The Effects of Solar Reflectance Index (SRI) on Roof Tiles for Climate Change Mitigation

by

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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Approved by,

(Dr. Mohd Faris b. Khamidi)

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TRONOH, PERAK
Sept 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgement, and the original work contained herein have not been undertaken or done by unspecified sources of persons.

MOHAMAD HELMI BIN MOHD NAWAWI

ABSTRACT

Temperature rise is a global phenomenon that has been occuring for a long time. This is due to the development that occurs everywhere around the world. As human continue their pursue of the latest technology and the tallest skyscrapper, we tend to neglect the negative impact it has on the world. Although we cannot dismiss the importance of developing a nation, we also need to ensure mitigation methods in order to cope with the ever-rising temperature. We tend to cope with this issue by using more air-conditioning units in our residents and work places. Green house gasses emission caused by excessive usage of air-conditioning units is one of the factors that cause the temperature rise. These gasses are one of the factors of global warming. Urban Heat Island effect is a huge problem that occurs in rural and urban areas. It is the effect of excessive heat gain on buildings. During the peak heat of the day, the temperature of an exposed area might rise up to 50°C [19]. Since the roof affects more of the heat gain compared to the envelope (walls) of a low-rise building, we conducted the experiment only on the roofs. A method that can be used to reduce the usage of air-conditioning units is by choosing light colored roof tiles, which has high SRI value. A standard white color has the SRI value of 100 while a standard black color has the SRI value of 0. Solar Emittance and Solar Reflectance affect these values with both ranging from 0 to 1. By choosing lighter colors, we can manage to reduce heat absorbtion of our building, especially during the peak heat of the day. The experiment consists of four roof tile colors, which are white, orange, dark brown and light grey. The data compared for these colors are the ambient temperature, indoor temperature, solar irradiation and relative humidity. The experiment was conducted at an experimental house with the size of 3m x 3m x 2.5m. The instruments used are a solarimeter, a multimeter and an internal automatic data logger. The duration of each color was six days.

ACKNOWLEDGEMENT

Alhamdulillah, first and foremost the author would like to express his gratitude to those who have helped him to complete the Final Year Project which focuses on studyng the effects of Solar Reflectance Index (SRI) for roof tiles for low rise building in Malaysia.

For the past 14 weeks of this semester, the author had received countless assist, guidance and moral support from his supervisor, Dr.Faris b. Khamidi and his partner, Mr. Ahmad Alyacouby. The author would like to thank all the people involved in making this project possible.

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LIST OF FIGURES

FIGURES

LIST OF TABLES

TABLE OF CONTENT

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND STUDY

According to the laws of thermodynamics and heat transfer, structures have the ability to exchange heat of thermal energy from one physical system to another. Heat transfer is caused by temperature difference, which causes heat to transfer from high temperature to low temperature region.

The mechanisms or mode of heat transfer are **conduction** or **diffusion**, **convection**, and **radiation**. **Conduction** is when heat is being transferred between objects by physical contact. This is caused by atoms and molecules that moves rapidly interact with neighboring atoms and molecules, causing some heat to be transferred to the neighboring atoms and molecules. There are two types of conduction, which are *Steady State Conduction* and *Transient Conduction.* Steady State Conduction is when the heat is being transferred when the temperature difference is constant. Transient Conduction occurs when the temperature of an object changes as a function of time [1] [4].

Convection heat transfer occurs when energy (heat) is being transferred between an object and the environment due to circular fluid motion. It is usually the dominant form of heat transfer in liquids and gasses. There are two types of convection, which are *Natural* and *Forced. Natural convection* occurs when the fluid motion is caused by buoyancy forces resulting from density variations due to variations of temperature in the fluid. *Forced convection* is when the fluid is forced to flow over the surface by external means—such as fans, stirrers, and pumps—creating an artificially induced convection current [1] [4].
Radiationoccurs when the energy is transferred to or from a body by emission or absorption of electromagnetic radiation. It is a result of random movements of atoms and molecules in matter. Electromagnetic radiation, which carries energy from the surfaces, is emitted because of the

movements of atoms and particles consisting of charged particles. It can be concentrated to a small spot by using by using reflecting mirrors [1] [4].

Solar Reflectance Index (SRI) is a numerical expression of a coating's ability to reject solar heat [10]. The information needed to determine the SRI value of a material is thermal emittance and solar reflectance. The envelope of a house, which refers to the wall and the roof, has the ability to avoid heat gain. The paint and material applied to the wall and roof may determine the ability of the building to reflect heat caused by solar. It is found out that less than 2% of houses in Malaysia are insulated which reduces the ability of houses to decrease heat gain. Areas in the tropical rainforest climate such as Malaysia, Brazil and Peru have no natural seasons due to Doldrums Low Pressure System domination for all year. This means these areas endure a climate of hot and rainy all year long. The sunlight and rain exposure of these areas are consistent for the whole year. Therefore the choice of coating material is very important in reducing heat gain due to solar ray. SRI value measures between 0-100 with 0 (0.05 reflectance, 0.90 emittance) being the warmest material (standard black)and 100 (0.80 reflectance, 0.90 emittance) being the coolest material (standard white). The values can actually measure as low as negative values and as high as greater than 100. Warm material absorbs most of the heat while cool materials reflect most of the heat. The diagram below shows the SRI values of certain colors;

Color - 35-Year Warranty	24 ga x 20"	24 ga x 24"	24 ga x 4' x 10'	26 ga x 24"	SRI*
Aged Copper	X	X	X		46
Antique Patina	X	X	X		28
Bone White	X	X	X		81
Bright Silver	X	X	X		64
Brilliance - 20-Year Warranty	X	X	X	X	44
Buckskin	X	X	X		25
Burgundy	X	X	X	X	29
Champagne	X	X	X		46
Charcoal Gray	X	X	X	X	25
Colonial Red	X	X	X	X	27
Dark Bronze	X	X	X	X	27
Deep Blue Sea	X	X	X		27
Dove Gray	X	X	X	X	42
Everglade Moss	X	X	X		30
Forest Green	X	X	X	X	29
Hartford Green	X	X	X	X	25
Hemlock	X	X	X		37
Island Blue	X	X	X		38
Mansard Brown	X	X	X	X	28
Matte Black	X	X	X	X	27
Medium Bronze	X	X	X	X	34
Metallic Copper	X	X	X		41
Pacific Blue	X	X	X		25
Patina Green	X	X	X		34
Pre-weathered Galvalume	X	X	X		28
Regal White	X	X	X		85
Sandstone	X	X	X		64
Sierra Tan	X	X	X		41
Slate Blue	X	X	X	X	38
Slate Gray	X	X	X	X	46
Surrey Beige	X	X	X		46
Teal Blue	X	X	X		29
Terra Cotta	X	X	X		46

*Solar Reflectance Index (SRI)

Figure 1 Solar Reflectance Index of Several Colors

Source:http://www.drexmet.com/Coils-and-Sheets.html

"Cool" products such as cool roofsare surfaces that are minimally heated by the sun, such as a bright white roof [11] [13]. The most important features of a cool roof are its surface strongly reflects sunlight. A cool roof should have both high **solar reflectance** (measured from 0 to 1, 0 indicates the roof absorbs all radiation while 1 indicates total reflectivity) and **thermal emittance**. These properties are described as **radiative** properties. Lighter colors usually have higher reflectivity compared to darker colors. Cool colors are medium and dark colors that strongly reflect near-infrared sunlight. The surface of a standard black colored roof can increase up to 50° C (122°F) in the heat of the full sun. This contributes certain problems such as:

- Increased cooling energy use and higher utility bills
- Reduced indoor comfort
- Higher peak electricity demand
- Accelerated deterioration of roofing materials
- Increased roof maintenance costs

By installing cool roof on buildings, we can gain many short term and long-term benefits such as:

- Reduce building heat-gain
- Enhance the life expectancy of both the roof membrane and the building's cooling equipment
- Improve thermal efficiency of the roof insulation
- Reduce the demand for electric power by as much as 10 percent on hot days
- Reduce resulting air pollution and greenhouse gas emissions

1.2 PROBLEM STATEMENT

There are several obstacles encountered in encouraging and convincing people to use light coloredroof. Issues encountered are as listed below:

1. The rise in temperature causes discomfort and also a significant rise in maintenance cost as utility bills gets higher. Peak electricity demand will also rise which increases maintenance cost.

2. Urban Heat Island Effect that causes particular spots to have higher temperature compared to others. This was caused by development that chooses heat-retaining materials in the heat of the sun which leads to temperature rise up [8] [15].

3. Green house gasses emission that leads to global warming.

4. Even though light color such as white is the best choice for heat gain avoidance, most people choose darker colors, as this is a matter of preference.

1.3 OBJECTIVE

The objective of the research is todetermine the most heat-reflecting color that can be used for roof tiles. This is because in a low-rise building, the heat absorbed by the roof has more significant impact on the indoor temperature compared to the walls. Theoretically, light colors are more heat reflecting compared to dark colors. This also indicates that light colors have higher Solar Reflectance Index value compared to dark colors. The roof material used for the experiment is concrete.

1.4 SCOPE OF WORK

This experiment focused on the effects of SRI on low-rise buildings in tropical climate area. As of now, the research for this climate has not been done yet, making this experiment unique.

The scope of work for this research is as listed below:

Table 1 Scope of Work for the Experiment

No.	Item to be tested	Description
1.	Paint Colors for roof	Colors to be tested are: i. White ii. Orange iii. Dark Brown iv. Light Grey
2.	Parameters to be tested	- Solar irradiation - Ambient temperature - Indoor temperature - Relative humidity - Lux
3.	Instruments	These are the instruments used for this experiment; • Data Logger Thermometer (KH100AO) • Solarimeter (KIMO SL 200) • Multi-functional Meter (AMI300-STD)
4.	Roof material to be tested	Concrete

1.5 RELEVANCY OF PROJECT

The research is in order to determine the best choice of heat reducing materials for house envelopes. By conducting this research, we will be able to choose the best roof color in order to reduce heat gain and the best material and slope for roof, with the help of survey. The research will benefit the public in terms of accessibility to choose materials with the best aesthetic value to their taste while being efficient in energy usage at the same time. By reducing heat gain, utility bills will be reduced, as less electrical power will be needed to air-condition a house.

1.6 FEASIBILITY OF THE PROJECT

The idea of the research is to find the best color choice that reflects heat by survey and the best roof material and roof angle. The research is already commenced with some of the initial test being conducted.

The research was conducted for two semesters starting from May 2011 semester. The time given was enough for the experiment, but repetition of the experiment for some colors require more time. This experiment also involves weather factor. It cannot be conducted under bad weather.

CHAPTER 2
LITERATURE REVIEW

2.1 THEORIES AND CONCEPT OF HEAT TRANSFER

As stated in the background study for this project, the theory and concept behind thermal and heat transfer is very important in this research. The SRI value, thermal emittance and solar reflectance value are closely related to the studies of heat transfer. Heat is being transferred by threemethods, which are **conduction/diffusion**, **convection**, and **radiation** [1] [4]. These three mechanisms are different in terms of mode of transferring the heat from a system to another.

Heat transfers from a higher temperature medium to a lower temperature medium and stops when the two mediums reach the same temperature. The first and second law of thermodynamics can be related with the research regarding heat transfer. The **first law of thermodynamics** states that the rate of energy transfer into a system equals the rate of increase of the energy in the system. It is also known as the **conservation of energy principle** [1] [4]. The equation below explains the energy conservation theory:

$$E_{in} - E_{out} = \Delta E_{system}$$

The**second law of thermodynamics** states that heat to be transferred in the direction of a lower temperature system [1] [4]. The rate of heat transfer per unit area is known as heat flux [4]. The presence of *temperature difference* is the most important factor of heat transfer. Heat transfer rate depends on the *temperature gradient*, which is the temperature difference per unit length. Larger temperature gradient equals to higher rate of heat transfer.

2.1.1 Heat Transfer Mechanism

There are three types of heat transfer mechanism. In this section, the heat transfer mechanisms will be explained.

Conduction is when heat is being transferred between objects by physical interactionsbetween more energetic particles to less energetic particles. It can occur in solids, liquids, and gases. In gases and liquids, conduction is the result of collisions and diffusion of molecules in random motion. In solids, conduction is a result of combination of the molecules in a lattice and the energy transport by free electrons [1] [4]. The factors affecting heat transfer by conduction are *geometry* of the medium, *material* of the medium, *thickness* of the medium and the *temperature difference* across the medium.

Convection heat transfer occurs when energy (heat) is being transferred between a solid surface and the adjacent liquid or gas that is in motion. This transfer mode involves the combined effects of conduction and fluid motion. Faster fluid motion results in greater convection heat transfer. There are two types of convection, which are *Natural Convection*and *Forced Convection*. *Natural convection* occurs when the fluid motion is caused by buoyancy forces resulting from density differences due to variations of temperature in the fluid. *Forced convection* is when the fluid is forced to flow over the surface by external means such as fans, stirrers, pumps or the wind. Heat transfer processes that involve change of phase of fluids are considered as convection due to the fluid motion involved. It is basically a conduction process that involves fluid motion.

Radiationis the energy emitted by matter in the form of *electromagnetic waves* (or *photons*) as a result of the changes in the electronic configurations of the atoms or molecules [1][4].Movements of atoms of charged particles cause electromagnetic radiation, which carries energy from surfaces. It does not require the presence of any *intervening medium*. It is a surface phenomenon for solids that are opaque to thermal radiation. The **Stefan-Boltzmann law** explains the maximum rate of radiation in the formula shown:

$q = \sigma T^4 A$

where

q= heat transfer per unit time (W)

σ= 5.6703 10^{-8} (W/m^2K^4) - ***TheStefan-Boltzmann Constant***

T= absolute temperature Kelvin (K) A= area of the emitting body (m^2)

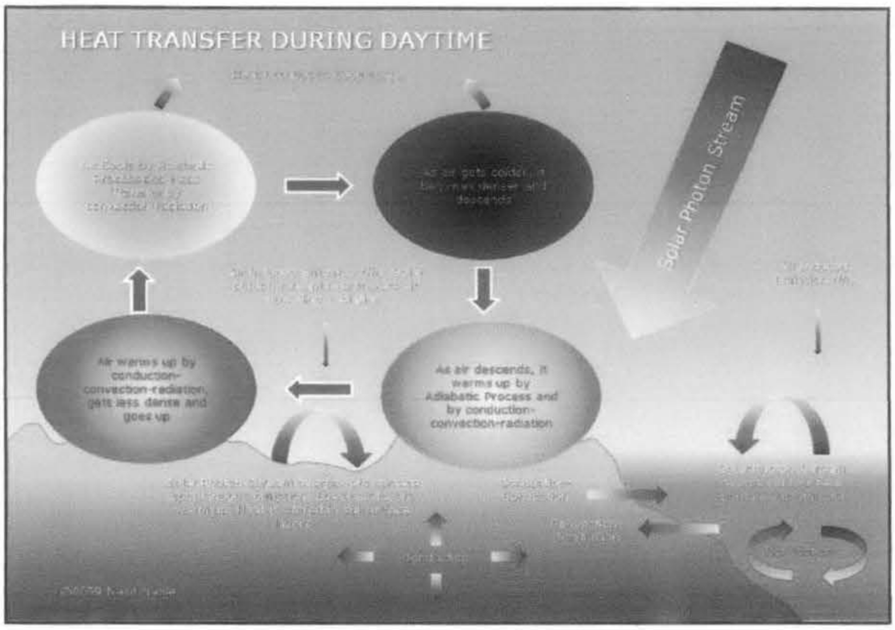

Figure 2 Heat Transfer During Daytime

Source: http://biocab.org/Heat_Transfer.html

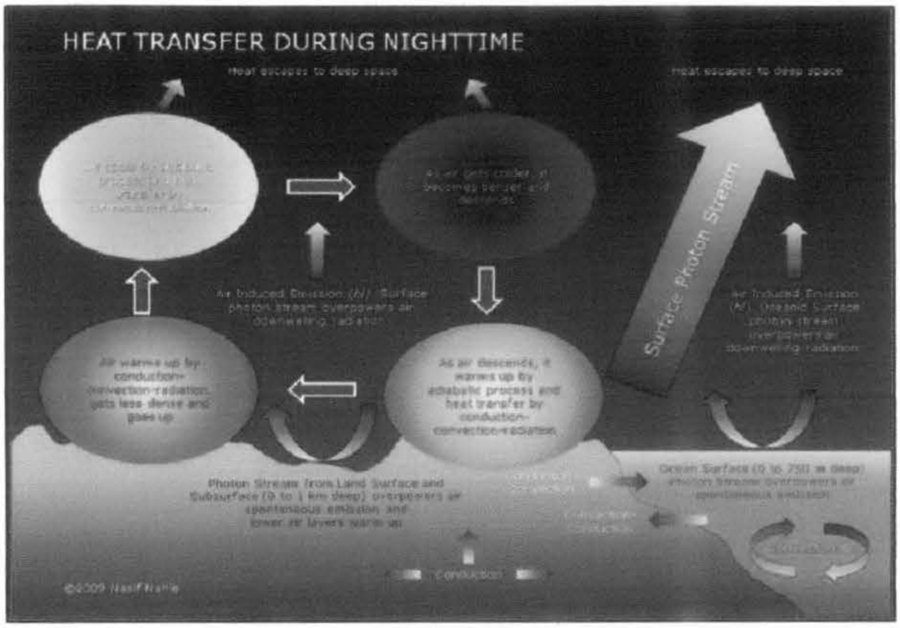

Figure 3 Heat Transfer During Nighttime
Source: http://biocab.org/Heat_Transfer.html

2.2 EFFECTS OF DIFFERENT ROOF COLORS ON HEAT GAIN

Different type of colors absorbs or reflects heat at different rate. Generally, dark colors absorb heat while light colors reflect heat. Since we are conducting a study based on low-rise buildings, we consider the colors for building wall to be negligible. We will only consider and conduct the study based on the roof colors of a low-rise building.A measurement used to indicate the rate of sun light absorption by a building is known as **Solar Reflectance Index (SRI)**. **SRI** value of 0 indicates an object as "Standard Black" (reflectance 0.05, emittance 090) while **SRI** value of 100 indicates an object as "Standard White" (reflectance 0.80, emittance 0.90) [11] [13].

Materials such as "cool" products have more cooling effect compared to products of the same color. The figure below shows the SRI values of several "cool" colors compared to its standard counterparts.

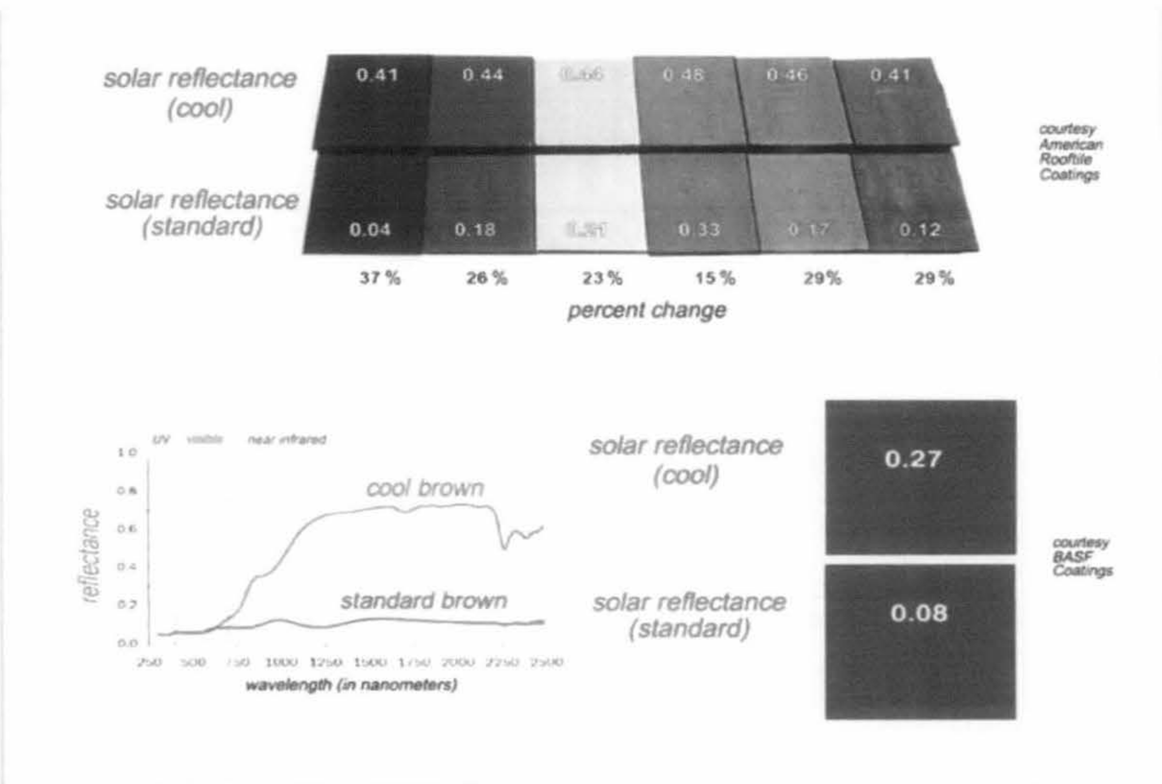

Figure 4 Solar Reflectance of Roofing Materials

Source: http://eetdnews.lbl.gov/nl19/eetd-nl19-1-cool.html

2.3 URBAN HEAT ISLAND

Urban Heat Island (UHI) occurs when an urban area have higher temperature compared to surrounding rural areas. The phenomenon is caused by many factors in an urban setting. One of the factors is when building surface absorbs excessive heat. This usually occurs at the peak heat hour of a day, especially in the summer. Since the focus of this experiment is on tropical climate, the area of the experiment will likely receive more or less the same amount of sunlight throughout the whole year.

There are two types of Urban Heat Island. They are Surface Urban Heat Island and Atmosphere Urban Heat Island. Exposed urban surface such as roofs and pavements can reach up to 27°C-50°C [19]. Canopy layer UHI are formed at the layer of air where human lives, while Boundary layer UHI forms at the rooftop or treetop to areas where urban landscapes no longer influence atmosphere.

Surface materials in urban areas usually have lower albeldo compared to in rural areas. This causes the materials to reflect less heat and absorb more energy emitted by the sun. As a result, heat is gained and the temperature increases. The main determinants for this occurrence are solar reflectance and thermal emittance. Thermal emittance is the ability to shed heat. Higher emittance means the material is cooler. Another factor affecting UHI is weather. UHI forms primary under clear skies because it allows the maximum amount of solar energy to reach urban surfaces thus minimizing the amount of heat that can be convected away.For this experiment, insulators were not installed at the roof. This is to allow direct heat transfer from the roof surface into the experimental house.

As the temperature rises, the demand for more usage of air conditioning unit rises. This leads to the increase of utility bills and Green House Gasses emission. According to Hashem Akbari, a study shows that peak urban electricity demand rises by 2-4% for each 1K rise in temperature above the threshold of 15-20 °C. This phenomenon contributes to 5-10% of urban peak electricity demand for the usage of air conditioning units in the United States [20][21]. A study shows that from 1930-1990, Los Angeles recorded growth of 0.5 °C for each decade. Each degree increment adds up to 500MW to air conditioning load [20][21].

Hashem Akbari also stated that in a journal by Berdahl&Bretz in 1997, for highly absorptive roofs, the surface and air temperature difference during peak heat hour can be as high as 50K, while the difference for less absorptive roofs are as little as 10K. The usage of less absorptive roofs allow more energy saving. In a field study by Akbari in 1997, a reported energy savings of 46% and peak power savings of 20% were obtained by increasing roof reflectance of two identical classrooms in Sacramento, California [20]. Another study by Akbari in 2003 that further proofs the theory is the reported energy savings of 31-39 Wh/m^2/day in two small commercial buildings by coating the roof with elastometer with 0.70 reflectivity [20][21].

As of now, there are no known researches based on the tropical climate such as Malaysia. This research allows us to study the effect of highly reflective roof colors on heat gain for this climate.

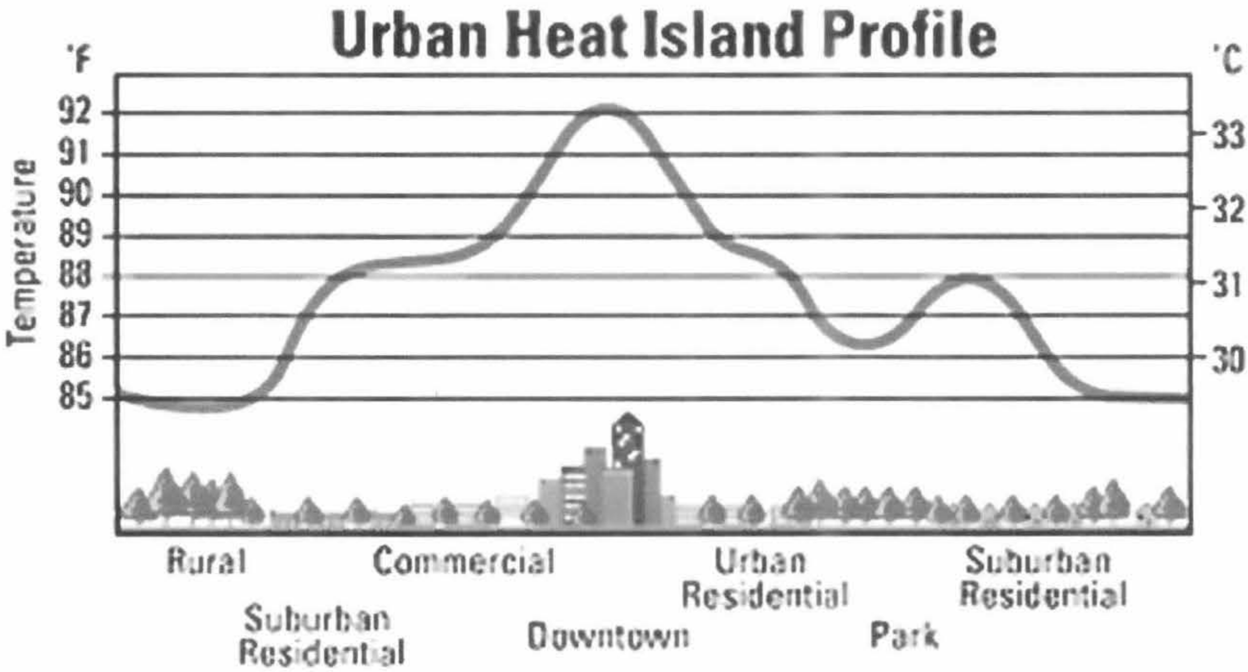

Figure 5Urban Heat Island Profile

Source: http://www.eoearth.org/files/118101_118200/118117/Heat_island_profile.gif

CHAPTER 3
METHODOLOGY

3.1 RESEARCH METHODOLOGY

The research is conducted in four stages. Each stage will be conducted separately in order to fully focus and acquire the best result. The stages are listed below:

3.1.1 Literature Review

This is the first stage of conducting the experiment. Before starting the experiment, paper research needs to be done in order to understand the basic theories of the subject. This can be done by reviewing journal, referring to books, and consulting lecturer.

3.1.2 Data Collection from Experimental House

The data reading for each roof tiles color will be taken on a daily basis. The colors are white, orange, dark brown, light grey. A Solarimeter (KIMO SL200) was used to obtain the data for Minimum and Maximum Solar Irradiation.A Multi-functional Meter (AMI300-STD) was used to obtain the data for Relative Humidity (RH)and Ambient Temperature and a Data Logger Thermometer was used to obtain the Indoor Temperature and Lux of the experimental house. The solarimeter and multi-functional meter was used for external data collection and the data recording was taken manually while the Data Logger Thermometer was installed in the experimental house to record data automatically. Weather conditions were noted during the experiment as it played a major part affecting the data recordingprocess. Data recorded during rainy days might be discarded if it does not show much fluctuation and the experiment will be conducted on another day. This is in order to maintain the consistency of the results obtained. An experimental house located near Block N was constructed for the experiment. The dimension of the structure is 3.0m (W), 3.0m (L), and 2.5m (H). The wall thickness is 125mm and a single clear-glazed window (120cm x 120cm) was installed. The door of the experimental house should not be opened during experiment hours because it can affect the indoor temperature reading. Insulation was not installed on the roof because the experiment was conducted to determine the heat transfer through the roof to internal space of the experimental house. The instruments must not be directly exposed to under direct sunlight or rain. It should be used under shaded and sheltered area of the structure. The reading is taken in an hour interval starting from 7.00am until 7.00pm. Below is the picture of the experimental house.

Figure 6 The Experimental house

Figure 7 Roof Tiles to be Tested

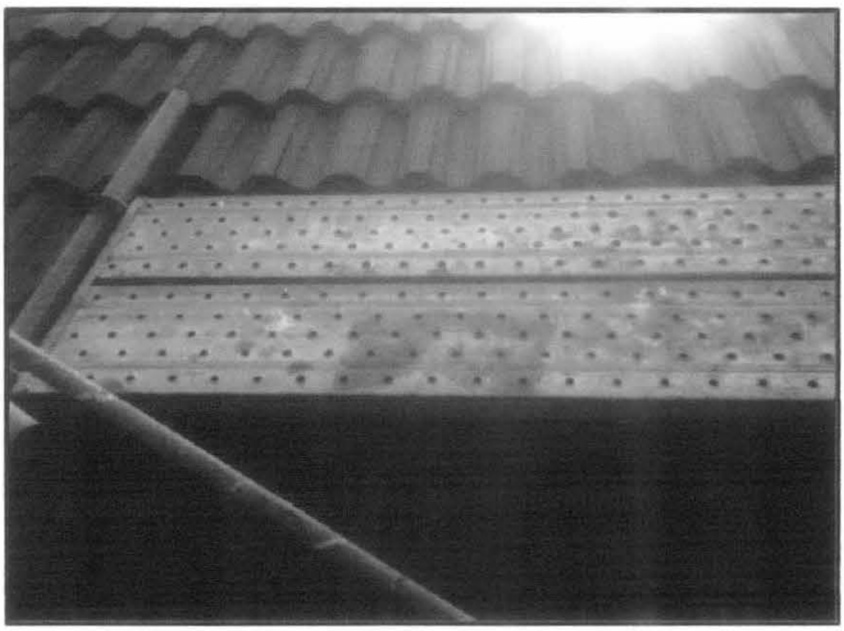

Figure 8 Changing Roof Tiles

3.1.3 Data Analysis and Discussion, Conclusion and Recommendation

Data obtained will be analyzed followed by discussion in order to determine the best option. A conclusion will be made after the best options have been decided. Furthermore, recommendations will be made based on extended research.

3.1.4 Determination of Best Color

Data from the experimental works will be compared to determine the best choice for roof color.

3.1.5 Documentation

The research works, methods and outcomes of the project will be documented for future use.

3.1.6 Flowchart

The diagram below shows the flowchart of the research methodology.

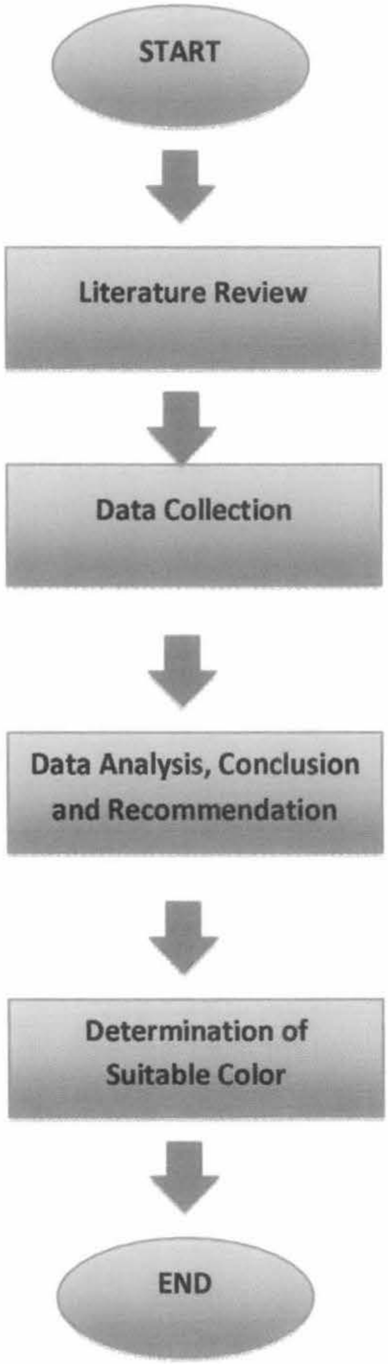

Figure 9 The Flow Chart

3.2 INSTRUMENTS REQUIRED

In order to complete the research, instruments and software needs to be utilized to obtain accurate result. The instruments and software are as listed below:

Table 2 Instruments Used in Experiment

INSTRUMENTS
KIMO SL200 Solarimeter -To measure solar irradiation
AMI 300 Std Multimeter -For external data collection such as outside temperature and relative humidity
Internal Data Logger -To automatically record indoor temperature and lux.

3.3 GANTT CHART

The Gantt Chart displays the activity in accordance to the timeline that should be completed for the two semesters, which is the total period of the research. Changes of activity may occur according to any events that may happen during the research period. Below is the Gantt Chart for the research:

<u>Gantt Chart for First Semester</u>

Table 3 Gantt Chart for First Semester

Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Literature Review														
Selection and Confirmation of Project Title														
Preliminary Research Work on Related Topics														
Submission of Extended Proposal														
Data Collecting and Research Work														
Proposal Defence														
Submission of Interim Draft Report														
Submission of Interim Final Report														

Gantt Chart for Second Semester

Table 4 Gantt Chart for Second Semester

Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Model Development and Modification Work	■	■	■	■	■	■	■	■						
Submission of Progress Report								■						
Testing and Validation work						■	■	■	■	■	■			
Results Analysis and Discussion										■	■	■	■	
Pre-EDX										■				
Submission of Draft Report											■			
Submission of Dissertation (soft bound)												■		
Submission of Technical Paper												■		
Oral Presentation													■	
Submission of Project Dissertation (soft bound)														■

3.4 KEY MILESTONE

Key milestone marks the completion of each part of the research. The table below shows the timeline for parts of the project.

Table 5 Key Milestone for First Semester and Second Semester

		SEMESTER 1													
No.	**Detail/Week**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Completion of preliminary research work														
2	Completion of interim report (Draft and Final)														
		SEMESTER 2													
No.	**Detail/Week**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Completion of model development														
2	Completion of testing and validation work														
3	Completion of results analysis and discussion														
4	Completion of final documentation														

CHAPTER 4
RESULTS AND DISCUSSION

4.1 RESULTS AND DISCUSSION

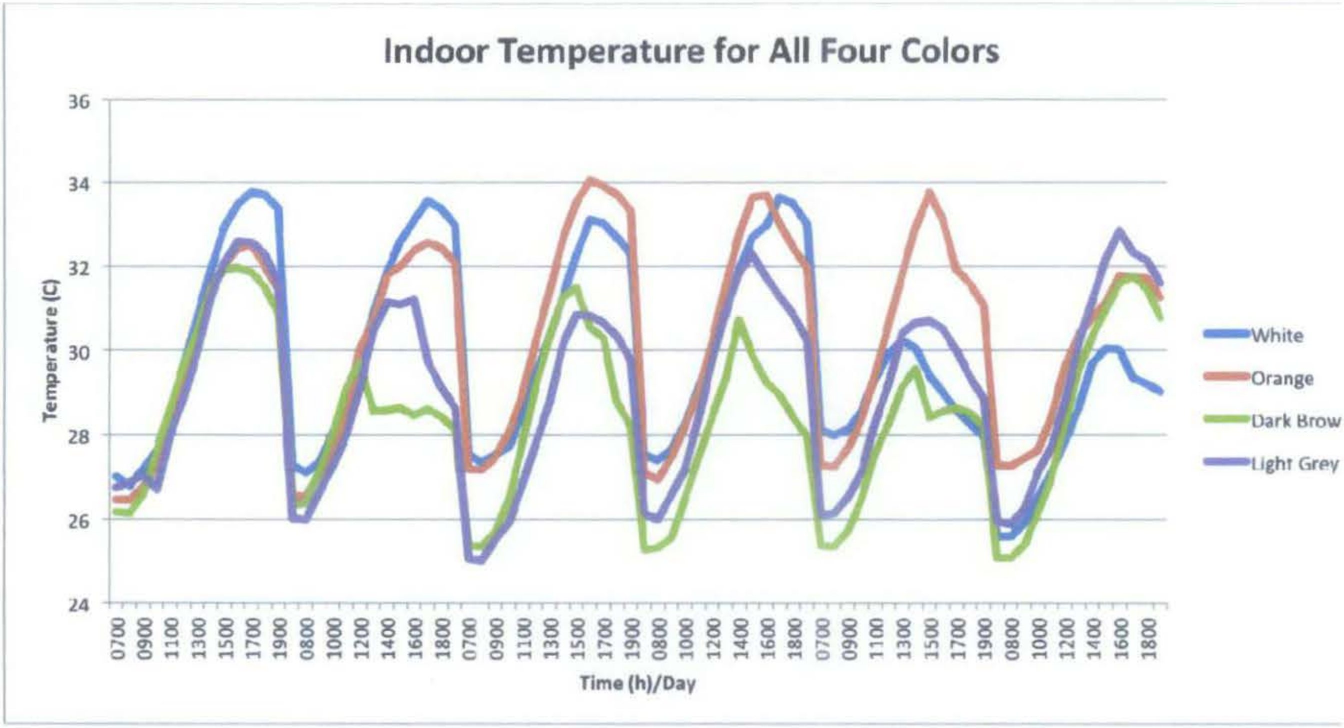

Figure 10 Indoor Temperature Comparison for All Color

The graph in **Figure 10** shows the indoor temperature for all colors from the first day until the sixth day of the experiment. The time interval of the graph is 1 hour, starting from 7.00am until 7.00pm every day. From this graph, we can see that during the experiment, white is the most stable color in terms of temperature. This is followed by orange, light grey, and dark brown. Ambient temperature affected the data obtained. The weather during experiment for white and orange were clear and sunny while for dark brown and light grey were rainy and cloudy.

Table 6 Average Indoor Temperature of The Colors

Time (h)	White (°C)	Orange (°C)	Dark Brown (°C)	Light Grey (°C)
0700	27.18	26.98	25.65	26.14
0800	27.04	26.93	25.65	26.09
0900	27.29	27.31	26.02	26.54
1000	27.80	27.87	26.81	27.03
1100	28.56	28.75	27.85	28.00
1200	29.46	30.04	28.84	29.06
1300	30.30	31.05	29.62	30.22
1400	31.12	32.05	30.16	31.17
1500	31.65	32.68	30.14	31.73
1600	31.95	32.90	30.10	31.84
1700	32.00	32.61	30.04	31.26
1800	31.80	32.32	29.57	30.71
1900	31.44	31.86	29.09	30.10

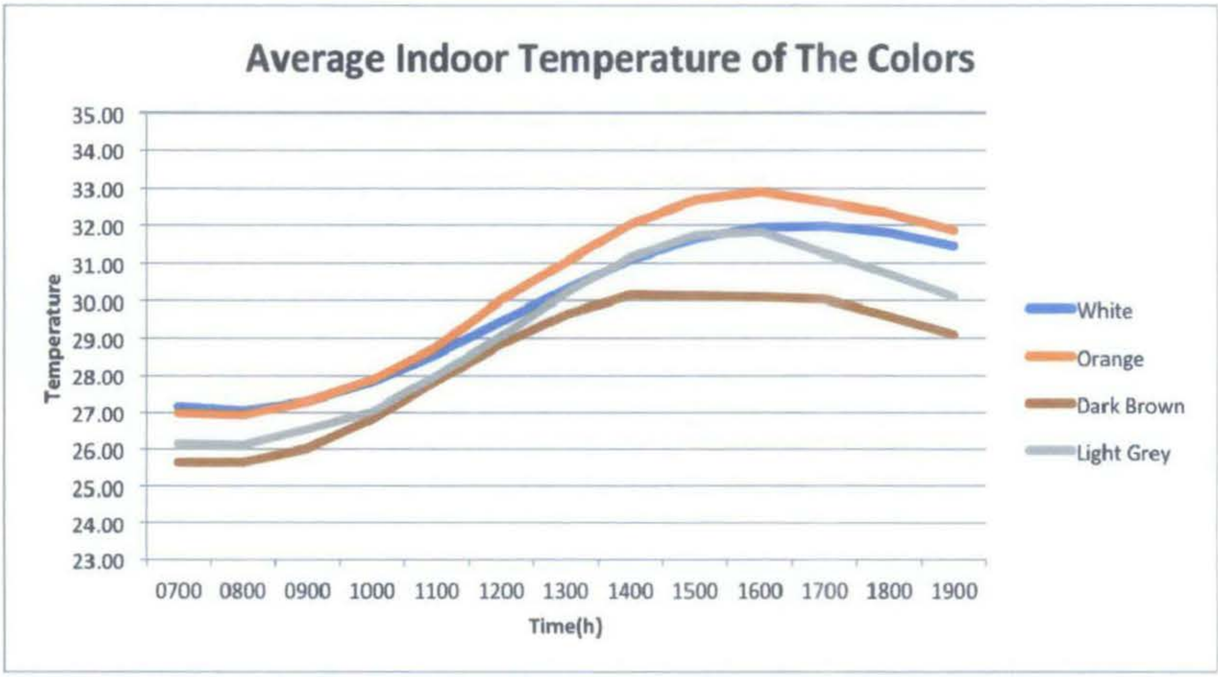

Figure 11 Average Indoor Temperature Comparison of The Colors

Table7 Average Indoor, Outdoor and Temperature Difference

White (^{0}C)			Orange (^{o}C)			Dark Brown (^{o}C)			Light Grey (^{o}C)		
idoor	Outdoor	Difference	Indoor	Outdoor	Difference	Indoor	Outdoor	Difference	Indoor	Outdoor	Differe
7.18	25.85	-1.33	26.98	25.08	-1.90	25.65	24.95	-0.70	26.14	24.75	-1.3
7.04	26.30	-0.73	26.93	27.02	0.09	25.65	25.60	-0.05	26.09	25.48	-0.6
7.29	28.23	0.94	27.31	28.78	1.48	26.02	27.57	1.55	26.54	27.88	1.3
7.80	29.75	1.96	27.87	30.43	2.57	26.81	28.65	1.84	27.03	29.23	2.2
8.56	31.07	2.51	28.75	32.60	3.85	27.85	30.92	3.06	28.00	30.80	2.8
9.46	32.28	2.82	30.04	33.43	3.40	28.84	32.47	3.63	29.06	32.30	3.2
0.30	33.23	2.93	31.05	35.05	4.00	29.62	31.42	1.79	30.22	32.98	2.7
1.12	33.48	2.37	32.05	34.93	2.88	30.16	31.55	1.39	31.17	33.22	2.0
1.65	33.55	1.90	32.68	33.70	1.02	30.14	29.77	-0.37	31.73	32.10	0.3

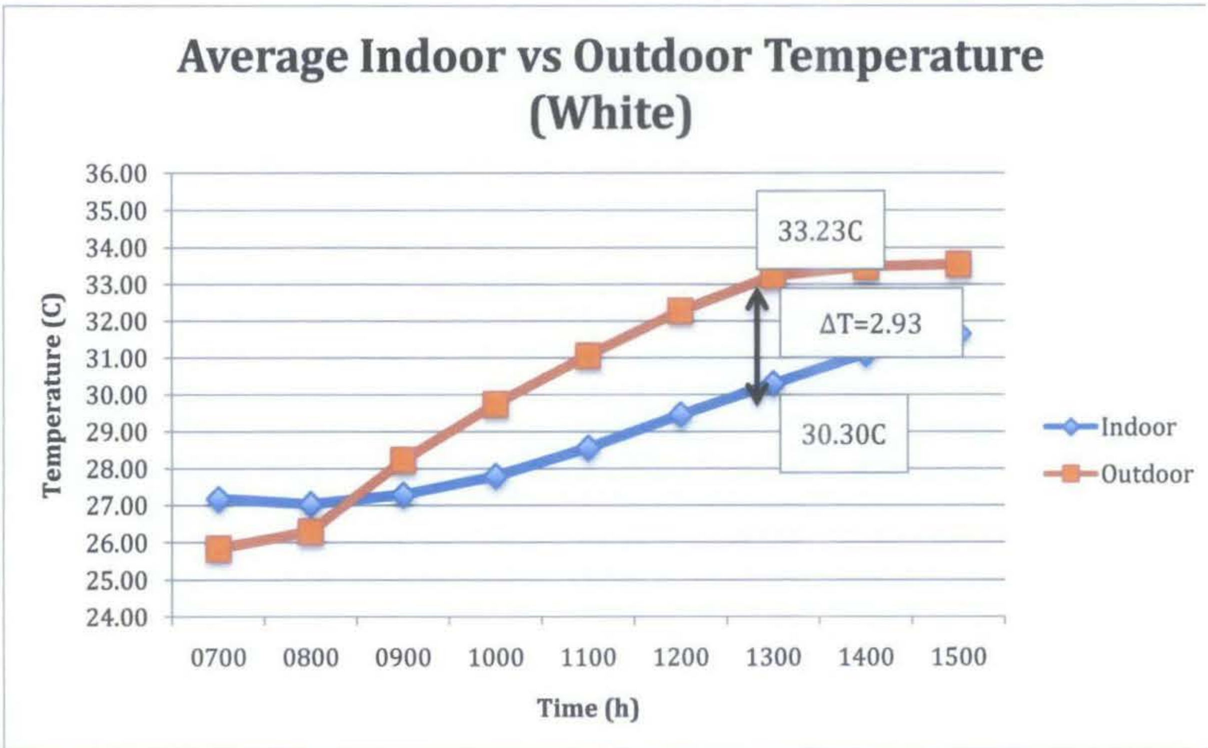

Figure 12 Average Indoor vs Outdoor Temperature (White)

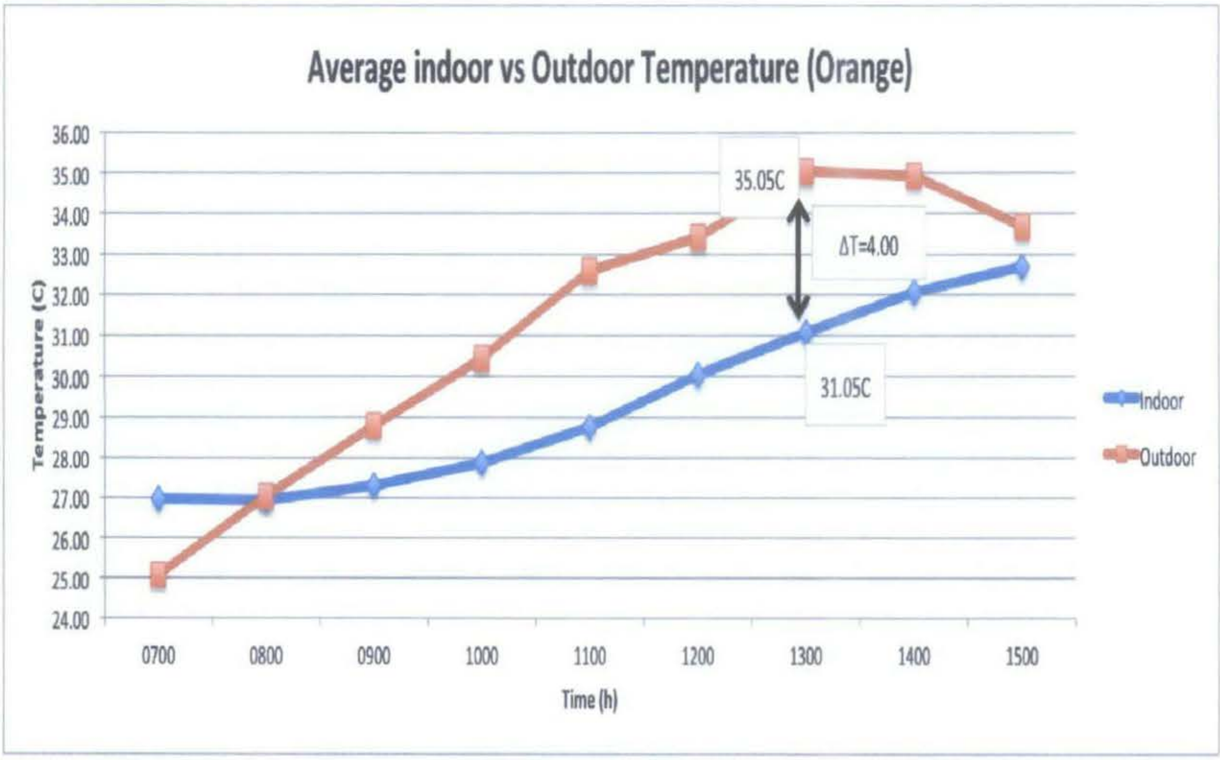

Figure 13 Average Indoor vs Outdoor Temperature (Orange)

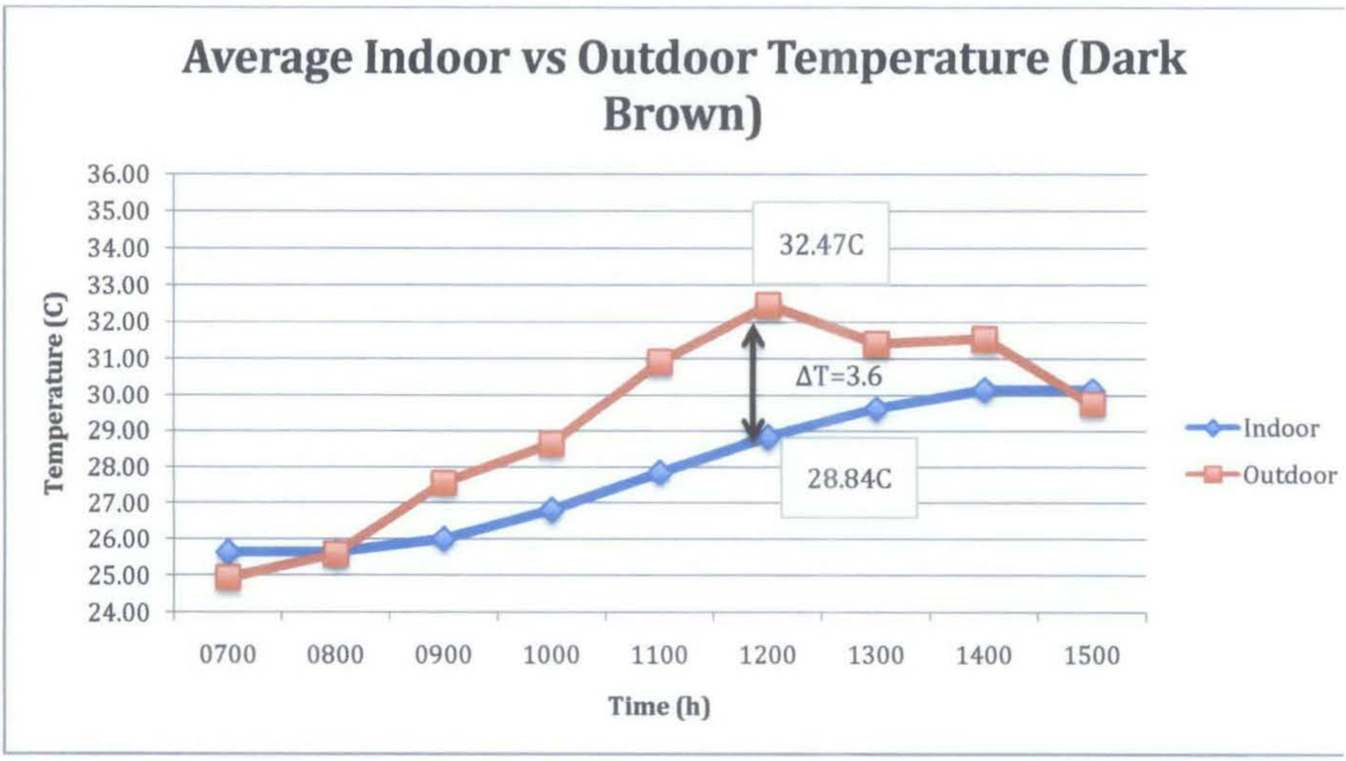

Figure 14 Average Indoor vs Outdoor Temperature (Dark Brown)

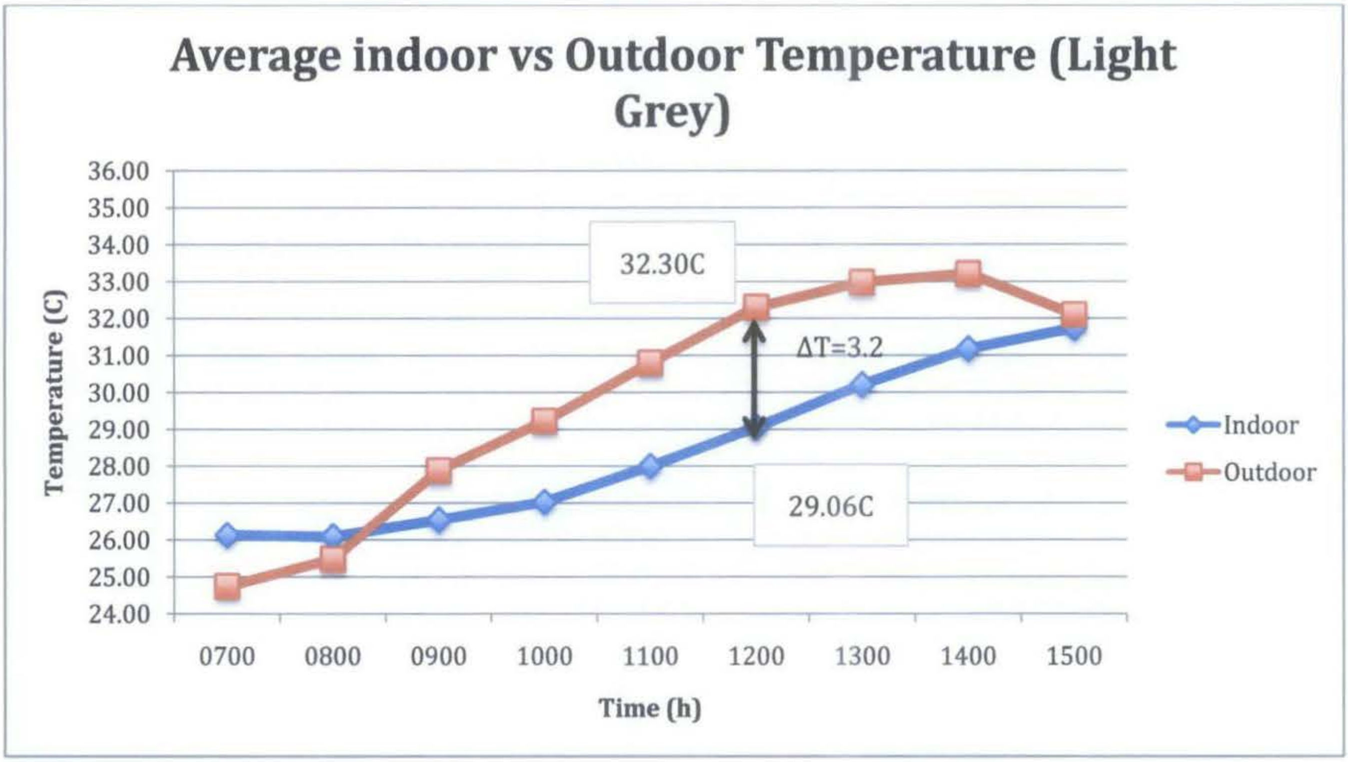

Figure 15 Average Indoor vs Outdoor Temperature (Light Grey)

From the graph obtained in **Figure 11**, the peak temperature for all colors occurs at 3.00pm. In that timeframe, the highest temperature recorded for white is 33.55°C at 3.00pm, for orange is 35.05°C at 1.00pm, for dark brown is 32.47°C at 12.00pm, and for light grey is 33.22°C at 2.00pm. Even though white recorded the second highest value out of all the colors, we were noted that for throughout the entire experiment, dark brown and light grey has low ambient temperature while orange shows a similar graph pattern to white. This shows that the weather condition during the data was recorded for white and orange is similar, which is hot and sunny. It shows that white is the cooler color compared to orange in the same weather condition.

The largest temperature difference was obtained from **Figure 12**, **13**, **14**, and **15**. For white, the largest temperature difference is 2.93°C, for orange is 4.00°C, for dark brown is 3.63°C, and for light grey is 3.24°C. The calculation below shows the percentage reduction for each color at peak temperature difference.

For white, temperature difference = 2.93°C

$\%T_{red}$= 2.93/33.23 x 100% = 8.82%

For orange, temperature difference = 4.00°C

$\%T_{red}$= 4.00/35.05 x 100% = 11.41%

For dark brown, temperature difference = 3.63°C

$\%T_{red}$= 3.63/32.47 x 100% = 11.18%

For light grey, temperature difference = 3.24°C

$\%T_{red}$= 3.24/32.30 x 100% = 10.03%

From the calculation above, we can see that the temperature difference for white is actually the lowest, followed by light grey, dark brown, and orange. However, we should consider the relative humidity factor for indoor and outdoor. Table 8 shows the recorded value for relative humidity. The value of outdoor and indoor relative humidity at highest temperature for all colors are as follows.

White at 3.00pm

Indoor RH = 68.95% Outdoor RH = 52.97%

Orange at 1.00pm

Indoor RH = 74.17% Outdoor RH = 50.43%

Dark Brown at 12.00pm

Indoor RH = 82.75% Outdoor RH = 58.63%

Light Grey at 2.00pm

Indoor RH = 76.08% Outdoor RH = 55.18%

From the data above, the value for outdoor RH for each color is almost similar. However, the value for indoor RH for white is noticeably low compared to the other colors. It means that the temperature condition in the experimental house at the particular time is dry and hot compared to the other colors. It affected the temperature of indoor temperature, thus reducing the temperature difference.

Table 8 Average Indoor and Outdoor Relative Humidity (All)

h)	White (°C)		Orange (°C)		Dark Brown (°C)		Light Grey (°C)	
	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor
	79.18	82.28	80.20	86.50	86.50	84.25	84.63	86.67
	79.78	80.96	81.15	80.57	87.25	82.83	85.65	85.75
	79.37	71.92	80.65	73.78	86.92	78.10	85.30	75.67
	79.65	65.98	80.07	64.85	86.43	72.40	84.12	69.47
	78.30	57.18	78.83	57.37	84.83	62.48	83.42	62.42
	76.23	52.84	76.75	54.85	82.75	58.63	81.35	58.98
	73.72	53.38	74.17	50.43	80.38	61.03	78.57	57.82
	70.20	52.28	71.53	50.13	79.25	63.88	76.08	55.18
	68.95	52.97	69.13	53.45	77.35	69.75	74.52	61.47
	68.10	57.07	67.95	59.27	77.82	74.50	73.32	70.35
	67.38	60.72	67.75	62.25	77.57	74.62	72.13	70.80
	67.15	63.90	67.87	69.82	76.88	78.27	72.88	78.08
	67.58	72.42	68.07	74.30	76.95	83.85	72.90	82.42

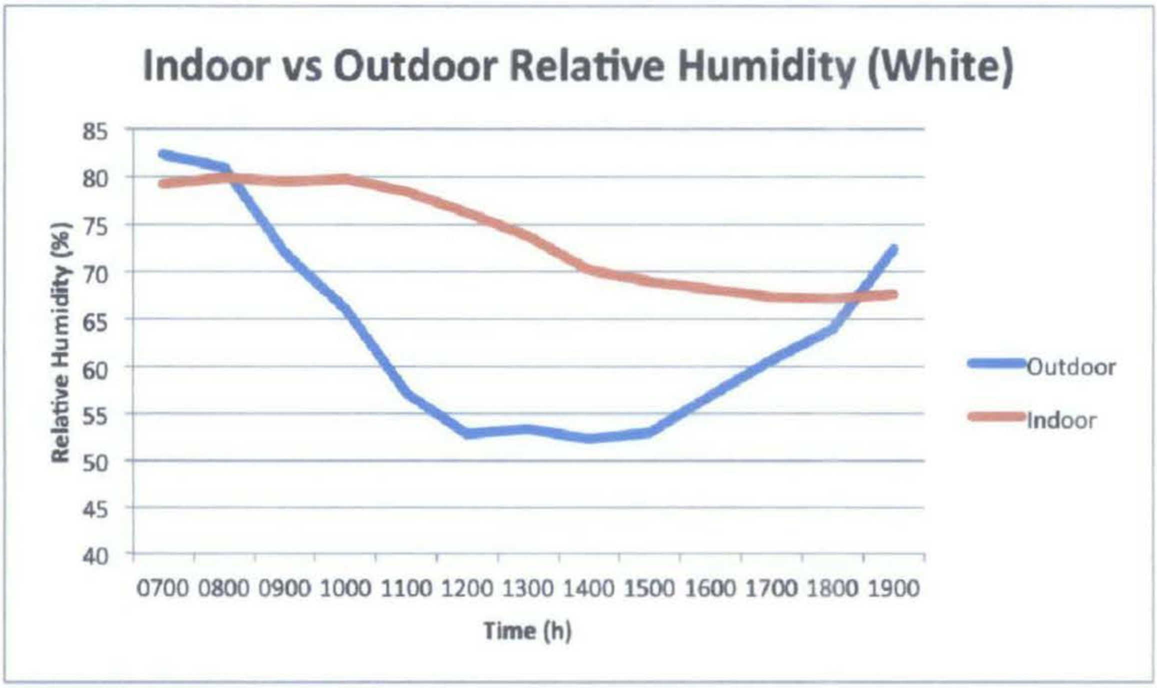

Figure 16 Average Indoor vs Outdoor Relative Humidity (White)

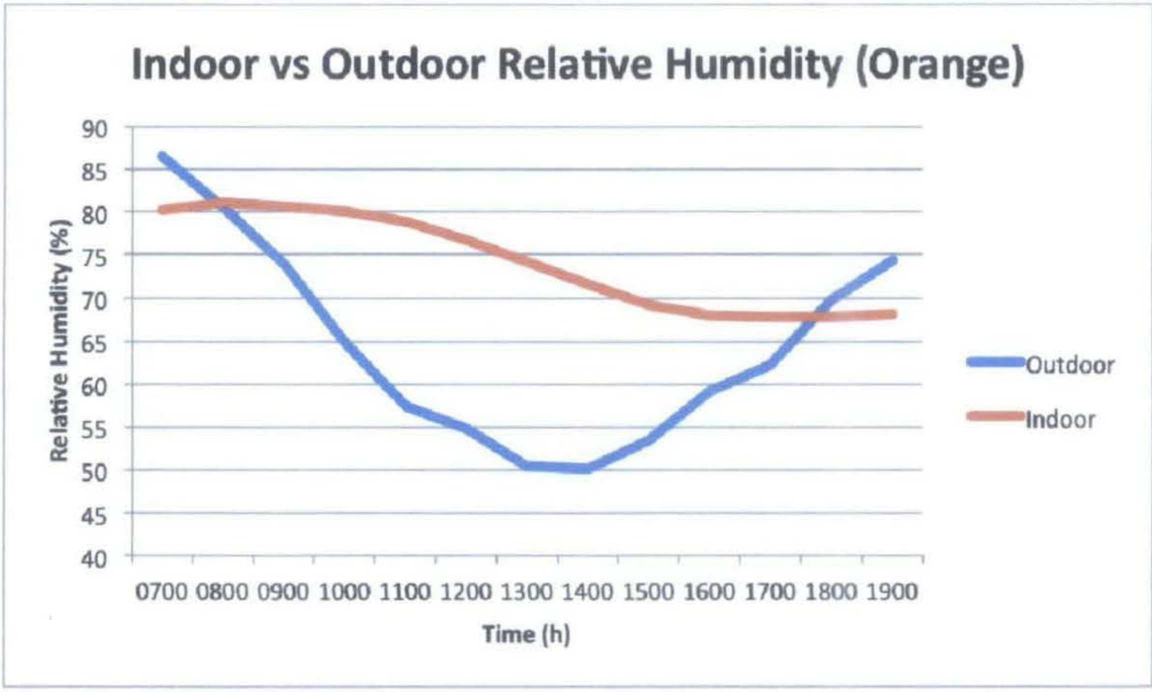

Figure 17 Average Indoor vs Outdoor Relative Humidity (Orange)

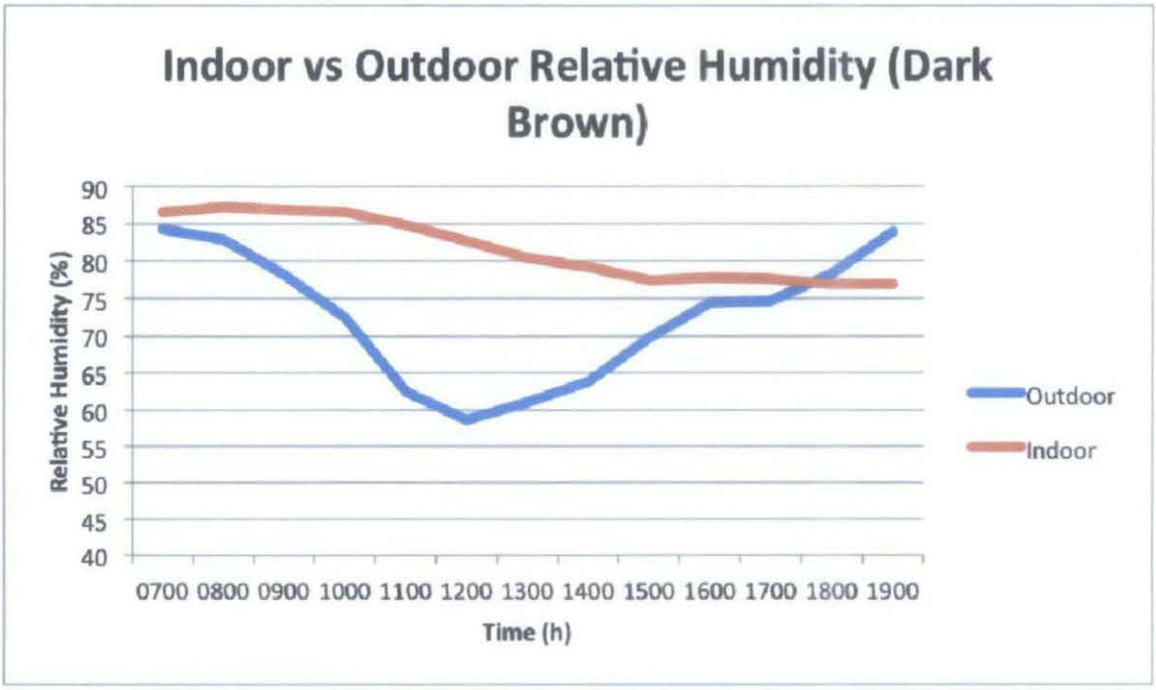

Figure 18 Average Indoor vs Outdoor Relative Humidity (Dark Brown)

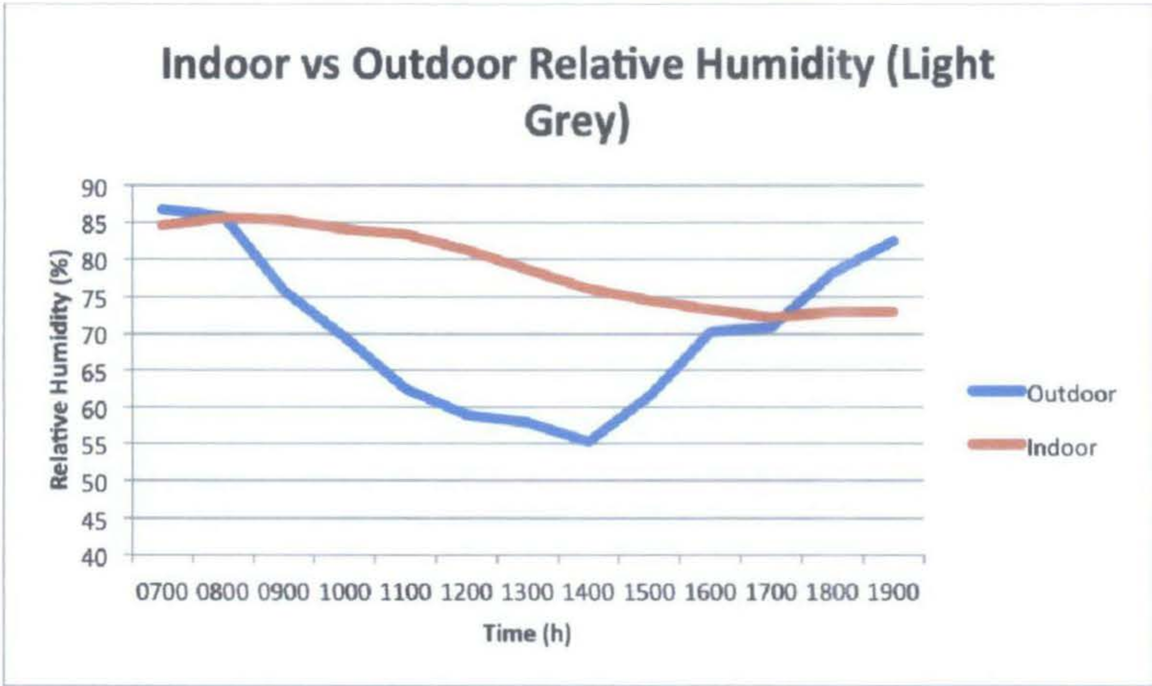

Figure 19 Average Indoor vs Outdoor Relative Humidity (Light Grey)

Figure 16, 17, 18, and **19**shows the average indoor vs outdoor relative humidity for all four colors. We should note that the experiment for each colors were done on separate days, therefore the ambient temperature and relative humidity are different for each colors. The relative humidity affects the temperature readings as lower humidity tend to have higher temperature thus affecting the temperature reading for outdoor and indoor data.Below are the percentage differences of relative humidity for all colors based on the lowest outdoor humidity. The lowest outdoor humidity value indicates the driest air temperature. The graphs plotted are similar and consistent for each colors, therefore we can assume that the weather condition during the experiment were of similar pattern.

Table 9 Average Temperature, Average RH, Lux and Solar Irradiation (White)

Time	Avg Temp (°C)		Avg RH (%)			
White	Indoor	Outdoor	Indoor	Outdoor	Lux (Indoor)	Irradiation (Outdoor)
0700	27.18	25.85	79.18	82.28	0.00	7.0
0800	27.04	26.30	79.78	80.96	69.83	33.0
0900	27.29	28.23	79.37	71.92	221.17	41.0
1000	27.80	29.75	79.65	65.98	309.00	46.0
1100	28.56	31.07	78.30	57.18	433.50	53.0
1200	29.46	32.28	76.23	52.84	440.33	58.0
1300	30.30	33.23	73.72	53.38	452.67	84.0
1400	31.12	33.48	70.20	52.28	368.67	81.0
1500	31.65	33.55	68.95	52.97	322.17	63.0
1600	31.95	32.62	68.10	57.07	243.33	
1700	32.00	31.57	67.38	60.72	181.50	
1800	31.80	30.75	67.15	63.90	120.83	
1900	31.44	28.97	67.58	72.42	41.50	

Table 10 Average Temperature, Average RH, Lux and Solar Irradiation (Orange)

Time	Avg Temp (°C)		Avg RH (%)			
Orange	Indoor	Outdoor	Indoor	Outdoor	Lux (Indoor)	Irradiation (Outdoor)
0700	26.98	25.08	80.20	86.50	0.33	5.0
0800	26.93	27.02	81.15	80.57	68.83	22.0
0900	27.31	28.78	80.65	73.78	203.17	33.0
1000	27.87	30.43	80.07	64.85	261.33	35.0
1100	28.75	32.60	78.83	57.37	338.33	39.0
1200	30.04	33.43	76.75	54.85	366.17	45.0
1300	31.05	35.05	74.17	50.43	369.83	61.0
1400	32.05	34.93	71.53	50.13	333.33	61.0
1500	32.68	33.70	69.13	53.45	273.17	43.0
1600	32.90	32.42	67.95	59.27	177.17	
1700	32.61	31.58	67.75	62.25	131.17	
1800	32.32	29.68	67.87	69.82	55.67	
1900	31.86	28.82	68.07	74.30	2.00	

Table 11 Average Temperature, Average RH, Lux and Solar Irradiation (Dark Brown)

Time	Avg Temp (°C)		Avg RH (%)			
Dark Brown	Indoor	Outdoor	Indoor	Outdoor	Lux (Indoor)	Irradiation (Outdoor)
0700	25.65	24.95	86.50	84.25	0.00	4.0
0800	25.65	25.60	87.25	82.83	59.83	16.0
0900	26.02	27.57	86.92	78.10	181.50	20.0
1000	26.81	28.65	86.43	72.40	303.67	23.0
1100	27.85	30.92	84.83	62.48	326.33	27.0
1200	28.84	32.47	82.75	58.63	327.67	33.0
1300	29.62	31.42	80.38	61.03	311.00	46.0
1400	30.16	31.55	79.25	63.88	257.17	38.0
1500	30.14	29.77	77.35	69.75	167.17	33.0
1600	30.10	29.03	77.82	74.50	216.00	
1700	30.04	28.62	77.57	74.62	123.00	
1800	29.57	27.47	76.88	78.27	39.50	
1900	29.09	26.40	76.95	83.85	0.00	

Table 12 Average Temperature, Average RH, Lux and Solar Irradiation (Light Grey)

Time	Avg Temp (°C)		Avg RH (%)			
Light Grey	Indoor	Outdoor	Indoor	Outdoor	Lux (Indoor)	Irradiation (Outdoor)
0700	26.14	24.75	84.63	86.67	0.00	5.0
0800	26.09	25.48	85.65	85.75	59.00	19.0
0900	26.54	27.88	85.30	75.67	149.67	21.0
1000	27.03	29.23	84.12	69.47	204.83	26.0
1100	28.00	30.80	83.42	62.42	267.00	28.0
1200	29.06	32.30	81.35	58.98	319.50	35.0
1300	30.22	32.98	78.57	57.82	327.67	48.0
1400	31.17	33.22	76.08	55.18	279.17	49.0
1500	31.73	32.10	74.52	61.47	238.33	43.0
1600	31.84	29.50	73.32	70.35	153.00	
1700	31.26	28.65	72.13	70.80	83.50	
1800	30.71	27.65	72.88	78.08	31.83	
1900	30.10	26.13	72.90	82.42	0.33	

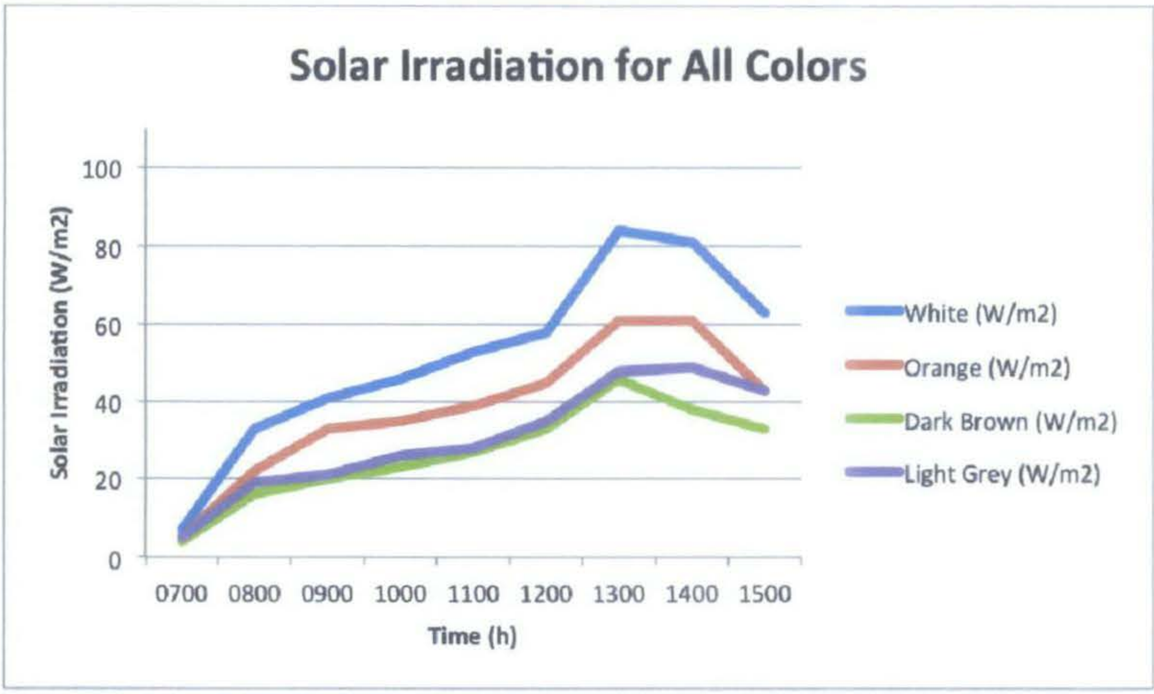

Figure20 Solar Irradiation for All Colors

From **Figure 20**, white has the highest solar irradiation, followed by orange, light grey and dark brown. The peak solar irradiation for each color occurs at 1300 (1.00pm). The irradiation values for the colors are 84.0 (white), 61.0 (orange), 48.0 (light grey), and 46.0 (dark brown). From the graph, we can conclude that the color with the highest SRI value, which is white, reflects most of the heat.

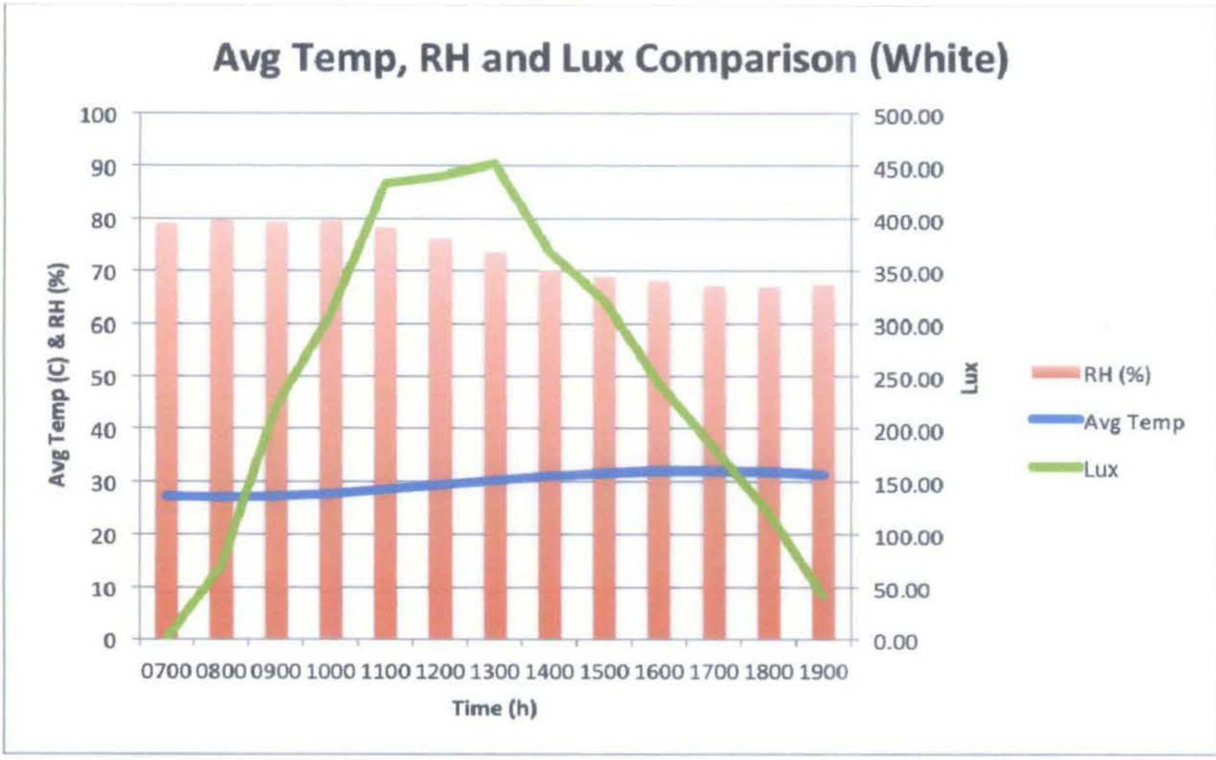

Figure 21 Average Temperature, RH and Lux for Indoor Data (White)

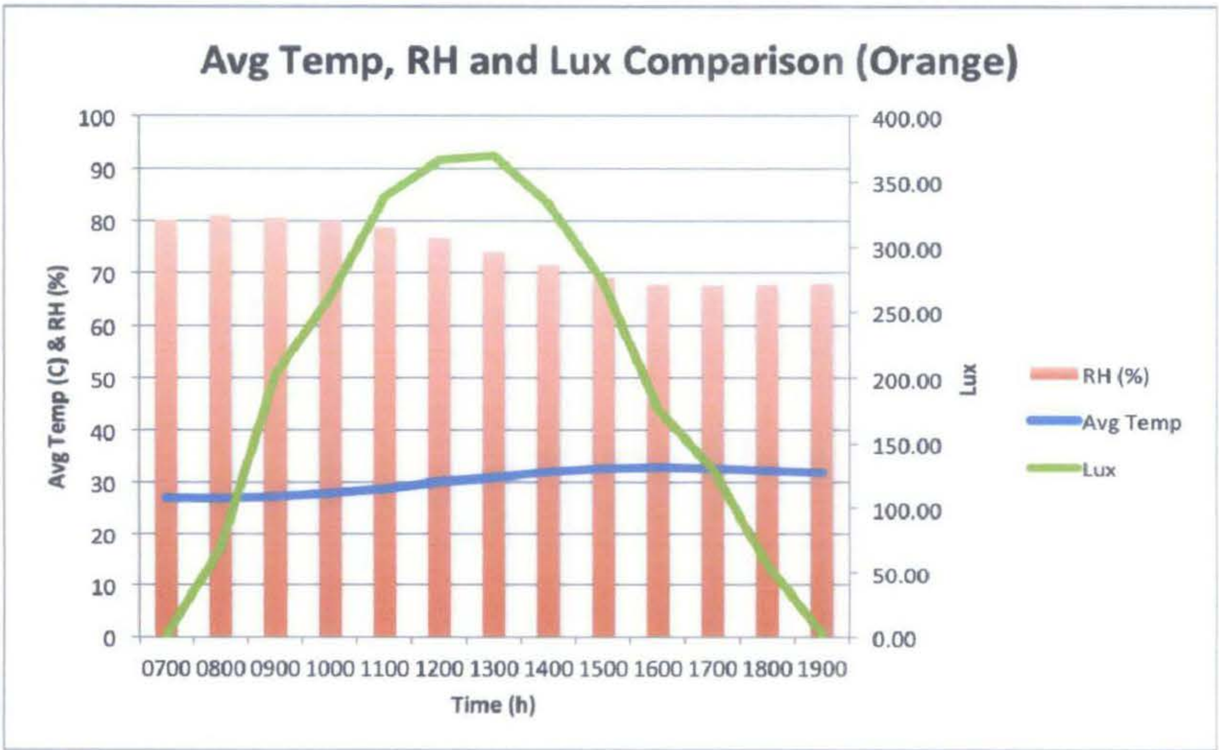

Figure 22Average Temperature, RH and Lux for Indoor Data (Orange)

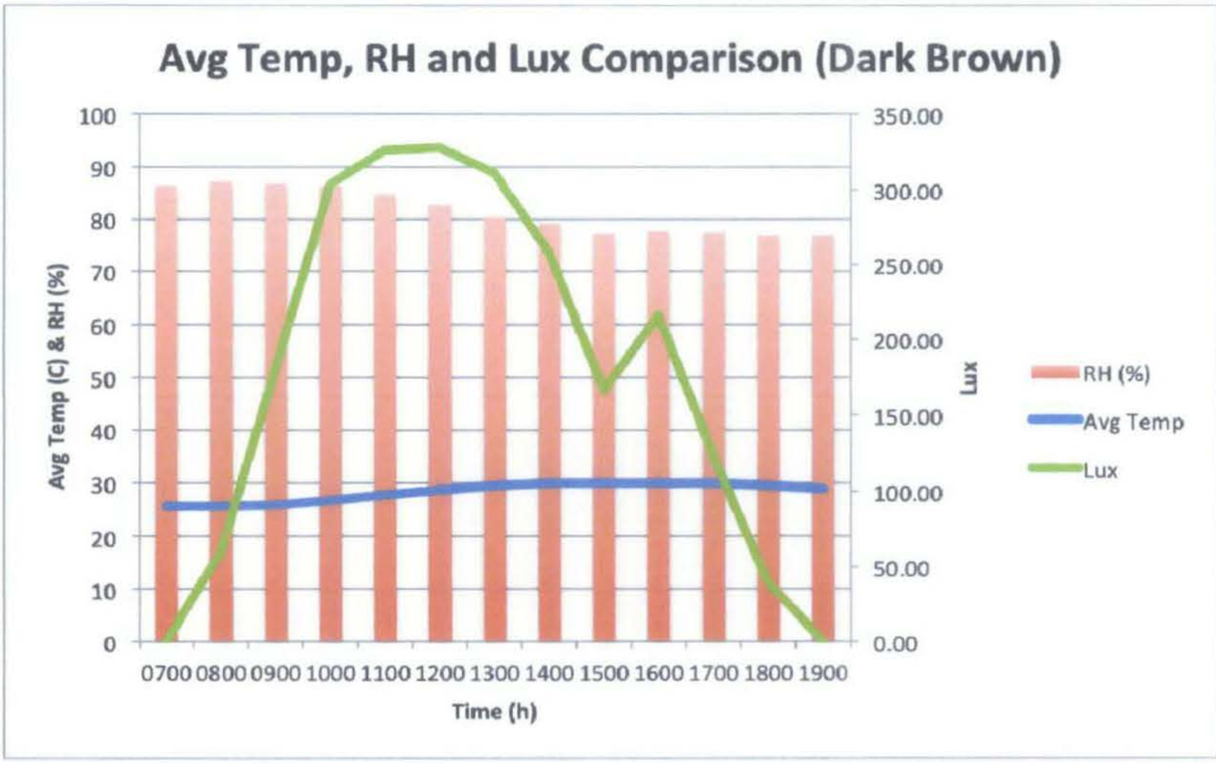

Figure 23 Average Temperature, RH and Lux for Indoor Data (Dark Brown)

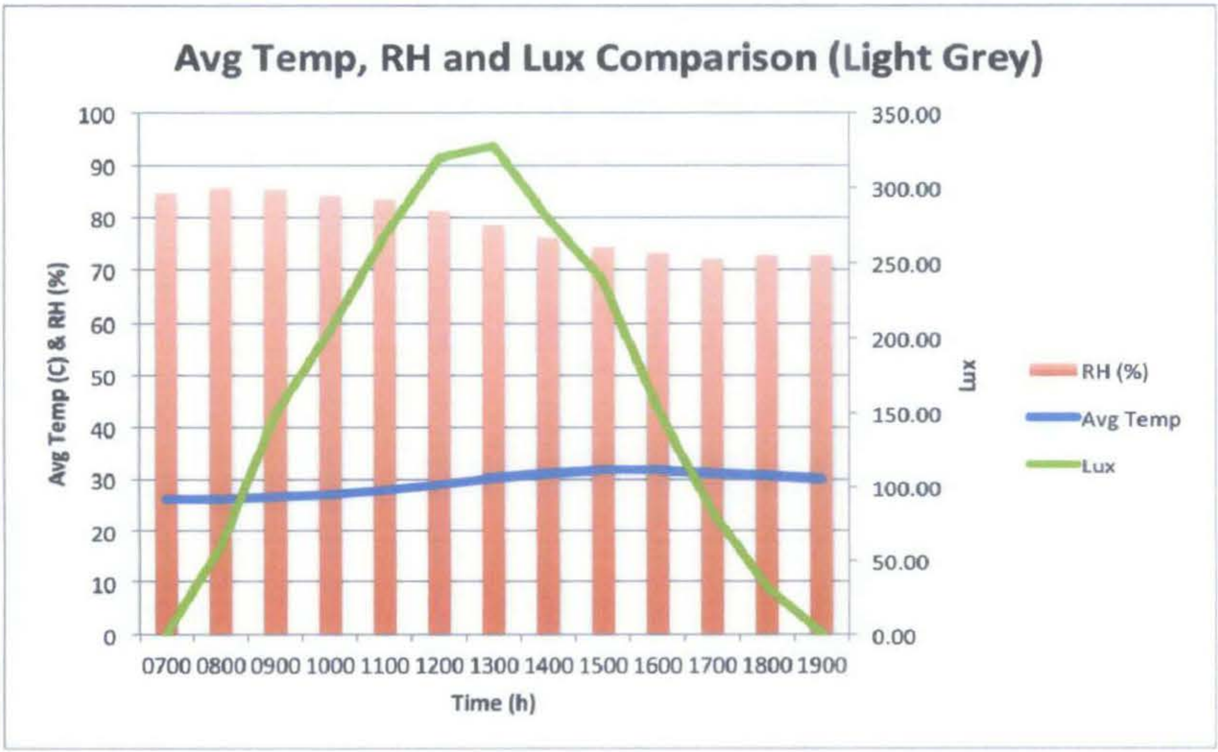

Figure 24 Average Temperature, RH and Lux for Indoor Data (Light Grey)

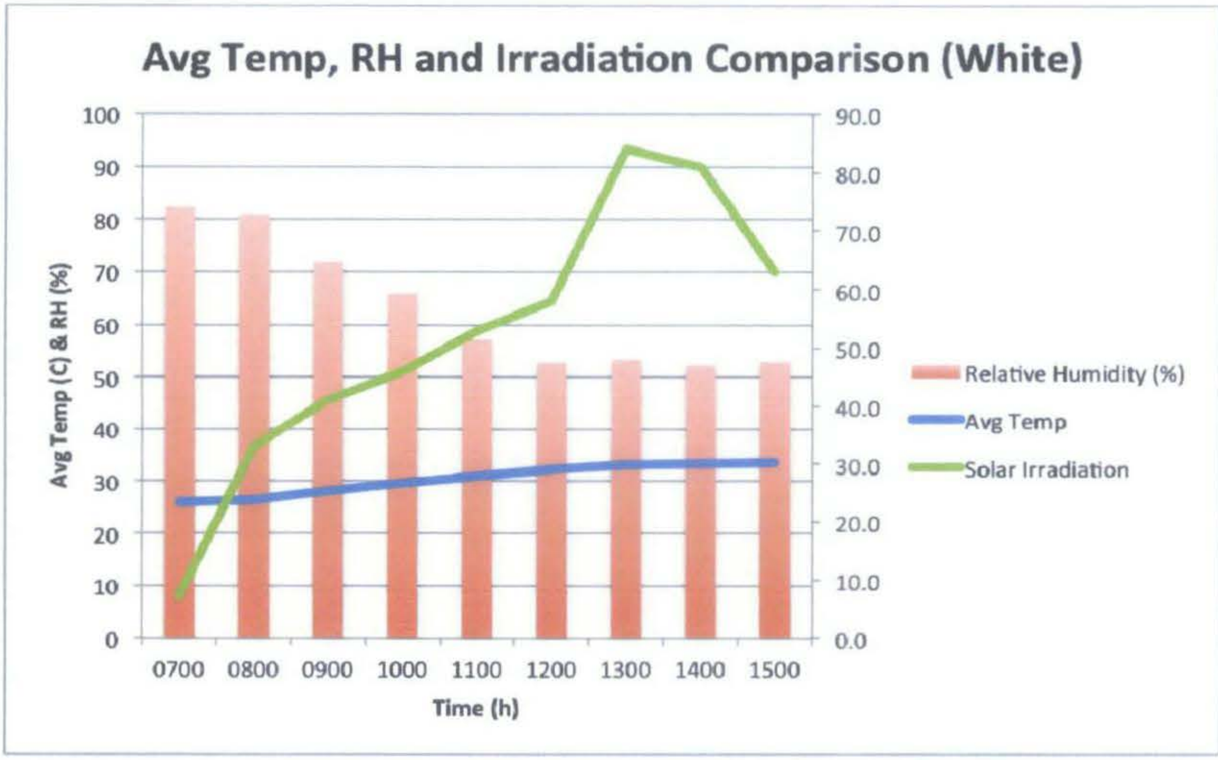

Figure 25 Average Temperature, RH and Lux for Irradiation Data (White)

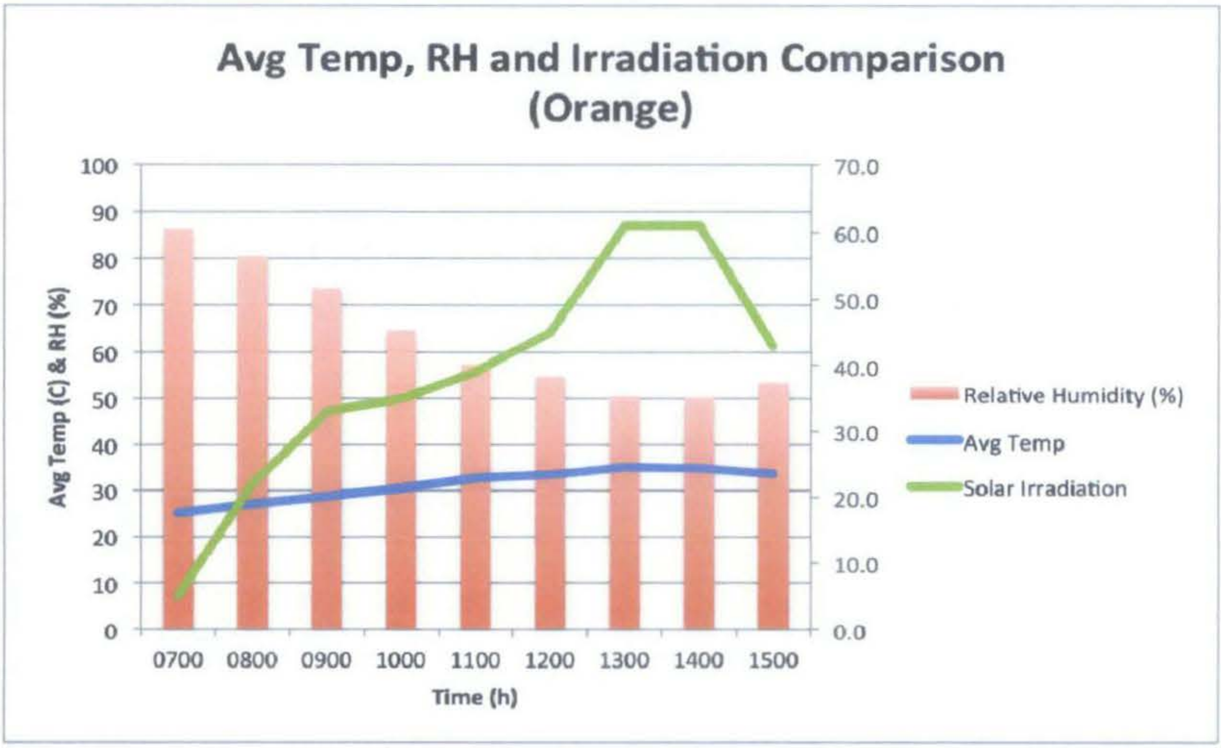

Figure 26 Average Temperature, RH and Lux for Irradiation Data (Orange)

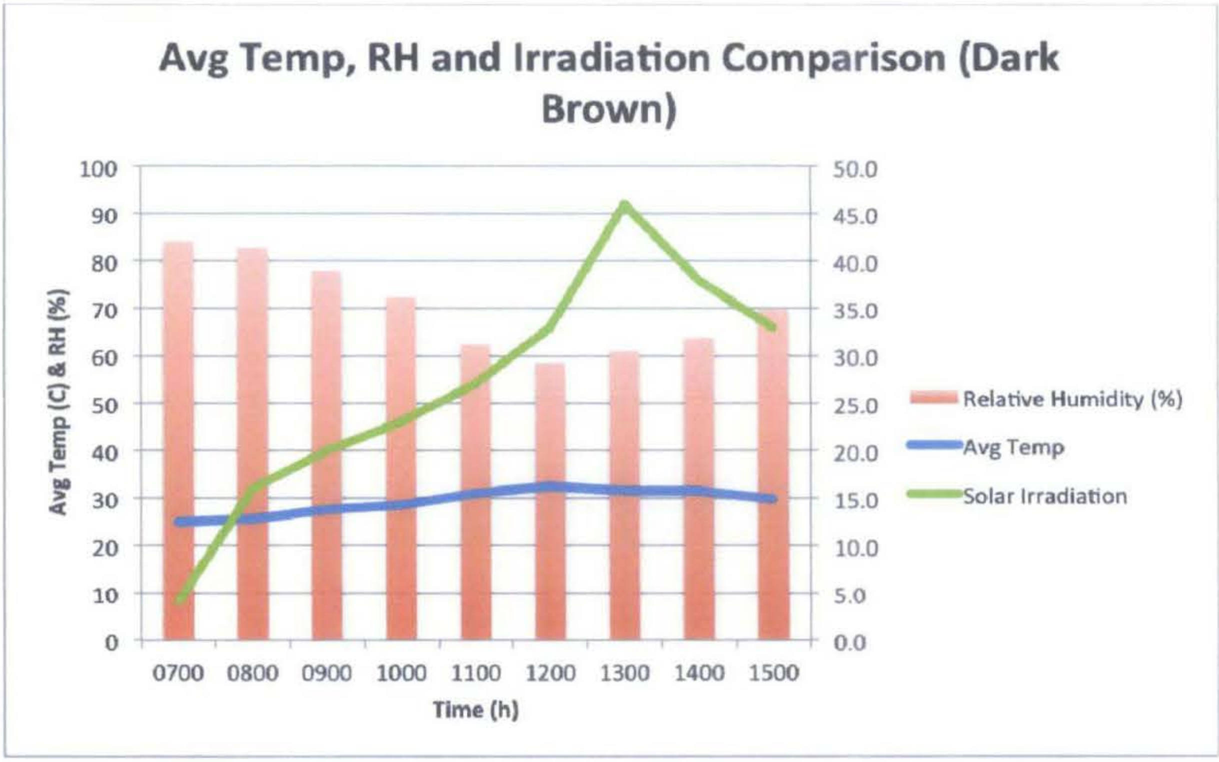

Figure 27 Average Temperature, RH and Lux for Irradiation Data (Dark Brown)

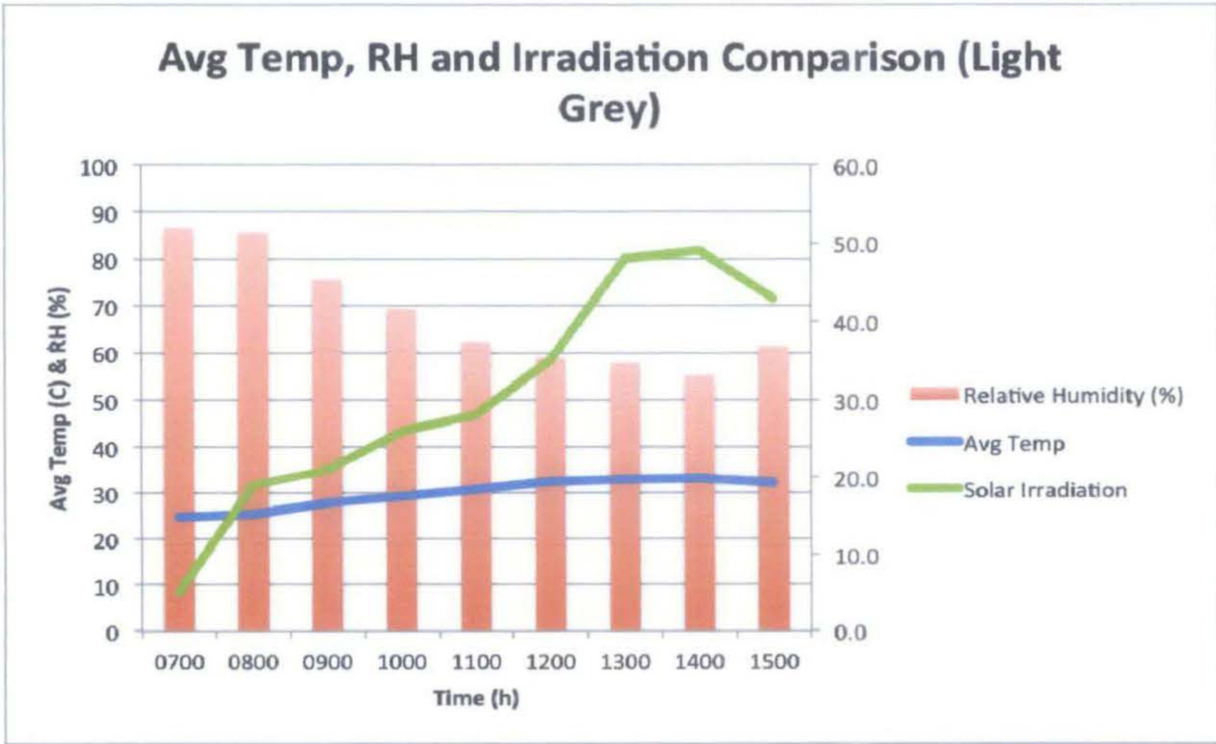

Figure 28 Average Temperature, RH and Lux for Irradiation Data (Light Grey)

The graphs obtained in **Figure 21, 22, 23, 24, 25, 26, 27** and **28** shows the average temperature, relative humidity, lux and solar irradiation comparison throughout the experiment. The graphs are similar in pattern, which shows that the results obtained are valid. The values shown are the control parameters of the experiment.

4.2 PROBLEMS ENCOUNTERED

There were several difficulties encountered during the experiments being conducted. On rainy days or certain period of rainy weather, data taken would not be considered, as the readings will have minimal fluctuation. We need to take the reading again on a clear day if the data needs to be discard. Data were unable to be collected in certain days because of the monsoon season. At some point of the experiment, the solarimeter malfunctioned, causing delay in the experiment period. We had to return the instrument to the manufacturer and wait for it to be returned back to us, which may take up to a week for it to be returned.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Based on the graphs for control parameters, we can see that the graphs plotted are similar with each other. It shows that the research data and the results obtained are valid and reliable. A color's ability to reflect can be determined by the temperature reduction. For white, the temperature reduction is 8.82%, 11.41% for orange, 11.18% for dark brown and 10.03% for light grey. Although the results obtained shows that white color reduces the least temperature, it is also noted that the indoor relative humidity for white color is the lowest compared to the other colors. The indoor relative humidity value for white is 68.95%, for orange is 74.14%, for dark brown is 82.75%, and for light grey is 76.08%. White has the driest air humidity, therefore affecting the temperature obtained. The values for relative humidity and temperature reduction are compared at the peak value for each parameter. Based on the average indoor temperature for all colors, white color recorded the lowest temperature for hot and sunny weather. It is also worth noting that the weather condition during the experiment was conducted for dark brown and light grey is rainy and cloudy. The solar irradiation graph indicates that white reflects the most solar irradiation, followed by orange, light grey and dark brown. This also indicates that lighter color reflects more solar irradiation compared to darker color.

From the experiment, we can conclude that colors with high SRI value such as white reflects more heat compared to colors with low SRI value. By switching roof tiles color to white, we can save cooling-energy used during peak heat hour of a day. It is also one of the cheapest methods to reduce heat gain. Air conditioning unit usage can also be lowered, which reduces Green House gas emission and prevents Urban Heat Island phenomenon.

5.2 RECOMMENDATION

It is recommended that if it is financially feasible to build a few more experimental houses to be used as a display unit to display the results of different roof colors. This will ensure that the result is visible and available for everybody to see, which indirectly can educate the public on this matter. It is recommended that the color white and black should have a separated experimental house to be set as benchmarks for SRI reading. It is also recommended that a thermometer to be placed at each house in order to display the effects of roof color on house temperature. If possible, all the experiments should be conducted on the same day in order for the weather condition and the ambient temperature would be the same for all colors. This will yield better results on the comparison.

REFERENCES

1. Cengel, Y.A. (2007) Introduction and Basic Concepts. *Heat and Mass Transfer: A Practical Approach (Third Edition)*

2. D.S Parker, S.FBarkaszi Jr. (1997), *Roof solar reflectance and cooling energy use field research results from Florida*

3. P. Berdahl, S.E Bretz (1997), *Preliminary survey of the solar reflectance of cool roofing materials*

4. DOE Fundamentals Handbook: Thermodynamics, Heat Transfer, and Fluid Flow Vol. 2, *Heat Transfer Fundamentals*,http://www.pdhengineer.com/courses/m/M-3003.pdf (accessed 28/6/2011)

5. William (Bill) Miller, PhD Lee Shoemaker, PhD Andre Desjarlais, Scott Kriner Russ, Dunlap Adam Youngquist, *Designing Low-Emittance Low-Slope Roofs that Comply with California Title 24 Requirements,* http://www.ornl.gov/sci/roofs+walls/staff/papers/18.pdf (accessed /6/2011)

6. Jessica Clark, Sherry Hao, (March 7 2011), *Cool Roofs 101*, http://www.arwmag.com/Articles/Feature_Article/BNP_GUID_9-5-2006_A_10000000000001009964 (accessed /6/2011)

7. Ronnen Levinson Lawrence, Berkeley National Laboratory (July 29, 2009), *Cool Roof Q & A*, http://coolcolors.lbl.gov/assets/docs/fact-sheets/Cool-roof-Q%2BA.pdf (accessed /6/2011)

8. *Heat Island Reduction*, http://www.concretethinker.com/solutions/Heat-Island-Reduction.aspx (accessed /6/2011)

9. Portland Cement Association, *Concrete Shines as Solar Reflectance Material,* http://www.archprecast.org/Solar%20Reflectance%20PCA%20note%20from%20Concrete%20Tech%20%2012-07.pdf (accessed /6/2011)

10. Astec Paints Australasia Pty Ltd, *What Are S.R.I Figures?* , http://www.astecpaints.com.au/energystar/downloads/what_are_sri_figures.pdf (accessed /6/2011)

11. *Definition and Terms of Cool Roof*, http://eetd.lbl.gov/coolroof/ref_01.htm (accessed /6/2011)

12. *Energy Efficient Housing Design for Tropical Climates Fact Sheet*, http://www.nt.gov.au/dlp/sustainability/factsheets/documents/EnergyEfficientHousingDesignforTropicalClimatesFactSheet.pdf (accessed /6/2011)

13. Science Beat Berkeley Lab, *Cool Colors, Cool Roofs* (August 27, 2004), http://www.lbl.gov/Science-Articles/Archive/sb/Aug-2004/3_coolroofs.html (accessed 7/1/2011)

14. Public Interest Energy Research Program, *Residential Roofs: Cool Colors, Cool Gaps,* http://www.esource.com/esource/getpub/public/pdf/cec/CEC-TB-15_CoolRoofs.pdf (accessed 7/1/2011)

15. RIZWAN Ahmed Memon, DENNIS Y.C. Leung□, LIU Chunho (2007), *A review on the generation, determination and mitigation of Urban Heat Island*

16. Harry Suehrcke, Eric L. Peterson, Neville Selby (2008), *Effect of roof solar reflectance on the building heat gain in a hot climate*

17. Racine T.A.P,Fabiana L.F (2005), *Measurement of albedo and analysis of its influence the surface temperature of building roof materials*

18.R.Levinson, P. Berdahl, H.Akbari, W.Miller, I.Joedicke, J.Reilly, Y.Suzuki, M.Vondran (2006), *Methods of creating solar-reflective nonwhite surfaces and their application to residential roofing materials*

19. Reducing Urban Heat Island: Compendium of Strategies http://www.epa.gov/heatisld/resources/pdf/BasicsCompendium.pdf (accessed 1/10/2012)

20. Akbari.H (2001), *Energy savings Potential and Air Quality Benefits of Urban Heat Island Mitigation*

21. Akbari.H, Bretz. S, Rosenfeld. A (1997), *Practical Issues for Using Solar-Reflective Materials to Mitigate Urban Heat Islands*

APPENDIX

INDOOR TEMPERATURE DATA

White

Time	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Mean
0700	27	27.3	27.52	27.53	28.11	25.59	27.18
0800	26.78	27.09	27.36	27.41	27.98	25.59	27.04
0900	27.16	27.34	27.53	27.66	28.13	25.92	27.29
1000	27.66	28.05	27.73	28.28	28.55	26.5	27.80
1100	28.59	28.77	28.5	29.08	29.34	27.09	28.56
1200	29.63	29.84	29.45	30.06	29.92	27.88	29.46
1300	30.84	30.88	30.34	30.88	30.24	28.63	30.30
1400	31.91	31.86	31.28	31.89	30.05	29.7	31.12
1500	32.92	32.59	32.25	32.69	29.41	30.06	31.65
1600	33.49	33.1	33.13	32.98	28.99	30.03	31.95
1700	33.77	33.58	33.03	33.66	28.58	29.36	32.00
1800	33.73	33.38	32.7	33.5	28.25	29.21	31.80
1900	33.38	32.98	32.3	33	27.96	29.02	31.44

Orange

Time	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Mean
0700	26.46	26.55	27.2	27.09	27.28	27.3	26.98
0800	26.45	26.52	27.16	26.92	27.24	27.27	26.93
0900	26.75	27.02	27.46	27.48	27.67	27.46	27.31
1000	27.28	27.63	28.05	28.23	28.38	27.63	27.87
1100	28.25	28.5	28.94	28.99	29.41	28.41	28.75
1200	29.48	30.02	30.2	30.24	30.66	29.63	30.04
1300	30.45	30.73	31.42	31.56	31.8	30.36	31.05
1400	31.48	31.77	32.63	32.74	32.92	30.77	32.05
1500	32.02	31.99	33.52	33.64	33.77	31.14	32.68
1600	32.42	32.38	34.06	33.7	33.09	31.77	32.90
1700	32.52	32.56	33.92	33.03	31.91	31.74	32.61
1800	32.02	32.45	33.73	32.44	31.56	31.7	32.32
1900	31.45	32.09	33.33	31.98	31.06	31.25	31.86

Light Grey

Time	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Mean
0700	26.74	26.02	25.05	26.13	26.1	25.94	26.00
0800	26.88	25.98	25	25.99	26.13	25.88	25.98
0900	27.02	26.63	25.5	26.59	26.52	26.27	26.42
1000	26.7	27.27	25.92	27.2	27.13	27.13	26.89
1100	28.02	27.98	26.81	28.36	28.28	27.69	27.86
1200	28.86	29.09	27.77	29.8	29.24	28.83	28.93
1300	29.99	30.48	28.77	30.96	30.42	30.16	30.13
1400	31.3	31.14	30.14	31.86	30.64	31.16	31.04
1500	32.06	31.09	30.84	32.31	30.69	32.19	31.53
1600	32.59	31.2	30.81	31.7	30.5	32.86	31.61
1700	32.56	29.73	30.66	31.28	29.99	32.34	31.09
1800	32.3	29.13	30.33	30.84	29.36	32.13	30.68
1900	31.58	28.64	29.77	30.23	28.86	31.59	30.11

Dark Brown

Time	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Mean
0700	26.16	26.34	25.38	25.28	25.38	25.08	25.60
0800	26.14	26.38	25.34	25.33	25.34	25.09	25.60
0900	26.56	27.13	25.69	25.56	25.73	25.39	26.01
1000	27.64	28.02	26.48	26.5	26.48	26.16	26.88
1100	28.63	29.11	27.77	27.45	27.55	26.98	27.92
1200	29.63	29.71	29.14	28.45	28.27	28.31	28.92
1300	30.52	28.56	30.35	29.36	29.14	29.55	29.58
1400	31.41	28.59	31.24	30.71	29.56	30.31	30.30
1500	31.91	28.64	31.5	29.88	28.41	30.98	30.22
1600	31.96	28.46	30.52	29.24	28.55	31.58	30.05
1700	31.85	28.6	30.3	28.95	28.64	31.75	30.02
1800	31.48	28.45	28.77	28.42	28.52	31.46	29.52
1900	30.88	28.13	28.19	27.95	28.19	30.77	29.02

OUTDOOR TEMPERATURE DATA

White

Time	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Mean
0700	25.6	25.6	25.4	27.5	26.9	24.1	25.85
0800	26.4	25.8	25.6	27.8	27.3	24.9	26.30
0900	29.6	28.7	27.1	28.6	27.6	27.8	28.23
1000	31.1	31.5	28.6	30.9	27.8	28.6	29.75
1100	31.6	32	32.3	32.6	27.8	30.1	31.07
1200	32.9	33	31.5	35.3	28.5	32.5	32.28
1300	34.1	34.6	32.4	34.1	29.4	34.8	33.23
1400	34.4	34.6	33.6	34.9	29.4	34	33.48
1500	37	33.2	33.3	35.6	28.5	33.7	33.55
1600	35.7	33.3	33	34.7	27.6	31.4	32.62
1700	34.4	33.4	32.6	33.7	26.2	29.1	31.57
1800	33.8	32.6	29.2	32.6	27	29.3	30.75
1900	30.9	31.3	28.8	31.8	25.5	25.5	28.97

)range

Time	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Mean
0700	24.4	25.2	25.8	24.9	25.1	25.1	25.08
0800	25.7	26.8	27.2	27	27.7	27.7	27.02
0900	26.9	28	28.6	29.4	29.9	29.9	28.78
1000	30.3	30	32.1	31.2	29.5	29.5	30.43
1100	32.1	33.6	32.1	32.1	33.9	31.8	32.60
1200	33.3	32	34.7	33.6	34	33	33.43
1300	34.1	34.5	35.9	35.1	34.9	35.8	35.05
1400	34.6	34.6	36.6	35.8	35.4	32.6	34.93
1500	33	33.2	34	35.7	33.8	32.5	33.70
1600	33.3	32.8	33.9	31.3	31.5	31.7	32.42
1700	31.9	31.6	32.8	30.1	29.7	33.4	31.58
1800	29.2	30.4	30.8	29.8	27.7	30.2	29.68
1900	27	29.2	29.3	29	28.4	30	28.82

Dark Brown

Time	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Mean
0700	25.3	25	25	25	25.1	24.3	24.95
0800	25.8	26	25.4	25.4	25.5	25.5	25.60
0900	29.6	27.8	27.7	26.7	26.8	26.8	27.57
1000	31.2	29.5	29.9	27.9	26.7	26.7	28.65
1100	31.6	32.4	30.2	32.1	29.6	29.6	30.92
1200	34.1	32.1	32.7	32.8	31.1	32	32.47
1300	33.9	24.4	33.1	32.9	32	32.2	31.42
1400	34.3	26.3	35.5	33.6	26.1	33.5	31.55
1500	33.8	28.3	31.8	26.8	25	32.9	29.77
1600	33	28	28	26.7	25.8	32.7	29.03
1700	31.9	28	27.4	26.2	27.5	30.7	28.62
1800	28.3	28.3	25.6	25.9	26.4	30.3	27.47
1900	27.8	27.8	25.7	25	25.2	26.9	26.40

Light Grey

Time	Day 1	Day2	Day 3	Day 4	Day 5	Day 6	Mean
0700	24.5	24.5	25.1	24.7	24.7	25	24.75
0800	26.2	26.1	24.3	25.1	25.1	26.1	25.48
0900	28.8	27.8	26.4	28.5	28.5	27.3	27.88
1000	29.8	29	27.2	30.4	29.5	29.5	29.23
1100	29.5	29.5	30.3	32.2	31.7	31.6	30.80
1200	32	32	32.4	31.3	33.7	32.4	32.30
1300	33	33.9	32.1	33	32.4	33.5	32.98
1400	33.5	33.5	32.4	34.1	31.1	34.7	33.22
1500	33.3	33.3	33.3	28.4	30.2	34.1	32.10
1600	32.5	28	28	28.3	28.9	31.3	29.50
1700	32	26.4	26.4	28.3	28	30.8	28.65
1800	28.5	24.7	27.8	27.8	26.9	30.2	27.65
1900	26	24	26.7	26.7	26.8	26.6	26.13

White			Orange			Dark Brown			Light Grey		
Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT
25.6	27	-1.4	24.4	26.46	-2.06	25.3	26.16	-0.86	24.5	26.74	-2.24
26.4	26.78	-0.38	25.7	26.45	-0.75	25.8	26.14	-0.34	26.2	26.88	-0.68
29.6	27.16	2.44	26.9	26.75	0.15	29.6	26.56	3.04	28.8	27.02	1.78
31.1	27.66	3.44	30.3	27.28	3.02	31.2	27.64	3.56	29.8	26.7	3.1
31.6	28.59	3.01	32.1	28.25	3.85	31.6	28.63	2.97	29.5	28.02	1.48
32.9	29.63	3.27	33.3	29.48	3.82	34.1	29.63	4.47	32	28.86	3.14
34.1	30.84	3.26	34.1	30.45	3.65	33.9	30.52	3.38	33	29.99	3.01
34.4	31.91	2.49	34.6	31.48	3.12	34.3	31.41	2.89	33.5	31.3	2.2
37	32.92	4.08	33	32.02	0.98	33.8	31.91	1.89	33.3	32.06	1.24
35.7	33.49	2.21	33.3	32.42	0.88	33	31.96	1.04	32.5	32.59	-0.09
34.4	33.77	0.63	31.9	32.52	-0.62	31.9	31.85	0.05	32	32.56	-0.56
33.8	33.73	0.07	29.2	32.02	-2.82	28.3	31.48	-3.18	28.5	32.3	-3.8
30.9	33.38	-2.48	27	31.45	-4.45	27.8	30.88	-3.08	26	31.58	-5.58

White			Orange			Dark Brown			Light Grey		
Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT
25.6	27.3	-1.7	25.2	26.55	-1.35	25	26.34	-1.34	24.5	26.02	-1.52
25.8	27.09	-1.29	26.8	26.52	0.28	26	26.38	-0.38	26.1	25.98	0.12
28.7	27.34	1.36	28	27.02	0.98	27.8	27.13	0.67	27.8	26.63	1.17
31.5	28.05	3.45	30	27.63	2.37	29.5	28.02	1.48	29	27.27	1.73
32	28.77	3.23	33.6	28.5	5.1	32.4	29.11	3.29	29.5	27.98	1.52
33	29.84	3.16	32	30.02	1.98	32.1	29.71	2.39	32	29.09	2.91
34.6	30.88	3.72	34.5	30.73	3.77	24.4	28.56	-4.16	33.9	30.48	3.42
34.6	31.86	2.74	34.6	31.77	2.83	26.3	28.59	-2.29	33.5	31.14	2.36
33.2	32.59	0.61	33.2	31.99	1.21	28.3	28.64	-0.34	33.3	31.09	2.21
33.3	33.1	0.2	32.8	32.38	0.42	28	28.46	-0.46	28	31.2	-3.2
33.4	33.58	-0.18	31.6	32.56	-0.96	28	28.6	-0.6	26.4	29.73	-3.33
32.6	33.38	-0.78	30.4	32.45	-2.05	28.3	28.45	-0.15	24.7	29.13	-4.43
31.3	32.98	-1.68	29.2	32.09	-2.89	27.8	28.13	-0.33	24	28.64	-4.64

White			Orange			Dark Brown			Light Grey		
Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT
25.4	27.52	-2.12	25.8	27.2	-1.4	25	25.38	-0.38	25.1	25.05	0.05
25.6	27.36	-1.76	27.2	27.16	0.04	25.4	25.34	0.06	24.3	25	-0.7
27.1	27.53	-0.43	28.6	27.46	1.14	27.7	25.69	2.01	26.4	25.5	0.9
28.6	27.73	0.87	32.1	28.05	4.05	29.9	26.48	3.42	27.2	25.92	1.28
32.3	28.5	3.8	32.1	28.94	3.16	30.2	27.77	2.43	30.3	26.81	3.49
31.5	29.45	2.05	34.7	30.2	4.5	32.7	29.14	3.56	32.4	27.77	4.63
32.4	30.34	2.06	35.9	31.42	4.48	33.1	30.35	2.75	32.1	28.77	3.33
33.6	31.28	2.32	36.6	32.63	3.97	35.5	31.24	4.26	32.4	30.14	2.26
33.3	32.25	1.05	34	33.52	0.48	31.8	31.5	0.3	33.3	30.84	2.46
33	33.13	-0.13	33.9	34.06	-0.16	28	30.52	-2.52	28	30.81	-2.81
32.6	33.03	-0.43	32.8	33.92	-1.12	27.4	30.3	-2.9	26.4	30.66	-4.26
29.2	32.7	-3.5	30.8	33.73	-2.93	25.6	28.77	-3.17	27.8	30.33	-2.53
28.8	32.3	-3.5	29.3	33.33	-4.03	25.7	28.19	-2.49	26.7	29.77	-3.07

White			Orange			Dark Brown			Light Grey		
Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT
27.5	27.53	-0.03	24.9	27.09	-2.19	25	25.28	-0.28	24.7	26.13	-1.43
27.8	27.41	0.39	27	26.92	0.08	25.4	25.33	0.07	25.1	25.99	-0.89
28.6	27.66	0.94	29.4	27.48	1.92	26.7	25.56	1.14	28.5	26.59	1.91
30.9	28.28	2.62	31.2	28.23	2.97	27.9	26.5	1.4	30.4	27.2	3.2
32.6	29.08	3.52	32.1	28.99	3.11	32.1	27.45	4.65	32.2	28.36	3.84
35.3	30.06	5.24	33.6	30.24	3.36	32.8	28.45	4.35	31.3	29.8	1.5
34.1	30.88	3.22	35.1	31.56	3.54	32.9	29.36	3.54	33	30.96	2.04
34.9	31.89	3.01	35.8	32.74	3.06	33.6	30.71	2.89	34.1	31.86	2.24
35.6	32.69	2.91	35.7	33.64	2.06	26.8	29.88	-3.08	28.4	32.31	-3.91
34.7	32.98	1.72	31.3	33.7	-2.4	26.7	29.24	-2.54	28.3	31.7	-3.4
33.7	33.66	0.04	30.1	33.03	-2.93	26.2	28.95	-2.75	28.3	31.28	-2.98
32.6	33.5	-0.9	29.8	32.44	-2.64	25.9	28.42	-2.52	27.8	30.84	-3.04
31.8	33	-1.2	29	31.98	-2.98	25	27.95	-2.95	26.7	30.23	-3.53

White			Orange			Dark Brown			Light Grey		
Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT
26.9	28.11	-1.21	25.1	27.28	-2.18	25.1	25.38	-0.28	24.7	26.1	-1.4
27.3	27.98	-0.68	27.7	27.24	0.46	25.5	25.34	0.16	25.1	26.13	-1.03
27.6	28.13	-0.53	29.9	27.67	2.23	26.8	25.73	1.07	28.5	26.52	1.98
27.8	28.55	-0.75	29.5	28.38	1.12	26.7	26.48	0.22	29.5	27.13	2.37
27.8	29.34	-1.54	33.9	29.41	4.49	29.6	27.55	2.05	31.7	28.28	3.42
28.5	29.92	-1.42	34	30.66	3.34	31.1	28.27	2.83	33.7	29.24	4.46
29.4	30.24	-0.84	34.9	31.8	3.1	32	29.14	2.86	32.4	30.42	1.98
29.4	30.05	-0.65	35.4	32.92	2.48	26.1	29.56	-3.46	31.1	30.64	0.46
28.5	29.41	-0.91	33.8	33.77	0.03	25	28.41	-3.41	30.2	30.69	-0.49
27.6	28.99	-1.39	31.5	33.09	-1.59	25.8	28.55	-2.75	28.9	30.5	-1.6
26.2	28.58	-2.38	29.7	31.91	-2.21	27.5	28.64	-1.14	28	29.99	-1.99
27	28.25	-1.25	27.7	31.56	-3.86	26.4	28.52	-2.12	26.9	29.36	-2.46
25.5	27.96	-2.46	28.4	31.06	-2.66	25.2	28.19	-2.99	26.8	28.86	-2.06

White			Orange			Dark Brown			Light Grey		
Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT	Outdoor	Indoor	ΔT
24.1	25.59	-1.49	25.1	27.3	-2.2	24.3	25.08	-0.78	25	25.94	-0.94
24.9	25.59	-0.69	27.7	27.27	0.43	25.5	25.09	0.41	26.1	25.88	0.22
27.8	25.92	1.88	29.9	27.46	2.44	26.8	25.39	1.41	27.3	26.27	1.03
28.6	26.5	2.1	29.5	27.63	1.87	26.7	26.16	0.54	29.5	27.13	2.37
30.1	27.09	3.01	31.8	28.41	3.39	29.6	26.98	2.62	31.6	27.69	3.91
32.5	27.88	4.62	33	29.63	3.37	32	28.31	3.69	32.4	28.83	3.57
34.8	28.63	6.17	35.8	30.36	5.44	32.2	29.55	2.65	33.5	30.16	3.34
34	29.7	4.3	32.6	30.77	1.83	33.5	30.31	3.19	34.7	31.16	3.54
33.7	30.06	3.64	32.5	31.14	1.36	32.9	30.98	1.92	34.1	32.19	1.91
31.4	30.03	1.37	31.7	31.77	-0.07	32.7	31.58	1.12	31.3	32.86	-1.56
29.1	29.36	-0.26	33.4	31.74	1.66	30.7	31.75	-1.05	30.8	32.34	-1.54
29.3	29.21	0.09	30.2	31.7	-1.5	30.3	31.46	-1.16	30.2	32.13	-1.93
25.5	29.02	-3.52	30	31.25	-1.25	26.9	30.77	-3.87	26.6	31.59	-4.99