.2	957.7	-190.5	866.5	1058.3	-191.8	1769.6	2031.1	-261.5	2807.4	3128.7
-167.8	823.9	1019.1	-195.3	767.8	958.5	-190.7	881.4	1078.2	-196.8	1432.7	1679.6	-246.9	1848.7	2113.4
-178.1	686.2	886.0	-199.9	626.0	829.2	-203.2	842.1	1025.1	-183.0	2101.9	2369.8	-267.9	3350.3	3695.8
-182.4	602.5	818.1	-215.7	616.3	819.8	-203.4	859.2	1042.4	-183.2	2386.9	2670.5	-283.7	3512.1	3869.1
-178.4			-207.7			-200.4			-181.4			-263.2		
34.0			10.6			6.6			10.0			24.1		

Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)
		17:00			18:00			19:00			20:00	
-343.6	2911.3	3181.4	-270.1	1391.3	1519.8	-128.5	263.1	273.0	-9.8	17.8	20.1	-2.2
-362.8	3831.9	4145.1	-313.2	1948.9	2094.3	-145.4	513.9	436.3	77.6	24.8	23.5	1.2
-393.7	4976.8	5333.6	-356.8	3144.1	3314.7	-170.6	682.3	554.1	128.3	28.5	24.2	4.4
-298.4	2107.1	2344.9	-237.8	1372.6	1500.6	-127.9	341.9	323.5	18.4	22.3	23.0	-0.7
-390.4	4991.2	5348.3	-357.1	3150.8	3321.6	-170.9	681.0	553.6	127.4	28.5	24.2	4.3
-388.9	4981.0	5337.5	-356.5	3151.6	3322.6	-171.1	687.8	558.9	129.0	29.8	25.5	4.4
-334.3	3217.1	3502.6	-285.5	1895.1	2040.0	-144.9	525.5	446.2	79.3	26.2	25.1	1.1
-362.9	3754.8	4063.1	-308.3	1603.1	1738.4	-135.3	425.1	390.6	34.5	27.5	27.1	0.4
-297.6	2099.5	2337.1	-237.6	1378.4	1507.0	-128.6	350.4	331.3	19.1	22.6	23.4	-0.8
-389.4	4969.5	5326.0	-356.5	3157.7	3329.0	-171.3	700.9	568.7	132.2	31.3	26.8	4.4
-157.3	707.0	825.5	-118.5	392.0	460.1	-68.1	121.2	144.7	-23.6	11.9	14.4	-2.5
-339.6	3690.8	3997.5	-306.7	1600.8	1736.4	-135.6	434.4	399.2	35.1	29.1	28.8	0.3
-233.8	1454.8	1641.8	-187.0	705.7	805.3	-99.5	196.2	219.9	-23.6	17.5	20.7	-3.2
-389.2	4980.5	5337.9	-357.4	3171.3	3342.9	-171.6	712.0	577.2	134.8	31.5	27.1	4.4
-389.4	4980.9	5338.1	-357.1	3183.0	3354.7	-171.8	727.6	584.5	143.2	31.8	27.3	4.5
-362.3	4015.9	4336.9	-321.0	2493.4	2651.7	-158.4	581.9	491.8	90.0	27.9	26.9	0.9
-233.1	1455.4	1642.7	-187.3	711.3	811.7	-100.4	200.7	224.8	-24.1	17.8	21.0	-3.3
-389.1	4975.8	5332.8	-357.1	3197.0	3369.4	-172.4	738.9	592.9	145.9	33.2	28.6	4.6
-334.2	3239.4	3526.8	-287.5	1931.5	2079.2	-147.7	538.6	460.2	78.4	29.0	28.4	0.6
-390.2	4996.6	5354.3	-357.8	3233.6	3407.2	-173.6	738.9	593.4	145.6	33.2	28.7	4.5
-235.3	1465.1	1650.4	-185.3	731.1	833.3	-102.2	211.7	236.2	-24.6	18.3	21.6	-3.3
-268.4	1709.5	1910.6	-201.1	971.2	1078.2	-107.0	285.8	299.3	-13.5	25.3	27.8	-2.5
-377.9	4955.8	5295.0	-339.2	3313.0	3491.5	-178.5	803.2	657.3	145.9	37.5	30.0	7.5
-347.5	3053.8	3327.3	-273.5	1453.6	1588.3	-134.7	251.3	271.8	-20.5	19.5	22.9	-3.4
-376.8	4928.0	5266.9	-338.9	3204.6	3380.4	-175.9	799.0	654.1	145.0	36.2	28.9	7.3
-232.6	1461.5	1647.5	-186.0	736.4	839.5	-103.1	216.8	241.7	-25.0	19.6	23.1	-3.5
-321.3	3494.6	3783.3	-288.7	2512.7	2673.8	-161.1	650.5	556.1	94.3	32.6	30.0	2.6
-264.7	1951.1	2177.6	-226.5	1390.0	1522.4	-132.4	490.2	453.9	36.3	29.3	28.2	1.1
-345.6	3828.1	4131.4	-303.3	2086.8	2242.1	-155.4	526.6	474.0	52.6	30.0	29.0	1.0
-357.0	3645.7	3938.1	-292.4	1126.1	1241.7	-115.6	225.9	250.0	-24.1	19.9	23.5	-3.5
-330.2			-285.1			-142.0			60.1			1.0
62.0			66.5			29.0			65.5			3.3

Simulated total Incident Solar radiation for the Month of August

day of the month	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)
		07:00			08:00			09:00			10:00			11:00
1	18.60	22.60	-4.00	135.87	165.87	-30.00	341.9	445.3	-103.4	545.2	740.7	-195.6	577.3	780.5
2	15.4	18.7	-3.30	121.6	148.7	-27.09	349.1	434.2	-85.0	571.4	707.8	-136.4	737.5	912.7
3	21.4	26.1	-4.67	149.7	189.2	-39.45	374.7	506.1	-131.4	543.1	732.5	-189.4	0.0	0.0
4	21.3	26.0	-4.70	150.1	182.9	-32.85	366.0	470.7	-104.7	545.9	741.1	-195.3	578.4	781.8
5	14.8	18.0	-3.20	119.9	146.7	-26.74	349.0	434.1	-85.0	571.8	708.2	-136.5	735.7	912.6
6	20.8	25.4	-4.60	151.2	196.7	-45.57	354.9	514.1	-159.2	480.1	692.4	-212.4	518.2	736.6
7	20.7	25.2	-4.50	150.4	186.3	-35.85	371.2	490.2	-118.9	546.6	742.3	-195.7	579.1	782.8
8	14.2	17.3	-3.10	117.8	144.0	-26.28	346.9	431.5	-84.6	569.7	705.8	-136.1	682.2	863.3
9	20.5	25.0	-4.50	148.2	180.4	-32.21	363.2	447.2	-84.0	573.7	710.8	-137.1	740.6	916.7
10	10.3	12.4	-2.10	90.3	109.1	-18.85	302.1	371.1	-68.9	567.2	704.5	-137.4	694.1	857.2
11	14.1	17.2	-3.10	117.7	144.1	-26.32	347.8	432.7	-84.9	571.8	708.2	-136.5	739.2	914.8
12	15.0	18.2	-3.20	121.0	148.0	-27.01	348.3	444.9	-96.6	554.0	730.6	-176.6	624.4	834.2
13	19.8	24.2	-4.40	148.9	191.2	-42.29	368.6	488.9	-120.3	570.6	708.6	-138.0	719.4	903.4
14	14.1	17.1	-3.00	117.7	144.1	-26.37	348.9	434.2	-85.4	575.2	712.7	-137.5	742.4	919.0
15	14.0	17.0	-3.04	117.7	144.1	-26.36	348.4	433.5	-85.2	573.8	710.8	-137.0	742.1	918.6
16	13.6	16.4	-2.85	102.6	124.0	-21.42	308.1	380.0	-71.9	565.6	710.0	-144.4	689.4	861.4
17	19.6	24.0	-4.41	148.6	184.0	-35.43	372.1	492.0	-119.9	548.6	745.7	-197.0	581.6	786.3
18	13.5	16.4	-2.90	122.5	153.0	-30.50	359.5	480.6	-121.1	548.8	746.7	-197.9	580.8	790.9
19	13.5	16.4	-2.90	116.1	142.1	-26.01	348.8	434.2	-85.4	545.4	694.0	-148.6	634.0	845.4
20	19.1	23.3	-4.20	147.1	182.1	-35.10	372.3	493.0	-120.6	548.9	746.9	-198.0	581.3	791.6
21	0.0	0.0	0.00	116.0	141.9	-25.91	338.3	418.6	-80.3	541.9	660.9	-118.9	641.0	782.0
22	0.0	0.0	0.00	147.0	181.9	-34.87	370.7	490.6	-119.9	582.4	774.4	-192.0	692.0	905.3
23	0.0	0.0	0.00	90.8	109.7	-18.91	286.4	347.2	-60.8	504.9	614.3	-109.4	741.0	907.2
24	0.0	0.0	0.00	147.0	181.8	-34.87	370.7	490.7	-120.0	549.7	743.8	-194.1	569.0	828.3
25	0.0	0.0	0.00	147.5	182.7	-35.15	371.9	492.9	-120.9	548.9	743.8	-194.9	581.1	825.6
26	0.0	0.0	0.00	119.7	151.0	-31.33	361.7	492.0	-130.3	528.0	720.3	-192.4	580.2	833.5
27	0.0	0.0	0.00	116.5	142.6	-26.10	351.0	437.3	-86.3	576.4	722.2	-145.8	653.7	888.1
28	0.0	0.0	0.00	116.5	142.6	-26.10	341.4	446.8	-105.4	550.5	745.6	-195.2	595.2	832.0
29	0.0	0.0	0.00	144.4	182.5	-38.05	372.2	508.7	-136.5	528.7	721.6	-192.9	562.8	827.1
30	0.0	0.0	0.00	116.5	142.7	-26.14	351.2	437.7	-86.5	579.7	718.0	-138.3	689.9	892.6
31	0.0	0.0	0.00	146.3	181.7	-35.38	366.4	486.9	-120.5	537.2	730.6	-193.4	583.0	828.2
AVG of the difference (°C)			-2.3			-30.5			-102.7			-166.1		
STD DEV of the difference (°C)			1.8			6.3			22.8			30.4		

Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)
		12:00			13:00			14:00			15:00:00			16:00
-203.2	700.1	922.5	-222.4	592.8	842.9	-250.1	874.9	1091.5	-216.6	2052.0	2334.4	-282.4	3722.0	4112.9
-175.2	833.6	1036.6	-203.0	739.3	937.4	-198.1	868.7	1066.4	-197.7	1409.8	1641.6	-231.8	1615.8	1857.7
0.0	585.0	837.3	-252.3	583.1	832.3	-249.2	890.3	1108.6	-218.3	1854.3	2120.7	-266.4	1711.1	1952.2
-203.4	701.2	924.0	-222.8	626.4	863.6	-237.2	900.2	1102.4	-202.3	1607.0	1852.8	-245.7	1079.6	1250.1
-176.9	817.1	1026.7	-209.6	943.4	1183.3	-239.9	1105.9	1354.5	-248.5	2044.6	2339.5	-294.9	3720.3	4111.2
-218.4	597.1	841.4	-244.3	500.4	761.9	-261.5	793.5	996.7	-203.2	1779.4	2025.6	-246.2	3404.4	3776.2
-203.7	702.4	925.2	-222.9	592.4	842.7	-250.3	900.3	1118.2	-218.0	2410.9	2704.1	-293.1	4281.8	4710.5
-181.1	630.9	873.4	-242.6	574.2	822.9	-248.7	918.6	1137.7	-219.2	2503.8	2798.8	-295.0	3753.9	4143.5
-176.1	836.2	1040.0	-203.7	740.0	938.8	-198.8	873.5	1072.2	-198.8	1423.8	1657.3	-233.5	1629.7	1872.9
-163.1	687.0	845.6	-158.6	803.7	999.4	-195.6	872.7	1071.3	-198.6	1418.2	1650.9	-232.7	1625.8	1868.4
-175.6	835.7	1039.1	-203.4	738.7	936.8	-198.2	923.1	1128.6	-205.5	1417.8	1650.4	-232.6	1621.0	1863.0
-209.8	703.5	927.1	-223.6	592.9	843.9	-250.9	921.1	1140.6	-219.5	2515.7	2811.8	-296.0	3769.6	4160.2
-184.0	675.8	913.3	-237.5	582.7	833.6	-250.9	883.1	1101.2	-218.1	2079.9	2364.8	-284.9	3681.1	4070.1
-176.6	838.3	1042.6	-204.3	739.8	938.5	-198.7	875.6	1074.5	-198.9	1641.1	1889.2	-248.1	2986.2	3332.9
-176.5	837.8	1041.9	-204.2	741.0	940.2	-199.2	935.0	1143.1	-208.1	2228.8	2519.4	-290.6	3734.4	4126.4
-172.0	693.4	867.2	-173.8	653.4	849.4	-196.1	734.7	894.9	-160.2	1087.1	1274.8	-187.7	2259.2	2544.7
-204.8	705.3	929.4	-224.0	628.1	866.1	-238.0	864.6	1060.7	-196.1	1433.8	1668.0	-234.2	1635.1	1878.2
-210.1	667.2	901.8	-234.6	578.9	823.2	-244.3	859.4	1072.9	-213.5	1559.2	1796.8	-237.6	2338.1	2636.2
-211.5	705.7	930.3	-224.5	594.7	846.6	-251.9	889.3	1108.2	-218.9	2198.0	2488.1	-290.1	4046.8	4459.9
-210.3	669.5	906.4	-236.9	585.4	836.4	-251.0	912.1	1131.7	-219.6	2364.4	2655.2	-290.8	3693.6	4081.7
-141.0	704.7	874.4	-169.7	851.8	1073.5	-221.7	898.2	1103.1	-204.9	1458.6	1696.7	-238.1	1647.2	1888.9
-213.3	815.4	1027.6	-212.2	742.7	949.4	-206.7	898.3	1103.0	-204.7	1457.5	1695.4	-237.9	1643.8	1885.0
-166.1	810.9	1009.8	-198.9	744.8	952.1	-207.3	900.6	1105.7	-205.1	1466.8	1705.7	-238.9	1650.3	1892.0
-259.3	610.2	904.4	-294.3	585.0	875.3	-290.3	938.8	1179.6	-240.8	2065.8	2358.6	-292.8	3420.5	3795.2
-244.5	700.6	917.2	-216.6	679.8	841.6	-161.8	754.7	918.9	-164.2	979.8	1153.7	-173.9	967.4	1127.6
-253.3	672.2	950.6	-278.3	594.2	884.7	-290.5	941.9	1182.9	-241.0	1684.9	1941.1	-256.2	984.9	1145.4
-234.3	631.5	926.8	-295.2	597.1	877.7	-280.7	959.6	1193.4	-233.7	1456.7	1698.8	-242.1	1656.7	1898.5
-236.8	720.1	944.5	-224.4	658.8	950.5	-291.8	973.2	1217.1	-243.9	2455.4	2763.7	-308.2	3844.1	4240.3
-264.4	609.3	918.3	-308.9	596.7	887.4	-290.7	946.4	1187.9	-241.5	2161.6	2459.4	-297.8	3862.9	4263.7
-202.8	639.8	934.9	-295.2	588.1	879.0	-290.9	966.0	1210.0	-244.0	1965.4	2246.7	-281.3	1761.9	2003.9
-245.2	714.4	958.0	-243.6	702.8	966.9	-264.0	966.6	1201.4	-234.8	2592.6	2906.2	-313.6	3831.4	4227.0
-196.6			-228.6			-238.9			-214.1			-261.1		
47.0			35.8			34.8			20.8			34.1		

Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)	Experimental Room 1 (W)	Control Room (W)	Difference (W)
		17:00			18:00			19:00			20:00	
-390.9	3865.9	4292.8	-426.9	1516.0	1766.9	-251.0	176.3	200.6	-24.3	8.1	9.8	-1.7
-241.9	1486.0	1703.6	-217.6	684.5	811.7	-127.3	176.3	200.0	-23.8	11.6	14.0	-2.4
-241.1	1967.4	2237.6	-270.2	2121.5	2444.0	-322.5	519.3	456.0	63.3	11.6	14.0	-2.4
-170.5	931.3	1087.1	-155.8	590.1	701.1	-111.0	171.6	195.4	-23.8	7.0	8.4	-1.5
-390.9	3792.2	4210.9	-418.7	1491.2	1726.6	-235.4	408.2	381.9	26.4	10.4	12.6	-2.2
-371.8	2652.0	2974.3	-322.2	869.0	1020.8	-151.8	169.3	192.7	-23.4	7.0	8.4	-1.5
-428.7	4505.6	4980.2	-474.6	1315.1	1539.1	-224.0	172.7	195.4	-22.6	11.5	13.9	-2.4
-389.5	4021.9	4465.0	-443.0	1891.8	2189.4	-297.6	420.9	379.8	41.1	10.4	12.6	-2.2
-243.2	1499.5	1718.2	-218.7	686.8	814.1	-127.3	168.2	190.8	-22.6	7.0	8.4	-1.5
-242.6	1491.3	1709.0	-217.7	683.4	810.2	-126.7	166.2	188.5	-22.3	7.0	8.4	-1.5
-242.0	1490.7	1708.2	-217.5	676.5	802.0	-125.6	163.4	185.5	-22.1	5.8	7.0	-1.2
-390.6	3804.7	4224.1	-419.4	1486.6	1721.2	-234.6	395.5	367.4	28.1	9.2	11.1	-1.9
-389.0	3691.2	4108.1	-417.0	1885.0	2182.0	-297.0	396.1	356.2	39.9	9.2	11.1	-1.9
-346.6	3397.8	3790.3	-392.5	1706.6	1976.3	-269.6	371.8	337.2	34.6	9.2	11.1	-1.9
-392.0	4201.0	4662.0	-461.0	2376.1	2741.4	-365.3	413.6	367.8	45.8	0.0	0.0	0.0
-285.5	4148.3	4611.1	-462.8	2544.9	2932.1	-387.3	472.3	410.7	61.6	0.0	0.0	0.0
-243.1	1452.0	1662.6	-210.6	606.3	720.3	-113.9	96.7	116.4	-19.7	0.0	0.0	0.0
-298.1	2675.2	3011.9	-336.7	1662.7	1928.4	-265.7	398.5	368.4	30.1	0.0	0.0	0.0
-413.1	3244.7	3618.2	-373.4	853.0	1001.6	-148.6	152.3	171.7	-19.3	0.0	0.0	0.0
-388.1	3675.0	4089.9	-414.8	1863.6	2157.0	-293.4	391.9	349.1	42.8	0.0	0.0	0.0
-241.6	1469.1	1682.2	-213.0	609.3	753.8	-144.5	144.3	163.0	-18.7	0.0	0.0	0.0
-241.2	1462.2	1674.2	-212.0	606.8	750.7	-143.9	142.6	160.8	-18.2	0.0	0.0	0.0
-241.7	1464.4	1676.5	-212.1	604.3	747.7	-143.4	141.7	159.2	-17.5	0.0	0.0	0.0
-374.8	3873.0	4292.8	-419.8	1574.6	1983.6	-409.0	327.9	286.2	41.7	0.0	0.0	0.0
-160.2	705.0	827.5	-122.5	340.8	416.9	-76.1	86.8	104.5	-17.7	0.0	0.0	0.0
-160.5	920.0	1074.4	-154.3	752.8	939.4	-186.6	135.1	151.4	-16.3	0.0	0.0	0.0
-241.8	1465.0	1676.3	-211.3	594.9	736.2	-141.3	133.5	149.2	-15.8	0.0	0.0	0.0
-396.2	4412.0	4893.1	-481.0	2236.2	2829.5	-593.2	322.5	275.7	46.8	0.0	0.0	0.0
-400.8	3761.6	4161.8	-400.2	1207.1	1516.1	-309.0	273.9	250.7	23.2	0.0	0.0	0.0
-242.1	1463.9	1674.6	-210.7	587.2	726.9	-139.6	126.1	140.2	-14.1	0.0	0.0	0.0
-395.6	3634.3	4036.5	-402.2	1565.4	1972.2	-406.9	338.5	287.5	51.0	0.0	0.0	0.0
-309.5			-319.7			-231.3			7.6			-0.8
83.8			112.8			115.9			31.6			1.0

Average wall surface temperature data loggers' readings for the Month of June

day of the month	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)
		01:00			02:00			03:00			04:00		
1	26.80	24.71	2.09	26.60	24.67	1.93	26.40	24.62	1.78	26.20	24.58	1.62	26.00
2	26.8	24.7	2.09	26.6	24.7	1.94	26.4	24.6	1.82	26.2	24.5	1.71	26.0
3	27.0	24.6	2.40	26.7	24.5	2.21	26.5	24.4	2.13	26.2	24.3	1.95	26.0
4	27.4	24.7	2.69	27.1	24.6	2.52	26.8	24.4	2.36	26.5	24.3	2.16	26.3
5	25.9	24.1	1.77	25.7	24.0	1.67	25.5	23.9	1.61	25.3	23.8	1.53	25.1
6	26.8	24.0	2.76	26.9	24.0	2.90	26.9	24.0	2.87	26.9	24.1	2.82	26.9
7	28.4	25.2	3.18	28.4	25.2	3.19	28.3	25.2	3.10	28.2	25.2	3.01	28.1
8	27.6	24.7	2.86	27.6	24.8	2.85	27.5	24.8	2.72	27.4	24.8	2.59	27.4
9	28.2	25.1	3.07	28.1	25.1	2.98	28.1	25.1	2.98	28.0	25.1	2.88	27.9
10	28.2	25.5	2.74	28.1	25.4	2.65	28.0	25.5	2.54	28.0	25.5	2.51	27.9
11	29.1	25.9	3.23	29.0	25.9	3.12	28.9	25.9	3.04	28.8	25.8	2.98	28.6
12	27.8	25.8	1.98	27.8	25.8	1.98	27.8	25.9	1.94	27.8	25.9	1.89	27.8
13	29.4	26.7	2.65	29.4	26.7	2.68	29.3	26.7	2.59	29.2	26.8	2.44	29.1
14	29.1	27.2	1.90	29.1	27.2	1.90	29.1	27.2	1.90	29.0	27.2	1.80	29.0
15	30.3	27.2	3.10	30.1	27.1	2.97	29.9	27.1	2.81	29.7	27.1	2.61	29.6
16	30.7	27.9	2.75	30.6	27.9	2.65	30.5	27.9	2.58	30.4	27.9	2.47	30.3
17	31.0	28.0	2.97	30.9	28.0	2.95	30.7	27.9	2.83	30.5	27.8	2.65	30.4
18	29.6	27.6	1.97	29.6	27.6	1.99	29.5	27.6	1.89	29.5	27.6	1.88	29.4
19	30.5	27.5	3.00	30.3	27.4	2.89	30.2	27.3	2.88	30.0	27.3	2.71	29.8
20	29.7	27.3	2.40	29.6	27.3	2.33	29.5	27.2	2.27	29.4	27.2	2.20	29.3
21	30.7	27.3	3.39	30.6	27.3	3.29	30.4	27.3	3.09	30.3	27.3	2.98	30.2
22	29.9	27.7	2.22	29.8	27.7	2.13	29.8	27.7	2.14	29.7	27.7	2.02	29.6
23	30.3	28.2	2.14	30.2	28.1	2.14	30.1	28.0	2.13	30.0	27.9	2.10	29.9
24	30.8	28.0	2.75	30.6	28.0	2.58	30.5	28.0	2.51	30.3	28.0	2.34	30.2
25	30.3	28.1	2.22	30.3	28.1	2.22	30.2	28.1	2.13	30.1	28.1	2.03	30.0
26	31.3	28.6	2.71	31.2	28.5	2.65	31.0	28.5	2.48	30.9	28.5	2.39	30.8
27	30.3	28.5	1.80	30.3	28.4	1.85	30.2	28.4	1.80	30.1	28.4	1.72	30.0
28	30.3	27.6	2.67	30.2	27.6	2.64	30.1	27.5	2.63	29.9	27.4	2.49	29.8
29	29.3	26.9	2.41	29.2	26.9	2.34	29.1	26.8	2.26	29.0	26.8	2.17	28.8
30	29.5	26.9	2.64	29.4	26.9	2.52	29.4	26.9	2.51	29.3	26.9	2.38	29.2
AVG of the difference (°C)			2.6			2.5			2.4			2.3	
STD DEV of the difference (°C)			0.4			0.4			0.4			0.4	
	0	0		0	0		0	0		0	0		0
	29	18		29	18		29	18		29	18		26
	3.3	40.0		3.3	40.0		3.3	40.0		3.3	40.0		13.3

Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
05:00			06:00			07:00			08:00			09:00	
24.53	1.47	25.90	24.48	1.42	25.70	24.43	1.27	25.60	24.38	1.22	25.5	24.4	1.1
24.4	1.61	25.8	24.3	1.53	25.7	24.2	1.49	25.5	24.2	1.34	25.4	24.2	1.2
24.1	1.85	25.8	24.1	1.74	25.6	24.0	1.64	25.4	23.9	1.49	25.2	24.0	1.2
24.2	2.06	26.1	24.1	1.96	25.8	24.1	1.74	25.6	24.0	1.62	25.4	23.9	1.5
23.6	1.46	24.9	23.5	1.37	24.7	23.5	1.24	24.6	23.4	1.23	24.4	23.3	1.1
24.1	2.75	26.9	24.2	2.67	26.9	24.3	2.58	26.9	24.4	2.49	26.8	24.5	2.3
25.2	2.94	28.0	25.1	2.87	27.9	25.1	2.81	27.7	25.1	2.62	27.6	25.1	2.5
24.8	2.59	27.3	24.8	2.50	27.3	24.8	2.47	27.2	24.9	2.32	27.1	25.0	2.1
25.1	2.85	27.8	25.0	2.82	27.7	25.0	2.72	27.6	25.0	2.61	27.4	25.0	2.4
25.5	2.38	27.9	25.5	2.35	27.8	25.6	2.21	27.8	25.7	2.13	27.7	25.8	1.9
25.8	2.83	28.5	25.8	2.74	28.4	25.8	2.61	28.3	25.8	2.49	28.1	25.9	2.2
26.0	1.85	27.8	26.0	1.79	27.9	26.1	1.80	27.9	26.2	1.74	27.8	26.3	1.5
26.8	2.30	29.0	26.8	2.19	29.0	26.8	2.20	28.9	26.8	2.10	28.7	26.8	1.9
27.1	1.85	28.9	27.1	1.81	28.9	27.1	1.83	28.8	27.1	1.70	28.7	27.1	1.6
27.1	2.51	29.5	27.1	2.42	29.3	27.1	2.22	29.2	27.1	2.13	29.1	27.1	2.0
27.9	2.37	30.2	27.9	2.27	30.1	27.9	2.16	30.0	28.0	2.05	29.9	28.0	1.9
27.8	2.59	30.2	27.8	2.42	30.1	27.8	2.33	29.9	27.7	2.16	29.8	27.7	2.1
27.6	1.79	29.3	27.6	1.72	29.3	27.6	1.72	29.2	27.6	1.62	29.1	27.6	1.5
27.2	2.56	29.7	27.2	2.53	29.5	27.1	2.36	29.4	27.1	2.29	29.2	27.1	2.1
27.2	2.13	29.2	27.1	2.05	29.1	27.1	1.96	29.0	27.2	1.85	28.9	27.2	1.7
27.3	2.86	30.1	27.4	2.74	29.9	27.4	2.53	29.8	27.4	2.44	29.7	27.4	2.3
27.6	1.95	29.5	27.6	1.92	29.5	27.6	1.94	29.4	27.6	1.85	29.3	27.6	1.7
27.8	2.09	29.8	27.7	2.11	29.6	27.6	1.99	29.5	27.6	1.95	29.4	27.5	1.9
28.0	2.24	30.1	28.0	2.12	30.0	28.0	2.03	29.9	28.0	1.91	29.7	28.0	1.7
28.1	1.92	30.0	28.1	1.90	29.9	28.1	1.77	29.8	28.2	1.65	29.7	28.2	1.5
28.5	2.30	30.7	28.5	2.21	30.5	28.5	2.02	30.4	28.4	1.96	30.3	28.5	1.8
28.4	1.62	30.0	28.4	1.64	29.9	28.3	1.60	29.8	28.2	1.57	29.7	28.2	1.5
27.4	2.44	29.7	27.3	2.39	29.5	27.3	2.23	29.4	27.2	2.15	29.2	27.2	2.0
26.7	2.15	28.9	26.7	2.21	28.8	26.7	2.15	28.7	26.7	2.04	28.6	26.7	1.9
26.9	2.27	29.2	26.9	2.27	29.1	26.9	2.16	29.0	27.0	2.03	28.9	27.0	1.9
	2.2			2.2			2.1			2.0			1.8
	0.4			0.4			0.4			0.4			0.4

Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
	10:00			11:00			12:00			13:00			14:00	
25.4	24.4	1.0	25.4	24.5	0.9	25.5	24.6	0.9	25.6	24.8	0.8	25.7	25.0	0.7
25.3	24.2	1.1	25.3	24.3	1.0	25.4	24.6	0.8	25.5	24.8	0.7	25.7	25.0	0.7
25.1	24.2	0.9	0.0	0.0	0.0	25.3	24.6	0.7	25.4	24.8	0.6	25.6	24.9	0.7
25.3	24.0	1.3	25.2	24.0	1.2	25.2	24.1	1.1	25.3	24.2	1.1	25.4	24.4	1.0
24.3	23.4	0.9	24.3	23.5	0.8	24.3	23.6	0.7	24.4	23.8	0.6	24.6	23.9	0.7
26.6	24.7	1.9	26.4	24.9	1.5	26.4	25.0	1.4	26.4	25.2	1.2	26.4	25.3	1.1
27.3	25.1	2.2	27.0	25.3	1.7	26.9	25.4	1.5	26.8	25.5	1.3	26.8	25.5	1.3
27.0	25.1	1.9	26.8	25.3	1.5	26.7	25.4	1.3	26.7	25.5	1.2	26.8	25.6	1.2
27.3	25.2	2.1	27.1	25.4	1.7	27.0	25.5	1.5	27.0	25.7	1.3	27.0	25.8	1.2
27.5	25.8	1.7	27.3	25.9	1.4	27.2	26.0	1.2	27.2	26.1	1.1	27.2	26.3	0.9
27.9	26.0	1.9	27.7	26.1	1.6	27.6	26.3	1.3	27.6	26.5	1.1	27.6	26.6	1.0
27.7	26.4	1.3	27.6	26.5	1.1	27.5	26.6	0.9	27.6	26.8	0.8	27.7	26.9	0.8
28.5	26.9	1.6	28.4	27.0	1.4	28.3	27.1	1.2	28.2	27.1	1.1	28.3	27.3	1.0
28.5	27.2	1.3	28.4	27.4	1.0	28.4	27.6	0.8	28.4	27.8	0.6	28.5	28.0	0.5
28.9	27.2	1.7	28.7	27.3	1.4	28.6	27.4	1.2	28.6	27.5	1.1	28.6	27.6	1.0
29.7	28.1	1.6	29.6	28.2	1.4	29.5	28.4	1.1	29.6	28.5	1.1	29.6	28.7	0.9
29.5	27.7	1.8	29.3	27.8	1.5	29.2	28.0	1.2	29.2	28.2	1.0	29.2	28.3	0.9
28.9	27.7	1.2	28.8	27.8	1.0	28.7	27.9	0.8	28.7	27.9	0.8	28.8	28.0	0.8
28.9	27.2	1.7	28.7	27.4	1.3	28.6	27.5	1.1	28.6	27.6	1.0	28.6	27.8	0.8
28.7	27.3	1.4	28.5	27.4	1.1	28.4	27.4	1.0	28.4	27.5	0.9	28.4	27.5	0.9
29.4	27.5	1.9	29.2	27.6	1.6	29.2	27.8	1.4	29.2	28.0	1.2	29.2	28.1	1.1
29.1	27.7	1.4	29.0	27.8	1.2	29.0	28.0	1.0	29.0	28.3	0.7	29.1	28.4	0.7
29.2	27.6	1.6	29.0	27.7	1.3	28.9	27.8	1.1	28.9	27.9	1.0	28.9	28.1	0.8
29.5	28.1	1.4	29.4	28.2	1.2	29.3	28.3	1.0	29.3	28.4	0.9	29.3	28.5	0.8
29.6	28.3	1.3	29.4	28.4	1.0	29.4	28.5	0.9	29.4	28.7	0.7	29.5	28.8	0.7
30.1	28.5	1.6	29.9	28.6	1.3	29.9	28.8	1.1	29.9	28.9	1.0	29.9	29.0	0.9
29.5	28.1	1.4	29.3	28.2	1.1	29.2	28.2	1.0	29.1	28.2	0.9	29.2	28.3	0.9
29.0	27.3	1.7	28.8	27.3	1.5	28.7	27.4	1.3	28.6	27.6	1.0	28.7	27.7	1.0
28.4	26.8	1.6	28.3	27.0	1.3	28.2	27.2	1.0	28.2	27.3	0.9	28.3	27.4	0.9
28.8	27.1	1.7	28.6	27.2	1.4	28.5	27.3	1.2	28.5	27.5	1.0	28.6	27.6	1.0
		1.5			1.3			1.1			1.0			0.9
		0.3			0.3			0.2			0.2			0.2

Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
15:00:00			16:00			17:00			18:00			19:00		
25.9	25.1	0.8	26.1	25.2	0.9	26.5	25.3	1.2	26.9	25.4	1.5	27.3	25.4	1.9
25.9	25.2	0.7	26.1	25.4	0.7	26.5	25.5	1.0	27.0	25.6	1.4	27.5	25.6	1.9
25.8	25.1	0.7	26.0	25.3	0.7	26.4	25.4	1.0	27.0	25.5	1.5	27.7	25.6	2.1
25.5	24.6	0.9	25.7	24.8	0.9	26.0	24.9	1.1	26.2	24.9	1.3	26.4	24.9	1.5
24.7	24.1	0.6	25.0	24.3	0.7	25.4	24.5	0.9	26.1	24.7	1.4	26.8	24.8	2.0
26.5	25.4	1.1	26.6	25.5	1.1	27.0	25.6	1.4	27.5	25.8	1.7	28.1	25.9	2.2
26.8	25.6	1.2	26.9	25.7	1.2	27.1	25.6	1.5	27.4	25.5	1.9	27.7	25.6	2.1
26.8	25.7	1.1	27.0	25.9	1.1	27.3	26.0	1.3	27.7	26.0	1.7	28.2	26.0	2.2
27.1	26.0	1.1	27.3	26.2	1.1	27.6	26.2	1.4	27.9	26.2	1.7	28.1	26.2	1.9
27.3	26.5	0.8	27.5	26.6	0.9	27.9	26.7	1.2	28.4	26.8	1.6	29.1	26.9	2.2
27.7	26.6	1.1	27.8	26.7	1.1	27.9	26.7	1.2	27.9	26.7	1.2	27.9	26.6	1.3
27.8	27.0	0.8	28.0	27.1	0.9	28.3	27.3	1.0	28.8	27.5	1.3	29.3	27.5	1.8
28.3	27.5	0.8	28.4	27.7	0.7	28.6	27.9	0.7	28.9	27.9	1.0	29.1	27.9	1.2
28.7	28.2	0.5	28.9	28.3	0.6	29.3	28.4	0.9	29.9	28.5	1.4	30.5	28.5	2.0
28.7	27.8	0.9	28.8	27.9	0.9	29.2	28.0	1.2	29.7	28.1	1.6	30.3	28.2	2.1
29.7	28.8	0.9	29.9	28.9	1.0	30.2	28.9	1.3	30.7	29.0	1.7	31.2	29.0	2.2
29.3	28.4	0.9	29.4	28.6	0.8	29.6	28.6	1.0	29.8	28.6	1.2	29.9	28.4	1.5
28.9	28.1	0.8	29.0	28.3	0.7	29.4	28.4	1.0	30.0	28.4	1.6	30.6	28.4	2.2
28.7	27.9	0.8	28.8	28.1	0.7	29.0	28.1	0.9	29.4	28.1	1.3	29.8	28.1	1.7
28.5	27.6	0.9	28.6	27.7	0.9	29.0	27.9	1.1	29.6	28.0	1.6	30.3	28.1	2.2
29.3	28.3	1.0	29.5	28.5	1.0	29.7	28.5	1.2	29.9	28.6	1.3	30.1	28.5	1.6
29.3	28.6	0.7	29.5	28.8	0.7	29.8	28.9	0.9	30.1	29.0	1.1	30.4	28.9	1.5
29.0	28.3	0.7	29.2	28.5	0.7	29.6	28.7	0.9	30.1	28.9	1.2	30.8	28.9	1.9
29.4	28.7	0.7	29.5	28.8	0.7	29.8	28.9	0.9	30.2	28.9	1.3	30.5	28.8	1.7
29.6	28.9	0.7	29.8	29.1	0.7	30.1	29.2	0.9	30.7	29.3	1.4	31.3	29.4	1.9
30.0	29.1	0.9	30.1	29.3	0.8	30.3	29.3	1.0	30.4	29.4	1.0	30.6	29.3	1.3
29.2	28.4	0.8	29.4	28.6	0.8	29.7	28.7	1.0	30.1	28.8	1.3	30.5	28.7	1.8
28.8	27.8	1.0	28.9	27.8	1.1	29.0	27.9	1.1	29.2	27.9	1.3	29.5	27.9	1.6
28.4	27.5	0.9	28.5	27.6	0.9	28.8	27.7	1.1	29.2	27.7	1.5	29.6	27.7	1.9
28.7	27.8	0.9	28.9	28.0	0.9	29.3	28.2	1.1	29.8	28.2	1.6	30.4	28.2	2.2
		0.8			0.9			1.1			1.4			1.8
-	-	0.2	-	-	0.2	-	-	0.2	-	-	0.2	-	-	0.3

Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
	20:00			21:00			22:00			23:00			00:00	
27.5	25.2	2.3	27.5	25.1	2.4	27.4	24.9	2.5	27.2	24.8	2.4	27.0	24.8	2.2
27.8	25.4	2.4	27.9	25.2	2.7	27.7	25.1	2.6	27.5	24.9	2.6	27.2	24.7	2.5
28.1	25.5	2.6	28.2	25.3	2.9	28.1	25.2	2.9	27.9	25.0	2.9	27.7	24.8	2.9
26.5	24.9	1.6	26.5	24.8	1.7	26.4	24.6	1.8	26.3	24.4	1.9	26.1	24.2	1.9
27.3	24.8	2.5	27.4	24.6	2.8	27.3	24.4	2.9	27.2	24.3	2.9	26.9	24.1	2.8
28.5	25.8	2.7	28.6	25.6	3.0	28.6	25.5	3.1	28.5	25.3	3.2	28.5	25.3	3.2
27.9	25.5	2.4	27.9	25.2	2.7	27.7	25.0	2.7	27.7	24.9	2.8	27.6	24.8	2.8
28.5	25.9	2.6	28.5	25.6	2.9	28.4	25.4	3.0	28.3	25.3	3.0	28.3	25.2	3.1
28.3	26.1	2.2	28.2	26.0	2.2	28.2	25.9	2.3	28.2	25.7	2.5	28.2	25.6	2.6
29.5	26.7	2.8	29.6	26.4	3.2	29.5	26.2	3.3	29.4	26.0	3.4	29.3	25.9	3.4
27.9	26.4	1.5	27.8	26.2	1.6	27.7	26.0	1.7	27.7	25.9	1.8	27.7	25.8	1.9
29.6	27.4	2.2	29.6	27.3	2.3	29.6	27.1	2.5	29.5	26.9	2.6	29.5	26.8	2.7
29.2	27.8	1.4	29.2	27.6	1.6	29.1	27.5	1.6	29.1	27.3	1.8	29.1	27.2	1.9
30.9	28.3	2.6	31.0	28.0	3.0	30.8	27.8	3.0	30.6	27.5	3.1	30.5	27.3	3.2
30.7	28.2	2.5	30.9	28.1	2.8	30.8	28.0	2.8	30.8	27.9	2.9	30.8	27.9	2.9
31.5	28.8	2.7	31.5	28.5	3.0	31.4	28.4	3.0	31.3	28.2	3.1	31.2	28.1	3.1
30.0	28.3	1.7	29.9	28.1	1.8	29.7	27.9	1.8	29.7	27.8	1.9	29.7	27.7	2.0
31.0	28.3	2.7	31.0	28.0	3.0	30.9	27.8	3.1	30.8	27.7	3.1	30.7	27.6	3.1
30.0	27.9	2.1	29.9	27.7	2.2	29.8	27.6	2.2	29.7	27.5	2.2	29.7	27.4	2.3
30.9	28.0	2.9	31.0	27.8	3.2	31.0	27.6	3.4	30.9	27.5	3.4	30.8	27.4	3.4
30.2	28.3	1.9	30.2	28.1	2.1	30.1	28.0	2.1	30.0	27.8	2.2	29.9	27.7	2.2
30.5	28.8	1.7	30.5	28.6	1.9	30.4	28.4	2.0	30.4	28.3	2.1	30.4	28.2	2.2
31.2	28.8	2.4	31.3	28.6	2.7	31.2	28.4	2.8	31.1	28.2	2.9	30.9	28.1	2.8
30.7	28.6	2.1	30.7	28.5	2.2	30.6	28.3	2.3	30.5	28.2	2.3	30.4	28.1	2.3
31.7	29.3	2.4	31.8	29.1	2.7	31.7	28.9	2.8	31.6	28.8	2.8	31.5	28.7	2.8
30.7	29.2	1.5	30.6	29.0	1.6	30.5	28.9	1.6	30.4	28.7	1.7	30.4	28.5	1.9
30.8	28.6	2.2	30.8	28.3	2.5	30.7	28.0	2.7	30.6	27.8	2.8	30.5	27.7	2.8
29.6	27.8	1.8	29.6	27.6	2.0	29.5	27.4	2.1	29.4	27.1	2.3	29.4	27.0	2.4
29.9	27.5	2.4	29.9	27.3	2.6	29.7	27.1	2.6	29.6	26.9	2.7	29.6	26.9	2.7
30.6	28.1	2.5	30.7	27.9	2.8	30.6	27.7	2.9	30.5	27.6	2.9	30.4	27.6	2.8
		2.2			2.5			2.5			2.6			2.6
		0.4			0.5			0.5			0.5			0.5

Average wall surface temperature data loggers' readings for the Month of August

day of the month	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)
		01:00			02:00			03:00			04:00		
1	24.00	25.90	-1.90	24.92	28.80	-3.88	24.80	28.70	-3.90	24.69	27.90	-3.21	24.54
2	24.6	27.1	-2.51	24.4	26.9	-2.47	24.3	27.1	-2.80	24.3	26.9	-2.57	24.2
3	24.0	27.0	-2.96	23.9	27.0	-3.10	24.5	27.5	-3.01	24.4	27.8	-3.37	24.4
4	24.3	25.2	-0.87	24.8	25.0	-0.27	24.7	25.1	-0.44	24.7	25.0	-0.30	24.6
5	24.6	27.8	-3.15	24.5	28.4	-3.93	24.5	29.3	-4.78	24.6	29.1	-4.52	24.6
6	23.4	27.7	-4.31	23.2	27.8	-4.62	23.2	27.8	-4.57	23.3	28.9	-5.68	23.5
7	24.9	29.2	-4.33	24.8	27.3	-2.47	24.6	27.8	-3.22	24.5	27.8	-3.32	24.3
8	26.2	27.3	-1.06	25.7	27.8	-2.17	25.3	27.8	-2.46	25.1	28.8	-3.69	24.9
9	25.4	28.9	-3.51	25.3	28.9	-3.63	24.9	25.1	-0.19	24.6	28.0	-3.44	24.4
10	24.2	29.7	-5.49	24.3	28.6	-4.28	24.4	28.4	-4.00	24.3	28.6	-4.35	24.4
11	24.0	29.6	-5.67	24.2	30.3	-6.04	25.0	28.9	-3.89	24.2	27.9	-3.68	24.4
12	24.0	28.6	-4.68	24.0	29.7	-5.71	24.1	29.1	-5.06	24.2	28.6	-4.46	24.2
13	25.0	28.4	-3.35	24.2	28.1	-3.92	26.4	28.1	-1.76	24.4	28.4	-3.98	23.8
14	24.4	28.6	-4.27	24.7	28.5	-3.80	25.3	28.1	-2.80	25.5	28.6	-3.14	24.9
15	24.4	29.7	-5.32	25.1	28.6	-3.47	24.7	28.1	-3.40	24.4	28.6	-4.26	24.4
16	25.4	28.5	-3.10	23.7	28.1	-4.41	24.8	28.4	-3.63	26.0	28.1	-2.10	25.7
17	24.8	28.9	-4.10	24.9	28.9	-4.00	25.5	28.9	-3.40	25.0	28.9	-3.89	24.2
18	24.9	25.5	-0.59	24.4	25.4	-1.01	24.2	25.2	-1.00	24.9	25.5	-0.60	24.0
19	24.2	28.9	-4.72	24.2	28.9	-4.67	25.0	25.8	-0.82	24.2	28.9	-4.72	26.4
20	25.5	29.2	-3.61	24.2	28.5	-4.30	24.4	29.5	-5.17	24.2	28.9	-4.63	24.4
21	24.4	29.3	-4.97	24.2	26.5	-2.35	24.1	26.6	-2.47	24.9	26.9	-1.95	24.8
22	24.2	26.4	-2.21	24.1	26.7	-2.64	24.9	27.1	-2.16	24.8	29.3	-4.49	24.7
23	24.7	29.5	-4.85	24.6	26.1	-1.57	24.5	29.5	-5.01	24.3	26.3	-1.96	24.2
24	24.2	29.5	-5.33	24.1	26.1	-2.01	24.1	26.4	-2.25	24.1	26.7	-2.60	24.9
25	24.9	26.7	-1.83	24.3	26.7	-2.35	24.3	26.6	-2.34	24.1	26.4	-2.32	24.1
26	24.9	26.6	-1.67	24.0	26.4	-2.39	24.3	26.1	-1.83	24.3	25.9	-1.57	24.1
27	24.1	26.2	-2.04	24.2	26.0	-1.81	24.3	25.5	-1.19	24.3	29.8	-5.54	24.1
28	24.1	26.0	-1.90	24.1	26.0	-1.83	24.1	25.9	-1.78	24.9	25.9	-0.95	24.3
29	24.3	27.6	-3.30	24.7	27.4	-2.72	24.5	27.1	-2.58	24.4	26.9	-2.48	24.1
30	24.2	28.1	-3.91	24.1	27.7	-3.59	24.1	27.4	-3.33	24.1	27.2	-3.12	24.9
31	24.2	28.0	-3.80	24.3	27.9	-3.60	24.7	27.8	-3.09	24.6	27.6	-3.08	24.4
AVG of the difference (°C)			-3.4			-3.2			-2.8			-3.2	
STD DEV of the difference (°C)			1.4			1.3			1.3			1.3	

Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
05:00			06:00			07:00			08:00			09:00	
28.60	-4.06	24.41	28.60	-4.19	24.26	27.20	-2.94	24.12	27.20	-3.08	24.1	27.2	-3.1
26.9	-2.72	24.2	27.9	-3.73	24.0	27.9	-3.86	23.9	26.9	-3.00	24.5	27.1	-2.6
27.8	-3.40	24.4	27.0	-2.62	24.3	27.8	-3.54	24.3	27.8	-3.55	24.4	27.8	-3.4
26.8	-2.16	24.4	26.8	-2.38	24.3	27.9	-3.59	24.2	27.5	-3.30	24.2	27.5	-3.3
28.4	-3.74	24.5	27.7	-3.15	24.3	27.8	-3.46	24.2	27.8	-3.53	24.3	28.9	-4.6
29.0	-5.50	23.6	29.2	-5.56	23.5	27.3	-3.77	23.6	27.8	-4.25	23.8	27.8	-4.0
28.8	-4.49	24.3	28.5	-4.19	24.3	29.1	-4.84	23.9	28.0	-4.15	23.9	27.8	-3.9
28.5	-3.63	24.7	29.1	-4.44	24.6	28.0	-3.39	24.6	27.8	-3.11	24.4	27.8	-3.4
28.7	-4.33	24.4	28.7	-4.26	24.5	28.7	-4.15	24.5	28.9	-4.44	24.5	28.9	-4.4
28.4	-4.03	24.4	28.2	-3.81	24.2	28.6	-4.43	24.3	28.4	-4.11	24.4	28.2	-3.8
25.7	-1.36	23.8	25.4	-1.51	24.2	29.1	-4.94	25.0	28.3	-3.35	24.1	28.1	-4.0
28.1	-3.88	24.4	28.1	-3.75	24.4	28.4	-4.00	24.5	28.6	-4.03	24.7	28.3	-3.6
28.1	-4.26	24.2	28.1	-3.94	25.0	28.4	-3.45	24.1	28.1	-4.04	23.8	28.1	-4.3
28.5	-3.60	25.2	28.1	-2.90	25.8	28.6	-2.84	24.4	28.5	-4.13	25.0	28.1	-3.1
28.4	-4.04	24.4	28.2	-3.88	24.3	28.6	-4.34	24.4	28.6	-4.16	24.4	28.2	-3.9
28.1	-2.41	25.2	28.4	-3.23	25.1	28.3	-3.20	24.7	28.7	-3.96	25.0	28.4	-3.4
28.9	-4.72	26.4	26.4	-0.06	26.2	26.8	-0.59	26.8	27.2	-0.37	24.1	27.1	-3.1
25.2	-1.20	24.5	28.9	-4.36	25.8	28.9	-3.15	24.4	28.9	-4.49	24.1	28.9	-4.8
28.9	-2.54	26.4	28.9	-2.50	24.2	28.9	-4.72	26.4	28.9	-2.54	24.4	28.9	-4.5
29.5	-5.09	25.5	28.6	-3.08	24.2	29.4	-5.21	24.1	29.5	-5.38	24.2	29.0	-4.8
29.5	-4.65	24.7	26.1	-1.44	24.6	26.4	-1.82	24.4	26.7	-2.32	24.3	27.1	-2.8
26.5	-1.83	24.6	26.6	-2.02	24.4	26.9	-2.44	24.3	29.5	-5.20	24.1	26.1	-2.0
29.3	-5.19	24.1	29.5	-5.42	24.1	26.1	-2.02	24.1	26.2	-2.07	24.2	26.9	-2.7
27.1	-2.13	24.3	29.3	-5.04	24.3	29.6	-5.33	24.1	29.2	-5.03	24.1	26.2	-2.1
26.3	-2.19	24.1	26.1	-1.99	24.9	26.1	-1.17	24.3	26.0	-1.68	24.3	26.0	-1.7
26.0	-1.92	24.1	26.1	-1.98	24.9	26.0	-1.08	24.0	25.7	-1.74	24.3	25.9	-1.6
30.6	-6.44	24.1	28.9	-4.85	24.1	29.8	-5.74	24.3	30.6	-6.27	24.3	28.9	-4.6
25.8	-1.49	24.3	25.8	-1.49	24.6	25.7	-1.12	24.5	25.3	-0.83	24.3	25.5	-1.1
26.5	-2.39	24.1	26.5	-2.42	24.1	26.5	-2.39	24.1	26.5	-2.45	24.9	26.6	-1.7
27.2	-2.31	24.3	27.0	-2.74	24.3	27.0	-2.74	24.6	27.0	-2.40	24.5	27.0	-2.5
27.6	-3.13	24.3	27.5	-3.22	24.1	27.5	-3.34	24.1	27.4	-3.31	24.1	27.4	-3.3
	-3.4			-3.2			-3.3			-3.4			-3.3
	1.3			1.3			1.3			1.3			1.0

Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
	10:00			11:00			12:00			13:00			14:00	
24.2	27.2	-3.0	24.8	27.2	-2.4	25.2	27.2	-2.0	26.0	27.2	-1.2	25.0	27.8	-2.8
24.2	27.9	-3.7	24.2	28.0	-3.8	24.0	28.2	-4.1	23.9	28.3	-4.4	24.2	27.6	-3.4
24.2	26.9	-2.6	0.0	0.0	0.0	24.7	26.9	-2.2	24.2	26.7	-2.4	24.2	27.8	-3.6
24.9	27.5	-2.6	25.8	27.8	-2.0	25.0	27.8	-2.8	25.2	28.9	-3.7	25.0	29.0	-4.0
24.6	29.0	-4.4	25.3	29.2	-3.9	25.4	27.3	-1.9	25.4	27.8	-2.4	25.1	27.8	-2.7
23.9	28.8	-4.9	24.3	28.5	-4.2	24.5	29.1	-4.6	24.8	28.0	-3.2	25.8	27.8	-2.0
24.2	27.8	-3.6	24.9	28.4	-3.6	25.9	29.3	-3.4	25.1	29.1	-4.0	25.1	29.2	-4.1
24.5	28.4	-3.9	24.6	29.3	-4.7	24.4	29.1	-4.7	24.4	28.4	-4.0	24.7	27.7	-3.0
24.5	28.9	-4.4	24.6	28.7	-4.0	24.6	28.7	-4.1	24.4	28.7	-4.3	24.2	28.1	-3.9
24.6	28.6	-4.1	24.1	28.4	-4.3	24.1	28.2	-4.1	24.0	28.6	-4.7	24.2	28.4	-4.2
24.7	29.1	-4.4	24.2	28.3	-4.1	23.9	28.1	-4.2	24.1	29.1	-5.1	24.7	28.3	-3.6
25.0	28.5	-3.5	25.0	28.4	-3.4	25.5	28.4	-2.8	25.8	28.2	-2.5	24.4	28.6	-4.3
25.0	28.4	-3.4	24.4	28.4	-4.0	24.4	28.1	-3.7	24.0	28.1	-4.1	24.9	28.4	-3.5
25.3	29.1	-3.8	24.4	28.3	-4.0	24.9	28.1	-3.2	25.1	29.1	-4.0	24.8	28.3	-3.5
24.4	28.6	-4.3	24.6	28.4	-3.8	24.4	28.2	-3.9	24.4	28.9	-4.5	24.4	28.1	-3.7
26.2	29.4	-3.2	25.6	29.4	-3.8	23.9	30.2	-6.3	23.7	29.1	-5.4	25.1	28.5	-3.4
24.2	27.1	-2.9	24.2	27.5	-3.2	24.4	27.5	-3.1	24.4	29.4	-5.0	25.8	29.6	-3.8
24.2	25.8	-1.6	26.2	27.3	-1.1	24.0	28.5	-4.5	24.5	29.2	-4.7	25.8	30.0	-4.3
24.4	26.1	-1.6	25.8	28.9	-3.1	24.4	28.9	-4.5	24.8	28.8	-4.0	24.2	28.9	-4.7
24.1	28.2	-4.1	24.2	29.5	-5.2	24.1	26.3	-2.2	24.9	26.4	-1.5	24.8	27.0	-2.2
24.1	29.3	-5.2	24.1	26.5	-2.4	24.9	26.6	-1.7	24.8	26.9	-2.1	24.7	29.5	-4.8
24.1	26.4	-2.2	24.1	26.7	-2.6	24.1	27.1	-3.0	24.3	29.5	-5.2	24.3	26.2	-1.9
24.3	29.6	-5.3	24.3	29.2	-4.9	24.1	26.2	-2.1	24.1	26.7	-2.6	24.1	27.1	-3.0
24.1	26.7	-2.6	24.2	27.1	-2.9	24.3	27.0	-2.7	24.3	27.8	-3.5	24.1	29.1	-4.9
24.1	26.7	-2.6	24.9	27.5	-2.6	24.3	28.3	-4.0	24.3	29.1	-4.8	24.2	29.7	-5.5
24.3	26.4	-2.1	24.9	27.1	-2.2	24.0	28.3	-4.3	24.3	29.7	-5.4	24.3	30.4	-6.1
24.3	29.8	-5.5	24.6	30.6	-5.9	24.5	28.9	-4.4	24.4	29.8	-5.4	24.2	30.6	-6.4
24.2	26.2	-2.0	24.1	27.0	-2.8	24.1	28.1	-4.0	24.1	29.2	-5.1	24.2	30.4	-6.2
24.0	26.9	-2.9	24.3	27.6	-3.3	24.7	28.2	-3.6	24.5	29.3	-4.7	24.4	31.1	-6.7
24.4	27.0	-2.7	24.2	27.2	-3.1	24.1	27.7	-3.6	24.1	27.5	-3.4	24.1	28.0	-3.9
24.1	27.4	-3.3	24.3	27.4	-3.1	24.3	27.4	-3.1	24.0	27.0	-3.0	25.0	28.8	-3.8
		-3.4			-3.4			-3.5			-3.9			-4.0
		1.0			1.2			1.0			1.2			1.2

Temperatures

Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
	15:00:00			16:00			17:00			18:00			19:00	
26.1	28.8	-2.7	26.1	29.9	-3.8	26.4	29.9	-3.5	26.1	28.9	-2.8	25.3	28.9	-3.6
24.1	28.4	-4.3	24.0	27.8	-3.8	24.2	27.7	-3.5	24.2	26.9	-2.7	24.0	25.8	-1.8
24.5	28.1	-3.5	24.3	27.8	-3.5	24.2	27.6	-3.4	24.4	27.2	-2.8	24.3	26.7	-2.4
25.3	29.2	-3.9	25.3	27.3	-2.0	25.3	27.8	-2.5	25.3	27.3	-2.0	25.3	26.1	-0.8
24.9	28.8	-3.9	25.6	28.5	-3.0	26.0	29.1	-3.1	25.9	28.0	-2.1	25.6	27.8	-2.2
26.8	27.8	-1.0	28.0	28.4	-0.4	27.6	29.3	-1.7	26.9	29.1	-2.2	26.5	28.4	-1.9
25.3	29.1	-3.8	25.7	29.1	-3.3	26.2	29.2	-3.0	26.7	29.0	-2.2	25.8	27.7	-1.9
25.2	27.8	-2.6	25.9	27.8	-1.8	25.9	28.9	-3.1	26.1	29.0	-3.0	26.1	29.2	-3.1
24.2	28.0	-3.8	24.3	28.1	-3.8	24.3	28.1	-3.8	24.5	28.1	-3.6	25.3	28.1	-2.8
24.1	28.2	-4.1	24.1	28.6	-4.6	23.9	28.4	-4.5	24.0	28.2	-4.3	24.5	28.6	-4.1
25.8	28.1	-2.3	24.5	29.7	-5.1	24.2	28.6	-4.4	23.9	28.1	-4.2	24.0	29.7	-5.7
26.8	28.4	-1.6	24.5	28.2	-3.7	23.9	28.6	-4.8	24.4	28.4	-4.0	25.5	28.2	-2.7
24.5	28.1	-3.6	24.9	28.1	-3.2	25.0	28.4	-3.4	25.5	28.1	-2.6	24.8	28.1	-3.3
25.0	28.1	-3.1	25.1	29.1	-4.0	25.3	28.3	-3.0	24.1	28.1	-4.0	24.9	29.7	-4.8
24.9	28.7	-3.8	24.4	28.1	-3.7	25.0	28.1	-3.1	24.4	28.4	-4.0	24.4	28.1	-3.7
24.0	26.9	-2.9	24.0	25.9	-1.9	23.2	26.9	-3.7	24.0	28.5	-4.5	26.7	28.0	-1.3
24.4	30.5	-6.1	26.8	29.3	-2.5	24.1	28.9	-4.8	24.7	28.3	-3.6	25.8	27.7	-1.9
24.4	30.2	-5.7	24.1	30.7	-6.7	24.2	30.5	-6.3	26.2	30.4	-4.1	24.0	28.9	-4.9
24.4	28.9	-4.5	24.9	25.7	-0.8	24.1	29.4	-5.4	24.7	29.5	-4.8	25.8	28.5	-2.6
24.7	27.0	-2.3	24.5	29.3	-4.8	24.4	26.5	-2.1	24.2	26.6	-2.3	24.1	26.9	-2.8
24.5	26.1	-1.6	24.4	26.4	-2.0	24.2	26.7	-2.5	24.1	27.1	-3.0	24.1	29.3	-5.2
24.3	26.7	-2.4	24.1	26.9	-2.7	24.1	29.5	-5.4	24.9	26.1	-1.2	24.0	29.3	-5.3
24.3	29.5	-5.2	24.3	26.3	-2.0	24.3	29.5	-5.2	24.1	26.2	-2.1	24.1	26.7	-2.6
24.1	28.8	-4.6	24.9	29.0	-4.1	24.7	29.9	-5.2	24.6	30.3	-5.7	24.5	29.8	-5.3
24.1	29.5	-5.4	24.9	30.8	-5.9	24.8	31.3	-6.5	24.7	31.1	-6.4	24.5	30.5	-6.0
24.1	31.6	-7.5	24.1	32.6	-8.5	24.9	33.0	-8.1	24.7	32.3	-7.7	24.6	31.7	-7.2
24.1	28.9	-4.8	24.1	28.8	-4.7	24.1	28.3	-4.2	24.9	28.4	-3.5	24.3	27.4	-3.1
24.3	31.7	-7.4	24.7	32.5	-7.8	24.6	31.9	-7.4	24.4	31.6	-7.2	24.3	31.4	-7.1
24.2	31.7	-7.5	24.1	33.2	-9.1	24.1	33.2	-9.1	24.1	33.5	-9.4	24.9	33.2	-8.2
24.9	26.5	-1.5	24.3	27.4	-3.1	24.3	27.7	-3.4	24.6	27.7	-3.2	24.5	27.7	-3.2
24.8	28.7	-3.9	24.7	27.9	-3.2	24.5	28.6	-4.1	24.4	28.6	-4.2	24.3	27.2	-2.9
		-3.9			-3.9			-4.3			-3.8			-3.7
		1.7			2.0			1.7			1.8			1.8

Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
	20:00			21:00			22:00			23:00			00:00	
25.0	28.9	-3.9	24.9	28.9	-4.0	24.7	26.9	-2.2	24.6	26.9	-2.3	24.7	26.9	-2.2
23.9	25.3	-1.4	24.7	25.3	-0.6	24.8	25.4	-0.5	24.2	25.3	-1.1	24.2	25.0	-0.8
24.2	25.9	-1.7	24.4	25.8	-1.4	24.4	25.6	-1.3	24.4	25.6	-1.2	24.2	25.4	-1.1
25.3	27.7	-2.4	25.5	27.8	-2.3	25.2	27.2	-2.0	25.0	26.3	-1.3	24.8	25.1	-0.3
24.7	27.8	-3.1	24.7	28.4	-3.7	24.7	29.3	-4.5	24.5	29.1	-4.6	23.8	28.4	-4.6
26.3	27.7	-1.4	25.6	27.8	-2.2	25.2	27.8	-2.5	25.0	28.9	-3.9	24.7	29.0	-4.3
25.7	27.8	-2.1	25.1	27.8	-2.7	27.9	28.9	-1.0	27.0	29.0	-2.0	27.1	29.2	-2.1
26.1	27.3	-1.2	25.4	27.8	-2.4	25.4	28.9	-3.5	25.4	28.0	-2.6	24.8	28.9	-4.1
26.3	28.1	-1.8	26.9	28.1	-1.2	24.1	28.1	-4.0	24.3	28.1	-3.8	24.2	28.1	-3.9
25.8	28.4	-2.7	24.4	28.2	-3.8	24.1	28.6	-4.6	24.7	28.4	-3.7	24.5	28.2	-3.7
24.5	28.6	-4.0	25.8	28.1	-2.3	24.4	29.7	-5.3	24.1	28.6	-4.5	23.8	28.1	-4.3
24.2	28.1	-3.9	26.2	28.1	-1.9	24.4	28.4	-3.9	24.0	28.1	-4.1	24.2	28.1	-3.9
25.2	28.4	-3.2	25.0	28.1	-3.1	24.1	28.1	-4.0	25.8	28.4	-2.6	25.2	28.1	-2.9
25.9	28.6	-2.7	24.4	28.1	-3.7	24.4	29.7	-5.3	24.4	28.6	-4.2	26.1	28.1	-2.0
24.4	29.0	-4.6	24.4	28.4	-4.0	23.5	28.1	-4.6	24.7	28.1	-3.4	25.4	28.4	-3.0
25.4	28.5	-3.1	24.9	28.5	-3.6	24.4	28.9	-4.5	24.8	28.9	-4.1	25.7	28.9	-3.2
24.5	26.8	-2.3	24.2	26.1	-2.0	24.2	25.8	-1.6	25.0	25.6	-0.6	24.2	26.1	-1.9
24.5	27.4	-2.8	25.8	26.8	-1.0	24.4	26.4	-2.0	24.1	26.3	-2.2	24.5	26.2	-1.7
24.1	27.1	-3.0	24.7	26.6	-1.9	24.1	26.0	-2.0	24.2	26.0	-1.8	24.4	29.6	-5.3
24.1	29.5	-5.4	25.0	26.1	-1.2	24.7	26.4	-1.7	24.6	26.7	-2.1	24.5	27.1	-2.6
25.0	26.5	-1.6	24.7	26.6	-1.9	24.6	26.9	-2.3	24.5	29.5	-5.0	24.4	26.1	-1.8
24.3	26.5	-2.2	24.3	26.6	-2.3	24.1	26.9	-2.8	24.1	29.5	-5.4	24.9	26.1	-1.2
25.0	26.9	-1.9	24.7	29.5	-4.7	24.6	26.3	-1.7	24.5	26.4	-1.9	24.4	27.0	-2.6
24.4	29.0	-4.6	24.2	28.2	-4.0	24.1	27.3	-3.2	24.1	27.0	-2.9	24.1	27.0	-2.9
24.4	29.8	-5.4	24.3	28.5	-4.2	24.1	27.6	-3.5	24.1	27.3	-3.1	24.1	26.9	-2.8
24.5	29.6	-5.1	24.3	28.1	-3.7	24.2	27.1	-2.9	24.1	26.6	-2.5	24.1	26.5	-2.4
24.6	26.8	-2.1	24.6	26.7	-2.1	24.5	26.2	-1.7	24.4	26.1	-1.7	24.2	26.0	-1.9
24.1	30.2	-6.1	24.1	29.2	-5.1	24.1	28.4	-4.3	24.1	28.2	-4.1	24.3	27.8	-3.5
24.0	32.5	-8.5	24.3	31.1	-6.8	24.6	30.0	-5.4	24.5	28.8	-4.3	24.4	28.2	-3.8
24.3	27.6	-3.3	24.2	27.6	-3.5	24.1	27.8	-3.6	24.1	28.3	-4.2	24.1	28.2	-4.1
24.1	27.2	-3.1	25.3	28.9	-3.6	25.0	28.9	-3.9	24.9	28.9	-4.0	24.7	26.9	-2.2
		-3.2			-2.9			-3.1			-3.1			-2.8
		1.6			1.4			1.4			1.3			1.2

Average indoor air temperature data loggers' readings for the Month of June

day of the month	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)
	01:00			02:00			03:00			04:00			05:00	
1	30.22	30.00	0.22	29.50	29.41	0.09	29.32	29.00	0.32	28.28	28.00	0.28	28.16	28.00
2	28.7	28.8	-0.09	28.5	28.4	0.07	28.1	27.9	0.16	27.2	27.5	-0.33	27.0	27.9
3	29.0	26.9	2.12	28.5	27.0	1.43	28.3	27.2	1.11	27.3	27.0	0.33	27.3	26.9
4	29.3	29.0	0.34	29.1	29.0	0.10	27.9	27.8	0.14	27.8	27.8	-0.02	27.4	27.3
5	27.9	29.0	-1.11	28.0	29.6	-1.62	27.8	30.4	-2.62	27.2	29.8	-2.52	27.1	29.5
6	27.4	28.2	-0.74	27.8	28.2	-0.43	27.5	26.4	1.03	27.2	26.6	0.64	27.0	26.8
7	28.0	28.2	-0.17	28.5	27.5	0.95	27.4	27.7	-0.33	26.7	27.9	-1.22	26.8	28.0
8	26.6	28.1	-1.45	26.4	28.3	-1.96	26.5	28.8	-2.24	27.0	28.8	-1.76	27.6	28.6
9	27.4	27.0	0.41	27.5	26.9	0.61	27.0	26.8	0.18	27.5	26.7	0.75	28.3	26.8
10	28.6	27.5	1.14	28.6	27.3	1.27	26.7	27.3	-0.63	27.2	27.0	0.13	27.8	26.9
11	29.4	26.3	3.16	29.4	26.2	3.20	29.4	26.2	3.27	27.5	26.1	1.37	27.6	25.8
12	26.9	27.9	-0.98	26.8	27.8	-0.95	26.7	27.7	-1.05	26.4	26.6	-0.19	26.4	26.9
13	28.1	27.6	0.51	28.1	28.3	-0.24	28.1	28.2	-0.15	28.1	27.7	0.34	27.1	27.0
14	28.3	27.5	0.78	28.2	28.3	-0.11	28.2	28.4	-0.21	27.9	27.9	0.00	27.7	26.5
15	26.9	27.2	-0.36	26.9	26.9	0.01	27.1	27.4	-0.32	26.8	28.9	-2.05	26.7	28.9
16	27.2	27.1	0.11	27.2	27.4	-0.25	27.3	28.5	-1.23	27.1	28.4	-1.30	27.1	28.1
17	27.0	26.9	0.14	26.8	27.4	-0.53	26.6	28.7	-2.14	26.2	28.8	-2.61	26.2	28.7
18	28.3	27.2	1.05	28.2	27.1	1.04	27.8	27.1	0.72	27.7	27.4	0.23	27.8	27.4
19	26.5	27.2	-0.75	28.0	27.0	1.04	29.1	27.2	1.93	28.2	27.6	0.55	27.8	27.9
20	28.8	26.7	2.12	28.8	26.8	2.00	28.4	27.2	1.22	28.4	27.5	0.93	26.5	27.8
21	27.1	28.7	-1.59	27.6	28.7	-1.13	27.9	29.1	-1.19	27.4	29.0	-1.54	27.2	28.9
22	28.5	27.4	1.14	28.0	27.2	0.74	27.9	26.5	1.40	27.2	27.1	0.12	27.1	27.6
23	26.8	27.1	-0.34	27.2	27.5	-0.27	26.5	27.9	-1.40	28.2	27.7	0.43	28.5	27.4
24	27.9	27.2	0.74	27.4	27.0	0.44	27.2	26.9	0.37	26.8	26.2	0.58	26.8	26.6
25	27.6	25.2	2.43	27.9	25.7	2.21	27.4	26.0	1.40	27.2	26.3	0.94	26.8	26.6
26	26.2	26.3	-0.15	26.1	26.3	-0.20	25.8	26.2	-0.39	25.8	26.0	-0.26	26.3	25.5
27	27.6	26.6	0.99	28.2	26.5	1.70	28.2	27.1	1.07	28.3	27.1	1.20	27.9	26.6
28	27.0	27.9	-0.88	27.5	27.9	-0.35	28.3	26.5	1.80	28.3	27.2	1.10	28.2	28.2
29	29.0	27.0	1.92	28.9	29.1	-0.12	28.8	29.3	-0.55	27.7	28.3	-0.67	28.3	28.0
30	27.9	26.7	1.20	28.1	25.5	2.64	28.7	28.5	0.19	28.7	28.5	0.25	29.1	28.9
AVG of the difference (°C)			0.4			0.4			0.1			-0.1		
STD DEV of the difference (°C)			1.2			1.2			1.3			1.1		

Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)
	06:00			07:00			08:00			09:00			10:00	
0.16	27.79	27.50	0.29	27.65	27.57	0.09	27.90	27.60	0.30	27.7	27.6	0.1	27.1	27.6
-0.91	27.0	27.7	-0.76	27.7	27.4	0.36	28.1	27.6	0.50	27.7	26.0	1.7	26.8	26.6
0.45	28.6	26.2	2.33	28.3	26.6	1.73	28.2	26.6	1.58	28.3	26.8	1.5	27.1	26.8
0.05	27.9	27.8	0.13	28.9	29.0	-0.15	29.4	29.0	0.37	28.9	29.0	-0.1	28.3	28.4
-2.42	27.1	27.6	-0.55	27.4	27.3	0.16	27.4	27.5	-0.06	27.3	27.3	-0.1	26.9	27.5
0.11	27.2	27.3	-0.11	27.6	27.7	-0.02	27.9	26.8	1.07	27.6	27.2	0.4	27.1	27.3
-1.24	27.2	28.2	-1.06	27.5	28.1	-0.58	27.8	27.9	-0.03	27.5	27.1	0.3	26.5	27.4
-1.08	27.6	27.6	0.08	27.9	27.8	0.14	27.5	27.7	-0.20	27.6	28.1	-0.5	27.6	28.2
1.50	27.7	26.6	1.12	27.5	26.5	0.99	28.7	26.8	1.90	27.0	26.8	0.2	27.2	26.6
0.88	27.5	26.8	0.70	27.5	26.8	0.75	27.4	26.7	0.62	27.4	26.8	0.6	27.4	26.8
1.83	28.2	25.8	2.43	27.7	26.3	1.34	27.3	27.7	-0.37	27.2	27.1	0.1	26.6	26.9
-0.55	26.8	27.8	-0.98	27.4	29.7	-2.33	27.3	28.7	-1.38	27.2	28.4	-1.2	27.0	26.9
0.13	27.9	27.1	0.81	28.1	27.3	0.81	27.9	27.4	0.47	27.7	27.7	0.0	27.4	27.1
1.26	27.9	27.0	0.83	28.2	29.8	-1.58	28.3	28.3	0.02	28.2	27.8	0.4	27.9	27.5
-2.21	27.2	28.7	-1.57	27.4	28.2	-0.79	27.2	27.4	-0.20	27.1	25.6	1.5	26.5	25.9
-0.97	27.5	27.3	0.25	27.4	27.0	0.36	27.0	27.9	-0.94	26.6	31.3	-4.6	26.0	27.6
-2.45	26.6	28.7	-2.04	26.7	28.7	-1.98	26.4	28.7	-2.25	26.2	28.7	-2.5	25.9	28.7
0.34	27.7	27.3	0.42	27.1	26.9	0.23	27.3	26.6	0.64	27.9	27.9	0.1	27.8	27.9
-0.02	27.0	27.6	-0.57	26.9	27.1	-0.21	27.3	27.1	0.13	27.9	27.9	-0.1	28.5	27.9
-1.34	28.2	27.5	0.70	28.5	26.5	2.03	28.0	26.6	1.38	27.9	27.7	0.2	27.2	27.4
-1.70	26.8	27.2	-0.39	26.8	27.3	-0.48	27.2	27.2	0.01	26.5	27.3	-0.8	28.2	27.6
-0.47	27.6	28.6	-1.01	27.9	28.5	-0.56	27.4	28.3	-0.86	27.2	28.2	-0.9	26.8	27.5
1.15	28.0	27.1	0.90	27.9	26.0	1.89	27.2	26.6	0.59	27.1	26.8	0.3	27.6	27.4
0.17	27.2	26.6	0.60	26.5	26.8	-0.32	28.2	26.8	1.36	28.5	26.7	1.8	28.0	26.5
0.15	26.8	26.6	0.18	27.2	26.4	0.86	26.5	25.9	0.61	28.2	26.4	1.8	28.5	26.5
0.80	27.7	26.1	1.61	27.1	26.5	0.61	26.9	26.8	0.08	26.3	26.8	-0.5	26.2	26.5
1.27	27.7	26.3	1.32	27.4	26.1	1.29	26.6	26.7	-0.12	27.0	27.3	-0.3	27.2	27.3
0.04	27.5	28.5	-0.97	27.7	29.1	-1.31	27.9	28.5	-0.64	28.0	28.3	-0.2	28.2	27.1
0.31	28.1	28.0	0.06	28.3	28.0	0.31	28.8	28.1	0.66	28.8	28.0	0.8	28.6	28.8
0.19	29.0	29.3	-0.30	28.9	28.4	0.58	27.2	27.3	-0.09	27.3	25.7	1.5	27.2	25.1
-0.2			0.1			0.1			0.2			0.0		
1.1			1.0			1.0			0.9			1.3		

Temperatures

Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
		11:00			12:00			13:00			14:00			15:00:00	
-0.5	27.3	27.6	-0.3	27.9	27.8	0.1	27.8	27.4	0.3	27.4	27.5	-0.1	27.7	27.3	0.4
0.2	26.6	26.8	-0.2	28.2	27.4	0.9	28.1	27.7	0.4	28.6	27.4	1.2	28.1	27.1	1.0
0.3	0.0	0.0	0.0	28.6	26.5	2.1	28.6	28.0	0.6	28.5	28.7	-0.2	28.1	27.9	0.2
-0.1	28.1	28.1	0.0	28.9	28.8	0.1	28.8	28.8	0.0	28.8	28.8	0.0	28.6	28.0	0.6
-0.6	26.6	27.4	-0.8	27.9	27.7	0.2	27.9	27.6	0.3	27.7	28.2	-0.6	27.3	28.2	-0.9
-0.2	27.1	27.4	-0.3	27.9	27.4	0.6	27.9	27.0	0.9	28.3	27.1	1.1	27.4	27.6	-0.1
-0.9	26.6	27.9	-1.3	27.7	27.9	-0.1	27.4	28.5	-1.1	27.6	28.1	-0.5	27.1	28.3	-1.2
-0.6	27.7	28.3	-0.7	27.3	28.3	-1.0	26.9	27.7	-0.9	26.7	27.8	-1.2	27.3	27.9	-0.6
0.6	28.1	26.6	1.5	27.5	26.6	0.9	27.6	26.6	1.1	27.1	26.6	0.5	27.1	26.6	0.5
0.6	28.0	26.7	1.3	27.6	26.6	1.1	27.8	26.6	1.2	27.2	26.7	0.5	27.1	26.7	0.3
-0.3	26.6	26.3	0.3	27.2	26.2	1.0	28.2	26.6	1.6	28.2	27.4	0.7	27.4	27.3	0.1
0.1	27.0	27.5	-0.5	27.6	28.1	-0.6	28.1	28.5	-0.4	27.8	28.5	-0.7	27.5	28.4	-1.0
0.3	27.4	26.4	1.1	28.1	27.1	1.0	28.9	27.4	1.5	28.6	27.6	1.0	28.3	27.6	0.7
0.4	27.9	26.1	1.7	28.7	26.4	2.3	29.0	26.9	2.1	28.9	26.7	2.3	28.1	26.5	1.6
0.6	26.5	26.0	0.5	27.6	28.7	-1.2	28.3	28.2	0.1	28.1	27.4	0.7	28.0	25.6	2.5
-1.6	26.0	27.6	-1.6	26.8	26.6	0.2	27.4	26.4	1.0	27.0	26.7	0.3	26.6	27.0	-0.4
-2.8	25.9	28.7	-2.7	26.6	28.7	-2.1	26.2	28.7	-2.5	25.9	28.7	-2.8	25.7	28.7	-3.0
-0.1	27.4	27.7	-0.2	27.7	27.3	0.4	26.8	26.0	0.8	26.7	26.4	0.3	28.4	29.4	-1.0
0.6	28.7	28.3	0.5	28.2	27.4	0.8	27.9	26.6	1.3	26.7	26.5	0.3	26.6	27.5	-0.9
-0.2	27.1	27.6	-0.5	27.6	27.1	0.5	27.9	26.4	1.5	27.4	26.4	1.0	27.2	27.2	0.0
0.6	28.5	27.5	1.0	28.0	27.3	0.6	27.9	27.1	0.8	27.2	27.0	0.1	27.1	26.9	0.2
-0.7	26.8	27.4	-0.6	27.2	27.5	-0.3	26.5	27.3	-0.8	28.2	27.3	0.9	28.5	27.2	1.3
0.3	27.9	27.7	0.2	27.4	27.4	0.1	27.2	27.1	0.1	26.8	26.2	0.6	26.8	26.8	0.0
1.5	27.9	25.9	2.0	27.2	26.2	1.0	27.1	26.6	0.5	27.6	26.3	1.3	27.9	26.3	1.6
2.0	28.0	26.9	1.1	28.5	27.7	0.8	28.0	27.0	0.9	28.0	26.8	1.2	26.8	26.1	0.7
-0.3	26.6	26.3	0.3	27.4	25.8	1.7	27.3	26.4	0.9	29.6	26.3	3.3	30.4	26.7	3.7
-0.1	27.6	27.3	0.3	28.0	27.9	0.1	28.2	28.0	0.2	28.2	28.0	0.2	26.4	26.0	0.5
1.1	28.1	27.4	0.7	27.9	27.6	0.3	27.1	27.9	-0.8	27.4	28.0	-0.5	27.9	27.9	0.0
-0.2	27.6	28.5	-0.9	27.8	27.3	0.5	27.7	25.4	2.4	28.1	28.0	0.1	28.2	27.0	1.3
2.1	27.3	27.0	0.3	27.6	29.0	-1.4	27.5	28.9	-1.4	29.3	27.5	1.8	27.1	26.0	1.1
0.1			0.1			0.4			0.4			0.4			0.3
0.9			1.0			0.9			1.1			1.1			1.2

Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)
	16:00			17:00			18:00			19:00			20:00		
26.8	27.0	-0.2	26.7	26.9	-0.2	28.4	28.6	-0.2	28.9	26.6	2.3	28.6	28.5	0.1	28.0
27.2	26.2	1.0	27.3	26.8	0.5	28.4	26.9	1.5	28.6	27.4	1.2	28.6	27.8	0.8	28.0
27.9	27.8	0.1	28.0	27.8	0.2	29.2	29.0	0.2	29.4	29.1	0.3	29.0	29.1	-0.1	28.6
28.3	28.1	0.2	28.1	27.8	0.3	28.9	28.7	0.2	28.8	28.7	0.1	28.8	28.6	0.2	28.6
26.0	28.3	-2.3	26.4	27.9	-1.5	29.4	27.7	1.7	28.8	27.4	1.4	28.6	26.6	2.1	28.4
26.6	28.0	-1.5	26.5	28.2	-1.7	27.5	28.1	-0.6	27.7	27.9	-0.2	27.5	26.9	0.7	27.1
26.4	27.4	-1.0	26.4	27.5	-1.2	27.2	28.1	-0.9	26.8	28.7	-1.9	26.8	29.0	-2.2	26.6
28.4	28.0	0.4	28.0	28.1	-0.1	28.0	28.2	-0.2	27.1	28.3	-1.2	27.1	27.9	-0.8	26.9
27.4	27.0	0.4	27.3	27.5	-0.2	26.7	27.9	-1.3	27.3	28.1	-0.8	27.3	28.3	-1.0	27.3
27.7	26.8	0.9	28.9	27.1	1.8	29.0	26.6	2.4	29.8	27.8	2.0	29.4	28.2	1.2	29.4
26.5	26.6	0.0	26.4	26.4	0.0	26.8	26.9	-0.1	27.9	28.2	-0.3	27.9	27.2	0.7	27.7
26.9	27.2	-0.3	26.9	27.4	-0.6	27.5	27.9	-0.4	28.3	26.0	2.4	28.1	25.8	2.3	28.1
27.7	26.8	1.0	27.7	26.1	1.6	28.1	26.5	1.5	28.8	27.0	1.8	28.5	27.5	1.0	28.2
27.3	26.7	0.6	27.2	26.5	0.7	27.2	26.5	0.7	27.5	26.5	1.0	27.3	27.0	0.3	27.4
27.6	25.9	1.6	27.5	26.0	1.5	27.5	25.6	1.9	27.2	25.4	1.8	27.0	26.9	0.1	27.0
26.1	26.4	-0.3	26.2	26.5	-0.3	26.9	26.3	0.6	27.4	26.6	0.8	27.1	27.9	-0.8	26.8
25.4	28.7	-3.3	25.4	28.7	-3.3	25.8	28.7	-2.9	25.7	28.7	-3.0	25.6	28.7	-3.1	29.5
28.9	28.8	0.1	28.6	28.6	-0.1	28.0	28.4	-0.3	26.7	27.4	-0.7	26.6	27.4	-0.8	28.2
28.2	27.7	0.5	29.0	27.5	1.4	28.4	27.1	1.3	28.6	26.3	2.3	28.3	26.2	2.0	28.0
26.8	26.8	0.0	26.8	26.8	0.0	27.2	26.6	0.7	26.5	26.0	0.5	28.2	26.0	2.1	28.5
27.6	26.9	0.7	27.9	26.9	1.0	27.4	26.9	0.6	27.2	26.9	0.3	26.8	26.7	0.1	26.8
28.0	27.1	0.9	27.9	26.6	1.3	27.2	26.7	0.5	27.1	26.8	0.3	27.6	26.9	0.7	27.9
27.2	26.9	0.3	26.5	27.4	-0.9	28.2	27.8	0.4	28.5	27.4	1.1	28.0	27.2	0.8	27.9
27.4	26.2	1.3	27.2	26.0	1.3	26.8	25.4	1.4	26.8	25.8	1.0	27.2	25.8	1.4	28.0
26.6	26.7	-0.1	27.8	27.0	0.8	28.2	26.9	1.3	27.9	26.8	1.1	27.3	26.7	0.6	26.4
29.8	26.9	2.9	29.5	26.8	2.8	27.6	26.5	1.1	27.3	26.1	1.2	27.5	26.7	0.8	27.3
26.6	27.0	-0.4	26.8	27.7	-0.8	27.3	27.2	0.1	27.7	27.0	0.7	28.0	26.5	1.6	28.2
27.9	27.6	0.3	28.5	26.8	1.7	28.1	26.9	1.2	28.3	27.2	1.0	28.3	28.7	-0.5	27.4
28.3	28.0	0.3	28.3	28.1	0.2	27.7	26.6	1.1	27.8	25.6	2.2	27.9	25.3	2.6	28.0
27.9	25.3	2.6	27.0	25.2	1.8	29.0	29.3	-0.3	29.0	29.3	-0.3	29.5	29.3	0.2	29.8
		0.2			0.3			0.4			0.6			0.4	
		1.2			1.3			1.1			1.3			1.3	

Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
21:00			22:00			23:00			00:00	
27.7	0.3	26.7	26.9	-0.2	26.6	26.4	0.2	28.2	28.3	-0.1
27.4	0.5	26.8	27.2	-0.3	26.7	26.3	0.4	29.4	26.6	2.8
29.1	-0.5	27.8	29.1	-1.3	27.8	25.7	2.0	28.8	28.0	0.8
28.4	0.2	27.0	27.4	-0.4	27.0	27.4	-0.4	27.3	27.6	-0.3
27.0	1.4	27.4	27.2	0.2	27.4	27.6	-0.2	27.9	28.0	-0.1
27.0	0.1	26.3	27.5	-1.3	26.2	28.3	-2.1	27.1	28.3	-1.2
28.9	-2.4	26.0	28.8	-2.8	26.0	27.7	-1.6	27.0	27.9	-0.9
28.1	-1.2	27.5	27.1	0.3	28.0	27.2	0.8	27.5	27.2	0.3
28.0	-0.8	30.2	27.7	2.5	29.5	27.6	1.9	29.0	27.5	1.5
27.9	1.5	29.4	27.3	2.2	29.4	26.4	3.0	29.4	26.3	3.2
27.1	0.6	27.2	26.8	0.3	27.1	27.5	-0.4	26.8	27.5	-0.7
25.8	2.2	28.1	25.4	2.6	28.1	25.0	3.0	28.1	26.0	2.0
27.9	0.3	27.6	26.6	1.0	27.6	25.9	1.6	27.7	27.0	0.7
28.3	-0.9	27.1	28.5	-1.4	27.1	28.5	-1.4	26.9	28.5	-1.6
27.9	-0.9	26.7	27.5	-0.8	26.6	27.2	-0.6	26.8	26.2	0.7
29.5	-2.7	26.4	28.1	-1.7	26.3	28.3	-2.0	26.9	28.0	-1.1
29.5	0.0	29.0	27.9	1.1	29.3	28.0	1.3	29.0	27.8	1.2
27.9	0.3	28.7	27.4	1.3	27.5	27.8	-0.3	26.6	27.5	-0.9
27.1	0.9	28.6	28.0	0.6	27.4	28.5	-1.1	28.8	27.4	1.4
27.0	1.5	28.0	26.6	1.4	27.9	26.4	1.6	27.2	26.4	0.8
27.1	-0.3	27.2	27.2	0.1	26.5	27.2	-0.7	28.2	27.4	0.7
27.2	0.7	27.4	27.2	0.2	27.2	27.2	0.1	26.8	27.1	-0.3
26.3	1.6	27.2	26.6	0.6	27.1	26.9	0.2	27.6	27.0	0.6
25.7	2.2	27.9	25.8	2.1	27.2	25.7	1.5	27.1	25.6	1.5
26.5	-0.1	26.3	25.8	0.4	26.3	25.8	0.4	26.2	26.3	-0.1
27.2	0.1	27.5	27.1	0.5	27.4	27.2	0.2	27.7	26.8	0.9
27.0	1.2	28.1	27.7	0.5	27.9	28.1	-0.2	26.9	28.3	-1.4
27.6	-0.1	27.5	25.6	1.9	28.1	25.0	3.1	28.7	28.0	0.7
24.9	3.2	28.1	27.8	0.3	28.2	25.6	2.6	28.3	29.4	-1.2
29.9	-0.1	29.7	29.9	-0.2	29.8	29.9	-0.1	0.0	0.0	0.0
	0.3			0.3			0.4			0.3
	1.3			1.2			1.5			1.2

Average indoor air temperature data loggers' readings for the Month of August

day of the month	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)
		01:00			02:00			03:00			04:00		
1	27.13	30.10	-2.97	27.15	29.80	-2.65	27.22	30.10	-2.88	27.23	29.80	-2.57	27.31
2	25.0	27.9	-2.90	25.5	28.4	-2.90	25.5	28.4	-2.90	26.6	28.4	-1.78	26.6
3	26.6	28.7	-2.07	26.6	28.7	-2.15	26.6	28.7	-2.15	26.5	28.7	-2.18	26.5
4	27.3	29.6	-2.33	27.3	29.6	-2.29	27.2	29.1	-1.86	27.2	29.1	-1.91	27.2
5	27.6	28.1	-0.56	27.6	28.5	-0.89	27.6	29.1	-1.54	27.6	28.5	-0.92	27.5
6	26.4	29.7	-3.25	26.3	29.6	-3.25	26.4	29.6	-3.23	26.4	29.7	-3.33	26.4
7	27.2	29.6	-2.42	27.2	29.7	-2.51	27.0	29.6	-2.59	26.9	29.6	-2.71	26.8
8	27.6	29.6	-2.04	27.5	28.6	-1.12	27.5	29.6	-2.14	27.3	29.7	-2.37	27.3
9	27.6	28.6	-0.99	27.5	29.6	-2.13	27.6	29.7	-2.14	27.7	29.7	-1.96	27.7
10	28.5	29.7	-1.19	28.5	29.7	-1.18	28.6	29.6	-1.04	28.5	29.6	-1.06	28.0
11	28.6	29.6	-0.95	29.3	29.6	-0.33	29.2	30.2	-1.00	28.7	30.5	-1.78	28.2
12	27.9	29.7	-1.78	28.0	29.7	-1.71	28.0	29.7	-1.66	28.1	29.7	-1.65	28.1
13	27.2	30.3	-3.14	26.8	29.7	-2.86	26.7	30.3	-3.57	26.7	29.7	-2.98	26.9
14	26.3	29.7	-3.37	26.3	29.7	-3.42	26.3	29.8	-3.52	26.3	29.8	-3.51	26.3
15	26.2	29.8	-3.62	26.0	29.8	-3.79	25.8	29.7	-3.86	25.8	29.8	-4.04	25.8
16	25.7	29.7	-4.04	25.6	29.8	-4.25	25.5	29.8	-4.32	25.5	29.8	-4.33	25.6
17	26.8	29.7	-2.87	26.8	29.8	-3.01	26.7	29.8	-3.12	26.7	29.8	-3.14	26.6
18	27.4	29.7	-2.28	27.3	29.8	-2.47	27.3	29.8	-2.52	27.2	28.9	-1.69	27.2
19	28.2	30.3	-2.14	28.0	30.4	-2.38	27.9	30.3	-2.43	27.7	30.3	-2.57	27.6
20	28.2	30.4	-2.21	28.2	30.4	-2.24	28.0	30.3	-2.31	27.7	29.6	-1.87	27.5
21	26.4	28.9	-2.49	26.4	29.7	-3.26	26.3	28.9	-2.59	26.0	28.9	-2.92	25.7
22	27.3	29.8	-2.52	27.2	29.8	-2.61	27.0	29.8	-2.83	26.8	29.8	-3.00	26.7
23	26.9	30.0	-3.14	26.9	29.8	-2.92	26.7	30.0	-3.26	26.5	29.8	-3.27	26.4
24	26.9	32.1	-5.22	26.9	28.5	-1.67	26.7	27.7	-0.94	26.7	29.8	-3.13	26.6
25	27.4	27.9	-0.59	27.4	29.3	-1.92	27.1	27.8	-0.72	26.9	30.0	-3.07	26.8
26	27.7	28.1	-0.44	27.4	28.0	-0.54	27.2	27.8	-0.60	27.1	27.9	-0.89	27.0
27	27.5	30.1	-2.64	27.3	29.8	-2.51	27.2	30.1	-2.85	26.9	29.9	-2.97	26.1
28	26.4	28.3	-1.87	26.4	28.8	-2.43	26.3	29.8	-3.53	26.2	29.8	-3.56	26.1
29	28.7	30.8	-2.08	28.9	30.8	-1.94	29.1	30.8	-1.75	28.6	30.8	-2.18	28.1
30	29.1	32.1	-3.00	29.4	32.3	-2.91	29.2	31.0	-1.77	29.2	31.5	-2.29	29.1
31	25.8	29.7	-3.89	25.7	29.8	-4.14	25.5	29.8	-4.27	25.4	29.7	-4.25	25.4
AVG of the difference (°C)			-2.4			-2.4			-2.4			-2.6	
STD DEV of the difference (°C)			1.1			0.9			1.0			0.9	

Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
05:00			06:00			07:00			08:00			09:00	
30.10	-2.79	27.30	29.80	-2.50	27.25	30.10	-2.85	26.52	29.90	-3.38	26.5	28.0	-1.5
28.3	-1.66	26.6	28.8	-2.25	26.5	29.8	-3.28	26.5	29.8	-3.28	26.4	29.8	-3.4
28.7	-2.19	26.5	28.5	-2.04	26.4	28.7	-2.31	26.3	28.7	-2.42	26.4	28.7	-2.3
29.6	-2.45	27.1	29.1	-2.01	27.1	29.1	-2.01	26.9	29.6	-2.68	26.9	29.1	-2.2
28.6	-1.11	27.5	28.0	-0.52	27.4	29.1	-1.70	27.0	28.5	-1.51	26.6	29.1	-2.5
29.6	-3.25	26.3	28.6	-2.31	26.3	29.5	-3.18	26.3	29.6	-3.29	26.3	29.7	-3.4
28.6	-1.78	26.7	29.6	-2.89	26.8	29.7	-2.94	26.6	29.7	-3.08	26.5	29.6	-3.1
29.7	-2.41	27.0	29.6	-2.56	26.9	29.6	-2.71	26.8	28.6	-1.84	26.8	29.6	-2.8
29.7	-1.96	27.7	29.6	-1.87	27.7	29.6	-1.86	27.8	29.6	-1.85	27.8	29.6	-1.8
28.6	-0.61	27.8	29.6	-1.82	27.7	29.7	-2.01	27.6	29.6	-2.00	27.5	29.6	-2.1
30.5	-2.29	27.9	30.5	-2.57	27.7	29.6	-1.85	28.2	29.6	-1.44	28.0	29.6	-1.6
29.7	-1.65	28.1	29.7	-1.60	28.1	29.7	-1.58	28.1	29.8	-1.69	28.1	29.8	-1.7
30.3	-3.38	27.2	30.3	-3.15	27.4	30.3	-2.93	27.8	30.3	-2.51	27.9	29.7	-1.8
29.7	-3.37	26.5	29.7	-3.17	26.8	29.8	-2.99	27.1	29.8	-2.74	27.1	29.8	-2.7
29.8	-3.97	26.2	29.7	-3.53	26.7	29.8	-3.09	27.2	29.8	-2.62	27.4	29.7	-2.3
29.8	-4.20	26.0	29.7	-3.70	26.3	29.7	-3.39	26.9	29.8	-2.86	27.1	29.8	-2.7
29.8	-3.16	26.6	29.8	-3.18	26.6	29.8	-3.16	26.6	29.8	-3.15	26.7	29.8	-3.1
28.9	-1.73	27.1	28.9	-1.83	27.0	28.9	-1.89	26.9	29.5	-2.64	26.7	29.8	-3.1
30.4	-2.85	27.4	30.4	-2.96	27.4	30.4	-3.01	27.3	29.6	-2.26	27.1	29.7	-2.6
29.7	-2.20	27.3	30.4	-3.10	27.1	30.4	-3.29	27.0	30.4	-3.44	26.9	29.6	-2.7
28.7	-3.00	25.5	28.9	-3.39	25.4	28.9	-3.51	25.3	29.6	-4.31	25.2	29.7	-4.5
27.4	-0.65	26.7	28.0	-1.25	26.5	28.8	-2.26	26.4	28.8	-2.42	26.3	28.9	-2.6
30.0	-3.64	26.2	29.8	-3.57	26.1	30.0	-3.92	26.0	26.1	-0.17	25.9	26.2	-0.3
27.7	-1.12	26.6	29.0	-2.44	26.5	28.9	-2.39	26.4	29.0	-2.55	26.4	29.8	-3.4
27.7	-0.88	26.7	29.8	-3.10	26.6	28.4	-1.84	26.4	27.4	-1.03	26.3	27.2	-1.0
27.9	-0.89	27.0	27.7	-0.67	26.9	29.8	-2.95	26.7	30.6	-3.88	26.6	27.9	-1.3
28.0	-1.90	26.1	28.3	-2.18	26.0	28.3	-2.33	26.0	29.0	-2.95	25.6	29.5	-3.9
29.8	-3.66	26.1	29.8	-3.68	26.1	29.8	-3.69	26.2	29.8	-3.62	26.2	29.8	-3.6
30.8	-2.67	28.3	30.8	-2.55	28.1	30.8	-2.67	27.6	30.8	-3.22	27.4	30.8	-3.4
31.5	-2.40	29.1	31.7	-2.59	29.0	31.5	-2.46	29.0	31.8	-2.83	28.6	31.5	-2.9
29.7	-4.30	25.4	29.8	-4.41	25.4	29.8	-4.43	25.3	29.7	-4.37	25.3	29.7	-4.4
	-2.4			-2.6			-2.7			-2.6			-2.6
	1.0			0.9			0.7			0.9			0.9

Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
	10:00			11:00			12:00			13:00			14:00	
26.9	28.3	-1.4	26.8	28.3	-1.5	27.0	29.0	-2.0	27.1	29.5	-2.4	27.2	28.9	-1.7
26.7	29.8	-3.1	27.0	29.8	-2.8	27.4	29.8	-2.4	27.4	29.8	-2.4	27.6	29.9	-2.3
26.7	28.7	-2.0	0.0	0.0	0.0	27.2	28.5	-1.3	27.0	28.7	-1.7	27.1	28.7	-1.6
27.0	29.1	-2.1	27.3	28.1	-0.9	27.6	28.5	-0.9	28.0	29.4	-1.4	28.3	29.1	-0.8
26.6	28.4	-1.8	27.0	28.6	-1.6	26.8	28.1	-1.2	26.7	29.1	-2.4	26.5	28.4	-1.9
26.4	29.6	-3.2	26.6	29.6	-3.0	26.7	28.6	-1.9	26.9	29.6	-2.7	26.6	29.7	-3.1
26.8	29.6	-2.8	26.8	28.6	-1.8	26.6	29.6	-3.0	26.6	29.6	-3.0	26.6	29.6	-3.0
26.7	29.7	-3.0	26.8	29.7	-2.9	26.8	29.6	-2.8	26.7	28.6	-1.9	26.6	29.5	-2.9
27.8	29.6	-1.8	27.8	29.6	-1.8	27.7	28.6	-0.9	27.6	29.6	-2.0	27.5	29.7	-2.2
27.6	28.6	-1.0	27.6	29.6	-2.0	27.5	29.6	-2.1	27.4	29.7	-2.3	27.6	29.6	-2.0
27.9	29.6	-1.7	28.0	29.6	-1.6	27.8	29.8	-2.0	27.7	29.8	-2.1	27.7	29.8	-2.1
28.2	29.8	-1.6	28.3	29.8	-1.5	28.4	29.8	-1.4	28.3	29.8	-1.5	27.9	29.7	-1.8
27.8	30.3	-2.5	27.7	30.3	-2.6	27.4	29.7	-2.3	27.4	30.3	-2.9	27.3	29.7	-2.4
27.2	29.8	-2.6	27.7	29.7	-2.0	27.8	29.7	-1.9	27.6	29.8	-2.2	27.4	29.8	-2.4
27.3	29.8	-2.5	27.3	29.8	-2.5	27.4	29.7	-2.3	27.3	29.8	-2.5	27.3	29.8	-2.5
27.5	29.8	-2.3	28.0	29.8	-1.8	28.5	29.7	-1.2	28.9	29.7	-0.8	28.9	29.8	-0.9
26.7	29.8	-3.1	26.7	29.8	-3.1	27.2	29.7	-2.5	27.7	29.7	-2.0	27.8	29.8	-2.0
26.7	29.8	-3.1	27.0	29.5	-2.5	27.3	29.8	-2.5	27.8	29.8	-2.0	28.4	29.5	-1.1
27.1	29.7	-2.6	27.3	29.6	-2.3	27.7	29.6	-1.9	28.0	28.6	-0.6	28.5	30.4	-1.9
26.8	29.7	-2.9	26.8	30.4	-3.6	26.8	30.4	-3.6	27.1	30.4	-3.3	27.4	29.6	-2.2
25.2	29.6	-4.4	25.3	29.7	-4.4	25.4	28.5	-3.1	25.9	28.5	-2.6	26.6	28.5	-1.9
26.2	29.1	-2.9	26.1	29.0	-2.9	26.2	28.7	-2.5	26.4	28.4	-2.0	26.4	29.3	-2.9
25.8	26.1	-0.3	25.9	26.2	-0.3	26.0	26.3	-0.3	26.1	26.6	-0.5	26.3	27.3	-1.0
26.3	27.2	-0.8	26.3	27.1	-0.8	26.3	27.4	-1.1	26.6	28.1	-1.4	27.0	27.9	-0.8
26.4	27.3	-0.9	26.6	29.5	-3.0	26.8	27.7	-0.9	27.0	29.8	-2.8	27.4	30.7	-3.3
26.6	27.4	-0.9	26.6	27.6	-1.0	26.9	27.9	-1.0	27.1	28.5	-1.4	27.4	28.9	-1.5
25.8	28.9	-3.1	26.1	28.9	-2.8	26.2	28.9	-2.7	26.3	28.9	-2.6	26.3	29.1	-2.8
26.9	28.5	-1.6	26.5	28.5	-2.0	26.7	28.5	-1.8	26.6	28.5	-1.9	27.9	28.9	-1.0
26.8	30.8	-4.0	26.7	30.8	-4.1	26.8	30.8	-4.0	27.1	30.8	-3.7	27.4	30.8	-3.4
27.6	31.5	-3.9	27.3	31.5	-4.2	27.3	31.8	-4.5	27.3	29.9	-2.6	25.7	29.9	-4.2
25.3	29.8	-4.5	26.7	29.8	-3.1	26.8	29.8	-3.0	27.1	29.8	-2.7	27.4	29.8	-2.4
		-2.4			-2.3			-2.1			-2.1			-2.1
		1.1			1.1			1.0			0.7			0.8

Temperatures

Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
	15:00:00			16:00			17:00			18:00			19:00	
27.1	28.9	-1.8	27.0	28.9	-1.9	26.9	28.9	-2.0	26.6	29.1	-2.5	26.4	29.4	-3.0
27.6	29.9	-2.3	27.4	28.5	-1.1	27.4	28.5	-1.1	27.2	28.9	-1.7	27.0	28.7	-1.7
27.2	28.7	-1.5	27.4	28.8	-1.4	27.3	28.7	-1.4	27.3	29.6	-2.3	27.2	28.7	-1.5
28.2	29.6	-1.4	28.0	28.5	-0.6	27.9	29.4	-1.5	27.8	29.1	-1.3	27.6	28.2	-0.7
26.5	28.6	-2.1	26.7	28.4	-1.7	26.9	28.6	-1.7	26.9	28.1	-1.1	26.7	29.1	-2.4
26.9	29.7	-2.8	27.1	29.6	-2.5	27.0	29.6	-2.6	27.1	28.6	-1.5	27.1	29.6	-2.5
26.6	29.6	-3.0	26.6	29.7	-3.1	26.6	29.7	-3.1	27.0	29.7	-2.7	27.5	29.6	-2.1
26.6	29.6	-3.0	26.7	29.7	-3.0	26.7	29.6	-2.9	26.8	29.6	-2.8	27.1	28.6	-1.5
27.5	29.6	-2.1	27.1	29.6	-2.5	26.8	28.6	-1.8	26.5	29.6	-3.1	26.5	29.6	-3.1
27.6	30.0	-2.4	27.5	28.6	-1.1	26.9	29.6	-2.7	26.7	29.7	-3.0	26.8	29.7	-2.9
27.7	29.7	-2.0	27.5	29.7	-2.2	27.1	29.8	-2.7	26.8	29.8	-3.0	27.3	29.8	-2.5
27.6	29.7	-2.1	27.5	29.8	-2.3	27.7	29.8	-2.1	27.7	29.7	-2.0	27.7	29.7	-2.0
27.1	29.8	-2.7	27.0	29.8	-2.8	26.9	29.7	-2.8	26.7	29.7	-3.0	26.7	29.8	-3.1
27.3	29.8	-2.5	27.1	29.8	-2.7	27.0	29.7	-2.7	26.9	29.7	-2.8	26.8	29.8	-3.0
27.1	29.8	-2.7	26.8	29.8	-3.0	26.7	29.8	-3.1	26.6	29.7	-3.1	26.5	29.7	-3.2
28.4	29.8	-1.4	28.1	29.7	-1.6	27.8	29.8	-2.0	27.6	29.8	-2.2	27.4	29.7	-2.3
28.1	29.8	-1.7	28.1	29.8	-1.7	28.1	29.8	-1.7	28.0	29.7	-1.7	27.9	29.7	-1.8
28.9	29.8	-0.9	29.2	30.3	-1.1	29.6	30.3	-0.7	29.8	30.3	-0.5	29.5	30.4	-0.9
29.0	30.4	-1.4	28.9	30.3	-1.4	28.8	29.6	-0.8	28.9	29.7	-0.8	28.8	30.4	-1.6
27.5	29.7	-2.2	27.0	28.9	-1.9	26.6	28.9	-2.3	26.5	28.9	-2.4	26.4	28.9	-2.5
27.5	28.5	-1.0	28.5	29.1	-0.6	28.3	29.1	-0.8	28.2	29.1	-0.9	28.4	30.6	-2.2
26.3	28.4	-2.1	26.5	27.4	-0.9	27.0	29.8	-2.8	27.4	29.8	-2.4	27.5	29.8	-2.3
26.8	27.2	-0.4	26.7	30.2	-3.5	26.8	31.5	-4.7	26.9	31.8	-5.0	27.0	29.1	-2.1
27.0	27.9	-0.9	27.2	32.1	-5.0	27.4	32.6	-5.2	27.8	33.6	-5.8	27.8	28.7	-0.9
27.5	29.2	-1.7	27.7	28.5	-0.8	28.3	31.0	-2.7	28.6	30.0	-1.4	28.5	30.0	-1.5
27.8	31.3	-3.5	28.2	31.6	-3.4	28.7	32.0	-3.4	28.9	30.9	-1.9	27.0	29.5	-2.5
27.2	29.4	-2.2	27.9	29.2	-1.3	27.0	29.5	-2.5	26.8	29.4	-2.6	26.6	28.0	-1.3
27.1	28.7	-1.6	26.8	28.7	-1.9	27.1	30.9	-3.8	27.1	31.0	-3.9	27.2	31.3	-4.1
27.7	30.8	-3.1	27.8	30.8	-3.0	27.9	30.8	-2.9	29.9	30.8	-0.9	29.1	30.8	-1.7
25.6	29.8	-4.2	26.0	29.5	-3.5	28.0	31.7	-3.7	25.8	31.5	-5.7	28.0	31.7	-3.7
27.7	29.8	-2.1	27.8	29.8	-2.0	27.9	29.8	-1.9	29.9	29.8	0.1	29.1	29.9	-0.8
		-2.1			-2.1			-2.4			-2.4			-2.2
		0.8			1.0			1.0			1.4			0.8

Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room (°C)	Difference (°C)
	20:00			21:00			22:00			23:00			00:00	
26.2	29.2	-3.0	26.6	29.5	-2.9	26.7	29.4	-2.7	26.8	29.4	-2.6	26.8	28.3	-1.5
26.9	28.7	-1.8	26.8	28.7	-1.9	26.8	28.7	-1.9	26.8	28.7	-1.9	26.7	28.7	-2.0
27.0	29.6	-2.6	26.9	29.6	-2.7	26.9	29.6	-2.7	27.2	29.1	-1.9	27.2	29.1	-1.9
27.3	28.5	-1.2	27.2	28.1	-1.0	27.4	28.5	-1.1	27.2	29.4	-2.2	27.5	28.0	-0.5
26.5	28.4	-1.9	26.4	28.6	-2.2	26.3	28.6	-2.3	26.2	29.6	-3.4	26.4	29.7	-3.3
26.9	29.7	-2.8	27.0	29.7	-2.7	27.0	29.6	-2.6	27.0	28.6	-1.6	27.1	29.5	-2.4
27.9	28.6	-0.7	28.1	29.5	-1.4	28.3	29.6	-1.3	28.0	29.7	-1.7	27.7	29.6	-1.9
27.5	29.6	-2.1	27.8	29.6	-1.8	28.2	29.7	-1.5	28.3	29.6	-1.3	27.9	30.0	-2.1
27.0	29.7	-2.7	27.3	29.6	-2.3	26.6	27.5	-0.9	27.7	28.6	-0.9	28.1	29.6	-1.5
26.9	29.6	-2.7	27.1	29.6	-2.5	27.4	28.6	-1.2	27.9	29.6	-1.7	28.3	29.7	-1.4
27.5	29.7	-2.2	27.6	29.7	-2.1	27.9	29.8	-1.9	27.5	29.8	-2.3	27.9	29.7	-1.8
27.7	29.8	-2.1	27.7	29.8	-2.1	27.5	29.7	-2.2	27.5	29.7	-2.2	27.3	30.3	-3.0
26.7	29.8	-3.1	26.6	29.7	-3.1	26.6	29.7	-3.1	26.5	29.8	-3.3	26.4	29.8	-3.4
26.6	29.8	-3.2	26.5	29.8	-3.3	26.4	29.8	-3.4	26.3	29.7	-3.4	26.2	29.7	-3.5
26.4	29.8	-3.4	26.3	29.8	-3.5	26.1	29.8	-3.7	26.0	29.8	-3.8	25.8	29.7	-3.9
27.3	29.8	-2.5	27.2	29.8	-2.6	27.1	29.7	-2.6	27.1	29.8	-2.7	26.9	29.8	-2.9
27.7	29.8	-2.1	27.6	29.8	-2.2	27.5	29.8	-2.3	27.4	29.8	-2.4	27.4	29.7	-2.3
28.9	30.3	-1.4	28.6	30.3	-1.7	28.5	30.4	-1.9	28.4	30.4	-2.0	28.3	30.3	-2.0
28.3	30.4	-2.1	28.3	30.3	-2.0	28.2	30.3	-2.1	28.2	29.6	-1.4	28.2	29.7	-1.5
26.3	28.9	-2.6	26.1	28.9	-2.8	26.1	28.9	-2.8	26.1	28.9	-2.8	26.3	28.9	-2.6
28.1	30.6	-2.5	27.8	29.7	-1.9	27.6	29.7	-2.1	27.4	29.7	-2.3	27.3	29.8	-2.5
27.3	29.8	-2.5	27.1	29.8	-2.7	27.0	29.8	-2.8	27.0	29.8	-2.8	26.9	29.8	-2.9
26.9	27.9	-1.0	26.8	27.6	-0.8	26.8	27.5	-0.7	26.7	27.2	-0.5	26.8	31.8	-5.0
27.8	30.0	-2.2	27.6	28.2	-0.6	27.3	27.9	-0.6	27.3	28.1	-0.8	27.3	28.1	-0.7
28.6	29.9	-1.3	28.4	29.8	-1.4	28.2	29.9	-1.7	27.9	28.5	-0.6	27.8	28.1	-0.3
28.7	29.8	-1.1	28.5	30.1	-1.6	28.3	29.8	-1.5	28.0	30.1	-2.1	28.1	29.8	-1.7
26.6	28.3	-1.7	25.0	28.0	-3.0	26.4	29.9	-3.5	26.3	27.3	-1.0	26.3	28.4	-2.1
29.4	31.3	-1.9	28.5	31.3	-2.8	29.0	31.2	-2.2	28.6	31.2	-2.6	28.4	31.2	-2.8
29.8	30.8	-1.0	29.4	30.8	-1.4	29.2	30.8	-1.6	29.4	31.0	-1.6	29.2	30.9	-1.7
25.7	28.3	-2.6	25.9	28.5	-2.6	26.0	29.0	-3.0	26.3	29.8	-3.5	26.0	29.7	-3.7
29.8	29.9	-0.1	29.4	30.1	-0.7	29.2	30.1	-0.9	29.4	30.1	-0.7	0.0	0.0	0.0
		-2.1			-2.1			-2.1			-2.1			-2.2
		0.8			0.8			0.8			0.9			1.1

Average Internal Relative Humidity data loggers’ readings for the Month of June

day of the month	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)
		01:00			02:00			03:00			04:00		
1	83.52	81.82	1.70	83.52	82.09	1.43	83.26	82.09	1.17	83.52	81.82	1.70	83.26
2	82.5	82.9	-0.42	82.5	83.2	-0.69	82.5	83.4	-0.95	82.5	84.0	-1.49	82.7
3	84.8	87.3	-2.45	84.6	87.3	-2.72	84.8	87.6	-2.73	84.8	87.8	-3.01	85.1
4	83.0	88.1	-5.13	83.3	88.1	-4.87	83.0	88.1	-5.13	83.3	88.1	-4.87	83.3
5	82.7	89.0	-6.23	83.3	89.0	-5.70	83.5	89.0	-5.44	83.8	88.7	-4.90	83.5
6	82.2	84.5	-2.30	82.2	84.0	-1.75	81.9	84.0	-2.01	81.7	84.0	-2.27	81.7
7	81.9	82.4	-0.41	81.9	82.6	-0.67	81.9	82.9	-0.94	81.9	82.6	-0.67	81.7
8	82.2	83.7	-1.48	82.2	85.3	-3.13	82.2	84.0	-1.75	81.9	84.2	-2.28	81.9
9	83.8	84.0	-0.18	83.8	84.2	-0.45	83.5	84.5	-0.99	83.3	84.5	-1.25	83.0
10	79.9	84.8	-4.93	79.9	84.5	-4.65	79.6	84.8	-5.20	79.3	84.8	-5.46	79.1
11	78.0	85.3	-7.32	78.0	85.3	-7.32	78.3	85.3	-7.06	78.8	85.3	-6.54	79.1
12	81.4	85.3	-3.92	81.4	85.3	-3.92	81.4	85.3	-3.92	81.4	85.6	-4.20	81.4
13	81.9	84.8	-2.84	81.9	84.8	-2.84	81.9	84.2	-2.28	82.2	84.5	-2.30	81.9
14	81.9	87.6	-5.62	82.2	89.8	-7.59	82.2	88.4	-6.19	82.2	87.8	-5.64	82.2
15	82.7	86.2	-3.44	82.7	86.2	-3.44	82.5	85.9	-3.43	81.7	86.2	-4.49	81.9
16	81.4	85.9	-4.47	81.7	85.9	-4.21	81.4	85.9	-4.47	81.4	85.9	-4.47	81.2
17	79.3	86.7	-7.41	79.1	86.7	-7.67	79.6	86.7	-7.14	79.6	86.7	-7.14	79.9
18	83.0	87.0	-4.02	82.5	87.3	-4.82	82.5	87.6	-5.10	81.9	87.6	-5.62	81.9
19	82.5	85.9	-3.43	82.5	85.3	-2.87	82.2	85.1	-2.85	82.5	84.5	-2.04	82.5
20	82.5	84.8	-2.32	82.5	85.3	-2.87	82.5	85.1	-2.59	82.7	85.1	-2.33	82.7
21	81.4	85.9	-4.47	79.9	86.2	-6.32	81.2	85.9	-4.74	80.9	85.6	-4.72	80.9
22	77.8	88.1	-10.37	77.8	88.1	-10.37	78.0	88.1	-10.11	78.0	88.4	-10.38	78.3
23	79.1	89.0	-9.89	79.6	88.7	-9.09	79.9	89.5	-9.66	80.1	89.8	-9.68	80.4
24	81.2	91.2	-10.02	81.7	90.9	-9.22	81.7	90.4	-8.66	81.9	89.8	-7.85	81.7
25	80.9	84.5	-3.61	80.9	84.8	-3.89	80.6	84.5	-3.87	80.6	84.2	-3.59	80.6
26	80.9	83.7	-2.79	80.6	83.7	-3.05	80.6	84.0	-3.32	80.4	84.2	-3.85	80.9
27	80.9	85.9	-5.00	80.9	86.2	-5.28	80.6	85.9	-5.26	80.9	85.9	-5.00	81.2
28	83.8	85.3	-1.56	83.8	85.1	-1.28	83.8	85.1	-1.28	83.8	85.1	-1.28	83.5
29	82.5	87.3	-4.82	82.5	87.3	-4.82	82.5	87.3	-4.82	82.7	87.6	-4.83	83.3
30	83.8	82.9	0.89	83.8	82.6	1.16	83.3	81.8	1.44	82.7	81.6	1.18	82.5
AVG of the difference (%)	81.8	85.7	-3.9	81.8	85.9	-4.1	81.8	85.7	-4.0	81.8	85.7	-4.0	81.8
STD DEV of the difference (%)			3.0			2.9			2.8			2.7	

Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)
05:00			06:00			07:00			08:00			09:00	
81.82	1.44	83.26	82.09	1.17	83.26	81.82	1.44	83.00	81.82	1.17	83.0	82.1	0.9
84.2	-1.50	82.7	84.2	-1.50	83.5	84.2	-0.71	84.0	84.2	-0.19	84.6	85.1	-0.5
87.8	-2.73	85.7	87.8	-2.19	85.7	87.6	-1.91	85.7	87.8	-2.19	85.4	88.1	-2.7
88.1	-4.87	83.3	88.4	-5.15	83.3	88.1	-4.87	83.3	88.1	-4.87	83.0	88.1	-5.1
88.4	-4.88	83.3	88.1	-4.87	83.5	88.1	-4.61	83.8	87.6	-3.79	84.0	87.8	-3.8
83.7	-2.00	81.4	83.7	-2.27	81.4	83.4	-2.00	81.4	83.4	-2.00	81.4	83.2	-1.7
82.6	-0.94	81.9	82.4	-0.41	81.9	82.4	-0.41	81.9	82.4	-0.41	81.7	82.4	-0.7
84.0	-2.01	81.9	83.7	-1.74	81.9	83.4	-1.48	81.7	83.7	-2.00	81.9	84.2	-2.3
84.5	-1.51	83.0	84.5	-1.51	82.7	84.5	-1.77	82.2	84.5	-2.30	81.7	84.5	-2.8
84.8	-5.72	78.8	84.8	-5.98	78.5	84.5	-5.96	78.5	84.5	-5.96	78.8	84.8	-6.0
85.3	-6.28	79.6	85.1	-5.47	79.6	85.1	-5.47	79.6	85.1	-5.47	79.9	85.1	-5.2
85.6	-4.20	81.4	85.9	-4.47	81.4	86.2	-4.75	81.4	86.2	-4.75	81.4	86.5	-5.0
84.5	-2.56	81.9	84.5	-2.56	82.2	84.2	-2.02	82.2	84.8	-2.58	82.2	84.8	-2.6
87.8	-5.64	82.5	87.8	-5.38	82.2	87.8	-5.64	82.2	87.6	-5.36	82.5	86.7	-4.3
85.9	-3.95	81.9	85.9	-3.95	82.7	85.9	-3.17	82.2	85.9	-3.69	80.9	85.6	-4.7
85.9	-4.74	80.6	85.9	-5.26	80.6	85.9	-5.26	80.6	85.9	-5.26	80.6	85.6	-5.0
86.7	-6.88	79.9	86.7	-6.88	79.3	86.5	-7.13	79.6	86.5	-6.86	79.6	86.5	-6.9
87.8	-5.90	81.9	88.1	-6.18	82.2	88.1	-5.92	82.5	87.8	-5.38	82.2	87.8	-5.6
84.2	-1.76	82.5	84.0	-1.49	82.7	83.7	-0.96	82.7	83.7	-0.96	82.7	83.4	-0.7
85.3	-2.61	82.7	85.3	-2.61	83.0	88.1	-5.13	83.3	88.4	-5.15	83.3	87.3	-4.0
85.9	-5.00	81.7	85.9	-4.21	80.9	86.2	-5.28	78.3	86.2	-7.90	79.3	86.2	-6.8
88.4	-10.12	78.3	88.4	-10.12	78.5	88.1	-9.58	78.8	88.1	-9.32	78.8	88.1	-9.3
89.5	-9.14	80.4	89.5	-9.14	80.1	89.5	-9.40	80.9	89.2	-8.34	81.2	89.8	-8.6
89.5	-7.83	81.9	89.8	-7.85	81.7	89.8	-8.11	81.7	89.2	-7.55	81.4	89.2	-7.8
84.2	-3.59	80.9	84.2	-3.33	80.9	84.0	-3.06	80.9	84.0	-3.06	80.6	84.2	-3.6
84.2	-3.33	80.9	84.5	-3.61	81.2	84.5	-3.35	81.4	84.5	-3.08	81.4	84.8	-3.4
86.2	-5.02	81.2	86.2	-5.02	81.4	86.2	-4.75	81.9	86.2	-4.23	81.7	86.2	-4.5
85.1	-1.54	83.0	85.1	-2.07	82.7	85.1	-2.33	82.5	85.1	-2.59	82.2	85.1	-2.9
87.6	-4.31	83.0	87.6	-4.57	83.3	87.6	-4.31	83.5	87.6	-4.05	83.5	87.6	-4.0
81.3	1.18	82.2	80.8	1.46	82.5	80.8	1.72	82.2	80.5	1.72	82.2	80.5	1.7
85.7	-3.9	81.8	85.7	-3.9	81.8	85.7	-3.9	81.8	85.7	-3.9	81.8	85.7	-3.9
	2.6			2.7			2.8			2.7			2.6
-		-	-		-	-		-	-		-	-	

Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)
10:00			11:00			12:00			13:00			14:00		
82.7	81.8	0.9	82.7	81.8	0.9	82.7	82.1	0.6	82.7	82.4	0.4	82.7	82.4	0.4
84.6	84.8	-0.2	84.8	85.6	-0.8	84.8	85.9	-1.1	84.8	86.7	-1.9	84.8	86.7	-1.9
85.4	88.4	-3.0	0.0	0.0	0.0	84.8	88.1	-3.3	85.1	88.1	-3.0	85.4	88.1	-2.7
83.0	88.1	-5.1	83.3	88.1	-4.9	82.7	88.1	-5.4	82.5	88.1	-5.7	82.5	89.8	-7.3
84.6	87.8	-3.3	84.8	87.6	-2.7	84.6	87.3	-2.7	84.8	87.0	-2.2	84.8	86.5	-1.6
81.4	82.9	-1.5	81.4	82.9	-1.5	81.4	82.6	-1.2	81.4	82.4	-0.9	81.4	82.1	-0.7
81.7	82.1	-0.4	81.9	82.4	-0.4	82.2	82.6	-0.4	82.2	82.9	-0.7	81.9	83.2	-1.2
81.9	84.2	-2.3	82.2	84.0	-1.7	82.2	83.2	-0.9	82.5	83.4	-1.0	82.7	83.2	-0.4
81.9	84.2	-2.3	81.4	84.5	-3.1	81.4	84.5	-3.1	80.9	84.5	-3.6	80.6	84.2	-3.6
78.5	84.2	-5.7	78.5	84.0	-5.4	78.8	83.7	-4.9	79.1	84.0	-4.9	78.8	84.0	-5.2
79.6	84.5	-4.9	79.9	84.2	-4.4	79.9	84.2	-4.4	80.1	84.2	-4.1	80.4	84.5	-4.1
81.4	86.5	-5.0	81.4	86.5	-5.0	81.4	86.5	-5.0	81.4	86.2	-4.8	81.7	86.7	-5.0
82.2	85.1	-2.9	82.2	85.3	-3.1	82.2	85.6	-3.4	82.2	85.9	-3.7	82.2	85.9	-3.7
82.5	86.7	-4.3	82.5	86.5	-4.0	82.7	86.7	-4.0	82.7	87.0	-4.3	83.0	87.0	-4.0
80.6	85.9	-5.3	80.9	85.9	-5.0	80.6	85.6	-5.0	80.9	85.9	-5.0	80.6	85.9	-5.3
80.6	85.6	-5.0	80.6	85.9	-5.3	80.4	85.6	-5.2	80.4	85.9	-5.5	80.4	85.9	-5.5
79.6	86.5	-6.9	79.9	86.5	-6.6	80.1	86.5	-6.3	80.1	86.5	-6.3	80.1	86.5	-6.3
82.5	87.8	-5.4	82.5	88.1	-5.7	82.5	88.1	-5.7	82.2	88.7	-6.5	82.2	88.4	-6.2
82.7	83.7	-1.0	82.5	84.0	-1.5	82.5	84.0	-1.5	82.5	84.0	-1.5	82.5	84.0	-1.5
83.3	87.0	-3.8	83.3	86.7	-3.5	83.3	86.5	-3.2	83.5	86.7	-3.2	83.5	87.3	-3.8
79.1	86.5	-7.4	79.1	86.5	-7.4	79.3	87.0	-7.7	78.8	87.0	-8.2	78.3	87.6	-9.3
78.0	88.1	-10.1	77.5	88.1	-10.6	77.5	88.1	-10.6	76.4	88.1	-11.7	77.0	88.1	-11.2
81.2	89.8	-8.6	81.2	90.1	-8.9	81.2	90.1	-8.9	81.2	90.1	-8.9	80.9	90.4	-9.5
81.2	89.0	-7.8	81.2	88.7	-7.5	81.2	88.4	-7.2	80.9	87.6	-6.7	80.9	87.3	-6.4
80.9	84.2	-3.3	80.6	84.0	-3.3	81.2	83.7	-2.5	80.6	84.0	-3.3	80.9	83.7	-2.8
81.9	84.5	-2.6	82.5	84.8	-2.3	81.7	88.1	-6.4	82.2	86.2	-4.0	82.5	85.9	-3.4
81.9	86.2	-4.2	82.2	86.5	-4.2	82.5	86.2	-3.7	82.7	86.5	-3.7	82.5	86.5	-4.0
81.9	85.1	-3.1	81.9	85.1	-3.1	81.4	85.1	-3.6	81.4	85.3	-3.9	81.2	85.3	-4.2
83.5	87.6	-4.0	83.5	87.6	-4.0	83.8	87.6	-3.8	83.5	87.6	-4.0	83.3	87.6	-4.3
82.2	80.5	1.7	82.2	80.5	1.7	82.2	80.0	2.3	82.2	79.7	2.5	82.2	79.4	2.8
81.8	85.6	-3.9	79.0	82.7	-3.8	81.8	85.7	-3.9	81.7	85.7	-4.0	81.7	85.8	-4.1
		2.7			2.8			2.7			2.8			2.9

Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)
	15:00:00			16:00			17:00			18:00			19:00	
82.5	82.4	0.1	82.5	82.1	0.4	82.5	82.4	0.1	82.2	82.4	-0.1	82.5	82.4	0.1
84.8	87.6	-2.7	84.8	87.6	-2.7	84.6	87.8	-3.3	85.1	87.8	-2.7	85.1	87.6	-2.5
85.7	88.1	-2.5	85.7	88.4	-2.7	85.1	88.4	-3.3	85.1	88.4	-3.3	84.8	88.4	-3.6
82.5	88.7	-6.2	82.5	89.0	-6.5	82.5	88.7	-6.2	82.5	89.0	-6.5	82.7	89.0	-6.2
84.6	86.2	-1.6	84.3	85.9	-1.6	83.8	85.6	-1.8	83.3	85.9	-2.6	82.7	85.6	-2.9
81.4	82.1	-0.7	81.7	82.4	-0.7	81.7	82.1	-0.4	81.7	82.1	-0.4	81.4	82.1	-0.7
81.9	83.2	-1.2	81.9	83.4	-1.5	81.9	83.7	-1.7	82.2	83.7	-1.5	82.2	83.7	-1.5
82.5	83.4	-1.0	82.7	83.4	-0.7	83.3	83.4	-0.2	83.5	83.4	0.1	83.5	83.4	0.1
80.6	84.5	-3.9	80.6	84.5	-3.9	80.4	84.5	-4.1	80.4	84.8	-4.4	80.4	84.8	-4.4
78.8	84.0	-5.2	79.1	84.0	-4.9	78.5	85.6	-7.1	78.0	85.6	-7.6	78.0	84.8	-6.8
80.6	84.8	-4.1	80.6	84.5	-3.9	80.6	84.5	-3.9	81.2	84.8	-3.6	81.4	84.8	-3.4
81.7	86.7	-5.0	81.4	86.7	-5.3	81.4	86.5	-5.0	81.4	86.2	-4.8	81.9	85.9	-4.0
82.2	85.9	-3.7	82.2	86.2	-4.0	82.5	86.2	-3.7	82.5	86.2	-3.7	82.5	86.2	-3.7
83.0	86.7	-3.7	83.3	86.7	-3.5	83.0	86.5	-3.5	83.0	86.7	-3.7	83.0	86.2	-3.2
81.4	85.9	-4.5	81.7	85.9	-4.2	81.9	85.9	-4.0	82.2	85.9	-3.7	82.2	85.9	-3.7
79.9	85.9	-6.0	79.9	85.9	-6.0	79.6	86.2	-6.6	79.6	86.7	-7.1	79.6	87.3	-7.7
80.4	86.5	-6.1	80.6	86.5	-5.8	80.6	86.5	-5.8	80.9	86.5	-5.6	80.9	86.5	-5.6
82.2	88.1	-5.9	82.2	87.3	-5.1	81.9	87.0	-5.1	82.2	87.6	-5.4	82.2	87.3	-5.1
82.2	84.0	-1.7	82.5	84.0	-1.5	82.5	84.0	-1.5	82.5	84.2	-1.8	82.5	84.2	-1.8
83.5	87.0	-3.5	82.7	86.7	-4.0	83.0	86.5	-3.5	83.0	86.7	-3.7	83.0	86.7	-3.7
76.7	87.6	-10.9	78.5	87.3	-8.7	78.8	87.6	-8.8	78.5	87.8	-9.3	78.8	87.8	-9.0
77.2	88.1	-10.9	77.8	88.1	-10.4	77.8	88.1	-10.4	78.0	88.1	-10.1	77.5	88.1	-10.6
80.9	90.4	-9.5	80.4	90.1	-9.7	80.4	89.8	-9.4	80.6	89.8	-9.2	80.6	90.1	-9.4
80.9	86.2	-5.3	80.9	86.5	-5.6	80.9	86.2	-5.3	81.2	86.2	-5.0	80.9	85.9	-5.0
80.9	83.7	-2.8	80.9	83.4	-2.5	80.6	83.2	-2.5	80.4	83.2	-2.8	80.4	82.9	-2.5
82.5	85.6	-3.1	83.0	85.6	-2.6	83.8	85.3	-1.6	83.3	85.3	-2.1	82.7	85.3	-2.6
83.0	86.2	-3.2	83.3	86.2	-2.9	83.3	86.2	-2.9	83.5	86.2	-2.7	83.8	85.6	-1.8
80.9	85.1	-4.2	81.2	85.9	-4.7	81.2	86.7	-5.6	81.2	86.5	-5.3	81.2	85.6	-4.5
84.3	87.6	-3.3	84.3	87.6	-3.3	84.3	87.6	-3.3	84.3	87.6	-3.3	84.6	87.6	-3.0
82.2	79.2	3.1	82.2	79.4	2.8	82.2	79.2	3.1	82.2	79.4	2.8	82.2	79.4	2.8
81.7	85.7	-4.0	81.8	85.7	-3.9	81.8	85.7	-3.9	81.9	85.8	-4.0	81.8	85.7	-3.9
		2.9			2.8			2.9			2.8			2.9

Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)
	20:00			21:00			22:00			23:00			00:00	
82.5	82.4	0.1	82.2	82.6	-0.4	82.2	82.6	-0.4	82.5	82.9	-0.4	82.5	82.9	-0.4
85.1	87.6	-2.5	84.8	87.6	-2.7	84.8	87.6	-2.7	84.8	87.6	-2.7	85.4	87.6	-2.2
84.8	88.1	-3.3	83.5	88.1	-4.6	83.3	88.1	-4.9	83.3	88.4	-5.1	83.0	88.1	-5.1
82.5	89.0	-6.5	82.5	89.0	-6.5	82.5	89.2	-6.8	82.5	89.0	-6.5	82.7	89.0	-6.2
82.7	85.3	-2.6	82.5	85.3	-2.9	82.5	84.8	-2.3	82.2	84.8	-2.6	82.2	84.5	-2.3
81.4	82.4	-0.9	81.4	82.4	-0.9	81.7	82.4	-0.7	81.7	82.6	-0.9	81.7	82.4	-0.7
82.2	84.0	-1.7	82.2	84.0	-1.7	82.2	84.0	-1.7	82.2	83.4	-1.2	82.2	83.7	-1.5
83.5	83.7	-0.2	83.8	83.7	0.1	83.8	83.7	0.1	83.5	83.7	-0.2	83.5	84.0	-0.4
80.6	84.8	-4.1	80.6	84.8	-4.1	80.6	84.8	-4.1	80.4	84.8	-4.4	79.9	84.5	-4.7
77.5	84.2	-6.7	78.3	85.3	-7.1	78.0	85.6	-7.6	78.3	85.6	-7.3	78.0	85.3	-7.3
81.2	84.8	-3.6	81.2	85.1	-3.9	81.2	85.1	-3.9	81.2	85.3	-4.2	81.4	85.3	-3.9
81.7	85.6	-3.9	81.7	85.6	-3.9	81.7	85.3	-3.7	81.7	85.3	-3.7	81.7	85.1	-3.4
82.2	86.5	-4.2	82.2	86.5	-4.2	81.9	86.5	-4.5	82.2	86.7	-4.5	81.9	86.7	-4.8
83.0	86.5	-3.5	83.0	86.5	-3.5	83.3	86.2	-2.9	83.0	86.2	-3.2	82.7	86.2	-3.4
82.2	85.6	-3.4	81.9	85.9	-4.0	81.9	85.9	-4.0	81.9	85.6	-3.7	81.9	85.6	-3.7
79.3	87.0	-7.7	79.1	88.4	-9.3	79.1	88.1	-9.1	79.1	87.3	-8.2	79.3	87.0	-7.7
81.7	86.5	-4.8	82.5	86.5	-4.0	83.0	86.5	-3.5	83.3	86.5	-3.2	83.3	86.7	-3.5
82.2	87.0	-4.8	82.2	87.0	-4.8	82.5	86.7	-4.3	82.5	86.5	-4.0	82.5	86.2	-3.7
82.5	84.2	-1.8	82.5	84.5	-2.0	82.5	84.5	-2.0	82.5	84.5	-2.0	82.5	84.8	-2.3
82.7	86.7	-4.0	82.7	86.7	-4.0	82.7	86.7	-4.0	82.2	86.2	-4.0	82.2	85.6	-3.4
78.8	87.8	-9.0	78.3	88.1	-9.8	78.5	87.8	-9.3	77.2	88.1	-10.9	77.8	88.1	-10.4
77.8	88.1	-10.4	77.8	88.1	-10.4	77.8	88.4	-10.6	78.0	89.2	-11.2	78.5	89.0	-10.4
80.4	90.1	-9.7	80.6	90.4	-9.7	81.2	90.6	-9.5	81.2	90.6	-9.5	81.2	90.9	-9.7
80.9	85.3	-4.4	80.9	84.8	-3.9	80.9	85.1	-4.2	80.9	85.1	-4.2	80.6	85.3	-4.7
80.6	83.2	-2.5	80.4	83.4	-3.0	80.4	83.2	-2.8	80.4	83.4	-3.0	80.4	83.7	-3.3
82.2	85.3	-3.1	81.9	85.9	-4.0	81.7	85.6	-3.9	81.4	85.9	-4.5	81.2	85.6	-4.5
84.0	85.3	-1.3	84.0	85.6	-1.6	84.0	85.6	-1.6	84.0	85.3	-1.3	83.8	85.3	-1.6
81.2	86.5	-5.3	81.2	87.3	-6.1	81.4	87.3	-5.9	81.7	87.3	-5.6	82.2	87.0	-4.8
84.6	87.6	-3.0	84.6	84.2	0.3	84.3	84.0	0.3	83.8	83.4	0.4	83.8	83.2	0.6
81.9	79.4	2.5	81.9	79.4	2.5	81.9	79.4	2.5	81.9	79.4	2.5	81.7	79.7	2.0
81.8	85.7	-3.9	81.7	85.8	-4.0	81.8	85.7	-3.9	81.7	85.7	-4.0	81.7	85.6	-3.9
		2.8			3.0			3.0			3.1			3.0

Average Internal Relative Humidity data loggers' readings for the Month of August

day of the month	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)
		01:00			02:00			03:00			04:00		
1	83.52	81.82	1.70	83.52	82.09	1.43	83.26	82.09	1.17	83.52	81.82	1.70	83.26
2	82.5	82.9	-0.42	82.5	83.2	-0.69	82.5	83.4	-0.95	82.5	84.0	-1.49	82.7
3	84.8	87.3	-2.45	84.6	87.3	-2.72	84.8	87.6	-2.73	84.8	87.8	-3.01	85.1
4	83.0	88.1	-5.13	83.3	88.1	-4.87	83.0	88.1	-5.13	83.3	88.1	-4.87	83.3
5	82.7	89.0	-6.23	83.3	89.0	-5.70	83.5	89.0	-5.44	83.8	88.7	-4.90	83.5
6	82.2	84.5	-2.30	82.2	84.0	-1.75	81.9	84.0	-2.01	81.7	84.0	-2.27	81.7
7	81.9	82.4	-0.41	81.9	82.6	-0.67	81.9	82.9	-0.94	81.9	82.6	-0.67	81.7
8	82.2	83.7	-1.48	82.2	85.3	-3.13	82.2	84.0	-1.75	81.9	84.2	-2.28	81.9
9	83.8	84.0	-0.18	83.8	84.2	-0.45	83.5	84.5	-0.99	83.3	84.5	-1.25	83.0
10	79.9	84.8	-4.93	79.9	84.5	-4.65	79.6	84.8	-5.20	79.3	84.8	-5.46	79.1
11	78.0	85.3	-7.32	78.0	85.3	-7.32	78.3	85.3	-7.06	78.8	85.3	-6.54	79.1
12	81.4	85.3	-3.92	81.4	85.3	-3.92	81.4	85.3	-3.92	81.4	85.6	-4.20	81.4
13	81.9	84.8	-2.84	81.9	84.8	-2.84	81.9	84.2	-2.28	82.2	84.5	-2.30	81.9
14	81.9	87.6	-5.62	82.2	89.8	-7.59	82.2	88.4	-6.19	82.2	87.8	-5.64	82.2
15	82.7	86.2	-3.44	82.7	86.2	-3.44	82.5	85.9	-3.43	81.7	86.2	-4.49	81.9
16	81.4	85.9	-4.47	81.7	85.9	-4.21	81.4	85.9	-4.47	81.4	85.9	-4.47	81.2
17	79.3	86.7	-7.41	79.1	86.7	-7.67	79.6	86.7	-7.14	79.6	86.7	-7.14	79.9
18	83.0	87.0	-4.02	82.5	87.3	-4.82	82.5	87.6	-5.10	81.9	87.6	-5.62	81.9
19	82.5	85.9	-3.43	82.5	85.3	-2.87	82.2	85.1	-2.85	82.5	84.5	-2.04	82.5
20	82.5	84.8	-2.32	82.5	85.3	-2.87	82.5	85.1	-2.59	82.7	85.1	-2.33	82.7
21	81.4	85.9	-4.47	79.9	86.2	-6.32	81.2	85.9	-4.74	80.9	85.6	-4.72	80.9
22	77.8	88.1	-10.37	77.8	88.1	-10.37	78.0	88.1	-10.11	78.0	88.4	-10.38	78.3
23	79.1	89.0	-9.89	79.6	88.7	-9.09	79.9	89.5	-9.66	80.1	89.8	-9.68	80.4
24	81.2	91.2	-10.02	81.7	90.9	-9.22	81.7	90.4	-8.66	81.9	89.8	-7.85	81.7
25	80.9	84.5	-3.61	80.9	84.8	-3.89	80.6	84.5	-3.87	80.6	84.2	-3.59	80.6
26	80.9	83.7	-2.79	80.6	83.7	-3.05	80.6	84.0	-3.32	80.4	84.2	-3.85	80.9
27	80.9	85.9	-5.00	80.9	86.2	-5.28	80.6	85.9	-5.26	80.9	85.9	-5.00	81.2
28	83.8	85.3	-1.56	83.8	85.1	-1.28	83.8	85.1	-1.28	83.8	85.1	-1.28	83.5
29	82.5	87.3	-4.82	82.5	87.3	-4.82	82.5	87.3	-4.82	82.7	87.6	-4.83	83.3
30	83.8	82.9	0.89	83.8	82.6	1.16	83.3	81.8	1.44	82.7	81.6	1.18	82.5
31	81.7	79.7	2.00	81.7	80.0	1.73	81.9	80.0	2.00	81.9	80.2	1.73	81.9
AVG of the difference (%)	81.78	85.53	-3.75	81.76	85.67	-3.91	81.77	85.55	-3.78	81.76	85.55	-3.79	81.78
STD DEV of the difference (%)	-	-	3.1			3.0			2.9			2.9	

Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)
05:00			06:00			07:00			08:00			09:00	
81.82	1.44	83.26	82.09	1.17	83.26	81.82	1.44	83.00	81.82	1.17	83.0	82.1	0.9
84.2	-1.50	82.7	84.2	-1.50	83.5	84.2	-0.71	84.0	84.2	-0.19	84.6	85.1	-0.5
87.8	-2.73	85.7	87.8	-2.19	85.7	87.6	-1.91	85.7	87.8	-2.19	85.4	88.1	-2.7
88.1	-4.87	83.3	88.4	-5.15	83.3	88.1	-4.87	83.3	88.1	-4.87	83.0	88.1	-5.1
88.4	-4.88	83.3	88.1	-4.87	83.5	88.1	-4.61	83.8	87.6	-3.79	84.0	87.8	-3.8
83.7	-2.00	81.4	83.7	-2.27	81.4	83.4	-2.00	81.4	83.4	-2.00	81.4	83.2	-1.7
82.6	-0.94	81.9	82.4	-0.41	81.9	82.4	-0.41	81.9	82.4	-0.41	81.7	82.4	-0.7
84.0	-2.01	81.9	83.7	-1.74	81.9	83.4	-1.48	81.7	83.7	-2.00	81.9	84.2	-2.3
84.5	-1.51	83.0	84.5	-1.51	82.7	84.5	-1.77	82.2	84.5	-2.30	81.7	84.5	-2.8
84.8	-5.72	78.8	84.8	-5.98	78.5	84.5	-5.96	78.5	84.5	-5.96	78.8	84.8	-6.0
85.3	-6.28	79.6	85.1	-5.47	79.6	85.1	-5.47	79.6	85.1	-5.47	79.9	85.1	-5.2
85.6	-4.20	81.4	85.9	-4.47	81.4	86.2	-4.75	81.4	86.2	-4.75	81.4	86.5	-5.0
84.5	-2.56	81.9	84.5	-2.56	82.2	84.2	-2.02	82.2	84.8	-2.58	82.2	84.8	-2.6
87.8	-5.64	82.5	87.8	-5.38	82.2	87.8	-5.64	82.2	87.6	-5.36	82.5	86.7	-4.3
85.9	-3.95	81.9	85.9	-3.95	82.7	85.9	-3.17	82.2	85.9	-3.69	80.9	85.6	-4.7
85.9	-4.74	80.6	85.9	-5.26	80.6	85.9	-5.26	80.6	85.9	-5.26	80.6	85.6	-5.0
86.7	-6.88	79.9	86.7	-6.88	79.3	86.5	-7.13	79.6	86.5	-6.86	79.6	86.5	-6.9
87.8	-5.90	81.9	88.1	-6.18	82.2	88.1	-5.92	82.5	87.8	-5.38	82.2	87.8	-5.6
84.2	-1.76	82.5	84.0	-1.49	82.7	83.7	-0.96	82.7	83.7	-0.96	82.7	83.4	-0.7
85.3	-2.61	82.7	85.3	-2.61	83.0	88.1	-5.13	83.3	88.4	-5.15	83.3	87.3	-4.0
85.9	-5.00	81.7	85.9	-4.21	80.9	86.2	-5.28	78.3	86.2	-7.90	79.3	86.2	-6.8
88.4	-10.12	78.3	88.4	-10.12	78.5	88.1	-9.58	78.8	88.1	-9.32	78.8	88.1	-9.3
89.5	-9.14	80.4	89.5	-9.14	80.1	89.5	-9.40	80.9	89.2	-8.34	81.2	89.8	-8.6
89.5	-7.83	81.9	89.8	-7.85	81.7	89.8	-8.11	81.7	89.2	-7.55	81.4	89.2	-7.8
84.2	-3.59	80.9	84.2	-3.33	80.9	84.0	-3.06	80.9	84.0	-3.06	80.6	84.2	-3.6
84.2	-3.33	80.9	84.5	-3.61	81.2	84.5	-3.35	81.4	84.5	-3.08	81.4	84.8	-3.4
86.2	-5.02	81.2	86.2	-5.02	81.4	86.2	-4.75	81.9	86.2	-4.23	81.7	86.2	-4.5
85.1	-1.54	83.0	85.1	-2.07	82.7	85.1	-2.33	82.5	85.1	-2.59	82.2	85.1	-2.9
87.6	-4.31	83.0	87.6	-4.57	83.3	87.6	-4.31	83.5	87.6	-4.05	83.5	87.6	-4.0
81.3	1.18	82.2	80.8	1.46	82.5	80.8	1.72	82.2	80.5	1.72	82.2	80.5	1.7
80.2	1.73	81.9	80.5	1.46	81.9	81.0	0.93	82.2	82.6	-0.41	82.2	83.4	-1.2
85.53	-3.75	81.80	85.53	-3.73	81.84	85.56	-3.72	81.81	85.58	-3.77	81.79	85.63	-3.85
	2.8			2.8			2.8			2.7			2.6

Experimental Room 1 (%) 10:00	Control Room (%) 10:00	Difference (%) 10:00	Experimental Room 1 (%) 11:00	Control Room (%) 11:00	Difference (%) 11:00	Experimental Room 1 (%) 12:00	Control Room (%) 12:00	Difference (%) 12:00	Experimental Room 1 (%) 13:00	Control Room (%) 13:00	Difference (%) 13:00	Experimental Room 1 (%) 14:00	Control Room (%) 14:00	Difference (%) 14:00
82.7	81.8	0.9	82.7	81.8	0.9	82.7	82.1	0.6	82.7	82.4	0.4	82.7	82.4	0.4
84.6	84.8	-0.2	84.8	85.6	-0.8	84.8	85.9	-1.1	84.8	86.7	-1.9	84.8	86.7	-1.9
85.4	88.4	-3.0	0.0	0.0	0.0	84.8	88.1	-3.3	85.1	88.1	-3.0	85.4	88.1	-2.7
83.0	88.1	-5.1	83.3	88.1	-4.9	82.7	88.1	-5.4	82.5	88.1	-5.7	82.5	89.8	-7.3
84.6	87.8	-3.3	84.8	87.6	-2.7	84.6	87.3	-2.7	84.8	87.0	-2.2	84.8	86.5	-1.6
81.4	82.9	-1.5	81.4	82.9	-1.5	81.4	82.6	-1.2	81.4	82.4	-0.9	81.4	82.1	-0.7
81.7	82.1	-0.4	81.9	82.4	-0.4	82.2	82.6	-0.4	82.2	82.9	-0.7	81.9	83.2	-1.2
81.9	84.2	-2.3	82.2	84.0	-1.7	82.2	83.2	-0.9	82.5	83.4	-1.0	82.7	83.2	-0.4
81.9	84.2	-2.3	81.4	84.5	-3.1	81.4	84.5	-3.1	80.9	84.5	-3.6	80.6	84.2	-3.6
78.5	84.2	-5.7	78.5	84.0	-5.4	78.8	83.7	-4.9	79.1	84.0	-4.9	78.8	84.0	-5.2
79.6	84.5	-4.9	79.9	84.2	-4.4	79.9	84.2	-4.4	80.1	84.2	-4.1	80.4	84.5	-4.1
81.4	86.5	-5.0	81.4	86.5	-5.0	81.4	86.5	-5.0	81.4	86.2	-4.8	81.7	86.7	-5.0
82.2	85.1	-2.9	82.2	85.3	-3.1	82.2	85.6	-3.4	82.2	85.9	-3.7	82.2	85.9	-3.7
82.5	86.7	-4.3	82.5	86.5	-4.0	82.7	86.7	-4.0	82.7	87.0	-4.3	83.0	87.0	-4.0
80.6	85.9	-5.3	80.9	85.9	-5.0	80.6	85.6	-5.0	80.9	85.9	-5.0	80.6	85.9	-5.3
80.6	85.6	-5.0	80.6	85.9	-5.3	80.4	85.6	-5.2	80.4	85.9	-5.5	80.4	85.9	-5.5
79.6	86.5	-6.9	79.9	86.5	-6.6	80.1	86.5	-6.3	80.1	86.5	-6.3	80.1	86.5	-6.3
82.5	87.8	-5.4	82.5	88.1	-5.7	82.5	88.1	-5.7	82.2	88.7	-6.5	82.2	88.4	-6.2
82.7	83.7	-1.0	82.5	84.0	-1.5	82.5	84.0	-1.5	82.5	84.0	-1.5	82.5	84.0	-1.5
83.3	87.0	-3.8	83.3	86.7	-3.5	83.3	86.5	-3.2	83.5	86.7	-3.2	83.5	87.3	-3.8
79.1	86.5	-7.4	79.1	86.5	-7.4	79.3	87.0	-7.7	78.8	87.0	-8.2	78.3	87.6	-9.3
78.0	88.1	-10.1	77.5	88.1	-10.6	77.5	88.1	-10.6	76.4	88.1	-11.7	77.0	88.1	-11.2
81.2	89.8	-8.6	81.2	90.1	-8.9	81.2	90.1	-8.9	81.2	90.1	-8.9	80.9	90.4	-9.5
81.2	89.0	-7.8	81.2	88.7	-7.5	81.2	88.4	-7.2	80.9	87.6	-6.7	80.9	87.3	-6.4
80.9	84.2	-3.3	80.6	84.0	-3.3	81.2	83.7	-2.5	80.6	84.0	-3.3	80.9	83.7	-2.8
81.9	84.5	-2.6	82.5	84.8	-2.3	81.7	88.1	-6.4	82.2	86.2	-4.0	82.5	85.9	-3.4
81.9	86.2	-4.2	82.2	86.5	-4.2	82.5	86.2	-3.7	82.7	86.5	-3.7	82.5	86.5	-4.0
81.9	85.1	-3.1	81.9	85.1	-3.1	81.4	85.1	-3.6	81.4	85.3	-3.9	81.2	85.3	-4.2
83.5	87.6	-4.0	83.5	87.6	-4.0	83.8	87.6	-3.8	83.5	87.6	-4.0	83.3	87.6	-4.3
82.2	80.5	1.7	82.2	80.5	1.7	82.2	80.0	2.3	82.2	79.7	2.5	82.2	79.4	2.8
82.7	71.7	11.1	82.7	71.1	11.6	82.7	70.6	12.1	82.7	70.6	12.1	83.0	70.6	12.4
81.79	85.19	-3.40	79.08	82.36	-3.28	81.80	85.23	-3.43	81.77	85.26	-3.49	81.77	85.30	-3.53
		3.7			3.8			3.9			4.0			4.1

Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)
	15:00:00			16:00			17:00			18:00			19:00	
82.5	82.4	0.1	82.5	82.1	0.4	82.5	82.4	0.1	82.2	82.4	-0.1	82.5	82.4	0.1
84.8	87.6	-2.7	84.8	87.6	-2.7	84.6	87.8	-3.3	85.1	87.8	-2.7	85.1	87.6	-2.5
85.7	88.1	-2.5	85.7	88.4	-2.7	85.1	88.4	-3.3	85.1	88.4	-3.3	84.8	88.4	-3.6
82.5	88.7	-6.2	82.5	89.0	-6.5	82.5	88.7	-6.2	82.5	89.0	-6.5	82.7	89.0	-6.2
84.6	86.2	-1.6	84.3	85.9	-1.6	83.8	85.6	-1.8	83.3	85.9	-2.6	82.7	85.6	-2.9
81.4	82.1	-0.7	81.7	82.4	-0.7	81.7	82.1	-0.4	81.7	82.1	-0.4	81.4	82.1	-0.7
81.9	83.2	-1.2	81.9	83.4	-1.5	81.9	83.7	-1.7	82.2	83.7	-1.5	82.2	83.7	-1.5
82.5	83.4	-1.0	82.7	83.4	-0.7	83.3	83.4	-0.2	83.5	83.4	0.1	83.5	83.4	0.1
80.6	84.5	-3.9	80.6	84.5	-3.9	80.4	84.5	-4.1	80.4	84.8	-4.4	80.4	84.8	-4.4
78.8	84.0	-5.2	79.1	84.0	-4.9	78.5	85.6	-7.1	78.0	85.6	-7.6	78.0	84.8	-6.8
80.6	84.8	-4.1	80.6	84.5	-3.9	80.6	84.5	-3.9	81.2	84.8	-3.6	81.4	84.8	-3.4
81.7	86.7	-5.0	81.4	86.7	-5.3	81.4	86.5	-5.0	81.4	86.2	-4.8	81.9	85.9	-4.0
82.2	85.9	-3.7	82.2	86.2	-4.0	82.5	86.2	-3.7	82.5	86.2	-3.7	82.5	86.2	-3.7
83.0	86.7	-3.7	83.3	86.7	-3.5	83.0	86.5	-3.5	83.0	86.7	-3.7	83.0	86.2	-3.2
81.4	85.9	-4.5	81.7	85.9	-4.2	81.9	85.9	-4.0	82.2	85.9	-3.7	82.2	85.9	-3.7
79.9	85.9	-6.0	79.9	85.9	-6.0	79.6	86.2	-6.6	79.6	86.7	-7.1	79.6	87.3	-7.7
80.4	86.5	-6.1	80.6	86.5	-5.8	80.6	86.5	-5.8	80.9	86.5	-5.6	80.9	86.5	-5.6
82.2	88.1	-5.9	82.2	87.3	-5.1	81.9	87.0	-5.1	82.2	87.6	-5.4	82.2	87.3	-5.1
82.2	84.0	-1.7	82.5	84.0	-1.5	82.5	84.0	-1.5	82.5	84.2	-1.8	82.5	84.2	-1.8
83.5	87.0	-3.5	82.7	86.7	-4.0	83.0	86.5	-3.5	83.0	86.7	-3.7	83.0	86.7	-3.7
76.7	87.6	-10.9	78.5	87.3	-8.7	78.8	87.6	-8.8	78.5	87.8	-9.3	78.8	87.8	-9.0
77.2	88.1	-10.9	77.8	88.1	-10.4	77.8	88.1	-10.4	78.0	88.1	-10.1	77.5	88.1	-10.6
80.9	90.4	-9.5	80.4	90.1	-9.7	80.4	89.8	-9.4	80.6	89.8	-9.2	80.6	90.1	-9.4
80.9	86.2	-5.3	80.9	86.5	-5.6	80.9	86.2	-5.3	81.2	86.2	-5.0	80.9	85.9	-5.0
80.9	83.7	-2.8	80.9	83.4	-2.5	80.6	83.2	-2.5	80.4	83.2	-2.8	80.4	82.9	-2.5
82.5	85.6	-3.1	83.0	85.6	-2.6	83.8	85.3	-1.6	83.3	85.3	-2.1	82.7	85.3	-2.6
83.0	86.2	-3.2	83.3	86.2	-2.9	83.3	86.2	-2.9	83.5	86.2	-2.7	83.8	85.6	-1.8
80.9	85.1	-4.2	81.2	85.9	-4.7	81.2	86.7	-5.6	81.2	86.5	-5.3	81.2	85.6	-4.5
84.3	87.6	-3.3	84.3	87.6	-3.3	84.3	87.6	-3.3	84.3	87.6	-3.3	84.6	87.6	-3.0
82.2	79.2	3.1	82.2	79.4	2.8	82.2	79.2	3.1	82.2	79.4	2.8	82.2	79.4	2.8
83.0	70.6	12.4	83.0	70.6	12.4	83.0	70.6	12.4	83.0	70.6	12.4	82.7	70.6	12.1
81.77	85.21	-3.44	81.88	85.21	-3.33	81.86	85.23	-3.38	81.89	85.33	-3.44	81.87	85.21	-3.34
		4.1			4.0			4.0			4.0			4.0

Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)	Experimental Room 1 (%)	Control Room (%)	Difference (%)
	20:00			21:00			22:00			23:00			00:00	
82.5	82.4	0.1	82.2	82.6	-0.4	82.2	82.6	-0.4	82.5	82.9	-0.4	82.5	82.9	-0.4
85.1	87.6	-2.5	84.8	87.6	-2.7	84.8	87.6	-2.7	84.8	87.6	-2.7	85.4	87.6	-2.2
84.8	88.1	-3.3	83.5	88.1	-4.6	83.3	88.1	-4.9	83.3	88.4	-5.1	83.0	88.1	-5.1
82.5	89.0	-6.5	82.5	89.0	-6.5	82.5	89.2	-6.8	82.5	89.0	-6.5	82.7	89.0	-6.2
82.7	85.3	-2.6	82.5	85.3	-2.9	82.5	84.8	-2.3	82.2	84.8	-2.6	82.2	84.5	-2.3
81.4	82.4	-0.9	81.4	82.4	-0.9	81.7	82.4	-0.7	81.7	82.6	-0.9	81.7	82.4	-0.7
82.2	84.0	-1.7	82.2	84.0	-1.7	82.2	84.0	-1.7	82.2	83.4	-1.2	82.2	83.7	-1.5
83.5	83.7	-0.2	83.8	83.7	0.1	83.8	83.7	0.1	83.5	83.7	-0.2	83.5	84.0	-0.4
80.6	84.8	-4.1	80.6	84.8	-4.1	80.6	84.8	-4.1	80.4	84.8	-4.4	79.9	84.5	-4.7
77.5	84.2	-6.7	78.3	85.3	-7.1	78.0	85.6	-7.6	78.3	85.6	-7.3	78.0	85.3	-7.3
81.2	84.8	-3.6	81.2	85.1	-3.9	81.2	85.1	-3.9	81.2	85.3	-4.2	81.4	85.3	-3.9
81.7	85.6	-3.9	81.7	85.6	-3.9	81.7	85.3	-3.7	81.7	85.3	-3.7	81.7	85.1	-3.4
82.2	86.5	-4.2	82.2	86.5	-4.2	81.9	86.5	-4.5	82.2	86.7	-4.5	81.9	86.7	-4.8
83.0	86.5	-3.5	83.0	86.5	-3.5	83.3	86.2	-2.9	83.0	86.2	-3.2	82.7	86.2	-3.4
82.2	85.6	-3.4	81.9	85.9	-4.0	81.9	85.9	-4.0	81.9	85.6	-3.7	81.9	85.6	-3.7
79.3	87.0	-7.7	79.1	88.4	-9.3	79.1	88.1	-9.1	79.1	87.3	-8.2	79.3	87.0	-7.7
81.7	86.5	-4.8	82.5	86.5	-4.0	83.0	86.5	-3.5	83.3	86.5	-3.2	83.3	86.7	-3.5
82.2	87.0	-4.8	82.2	87.0	-4.8	82.5	86.7	-4.3	82.5	86.5	-4.0	82.5	86.2	-3.7
82.5	84.2	-1.8	82.5	84.5	-2.0	82.5	84.5	-2.0	82.5	84.5	-2.0	82.5	84.8	-2.3
82.7	86.7	-4.0	82.7	86.7	-4.0	82.7	86.7	-4.0	82.2	86.2	-4.0	82.2	85.6	-3.4
78.8	87.8	-9.0	78.3	88.1	-9.8	78.5	87.8	-9.3	77.2	88.1	-10.9	77.8	88.1	-10.4
77.8	88.1	-10.4	77.8	88.1	-10.4	77.8	88.4	-10.6	78.0	89.2	-11.2	78.5	89.0	-10.4
80.4	90.1	-9.7	80.6	90.4	-9.7	81.2	90.6	-9.5	81.2	90.6	-9.5	81.2	90.9	-9.7
80.9	85.3	-4.4	80.9	84.8	-3.9	80.9	85.1	-4.2	80.9	85.1	-4.2	80.6	85.3	-4.7
80.6	83.2	-2.5	80.4	83.4	-3.0	80.4	83.2	-2.8	80.4	83.4	-3.0	80.4	83.7	-3.3
82.2	85.3	-3.1	81.9	85.9	-4.0	81.7	85.6	-3.9	81.4	85.9	-4.5	81.2	85.6	-4.5
84.0	85.3	-1.3	84.0	85.6	-1.6	84.0	85.6	-1.6	84.0	85.3	-1.3	83.8	85.3	-1.6
81.2	86.5	-5.3	81.2	87.3	-6.1	81.4	87.3	-5.9	81.7	87.3	-5.6	82.2	87.0	-4.8
84.6	87.6	-3.0	84.6	84.2	0.3	84.3	84.0	0.3	83.8	83.4	0.4	83.8	83.2	0.6
81.9	79.4	2.5	81.9	79.4	2.5	81.9	79.4	2.5	81.9	79.4	2.5	81.7	79.7	2.0
83.0	70.6	12.4	83.0	81.0	2.0	83.0	81.0	2.0	83.0	81.0	2.0	0.0	0.0	0.0
81.84	85.19	-3.36	81.79	85.60	-3.81	81.82	85.56	-3.74	81.75	85.54	-3.79	79.09	82.87	-3.79
		4.0			3.2			3.2			3.2			3.0

Average External air temperature data loggers' readings for the Month of June

	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experime ntal Room 1 (°C)
day of the month		00:00			01:00			02:00			03:00			04:00		
1	30.1 °C	30.2 °C	-0.1	30.1 °C	30.2 °C	-0.1	33.0 °C	33.1 °C	-0.1	34.0 °C	34.2 °C	-0.2	30.0 °C	30.1 °C	-0.1	32.0 °C
2	30.1 °C	30.3 °C	-0.2	29.7 °C	28.9 °C	0.8	29.8 °C	30.0 °C	-0.2	29.6 °C	29.6 °C	0.0	29.9 °C	29.9 °C	0.0	30.1 °C
3	29.5 °C	30.1 °C	-0.6	29.8 °C	30.3 °C	-0.5	30.1 °C	30.3 °C	-0.2	29.7 °C	29.9 °C	-0.2	28.8 °C	28.9 °C	-0.1	28.7 °C
4	29.7 °C	29.8 °C	-0.1	29.9 °C	30.0 °C	-0.1	29.7 °C	29.7 °C	0.0	29.8 °C	29.8 °C	0.0	29.8 °C	29.8 °C	0.0	29.7 °C
5	28.6 °C	28.6 °C	0.0	28.7 °C	28.7 °C	0.0	29.0 °C	29.0 °C	0.0	29.0 °C	29.0 °C	0.0	29.5 °C	29.5 °C	0.0	29.8 °C
6	30.5 °C	30.5 °C	0.0	30.5 °C	30.5 °C	0.0	30.5 °C	30.5 °C	0.0	31.1 °C	31.1 °C	0.0	31.2 °C	31.2 °C	0.0	31.2 °C
7	29.6 °C	29.6 °C	0.0	29.6 °C	29.6 °C	0.0	29.5 °C	29.5 °C	0.0	30.1 °C	30.1 °C	0.0	28.9 °C	28.9 °C	0.0	28.4 °C
8	30.6 °C	30.6 °C	0.0	30.6 °C	30.6 °C	0.0	30.6 °C	30.6 °C	0.0	29.8 °C	29.8 °C	0.0	29.9 °C	29.9 °C	0.0	29.6 °C
9	29.6 C	29.7 C	-0.1	30.4 C	30.2 C	0.2	29.8 C	30.2 C	-0.4	29.5 C	29.7 C	-0.2	27.6 C	28.1 C	-0.4	27.3 C
10	28.2 C	28.7 C	-0.5	26.4 C	26.5 C	0.0	26.6 C	27.2 C	-0.6	26.8 C	28.2 C	-1.3	27.3 C	28.7 C	-1.5	27.7 C
11	28.0 C	28.9 C	-0.9	28.2 C	28.8 C	-0.6	28.1 C	28.6 C	-0.4	27.9 C	28.5 C	-0.6	26.9 C	26.7 C	0.1	27.0 C
12	27.4 C	27.8 C	-0.4	27.5 C	28.6 C	-1.0	28.1 C	29.3 C	-1.2	28.7 C	29.7 C	-1.0	29.0 C	29.8 C	-0.9	28.9 C
13	28.0 C	28.7 C	-0.6	28.1 C	29.0 C	-0.9	28.2 C	28.8 C	-0.6	28.3 C	29.1 C	-0.8	27.9 C	27.7 C	0.2	28.1 C
14	26.9 C	27.5 C	-0.6	26.7 C	26.6 C	0.2	27.1 C	27.4 C	-0.3	27.2 C	27.9 C	-0.7	27.2 C	28.0 C	-0.8	27.4 C
15	26.8 C	27.2 C	-0.4	26.9 C	27.7 C	-0.8	27.2 C	27.9 C	-0.6	27.2 C	27.6 C	-0.4	27.2 C	27.6 C	-0.4	27.1 C
16	27.4 C	27.9 C	-0.5	27.2 C	28.3 C	-1.1	26.3 C	26.9 C	-0.6	26.6 C	27.0 C	-0.4	26.9 C	27.2 C	-0.3	27.0 C
17	25.8 C	27.0 C	-1.2	25.8 C	27.0 C	-1.2	25.7 C	26.9 C	-1.1	25.8 C	26.4 C	-0.6	25.7 C	26.7 C	-1.0	25.6 C
18	26.8 C	27.7 C	-0.9	26.7 C	28.0 C	-1.2	26.5 C	27.9 C	-1.4	25.8 C	26.5 C	-0.6	25.8 C	26.8 C	-0.9	26.3 C
19	26.1 C	26.6 C	-0.6	26.7 C	27.8 C	-1.1	27.2 C	27.8 C	-0.6	27.1 C	27.8 C	-0.8	27.2 C	27.9 C	-0.7	26.8 C
20	26.5 C	26.4 C	0.0	27.0 C	27.2 C	-0.2	27.7 C	27.5 C	0.1	28.1 C	28.0 C	0.2	28.3 C	28.0 C	0.2	27.9 C
21	27.2 C	27.9 C	-0.7	27.4	27.1 C	0.3	26.3	26.2 C	0.1	25.4	26.2 C	-0.7	24.8	25.9 C	-1.1	27.3
22	25.4	27.4 C	-2.0	24.0	27.5 C	-3.6	25.1	26.3 C	-1.2	27.1	26.1 C	0.9	26.2	26.5 C	-0.3	26.0
23	27.9	26.2 C	1.6	27.9	26.4 C	1.5	26.4	26.5 C	-0.1	25.3	27.4 C	-2.1	24.9	27.0 C	-2.0	24.7
24	27.1	26.0 C	1.1	29.0	25.8 C	3.3	29.3	25.7 C	3.6	28.5	25.4 C	3.1	26.3	25.4 C	0.9	25.1
25	26.7	26.5 C	0.2	25.4	26.7 C	-1.3	24.6	27.1 C	-2.5	24.3	26.9 C	-2.6	28.9	26.7 C	2.2	28.8
26	25.2	25.7 C	-0.5	28.8	25.9 C	2.9	26.0	26.1 C	-0.1	26.0	26.1 C	-0.1	28.1 C	28.0 C	0.2	26.2
27	27.6	27.4 °C	0.2	28.0	27.7 °C	0.3	24.9	25.0 °C	-0.1	24.5	25.1 °C	-0.5	26.1	26.2 °C	-0.1	27.0
28	26.0	26.6 °C	-0.6	26.1	26.0 °C	0.1	25.3	25.0 °C	0.3	25.1	25.3 °C	-0.2	28.6	27.6 °C	1.0	27.2
29	25.8	25.6 °C	0.2	26.1	25.8 °C	0.3	26.6	26.0 °C	0.6	25.6	24.9 °C	0.7	24.5	26.5 °C	-2.0	29.5
30	24.4 °C	25.9 °C	-1.4	26.0 °C	25.5 °C	0.6	26.9 °C	24.7 °C	2.3	25.9 °C	24.8 °C	1.1	25.4 °C	27.0 °C	-1.6	25.1 °C
AVG of the difference (°C)	27.7 °C	28.0 °C	-0.3	27.8 °C	28.0 °C	-0.1	27.7 °C	27.9 °C	-0.2	27.7 °C	27.9 °C	-0.3	27.6 °C	27.9 °C	-0.3	27.8 °C
STD DEV of the difference (°C)																

Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)
05:00			06:00			07:00			08:00			09:00			10:00	
32.1 °C	0.1 °C	28.0 °C	28.2 °C	0.2 °C	29.5 °C	29.6 °C	0.1 °C	29.9 °C	29.5 °C	-0.4 °C	30.5 °C	30.7 °C	0.2 °C	31.3 °C	31.5 °C	0.2 °C
30.1 °C	0.0 °C	28.7 °C	28.7 °C	0.0 °C	28.6 °C	28.9 °C	0.3 °C	28.7 °C	28.9 °C	0.2 °C	28.8 °C	28.9 °C	0.1 °C	28.9 °C	29.1 °C	0.2 °C
28.9 °C	0.2 °C	28.8 °C	28.9 °C	0.1 °C	30.0 °C	30.2 °C	0.2 °C	30.3 °C	30.3 °C	0.0 °C	30.5 °C	30.6 °C	0.1 °C	31.0 °C	30.8 °C	-0.2 °C
29.7 °C	0.0 °C	30.1 °C	30.1 °C	0.0 °C	30.2 °C	30.2 °C	0.0 °C	30.2 °C	30.2 °C	0.0 °C	29.7 °C	29.7 °C	0.0 °C	29.6 °C	29.6 °C	0.0 °C
29.8 °C	0.0 °C	29.8 °C	29.8 °C	0.0 °C	28.3 °C	28.3 °C	0.0 °C	28.1 °C	28.1 °C	0.0 °C	28.9 °C	28.9 °C	0.0 °C	28.5 °C	28.5 °C	0.0 °C
31.2 °C	0.0 °C	31.2 °C	31.2 °C	0.0 °C	30.8 °C	30.8 °C	0.0 °C	29.9 °C	29.9 °C	0.0 °C	29.6 °C	29.6 °C	0.0 °C	29.6 °C	29.6 °C	0.0 °C
28.4 °C	0.0 °C	29.0 °C	29.0 °C	0.0 °C	29.2 °C	29.2 °C	0.0 °C	29.2 °C	29.2 °C	0.0 °C	29.8 °C	29.8 °C	0.0 °C	29.7 °C	29.7 °C	0.0 °C
29.6 °C	0.0 °C	29.5 °C	29.5 °C	0.0 °C	29.7 °C	29.7 °C	0.0 °C	29.9 °C	29.9 °C	0.0 °C	29.7 °C	29.7 °C	0.0 °C	29.8 °C	29.8 °C	0.0 °C
27.5 C	0.3 °C	27.5 C	27.8 C	0.3 °C	27.3 C	27.5 C	0.1 °C	27.5 C	27.6 C	0.1 °C	27.4 C	27.6 C	0.2 °C	27.7 C	27.0 C	-0.7 °C
28.7 C	1.1 °C	27.9 C	28.7 C	0.8 °C	27.9 C	28.6 C	0.6 °C	27.1 C	26.9 C	-0.2 °C	26.8 C	27.0 C	0.2 °C	26.8 C	27.4 C	0.6 °C
28.4 C	1.5 °C	27.5 C	29.6 C	2.0 °C	28.3 C	29.7 C	1.4 °C	28.3 C	29.0 C	0.6 °C	28.2 C	28.5 C	0.3 °C	27.5 C	27.2 C	-0.3 °C
29.4 C	0.4 °C	28.8 C	29.1 C	0.4 °C	27.7 C	27.8 C	0.1 °C	27.9 C	29.3 C	1.4 °C	28.1 C	28.8 C	0.8 °C	28.3 C	28.0 C	-0.3 °C
29.1 C	1.0 °C	28.7 C	29.4 C	0.7 °C	28.7 C	29.3 C	0.5 °C	29.1 C	29.6 C	0.5 °C	29.0 C	29.3 C	0.3 °C	28.9 C	29.4 C	0.4 °C
28.0 C	0.6 °C	27.4 C	27.8 C	0.4 °C	27.2 C	28.0 C	0.8 °C	26.5 C	26.5 C	0.0 °C	27.1 C	28.3 C	1.3 °C	27.6 C	29.4 C	1.9 °C
27.2 C	0.0 °C	27.1 C	27.2 C	0.1 °C	27.5 C	27.9 C	0.4 °C	27.9 C	28.1 C	0.2 °C	27.7 C	28.1 C	0.4 °C	27.4 C	27.9 C	0.5 °C
27.4 C	0.4 °C	27.2 C	27.7 C	0.5 °C	27.0 C	27.4 C	0.4 °C	26.9 C	28.2 C	1.4 °C	26.2 C	26.6 C	0.4 °C	26.6 C	27.1 C	0.5 °C
26.7 C	1.1 °C	25.2 C	25.8 C	0.6 °C	25.7 C	26.6 C	0.9 °C	26.0 C	26.8 C	0.8 °C	26.3 C	27.1 C	0.8 °C	26.6 C	26.0 C	-0.6 °C
27.2 C	1.0 °C	26.3 C	27.0 C	0.7 °C	26.3 C	26.9 C	0.5 °C	26.2 C	27.3 C	1.1 °C	26.0 C	27.5 C	1.4 °C	25.5 C	26.2 C	0.7 °C
28.1 C	1.3 °C	26.6 C	27.8 C	1.2 °C	26.5 C	26.3 C	-0.3 °C	27.1 C	26.5 C	-0.6 °C	27.1 C	26.3 C	-0.8 °C	26.6 C	26.8 C	0.2 °C
27.7 C	-0.2 °C	27.9 C	27.8 C	-0.1 °C	26.5 C	26.1 C	-0.4 °C	27.2 C	27.2 C	-0.1 °C	28.2 C	27.8 C	-0.4 °C	28.5 C	28.9 C	0.4 °C
25.1 C	-2.2 °C	27.1	25.4 C	-1.7 °C	28.0	26.0 C	-2.0 °C	28.3	27.1 C	-1.2 °C	25.7	28.0 C	2.2 °C	25.5	25.0 C	-0.5 °C
27.1 C	1.2 °C	25.0	27.3 C	2.2 °C	24.7	27.8 C	3.1 °C	24.8	27.6 C	2.8 °C	27.2	25.9 C	-1.3 °C	27.4	26.1 C	-1.3 °C
26.8 C	2.1 °C	25.4	26.3 C	0.9 °C	24.7	26.8 C	2.2 °C	25.8	27.0 C	1.2 °C	25.6	27.4 C	1.8 °C	24.9	29.1 C	4.2 °C
26.9 C	1.8 °C	24.2	27.4 C	3.2 °C	28.1	27.8 C	-0.3 °C	28.5	27.8 C	-0.6 °C	27.8	26.0 C	-1.8 °C	28.5	26.9 C	-1.6 °C
26.5 C	-2.4 °C	28.1	26.8 C	-1.3 °C	27.1	26.4 C	-0.6 °C	25.6	27.9 C	2.3 °C	24.9	28.9 C	4.0 °C	24.2	25.0 C	0.8 °C
26.6 °C	0.4 °C	25.5	25.1 °C	-0.4 °C	25.0	25.1 °C	0.1 °C	29.3	24.2 °C	-5.1 °C	29.6	29.1 °C	-0.5 °C	28.8	28.6 °C	-0.2 °C
27.1 °C	0.1 °C	26.0	26.2 °C	0.2 °C	26.0	25.5 °C	-0.5 °C	27.6	27.4 °C	-0.2 °C	25.6	25.4 °C	-0.2 °C	26.0	26.0 °C	0.0 °C
27.9 °C	0.7 °C	26.4	26.9 °C	0.5 °C	26.0	26.1 °C	0.1 °C	28.2	28.0 °C	-0.2 °C	25.7	25.4 °C	-0.3 °C	28.0	28.0 °C	0.0 °C
28.9 °C	-0.6 °C	31.8	30.9 °C	-0.9 °C	26.1	25.3 °C	-0.8 °C	25.0	24.1 °C	-0.9 °C	25.0	24.2 °C	-0.8 °C	26.2	27.0 °C	0.8 °C
26.9 °C	1.7 °C	25.9 °C	25.7 °C	-0.3 °C	28.4 °C	25.4 °C	-3.0 °C	26.5 °C	25.0 °C	-1.5 °C	25.4 °C	25.3 °C	-0.1 °C	25.1 °C	25.0 °C	-0.1 °C
28.2 °C	0.4 °C	27.6 °C	28.0 °C	0.3 °C	27.6 °C	27.7 °C	0.1 °C	27.8 °C	27.8 °C	0.1 °C	27.6 °C	27.9 °C	0.3 °C	27.7 °C	27.9 °C	0.2 °C

Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)
11:00			12:00			13:00			14:00			15:00			16:	
30.1 °C	30.3 °C	0.2 °C	30.5 °C	30.7 °C	0.2 °C	30.5 °C	30.7 °C	0.2 °C	30.2 °C	30.5 °C	0.3 °C	29.8 °C	29.9 °C	0.1 °C	28.7 °C	28.8 °C
28.7 °C	29.2 °C	0.5 °C	29.1 °C	29.3 °C	0.2 °C	29.2 °C	29.4 °C	0.2 °C	29.4 °C	29.7 °C	0.3 °C	29.9 °C	30.0 °C	0.1 °C	30.0 °C	30.5 °C
31.2 °C	30.8 °C	-0.4 °C	31.5 °C	31.7 °C	0.2 °C	29.7 °C	29.7 °C	0.0 °C	29.7 °C	29.8 °C	0.1 °C	30.2 °C	30.3 °C	0.1 °C	30.5 °C	30.6 °C
29.6 °C	29.6 °C	0.0 °C	29.7 °C	29.7 °C	0.0 °C	29.7 °C	29.7 °C	0.0 °C	30.1 °C	30.1 °C	0.0 °C	30.2 °C	30.2 °C	0.0 °C	30.5 °C	30.5 °C
28.9 °C	28.9 °C	0.0 °C	28.4 °C	28.4 °C	0.0 °C	29.0 °C	29.0 °C	0.0 °C	29.2 °C	29.2 °C	0.0 °C	29.2 °C	29.2 °C	0.0 °C	29.8 °C	29.8 °C
29.4 °C	29.4 °C	0.0 °C	29.4 °C	29.4 °C	0.0 °C	29.4 °C	29.4 °C	0.0 °C	29.2 °C	29.2 °C	0.0 °C	29.6 °C	29.6 °C	0.0 °C	29.7 °C	29.7 °C
29.7 °C	29.7 °C	0.0 °C	29.4 °C	29.4 °C	0.0 °C	29.6 °C	29.6 °C	0.0 °C	29.6 °C	29.6 °C	0.0 °C	30.0 °C	30.0 °C	0.0 °C	30.3 °C	30.3 °C
29.8 °C	29.8 °C	0.0 °C	29.7 °C	29.7 °C	0.0 °C	30.1 °C	30.1 °C	0.0 °C	30.2 °C	30.2 °C	0.0 °C	30.2 °C	30.2 °C	0.0 °C	29.7 °C	29.7 °C
27.6 C	27.4 C	-0.2 °C	28.2 C	28.5 C	0.3 °C	28.2 C	28.1 C	-0.1 °C	28.3 C	27.9 C	-0.4 °C	27.9 C	27.9 C	0.0 °C	27.7 C	27.7 C
26.9 C	26.8 C	-0.1 °C	26.9 C	27.8 C	0.9 °C	26.9 C	28.2 C	1.3 °C	26.4 C	26.8 C	0.4 °C	26.5 C	28.1 C	1.5 °C	26.8 C	28.3 C
27.7 C	28.2 C	0.5 °C	27.9 C	28.6 C	0.7 °C	28.0 C	28.7 C	0.6 °C	28.2 C	28.6 C	0.4 °C	28.1 C	28.3 C	0.3 °C	27.9 C	28.5 C
28.8 C	29.8 C	1.0 °C	28.8 C	29.3 C	0.5 °C	28.6 C	29.0 C	0.4 °C	27.6 C	27.3 C	-0.2 °C	27.8 C	28.1 C	0.3 °C	27.7 C	28.0 C
27.2 C	27.0 C	-0.2 °C	27.3 C	27.1 C	-0.2 °C	27.2 C	27.3 C	0.0 °C	27.3 C	27.4 C	0.1 °C	27.6 C	28.0 C	0.5 °C	27.5 C	27.8 C
28.6 C	29.7 C	1.0 °C	28.5 C	29.1 C	0.6 °C	28.3 C	28.7 C	0.4 °C	28.2 C	28.8 C	0.6 °C	27.5 C	27.3 C	-0.1 °C	27.4 C	27.5 C
27.1 C	27.0 C	-0.1 °C	26.0 C	26.5 C	0.4 °C	26.6 C	27.3 C	0.8 °C	26.8 C	27.5 C	0.7 °C	27.4 C	28.0 C	0.7 °C	27.7 C	28.0 C
26.6 C	27.0 C	0.4 °C	26.8 C	27.8 C	1.0 °C	26.8 C	27.8 C	1.0 °C	26.7 C	27.4 C	0.7 °C	26.5 C	28.0 C	1.5 °C	25.9 C	26.4 C
26.6 C	27.9 C	1.2 °C	26.4 C	27.9 C	1.6 °C	25.9 C	26.9 C	1.0 °C	26.4 C	27.0 C	0.6 °C	26.5 C	27.0 C	0.5 °C	26.9 C	27.5 C
26.1 C	26.8 C	0.7 °C	26.5 C	27.3 C	0.7 °C	26.8 C	27.4 C	0.6 °C	26.8 C	27.3 C	0.6 °C	26.5 C	27.1 C	0.6 °C	26.3 C	27.1 C
26.3 C	26.5 C	0.1 °C	26.1 C	26.2 C	0.1 °C	25.9 C	26.9 C	1.0 °C	25.2 C	25.8 C	0.6 °C	25.4 C	26.8 C	1.4 °C	25.8 C	26.4 C
29.1 C	29.5 C	0.4 °C	28.5 C	29.0 C	0.4 °C	28.3 C	28.8 C	0.5 °C	27.1 C	26.3 C	-0.8 °C	27.4 C	27.8 C	0.5 °C	27.6 C	28.1 C
25.0	25.6 C	0.6 °C	27.4	27.2 C	-0.2 °C	26.8	27.0 C	0.1 °C	26.5	27.1 C	0.6 °C	26.4	27.4 C	1.0 °C	25.8	27.3 C
27.4	27.0 C	-0.4 °C	26.7	27.3 C	0.6 °C	24.8	28.0 C	3.2 °C	25.0	28.6 C	3.6 °C	25.1	28.6 C	3.5 °C	28.0	26.8 C
24.7	25.1 C	0.4 °C	28.3	28.7 C	0.4 °C	28.6	27.8 C	-0.9 °C	25.9	26.9 C	1.0 °C	25.9	26.9 C	1.0 °C	25.1	27.2 C
26.2	27.4 C	1.3 °C	25.3	28.3 C	3.0 °C	24.7	28.6 C	3.8 °C	27.1	28.5 C	1.4 °C	28.4	28.6 C	0.2 °C	28.1	26.5 C
28.9	28.3 C	-0.6 °C	28.7	28.3 C	-0.3 °C	29.4	27.0 C	-2.3 °C	28.7	26.9 C	-1.7 °C	25.7	27.4 C	1.7 °C	24.7	27.6 C
28.7	28.6 °C	-0.1 °C	26.1	25.8 °C	-0.3 °C	25.1	25.7 °C	0.6 °C	24.7	25.4 °C	0.7 °C	26.4	26.1 °C	-0.3 °C	26.0	26.0 °C
24.1	25.0 °C	0.9 °C	26.9	26.1 °C	-0.8 °C	28.9	25.5 °C	-3.5 °C	27.7	25.3 °C	-2.4 °C	27.0	26.1 °C	-0.9 °C	25.4	26.4 °C
28.7	28.3 °C	-0.4 °C	26.3	26.7 °C	0.4 °C	25.4	25.9 °C	0.5 °C	26.0	25.4 °C	-0.6 °C	26.0	26.2 °C	0.2 °C	27.6	27.9 °C
25.1	25.0 °C	-0.1 °C	26.0	25.2 °C	-0.8 °C	24.8	24.4 °C	-0.4 °C	25.9	23.8 °C	-2.1 °C	25.8	24.1 °C	-1.7 °C	26.0	27.0 °C
24.6 °C	25.0 °C	0.4 °C	25.2 °C	24.8 °C	-0.4 °C	25.0 °C	24.4 °C	-0.6 °C	26.0 °C	24.0 °C	-2.0 °C	26.8 °C	24.3 °C	-2.5 °C	24.0 °C	24.1 °C
27.6 °C	27.9 °C	0.2 °C	27.8 °C	28.1 °C	0.3 °C	27.6 °C	27.9 °C	0.3 °C	27.5 °C	27.6 °C	0.1 °C	27.6 °C	27.9 °C	0.3 °C	27.5 °C	27.9 °C

Difference (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)
:00	17:00			18:00			19:00			20:00			21	
0.1 °C	28.7 °C	28.9 °C	0.2 °C	28.9 °C	29.2 °C	0.3 °C	29.1 °C	29.5 °C	0.4 °C	29.5 °C	29.7 °C	0.2 °C	29.7 °C	29.9 °C
0.5 °C	30.5 °C	30.8 °C	0.3 °C	30.5 °C	31.0 °C	0.5 °C	29.8 °C	31.1 °C	1.3 °C	29.7 °C	30.0 °C	0.3 °C	29.7 °C	30.0 °C
0.1 °C	30.6 °C	30.7 °C	0.1 °C	30.6 °C	30.8 °C	0.2 °C	30.6 °C	30.9 °C	0.3 °C	29.8 °C	29.9 °C	0.1 °C	29.9 °C	30.0 °C
0.0 °C	31.0 °C	31.0 °C	0.0 °C	31.1 °C	31.1 °C	0.0 °C	31.2 °C	31.2 °C	0.0 °C	29.9 °C	29.9 °C	0.0 °C	29.7 °C	29.7 °C
0.0 °C	29.7 °C	29.7 °C	0.0 °C	29.7 °C	29.7 °C	0.0 °C	29.4 °C	29.4 °C	0.0 °C	29.6 °C	29.6 °C	0.0 °C	29.6 °C	29.6 °C
0.0 °C	29.7 °C	29.7 °C	0.0 °C	29.8 °C	29.8 °C	0.0 °C	29.8 °C	29.8 °C	0.0 °C	29.8 °C	29.8 °C	0.0 °C	29.2 °C	29.2 °C
0.0 °C	30.5 °C	30.5 °C	0.0 °C	30.5 °C	30.5 °C	0.0 °C	30.5 °C	30.5 °C	0.0 °C	31.1 °C	31.1 °C	0.0 °C	31.2 °C	31.2 °C
0.0 °C	30.1 °C	30.1 °C	0.0 °C	30.2 °C	30.2 °C	0.0 °C	30.2 °C	30.2 °C	0.0 °C	29.8 °C	29.8 °C	0.0 °C	29.7 °C	29.7 °C
0.1 °C	27.4 C	27.5 C	0.1 °C	26.6 C	26.7 C	0.2 °C	27.0 C	28.4 C	1.4 °C	27.2 C	27.0 C	-0.2 °C	27.6 C	28.9 C
1.5 °C	27.2 C	28.3 C	1.2 °C	27.3 C	27.0 C	-0.3 °C	27.4 C	28.1 C	0.7 °C	27.4 C	27.0 C	-0.4 °C	27.0 C	27.3 C
0.6 °C	27.1 C	27.3 C	0.1 °C	27.4 C	27.8 C	0.4 °C	27.9 C	28.6 C	0.7 °C	27.9 C	28.5 C	0.6 °C	28.5 C	29.0 C
0.3 °C	28.1 C	29.3 C	1.2 °C	28.2 C	28.0 C	-0.2 °C	28.3 C	28.8 C	0.5 °C	28.3 C	29.2 C	0.9 °C	27.7 C	28.0 C
0.3 °C	27.3 C	28.2 C	0.8 °C	27.1 C	27.1 C	0.0 °C	27.0 C	27.0 C	0.0 °C	26.9 C	27.1 C	0.2 °C	26.9 C	27.4 C
0.0 °C	27.5 C	27.9 C	0.3 °C	27.3 C	27.6 C	0.3 °C	27.3 C	27.5 C	0.2 °C	27.2 C	27.4 C	0.2 °C	27.1 C	27.7 C
0.3 °C	27.4 C	27.7 C	0.3 °C	27.1 C	27.7 C	0.6 °C	26.2 C	26.2 C	0.1 °C	26.8 C	27.1 C	0.2 °C	26.9 C	27.2 C
0.4 °C	26.2 C	26.6 C	0.4 °C	26.6 C	27.1 C	0.5 °C	26.3 C	26.9 C	0.6 °C	26.3 C	26.9 C	0.6 °C	26.2 C	26.7 C
0.6 °C	27.7 C	27.8 C	0.0 °C	27.0 C	28.1 C	1.0 °C	26.8 C	27.7 C	1.0 °C	26.1 C	26.8 C	0.7 °C	26.7 C	27.2 C
0.8 °C	25.8 C	26.4 C	0.6 °C	26.4 C	25.0 C	-1.4 °C	26.3 C	27.1 C	0.7 °C	26.7 C	27.3 C	0.7 °C	26.9 C	27.3 C
0.6 °C	26.4 C	25.0 C	-1.4 °C	26.2 C	27.7 C	1.5 °C	26.2 C	26.0 C	-0.2 °C	26.0 C	26.0 C	0.0 °C	27.0 C	27.9 C
0.5 °C	27.9 C	28.3 C	0.4 °C	28.0 C	28.5 C	0.5 °C	27.9 C	28.6 C	0.7 °C	27.6 C	28.6 C	1.0 °C	26.8 C	26.9 C
1.5 °C	25.3	25.0 C	-0.3 °C	24.2	25.0 C	0.8 °C	25.4	25.0 C	-0.4 °C	28.4	28.0 C	-0.4 °C	25.9	27.1 C
-1.2 °C	25.9	26.6 C	0.7 °C	27.6	27.0 C	-0.6 °C	27.0	27.6 C	0.6 °C	26.0	26.0 C	0.0 °C	25.3	25.0 C
2.1 °C	24.5	25.0 C	0.5 °C	27.2	27.0 C	-0.2 °C	28.7	28.8 C	0.2 °C	27.8	28.7 C	0.9 °C	25.8	27.6 C
-1.6 °C	26.4	27.2 C	0.7 °C	25.5	25.0 C	-0.5 °C	25.2	25.0 C	-0.2 °C	24.9	25.0 C	0.1 °C	27.7	29.0 C
2.9 °C	24.8	25.0 C	0.2 °C	29.3	28.6 C	-0.6 °C	29.9	29.0 C	-0.9 °C	28.3	27.8 C	-0.5 °C	27.3	27.3 C
0.0 °C	26.0	26.0 °C	0.0 °C	24.2	24.8 °C	0.6 °C	23.6	24.6 °C	1.0 °C	23.4	23.8 °C	0.4 °C	23.7	24.7 °C
1.0 °C	24.8	25.0 °C	0.2 °C	26.0	26.6 °C	0.6 °C	26.4	26.1 °C	-0.2 °C	26.9	26.3 °C	-0.6 °C	26.0	26.0 °C
0.3 °C	27.4	27.6 °C	0.2 °C	26.5	27.2 °C	0.7 °C	25.3	24.0 °C	-1.3 °C	24.8	23.9 °C	-0.8 °C	25.4	24.1 °C
1.0 °C	26.1	26.0 °C	-0.1 °C	25.3	25.0 °C	-0.3 °C	28.9 °C	28.5 °C	-0.4 °C	28.9 °C	28.5 °C	-0.4 °C	27.3 °C	27.1 °C
0.1 °C	25.3 °C	25.0 °C	-0.3 °C	24.3 °C	24.0 °C	-0.3 °C	24.3 °C	24.6 °C	0.3 °C	28.5 °C	28.0 °C	-0.5 °C	26.7 °C	24.7 °C
0.4 °C	27.4 °C	27.7 °C	0.2 °C	27.6 °C	27.7 °C	0.1 °C	27.7 °C	27.9 °C	0.2 °C	27.7 °C	27.8 °C	0.1 °C	27.5 °C	27.8 °C

Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)
:00	22:00			23:00		
0.2 °C	29.7 °C	29.9 °C	0.2 °C	30.0 °C	30.3 °C	0.3 °C
0.3 °C	29.6 °C	29.8 °C	0.2 °C	29.7 °C	29.9 °C	0.2 °C
0.1 °C	29.6 °C	29.7 °C	0.1 °C	29.5 °C	29.7 °C	0.2 °C
0.0 °C	28.9 °C	28.9 °C	0.0 °C	28.9 °C	28.9 °C	0.0 °C
0.0 °C	30.0 °C	30.0 °C	0.0 °C	30.3 °C	30.3 °C	0.0 °C
0.0 °C	29.2 °C	29.2 °C	0.0 °C	29.7 °C	29.7 °C	0.0 °C
0.0 °C	31.2 °C	31.2 °C	0.0 °C	30.5 °C	30.5 °C	0.0 °C
0.0 °C	29.7 °C	29.7 °C	0.0 °C	29.0 C	29.5 C	0.6 °C
1.3 °C	28.0 C	28.0 C	0.0 °C	28.2 C	28.8 C	0.7 °C
0.3 °C	27.1 C	27.0 C	-0.1 °C	27.6 C	28.6 C	1.0 °C
0.5 °C	28.1 C	28.6 C	0.5 °C	28.3 C	28.9 C	0.7 °C
0.3 °C	27.8 C	28.4 C	0.6 °C	27.9 C	27.8 C	-0.1 °C
0.5 °C	26.9 C	27.1 C	0.2 °C	26.9 C	27.4 C	0.5 °C
0.6 °C	26.6 C	26.9 C	0.3 °C	26.7 C	27.1 C	0.4 °C
0.2 °C	27.4 C	27.7 C	0.3 °C	27.8 C	28.2 C	0.4 °C
0.6 °C	26.0 C	26.0 C	0.0 °C	25.4 C	26.1 C	0.7 °C
0.5 °C	27.0 C	27.7 C	0.7 °C	26.9 C	27.5 C	0.7 °C
0.5 °C	26.8 C	27.3 C	0.5 °C	26.5 C	27.1 C	0.6 °C
0.9 °C	27.7 C	28.2 C	0.5 °C	27.2 C	27.0 C	-0.2 °C
0.1 °C	26.9 C	27.4 C	0.5 °C	26.9 C	27.4 C	0.5 °C
1.2 °C	26.0	27.0 C	1.0 °C	25.7	25.5 C	-0.2 °C
-0.3 °C	25.1	25.0 C	-0.1 °C	25.1	25.0 C	-0.1 °C
1.9 °C	24.2	27.4 C	3.1 °C	24.0	24.9 C	0.9 °C
1.3 °C	25.6	27.7 C	2.1 °C	29.3	29.0 C	-0.3 °C
0.0 °C	26.0	25.5 C	-0.5 °C	25.1	25.0 C	-0.1 °C
1.0 °C	27.5	27.6 °C	0.1 °C	27.0	27.5 °C	0.5 °C
0.0 °C	27.4	27.8 °C	0.4 °C	28.0	28.2 °C	0.2 °C
-1.3 °C	30.3	30.1	-0.2 °C	27.5	27.2 °C	-0.3 °C
-0.2 °C	27.0 °C	26.9 °C	-0.1 °C	25.9 °C	26.0 °C	0.1 °C
-1.9 °C	25.8 °C	25.1 °C	-0.7 °C	25.1 °C	25.2 °C	0.1 °C
0.3 °C	27.6 °C	28.0 °C	0.3 °C	27.5 °C	27.8 °C	0.3 °C

Average External air temperature data loggers' readings for the Month of August

	1			2			3			4			5			6			7	
	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)
1	25.0 °C	28.0 °C	-3.0 °C	25.0 °C	28.9 °C	-3.9 °C	24.8 °C	28.9 °C	-4.1 °C	24.7 °C	28.9 °C	-4.2 °C	24.5 °C	28.1 °C	-3.6 °C	24.4 °C	29.2 °C	-4.8 °C	23.9 °C	28.3 °C
2	24.7 °C	28.3 °C	-3.6 °C	24.4 °C	28.3 °C	-3.9 °C	24.2 °C	28.3 °C	-4.1 °C	24.3 °C	28.3 °C	-4.0 °C	24.2 °C	29.7 °C	-5.5 °C	24.2 °C	29.7 °C	-5.5 °C	24.1 °C	29.7 °C
3	24.7 °C	28.3 °C	-3.6 °C	24.7 °C	28.3 °C	-3.6 °C	24.6 °C	28.3 °C	-3.7 °C	24.5 °C	28.3 °C	-3.8 °C	24.5 °C	28.3 °C	-3.8 °C	24.5 °C	28.3 °C	-3.8 °C	24.5 °C	28.3 °C
4	24.8 °C	29.7 °C	-4.9 °C	24.8 °C	29.7 °C	-4.9 °C	24.8 °C	28.1 °C	-3.3 °C	24.9 °C	29.2 °C	-4.3 °C	24.7 °C	28.8 °C	-4.1 °C	24.4 °C	28.3 °C	-3.9 °C	24.3 °C	28.3 °C
5	24.6 °C	27.7 °C	-3.1 °C	24.5 °C	28.9 °C	-4.4 °C	24.6 °C	29.7 °C	-5.1 °C	24.7 °C	29.4 °C	-4.7 °C	24.7 °C	29.7 °C	-5.0 °C	24.5 °C	29.5 °C	-5.0 °C	24.3 °C	28.1 °C
6	25.0 °C	26.8 °C	-1.8 °C	25.3 °C	27.8 °C	-2.5 °C	25.3 °C	26.8 °C	-1.5 °C	25.3 °C	26.8 °C	-1.5 °C	25.3 °C	28.3 °C	-3.0 °C	24.9 °C	28.6 °C	-3.7 °C	25.0 °C	28.3 °C
7	25.6 °C	29.7 °C	-4.1 °C	24.8 °C	29.7 °C	-4.9 °C	24.5 °C	29.7 °C	-5.2 °C	25.8 °C	29.7 °C	-3.9 °C	25.8 °C	26.8 °C	-1.0 °C	25.8 °C	26.8 °C	-1.0 °C	24.1 °C	27.0 °C
8	26.1 °C	26.8 °C	-0.7 °C	25.5 °C	26.8 °C	-1.3 °C	25.3 °C	26.8 °C	-1.5 °C	25.0 °C	26.8 °C	-1.8 °C	24.9 °C	26.9 °C	-2.0 °C	24.6 °C	27.1 °C	-2.5 °C	24.7 °C	27.1 °C
9	25.9 °C	28.0 °C	-2.1 °C	25.3 °C	28.1 °C	-2.8 °C	25.1 °C	28.1 °C	-3.0 °C	24.9 °C	27.6 °C	-2.7 °C	25.3 °C	27.6 °C	-2.3 °C	24.6 °C	27.6 °C	-3.0 °C	25.6 °C	28.0 °C
10	24.7 °C	27.9 °C	-3.2 °C	24.5 °C	29.9 °C	-5.4 °C	24.9 °C	29.9 °C	-5.0 °C	25.0 °C	27.6 °C	-2.6 °C	24.7 °C	28.1 °C	-3.4 °C	24.9 °C	28.1 °C	-3.2 °C	25.3 °C	28.1 °C
11	25.4 °C	29.2 °C	-3.8 °C	25.0 °C	29.7 °C	-4.7 °C	25.1 °C	30.1 °C	-5.0 °C	25.3 °C	29.0 °C	-3.7 °C	25.4 °C	28.1 °C	-2.7 °C	25.3 °C	27.0 °C	-1.7 °C	25.1 °C	28.0 °C
12	23.8 °C	27.8 °C	-4.0 °C	23.6 °C	28.2 °C	-4.6 °C	23.5 °C	28.3 °C	-4.8 °C	23.3 °C	27.9 °C	-4.6 °C	23.1 °C	27.9 °C	-4.9 °C	23.5 °C	27.9 °C	-4.4 °C	25.1 °C	28.1 °C
13	23.9 °C	28.2 °C	-4.4 °C	24.0 °C	27.8 °C	-3.8 °C	24.0 °C	27.9 °C	-4.0 °C	24.5 °C	26.5 °C	-1.9 °C	24.5 °C	25.7 °C	-1.2 °C	24.5 °C	25.4 °C	-0.9 °C	26.6 °C	28.7 °C
14	24.3 °C	27.0 °C	-2.7 °C	23.4 °C	27.8 °C	-4.5 °C	23.3 °C	26.6 °C	-3.3 °C	26.0 °C	29.0 °C	-3.0 °C	24.2 °C	27.2 °C	-3.0 °C	23.3 °C	27.9 °C	-4.6 °C	23.6 °C	26.4 °C
15	23.6 °C	29.6 °C	-6.0 °C	24.3 °C	28.8 °C	-4.5 °C	23.3 °C	26.5 °C	-3.2 °C	23.1 °C	25.2 °C	-2.2 °C	24.4 °C	28.0 °C	-3.6 °C	24.0 °C	27.4 °C	-3.4 °C	24.3 °C	28.0 °C
16	23.6 °C	27.4 °C	-3.8 °C	25.2 °C	27.8 °C	-2.6 °C	24.5 °C	26.6 °C	-2.1 °C	24.0 °C	28.9 °C	-4.9 °C	24.0 °C	27.0 °C	-3.0 °C	23.3 °C	27.3 °C	-4.0 °C	23.6 °C	28.0 °C
17	26.9 °C	31.0 °C	-4.1 °C	25.0 °C	26.0 °C	-1.0 °C	24.0 °C	29.0 °C	-5.0 °C	24.7 °C	27.0 °C	-2.3 °C	25.2 °C	27.8 °C	-2.6 °C	24.5 °C	28.8 °C	-4.3 °C	25.9 °C	28.9 °C
18	23.9 °C	28.2 °C	-4.4 °C	23.9 °C	28.3 °C	-4.4 °C	23.8 °C	28.3 °C	-4.5 °C	23.9 °C	28.2 °C	-4.4 °C	24.0 °C	27.8 °C	-3.8 °C	24.0 °C	27.9 °C	-4.0 °C	24.5 °C	26.5 °C
19	23.3 °C	25.4 °C	-2.2 °C	23.1 °C	28.3 °C	-5.2 °C	23.5 °C	27.9 °C	-4.3 °C	24.7 °C	27.9 °C	-3.2 °C	24.5 °C	27.9 °C	-3.4 °C	24.2 °C	28.1 °C	-3.9 °C	23.9 °C	28.2 °C
20	27.4 °C	29.0 °C	-1.6 °C	26.0 °C	30.0 °C	-4.0 °C	26.2 °C	31.0 °C	-4.8 °C	26.3 °C	29.0 °C	-2.7 °C	27.1 °C	28.0 °C	-0.9 °C	25.9 °C	30.0 °C	-4.1 °C	23.0 °C	31.0 °C
21	24.1 °C	28.0 °C	-3.9 °C	25.7 °C	30.0 °C	-4.3 °C	25.6 °C	32.0 °C	-6.4 °C	25.9 °C	29.0 °C	-3.1 °C	25.4 °C	28.0 °C	-2.6 °C	24.8 °C	30.0 °C	-5.2 °C	24.2 °C	29.5 °C
22	24.7 °C	28.0 °C	-3.3 °C	25.5 °C	30.0 °C	-4.5 °C	26.9 °C	30.1 °C	-3.2 °C	26.0 °C	29.0 °C	-3.0 °C	25.6 °C	28.0 °C	-2.4 °C	25.2 °C	30.0 °C	-4.8 °C	25.0 °C	31.0 °C
23	25.8 °C	30.0 °C	-4.2 °C	25.3 °C	32.0 °C	-6.7 °C	25.0 °C	29.0 °C	-4.0 °C	25.0 °C	28.0 °C	-3.0 °C	25.9 °C	30.0 °C	-4.1 °C	24.8 °C	31.0 °C	-6.2 °C	25.2 °C	30.0 °C
24	23.8 °C	29.0 °C	-5.2 °C	25.0 °C	28.0 °C	-3.0 °C	25.6 °C	30.0 °C	-4.4 °C	25.3 °C	31.0 °C	-5.7 °C	25.7 °C	30.0 °C	-4.3 °C	24.8 °C	28.0 °C	-3.2 °C	25.0 °C	30.0 °C
25	26.0 °C	28.0 °C	-2.0 °C	24.8 °C	30.0 °C	-5.2 °C	25.9 °C	31.0 °C	-5.1 °C	25.5 °C	30.0 °C	-4.5 °C	25.2 °C	28.0 °C	-2.8 °C	24.7 °C	32.0 °C	-7.3 °C	24.9 °C	29.0 °C
26	24.9 °C	28.0 °C	-3.1 °C	25.0 °C	30.0 °C	-5.0 °C	25.4 °C	31.0 °C	-5.6 °C	25.7 °C	30.0 °C	-4.3 °C	25.3 °C	28.0 °C	-2.7 °C	23.2 °C	30.0 °C	-6.8 °C	23.9 °C	32.0 °C
27	24.3 °C	28.0 °C	-3.7 °C	24.6 °C	30.0 °C	-5.4 °C	24.8 °C	32.0 °C	-7.2 °C	24.3 °C	29.0 °C	-4.7 °C	24.7 °C	28.0 °C	-3.3 °C	26.0 °C	30.0 °C	-4.0 °C	25.8 °C	31.0 °C
28	23.8 °C	28.0 °C	-4.2 °C	25.7 °C	30.0 °C	-4.3 °C	25.2 °C	31.0 °C	-5.8 °C	24.6 °C	30.0 °C	-5.4 °C	24.7 °C	28.0 °C	-3.3 °C	24.1 °C	26.5 °C	-2.3 °C	24.1 °C	25.3 °C
29	24.3 °C	29.0 °C	-4.7 °C	24.3 °C	28.1 °C	-3.8 °C	24.7 °C	28.5 °C	-3.8 °C	24.5 °C	28.0 °C	-3.5 °C	23.2 °C	26.0 °C	-2.8 °C	23.7 °C	27.0 °C	-3.3 °C	24.1 °C	27.8 °C
30	25.1 °C	31.0 °C	-5.9 °C	25.0 °C	29.0 °C	-4.0 °C	24.9 °C	29.0 °C	-4.1 °C	24.3 °C	28.0 °C	-3.7 °C	24.9 °C	30.0 °C	-5.1 °C	23.3 °C	28.0 °C	-4.7 °C	24.1 °C	28.9 °C
31	25.3 °C	28.3 °C	-3.0 °C	25.0 °C	29.6 °C	-4.6 °C	25.1 °C	30.0 °C	-4.9 °C	24.5 °C	28.0 °C	-3.5 °C	24.3 °C	28.0 °C	-3.7 °C	24.9 °C	27.5 °C	-2.6 °C	24.9 °C	28.8 °C
AVG of the difference (°C)	24.8 °C	28.4 °C	-3.6 °C	24.8 °C	28.9 °C	-4.1 °C	24.8 °C	29.0 °C	-4.3 °C	24.9 °C	28.4 °C	-3.6 °C	24.8 °C	28.1 °C	-3.2 °C	24.5 °C	28.4 °C	-3.9 °C	24.6 °C	28.6 °C
STD DEV of the difference (°C)			1.2 °C			1.2 °C			1.3 °C			1.0 °C			1.1 °C			1.4 °C		

		8			9			10			11			12			13			14
Differenc e (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)	Differenc e (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)	Differenc e (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)	Differenc e (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)	Differenc e (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)	Differenc e (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)	Differenc e (°C)	Experime ntal Room 1 (°C)	Control Room 10 (°C)
-4.4 °C	23.8 °C	28.3 °C	-4.5 °C	23.7 °C	28.3 °C	-4.6 °C	24.1 °C	28.3 °C	-4.2 °C	24.5 °C	28.3 °C	-3.8 °C	25.2 °C	28.3 °C	-3.1 °C	25.7 °C	28.3 °C	-2.6 °C	25.7 °C	28.3 °C
-5.6 °C	24.1 °C	29.7 °C	-5.6 °C	24.8 °C	28.1 °C	-3.3 °C	25.5 °C	29.2 °C	-3.7 °C	24.8 °C	28.3 °C	-3.5 °C	25.0 °C	28.3 °C	-3.3 °C	25.1 °C	28.3 °C	-3.2 °C	25.1 °C	28.3 °C
-3.8 °C	24.4 °C	28.3 °C	-3.9 °C	25.0 °C	29.7 °C	-4.7 °C	25.9 °C	29.7 °C	-3.8 °C	24.8 °C	29.7 °C	-4.9 °C	25.0 °C	29.7 °C	-4.7 °C	26.1 °C	28.1 °C	-2.0 °C	25.7 °C	29.2 °C
-4.0 °C	24.3 °C	27.8 °C	-3.5 °C	24.3 °C	28.3 °C	-4.0 °C	25.1 °C	28.3 °C	-3.2 °C	25.8 °C	28.3 °C	-2.5 °C	26.8 °C	28.3 °C	-1.5 °C	25.6 °C	29.7 °C	-4.1 °C	25.4 °C	29.7 °C
-3.8 °C	25.9 °C	29.2 °C	-3.3 °C	25.6 °C	28.3 °C	-2.7 °C	24.6 °C	28.9 °C	-4.3 °C	25.4 °C	28.3 °C	-2.9 °C	25.5 °C	28.3 °C	-2.8 °C	25.2 °C	28.4 °C	-3.2 °C	24.3 °C	28.3 °C
-3.3 °C	25.2 °C	28.3 °C	-3.1 °C	24.1 °C	29.7 °C	-5.6 °C	24.0 °C	29.7 °C	-5.7 °C	24.1 °C	29.7 °C	-5.6 °C	24.2 °C	29.7 °C	-5.5 °C	24.7 °C	28.9 °C	-4.2 °C	25.7 °C	29.0 °C
-2.9 °C	23.6 °C	26.8 °C	-3.2 °C	23.6 °C	27.8 °C	-4.2 °C	24.1 °C	26.8 °C	-2.7 °C	24.6 °C	26.8 °C	-2.2 °C	25.8 °C	26.8 °C	-1.0 °C	24.3 °C	28.9 °C	-4.6 °C	24.6 °C	28.3 °C
-2.4 °C	24.6 °C	27.6 °C	-3.0 °C	26.0 °C	28.0 °C	-2.0 °C	24.6 °C	27.1 °C	-2.5 °C	26.0 °C	27.1 °C	-1.1 °C	24.2 °C	28.4 °C	-4.2 °C	24.3 °C	27.5 °C	-3.2 °C	24.6 °C	27.5 °C
-2.4 °C	24.5 °C	27.6 °C	-3.1 °C	25.0 °C	28.5 °C	-3.5 °C	24.5 °C	27.6 °C	-3.1 °C	24.6 °C	27.6 °C	-3.0 °C	24.6 °C	27.6 °C	-3.0 °C	25.1 °C	28.5 °C	-3.4 °C	24.2 °C	27.6 °C
-2.8 °C	24.9 °C	25.0 °C	-0.1 °C	24.7 °C	26.3 °C	-1.7 °C	24.6 °C	27.6 °C	-3.0 °C	24.3 °C	27.6 °C	-3.3 °C	24.1 °C	27.6 °C	-3.5 °C	24.0 °C	27.6 °C	-3.6 °C	23.9 °C	27.6 °C
-2.9 °C	24.9 °C	27.9 °C	-3.0 °C	24.8 °C	30.0 °C	-5.2 °C	24.3 °C	29.9 °C	-5.6 °C	24.2 °C	29.2 °C	-5.0 °C	23.9 °C	29.7 °C	-5.8 °C	23.8 °C	28.6 °C	-4.8 °C	24.9 °C	28.1 °C
-3.0 °C	24.9 °C	28.2 °C	-3.4 °C	24.8 °C	28.3 °C	-3.5 °C	24.3 °C	28.3 °C	-4.0 °C	24.2 °C	28.2 °C	-4.0 °C	23.9 °C	27.8 °C	-3.9 °C	23.8 °C	27.9 °C	-4.1 °C	23.6 °C	26.5 °C
-2.1 °C	27.2 °C	27.9 °C	-0.7 °C	27.3 °C	30.0 °C	-2.7 °C	27.2 °C	30.0 °C	-2.8 °C	25.1 °C	28.0 °C	-2.9 °C	24.3 °C	28.0 °C	-3.7 °C	23.3 °C	27.0 °C	-3.7 °C	23.1 °C	28.8 °C
-2.8 °C	23.3 °C	24.8 °C	-1.5 °C	23.1 °C	26.5 °C	-3.4 °C	25.0 °C	29.0 °C	-4.0 °C	24.4 °C	27.9 °C	-3.5 °C	25.2 °C	29.5 °C	-4.3 °C	24.5 °C	27.3 °C	-2.8 °C	24.0 °C	29.0 °C
-3.7 °C	24.5 °C	27.8 °C	-3.3 °C	23.4 °C	27.0 °C	-3.6 °C	23.0 °C	26.7 °C	-3.7 °C	27.2 °C	29.0 °C	-1.8 °C	24.9 °C	26.6 °C	-1.7 °C	25.8 °C	29.7 °C	-3.9 °C	24.9 °C	27.5 °C
-4.4 °C	23.0 °C	28.8 °C	-5.8 °C	26.5 °C	27.0 °C	-0.5 °C	25.0 °C	28.0 °C	-3.0 °C	24.4 °C	28.0 °C	-3.6 °C	24.5 °C	28.0 °C	-3.5 °C	24.0 °C	27.9 °C	-3.9 °C	24.0 °C	27.8 °C
-3.0 °C	24.0 °C	25.2 °C	-1.3 °C	24.4 °C	27.2 °C	-2.8 °C	24.0 °C	28.0 °C	-4.0 °C	25.7 °C	24.3 °C	1.4 °C	25.0 °C	27.8 °C	-2.8 °C	24.0 °C	26.6 °C	-2.6 °C	24.2 °C	28.2 °C
-1.9 °C	25.6 °C	26.5 °C	-0.9 °C	25.7 °C	26.5 °C	-0.8 °C	25.1 °C	28.7 °C	-3.6 °C	25.5 °C	27.9 °C	-2.4 °C	25.3 °C	30.0 °C	-4.7 °C	26.0 °C	30.0 °C	-4.0 °C	25.1 °C	28.0 °C
-4.4 °C	23.9 °C	28.3 °C	-4.4 °C	23.8 °C	28.3 °C	-4.5 °C	23.9 °C	28.2 °C	-4.4 °C	24.0 °C	27.8 °C	-3.8 °C	24.0 °C	27.9 °C	-4.0 °C	24.5 °C	26.5 °C	-1.9 °C	25.6 °C	26.5 °C
-8.0 °C	25.1 °C	30.0 °C	-4.9 °C	26.4 °C	28.0 °C	-1.6 °C	26.0 °C	30.0 °C	-4.0 °C	25.3 °C	32.0 °C	-6.7 °C	25.4 °C	29.0 °C	-3.6 °C	25.8 °C	28.0 °C	-2.2 °C	26.1 °C	30.0 °C
-5.3 °C	25.9 °C	30.0 °C	-4.1 °C	26.2 °C	28.0 °C	-1.8 °C	25.1 °C	30.0 °C	-4.9 °C	24.7 °C	32.0 °C	-7.3 °C	24.5 °C	29.0 °C	-4.5 °C	24.0 °C	28.0 °C	-4.0 °C	24.1 °C	30.0 °C
-6.0 °C	25.1 °C	30.0 °C	-4.9 °C	25.4 °C	28.0 °C	-2.6 °C	25.2 °C	30.0 °C	-4.8 °C	25.3 °C	32.0 °C	-6.7 °C	25.2 °C	29.0 °C	-3.8 °C	25.3 °C	28.0 °C	-2.7 °C	25.2 °C	30.0 °C
-4.8 °C	25.2 °C	28.0 °C	-2.8 °C	24.8 °C	32.0 °C	-7.2 °C	24.9 °C	29.0 °C	-4.1 °C	24.8 °C	28.0 °C	-3.2 °C	24.7 °C	30.0 °C	-5.3 °C	25.1 °C	31.0 °C	-5.9 °C	25.5 °C	30.0 °C
-5.0 °C	25.3 °C	32.0 °C	-6.7 °C	25.7 °C	29.0 °C	-3.3 °C	25.6 °C	28.0 °C	-2.4 °C	25.1 °C	30.0 °C	-4.9 °C	23.9 °C	31.0 °C	-7.1 °C	24.1 °C	30.0 °C	-5.9 °C	24.9 °C	28.0 °C
-4.1 °C	24.8 °C	28.0 °C	-3.2 °C	25.6 °C	30.0 °C	-4.4 °C	25.5 °C	31.0 °C	-5.5 °C	25.2 °C	30.0 °C	-4.8 °C	25.0 °C	28.0 °C	-3.0 °C	25.3 °C	30.0 °C	-4.7 °C	25.1 °C	32.0 °C
-8.1 °C	25.9 °C	29.0 °C	-3.1 °C	25.3 °C	28.0 °C	-2.7 °C	25.7 °C	30.0 °C	-4.3 °C	24.5 °C	31.0 °C	-6.5 °C	24.4 °C	30.0 °C	-5.6 °C	24.8 °C	28.0 °C	-3.2 °C	25.8 °C	30.0 °C
-5.2 °C	25.5 °C	30.0 °C	-4.5 °C	25.0 °C	28.0 °C	-3.0 °C	25.4 °C	30.0 °C	-4.6 °C	25.1 °C	28.0 °C	-2.9 °C	25.0 °C	30.0 °C	-5.0 °C	24.7 °C	32.0 °C	-7.3 °C	24.8 °C	29.0 °C
-1.2 °C	24.1 °C	25.9 °C	-1.8 °C	24.3 °C	25.9 °C	-1.6 °C	24.8 °C	28.0 °C	-3.2 °C	24.7 °C	30.0 °C	-5.3 °C	24.5 °C	31.0 °C	-6.5 °C	24.4 °C	30.0 °C	-5.6 °C	25.0 °C	28.0 °C
-3.7 °C	25.7 °C	28.0 °C	-2.3 °C	26.3 °C	28.9 °C	-2.6 °C	24.9 °C	28.0 °C	-3.1 °C	24.8 °C	28.0 °C	-3.2 °C	23.6 °C	27.0 °C	-3.4 °C	23.6 °C	28.0 °C	-4.4 °C	26.0 °C	29.0 °C
-4.8 °C	25.0 °C	29.0 °C	-4.0 °C	25.1 °C	28.0 °C	-2.9 °C	24.3 °C	30.0 °C	-5.7 °C	23.3 °C	28.0 °C	-4.7 °C	23.1 °C	28.5 °C	-5.4 °C	25.0 °C	28.8 °C	-3.8 °C	25.1 °C	29.0 °C
-3.9 °C	25.0 °C	29.5 °C	-4.5 °C	25.1 °C	29.0 °C	-3.9 °C	24.7 °C	28.5 °C	-3.8 °C	24.5 °C	27.9 °C	-3.4 °C	24.9 °C	30.0 °C	-5.1 °C	23.3 °C	28.0 °C	-4.7 °C	24.1 °C	28.9 °C
-4.0 °C	24.8 °C	28.2 °C	-3.4 °C	25.0 °C	28.3 °C	-3.3 °C	24.9 °C	28.8 °C	-3.9 °C	24.9 °C	28.7 °C	-3.8 °C	24.7 °C	28.7 °C	-4.0 °C	24.7 °C	28.6 °C	-3.9 °C	24.8 °C	28.6 °C
1.5 °C			1.5 °C			1.4 °C			0.9 °C			1.8 °C			1.4 °C			1.2 °C		

	15			16			17			18			19			20			21	
Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)
-2.6 °C	25.7 °C	29.7 °C	-4.0 °C	26.3 °C	29.7 °C	-3.4 °C	26.4 °C	29.7 °C	-3.3 °C	26.0 °C	29.7 °C	-3.7 °C	25.2 °C	28.1 °C	-2.9 °C	25.0 °C	29.2 °C	-4.2 °C	24.9 °C	28.3 °C
-3.2 °C	26.8 °C	28.3 °C	-1.5 °C	26.0 °C	28.3 °C	-2.3 °C	26.1 °C	28.3 °C	-2.2 °C	26.8 °C	28.3 °C	-1.5 °C	26.4 °C	29.7 °C	-3.3 °C	24.6 °C	29.7 °C	-5.1 °C	24.6 °C	29.7 °C
-3.5 °C	25.0 °C	28.3 °C	-3.3 °C	25.5 °C	28.3 °C	-2.8 °C	25.0 °C	28.3 °C	-3.3 °C	27.1 °C	28.3 °C	-1.2 °C	26.7 °C	28.3 °C	-1.6 °C	25.9 °C	28.3 °C	-2.4 °C	25.3 °C	28.3 °C
-4.3 °C	25.3 °C	29.7 °C	-4.4 °C	25.1 °C	29.7 °C	-4.6 °C	25.3 °C	28.1 °C	-2.8 °C	26.9 °C	29.2 °C	-2.3 °C	26.8 °C	28.3 °C	-1.5 °C	25.2 °C	27.6 °C	-2.4 °C	25.1 °C	28.3 °C
-4.0 °C	25.3 °C	29.0 °C	-3.7 °C	25.6 °C	28.5 °C	-2.9 °C	26.0 °C	29.7 °C	-3.7 °C	25.9 °C	29.8 °C	-3.9 °C	25.1 °C	29.7 °C	-4.6 °C	24.8 °C	29.7 °C	-4.9 °C	25.8 °C	26.8 °C
-3.3 °C	26.7 °C	27.9 °C	-1.2 °C	25.9 °C	26.8 °C	-0.9 °C	26.1 °C	26.8 °C	-0.7 °C	26.8 °C	27.5 °C	-0.7 °C	26.5 °C	27.9 °C	-1.4 °C	26.3 °C	28.9 °C	-2.6 °C	25.7 °C	29.0 °C
-3.7 °C	25.0 °C	28.3 °C	-3.3 °C	25.7 °C	28.3 °C	-2.6 °C	26.0 °C	29.7 °C	-3.7 °C	25.7 °C	29.7 °C	-4.0 °C	25.7 °C	29.7 °C	-4.0 °C	26.0 °C	29.7 °C	-3.7 °C	25.3 °C	30.0 °C
-2.9 °C	25.3 °C	27.1 °C	-1.8 °C	26.0 °C	29.0 °C	-3.0 °C	25.8 °C	27.5 °C	-1.7 °C	24.3 °C	27.5 °C	-3.2 °C	24.6 °C	28.6 °C	-4.0 °C	25.3 °C	27.5 °C	-2.2 °C	26.0 °C	28.4 °C
-3.4 °C	24.2 °C	27.6 °C	-3.4 °C	24.1 °C	28.1 °C	-4.0 °C	24.3 °C	28.1 °C	-3.8 °C	25.7 °C	29.3 °C	-3.6 °C	24.5 °C	29.0 °C	-4.5 °C	25.5 °C	26.3 °C	-0.8 °C	26.8 °C	27.6 °C
-3.7 °C	23.7 °C	27.6 °C	-3.9 °C	23.4 °C	27.6 °C	-4.2 °C	23.4 °C	27.6 °C	-4.2 °C	23.3 °C	28.1 °C	-4.8 °C	24.0 °C	28.1 °C	-4.1 °C	25.0 °C	27.0 °C	-2.0 °C	25.0 °C	28.0 °C
-3.2 °C	24.7 °C	27.0 °C	-2.3 °C	24.7 °C	28.0 °C	-3.3 °C	24.7 °C	27.9 °C	-3.2 °C	24.7 °C	30.0 °C	-5.3 °C	25.1 °C	29.9 °C	-4.8 °C	24.9 °C	29.2 °C	-4.3 °C	24.8 °C	29.7 °C
-2.9 °C	23.5 °C	25.7 °C	-2.3 °C	23.3 °C	25.4 °C	-2.2 °C	23.1 °C	28.3 °C	-5.2 °C	23.5 °C	27.9 °C	-4.3 °C	24.7 °C	27.9 °C	-3.2 °C	24.5 °C	27.9 °C	-3.4 °C	24.2 °C	28.1 °C
-5.7 °C	26.0 °C	29.0 °C	-3.0 °C	27.4 °C	29.0 °C	-1.6 °C	25.2 °C	28.0 °C	-2.8 °C	24.5 °C	26.9 °C	-2.4 °C	24.0 °C	28.0 °C	-4.0 °C	24.0 °C	27.8 °C	-3.9 °C	25.0 °C	29.0 °C
-5.0 °C	24.9 °C	28.9 °C	-4.0 °C	25.7 °C	29.0 °C	-3.3 °C	25.0 °C	31.0 °C	-6.0 °C	25.1 °C	29.5 °C	-4.4 °C	27.0 °C	29.9 °C	-2.9 °C	24.3 °C	27.8 °C	-3.5 °C	25.0 °C	27.9 °C
-2.6 °C	24.3 °C	27.9 °C	-3.6 °C	25.0 °C	26.9 °C	-1.9 °C	25.0 °C	28.8 °C	-3.8 °C	26.5 °C	28.9 °C	-2.4 °C	25.2 °C	29.0 °C	-3.8 °C	24.4 °C	30.0 °C	-5.6 °C	24.3 °C	29.0 °C
-3.9 °C	23.4 °C	27.2 °C	-3.8 °C	24.0 °C	28.0 °C	-4.0 °C	23.0 °C	27.8 °C	-4.8 °C	25.0 °C	29.0 °C	-4.0 °C	25.0 °C	29.0 °C	-4.0 °C	25.2 °C	28.0 °C	-2.8 °C	24.5 °C	28.8 °C
-4.0 °C	24.9 °C	27.8 °C	-2.9 °C	25.3 °C	27.9 °C	-2.6 °C	25.7 °C	28.9 °C	-3.2 °C	23.5 °C	28.7 °C	-5.2 °C	24.2 °C	25.4 °C	-1.2 °C	23.1 °C	29.0 °C	-5.9 °C	23.5 °C	27.9 °C
-2.9 °C	24.3 °C	28.0 °C	-3.7 °C	23.3 °C	27.0 °C	-3.7 °C	23.1 °C	28.8 °C	-5.7 °C	26.0 °C	29.0 °C	-3.0 °C	25.6 °C	29.0 °C	-3.4 °C	24.2 °C	28.2 °C	-4.0 °C	23.9 °C	27.8 °C
-0.9 °C	25.6 °C	26.5 °C	-0.9 °C	26.6 °C	28.7 °C	-2.1 °C	26.6 °C	27.9 °C	-1.3 °C	27.3 °C	30.0 °C	-2.7 °C	27.2 °C	30.0 °C	-2.8 °C	25.1 °C	28.0 °C	-2.9 °C	24.3 °C	28.0 °C
-3.9 °C	26.0 °C	31.0 °C	-5.0 °C	25.3 °C	30.0 °C	-4.7 °C	25.0 °C	28.0 °C	-3.0 °C	25.7 °C	30.0 °C	-4.3 °C	25.0 °C	32.0 °C	-7.0 °C	25.1 °C	29.0 °C	-3.9 °C	25.3 °C	28.0 °C
-5.9 °C	25.7 °C	29.5 °C	-3.8 °C	25.7 °C	30.0 °C	-4.3 °C	25.5 °C	28.0 °C	-2.5 °C	25.4 °C	30.0 °C	-4.6 °C	25.9 °C	32.0 °C	-6.1 °C	25.1 °C	32.0 °C	-6.9 °C	25.3 °C	28.0 °C
-4.8 °C	25.3 °C	31.0 °C	-5.7 °C	25.3 °C	30.0 °C	-4.7 °C	25.5 °C	28.0 °C	-2.5 °C	25.5 °C	32.0 °C	-6.5 °C	25.9 °C	29.0 °C	-3.1 °C	26.0 °C	28.0 °C	-2.0 °C	25.9 °C	30.0 °C
-4.5 °C	25.7 °C	28.0 °C	-2.3 °C	25.1 °C	30.0 °C	-4.9 °C	25.9 °C	32.0 °C	-6.1 °C	25.3 °C	29.0 °C	-3.7 °C	25.9 °C	28.0 °C	-2.1 °C	26.0 °C	30.0 °C	-4.0 °C	25.9 °C	31.0 °C
-3.1 °C	26.2 °C	32.0 °C	-5.8 °C	25.1 °C	29.0 °C	-3.9 °C	24.5 °C	28.0 °C	-3.5 °C	23.7 °C	30.0 °C	-6.3 °C	24.2 °C	31.0 °C	-6.8 °C	25.7 °C	30.0 °C	-4.3 °C	25.0 °C	28.0 °C
-6.9 °C	26.3 °C	29.0 °C	-2.7 °C	24.5 °C	28.0 °C	-3.5 °C	24.4 °C	30.0 °C	-5.6 °C	25.0 °C	31.0 °C	-6.0 °C	24.4 °C	30.0 °C	-5.6 °C	25.0 °C	28.0 °C	-3.0 °C	26.4 °C	30.0 °C
-4.2 °C	25.8 °C	28.0 °C	-2.2 °C	25.1 °C	30.0 °C	-4.9 °C	24.9 °C	32.0 °C	-7.1 °C	24.6 °C	29.0 °C	-4.4 °C	24.7 °C	28.0 °C	-3.3 °C	25.8 °C	30.0 °C	-4.2 °C	24.5 °C	31.0 °C
-4.2 °C	25.1 °C	28.0 °C	-2.9 °C	25.4 °C	30.0 °C	-4.6 °C	24.8 °C	31.0 °C	-6.2 °C	24.4 °C	30.0 °C	-5.6 °C	24.4 °C	28.0 °C	-3.6 °C	25.0 °C	30.0 °C	-5.0 °C	25.0 °C	28.0 °C
-3.0 °C	25.1 °C	29.0 °C	-3.9 °C	25.2 °C	27.9 °C	-2.7 °C	24.8 °C	28.8 °C	-4.0 °C	24.3 °C	27.8 °C	-3.5 °C	24.3 °C	29.0 °C	-4.7 °C	25.0 °C	30.0 °C	-5.0 °C	25.2 °C	29.2 °C
-3.0 °C	26.0 °C	29.5 °C	-3.5 °C	25.3 °C	27.8 °C	-2.5 °C	24.6 °C	27.0 °C	-2.4 °C	24.2 °C	27.6 °C	-3.4 °C	24.3 °C	27.0 °C	-2.7 °C	26.0 °C	28.9 °C	-2.9 °C	25.1 °C	29.0 °C
-3.9 °C	25.2 °C	29.9 °C	-4.7 °C	24.5 °C	29.8 °C	-5.3 °C	24.0 °C	28.0 °C	-4.0 °C	24.0 °C	28.0 °C	-4.0 °C	24.1 °C	29.0 °C	-4.9 °C	25.0 °C	28.0 °C	-3.0 °C	23.0 °C	28.0 °C
-4.8 °C	25.2 °C	29.9 °C	-4.7 °C	24.5 °C	29.8 °C	-5.3 °C	24.0 °C	28.0 °C	-4.0 °C	24.0 °C	28.0 °C	-4.0 °C	24.1 °C	29.0 °C	-4.9 °C	25.0 °C	28.0 °C	-3.0 °C	23.0 °C	28.0 °C
-3.8 °C	25.2 °C	28.6 °C	-3.4 °C	25.2 °C	28.6 °C	-3.4 °C	25.0 °C	28.7 °C	-3.8 °C	25.2 °C	29.0 °C	-3.8 °C	25.2 °C	29.0 °C	-3.8 °C	25.1 °C	28.8 °C	-3.7 °C	25.0 °C	28.7 °C
1.1 °C			1.2 °C			1.1 °C			1.5 °C			1.4 °C			1.4 °C			1.3 °C		

		22			23			0	
Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)	Experimental Room 1 (°C)	Control Room 10 (°C)	Difference (°C)
-3.4 °C	24.6 °C	28.3 °C	-3.7 °C	24.7 °C	28.3 °C	-3.6 °C	24.7 °C	28.3 °C	-3.6
-5.1 °C	24.8 °C	29.7 °C	-4.9 °C	25.0 °C	28.1 °C	-3.1 °C	24.8 °C	28.3 °C	-3.5
-3.0 °C	25.3 °C	28.3 °C	-3.0 °C	25.2 °C	29.7 °C	-4.5 °C	25.0 °C	29.2 °C	-4.2
-3.2 °C	24.9 °C	28.3 °C	-3.4 °C	24.8 °C	27.5 °C	-2.7 °C	25.1 °C	29.7 °C	-4.6
-1.0 °C	24.8 °C	26.8 °C	-2.0 °C	24.5 °C	27.9 °C	-3.4 °C	24.7 °C	28.3 °C	-3.6
-3.3 °C	25.2 °C	28.3 °C	-3.1 °C	24.9 °C	28.3 °C	-3.4 °C	23.0 °C	26.8 °C	-3.8
-4.7 °C	27.8 °C	31.0 °C	-3.2 °C	27.9 °C	30.9 °C	-3.0 °C	24.7 °C	28.3 °C	-3.6
-2.4 °C	25.8 °C	27.5 °C	-1.7 °C	25.8 °C	27.7 °C	-1.9 °C	27.1 °C	29.9 °C	-2.8
-0.8 °C	26.8 °C	27.6 °C	-0.8 °C	25.9 °C	27.6 °C	-1.7 °C	26.0 °C	28.9 °C	-2.9
-3.0 °C	25.3 °C	27.9 °C	-2.6 °C	26.0 °C	30.0 °C	-4.0 °C	25.4 °C	28.7 °C	-3.3
-4.9 °C	24.3 °C	28.6 °C	-4.3 °C	24.2 °C	27.8 °C	-3.6 °C	25.4 °C	29.9 °C	-4.5
-3.9 °C	23.9 °C	28.2 °C	-4.4 °C	23.9 °C	28.3 °C	-4.4 °C	23.8 °C	28.3 °C	-4.5
-4.0 °C	25.0 °C	28.0 °C	-3.0 °C	23.0 °C	28.0 °C	-5.0 °C	23.8 °C	28.3 °C	-4.5
-2.9 °C	25.0 °C	28.9 °C	-3.9 °C	25.0 °C	29.0 °C	-4.0 °C	24.9 °C	30.0 °C	-5.1
-4.7 °C	26.8 °C	30.5 °C	-3.7 °C	23.1 °C	27.8 °C	-4.8 °C	25.8 °C	30.0 °C	-4.2
-4.3 °C	24.0 °C	29.1 °C	-5.1 °C	24.0 °C	28.8 °C	-4.8 °C	24.0 °C	28.8 °C	-4.8
-4.3 °C	24.7 °C	27.9 °C	-3.2 °C	24.5 °C	27.9 °C	-3.4 °C	27.2 °C	30.0 °C	-2.8
-3.9 °C	23.8 °C	27.9 °C	-4.1 °C	23.6 °C	26.5 °C	-2.9 °C	24.2 °C	28.1 °C	-3.9
-3.7 °C	25.8 °C	27.0 °C	-1.2 °C	26.7 °C	28.8 °C	-2.1 °C	23.5 °C	25.7 °C	-2.3
-2.7 °C	25.6 °C	30.0 °C	-4.4 °C	23.5 °C	31.0 °C	-7.5 °C	26.0 °C	29.0 °C	-3.0
-2.7 °C	25.7 °C	30.0 °C	-4.3 °C	24.8 °C	31.0 °C	-6.2 °C	23.3 °C	30.0 °C	-6.7
-4.1 °C	26.6 °C	31.0 °C	-4.4 °C	26.0 °C	30.0 °C	-4.0 °C	24.4 °C	30.0 °C	-5.6
-5.1 °C	25.8 °C	30.0 °C	-4.2 °C	25.5 °C	28.0 °C	-2.5 °C	25.5 °C	28.0 °C	-2.5
-3.0 °C	25.1 °C	30.0 °C	-4.9 °C	25.8 °C	32.0 °C	-6.2 °C	26.1 °C	32.0 °C	-5.9
-3.6 °C	25.1 °C	28.0 °C	-2.9 °C	24.6 °C	30.0 °C	-5.4 °C	25.4 °C	29.0 °C	-3.6
-6.5 °C	24.5 °C	30.0 °C	-5.5 °C	24.4 °C	28.0 °C	-3.6 °C	24.4 °C	29.0 °C	-4.6
-3.0 °C	25.3 °C	30.0 °C	-4.7 °C	25.1 °C	32.0 °C	-6.9 °C	24.0 °C	30.0 °C	-6.0
-4.0 °C	24.8 °C	29.3 °C	-4.5 °C	24.5 °C	27.9 °C	-3.4 °C	23.9 °C	29.0 °C	-5.1
-3.9 °C	24.6 °C	28.0 °C	-3.4 °C	24.3 °C	28.0 °C	-3.7 °C	24.3 °C	28.0 °C	-3.7
-5.0 °C	24.9 °C	27.0 °C	-2.1 °C	24.3 °C	27.8 °C	-3.5 °C	24.2 °C	29.0 °C	-4.8
-5.0 °C	24.9 °C	27.0 °C	-2.1 °C	24.3 °C	27.8 °C	-3.5 °C	24.2 °C	29.0 °C	-4.8
-3.7 °C	25.2 °C	28.7 °C	-3.5 °C	24.8 °C	28.8 °C	-4.0 °C	24.8 °C	29.0 °C	-4.2 °C
1.2 °C			1.2 °C			1.4 °C			1.1 °C