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Determination of thermal insulation properties of buildings and structures' external envelope using infrared thermal imaging

Determination of thermal insulation properties of buildings and structures' external envelope using infrared thermal imaging.

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Abstract

The primary thrust of this study is to quantify the thermal properties of the various components in the building structural and insulation envelope; to that end the heat flux through the structural envelope must be quantified. If one assumes zero mass flow through the envelope then all heat lost from the building is in the form of radiation and a combined convection/conduction at the external surfaces.

This study identifies methods of quantification of heat flux through building thermal envelope components in terms of conductive, convective and radiative heat transfer. Each type of heat flux is considered in sufficient depth to allow quantification and development of models to be used in a database with a graphical user interface.

The author quantifies the radiative and convection/conduction heat loss at the building external surface and then calculates the conductive heat flux *through* the building structural envelope. With a knowledge of inner and outer temperatures and the quantified heat flux the author develops a model to calculate the thermal resistance, thermal conductivity and, with the surface area, the U-values.

The model developed is used in a MS-Access database to record parameters necessary to calculate U and R values for each building component. Local area environmental parameters are then used with the calculated U-value to predict annual energy loss through the building envelope in terms of kilowatt hours and in financial terms.

The study finishes with a thorough evaluation of a large commercial building with recommendations for improvement of insulation in accordance with this study and legislative requirements.

Word count = 17,343

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Acronyms and Abbreviations

ΔT	temperature difference (°C or K)
µ	dynamic viscosity (kg/m.s)
A	Surface area of component under study (m^2)
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
C_f	Skin friction coefficient
CHTC	Convective Heat Transfer Coefficient ($W/m^2.K$)
Cp	specific heat at constant pressure (J/kg.K)
E	infrared emittance
ε	infrared emittance
GUI	Graphical user Interface
h	Planck's constant
h_c	Convective Heat Transfer Coefficient ($W/m^2.K$)
K_b	Wien's Displacement Constant (2.897 7685 x 10^{-6} m.K)
k	K-Factor - thermal conductivity (W/m.K)
L	Linear dimension (m)
λ	lambda - wavelength (m)
MoWiTT	Mobile Window Thermal Test facility
Nu	Nusselt number
Pr	Prandtl number
Q	Heat flow (W)
q	heat flux (W/m^2)
Qc	Convective heat flux (W)
Qcond	Conductive heat flux (W)
Qir	Heat loss by radiation (W)
Qsky	thermal radiation from the sky (clouds & buildings) (W)
Qsolar	thermal radiation from the sun (W)
R	infrared reflectance
R_f	ASHRAE roughness factor
Re	Reynolds number
R-Value	thermal resistance
σ	Stefan-Boltzmann Constant (5.6704 x 10^{-8} W/m^2)
T	infrared transmittance
Ta	Temperature of air at edge of boundary layer (°C or K)
Ts	Temperature of emitting surface (°C or K)
u	Wind velocity normal to the surface (m/s)
U_∞	Mean air velocity (m/s) of free air stream
U-Value	thermal conductance ($W/m^2.K$)
V	Wind velocity
v	Wind velocity parallel to the surface (m/s)
w	Wind velocity vertical to the surface (m/s)
W_b	blackbody spectral radiant emittance at wavelength lambda (W/m^2)
ρ	density (kg/m^3)

Chapter 1

1.0 Introduction

In 2004 the author was asked by Blackpool Borough Council to produce a thermal map of the Blackpool Metropolitan area. The thermal map was to be used as an interactive display at the Solaris Centre which is the showpiece of environmental conservation for the council. The intention of the map was to allow residents to identify their home using a graphical user interface (GUI) on a PC and see just how much heat was being lost from their homes.

The process of collecting thermal images necessitated hiring a small aeroplane with a pilot and flying at 500 feet over Blackpool in a grid pattern so that each image could be referenced to a map location for later inclusion into the GUI. After collating the images into the software the author showed the resultant system to his wife and family for their impressions before the author submitted it to the council. Almost immediately his wife asked "Can I see our house?" With a flourish the author clicked onto the section showing the part of the street with his house and his wife exclaimed "Why does our house look so red?" With considerable embarrassment the author had to reply to her that it was because her house was losing the most heat in the street (figure 1).

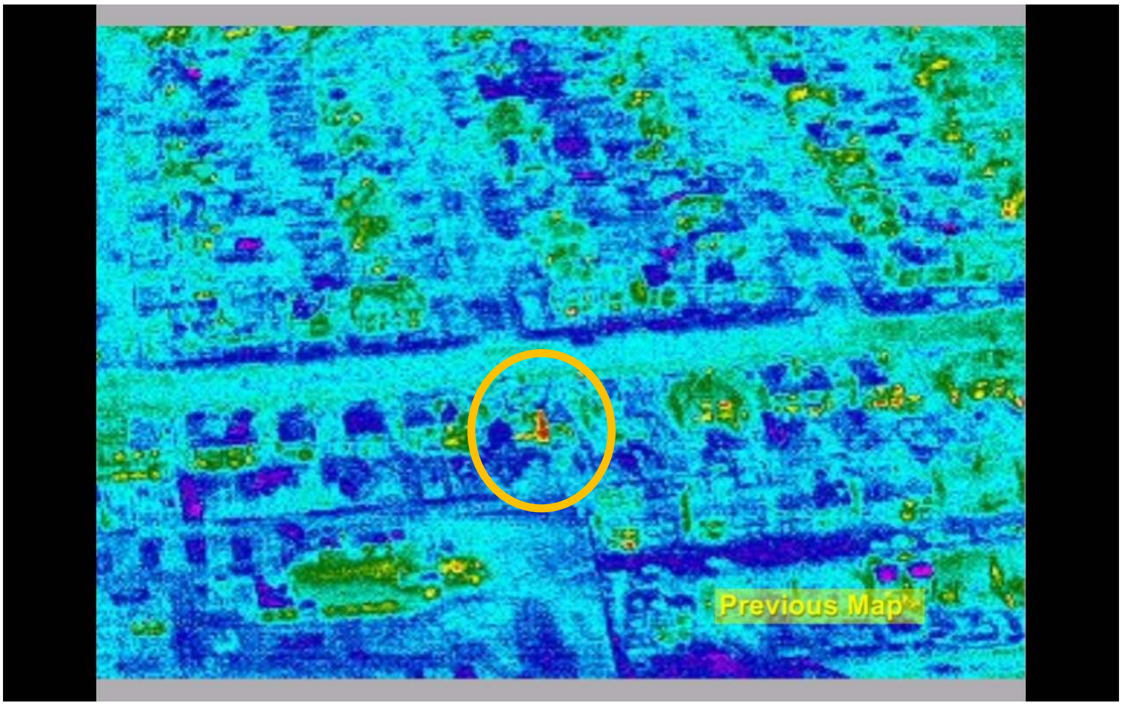

Figure 1 Thermal image of Blackpool South Shore, showing the author's home (ringed)

Blackpool Council was very pleased with the resulting programme and many people used the interface to look at their homes in infrared. However, the author had to embark on a journey to identify exactly where his house was losing the heat and to come up with a cost effective solution for insulating the house. The author was horrified at the cost of double glazing but he could not be sure how effective cavity wall insulation would be and which of the two solutions would be the most effective. The author also looked at options of improving existing insulation in the converted attic space. Relying on previous thermal imaging surveys carried out to determine the effectiveness of cavity wall insulation the author realised that the conventional process of using “industry standard” values for insulation effectiveness was fraught with problems:

- U-value depends on the way in which the insulation is applied
- Air leaks (mass transfer) have a huge effect on heat loss
- Specified U-values for double glazed windows are dependent on “standard” environmental conditions that rarely reflect real life conditions.

- The amount of heat loss depends on how the interior of the house is heated and the use factor of individual rooms.

The author decided to start an empirical process in which he would measure the heat loss from individual rooms by measuring internal and external temperatures using standard thermocouples as well as a thermal imaging camera. It soon became apparent that the amount of heat loss was very dependent on how windy it was as well as outside temperature, the wind direction (those rooms facing the wind lost more heat) and whether it was raining or not (more heat was lost on wet days).

The author decided to treat each different type of material separately, i.e.

- Doors
- Walls
- Flat Roofs
- Pent Roofs
- Vertical Windows
- Pent Roof Windows

The intention was to determine the amount of heat loss from each external surface and sum those heat losses for each room thereby identifying if it would be more cost effective to install double glazing, cavity wall insulation or even additional roof insulation. The result should be able to identify which rooms would benefit the most from the improved insulation.

To make the eventual outcome as useable as possible the author decided to correlate the heat loss with the actual cost of the heating fuel, be that gas, oil or electricity with the intention of predicting the actual cost of heating the home; the end result would be that he could make an informed decision on the most cost effective method of insulating the home.

1.2 Aims

To determine the thermal insulation properties of buildings and structures' external envelope by measurement of surface and air temperatures with special regard to conductive heat flow through the envelope, thermal radiation heat loss and the effect of air movement on convection effects.

1.3 Objectives.

1. To perform a literature study of the field of solid/air convective and radiative heat transfer and the use of infrared thermal imaging for radiometric surface temperature measurement.

2. To identify the components needed to create a model of heat transfer through various types of building components in vertical, horizontal and angled planes when subject to a range of external air movements.

3. To develop a model for the calculation of R and U insulation factors by calculation of total heat conductive, convective and radiative heat flow.

4. To embed the model within a GUI and to provide the following functionality:

    a. Determination of total heat loss from each surface component and each external elevation.
    b. Determination of U and R value for each surface component.
    c. Calculation of total heat loss from each room in a building.
    d. Calculation of the cost of heating/cooling a building

5. To evaluate the model using experimental / baseline test-set data by measurement of heat transfer through a component wall with a set temperature differential when the cooler side of the wall is subject to a range of air speeds and directions.

6. To refine the model with an accurate compensation for wind speed and angle of attack.

7. To trial the model on several dwellings and/or commercial buildings in Britain during autumn and winter months thereby correlating calculated heat loss data with actual heating fuel consumption.

8. To draw conclusions and to make recommendations for further development work.

1.4 Methods of Research

The research project was necessarily carried out using a combination of numerical and experimental methods.

The initial research was to determine existing models of heat transfer and determine if any of these existing models were suitable for inclusion in a comprehensive model for determination of building component U-values and R-values. The literature research revealed several possible models for convective heat transfer whereas the Stefan-Boltzmann model for radiative and the Fourier model for conductive heat transfer were identified as being mature and well proven.

As the model for convective heat transfer was to be used on buildings, the research focused no those models using wind as the heat transfer medium against vertical and inclined surfaces.

The next stage in the research was to prove the models. To this end a hot box was constructed and various building materials used to make one wall for each test. A heat source of a known wattage was placed inside the hot box and the radiative heat loss was calculated. As the conductive heat loss through the wall must equal the radiative heat loss plus the convective heat loss, the convective models could be proven by comparing the model predictions against the calculated difference between actual heat input and calculated radiative losses.

Once the most accurate convective heat model was selected this model was used along with the radiative model to calculate the total conductive heat flow through each component. With a known value of the conductive heat flow and physical dimensions of the thermal boundary components it was then possible to calculate the U and R-values.

The complete model was used as the base calculation in a database to calculate the U-value and R-value of discrete components in the buildings structural and thermal envelope.

Chapter 2

2.0 Literature Review

In this chapter the author collates information from several sources so as to build a foundation on which to construct the model for heat flux through the building's thermal envelope.

The literature review was aimed at three areas of concern:

1) Convective heat losses from buildings
2) Radiative heat losses from buildings
3) The use of infrared thermal imaging cameras to detect building component surface temperatures.

2.1 Convective Heat Losses from Buildings

In 1985 Klems (1) suggested a standardised method for measuring window (fenestration) performance using a MObile WIndow Thermal Test (MoWITT) facility. The MoWITT measures the heat flow through a fenestration system considering heat losses and inputs from inside and outside (Figure 2).

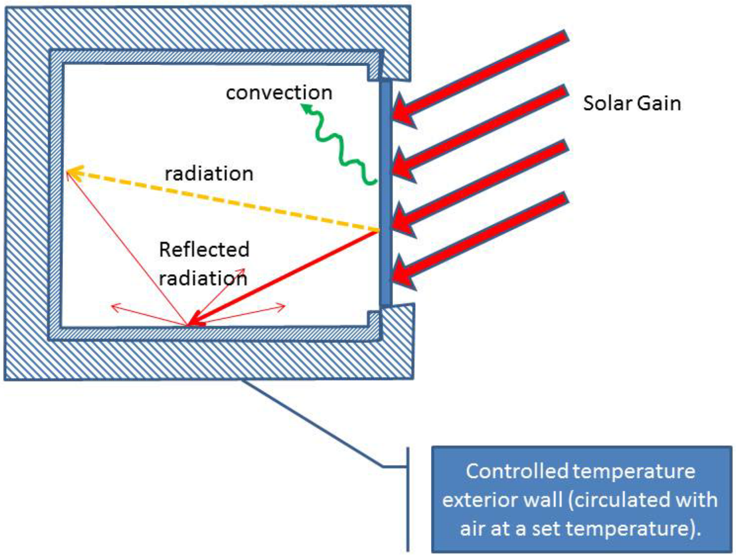

Figure 2 The MoWITT measures the net energy flow through a fenestration system by determining the net heat balance on the adjacent room-sized space

The MoWITT was a large portable facility and was delivered to various locations and left on site so as to be exposed to a wide range of climatic conditions. Klems claimed that existing heat flow models suffered inherent inaccuracies due to the ASHRAE imposed "standardized" conditions especially the standard wind speed of 15mph.

Klems' achievement was the development of a portable facility that facilitated the calculation of U and R values from measurement of physical values. A prime difficulty facing Klems was the difficulty in accurate measurement of the surface temperature across the complete surface and thus heat flow through the envelope; his technique was to estimate the *average* heat flow through the envelope component under investigation from several discreet heat flow measurements. By quantifying the total heat flow through the wall as heat loss (this was a controlled variable as the wall temperature was controlled) and calculating the radiated heat flow from the hot fenestration to the inside of the MoWITT, Klems was able to calculate the convective heat flow from the fenestration as well as the conductive heat flow through the fenestration and thus the U-value.

In 1999 Svoboda (2) presented a numerical model of convective-conductive heat transfer in building components. The model demonstrated that wherever the insulation of the envelope was non-uniform or where cracks had developed then air movement within the insulation enabled relatively vigorous heat flow. One major implication of the Svoboda study is that calculation of convective, conductive or radiative heat flow is only accurate if mass flow across the insulating medium is negligible.

Clear et al (3) in 2001 carried out measurements that eventually allowed the development of a correlation of the outside convective air film coefficient as a function of ΔT (inside and outside air temperature), wind speed, wind direction, area and surface roughness. The study was limited to flat roofs but it laid down a basis for future development of Convective Heat Transfer Coefficient (CHTC) by extending the results to a study of tilted roof (see conclusion in paragraph 4, page 27 of the study).

In the Discussion (page 26) Clear notes that the correlation developed in the study is not a direct correlation of several variables with CHTC but rather correlations of these variables to net heat flow. The components of the net heat flow included radiation heat flow due to solar radiation (Qsolar), radiation from the sky (clouds and buildings) (Qsky), heat flow across the roof by conduction (Qcond) as well as heat *losses* by radiation (Qir). A heat balance was an essential component of the study to determine the heat loading into the building and thence the air conditioning load requirement. By determining the heat load, the temperature difference and the roof area Clear was able to calculate CHTC.

$$\mathbf{Q_{solar} + Q_{sky} + Q_{cond} - Q_{IR} - h_c \Delta T = 0} \quad \text{……………………..Eq1}$$

Where:

- $\mathbf{Q_{solar}}$ = solar radiation absorbed by roof (W/m^2)
- $\mathbf{Q_{sky}}$ = sky long-wave radiation absorbed by roof (W/m^2)
- $\mathbf{Q_{cond}}$ = conductive heat flow into roof (W/m^2)
- $\mathbf{Q_{IR}}$ = long-wave radiation emitted by roof (W/m^2)
- $\mathbf{h\Delta T}$ = the convective heat transfer from the roof to the outside air (W/m^2)
- $\mathbf{h_c}$ = surface convection coefficient (W/m^2-K)

- **ΔT =** roof outside surface temperature minus outside air temperature (K)

The positive and negative signage is explained as the Clear study was considering buildings in high ambients so he was concerned with heat *absorbed* by the building in order to estimate air conditioning loads. Heat absorbed by the building was signed positive whereas heat lost by the building was signed negative.

Clear's study took special note of the influence that solar heating had on the heat flow through the roof as his main objective was to determine the cooling load. Clear determined that solar heating was not the only heat load and he quantified heating from the sky via infrared radiation with the main difference between solar and sky radiation being the wavelength (see wavelength against object temperature figure 9).

All convective heat calculations carried out by Clear were carried out using the turbulent, forced convection model where:

$$\mathbf{10^5 < Re < 10^8} \quad \text{……………………………………………..Eq2}$$

See discussion of Reynolds Number on page18.

and a Nusselt number of:

$$\mathbf{Nu = 0.0269\ Re_x^{4/5}.Pr^{1/3}} \quad \text{………………………………..Eq3}$$

See discussion of Nusselt Number (section 3.1) on page 29.

Where

- *x* = the distance from the leading edge of the roof to the point at which the Reynolds number is evaluated (metres).
- *Re* = the Reynolds Number
- *Pr* = the Prandtl Number (0.713 for air at 20°C)
- *Nu* = the Nusselt Number

The study showed no correlation with wind direction but, as the study was based on flat roofs, this is not surprising. Heat flux through a flat roof is expected to be independent of wind direction assuming the building profile is consistent on all elevations. The roofs under consideration by Clear were uniform in all directions so wind flow across the roof would be similar no matter from which direction the wind was coming.

A further and more important outcome from Clear's study is that natural and forced convections are <u>additive</u> and this is shown in the CHTC values at zero wind speed as shown in Figure 3 which shows a value for CHTC of approximately 5 $W/m^2.K$ at zero wind speed (i.e. natural unforced convection).

Figure 3 shows data of CHTC against wind speed. A curve fit of the data in figure 3 shows a linear curve fit line (y=ax+b) which crosses the zero wind speed line at a value of CHTC=5 W/m^2K. This indicates that natural convection of the flat roof gives a CHTC of value 5, but as the wind speed increases and the convection becomes forced convection, the CHTC increases linearly (within the bounds of data scatter) inferring that the natural and forced convection effects are additive.

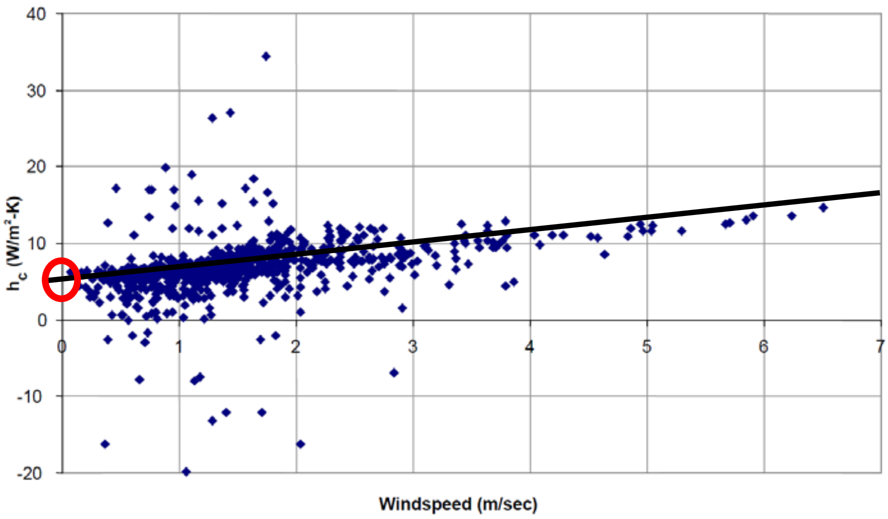

Figure 3 Measured convective heat transfer coefficient at roof center against wind speed
(reused here by kind permission of Elsevier – license No. 2731430520618)
n.b. the line has been added by the author of this document.

A further evaluation of Reynolds Number (Re) indicated that the value of Re varies linearly with distance from the wind entry edge but that it is possible to make a valid estimation by averaging over the complete area. Clear showed that it is possible to make an evaluation at the centre point and use that as the average.

Hatton and Awbi (4) presented results for heated surfaces adjacent to cool walls and empirically derived values of CHTC for laminar and turbulent convection. In their experiment Hatton and Awbi not only used traditional platinum resistance thermometers for point temperature measurements but they also used an infrared imaging camera. The infrared camera was used not only to investigate the temperature distribution on the cold wall but also to determine the emissivity of the surfaces under consideration.

Hatton and Awbi calculated the convective heat flux by measuring the known heat flux from a heating element (Qin) and then subtracting the radiative losses (Qir). A subsequent calculation (Eq5) was then used to calculate CHTC.

$$h_c = \frac{Q_c}{A(T_s - T_a)} \quad \text{……………………………………………………………Eq4}$$

Where

- h_c = is the Convective Heat Transfer Coefficient (W/m^2-K)
- Q_c = Convective heat flow (Watts)
- A = Surface area of the component (m^2)
- T_s = Temperature of the emitting surface (K)
- T_a = Temperature of the air at the edge of the boundary layer (K)

Hagishima et al (9) compared the results of experimental results for CHTC of various urban surfaces. In this study it Hagishima concluded that (for a vertical wall) that although the effect of wind direction is small, the effect of whether or not the wall exterior is in way of the wind or not is significant; in other words, the flow path of the wind.

The Hagashima study concurred with the Clear study that there is a correlation between CHTC and wind speed on various surfaces. The various studies examined indicated a correlation exists whether the surfaces be oriented vertically, horizontally or slanted. One important conclusion of the study was that the use of models of buildings for determination of CHTC, while being useful for approximation of CHTC, gave results that vary significantly from full size building; the reason given for the difference in results (model/full size) is the difference in Reynolds and Nusselt numbers. A discussion of Reynolds and Nusselt numbers is given later in this document.

In a prior study, Hagishima and Tanimoto (6) conducted research into various techniques to measure CHTC. Hagashima used a linear curve fit of the data to predict CHTC using ax+b curve fit where b is a factor related to wind speed and a is indicative of the amount of natural convective heat loss with zero wind. The study further showed that the curve fit formula changed depending on whether the measurement was carried out on a flat vertical wall or a roof with the implication that the wind flow is dependent on the surface under observation.

One of their conclusions was that on flat surfaces the CHTC can be correlated successfully to the summation of the wind velocities for horizontal surfaces (Eq5):

$$h_c = 3.96\sqrt{u2+v2+w2} + 6.42 \text{ ....Eq5}$$

and for vertical surfaces (Eq6):

$$h_c = 10.21\sqrt{u2+v2+w2} + 4.47 \text{..............................Eq6}$$

where u, v and w are wind velocities normal, parallel and vertical to the surface under examination.

The Hagishima study went one stage further by combining horizontal and vertical surfaces into a dimensionless analysis using Nusselt and Reynolds numbers (Eq7).

$$N_u = 0.023 \cdot Re^{0.891} \text{..Eq7}$$

Hagishima then went on to substitute the Prandtl number for air at 20°C to finally give Eq8.

$$h_c = 11.42 \cdot l^{-0.109} \cdot (\sqrt{(}\frac{}{u^2+v^2+w^2})^{0.891} \quad \text{...........................Eq8}$$

Equation 8 is, again, an estimation but it shows that the CHTC is a function of ***l*** (the distance from the edge) as well as the wind velocity such that CHTC will be much larger for small components such as test models. By making ***l*** the midpoint of the surface, Eq8 allows for an average calculation of the entire surface.

The conclusion of Hagishima and Tanimoto is very important to this study as it clearly demonstrates that the convective heat transfer coefficient of any flat surface may be estimated purely by a knowledge of the wind speed and the size of the component. This knowledge will be applied further in the study to help in the calculation of total heat flux and thence the U-values of various building components.

Wallenden (16) examined CHTC calculations from various sources and concluded that the best accuracy was ±15% for a window and ±20% for a wall. The author will endeavour to prove that better accuracy can be achieved by taking into account the size of the surface under examination, the temperature difference between the wall surface and the ambient as well as consideration of the heat flux quantity.

2.2 Radiative Heat Loss from Buildings

In Fairey's study on radiant energy transfer and radiant barrier systems (12) he identifies that infrared radiation as a means of transferring energy has the major dissimilarity from conduction or convection in that it does not require a physical medium. The importance of this fact for this study is that the amount of radiation leaving the building is independent of wind (unlike convection) or any contact with a thermally conductive medium (unlike conduction). In figure 9 we see that a surface at 300K (23°C) has a maximum amplitude wavelength at about 10µm (this is calculated using Wien's Displacement Law – Eq19).

As the surface of the building thermal envelope will be close to ambient then the radiative heat energy being lost is being removed at close to 10µm. According to an article published by Protek-USA (14) the infrared radiation being emitted from the surface of the building has no temperature, only energy. The factor that affects the amount of energy is the surface temperature and it's emissivity (see a further discussion on emissivity on page 32).

2.3 The use of infrared thermal imaging cameras to detect building component surface temperatures

Bradley (11) identified that fabric heat loss from a building is a combination of radiative, convective and conduction exchanges. He further goes on to state that "research carried out for the Low Carbon Housing Learning Zone at Leeds Met has shown that a significant discrepancy exists between the energy performance of a dwelling as designed and that realised in practice, typically around 20% higher than predicted by modelling.".

He goes on to suggest that the difference may be accounted for by problems with thermal bridging, actual U-values being different to predicted U-values and building errors such as leaks allowing mass transfer. The comments by Bradley indicate the need for an actual measurement of the building insulation performance "as-built" instead of a theoretical calculation.

Ocaña et al (13) pointed out the theoretical basis of using infrared radiation to quantify heat loss is the ability of a thermal detector to turn the emission pattern of an object into a visible image. The result of a thermal image based on the infrared portion of the electromagnetic spectrum is shown in figure 4. Note that figure 4 shows spot temperatures (those temperatures prefixed with SP) and area temperatures (those temperatures prefixed by AR). It is possible to record average, maximum or minimum temperatures of any given area using the software supplied with the thermal imaging infrared camera.

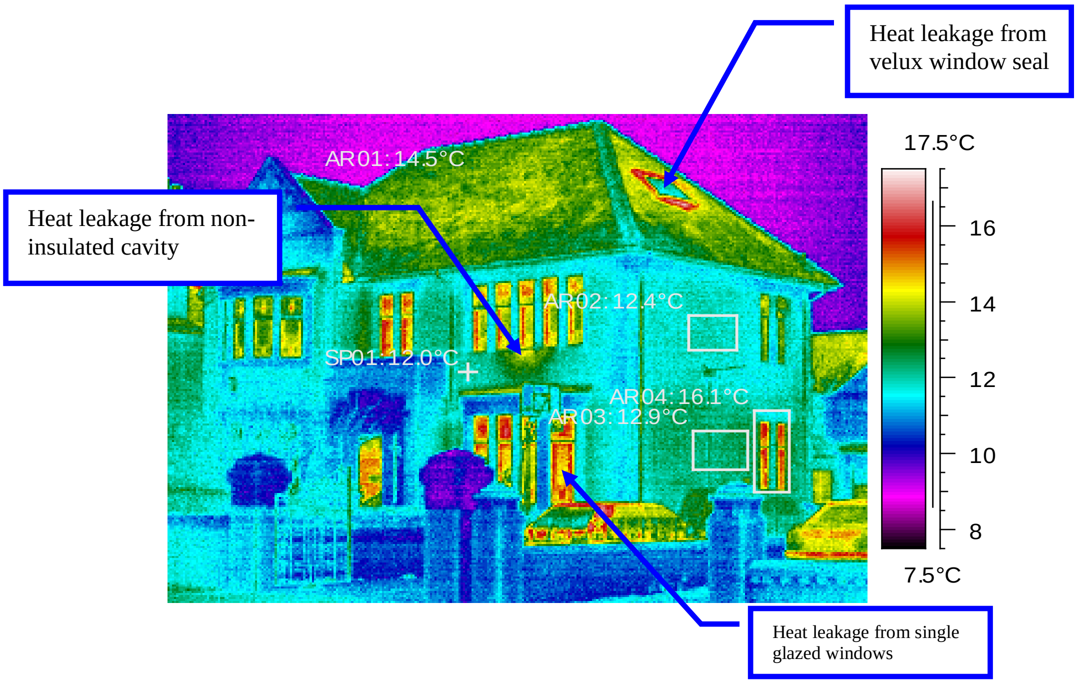

Figure 4 Radiometric thermal image of the author's home - taken at night

Snell (15) has identified several problems that can be identified by using thermal imaging cameras on building envelopes:

1) excessive energy use due to missing or damaged insulation, insulation that is performing inadequately, and excessive air-leakage across the thermal perimeter
2) moisture damage due to leaks or condensation, especially in the walls or roofs
3) ice damage to sloped roofs
4) poor HVAC distribution or performance
5) inadequate verification of construction details or structural performance
6) delaminations of façade materials
7) "sick building syndrome," mold growth and other health related issues

Snell notes that it is quite easy to identify damaged or non-performing insulation as well as certain construction details such as thermal bridging which could have an effect on the overall thermal performance of the building. Snell further goes on to identify the benefits of using a thermal imager, as opposed to point temperature readings, is the ability to take readings non-contact and to measure a complete map of a surface enabling measurement of maximum, average or minimum temperatures within an area.

2.4 A Discussion on Dimensionless Numbers

According to the Free Dictionary by Farlex (http://www.the freedictionary.com) "a dimensionless number is a number representing a property of a physical system, but not measured on a scale of physical units (as of time, mass, or distance). Drag coefficients and stress, for example, are measured as dimensionless numbers".

To investigate fluid flow near and around buildings, the literature review has shown a requirement to use certain factors describing and characterising the flow of air. In this chapter the author aims to identify and describe the dimensionless numbers that may be used in the analyses in subsequent chapters to develop a working model of heat flux in line with objectives 2 and 3 (page 11). These dimensionless numbers are used in this study to develop models of heat flow.

The dimensionless numbers of interest in this study are:

- Reynolds Number
- Nusselt Number
- Prandtl Number

2.5 Reynolds Number (Re)

The purpose of the Reynolds Number (7) is to characterise flow regimes (e.g. laminar or turbulent). Low Reynolds Number indicates laminar flow (where viscous forces dominate) whereas a high Reynolds Number indicates turbulent flow (where inertial forces dominate); the calculation of the Reynolds Number therefore requires quantification of the inertial forces and the viscous forces and this is calculated as a ratio of inertial/viscous properties.

Reynolds' (1842-1912) work on turbulence was initially based on the analysis of fluid dynamics by George Gabriel Stokes. Stokes published papers on the flow of incompressible fluids in the mid nineteenth century with detailed analysis of friction of moving fluids and motion and equilibrium of elastic solids. Stokes reviewed the methods and hypotheses of Navier, Poisson, Saint-Venant (8) and his own work to present a rational derivation of the Navier-Stokes equations which describe the movement of incompressible fluids.

The inertial properties of the Reynolds Number are characterised by density, velocity and distance (Eq9):

$$inertia\ force = \rho v^2 L^2 \ldots\ldots\ldots\ldots\ldots\ldots\text{Eq 9}$$

The viscous forces are characterised by the viscosity. The viscous force (Eq10).is shown by

$$viscous\ force = \mu\, v\, L \ldots\ldots\ldots\ldots\ldots\ldots\text{Eq 10}$$

Where :

- ρ = density of the fluid (kg/m^3)
- *v* = mean velocity of the fluid (m/s)
- L = characteristic linear dimension (m)
- μ = dynamic viscosity of the fluid. (kg/m.s)

Taking the ratio of inertial/viscous forces we obtain (Eq11):

$$Re = \frac{\rho\, v\, L}{\mu} \ldots\ldots\ldots\ldots\ldots\ldots\text{Eq 11}$$

Once the Reynolds Number of a particular flow regime is known an estimate may be made as to whether the flow is laminar or turbulent. Reynolds discovered that (with liquid flow) the flow would always be laminar if Re<2100 (8) although with care the laminar flow could persist up to Re = 10,000. At larger values of Re the layer of fluid contacting the wall (the boundary layer) exhibits vortexing and becomes unstable until, with even higher values of Re, the flow becomes fully turbulent.

For the purpose of this study it is important to understand whether the flow is turbulent or not as this will affect the rate of heat transfer. If a fluid flow is laminar the heat flow is restricted to a boundary layer that is fairly static and beyond the boundary layer the fluid flow is parallel to the component. If the flow is turbulent then the resulting vortexing will mean the boundary layer will be much thinner and may even collapse, leading to greater degree of contact between the wall and the fluid and hence greater heat flow.

A calculation of the Reynolds number of air flow against the vertical wall of a dwelling may be calculated quite easily using Eq11. For a dwelling with a 10m high vertical wall, a wind speed of 5m/s at 23°C (300K) the following parameters apply:

- Dynamic viscosity: 1.983 x 10^{-5} kg/m.s
- Density 1.205 kg/m^3

- Mid point of wall 5m (to determine average Reynolds Number)
- Wind velocity 5m/s

$$Re = \frac{1.205 \cdot 5 \cdot 5}{19.83 \cdot 10^{-6}} = 1519162.885$$

Keeping dimensions the same but calculating for a variety of wind speeds from 0.5 to 5.0 m/s we get the following Reynolds Numbers.

Table 1 Reynolds number against wind speed for a height of 5m at 20°C

Wind velocity m/s	Reynolds No.
0.5	151916.2885
1	303832.5769
2	607665.1538
3	911497.7307
4	1215330.308
5	1519162.885

Using the same correlations for laminar/turbulent as Clear et al (3) (table 2) we see that the Reynolds number for forced convection (i.e. a wind speed > 0 m/s) a Reynolds number greater than 10^5 indicates turbulent air flow. Table 1 shows that any wind velocity of 0.5 m/s or greater is turbulent when measured at the midpoint of a 10m high wall for air at 20°C.

Table 2 Reynolds number correlation for air flow against a building (Clear – 3)

Type of convection	**Applicable range**
Laminar	$Re < 10^5$
Turbulent	$10^5 < Re < 10^8$

2.6 Nusselt Number (Nu)

The Nusselt number is the ratio of convection heat flux over conductive heat flux (10) into the thermal boundary layer so that a Nusselt number of near unity means that convection and conduction are of similar magnitude. Leinhard (9 page 274) gives a definition formula for Nusselt number in Eq 12:

$$Nu = \frac{convective\ heat\ transfer}{conductive\ heat\ transfer} = \frac{h_c.\Delta T}{k.\Delta T} = \frac{h_c L}{k} \quad \text{..............Eq 12}$$

Where

- hc – convective heat transfer coefficient (W/m^2.K)
- L – linear length
- K – thermal conductivity (W/m.K)
- ΔT – temperature difference between surface of the wall and the temperature of the free stream fluid.

A larger Nusselt number indicates the flow is much more turbulent – typically above 10^2. As the air flows in this study are in the main turbulent, large Nusselt numbers are expected.

According to Leinhard (9 – page 325) the Nusselt number may be calculated as follows (Eq13):

$$Nu = 0.032 Re_x^{0.8}\ P_r^{0.43} \quad \text{.....................................Eq 13}$$

2.7 Prandtl Number(Pr)

The Prandtl number is the ratio of momentum diffusivity (kinematic viscosity) to thermal diffusivity (9 page 297).

$$\mathrm{Pr} = \frac{v}{\alpha} = \frac{viscous\ diffusion\ rate}{thermal\ diffusion\ rate} = \frac{c_p \mu}{k} \quad \text{..................Eq 14}$$

Where

- v = kinematic viscosity (m^2/s)
- α = thermal diffusivity (m^2/s)
- μ = dynamic viscosity (Pa s = (N.s)/m^2)
- k = thermal conductivity (W/(m.K))
- c_p = specific heat at constant pressure (J/(kg.K))

Note that unlike the Reynolds number, the Prandtl number does not require a dimensional component of the surface under consideration, therefore the Prandtl number is a property of the fluid only. A high Prandtl number means that the fluid has good convective properties and a low Prandtl number indicates suitability for conduction as the heat diffuses quickly even at low fluid velocities.

The Prandtl number (Pr) for air varies from 0.711 at 40°C to 0.715 at 0°C.

2.8 Heat Transfer Mechanisms

In order to identify the components needed to create a model of heat transfer through various types of building components in vertical, horizontal and angled planes when subject to a range of external air movements in a realistic and practical model of heat transfer through components in the building envelope it is necessary to have a thorough understanding of the methods of heat transfer. This chapter will consider the base calculations used to calculate the heat flux and build on the concepts explored in the literature review.

Heat can be transferred from one material or body to another in one of four ways

1. Conduction
2. Convection
3. Radiation
4. Mass transfer

This study will concern itself with the first three methods of heat transfer as the primary focus is on heat transmission through building's structural envelope without physical exchange of air from inside to outside or vice versa.

The second law of thermodynamics concerns the state of entropy in a closed system and dictates that over time the entropy of such a system which is not in equilibrium will tend to increase. The second law can be written as $\Delta s \geq 0$ (where Δs is the entropy change). The second law of thermodynamics therefore necessitates that energy (or heat) can only travel from a higher temperature to a lower as a reverse flow would *reduce* entropy. In the building envelope under consideration our heat flow is from the warm interior to the cold outside.

For the purpose of this study it is necessary to quantify this heat transfer. The target is to determine the conductive heat flow through the envelope which must necessarily flow from the warmer surface to the cooler surface. All heat flowing through the surface will be dissipated to the external environment assuming a warm building interior with a cooler exterior environment. With zero mass flow the exterior heat flow dissipation must be via radiation and a combined conductive/convective heat flow mechanism at the exterior wall/atmospheric interface. The next section explores each of these heat flow mechanisms.

2.9 Conduction

Conduction is the process of transferring heat across a body or from one body to another when they are in physical contact and a temperature gradient exists. Examples of this are:

- A cooking pan on an electric hob,
- Household walls where insulation is used to reduce the heat transfer through conduction
- Double glazing - A vacuum or gas gap is inserted between the glass panes to reduce heat loss through conduction

Conductive heat is transferred through a body by excitation of the molecules. As molecules receive energy in the form of heat, they tend to vibrate at higher amplitudes; this molecular vibration causes some of the energy to be passed on to adjacent molecules that in turn pass their energy on to others and so on. Materials that are poor insulators (therefore good thermal conductors) have very active and free molecules. On the other hand, materials that are poor thermal conductors (good insulators) have very tightly bound molecules and very few free electrons.

As the number of molecules available for heat transfer decreases so does the density and the thermal conductivity, so fluids (especially gases) generally do not conduct heat as well as solids. For most solids it is possible to identify rates of heat transfer by referencing well known and documented thermal conductivity and thermal resistance tables. The unit of thermal conductivity was defined by Fourier and is:

watts/Kelvin/m (W/K/m)

2.9.1 Fourier's Law of Heat Conduction

According to Fourier the rate of heat transfer through a material is directly proportional to the temperature gradient, directly proportional to the area and is perpendicular to the gradient giving equation 15:

$$q = k\Delta T \qquad \text{Eq15}$$

Where

- q = local heat flux W/m^2
- k = conductivity of the material W/m/K
- ΔT = temperature gradient K/m

Integrating Eq14 over the surface of the material we get Eq16 for heat flow in a homogenous material between two points:

$$\Delta Q = kA\frac{\Delta T}{\Delta x} \qquad \text{Eq16}$$

Where

- ΔQ = heat flow |(Watts)
- A = cross sectional area (m^2)
- ΔT = temperature difference across the ends (K)
- Δx = distance between the ends (m)
- k = conductivity (W/m.K)

The conductance (U) of a material is the conductivity divided by the thickness:

$$U = \frac{k}{\Delta x} \quad (\text{W/m}^2.\text{K}) \qquad \text{Eq17}$$

The thermal resistance (R) is the reciprocal of the conductance.

2.10 Radiation

Radiation is an emotive word implying the horrors of atomic bomb blasts and subsequent radiation sickness with everything that entails. However, radiation from the bomb is only one small part of the electromagnetic spectrum. A major part of the electromagnetic spectrum is light between 0.4 and 0.8 micron wavelength (see figure 5).

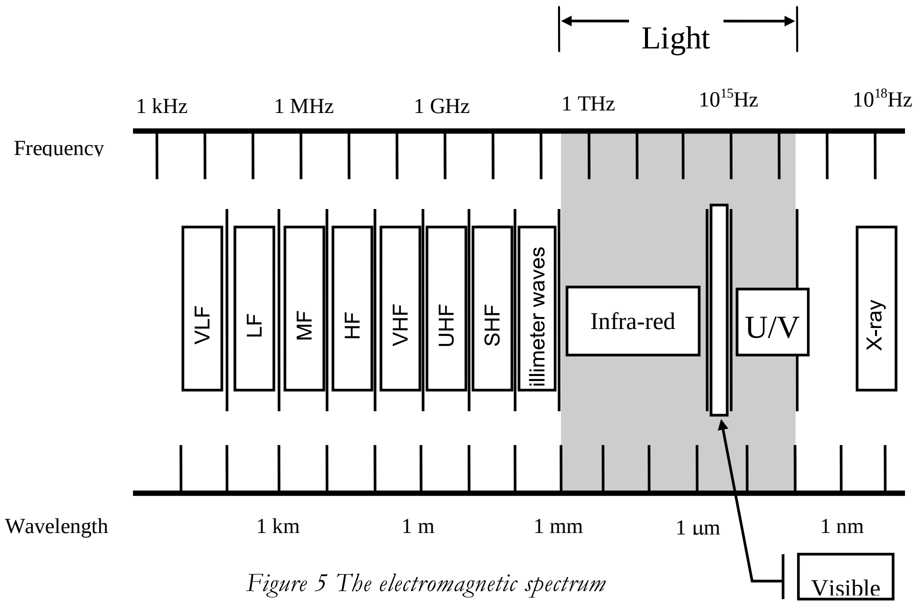

Figure 5 The electromagnetic spectrum

Prepared using data from Fundamentals of Photonics (22 – page 158)

Infrared radiation is the type of heat transfer that interests us at this point. Every object will emit energy in the form of radiation and the amount of heat a body radiates away depends upon its emissivity and its absolute temperature. At the same time that the body is *emitting* radiation, it is also *absorbing* radiation. So long as the amount of radiation emitted from a body is the same as the amount of radiation that is absorbed, then the temperature of the body will remain the same – in other words it is in thermal equilibrium.

The wavelengths of infrared radiation are divided (somewhat arbitrarily) along the following lines:

Table 3 Wavelength division of the Infrared portion of the spectrum (http://paths.sheffield.ac.uk/wikiana/wiki/Infra-red)

	International Commission on Illumination	ISO 20473	Sensor response division scheme
Near Infrared (NIR)	0.7-1.4 µm	0.78-3 µm	0.7-1.0 µm
Short Wave Infrared	N/A	N/A	1.0-3.0 µm
Mid Infrared (MIR)	1.4-3.0 µm	3-50 µm	3.0-5.0 µm
Long Wave (far) Infrared (FAR)	> 3.0 µm	50-1000 µm	8.0-12.0 µm
Very Long Wave Infrared	N/A	N/A	12.0-30.0 µm

The Sensor Response Division Scheme is based on response of various detectors.

- Near infrared: from 0.7 to 1.0 µm. From human eye response
- Short-wave infrared: 1.0 to 3 µm (from the cut off of silicon to that of the MWIR atmospheric window. InGaAs covers to about 1.8 µm; the less sensitive lead salts cover this region.
- Mid-wave infrared: 3 to 5 µm (defined by the atmospheric window and covered by Indium antimonide and HgCdTe and partially by lead selenide).
- Long-wave infrared: 8 to 12 µm, or 7 to 14 µm: the atmospheric window (Covered by HgCdTe and microbolometers).
- Very-long wave infrared (VLWIR): 12 to about 30 µm, covered by doped silicon.

2.10.1 Blackbody Radiation

A “Black Body” is defined as an object that absorbs all (but does not reflect or transmit any) electromagnetic radiation that falls on it at any wavelength (17 – p47).

Kirchhoff's law also states that any body capable of absorbing such radiation would also be capable of emitting radiation. Because a Black Body is considered to be a perfect emitter we say that it has an emissivity of 1 (or 100%). In other words, all of the radiation coming off the body is emitted because of its temperature.

At low temperatures the emitted radiation is invisible to the human eye but as the temperature increases to above 525°C the source becomes visible indicating that the wavelength has moved into the visible portion of the electromagnetic spectrum. As the temperature increases further we see that the colour of the radiation changes from red, through orange, yellow and eventually white. As the temperature has increased the wavelength of the radiation has changed.

E (emissivity) = A (absorbency)

If the law of conservation of energy can written by the relative fractions:

$$E + R + T = 1 \qquad \text{Eq18}$$

where

E = Emissivity

R = Reflectance

T = Transmittance

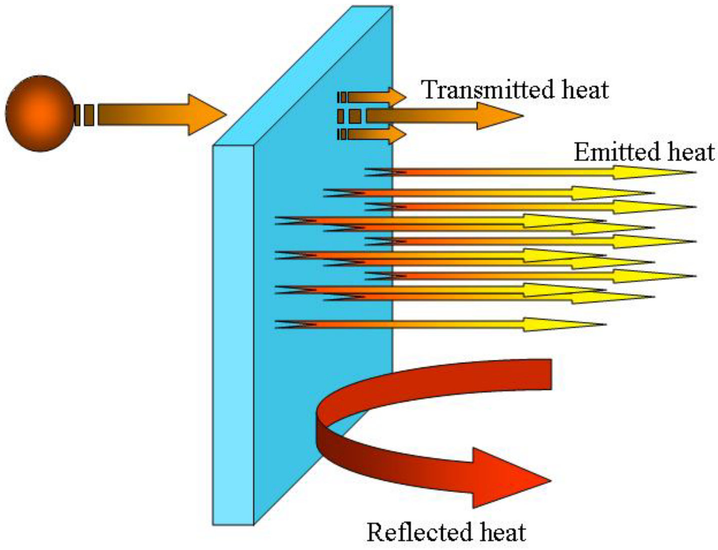

Figure 6 E+R+T=1

2.10.2 Emissivity

As a Black Body can absorb or emit infrared radiation so can other heat sources; the difference is that the Black Body cannot reflect or transmit light so R=0 and T=0 therefore E=1. In the real world most objects will allow some heat from other sources to be reflected so the observer could overestimate the temperature of the body if he tried to correlate the wavelength to the temperature without compensation for the reflection. For most components in the building envelope (apart from glass) transmittance will be zero, so as the reflectivity increases the emissivity decreases.

The value of emissivity is dependant therefore on the percentage of heat reflected and the amount of heat transmitted – anything left is absorbed or emitted.

For most components there are published tables of emissivity. The emissivity values of several materials are shown in appendix 3, table 10.

2.10.3 Reflectance

This causes more errors when carrying out thermographic readings than any other single aspect. In figure 7 we see three phases of bus bars which were recorded inside an electrical cabinet. The bars were of bright copper that had a low emissivity (therefore high reflectivity). The operator first thought that the left bar had a higher temperature than the others. On closer inspection, however, the supposed “high temperature” moved relative to the bar every time the operator moved; this could not happen if he was looking at a fixed heat source. The operator, in fact, was looking at his own reflection in the bus bar.

With a little care it is possible to look at the reflection and see the dark spots where the operator was wearing safety glasses in the left-most bus bar (spot 1) with a temperature of 29.6°C.

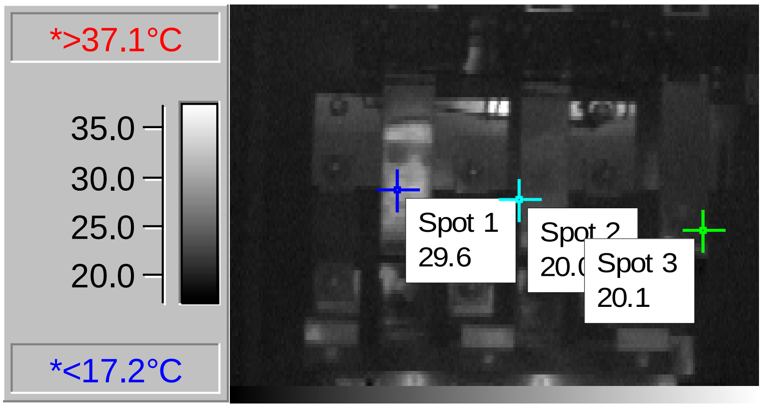

Figure 7 Example of reflectance in a thermographic image (recorded by the author)

Typical reflections in the infrared include lamps, personnel, solar reflections or anything behind the operator that is at a relatively high temperature.

2.10.4 Transmittance

Most materials will not allow infrared radiation to pass *through* (or be transmitted through) the body. However, some materials, such as thin Perspex, will transmit a certain amount of IR radiation. Figure 8 shows how certain materials transmit particular wavelengths of light.

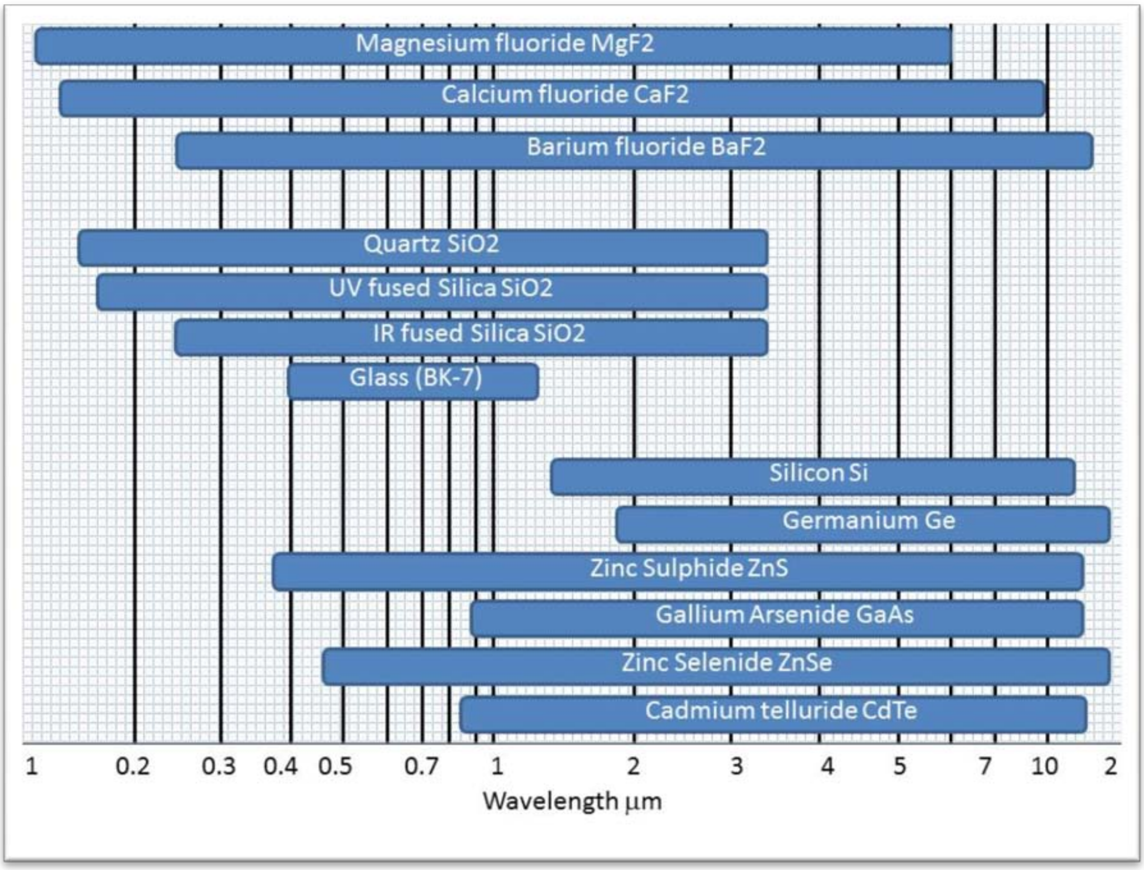

Figure 8 Transmittance values of various materials

Prepared using data from Fundamentals of Photonics (22 – page 175)

Due to the thickness of most components of the building envelope, transmittance is assumed to be zero for brick and roof components in this paper.

Generally speaking, "long wavelength" thermal imaging cameras use lenses that are constructed from germanium and shorter wavelength cameras use lenses which are made from silicon. This allows cameras using germanium lenses to detect lower temperatures whereas silicon lens cameras can, in theory, detect very high temperatures.

2.10.5 Planck's Law

Max Planck (17 – page 48) described the wavelength distribution of electromagnetic radiation from a Black Body with the formula shown in Eq19 :

$$W\lambda_b = \frac{2\pi hc^2}{\lambda^5 (e^{\frac{hc}{\lambda kT}} - 1)} x10^{-6} [Watt / m^2 \mu m] \qquad \text{Eq19}$$

Where:

- $W\lambda_b$ = blackbody spectral radiant emittance at wavelength λ (W/m^2)
- c = speed of light (299,792,458 m/s)
- h = Planck's constant ($6.62606896*10^{-34}$)
- k = Boltzmann's constant ($1.3806504*10^{-23}$)
- T = Temperature (K)
- λ = wavelength (m)

It can be readily seen that as the temperature increases the shorter the wavelength at which maximum emittance occurs. This formula gives a distinct wavelength at which the emittance is maximum as shown in Figure 8 for a black body at a temperature of 300K.

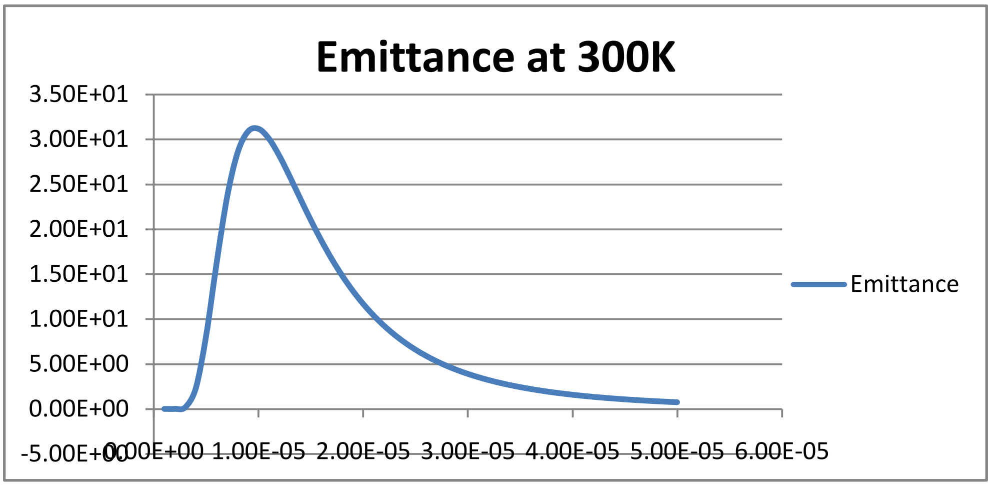

Figure 9 Radiant emittance o a black body at 300K - Emittance - v- Wavelength

2.10.6 Wien's Displacement Law

By differentiating Planck's Law with respect to wavelength and finding the maximum we get Wiens's displacement law (17 – page 49) Eq11:

$$\lambda_{max} = \frac{k_b}{T} \qquad \text{Eq20}$$

Where:

- λ_{max} = peak wavelength (m)
- Kb = Wien's Displacement Constant (2.897 7685 x 10^{-6} m.K)
- T = Absolute temperature (K)

Inputting data for temperatures of 0°C to 50°C into Eq20 we get the resultant curve shown in Figure 10.

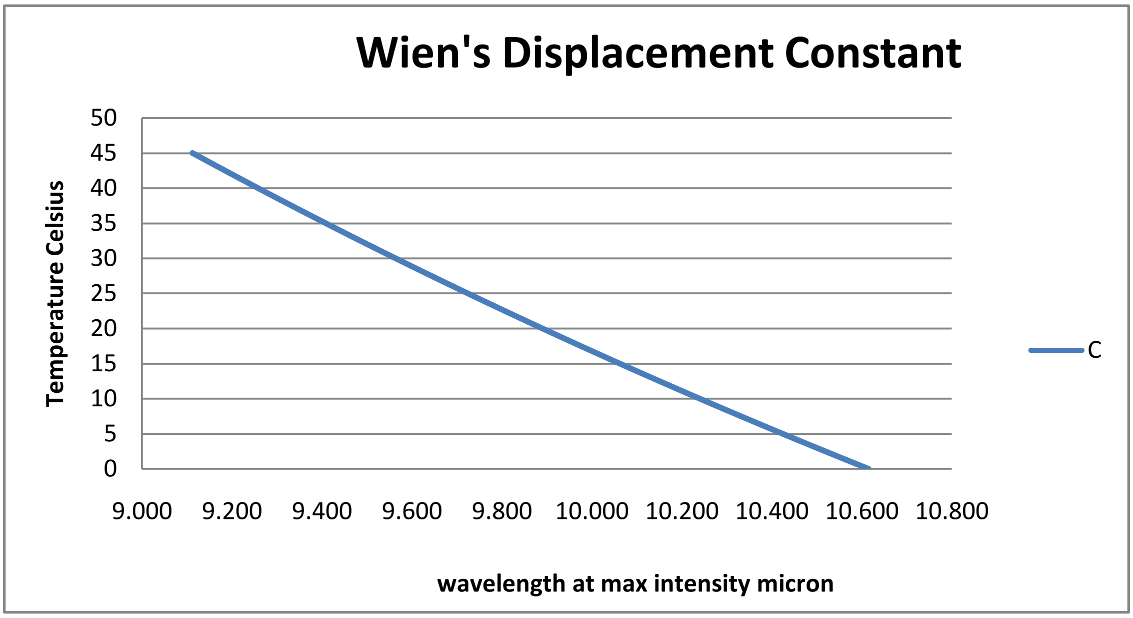

Figure 10 Wien's Displacement Curve for 0 to 50℃

2.10.7 The Stefan-Boltzmann Law

Instead of differentiating Planck's Law (as with Wien's Law) we integrate it from $\lambda=0$ to $\lambda=\infty$ we get the Stefan-Boltzmann formula (17 – page 50) (Eq21) for the total radiant emittance (W_b) from a black body.

$$W_b = \sigma T^4 \qquad \text{Eq21}$$

Where:

- W_b = Total radiant Emittance (W/m^2)
- σ = Stefan-Boltzmann Constant (5.6704×10^{-8} W/m^2)
- T = Absolute temperature (K)

This only considers the radiation from a black body but in the real world the object will not be a black body so it will have a value for emissivity (ε) other than 1. It will also receive radiation from the environment so for practical applications the formula is modified to take into account the surrounding temperature and the area of the surface that is radiating (Eq22).

$$W = \varepsilon \, \sigma \, (T_h^4 - T_c^4) \, A_c \qquad \text{Eq22}$$

Where:

- W = emitted power (W)
- ε = emittance
- T_h = Hot body temperature (K)
- T_c = Surroundings temperature (K)
- A_c = Surface area of the emitting object (m^2)

2.11 Convection

Convection is the process of heat transfer using mass transfer of a fluid (liquid or gas) as a medium. By using an infrared thermographic camera it is possible to see the effect of this heat transfer process as a change in temperature of a dynamically moving stream of air in way of a hot component.

A common example of convection is the cooling coil at the back of a refrigerator. The refrigeration system dumps its excess heat into the coil and air is gradually warmed by the heat from the coil. As the air warms it rises as the thermal expansion of the air reduces its specific gravity, allowing cooler air to come into its place continuing the heat transfer process – this is convection. A common example often seen in the home is a suspended ceiling lamp above a central heating radiator – the convection air currents act on the lamp causing it to move apparently erratically.

Study of various papers including Winkelmann et al (3), Defraeye et al (20) and Saha et al (21) show that there are three accepted modes of convective heat transfer:

1. Natural Convection (with a robust boundary layer)
2. Forced Convection (with a reduced boundary layer due to high wind velocities)
3. Evaporative Cooling (Convection on a surface wetted by rain).

2.11.1 Natural Convection

According to Defraeye et al (20) the Convective Heat Transfer Coefficient (CHTC) of an external wall may be modelled by relating the heat flux ($q_{c,w}$) normal to the external surface of the wall to the wall surface temperature T_w and the reference air temperature T_{ref} far enough away from the wall to be unaffected by the wall temperature. The CHTC is defined in Eq1 as:

$$h_{c,e} = \frac{q_{c,w}}{(T_w - T_{ref})} \qquad \text{Eq23}$$

Newton's Law of Cooling further states that if the surface area A of the convective body is included we have:

$$h = \frac{Q}{A(T_w - T_{ref})} \qquad \text{Eq24}$$

The work of Clear et al (3) shows that the Convective Heat Transfer Coefficient for flat roofs to air at very low wind conditions (natural convection) is about 7 but Clear states that this data should not be used on vertical walls.

Hagishima (5, 6) on the other hand has a variation of Clear's linear prediction and has further refined this for vertical and horizontal surfaces with a further adjustment for wall length or height (depending on the direction of the wind). Hagishima's refinement however would indicate that the heat flux would be zero at zero wind speeds (Eq 8). Clear stated that turbulent convective heat flux and natural (laminar) convective heat flux are additive which is at odds with Hagishima's results. Later in the study the author will show empirically how to resolve the differences between Clear and Hagishima.

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2.11.2 Forced Convection

According to Leinhard (9) a boundary layer will remain laminar on a flat plate even with large levels of disturbance

$$(Re_x \leq 6 \times 10^4)$$

where x is the thickness of the boundary layer (9 – page 274). With relatively undisturbed conditions, a transition value may be realised for Re_x of between, approximately, 3×10^5 to 5×10^5. In extreme conditions, (say laboratory conditions) it is possible to remain laminar up to $Re_x \approx 3 \times 10^6$ but the transition to turbulent can practically be said to be complete before $Re_x \approx 4 \times 10^6$ and usually much earlier. These specifications are for a smooth, flat plate or wall. If the surface is not flat or smooth such as the wall of a building, then turbulence will happen much earlier at significantly lower values if Re_x.

So if the Reynolds number of the wind flow is more than 10^5 we can say that the flow of the wind is turbulent. The actual value of the transition depends upon several factors including the shape of the leading edge, the roughness of the wall, and other acoustic or structural borne vibrations.

In the case of a building we can express the Reynolds's number for a fluid (air) in a free stream as follows (9 – page 271):

$$Re = U\infty . \frac{x}{\nu} \qquad \text{Eq 25}$$

Where

- $U\infty$ = Velocity of the free air stream (m/s)
- x = Distance from the plate or wall leading edge (m)
- ν = kinematic viscosity (m^2/s)

So for wind at 23°C and a speed of 5m/s at a distance of 5m from the wall edge we achieve a Reynolds number of $5.\frac{5}{15.68 \text{ x } 10-6}$ = 1.594×10^{-6}. This value is typical for a value midway along and/or halfway up a vertical wall and is typical of a turbulent condition.

According to Leinhard et al (9 – page 322) an accurate formula for skin friction coefficient (Cfx) may be calculated as follows:

$$Cf_x = \frac{0.455}{[(Ln(0.06.Re_x)]^2} \qquad \text{Eq26}$$

Leinhard also gives us the following two forms for calculating the CHTC in turbulent boundary layers (9 – page 322/328) based on the Stanton Number (9-Appendix C page 731).:

$$h_{x=\rho\times \text{Cp}\times U_\infty} \ \frac{Cf/2}{1+12.8\times(Pr^{0.68}-1)\sqrt{Cf/2}} = \qquad \text{Eq27}$$

Where:

- hx = CHTC at a distance *x* from the component surface (W/m^2.K)
- ρ = density (kg/m^3)
- *Cp* is the specific heat under constant pressure (for dry air @20°C = 1005 j/kgK)
- $U\infty$ is the mean air velocity (m/s)
- *Cf* is the skin friction factor
- *Pr* is the Prandtl Number (for dry air at @20°C = 0.713)

Alternatively, based on the Nusselt number correlation of Equation 28

$$hx = \frac{k}{x} \times 0.032 {Re_x}^{0.8} \times Pr^{0.43} \ \ldots\ldots\ldots\ldots\ldots\ldots \ \text{Eq28}$$

Where

- hx = CHTC at a distance *x* from the component surface (W/m^2.K)
- *Re* is the Reynolds Number
- *k* is the thermal conductivity of the air W/m.K
- *Pr* is the Prandtl number (for dry air at @20°C = 0.713)
- *x* is the distance away from the wall (m)

Equation 28 is based on the Nusselt number calculation (Eq4) which is the ratio of convective to conductive heat transfer. While this is perfectly acceptable for heat flow across heat exchangers, particularly with a liquid medium, Leinhard insists this method is not as accurate for extremely turbulent flow (such as onto a building wall) where the convective heat flow far outstrips the conductive heat flow into the air.

2.11.3 Surface Roughness

The ASHRAE *Hand Book of Fundamentals* gives the data shown in Table 4. The value for CHTC is directly affected by the surface roughness (R_f) as shown in Equation 29.

$$Nu_{fx} = R_f 0.0296 {Re_x}^{0.8} Pr^{0.43} \qquad \text{Eq29}$$

Note that ASHRAE give a value for the multiplier (0.0269) in this formula which is at odds with the value given by Leinhard and several other sources (0.032). The difference is due to whether the writer of individual articles is investigating a liquid or a gaseous (air) medium. Leinhard suggests manipulating the constant (9 – page 325) to get better agreement with the data for specific Reynold Number conditions.

As the Nusselt number is directly affected and the CHTC is a direct function of the Nusselt number (Eq 27 & Eq 28), there is a direct relationship between R_f and CHTC (shown in Eq 21 as h_{fx}).

$$h_{fx=Rf\times \rho \times Cp\times U_\infty} \frac{Cf/2}{1+12.8\times(Pr^{0.68}-1)\sqrt{Cf/2}} \qquad \text{……….Eq 30}$$

Where

- h_{fx} is CHTC considering roughness factor at a distance *x* from the component surface

Table 4 Forced convection surface roughness number

ASHRAE Roughness number	Example surfaces with this roughness number	Forced convection multiplier, R_f
6	Glass, paint on pine	1.00
5	Smooth plaster	1.11
4	Clear pine	1.13
3	Concrete	1.52
2	Brick, rough plaster	1.67
1	Stucco	2.10

2.12 Literature Review Summary

This chapter has collated information from several sources that will be used later in the document to build a working model for heat flux through buildings' external envelope.

The model for radiative heat transfer is well documented and the Stefan-Boltzmann model will be used henceforth to calculate heat flow radiated from a hot surface to a cool surface. The Fourier model of conductive heat transfer is again a proven model and shall be used henceforth to calculate heat flow through a solid material.

The convective model is not so clear cut. When concentrating on convective heat loss from buildings the literature review has identified three possible models:

1. The Clear model (further refined by Hagishima) in Equation 6.
2. The modified Hagishima model (Eq 8) that also considers turbulence and wall size, and
3. The Leinhard model as modified by ASHRAE (Eq30).

The ASHRAE model additionally makes use of ROUGHNESS Factor that will be included in the Hagishima models for improved accuracy in the research herein. Each of the three convective models will be tested experimentally in ensuing chapters.

The use of infrared thermal imaging cameras will be addressed further into the research document to allow for quicker spot measurements and temperatures averaged over a surface for greater accuracy.

The amount of heat flowing through any component in the building's thermal envelope is now seen to be:

1. conductive flow from the interior, through the fabric of the component and then
2. a radiative heat flow from the component surface to the environment in parallel with
3. a convective heat flow from the component surface to the environment via air.

$$Q_{cond} = Q_{rad} + Q_{conv} \quad \text{.....................................Eq 31}$$

Where

- Qcond = Conductive heat flux through the component
- Qrad = Radiative heat flux from the surface of the component
- Qconv = Convective heat flow from the surface via air

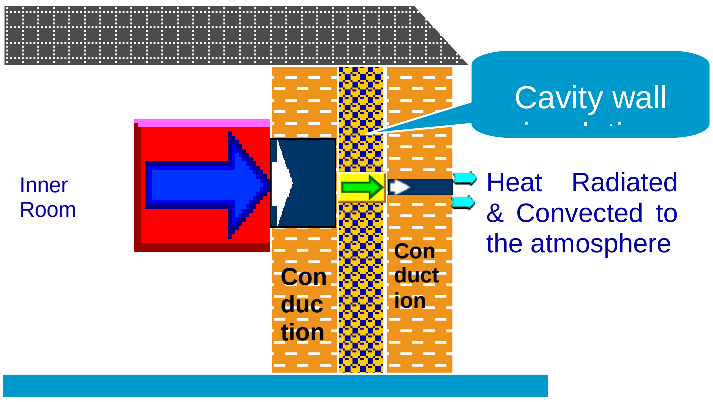


Figure 11 Visual representation of heat loss model from a building

In order to develop a comprehensive model for the heat flow and, ultimately, for the U-value it is necessary to build models for convective and radiative heat flows.

3.1 Radiation

The Stefan-Boltzmann equation to determine the amount of heat follow from the building is shown at Equation 22.

The variables required to calculate the radiation heat loss for each component are:

- ε = Emittance
- T_h = Temperature of the wall surface (K)
- T_c = Surroundings temperature (K)
- A_c = Surface area of the emitting component (m^2)

For each building component surface the emittance, the surface temperature and the surface area must be measured. For the surface shown in figure 12, as example, the components would be identified as follows:

Figure 12 Front elevation visual image of semi-detached dwelling (left-most building)

Front Elevation components:

1. Front door
2. Ground floor front window
    a. Glazing
    b. Window frame
3. First floor window – bedroom 1
    a. Glazing
    b. Window frame
4. First floor window – bedroom 2
    a. Glazing
    b. Window frame
5. Brick wall
    a. Below ground floor front window
    b. Between ground floor and first floor front windows
    c. Gable wall above first floor window
    d. Front wall around front door (hall exterior surface)
    e. Front wall on either side of ground floor front window
    f. Front wall on either side of first floor front window (bedroom 1)
    g. Front wall surrounding first floor window (bedroom 2).

Due to the differing possible internal temperatures, U-values and thus external temperatures, care should be taken in the decision of what constitutes a component.

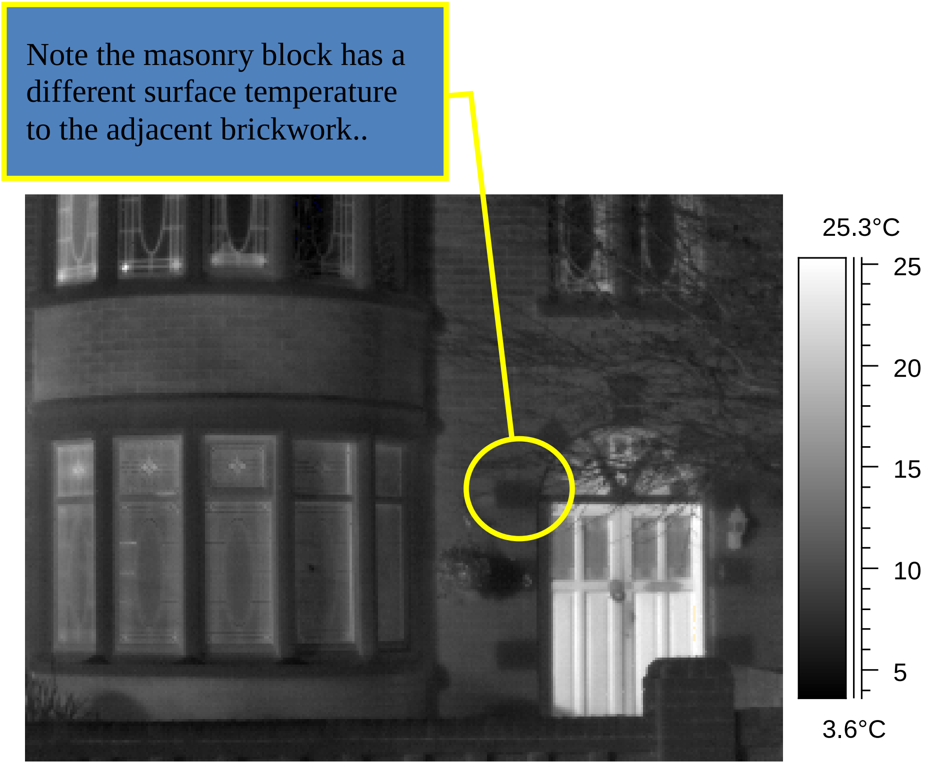


Figure 13 Thermal image of building shown in figure 12

Examination of figure 13 shows significant differences in external temperature for the glazing and the window frame, probably caused by differing emissivities as well as differences in actual surface temperatures.

Around the front door it is also possible to see differences in apparent temperature on the masonry blocks surrounding the front door as compared to the local brickwork. As the emissivity of paint of the masonry block (ε=0.94) and brickwork (ε=0.93) are very similar (see Appendix 3 - Table 10 and Emissivity Tables (19)) the temperatures must be substantially different indicating different heat flow through the brick as compared to heat flow through the masonry block and therefore different U-values. This demonstrates the importance of identifying specific components if accurate heat flux must be calculated.

There is no apparent reason for not using the Stefan Boltzmann mathematical model for radiative heat flow so equation 22 will be used for the radiation heat flux although accurate modeling will require calculations for each type of surface.

3.2 Convection

Although convection uses the same basic Fourier formula for heat flow as conduction it is not usually possible to calculate CHTC directly as the heat flow would first be required as per Equation 24.

The intention is to calculate the heat flow so we must first calculate the CHTC. At this stage the author was not sure which model would be the most effective so data was collected to satisfy Leinhard, Clear and Hagishima's models. The following variables were collected:

1. Ambient conditions:
    a. Ambient air temperature
    b. Wind speed
    c. Wind direction
    d. Air density
    e. Air dynamic viscosity
    f. Specific heat of air at constant pressure
    g. Air Prandtl number
2. For each component
    a. Surface roughness
    b. Surface area
    c. Surface temperature

The various methods of calculating CHTC that have been discussed are evaluated below for a particular set of conditions:

1. Method 1: Linear curve fit ax+b as per Clear (3) and later modified by Hagishima (6) Eq 6
2. Method 2: Equation 8 as per Hagishima et al (6)
3. Method 3: Equation 30 as per Leinhard (9), modified by ASHRAE

This section illustrates the quantitative differences between the three methods when considering identical variables on a typical building. Three scenarios where considered for the comparison:

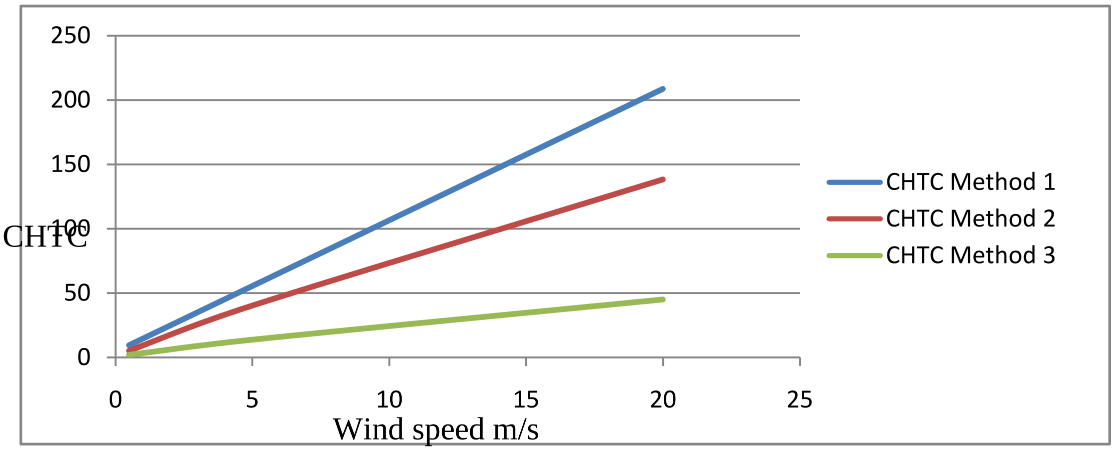
1) Low wind conditions (wind speed = 0.5m/s)
2) Light wind conditions (wind speed = 5m/s)
3) Heavy wind conditions (wind speed = 20 m/s)

Variables set as follows:

a. Ambient air temperature — 5°C
b. Wind direction — normal to surface
c. Air density — 1.205 kg/m^3
d. Air dynamic viscosity — 1.983x10-5 kg/m.s
e. Specific heat of air at constant pressure — 1005 j/kg.K
f. Air Prandtl number — 0.719
g. Surface roughness (assume brick wall) — 1.67
h. Surface area — 10 m^2
i. Surface temperature — 9°C

Table 5 Calculated CHTC (W/m^2.K) for three different calculation methods

wind speed m/s	Method 1	Method 2	Method 3
0.5	9.575	5.167264	2.046412
5	55.52	40.2032	13.80629
20	208.67	138.2599	45.02422



From table 5 it is apparent that while the relationship between CHTC and wind speed is virtually linear in all cases there are substantial differences between the methodologies as the wind speed is increased.

- Method 1 uses a very simplistic application of wind speed only (ax+b) and does not consider the size of the wall under consideration. The fluid properties are intrinsic as the results are based on empirical data collected on air blown buildings but as Hagishima pointed out, the results will vary depending on building size as the amount of turbulence will vary depending on the distance from the wall edge.
- Method 2 again uses empirical data to compensate for fluid (air) properties and the size of the wall is included in the calculation.
- Method 3 is theoretical and has been compiled for gaseous and liquid fluids. The values of certain fixed parameters should be changed depending on fluid type (Leinhard – 9 page 324). The fixed parameter values given by Leinhard and ASHRAE are generic and, as with method 1, there is no adjustment for wall size.

The experimental data section will set out to determine CHTC values empirically and will be used to decide which of the above models is most suitable for buildings.

3.3 Model development

To calculate the U-value and R-value of the building thermal envelope components one must first calculate the heat flow through the building envelope. Combining the heat flow and dividing by the component surface area and the temperature gradient across the component one arrives at the U-value.

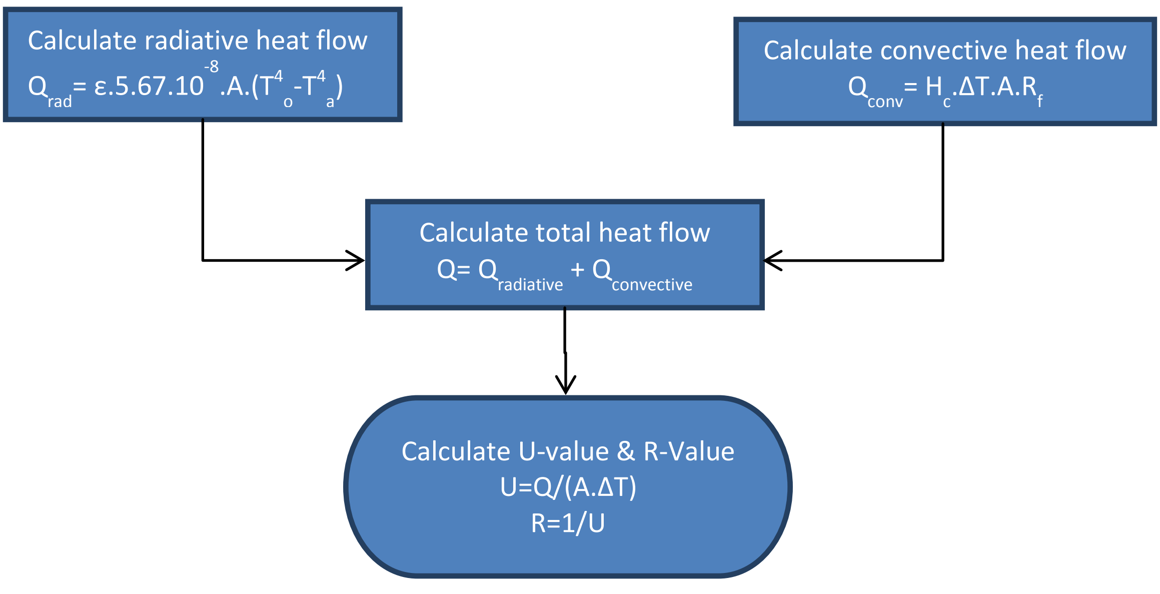


Figure 14 Model workflow to calculate U-value

Figure 14 gives a summary workflow of the model to calculate U-value and R-value. All components are well understood with the exception of the calculation of h_c (CHTC). The techniques available and identified in this study to calculate CHTC have been listed in section 5.0 (page 53) – the author identifies the most effective method of calculating CHTC in chapter 4 by the use of experiment.

Chapter 3 and Chapter 2 have defined the measurements required to identify heat loss through the building so objective 2 is satisfied.

Chapter 4

4.0 Experimental Data

4.1 Setup

To determine the total amount of heat loss from the building envelope via discrete components it is assumed that there is zero mass transfer. This means that the heat transfer from the exterior surface is limited to either conduction, convection or radiation. The Literature Review shows that the current state of empirical knowledge regarding convective heat transfer typically incorporates any conductive heat transfer at the external envelope surface by incorporating the boundary layer, the transitional layer and the free air layer.

Empirical data for external heat transfer therefore needs only to include radiation and a convective/conductive mechanism. Summing the external heat mechanisms gives the total heat loss from the external surface. The heat flux travels from the building interior to the exterior via conduction and convection (in the case of a cavity). If one assumes that the total heat flux from internal to external surface is via conduction then one can calculate the *equivalent* heat conductivity or resistivity for each component allowing direct comparison of one component to another for thermal insulation purposes.

In order to develop a realistic model for heat loss the author needed to develop a specific model for CHTC. The author decided to follow the hotbox/MoWITT path and test three different materials under controlled conditions. A box with five insulated sides was prepared so that the open side could be fitted with the test media. The box selected was a COLEMAN 50 litre cool-box with removable lid and a separate drain connection. There are no data on the actual insulation value of the cool-box walls (despite numerous requests to Coleman) but there was no measureable temperature difference to ambient at the outside of the box once the tests were under way so it may be assumed that thermal resistivity of the box walls is so high as to allow only insignificant heat flux.

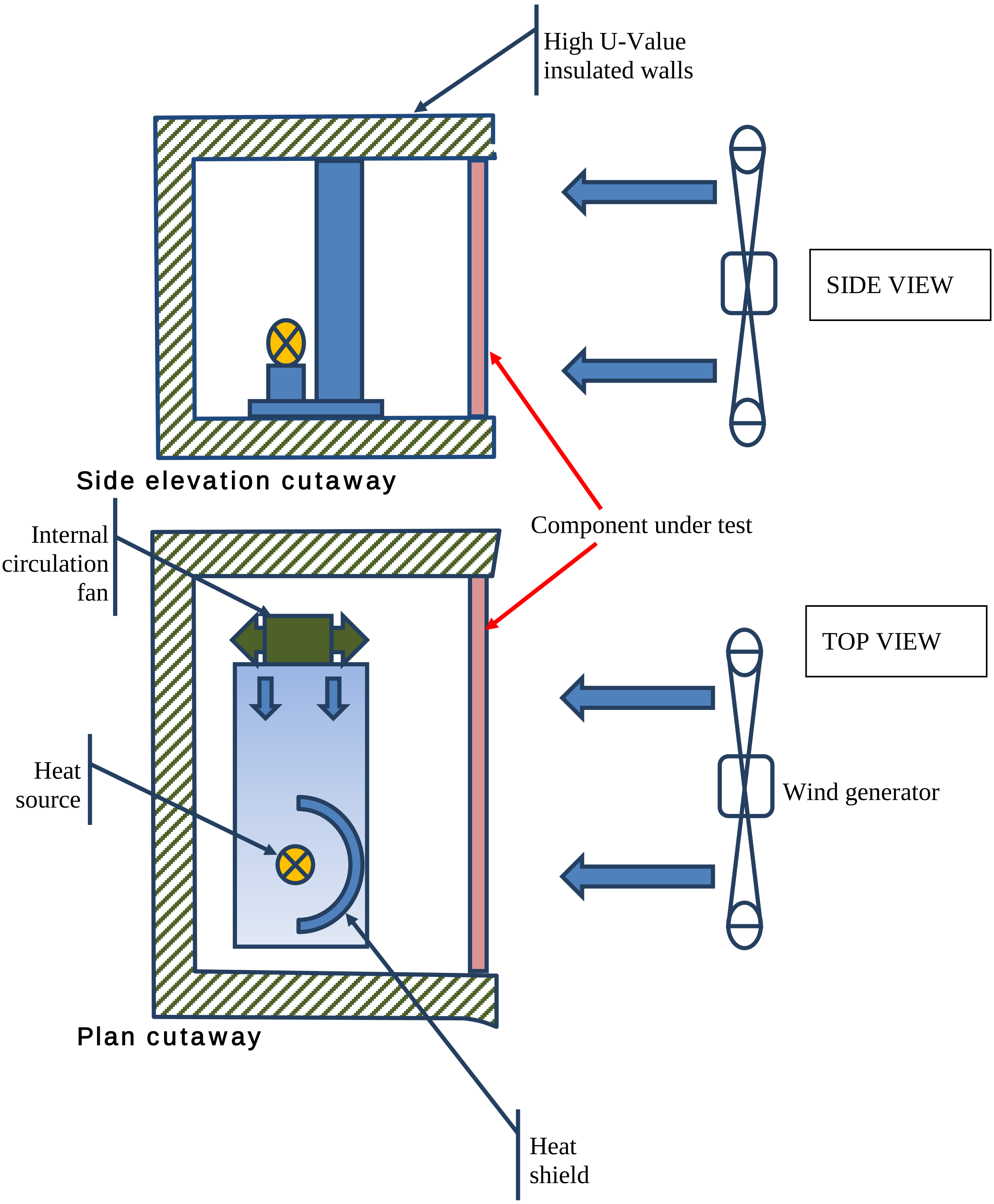


Figure 15 Hotbox layout

A heat source was placed inside the hotbox as shown in figure 15. The heat source was an electric lamp of known wattage. A 13w fan was also fitted inside the hotbox to ensure optimal temperature distribution. A heat shield was placed between the heat source and the tested component to minimise radiation transmission through the tested component.

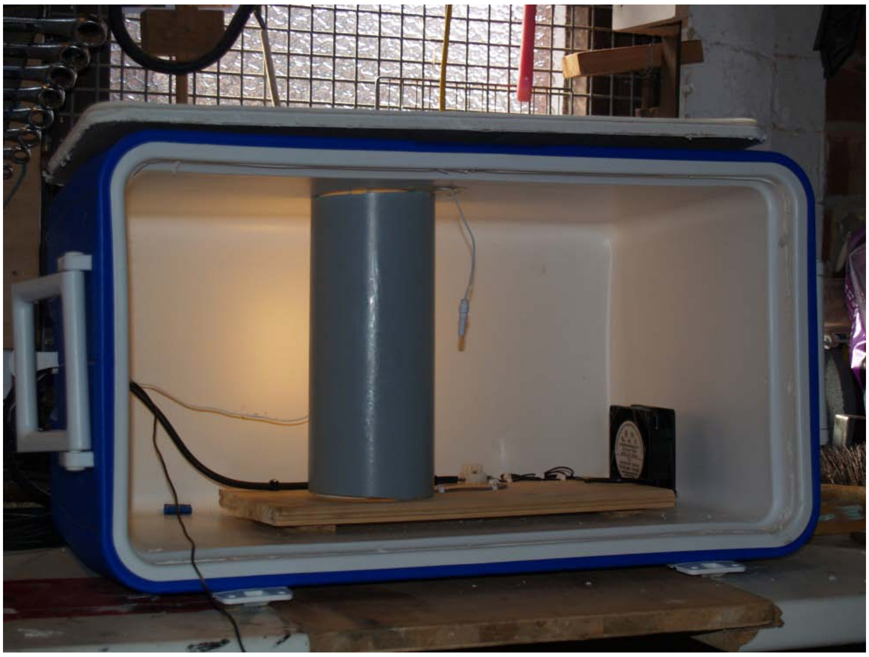


Figure 16 Hotbox fitted with heat source lamp & circulation fan

Temperature probes were fitted at the following positions:

1. Inside the hotbox at the horizontal mid-position, 5cm from the test medium wall and 5cm from the top of the hotbox.
2. At the geometric centre of the test medium wall inside in contact with the test medium.
3. Outside the hotbox in the wind flow.

The three media tested were as follows:

1. Plasterboard – 9mm thickness - British Gypsum Gyproc
    a. The Gyproc was trimmed to size and fitted inside the coolbox lid spigot in the same manner as the glass media. The gyproc was sealed to the coolbox wall to avoid mass transfer.

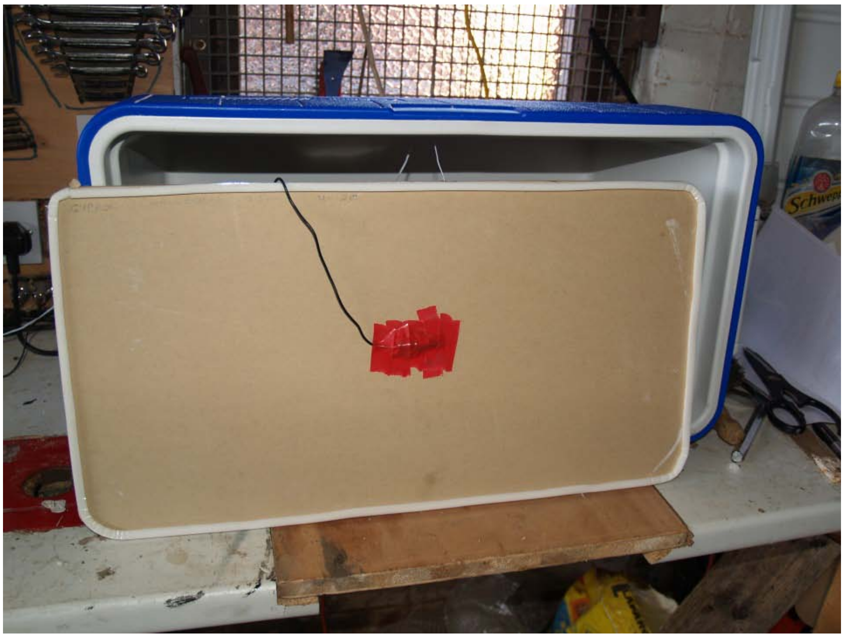
b. 

Figure 17 Gyproc prior to installing into lid spigot showing inside location of digital thermometer sensor

c. 

Figure 18 Gyproc installed into lid spigot showing silicon sealant

2. Glass – single thickness of 6mm – Pilkington’s Optifloat Glass.
   a. The glass was purchased locally and trimmed to size by the vendor so as to fit inside the spigot surface. To ensure maximum strength, the glass was fitted in a wooden frame as shown in Figure 18, which was inserted into the spigot.

b. The optifloat was sealed into the wooden frame and the wooden frame into the lid spigot using silicon white sealant to avoid heat transfer through air leakage (mass transfer).
c. The glass was painted with white spray paint on the inside to minimise radiation being transmitted through the glass during the test (figure 19). Several spots of red electrical insulating tape of known emissivity value were placed on the outside of the glass.
d. 

Figure 19 6mm Optifloat glass fitted & sealed inside wooden frame

e. 

Figure 20 6mm Optifloat fitted into coolbox lid spigot after spray painting

3. Brick – Single layer standard brick.
    a. Due to the much thicker dimension of the brick it was considered unfeasible to trim the brick to the spigot size. In this case the coolbox was attached to an existing wall and sealed against the wall around the outer edges of the coolbox opening.

    b. 

Figure 21 Exterior brick surface. Red tape indicates position of hotbox on the other side of the wall.

4.2 Experiment Results

After setting up the hotbox and energizing the heat source, three sets of readings were taken for the glass and the gyproc.

1. No external air movement (forced convection) so that natural convection takes place.

2. Air mover (fan) placed 1 metre from the hotbox with an air speed controlled at 2.7 and then 5.4 m/s.

3. Air mover placed at an angle of 45° to the hotbox with an air speed of 5.4 m/s.

Due to space limitations the brick wall was tested under wind conditions of

a. Natural convection and
b. Air speed of 2.7 m with the air mover at a fixed position so that wind direction is normal to the wall

The infrared thermal images are attached in Table 9.

Data is attached in Table 6. In each scenario the time to achieve thermal stability was significant and measured in hours. Scenario 3 (single brick envelope) took ten hours to achieve thermal stability under natural convection conditions. Due to the long time to collect the data the number of data are limited.

4.3 Thermal sensor error compensation.

Even though the thermometers were sold as accurate to ±0.1°C it was considered prudent to check the accuracy; to that effect the sensors were placed in a bath of ice and fresh water which was agitated and mixed well to achieve an actual temperature of 0.0°C. Several thermal images were taken and one is shown below as figure 22.

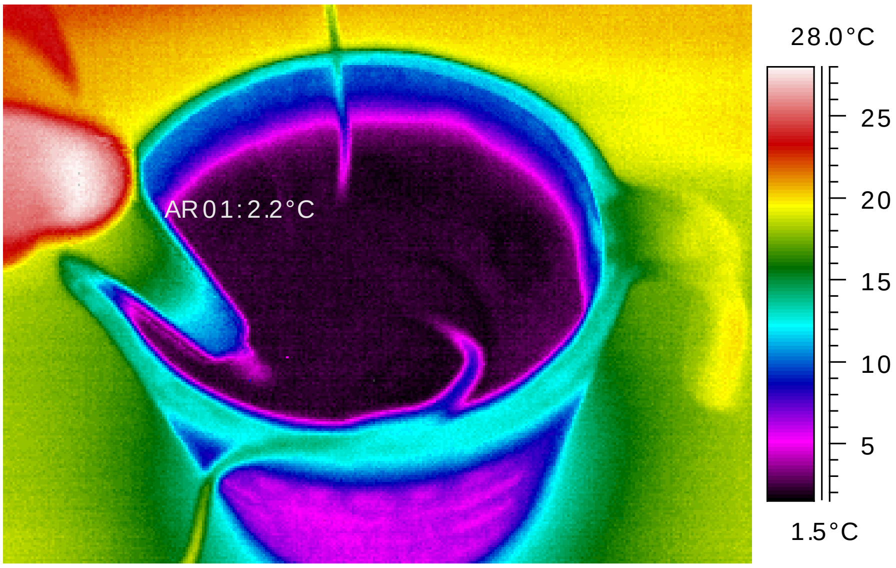


Figure 22 - Thermal sensor error measurement

Of the temperature measurement taken the following errors were noted:

Table 6 Temperature Corrections

1. Outside air temperature: reading was 0.5°C high
2. Inside wall temperature : reading was 0.3°C low
3. Thermal Imaging camera: reading was 2.2°C high

The thermal imager consistently read 2.2°C high at an actual temperature of 0°C. Imager documentation claims a *sensitivity* of <0.1°C whereas it claims an *accuracy* of ±2%. The sensitivity only means that temperature differences of better than 0.1°C may be identified using the thermal imager. The accuracy is worse, however and (even with an accurate emissivity value) the actual error of the camera should be checked if accurate data are required.

For all calculations involving temperature, the corrected temperature is used in this document.

4.4 The Calculation & Analysis Steps

Step 1

The temperature data collected were corrected accordingly as per table 6.

Step 2

The area of the tested fabric was calculated.

Step 3

The outside temperature of the tested component was averaged over the subject area using the IRWIN software. The averaged temperature is shown on each image in Table 5 as AR01 (before error correction).

Step 4

The wind speed was recorded using the ultrasonic anemometer.

The wind value was further recorded and modified by direction to give an effective wind speed. *The purpose of this step is to identify any differences in CHTC affected by the angle of attack.*

$$W_{eff} = V \times \sqrt{Sin\Theta} \qquad \text{Eq32}$$

Where

- W_{eff} = effective wind speed (m/s)
- V = wind velocity (m/s)
- Θ = Angle of attack of air against the wall (90° is normal to the wall, 0° is parallel to the wall).

Step 5

The radiant heat loss was calculated as per equation 21.

Step 6

The convective heat transfer coefficient was calculated. Using various power consumptions at zero wind speed on each of the materials under investigation, an average value of $CHTC_{laminar}$ was calculated: The wide differences in

CHTC were a matter of concern to the author until he applied the ASHRAE roughness factors.

By subtracting the radiant power from the input power we are left with the power being convected. By averaging the convective power at zero wind speed we obtained a base value for $CHTC_{laminar}$.

AVG (11.181*gyproc*, 9.6803*optifloat*, 12.403*optifloat*, 19.662*brick*) = 13.232

By dividing each CHTC by the appropriate ASHRAE roughness factor a commonised value for CHTC was obtained.

AVG (10.0725*gyproc*, 9.6803*optifloat*, 12.403 *optifloat*, 10.9825, *brick*) = 10.9825

Step 7

The turbulent CHTC was calculated using the three models being evaluated. Where applicable the CHTC was added to the laminar CHTC to give an overall CHTC. Each value was then compared to the input power and the calculated convective power (input less radiant) to see which was most accurate.

Step 8

a) CHTC was calculated using Leinhard's format. As the Leinhard formula gives zero CHTC at zero wind speed, the averaged CHTC at zero wind speed based on the difference between input heat and radiant heat was added to the calculated CHTC.
b) CHTC was then calculated using Hagishima's refined model (Eq 8). As this model gives zero CHTC at zero wind speed, the averaged CHTC at zero wind speed based on the difference between input heat and radiant heat was added to the calculated CHTC.
c) Using Hagishima's format for derivation of CHTC (ax+b) with a value of 10.21 for a and 4.47 for b the value for CHTC thus became

$$CHTC = 10.21 \times U_{\infty} + 4.47 \qquad \text{Eq33}$$

The convective heat loss power was calculated using Equation 16.

Step 9

Values were then calculated for

- Conductive heat loss

Step 10

Values were calculated for

- K-value, $K = \frac{Q \times t}{A \times \Delta T}$
- U-value $U = \frac{Q}{A \times \Delta T}$
- R-value. $R = \frac{A \times \Delta T}{Q}$

4.4.1 Discussion of Results

Table 7 shows the data reduced to those data recorded under steady state conditions.

Table 7 Reduced Data

Power W	Date	Time	Image #	Surface	Ambient	Corrected Ambient	Area	Tinside wall	Tair inside	Thickness	Wind Speed	Wind Direction	Internal Air Speed	emissivity	ASHRAE Roughness factor
53	31/08/2010	13:40	7	Gyproc 9.5	18.00	17.50	0.161	36.10		0.0095	3	90		0.95	1.11
53	31/08/2010	14:10	10	Gyproc 9.5	18.30	17.80	0.161	34.30		0.0095	5.4	90		0.95	1.11
53	31/08/2010	14:25	14	Gyproc 9.5	18.50	18.00	0.161	35.70		0.0095	5.4	45		0.95	1.11
	25W+13W														
38	01/09/2010	13:15	8	Gyproc 9.5	18.20	17.70	0.161	39.50	44.50	0.0095	0	0	2	0.95	1.11
38	01/09/2010	14:10	11	Gyproc 9.5	18.60	18.10	0.161	34.30	40.90	0.0095	2.7	90	2	0.85	1.11
38	01/09/2010	14:55	14	Gyproc 9.5	19.30	18.80	0.161	33.70	39.80	0.0095	5.4	90	2	0.85	1.11
38	01/09/2010	15:20	16	Gyproc 9.5	19.30	18.80	0.161	33.90	39.80	0.0095	5.4	45	2	0.85	1.11
	12W+13W														
25	01/09/2010	18:05	17	6mm Float	19.10	18.60	0.125	32.90	38.30	0.006	0	90	2	0.93	1
25	01/09/2010	18:45	18	6mm Float	19.00	18.50	0.125	26.60	34.20	0.006	2.7	90	2	0.93	1
25	02/09/2010	09:55	2	6mm Float	17.10	16.60	0.125	22.30	29.80	0.006	5.4	90	2	0.93	1
25	02/09/2010	10:10	3	6mm Float	17.40	16.90	0.125	22.60	29.80	0.006	4.9	45	2	0.93	1
	Painted														
25	02/09/2010	15:45	3	6mm Float	20.30	19.80	0.125	24.80	29.60	0.006	5.4	45	2	0.93	1
	Painted/Shielded/Potted														
25	03/09/2010	10:35	4	6mm Float	17.70	17.20	0.125	31.50	36.10	0.006	0	0	2	0.93	1
25	03/09/2010	10:35	5	6mm Float	17.70	17.20	0.125	27.00	33.50	0.006	3.2	90	2	0.93	1
53	03/09/2010	16:35	16	Single Brick	22.40	21.90	0.209	38.20	43.30	0.11	0	90	2	0.96	1.67
53	04/09/2010	08:10	1	Single Brick	18.60	18.10	0.209	37.90	43.30	0.11	2.7	90	2	0.96	1.67

The data shown in table 7 reflects those data taken recorded during steady state thermal conditions. Much of the recorded data was taken as the temperatures were increasing – those data may not be used in the analysis as the heat flow analysis requires a steady state condition in which the heat entering the building envelope component equals the heat flow from the component and the component temperature is exhibiting no recordable temperature change.

Table 8 CHTC calculation comparison 6

Leinhard Method Eq 30			Hagishima Method Eq 8					Hagishima Method Eq 6			
Est CHTC Turb + Lam Eq29	Est Qh Eq30 Watts	least squares	Eq8 CHTC	Eq8 CHTC + Lam	Eq8 CHTC OR Lam	Eq8 Watts	least squares	Eq6 CHTC	Eq6 Watts	least squares	Target Conv watt
21.57537	28.1277	340.3443	32.40807	45.63969	32.40807	42.25024	18.71325	23.62	30.79328	249.0983	46.57612391
26.66925	24.89602	554.3339	54.71432	67.94594	54.71432	51.07637	6.948777	34.348	32.0642	268.177	48.44031196
24.90025	22.84387	658.8568	46.88637	60.11798	46.88637	43.01426	30.226	34.348	31.51137	289.0239	48.51207337
13.23162	30.87962	22.91323	0	13.23162	10.9825	25.63068	0.213589	10.21	23.82784	5.130212	26.09283986
20.89759	25.226	46.34802	29.50416	42.73578	29.50416	35.61521	12.82553	22.279	26.89354	26.4237	32.03393665
26.66925	20.6036	185.0601	54.71432	67.94594	54.71432	42.2701	65.00904	34.348	26.53589	58.85017	34.20727722
24.90025	22.4431	123.5184	46.88637	60.11798	46.88637	42.25962	75.73597	34.348	30.95854	6.751885	33.55697823
13.23162	21.65811	33.78955	0	13.23162	10.9825	17.97665	4.54296	10.21	16.71219	0.751619	15.84522767
20.18809	18.27012	3.321912	29.62243	42.85405	29.62243	26.80815	45.09683	22.279	20.16238	0.004851	20.09273172
25.41972	14.79199	51.18287	54.93364	68.16526	54.93364	31.96643	100.4049	34.348	19.98744	3.836759	21.94620938
23.01392	15.11739	41.1398	43.17037	56.40199	43.17037	28.35776	46.59889	32.113	21.09439	0.190996	21.53141794
23.81642	9.055122	193.2161	47.07431	60.30593	47.07431	17.89789	25.57783	34.348	13.05928	97.93198	22.95534012
13.23162	18.51685	1.343897	0	13.23162	10.9825	15.36935	3.953095	10.21	14.28828	9.42064	17.3575885
21.20633	19.34303	0.600024	34.46388	47.6955	34.46388	31.43571	128.0986	24.514	22.36008	5.028496	20.11764666
13.23162	27.63291	180.3635	0	13.23162	10.9825	22.93585	328.5883	10.21	21.32256	389.6792	41.06285711
22.32941	30.41266	229.7776	25.65659	38.88821	25.65659	34.94428	112.9289	22.279	30.344	231.864	45.5710785
	349.8181	2666.11				509.8085	1005.462		381.9153	1642.164	
	Least squares Sum	51.63439				Least squares Sum	31.70903		Least squares Sum	40.52362	
	Least squares Error	14.76%				Least squares Error	6.22%		Least squares Error	10.61%	

Table 8 shows the three different methods of calculating CHTC:

1. Leinhard and ASHRAE method as per Equation 30
2. Hagishima method as per Equation 8
3. Hagishima method as per Equation 6

Considering the fact that the convective heat flux was determined by the heat source (assuming no heat loss through the insulated walls), then the convective heat loss is the conductive heat flow through the target material less the radiative heat loss from the target material.

The wind speed was modified by the SINE of the angle of attack in STEP 4 of the Analysis of Results and gave more consistent results than just using the wind speed alone (see tables 7 and 8). This satisfies Objective 5.

The methodology used to calculate the "least squares" error was as follows:

1. Determine the actual heat input into the hotbox.
   a. This is the wattage of the lamp plus the wattage of the circulating fan inside the hotbox.
2. Calculate the radiant heat loss using Stefan-Boltzmann Eq22.
3. Subtract the radiant heat loss from the actual heat input to determine the "target" convective heat loss.
4. Subtract the calculated heat loss from the target heat loss to determine the error.
5. Square the error and add the squares to provide a sum of error squares.
6. Calculate the square root of the error squares and compare that to the sum of the actual convective heats to provide a percentage error, independent of sign.

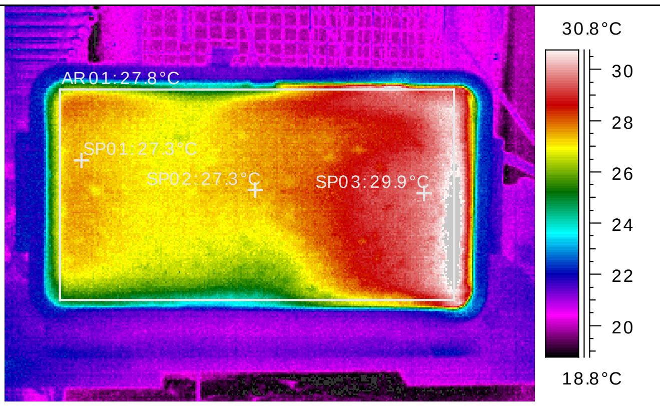
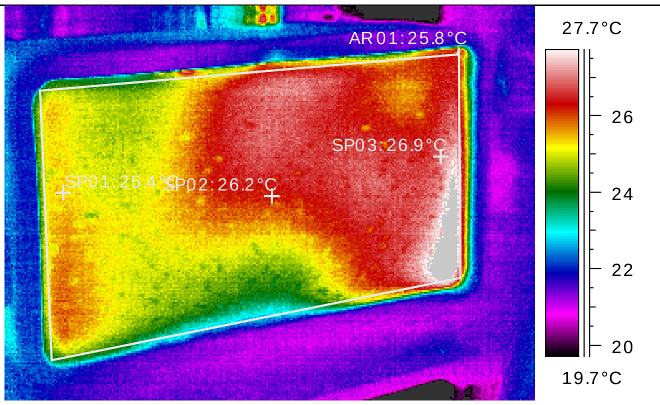
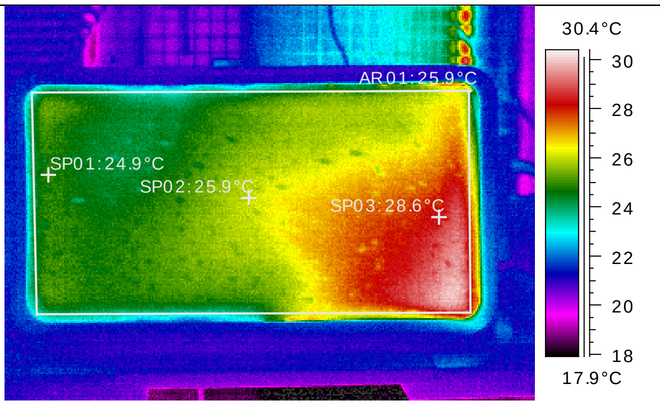
The best result of the least squares comparison was the Hagishima Eq8 methodology.

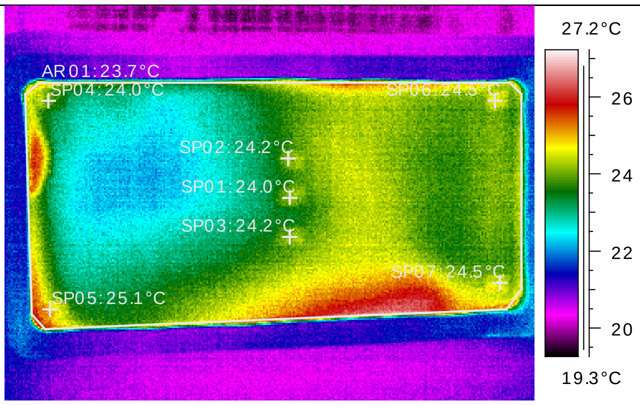
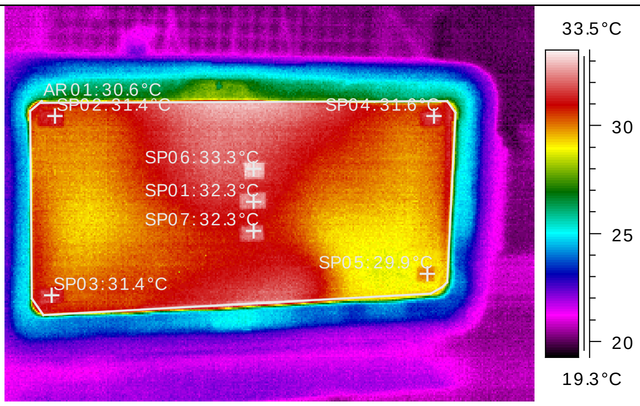
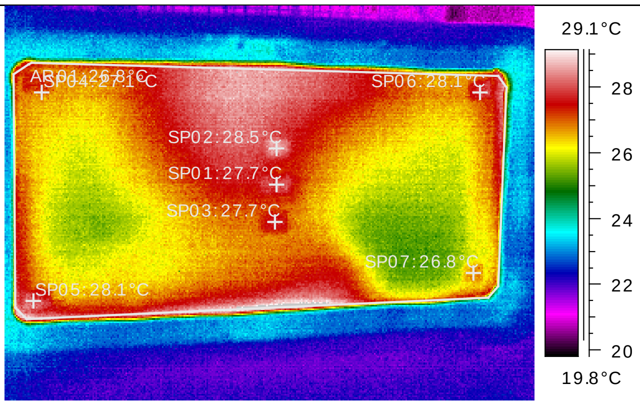
The least squares error is quantification of the error between the calculated convective heat flux and the actual convective heat flux. The least squares error for Hagishima method Equation 8 (6.4 step 8c) gives the least error at 6.22% so this is the method to be used in the model.

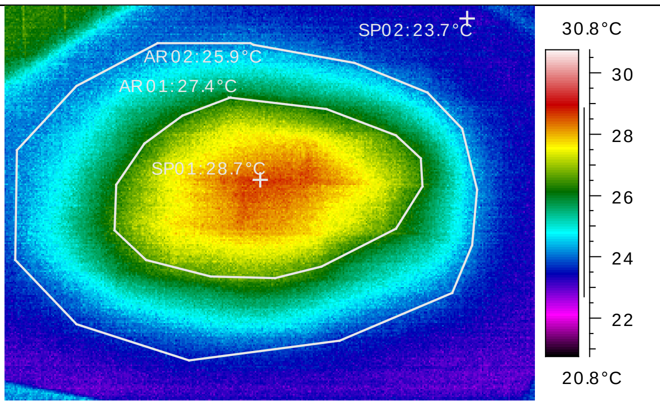
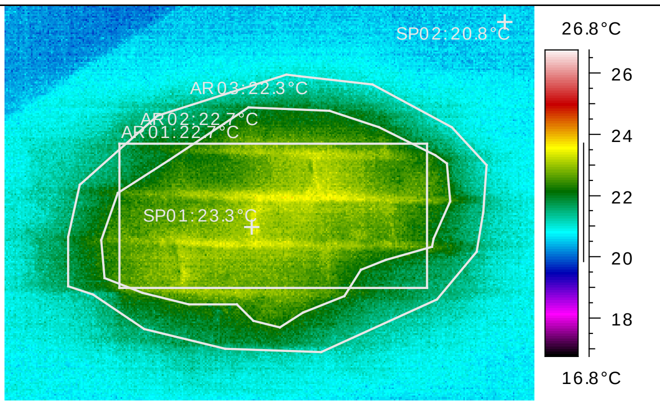
Chapter 4 has so far identified a working and proven model so Objectives 3 and 4 are satisfied.

Table 9 shows thermal images of the hotbox during test conditions.

Table 9 Thermal Images

Image #	Date/Time	Test Material	
A0831-07	31 Aug 2010 13:40 hrs	Gyproc 9.5 mm	
A0831-10	31 Aug 2010 14:10 hrs	Gyproc 9.5 mm	
A0831-14	31 Aug 2010 14:25 hrs	Gyproc 9.5 mm	

A0902-02	2 Sept 2010 15:45 hrs	Floatglass 6mm	
A0902-03	3 Sept 2010 10:35 hrs	Floatglass 6mm	
A0902-05	3 Sept 2010 10:35 hrs	Floatglass 6mm	

A0903-16	3 Sept 2010 16:35 hrs	Single Brick	
A0904-01	4 Sept 2010 08:10 hrs	Single Brick	

It should be noted that the time taken to achieve thermal stability was significant so the number of data collected is necessarily limited.

The thermal images of the GYPROC (A0831-7, A0831-10, A0831-14) test show substantial differences in temperature (up to 3.9°C) across the test surface. The temperature differences are probably due to variations in the heat flow inside the hot box. The internal fan was placed at the right hand side of the hot box (viewed from the front) and was chosen to distribute the heat as uniformly as possible throughout the hot box by blowing onto the internal lamp heater.

The heat capacity of Gypsum is 1.09 J/g.K whereas Silica Glass is 0.84 (according to The Engineering Toolbox - http://www.engineeringtoolbox.com/specific-heat-solids-d_154.html) but glass has a higher density (2579 kg/m^3) than Pulverised Gypsum (1121 kg/m^3) so the actual heat capacity of the gypsum used in the experiment is much less than of the glass. This means that transient temperatures inside the hot box will show more quickly at the exterior of the Gypsum than at the exterior of the glass as is seen in the thermal images in table 5. As the brick is even heavier it is not possible to see the apparent temperature differences in A0903-16 and A0904-1.

4.5 Proving the Model

On the 18th February 2011 a survey was carried out at the Priory Hospital in Bartle, near Preston. The Chief Engineer, Mr Nick Erdbeer, gave his kind permission to use the hospital to prove or adjust the model as necessary.

The methodology for selecting and proving the model is shown in figure 23.

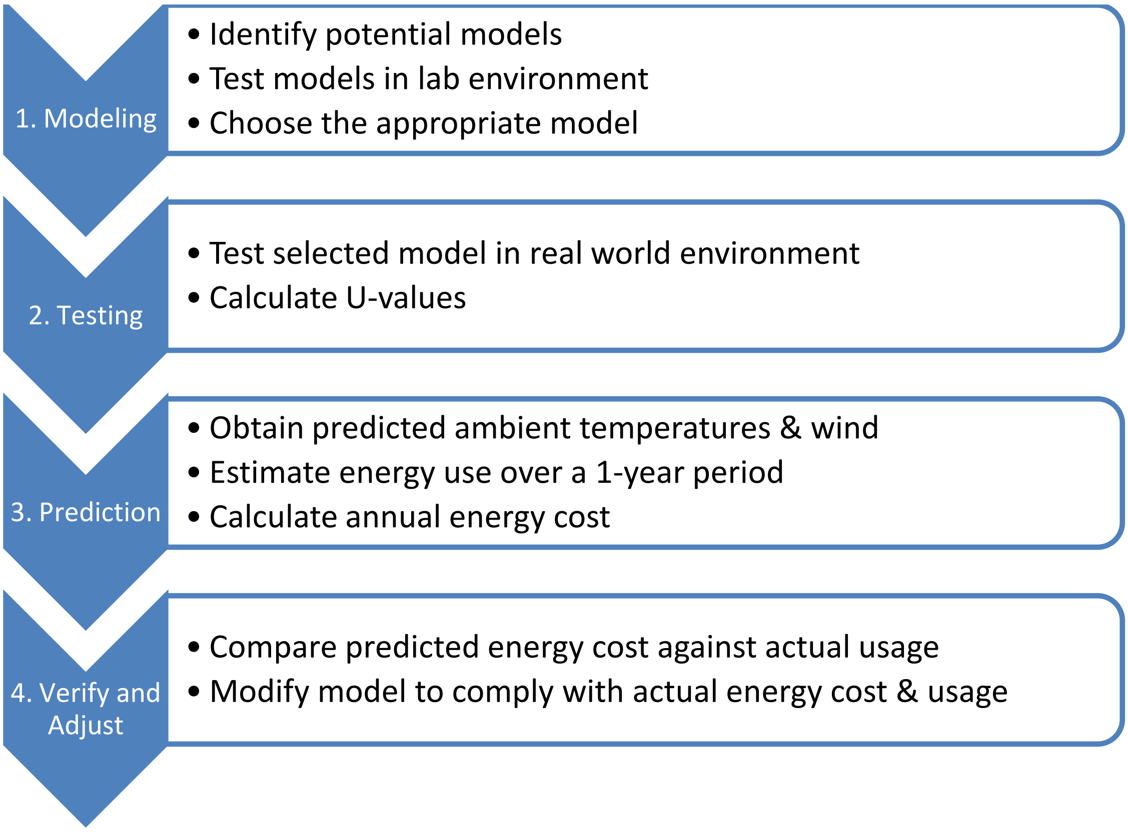


Figure 23 Methodology for proving the model

Part 1 has been addressed previously. The remaining parts will be addressed herein.

Part 2 is considered in section 6.5.1 by carrying out a physical survey on a large multi storey commercial building.

4.5.1 Survey details

Priory hospital has residential facilities for nineteen patients as well as day care and a therapy services department.

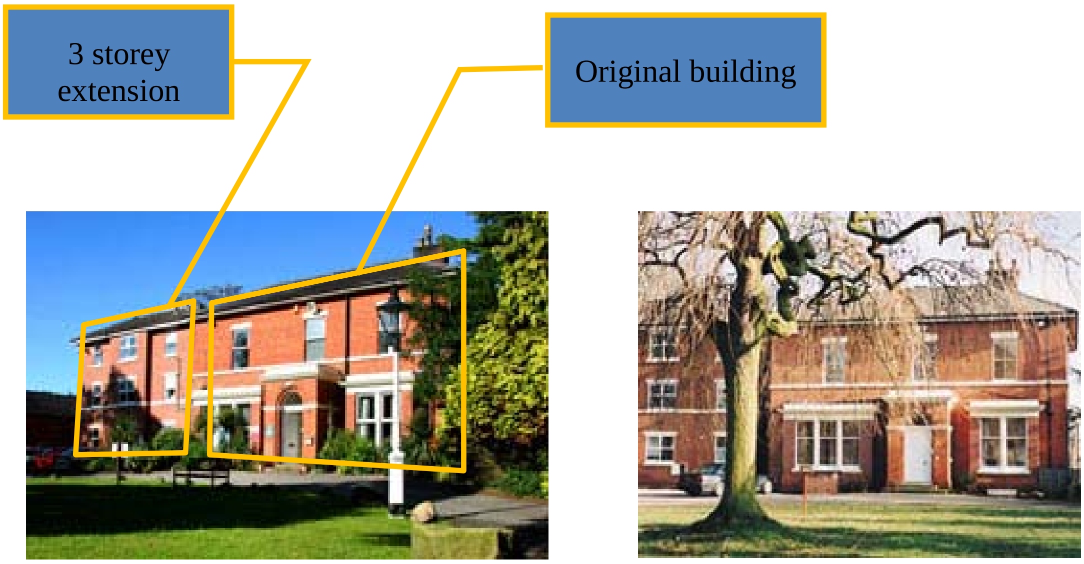


Figure 24 Priory Hospital, Preston

The original building is shown in figure 24 (to the right of the tree) with a newer (larger) extension on three floors added later to the left of the main building. The services department intends to keep the inside temperature at about 23°C but are aware of heating losses in both buildings but particularly in the older building which is a converted manor house.

The complete building has UPVC double glazing fitted throughout but the quality of the fitting varies from one window to another. The building is heating throughout with hot water radiators. The hot water circulating system is heated by a LPG fired boiler with a quoted efficiency of 80%. Mr Erdbeer advised that the annual cost of energy at the hospital during 2010 was:

- LPG £28,071.35
- Water £583.55
- Electric £5551.79

According to the Biomass Energy Centre *(http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,59188&_dad=portal)*

the cost of bulk LPG is as follows:

Price per Litre	kWh per litre	Pence per kWh
49p	6.6 kWh/ltr	7.4p /kWh

4.5.2 Survey Procedure

The survey was carried out on 10 February 2011. The author, with an assistant, arrived at the hospital at 9am and met with the chief engineer who gave the required site entry authorisation.

The equipment used on site was:

- FLIR PM575 thermal imaging camera
- Samsung handheld visual camera
- 5m steel measurement tape
- LCD digital thermometer for ambient temperature (corrected as per section 6.3 table 6 item 2.
- Ultrasonic wind speed meter.

The survey was carried out as follows:

1. Ambient data was collected at the start of the survey
    a. Wind direction and strength
    b. Ambient temperature
2. Thermal images and visual images were taken of each external elevation
3. The thermal imaging camera was used to measure average internal surface temperatures for each component in each room.
4. Physical size measurements were recorded for each external component (doors, windows, walls, roof etc.).
5. The survey was completed by 11am and ambient data recorded again.

4.5.3 Analysis of on-site data

The thermal images were analysed using IRWIN software from AGEMA systems and the average external temperature was extracted from each thermal image for each component:

Averaged external and internal temperatures were corrected as per section 6.3, table 6, item 1. The ambient and component temperature and wind data were recorded into a database and U-values for each component calculated using Equation 8.

Average ambient data was collected from the following sources for future energy prediction:

1. Wind
    a. Department of Energy & Climate Change
        i. Wind speed database – data can be extracted for any National Grid location at various heights above the ground. Data for 10m above ground was used for this survey.
        ii. http://www.decc.gov.uk/en/windspeed/default.aspx
2. Temperature
    a. UK National Meteorological Office
        i. Climate averages for specific locations – the location used for this survey was Blackpool – it is the closest available to the Priory Hospital at a distance of 11.3 miles.
        ii. http://www.metoffice.gov.uk/climate/uk/averages/19712000/

Using the calculated U-values and the averaged ambient data, an estimate was made of predicted energy usage for heating for this building.

4.5.4 Reconciliation of the Model to the results

Using only equation 8 for the calculation of CHTC was not possible on the day of the survey as there was no wind. The Hagishima model Equation 8 requires turbulent air flow (Re > 10^5), at each component external surface - a modification was therefore required.

The alternative Hagishima model (equation 6) was used to calculate CHTC in the event of laminar convective flow (Re < 10^5 or zero wind flow) and the primary Hagishima model (equation 8) was used if wind was measureable.

Combining Hagishima Equation 6 and Equation 8 in the database as follows:

$$Hc: IIf([We]<0.01,[NoWind],11.42*([WL]/2^{)\wedge-0.109}*[We]^{\wedge 0.891})$$

Where:

- Hc = CHTC
- We = effective wind speed
- NoWind = is the zero wind speed crossing value (4.47 in Equation 6).
- WL/2 = Distance from the component centre point to the component edge

The calculated energy loss using this method was £27,034.90 against an actual cost of £28,071.35 giving an error of 3.69%. The model satisfies the requirements as stated in Objective 7.

The report attached as appendix 9 calculates the heat loss by component type and ranks the heat loss as follows (highest loss first):

1. Brick walls
2. Roof
3. Windows
4. Doors.

From the data (see Appendix 8 and appendix 9) it is apparent that the most cost effective solution for the hospital would be to improve the insulation of the walls – probably through cavity wall insulation and secondly to improve the roof thermal insulation.

Chapter 5

5 Development of the Graphical User Interface.

5.1 Introduction

Determination of heat loss through a building requires a great many calculations leading to a requirement for computational capability. In the first part of this document the calculations were carried out using spreadsheets but it soon became apparent to the author that the very large spreadsheets became ungainly and difficult to use.

This chapter will describe the development of a database to enable manipulation of large amounts of data with an easy to understand visual output for the layman.

The database software used was Microsoft Access 2010.

5.2 Database Structure

5.2.1 Tables

The database is designed to accept data input and then carry out calculations of various parameters such as CHTC, radiation heat flux, conductive heat flux etc. The first stage therefore is to ensure the necessary data for the calculations are available within subsets or tables.

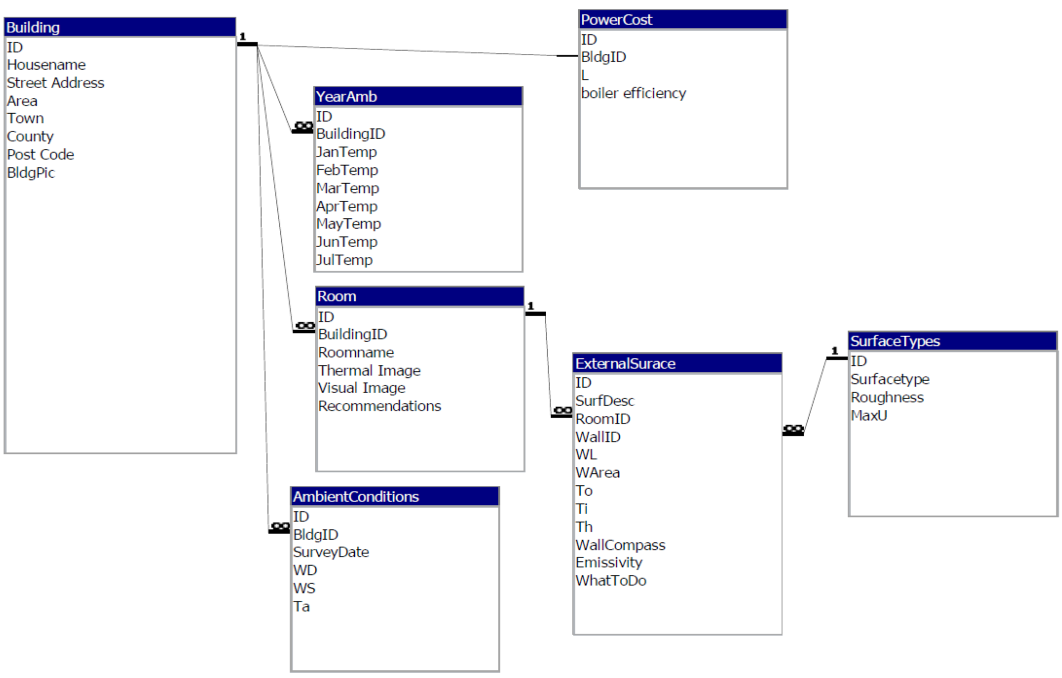


Figure 25 Relationships of tables

Figure 24 shows the base tables for data entry. The lines joining the tables show the relationships to enable the database to function and to enable the build of queries and reports. The leftmost table in figure 24 is titled **“Building”**. The **Building** table is the master table from which all other tables are eventually joined,

The **Building** table has the basic data for identification of the building being surveyed with the following fields:

- ID *a unique identifier*
- Housename *a text field to identify the building*
- Street Address
- Area
- Town
- County
- Post Code
- BldgPic *this is a link to a visual image of the building*.

The other tables such as **Room** include information about each room such as the name of each room as well as fields for the storage of thermal and visual images. The **ExternalSurace** table holds temperature data for each surface as well as the type of surface component (door, window, wall etc.), and emissivity. If there is a recommendation for improvement, that is also stored in the **ExternalSurace** table.

The **SurfaceTypes** table stores data about each various types of surface such as ASHRAE roughness factor and the maximum allowable U-value for each component based on Part L ADL2B and ADL2A 2010 Building Regulations 2000.

Several other tables also exist for storage of information such as the value of zero wind crossing factor as specified in Equation 6 as well as ambient data for each survey, power costs and annual average ambient data for different areas.

5.3.2 Calculations and Queries

Before any reports can be generated several basic calculations must be performed and data organised into *queries* so that similar data or data required for a particular report are grouped.

Within the database there are four main queries (not including queries for data entry etc.):

- Base Queries
    - Calc Query 1
        - This is used for the initial calculation of U-value under “as measured” conditions
    - Calc Query Avg
        - This is used to gather the data and initial calculation for energy and cost predictions.
- Report Preparation Queries
    - report detail query
        - This is used to prepare data and calculations for presentation into reports based on “as measured” data.
    - Report Avg Detail Query
        - This query prepares data and calculations for reports of predicted energy usage and future costs.

5.3.3 Data Entry Forms

To make the database as user friendly as possible the author decided to have data entered through pre-defined forms that are linked to the data tables.

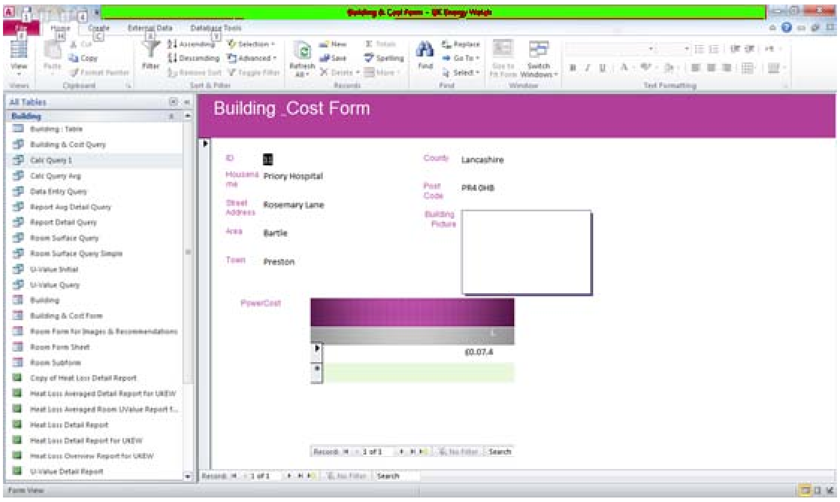


Figure 26 Data entry form for Building data

Figure 25 shows the data entry form for basic information such as address and location of the building under survey.

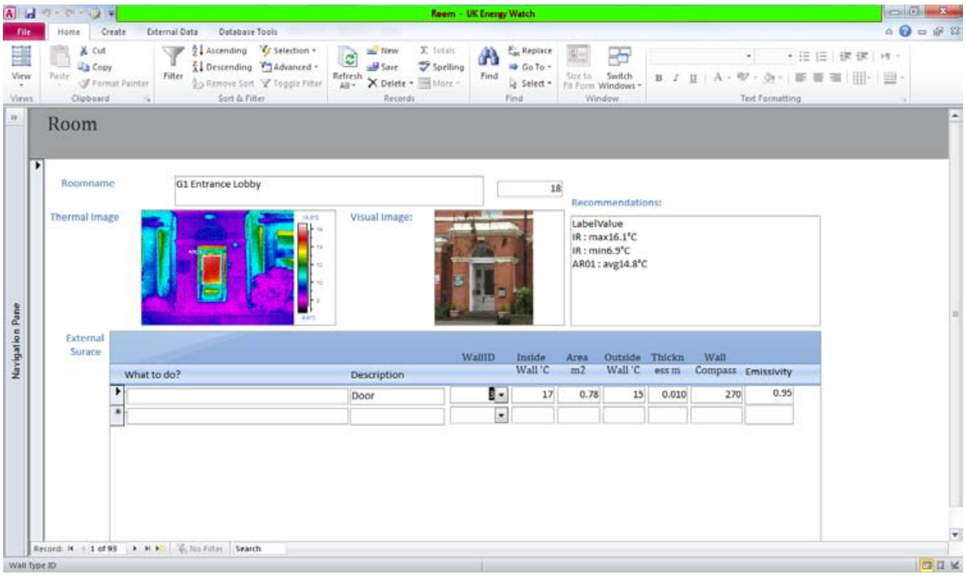


Figure 27 Detailed entry form for temperatures and areas

Figure 26 shows the data entry form for more detailed information about each component. In this form is entered such information as the visual and thermal images as well as essential data such as areas, temperatures, wall thickness, emissivity and the compass direction of the external surface.

5.3.4 Menu Structure

Within MS-Access the default menu system is based around "Switchboards". The main switchboard is shown in figure 27.

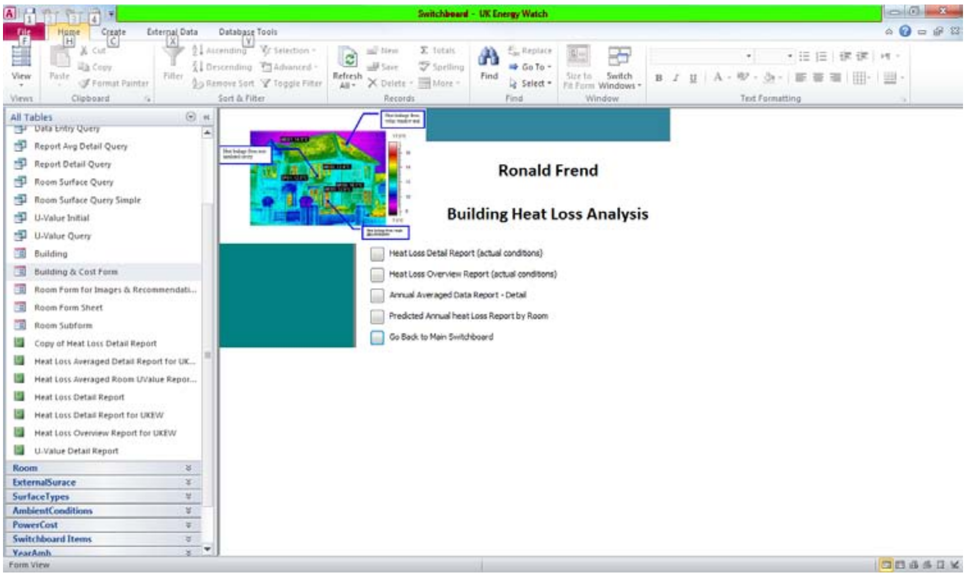


Figure 28 Main Switchboard

The main switchboard has a number of "push buttons" for quick and easy access to each of the main functions such as data entry, data editing and report generation.

5.3.5 Report Generation

The database has five reports defined from the main switchboard:

- Initial Conditions
  - Heat Loss Detail Report
  - Heat Loss Overview Report
- Future Energy Usage & Cost Prediction
  - Annual Averaged Data Report
    - *This report provides a prediction of heat energy usage over a 12 month period.*
  - Predicted Annual Heat Loss Report by Room
    - *This is a more detailed report giving heat loss per component and per room with an estimate of energy and cost savings if the component is brought up to Part L ADL2 minimum requirements.*

- Predicted Heat Loss by Component
    - *An overview report of predicted heat loss by component type.*

A copy of each report is provided in the appendix.

As the database is working as a GUI with the following functionality, Objective 7 has been achieved.

a. Determination of total heat loss from each surface component and each external elevation.
b. Determination of U and R value for each surface component.
c. Calculation of total heat loss from each room in a building.
d. Calculation of the cost of heating/cooling a building

Chapter 6

6 Conclusions and Recommendations for Further Development

6.1 Discussion of Results

6.1.1 Model veracity

The primary conclusion is that is possible to estimate with a reasonable degree of accuracy (<5%) the quantitative heat loss from a building by using a thermal imaging camera and some simple additional tools.

The model used in the calculation of predicted heat energy losses is based on a heat energy balance (Eq30) in which the total heat loss (i.e. the conductive heat loss through the building fabric for each component) is a sum of the radiative and convective heat flows (see figure 14). In order to calculate the convective heat loss it was found necessary to first determine the convective heat transfer coefficient and the method thereof was determined to be a combination of Hagishima's methods described in equations 6 and 8 (see section 6.4 page 69).

The convective heat loss from the external surface of a building may be accurately estimated by using the empirical formulae developed by Hagishima et al as follows:

a. With laminar wind flow ($Re < 10^5$) use:

$$h = 10.21\sqrt{u2 + v2 + w2} + 4.47$$

b. With turbulent wind flow ($Re > 10^5$) use:

$$h = 11.42 \cdot l^{-0.109} \cdot (\sqrt{(\overline{u^2 + v^2 + w^2}})^{0.891}$$

The report in appendix 8 shows a predicted heat loss cost of £27,034.90 whereas the actual heat loss cost in 2010 was £28,071.35 (page 74) giving an error of only -3.69%.

A further benefit of the accuracy of the model is shown in figure 29. The detailed breakdown of each type of component for the Priory Hospital shows that of the four types of components considered, the highest energy loss was from the walls.

1. Brick Walls
   a. Heat loss = 16.89kW
   b. Energy loss cost per annum = £13,685.56

2. Roofs
    a. Heat loss = 10.49kW
    b. Energy loss cost per annum = £8,503.11
3. Windows
    a. Heat loss = 5.63kW
    b. Energy loss cost per annum = £4,562.73
4. Doors
    a. Heat loss = 0.35kW
    b. Energy loss cost per annum = £283.50

The conclusion for the building is that the highest energy loss is through the walls. Associated CO_2 emissions would be most reduced by insulating the walls to the standard required by Part L ADL2 2010 Building Regulations (see section 7.2.1).

Brick Wall					Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)	
	Total heat loss from this component	16.88949858	kW	Totals	5737.2	watts	11152.3	watt	16889.499	watts
	Cost of heating per calendar month	£1,140.46								
	Cost of heating per year	£13,685.56								

Door					Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)	
	Total heat loss from this component	0.349865128	kW	Totals	96.764	watts	253.102	watt	349.86513	watts
	Cost of heating per calendar month	£23.62								
	Cost of heating per year	£283.50								

PentRoof					Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)	
	Total heat loss from this component	10.49378136	kW	Totals	2124.9	watts	8368.86	watt	10493.781	watts
	Cost of heating per calendar month	£708.59								
	Cost of heating per year	£8,503.11								

Window					Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)	
	Total heat loss from this component	5.630917765	kW	Totals	2056.9	watts	3574.03	watt	5630.9178	watts
	Cost of heating per calendar month	£380.23								
	Cost of heating per year	£4,562.73								

Figure 29 Extract from Report 5 summarising heat loss and costs by component.

6.1.2 U-Value Calculation

Once the methodology for determining the CHTC was selected (section 8.1) the actual heat loss may be calculated using Newton's law of cooling (equation 24 page 45).

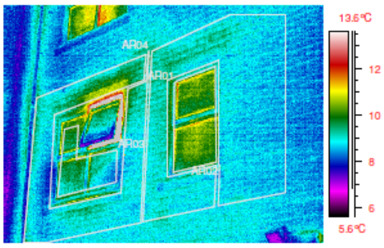
The conductance is a property of a given material (equation 16) whereas the conductivity or U-value (equation 16) is specific to a given component that has been constructed and incorporated into the building's thermal envelope.

The detail components required to calculate U-value (figure 14) are:

- Q = heat flow (watts)
- A = component surface are (m^2)
- T_o = outside wall temperature (°C)
- T_i = inside wall temperature (°C)

Report 3 (appendix 8 – see excerpt figure 30) gives calculated U-value for all components in the building. Perusal of the calculated U-values reveals a significant variation in value in (apparently) identical components (see figure 30).

F4 Bedroom 10		Area sq m	Outside Surface Temperature °C	Intside Surface Temperature °C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	East Wall	9.75	11	22	202.264	413.670	615.934	4.804
Window	East Window	0.7525	11	19	14.789	22.326	37.115	4.859
Brick Wall	South Wall	14.257	10	22	225.769	430.544	656.313	3.372
Window	South Window	0.55	12	19	13.394	23.034	36.428	6.864
				Totals	456.22 watts	889.573 watt	1345.7899 watts	



LabelValue
IR : max23.1°C
IR : min6.6°C
AR01 : avg10.2°C
AR02 : avg8.8°C
AR03 : avg9.4°C
AR04 : avg9.0°C

Cost per kWh £0.0740
Boiler Efficiency 80%
Total heat loss from this room 1.345789858 kW
Cost of heating the room per hour: £0.1245
Cost of heating the room per day £2.9877
Cost of heating the room per calendar month £90.87
Cost of heating the room per year £1,090.49

Figure 30 Excerpt from report 3 showing differences in calculated U-value for adjacent similar components in F4 Bedroom 10.

Whereas government building regulations give guidelines on how to calculate U-value and thus heat loss using target U-values and conductivity for materials it is apparent that the U-values of the installed components varies significantly (section 2.3 - Bradley).

The conclusion must be that an accurate calculation of U-value using typical conductivities of materials is subject to a degree of inaccuracy. Actual U-values may be measured accurately using the methodology described herein.

The U-values of components calculated using the methodology in this paper are more accurate and easier to calculate than the methodology advised in the Building regulations 2000 as the Building Regulations require a separate calculation for each sub component and that they be combined into an effective U-value.

6.1.3 Thermal Imaging Camera Accuracy

An intrinsic component of the methodology to determine U-value and R-value in this paper is determination of the radiative heat flow (equations 21 and 30). The method used in this paper to measure the wall surface temperatures to be used in the determination of radiative heat flow was an infrared thermal imaging camera FLIR PM575.

It was discovered during the course of the experimentation with the hot box to identify the best model for heat loss that the thermal imaging (InfraRed or IR) camera was reading high by 2.2°C (section 6.1 and figure 22). The quoted sensitivity of the subject IR camera is less than 0.1°C but the measurement accuracy is ±2%. With a range of -20°C to +350°C (appendix 2) a 2% error equates to an actual error of 7.4°C.

While the IR camera used in the data gathering was within the quoted error, it is too high an error to be used for quantitative measurement without error compensation (section 6.1).

6.2 Conclusions

1. The literature study

    a. The literature study identified several possible models in the field of solid/air convective and radiative heat transfer as per the requirements of the initial objectives. The model selected for radiative heat transfer was the Stefan-Boltzmann model and the model for convective heat flow was short listed to

        i. The Clear/Hagishima Linear curve fit (Eq6)
        ii. The Hagishima model including wall size (Eq8)
        iii. The ASHRAE model (Eq30).

    b. The study also identified precedent for the use of infrared thermal imaging for radiometric surface temperature measurement. Thermal imaging cameras allow for temperature averaging over a complete surface which improves the accuracy of the selected models.

2. Based on the selected models, the components needed to create a model of heat transfer through various types of building components in vertical, horizontal and angled planes when subject to a range of external air movements were identified as follows:

    i. Wall surface temperature, inside and outside
    ii. Free outside air temperature
    iii. Wind speed and direction relative to the building surface
    iv. Wall physical properties.
        1. Dimensional height, width & thickness
        2. Outside wall Roughness factor
        3. Outside wall Emissivity

3. The Hagishima Eq8 model was selected for the convective model. Adding the convective heat flow (watts) to the radiative heat flow (watts) the total conductive heat flow was calculated. With knowledge of the dimensions of each component and the thickness, the author was then able to calculate the

U-value for each component and thence the R-value as required in the initial objectives.

4. The model was embedded within a GUI and providing the following functionality as per initial objectives:

   a. Determination of total heat loss from each surface component and each external elevation.
   b. Determination of U and R value for each surface component.
   c. Calculation of total heat loss from each room in a building.
   d. Calculation of the cost of heating a building

5. The model was evaluated using a hot box with a known internal heat source. The experimental data correlated well with the published U-value data for GYPROC, OPTIFLOAT and SINGLE BRICK when the outside wall was subject to fan blown air. This proves that the models selected were accurate when used in the experimental environment as per the initial objectives.

6. The hot box was subject to various wind speeds and angle of attack. The wind speed was directly compensated for with the selected convective model but greater accuracy was realised when the wind speed was multiplied by the SINE of the angle of attack. The author postulates that a wind angle of attack normal to the wall will disrupt the boundary layer severely whereas an angle of attack parallel to the wall will have less effect on the boundary layer – this should be a matter for further research.

7. The model was trialled on a working hospital during the winter of early 2011. The projected results were consistent with actual heat losses and costs from the previous twelve month period with a projected cost error of less than 5%. This objectively proves the veracity of the final model and satisfies objective seven.

6.3 Recommendations for Further Development

1. While the calculation for radiative heat loss is well understood, the method used for calculating convective heat loss from a building should be considered as being based on an effective theory and not a quantitative theory. The method described in this paper is largely empirical even though it is based on sound science.

   As the Hagishima formulae are divided into two distinct regimes, a suitable topic for further investigation would be to analyse how the changeover from laminar flow to turbulent flow occurs on large external windblown structures and combine both formulae into one coherent formula. A review of angle of attack should be included in this research.

2. The GUI developed by the author for this paper should be further developed for air cooled buildings to assess air conditioning load.
3. This paper does not consider mass exchange. A development of this paper would be to measure and include the amount of energy lost because of fresh air exchange in the normal ventilation of a building, both commercial and dwelling.

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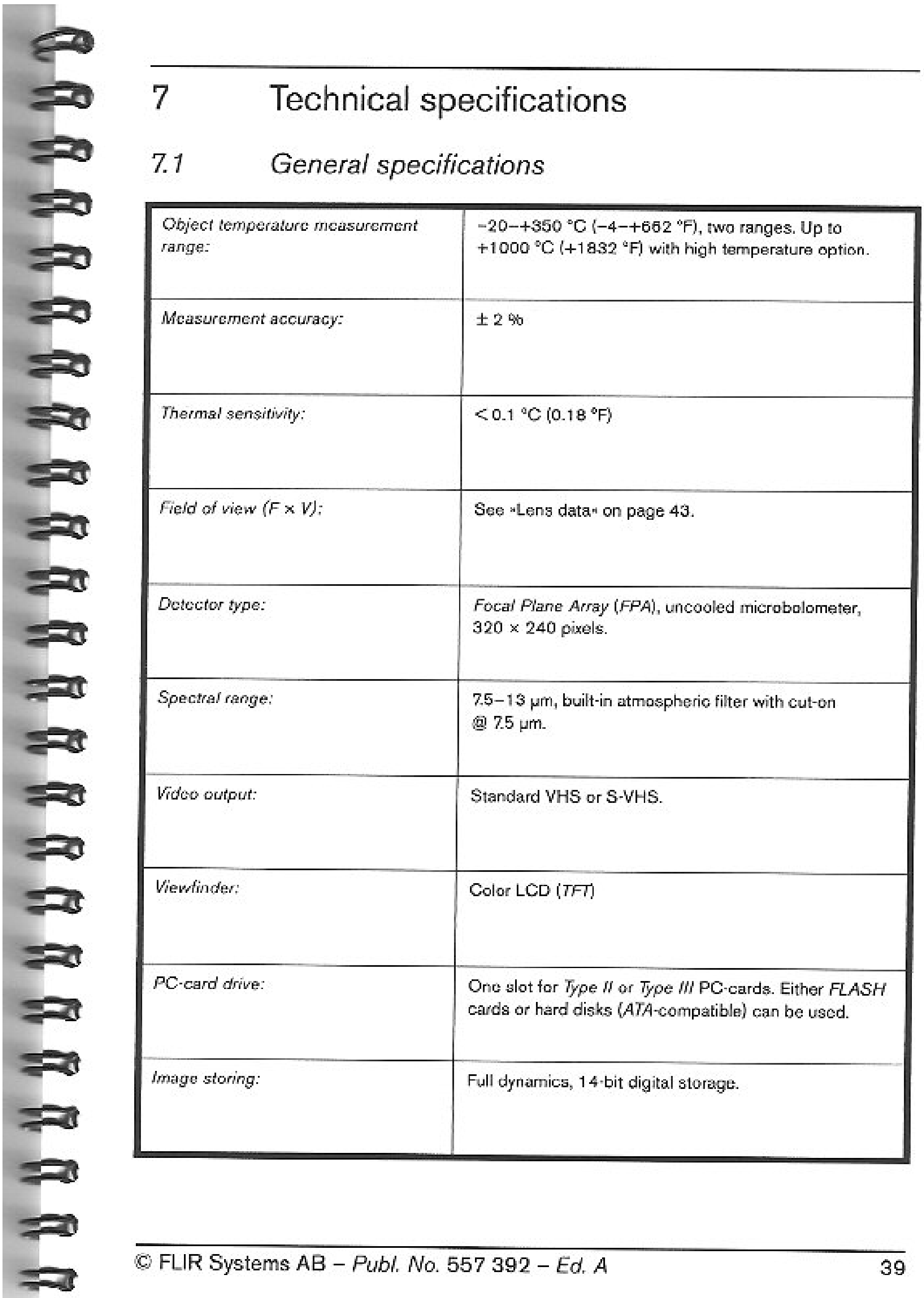
Appendix 2 - Thermal Imaging Camera Specifications



7 Technical specifications

7.1 General specifications

Object temperature measurement range:	–20–+350 °C (–4–+662 °F), two ranges. Up to +1000 °C (+1832 °F) with high temperature option.
Measurement accuracy:	± 2 %
Thermal sensitivity:	< 0.1 °C (0.18 °F)
Field of view (F × V):	See »Lens data« on page 43.
Detector type:	*Focal Plane Array* (*FPA*), uncooled microbolometer, 320 × 240 pixels.
Spectral range:	7.5–13 µm, built-in atmospheric filter with cut-on @ 7.5 µm.
Video output:	Standard VHS or S-VHS.
Viewfinder:	Color LCD (*TFT*)
PC-card drive:	One slot for *Type II* or *Type III* PC-cards. Either *FLASH* cards or hard disks (*ATA*-compatible) can be used.
Image storing:	Full dynamics, 14-bit digital storage.

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Figure 31 Thermal Imager Technical Specifications

Appendix 3 - Emissivity Values

Table 10 Emissivity values for building materials from ASHRAE Handbook Fundamentals 2009

MATERIAL SURFACE	EMISSIVITY
Asphalt	0.90 – 0.98
Aluminium Foil	0.03 – 0.05
Brick	0.93
Concrete	0.85 – 0.95
Glass (unglazed)	0.95
Fibreglass	0.80 – 0.90
Limestone	0.36 – 0.90
Marble	0.93
Paper	0.92
Plaster	0.91
Silver	0.02
Mild Steel	0.12
Wood	0.90

Appendix 4 – Reuse License

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Appendix 5. (Report 1.pdf)

Appendix 6 (Report 2.pdf)

Appendix 7 (Report 3.pdf)

Appendix 8 (Report 4.pdf)

Appendix 9 (Report 5.pdf)

Heat Loss Snapshot Detail Report

Please note: This report is based only on ambient conditions encountered during the on-site survey.

Thermal Imaging Heat Loss Report

Client Name: The Priory Hospital

Location: Rosemary Lane, Bartlett, Preston, PR4 0HB

Contact: Mr Nick Erdbeer

Project Number: 000214

Date: 18th February 2011

Priory Hospital

Rosemary Lane

Preston

Lancashire

PR4 0HB

Date of Survey:

10/02/2011

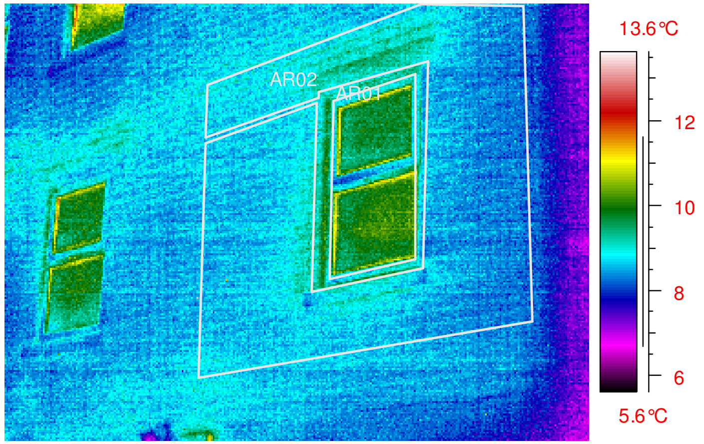
Cost per kWhour: 0.074

Wind Speed m/s: 0.000

Wind Direction (compass angle) 0.000

F10 Asst Ward Manager

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	North Window	0.7425	10	21	11.139	10.953	22.092	2.705	0.370
Brick Wall	North Wall	6.9375	9	24	76.160	119.112	195.272	1.876	0.533
Window	West Window	0.7425	10	21	11.139	10.953	22.092	2.705	0.370
Brick Wall	West Wall	6.9375	9	24	76.160	119.112	195.272	1.876	0.533



174.599 watts 260.1289 watt 434.72753 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.434727528 kW

Cost of heating the room per hour: £0.0402

Cost of heating the room per day £0.9651

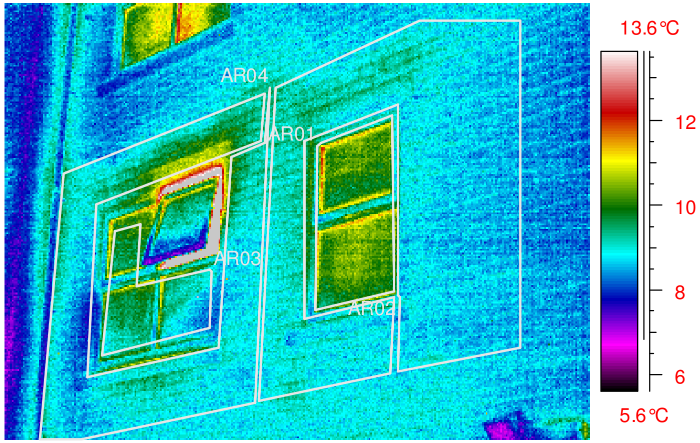
Cost of heating the room per calendar month £29.35

Cost of heating the room per year £352.26

Recommendations

LabelValue
IR : max14.5°C
IR : min6.3°C
AR01 : avg9.8°C

F11 Store Room		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	5.86	9	24	64.331	100.612	164.943	1.876	0.533
Window	Window	0.7425	10	21	11.139	10.953	22.092	2.705	0.370



75.4705 watts 111.5645 watt 187.03503 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.187035031 kW

Cost of heating the room per hour: £0.0173

Cost of heating the room per day £0.4152

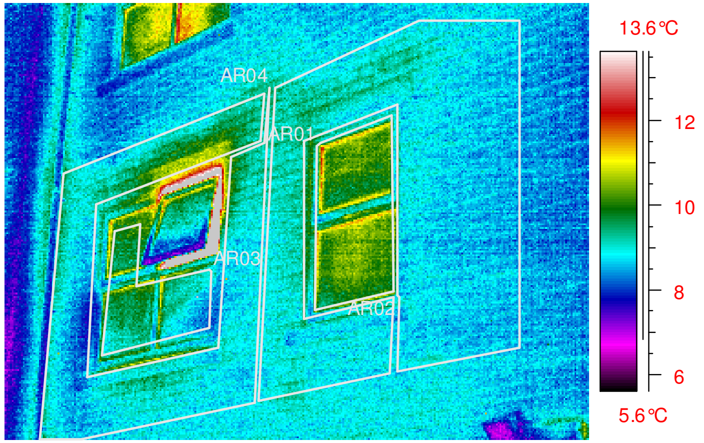
Cost of heating the room per calendar month £12.63

Cost of heating the room per year £151.55

Recommendations

LabelValue
IR : max23.1℃
IR : min6.6℃
AR01 : avg10.2℃

F13 Bedroom 2		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	6.965	9	24	76.462	119.584	196.046	1.876	0.533
Window	Window	0.7425	9	21	7.722	7.634	15.356	1.723	0.580



84.1843 watts 127.2176 watt 211.40189 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.211401889 kW

Cost of heating the room per hour: £0.0196

Cost of heating the room per day £0.4693

Cost of heating the room per calendar month £14.27

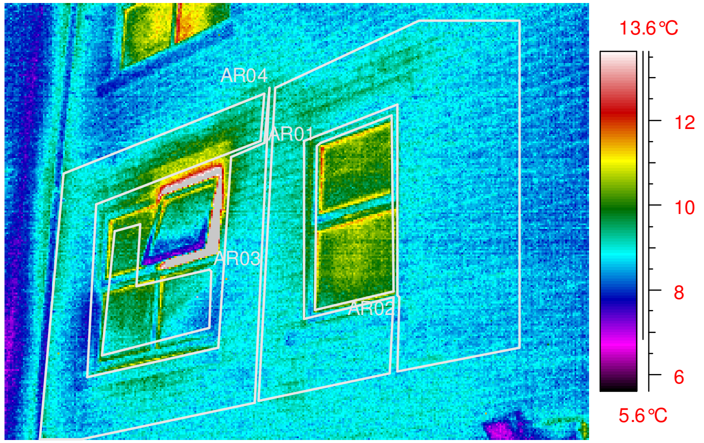
Cost of heating the room per year £171.30

Recommendations

LabelValue
IR : max23.1°C
IR : min6.6°C
AR01 : avg10.2°C

F14 Bedroom 3

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	6.965	9	24	76.462	119.584	196.046	1.876	0.533
Window	Window	2.041	10	21	30.620	30.107	60.726	2.705	0.370



107.082 watts 149.6908 watt 256.77236 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.256772356 kW

Cost of heating the room per hour: £0.0238

Cost of heating the room per day £0.5700

Cost of heating the room per calendar month £17.34

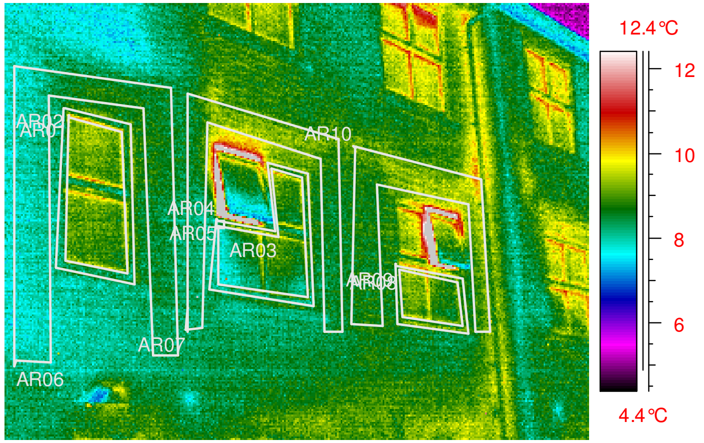
Cost of heating the room per year £208.06

Recommendations

LabelValue
IR : max23.1°C
IR : min6.6°C
AR01 : avg10.2°C

F15 Bedroom 4

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	6.965	9	24	76.462	119.584	196.046	1.876	0.533
Window	Window	0.7425	10	21	11.139	10.953	22.092	2.705	0.370



87.6012 watts 130.5366 watt 218.13782 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.218137815 kW

Cost of heating the room per hour: £0.0202

Cost of heating the room per day £0.4843

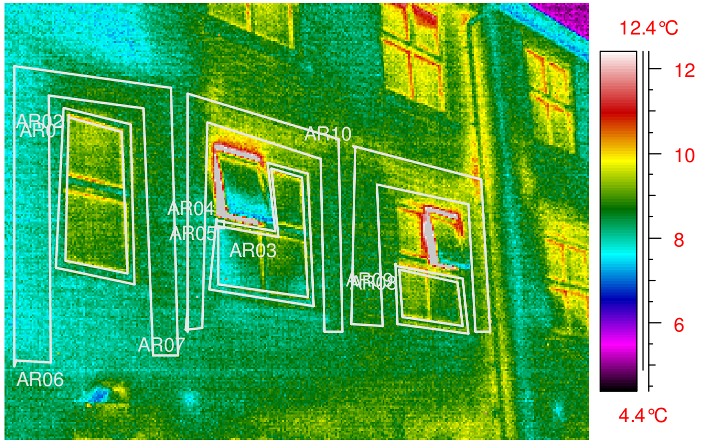
Cost of heating the room per calendar month £14.73

Cost of heating the room per year £176.76

Recommendations

LabelValue
IR : max19.8℃
IR : min4.7℃
AR01 : avg9.2℃

F16 Bedroom 5		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	6.965	9	24	76.462	119.584	196.046	1.876	0.533
Window	Window	0.7425	9	21	7.722	7.634	15.356	1.723	0.580



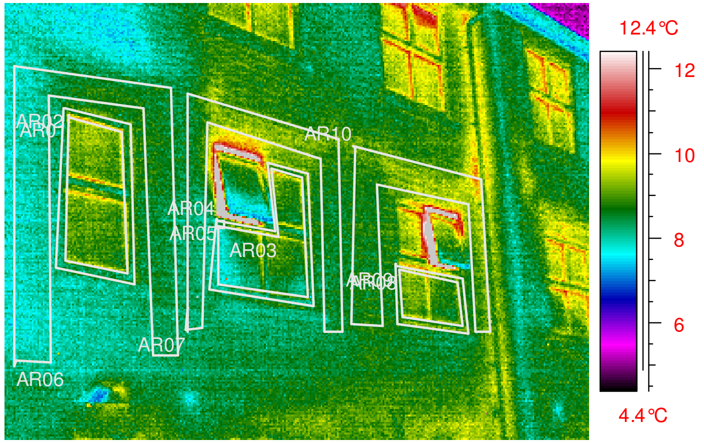
84.1843 watts 127.2176 watt 211.40189 watts

Cost per kWh	**£0.0740**
Boiler Efficiency	**80%**
Total heat loss from this room	0.211401889 kW
Cost of heating the room per hour:	£0.0196
Cost of heating the room per day	£0.4693
Cost of heating the room per calendar month	£14.27
Cost of heating the room per year	£171.30

Recommendations

LabelValue
IR : max19.8℃
IR : min4.7℃
AR01 : avg9.2℃

F17 Bedroom 6		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	0.7425	9	16	7.722	7.634	15.356	2.954	0.338
Brick Wall	Wall	6.965	9	20	76.462	119.584	196.046	2.559	0.391



84.1843 watts 127.2176 watt 211.40189 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.211401889 kW

Cost of heating the room per hour: £0.0196

Cost of heating the room per day £0.4693

Cost of heating the room per calendar month £14.27

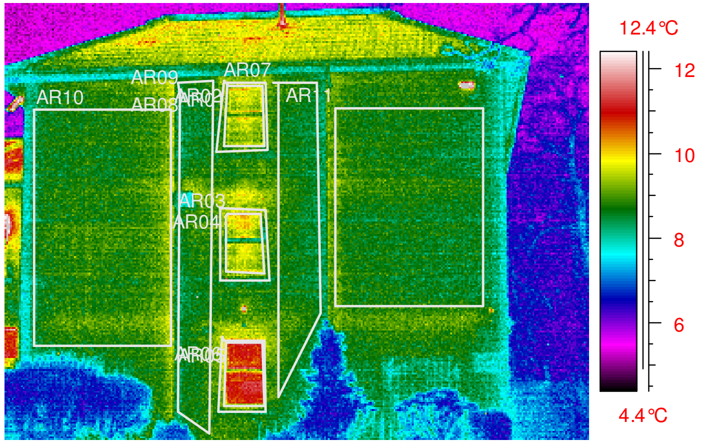
Cost of heating the room per year £171.30

Recommendations

LabelValue
IR : max19.8℃
IR : min4.7℃
AR01 : avg9.2℃

F19 Bedroom 7

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	9.244	12	24	237.632	365.729	603.361	5.439	0.184
Window	Window	2.756	15	21	106.808	102.250	209.058	12.643	0.079



344.439 watts 467.9797 watt 812.4189 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.812418896 kW

Cost of heating the room per hour: £0.0751

Cost of heating the room per day £1.8036

Cost of heating the room per calendar month £54.86

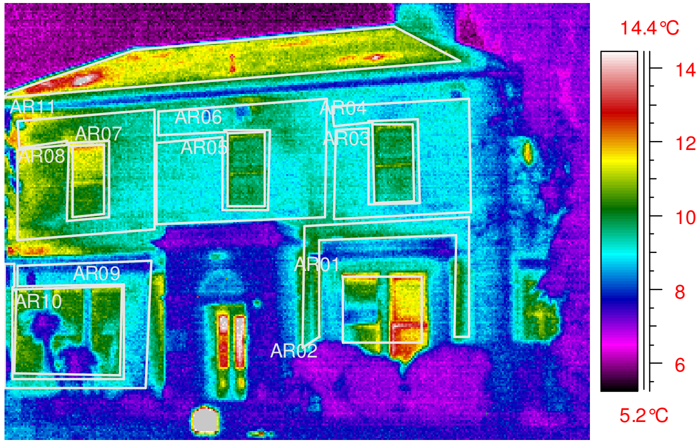
Cost of heating the room per year £658.30

Recommendations

LabelValue
IR : max20.4°C
IR : min4.7°C
AR01 : avg9.5°C

F2 Bedroom 12

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	1.485	11	19	29.185	28.543	57.728	4.859	0.206
Brick Wall	Wall	13.515	11	24	280.369	433.819	714.188	4.065	0.246



309.554 watts 462.3621 watt 771.91649 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.771916486 kW

Cost of heating the room per hour: £0.0714

Cost of heating the room per day £1.7137

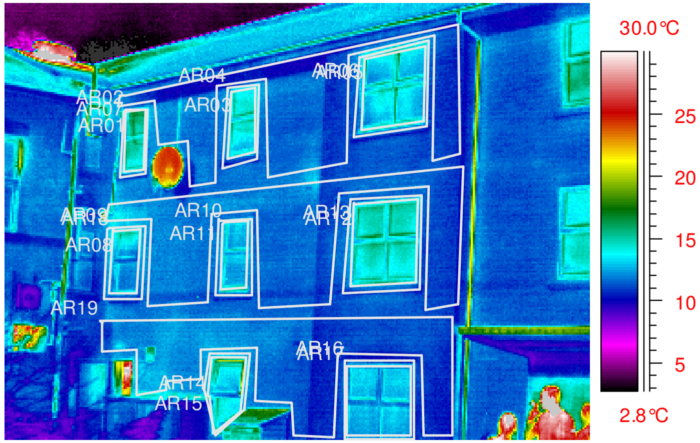
Cost of heating the room per calendar month £52.12

Cost of heating the room per year £625.48

Recommendations

F21A Bedroom

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	2.756	13	21	80.210	77.612	157.822	7.158	0.140
Brick Wall	Wall	6.965	12	24	179.046	275.563	454.609	5.439	0.184



259.256 watts 353.1748 watt 612.43089 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.612430892 kW

Cost of heating the room per hour: £0.0566

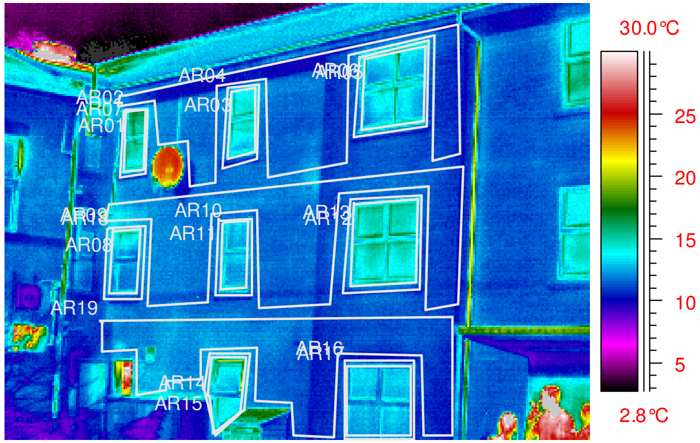
Cost of heating the room per day £1.3596

Cost of heating the room per calendar month £41.35

Cost of heating the room per year £496.25

Recommendations

F21B Bedroom		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	2.756	13	21	80.210	77.612	157.822	7.158	0.140
Brick Wall	Wall	6.965	12	24	179.046	275.563	454.609	5.439	0.184



259.256 watts 353.1748 watt 612.43089 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.612430892 kW

Cost of heating the room per hour: £0.0566

Cost of heating the room per day £1.3596

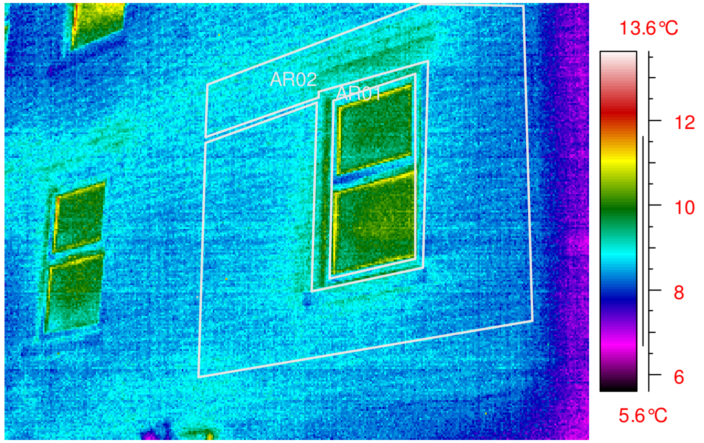
Cost of heating the room per calendar month £41.35

Cost of heating the room per year £496.25

Recommendations

F3 Bedroom 11

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	20	9	22	219.561	343.385	562.946	2.165	0.462
Window	Window	1.1	10	21	16.502	16.226	32.729	2.705	0.370



236.063 watts 359.6115 watt 595.67486 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.595674855 kW

Cost of heating the room per hour: £0.0551

Cost of heating the room per day £1.3224

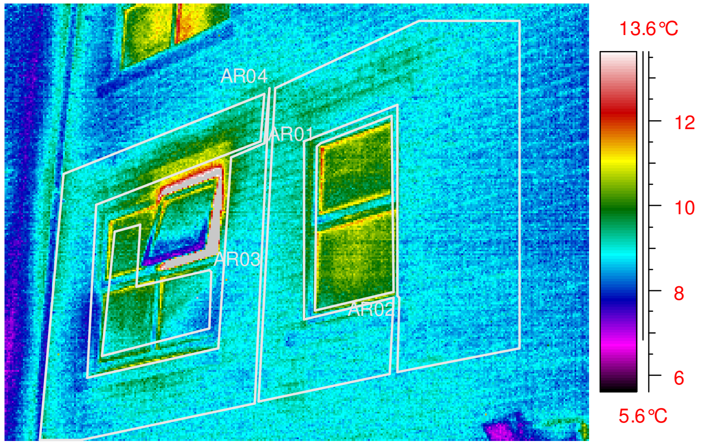
Cost of heating the room per calendar month £40.22

Cost of heating the room per year £482.68

Recommendations

LabelValue
IR : max14.5℃
IR : min6.3℃
AR01 : avg9.8℃

F4 Bedroom 10		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	East Wall	9.75	11	22	202.264	312.966	515.230	4.804	0.208
Window	East Window	0.7525	11	19	14.789	14.464	29.253	4.859	0.206
Brick Wall	South Wall	14.257	10	22	225.769	351.209	576.978	3.372	0.297
Window	South Window	0.55	12	19	13.394	13.030	26.425	6.864	0.146



456.217 watts 691.6691 watt 1147.886 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 1.147885972 kW

Cost of heating the room per hour: £0.1062

Cost of heating the room per day £2.5483

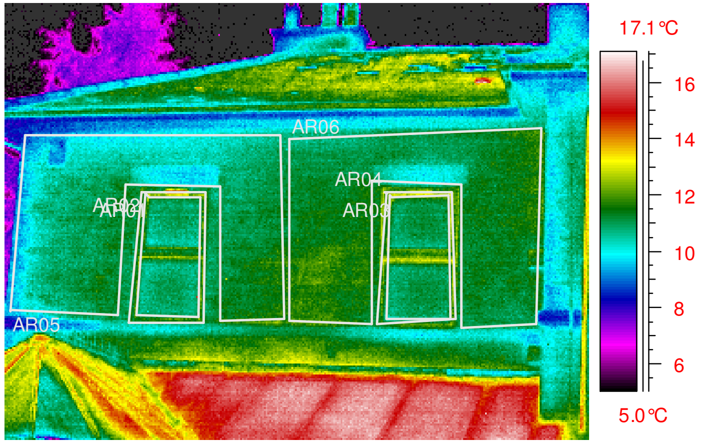
Cost of heating the room per calendar month £77.51

Cost of heating the room per year £930.13

Recommendations

LabelValue
IR : max23.1℃
IR : min6.6℃
AR01 : avg10.2℃

F5 Bedroom 9		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	0.7525	11	19	14.789	14.464	29.253	4.859	0.206
Brick Wall	Wall	14.2575	11	22	295.773	457.652	753.425	4.804	0.208



310.562 watts 472.1163 watt 782.67789 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.78267789 kW

Cost of heating the room per hour: £0.0724

Cost of heating the room per day £1.7375

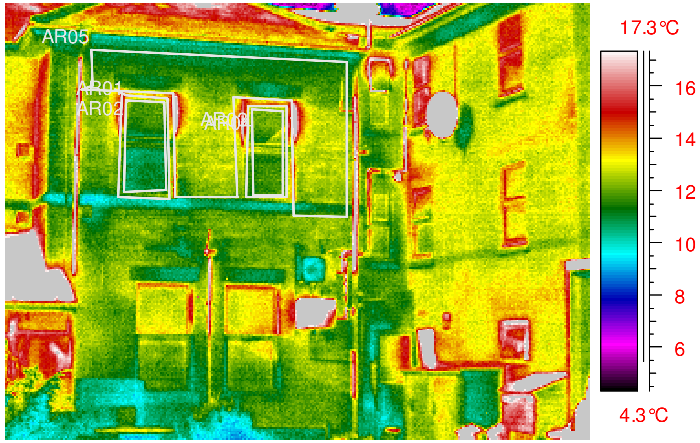
Cost of heating the room per calendar month £52.85

Cost of heating the room per year £634.20

Recommendations

LabelValue
IR : max17.3℃
IR : min4.1℃
AR01 : avg11.0℃

F6 Bartle Room		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	1.485	12	21	36.165	35.181	71.346	5.338	0.187
Brick Wall	Wall	13.515	10	24	214.019	332.931	546.950	2.891	0.346



250.184 watts 368.1119 watt 618.29603 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.618296034 kW

Cost of heating the room per hour: £0.0572

Cost of heating the room per day £1.3726

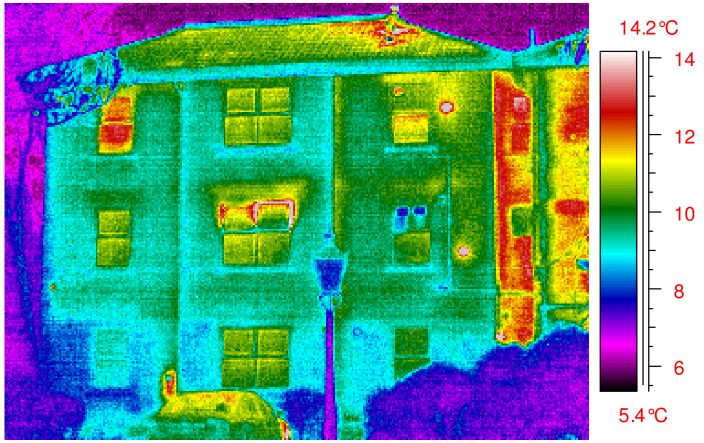
Cost of heating the room per calendar month £41.75

Cost of heating the room per year £501.01

Recommendations

LabelValue
IR : max60.8°C
IR : min5.2°C
AR01 : avg11.3°C

F8&9 Nurse Station/Sluice		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	1.485	9	21	15.444	15.267	30.712	1.723	0.580
Brick Wall	Wall	10.515	10	24	166.512	259.028	425.540	2.891	0.346



181.956 watts 274.2956 watt 456.25197 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.456251972 kW

Cost of heating the room per hour: £0.0422

Cost of heating the room per day £1.0129

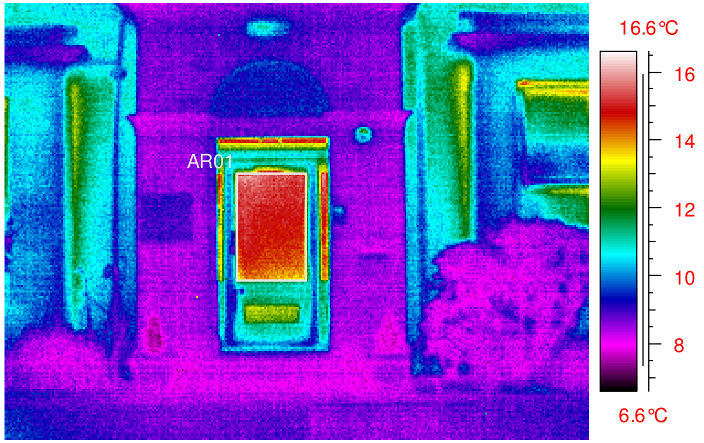
Cost of heating the room per calendar month £30.81

Cost of heating the room per year £369.70

Recommendations

LabelValue
IR : max55.5°C
IR : min5.4°C

G1 Entrance Lobby		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Door	Door	0.78	15	17	31.908	28.939	60.847	39.004	0.026



31.9079 watts 28.93878 watt 60.846728 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.060846728 kW

Cost of heating the room per hour: £0.0056

Cost of heating the room per day £0.1351

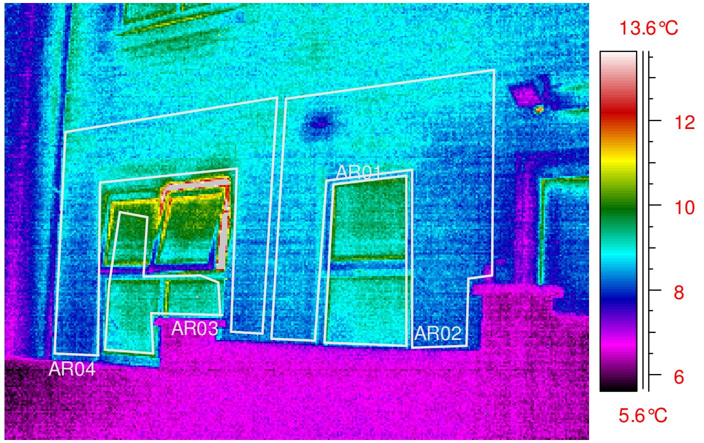
Cost of heating the room per calendar month £4.11

Cost of heating the room per year £49.30

Recommendations

LabelValue
IR : max16.1℃
IR : min6.9℃
AR01 : avg14.8℃

G12 Consulting Room 1		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	5.4214	9	25	59.516	93.081	152.598	1.759	0.568
Window	Window	2.1306	9	20	22.159	21.905	44.063	1.880	0.532



81.6752 watts 114.9862 watt 196.66134 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.196661341 kW

Cost of heating the room per hour: £0.0182

Cost of heating the room per day £0.4366

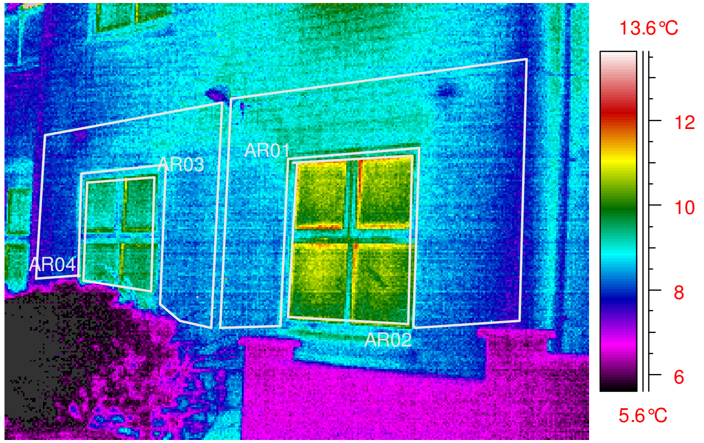
Cost of heating the room per calendar month £13.28

Cost of heating the room per year £159.35

Recommendations

G13 Consulting Room 2

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	5.4214	8	25	33.460	52.611	86.071	0.934	1.071
Window	Window	2.1306	10	20	31.964	31.428	63.392	2.975	0.336



65.4237 watts 84.03975 watt 149.46342 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.149463422 kW

Cost of heating the room per hour: £0.0138

Cost of heating the room per day £0.3318

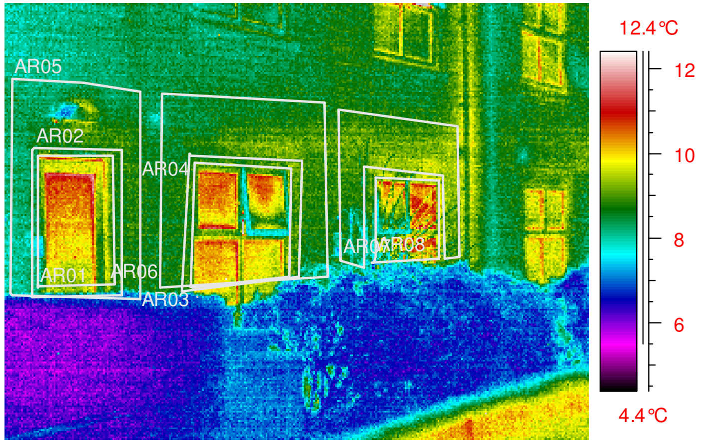
Cost of heating the room per calendar month £10.09

Cost of heating the room per year £121.11

Recommendations

LabelValue
IR : max17.8℃
IR : min4.4℃
AR01 : avg10.3℃

G14 Hospital Manager		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	5.4214	8	23	33.460	52.611	86.071	1.058	0.945
Window	Window	2.1306	9	20	22.159	21.905	44.063	1.880	0.532
					55.6187 watts	74.51597 watt	130.13472 watts		



Cost per kWh **£0.0740**

Boiler Efficiency **80%**

Total heat loss from this room 0.130134717 kW

Cost of heating the room per hour: £0.0120

Cost of heating the room per day £0.2889

Cost of heating the room per calendar month £8.79

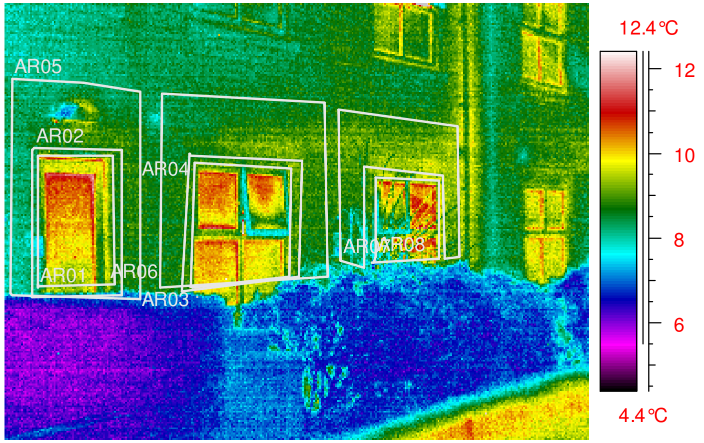
Cost of heating the room per year £105.45

Recommendations

LabelValue
IR : max18.0°C
IR : min5.0°C
AR01 : avg9.8°C

G15 Therapy Service

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	2.1306	10	20	31.964	31.428	63.392	2.975	0.336
Brick Wall	Wall	5.4214	9	23	59.516	93.081	152.598	2.011	0.497



91.4801 watts 124.51 watt 215.99005 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.215990046 kW

Cost of heating the room per hour: £0.0200

Cost of heating the room per day £0.4795

Cost of heating the room per calendar month £14.58

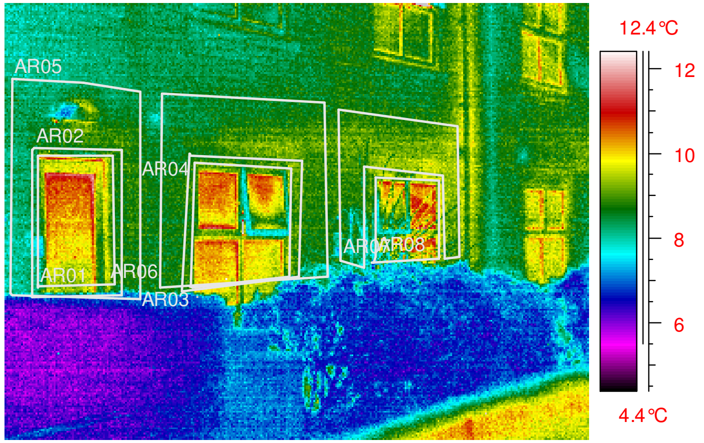
Cost of heating the room per year £175.02

Recommendations

LabelValue
IR : max18.0℃
IR : min5.0℃
AR01 : avg9.8℃

G16 Marketing Office

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	2.1306	10	20	31.964	31.428	63.392	2.975	0.336
Brick Wall	Wall	5.4214	10	23	85.851	133.552	219.403	3.113	0.321



117.815 watts 164.9802 watt 282.79535 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.282795346 kW

Cost of heating the room per hour: £0.0262

Cost of heating the room per day £0.6278

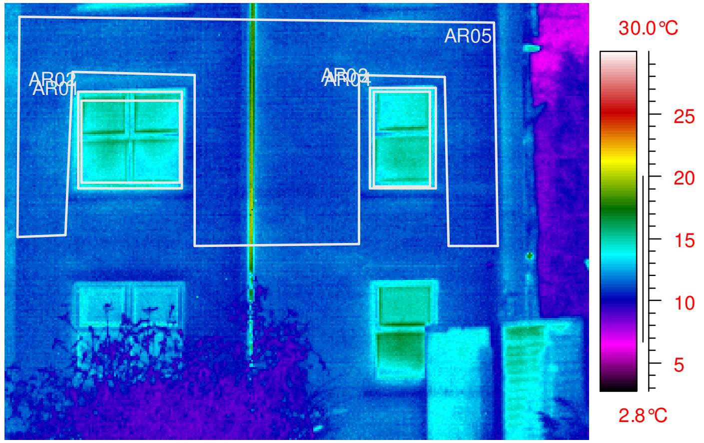
Cost of heating the room per calendar month £19.10

Cost of heating the room per year £229.15

Recommendations

LabelValue
IR : max18.0°C
IR : min5.0°C
AR01 : avg9.8°C

G18 Assisted Bath		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	10.1124	12	25	259.955	400.087	660.042	5.021	0.199
Window	Window	2.8676	13	21	83.458	80.754	164.212	7.158	0.140



343.413 watts 480.8412 watt 824.25414 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.824254136 kW

Cost of heating the room per hour: £0.0762

Cost of heating the room per day £1.8298

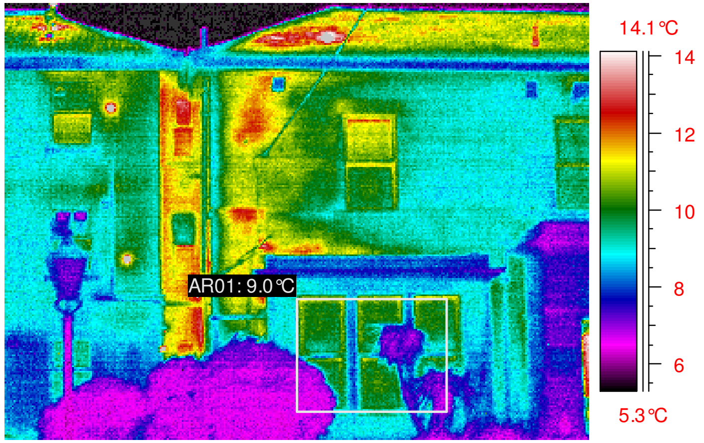
Cost of heating the room per calendar month £55.66

Cost of heating the room per year £667.89

Recommendations

LabelValue
IR : max20.5°C
IR : min6.4°C
AR01 : avg14.5°C

G2 Reception		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Windows	2.97	9	21	30.889	30.535	61.423	1.723	0.580
Brick Wall	Wall	12.03	11	20	249.563	386.152	635.715	5.872	0.170



280.452 watts 416.6864 watt 697.1381 watts

Cost per kWh £0.0740

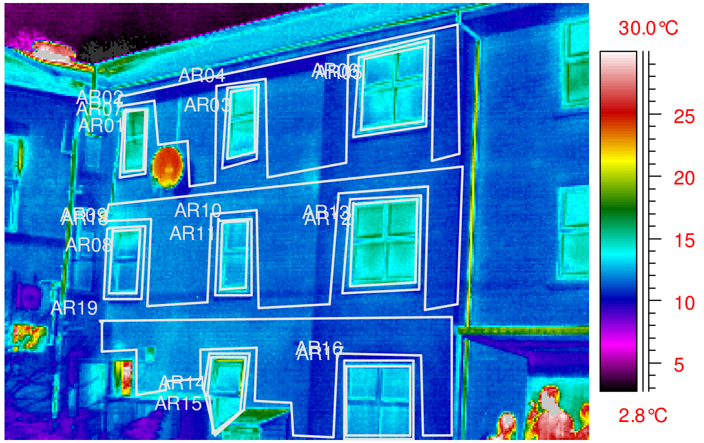
Boiler Efficiency 80%

Total heat loss from this room	0.697138097 kW
Cost of heating the room per hour:	£0.0645
Cost of heating the room per day	£1.5476
Cost of heating the room per calendar month	£47.07
Cost of heating the room per year	£564.89

Recommendations

LabelValue
IR : max56.8℃
IR : min4.6℃
AR01 : avg9.0℃

G21 Hospital Director		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	3.983	12	25	102.389	157.583	259.973	5.021	0.199
Window	Window	0.737	14	21	24.987	24.049	49.036	9.505	0.105



127.376 watts 181.6323 watt 309.00881 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.309008815 kW

Cost of heating the room per hour: £0.0286

Cost of heating the room per day £0.6860

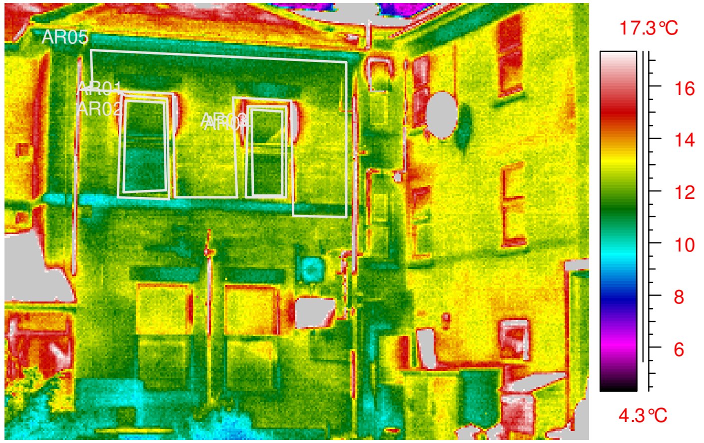
Cost of heating the room per calendar month £20.87

Cost of heating the room per year £250.39

Recommendations

G27 Dining Room

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	10.02	12	25	257.580	396.431	654.011	5.021	0.199
Window	Window	1.98	13	21	57.625	55.759	113.384	7.158	0.140



315.205 watts 452.1898 watt 767.39497 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.767394972 kW

Cost of heating the room per hour: £0.0710

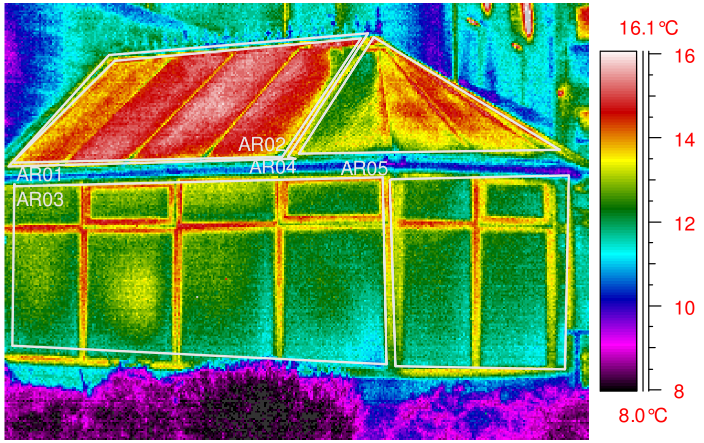
Cost of heating the room per day £1.7036

Cost of heating the room per calendar month £51.82

Cost of heating the room per year £621.82

Recommendations

G30 Conservatory		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
PentRoof	Glass Roof	14.875	14	18	504.321	728.079	1,232.400	20.713	0.048
Window	Glass Wall	24.5	13	19	713.041	689.945	1,402.986	9.544	0.105
Brick Wall	Lower Wall	10.5	11	24	217.823	337.040	554.863	4.065	0.246



1435.19 watts 1755.064 watt 3190.2492 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 3.190249178 kW

Cost of heating the room per hour: £0.2951

Cost of heating the room per day £7.0824

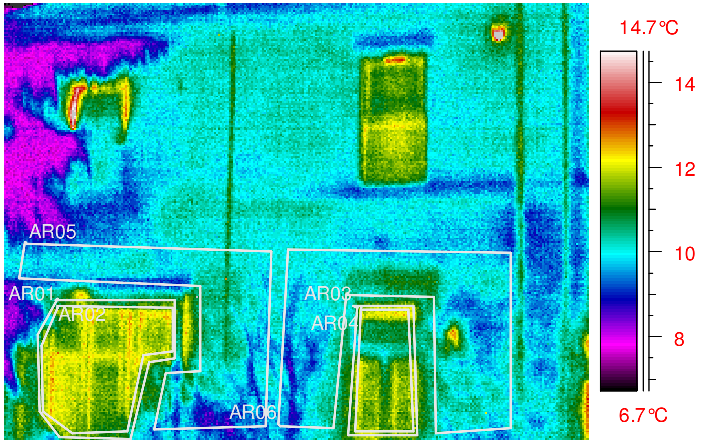
Cost of heating the room per calendar month £215.42

Cost of heating the room per year £2,585.06

Recommendations

LabelValue
IR : max17.3℃
IR : min7.4℃
AR01 : avg14.6℃

G31 Multi Function Space		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Door	Door	3.3	11	19	64.856	63.429	128.285	4.859	0.206
Brick Wall	Wall	11.7	10	22	185.277	288.220	473.497	3.372	0.297



250.133 watts 351.6491 watt 601.78194 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.601781942 kW

Cost of heating the room per hour: £0.0557

Cost of heating the room per day £1.3360

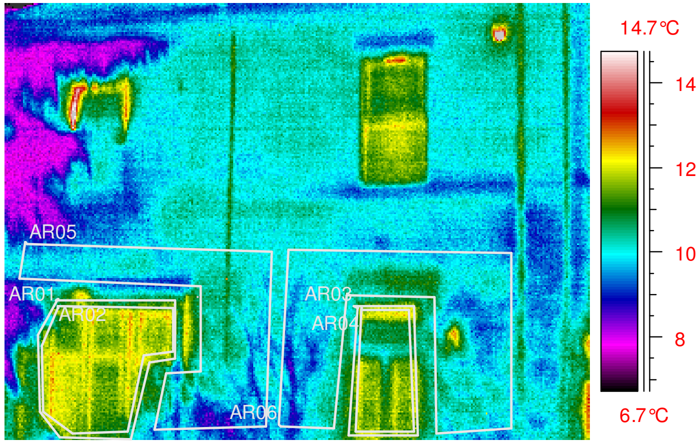
Cost of heating the room per calendar month £40.64

Cost of heating the room per year £487.62

Recommendations

LabelValue
IR : max17.7°C
IR : min4.9°C
AR01 : avg11.8°C

G32 Multi Function Space		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	1.98	12	19	48.220	46.908	95.128	6.864	0.146
Brick Wall	Wall	13.02	10	22	206.180	320.737	526.917	3.372	0.297



254.400 watts 367.6451 watt 622.04554 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.622045540 kW

Cost of heating the room per hour: £0.0575

Cost of heating the room per day £1.3809

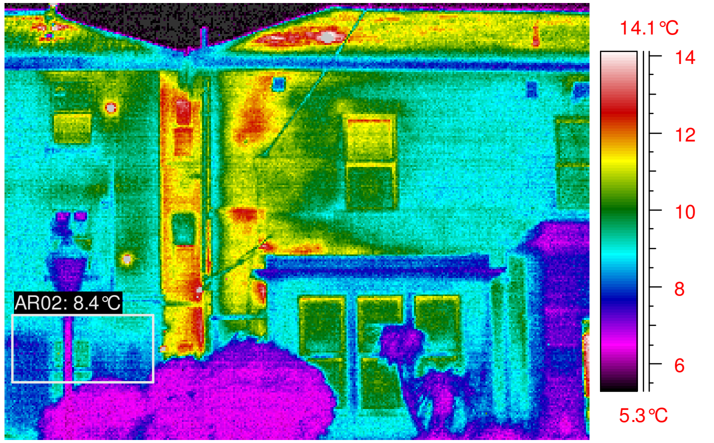
Cost of heating the room per calendar month £42.00

Cost of heating the room per year £504.04

Recommendations

LabelValue
IR : max17.7℃
IR : min4.9℃
AR01 : avg11.8℃

G6 Changing Room		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	3.983	9	23	43.726	68.385	112.111	2.011	0.497
Window	Window	0.737	10	20	11.057	10.871	21.928	2.975	0.336



54.7822 watts 79.25669 watt 134.03888 watts

Cost per kWh **£0.0740**

Boiler Efficiency **80%**

Total heat loss from this room 0.134038875 kW

Cost of heating the room per hour: £0.0124

Cost of heating the room per day £0.2976

Cost of heating the room per calendar month £9.05

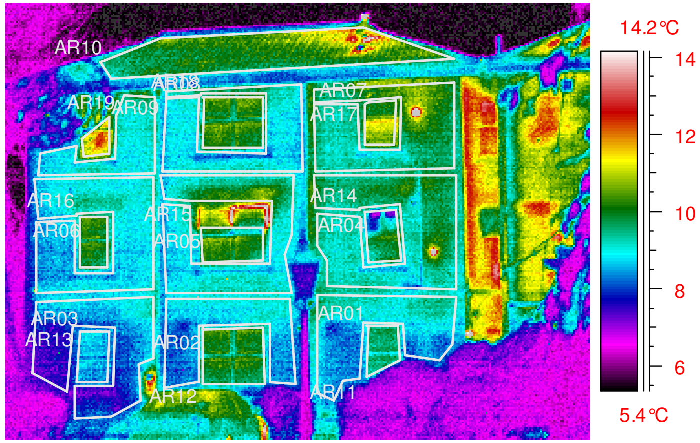
Cost of heating the room per year £108.61

Recommendations

LabelValue
IR : max56.8℃
IR : min4.6℃
AR01 : avg9.0℃

G7 Waiting Area

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	2.1306	10	20	31.964	31.428	63.392	2.975	0.336
Brick Wall	Wall	2.5894	9	23	28.427	44.458	72.885	2.011	0.497



60.3903 watts 75.88659 watt 136.27685 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.136276847 kW

Cost of heating the room per hour: £0.0126

Cost of heating the room per day £0.3025

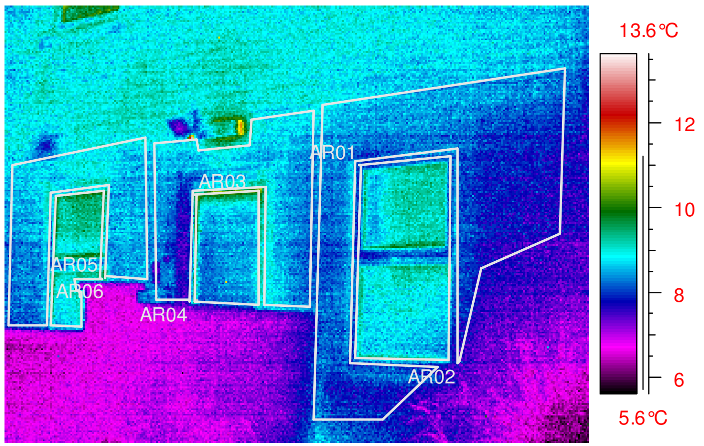
Cost of heating the room per calendar month £9.20

Cost of heating the room per year £110.43

Recommendations

G9 Pantry

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	West Wall	3.983	8	22	24.582	38.653	63.235	1.134	0.882
Brick Wall	North Wall	3.983	8	22	24.582	38.653	63.235	1.134	0.882
Window	West Window	0.737	9	21	7.665	7.577	15.242	1.723	0.580
Window	North Window	0.737	9	21	7.665	7.577	15.242	1.723	0.580



64.4948 watts 92.45921 watt 156.95399 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.156953986 kW

Cost of heating the room per hour: £0.0145

Cost of heating the room per day £0.3484

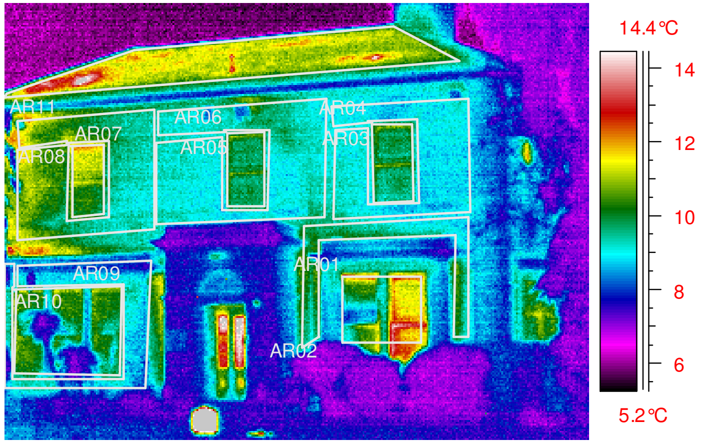
Cost of heating the room per calendar month £10.60

Cost of heating the room per year £127.18

Recommendations

SE1 Roof Space

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
PentRoof	Roof Void West	79.8	11	13	1,620.603	2,300.754	3,921.357	24.570	0.041



1620.60 watts 2300.754 watt 3921.3571 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 3.921357055 kW

Cost of heating the room per hour: £0.3627

Cost of heating the room per day £8.7054

Cost of heating the room per calendar month £264.79

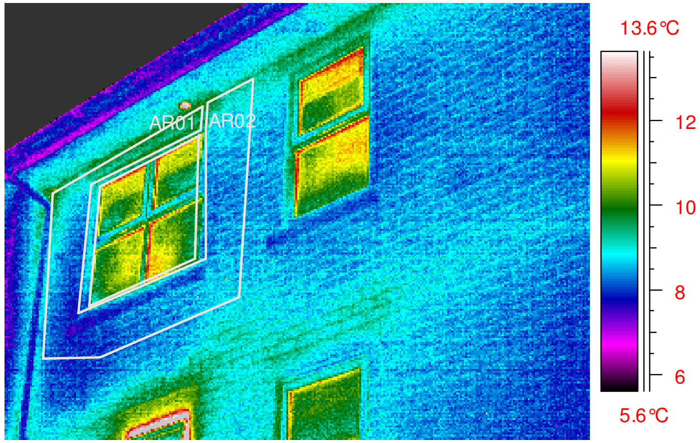
Cost of heating the room per year £3,177.48

Recommendations

LabelValue
IR : max17.5℃
IR : min5.0℃
AR01 : avg10.7℃

SE11 Bedroom 14

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	2.028	10	21	30.424	29.915	60.340	2.705	0.370
Brick Wall	Wall	5.58	9	24	61.257	95.805	157.062	1.876	0.533



91.682 watts 125.7196 watt 217.40153 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.217401532 kW

Cost of heating the room per hour: £0.0201

Cost of heating the room per day £0.4826

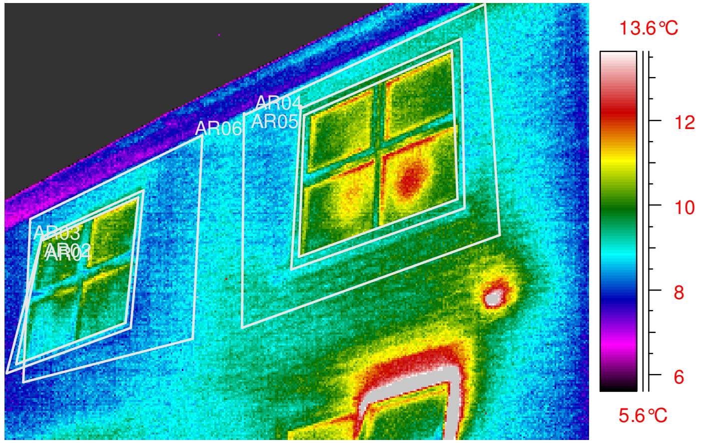
Cost of heating the room per calendar month £14.68

Cost of heating the room per year £176.16

Recommendations

LabelValue
IR : max16.8℃
IR : min2.9℃
AR01 : avg10.3℃

SE12 Bedroom 15		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	5.58	10	24	88.363	137.459	225.822	2.891	0.346
Window	Window	2.028	10	21	30.424	29.915	60.340	2.705	0.370



118.787 watts 167.3737 watt 286.16118 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.286161183 kW

Cost of heating the room per hour: £0.0265

Cost of heating the room per day £0.6353

Cost of heating the room per calendar month £19.32

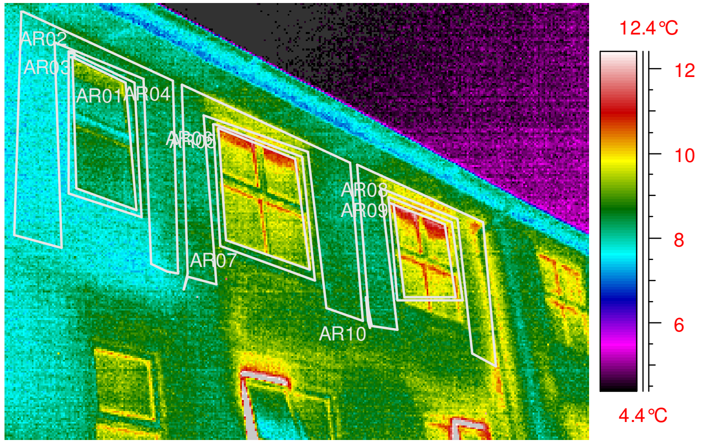
Cost of heating the room per year £231.88

Recommendations

LabelValue
IR : max21.9℃
IR : min3.3℃
AR01 : avg9.6℃

SE13 Bedroom 16

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	5.58	8	22	34.439	54.150	88.589	1.134	0.882
Window	Window	2.028	9	24	21.092	20.850	41.942	1.379	0.725



55.5305 watts 75.00025 watt 130.53079 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.130530785 kW

Cost of heating the room per hour: £0.0121

Cost of heating the room per day £0.2898

Cost of heating the room per calendar month £8.81

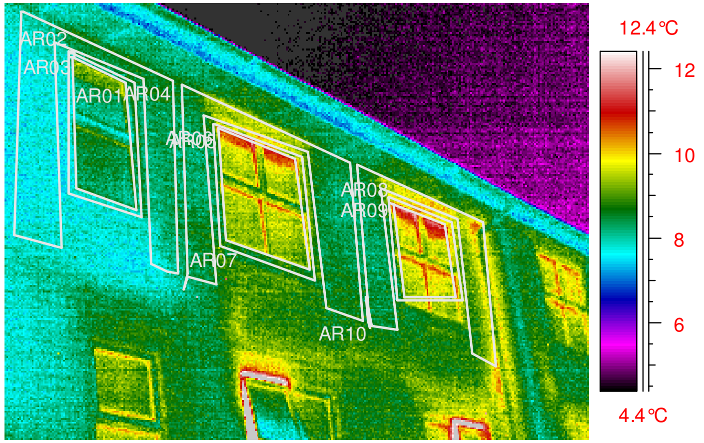
Cost of heating the room per year £105.77

Recommendations

LabelValue
IR : max20.0℃
IR : min3.2℃
AR01 : avg8.5℃

SE14 Bedroom 17

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	5.58	9	24	61.257	95.805	157.062	1.876	0.533
Window	Window	2.028	10	21	30.424	29.915	60.340	2.705	0.370



91.682 watts 125.7196 watt 217.40153 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.217401532 kW

Cost of heating the room per hour: £0.0201

Cost of heating the room per day £0.4826

Cost of heating the room per calendar month £14.68

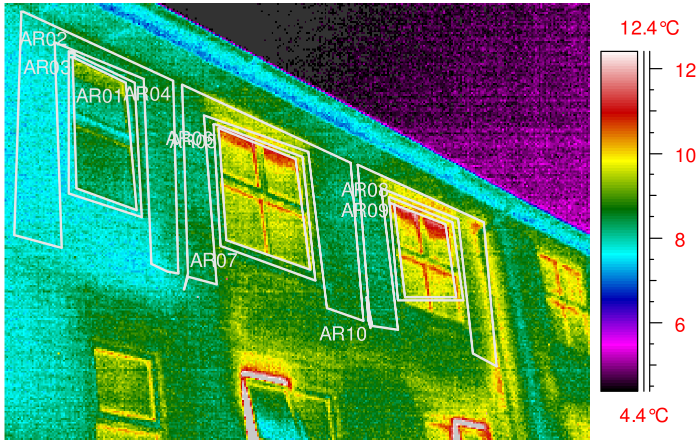
Cost of heating the room per year £176.16

Recommendations

LabelValue
IR : max20.0℃
IR : min3.2℃
AR01 : avg8.5℃

SE15 Bedroom 18

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	2.028	10	21	30.424	29.915	60.340	2.705	0.370
Brick Wall	Wall	5.58	9	24	61.257	95.805	157.062	1.876	0.533



91.682 watts 125.7196 watt 217.40153 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.217401532 kW

Cost of heating the room per hour: £0.0201

Cost of heating the room per day £0.4826

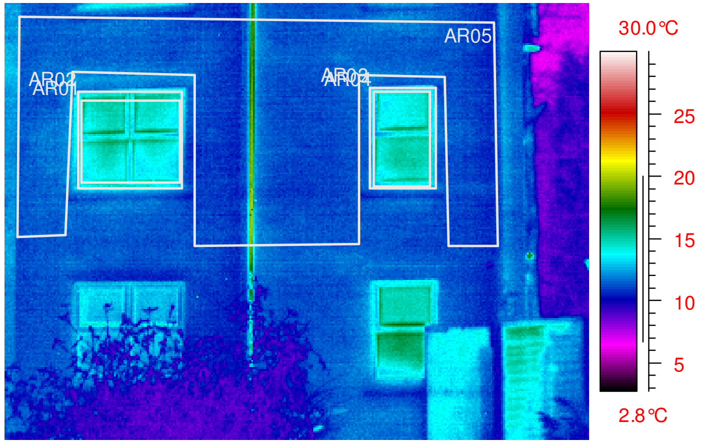
Cost of heating the room per calendar month £14.68

Cost of heating the room per year £176.16

Recommendations

LabelValue
IR : max20.0℃
IR : min3.2℃
AR01 : avg8.5℃

SE18 Group Room		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	Wall	9.257	12	24	237.966	366.244	604.209	5.439	0.184
Window	Window	2.743	14	21	92.998	89.507	182.505	9.505	0.105



330.964 watts 455.7505 watt 786.71473 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.786714733 kW

Cost of heating the room per hour: £0.0728

Cost of heating the room per day £1.7465

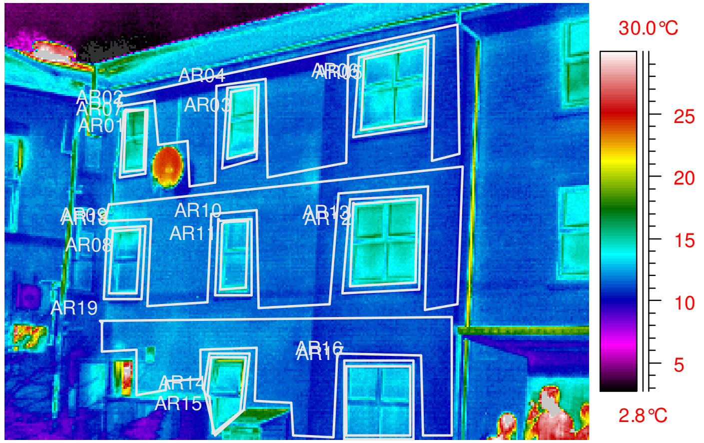
Cost of heating the room per calendar month £53.12

Cost of heating the room per year £637.47

Recommendations

LabelValue
IR : max20.5℃
IR : min6.4℃
AR01 : avg14.5℃

SE19 ATP Office		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	2.028	13	21	59.022	57.111	116.133	7.158	0.140
Brick Wall	Wall	5.58	12	24	143.443	220.767	364.210	5.439	0.184



202.465 watts 277.8775 watt 480.34247 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.480342475 kW

Cost of heating the room per hour: £0.0444

Cost of heating the room per day £1.0664

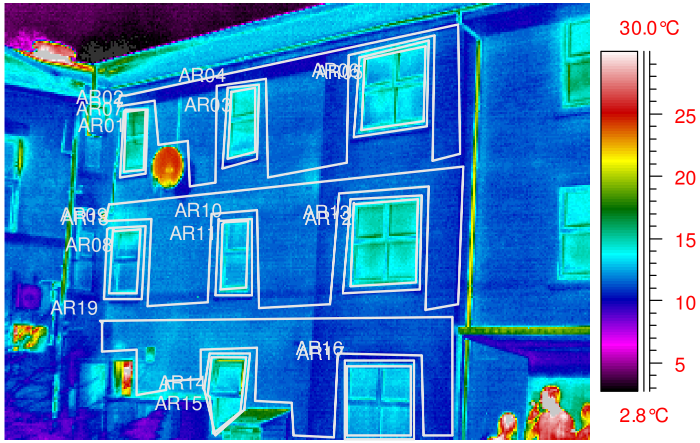
Cost of heating the room per calendar month £32.44

Cost of heating the room per year £389.22

Recommendations

SE20 Bedroom

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	2.028	13	21	59.022	57.111	116.133	7.158	0.140
Brick Wall	Wall	5.58	12	24	143.443	220.767	364.210	5.439	0.184



202.465 watts 277.8775 watt 480.34247 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.480342475 kW

Cost of heating the room per hour: £0.0444

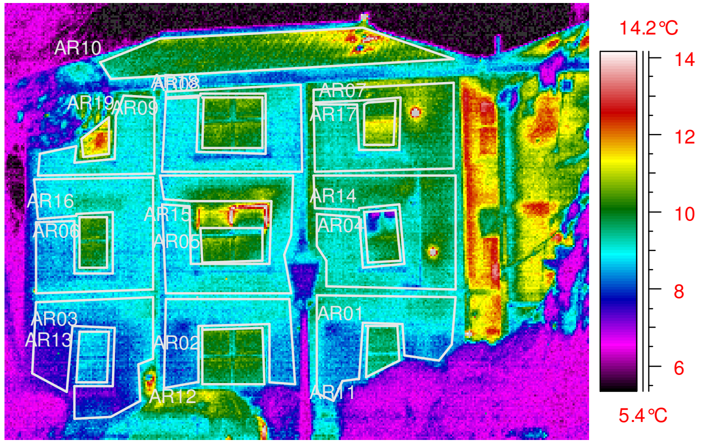
Cost of heating the room per day £1.0664

Cost of heating the room per calendar month £32.44

Cost of heating the room per year £389.22

Recommendations

SE8 Medical Secretary		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Window	Window	1.485	10	21	22.278	21.905	44.184	2.705	0.370
Brick Wall	Wall	10.515	9	24	115.434	180.535	295.969	1.876	0.533



137.712 watts 202.4401 watt 340.15255 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.340152545 kW

Cost of heating the room per hour: £0.0315

Cost of heating the room per day £0.7551

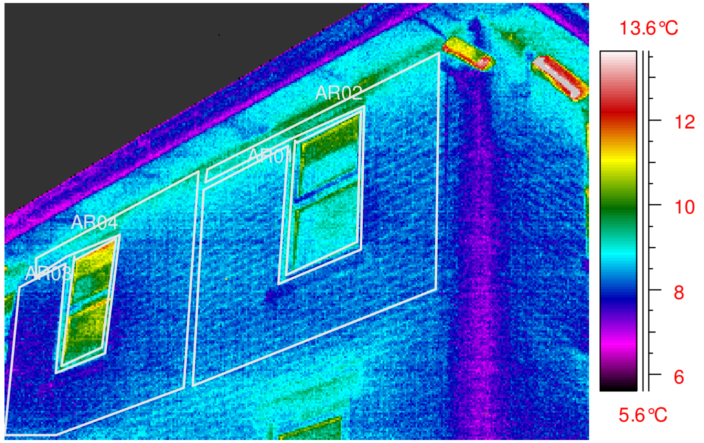
Cost of heating the room per calendar month £22.97

Cost of heating the room per year £275.63

Recommendations

SE9 Bedroom 13

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value	R Value
Brick Wall	North Wall	6.965	8	24	42.987	67.591	110.578	0.992	1.008
Window	West Window	0.715	10	21	10.727	10.547	21.274	2.705	0.370
Brick Wall	West Wall	6.965	9	24	76.462	119.584	196.046	1.876	0.533
Window	North Window	0.715	9	21	7.436	7.351	14.787	1.723	0.580



137.612 watts 205.0728 watt 342.68444 watts

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.342684439 kW

Cost of heating the room per hour: £0.0317

Cost of heating the room per day £0.7608

Cost of heating the room per calendar month £23.14

Cost of heating the room per year £277.68

Recommendations

LabelValue
IR : max15.3°C
IR : min2.6°C
AR01 : avg9.2°C

Total radiant loss	10,015.732 watts	Total convective loss	14,020.655 watts

Total heat loss from the building	24.036386559 kW
Cost of heating the building per hour:	£2.22
Cost of heating the building per day	£53.36
Cost of heating the building per calendar month	£1,623.06
Cost of heating the building per year	£19,476.68

Heat Loss Snapshot Overview Report

Please note: This report is based on actual ambient conditions encountered during the on-site survey

Priory Hospital

Rosemary Lane
Preston
Lancashire
PR4 0HB

Date of Survey: 10/02/2011

Cost per kWhour: 0.074

Wind Speed m/s: 0.000

Wind Direction (compass angle) 0.000

Total radiant loss 10,015.732 watts

Total convective loss 14,020.655 watts

Total heat loss from the building	24.036386559 kW
Cost of heating the building per hour:	£2.22
Cost of heating the building per day	£53.36
Cost of heating the building per calendar month	£1,623.06
Cost of heating the building per year	£19,476.68

Annual Averaged Heat Loss Detailed Report

Please note: This report estimates the costs associated with heat losses over a 12 month period based on averaged ambient data.

Priory Hospital

Rosemary Lane
Preston
Lancashire
PR4 0HB

Date of Survey:
10/02/2011

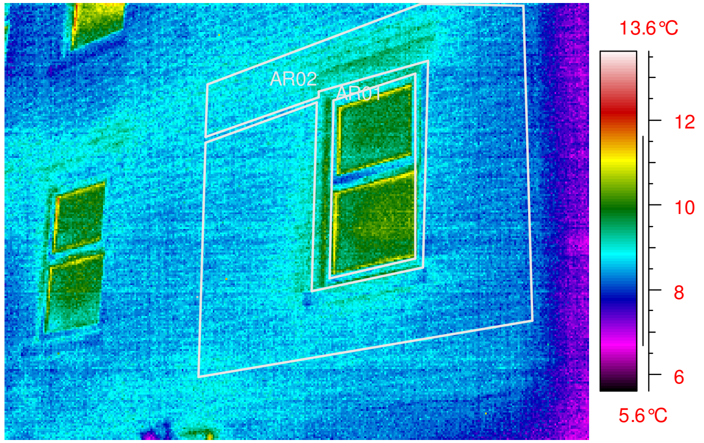
Cost per kWhour: 0.074

Annual Average Conditions

Wind Speed m/s: 3.500

F10 Asst Ward Manager

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	North Window	0.7425	10	21	11.139	14.266	25.406	2.705
Brick Wall	North Wall	6.9375	9	24	76.160	134.083	210.243	1.876
Window	West Window	0.7425	10	21	11.139	14.266	25.406	2.705
Brick Wall	West Wall	6.9375	9	24	76.160	134.083	210.243	1.876
				Totals	174.6 watts	296.698 watt	471.29676 watts	



LabelValue
IR : max14.5℃
IR : min6.3℃
AR01 : avg9.8℃
AR02 : avg8.6℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.471296763 kW

Cost of heating the room per hour: £0.0436

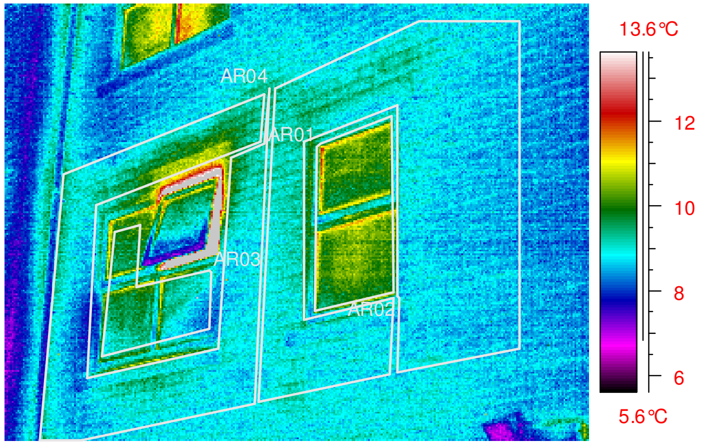
Cost of heating the room per day £1.0463

Cost of heating the room per calendar month £31.82

Cost of heating the room per year £381.89

F11 Store Room

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	5.86	9	24	64.331	113.258	177.589	1.876
Window	Window	0.7425	10	21	11.139	14.266	25.406	2.705
				Totals	75.470 watts	127.524 watt	202.99445 watts	



LabelValue
IR : max23.1℃
IR : min6.6℃
AR01 : avg10.2℃
AR02 : avg8.8℃
AR03 : avg9.4℃
AR04 : avg9.0℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.202994445 kW

Cost of heating the room per hour: £0.0188

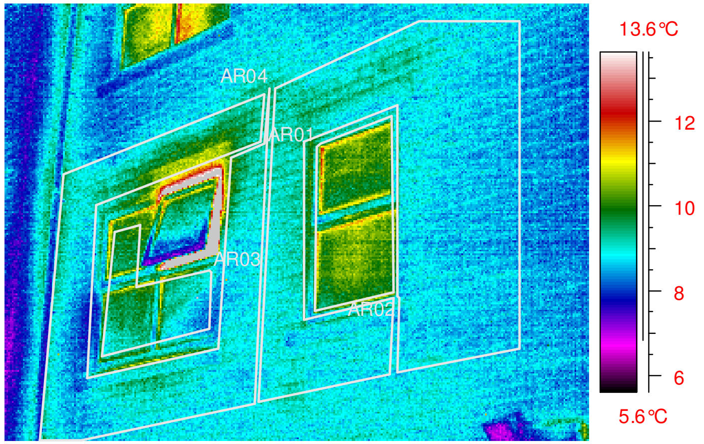
Cost of heating the room per day £0.4506

Cost of heating the room per calendar month £13.71

Cost of heating the room per year £164.49

F13 Bedroom 2

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)		U Value
Brick Wall	Wall	6.965	9	24	76.462		134.614		211.076		1.876
Window	Window	0.7425	9	21	7.722		9.105		16.827		1.723
				Totals	84.184	watts	143.719	watt	227.90369	watts	



LabelValue
IR : max23.1℃
IR : min6.6℃
AR01 : avg10.2℃
AR02 : avg8.8℃
AR03 : avg9.4℃
AR04 : avg9.0℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.227903688 kW

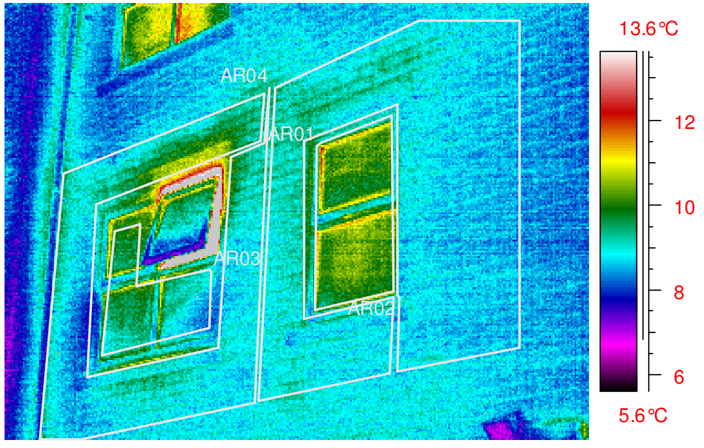
Cost of heating the room per hour: £0.0211

Cost of heating the room per day £0.5059

Cost of heating the room per calendar month £15.39

Cost of heating the room per year £184.67

F14 Bedroom 3		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	6.965	9	24	76.462	134.614	211.076	1.876
Window	Window	2.041	10	21	30.620	39.216	69.835	2.705
				Totals	107.08 watts	173.83 watt	280.9115 watts	



LabelValue
IR : max23.1℃
IR : min6.6℃
AR01 : avg10.2℃
AR02 : avg8.8℃
AR03 : avg9.4℃
AR04 : avg9.0℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.280911499 kW

Cost of heating the room per hour: £0.0260

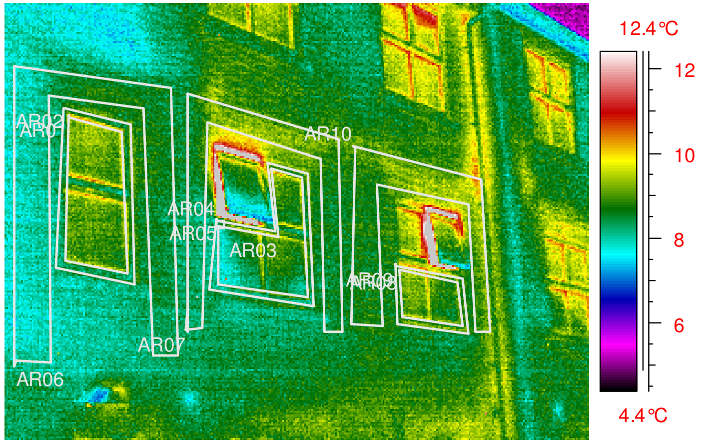
Cost of heating the room per day £0.6236

Cost of heating the room per calendar month £18.97

Cost of heating the room per year £227.62

F15 Bedroom 4

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	6.965	9	24	76.462	134.614	211.076	1.876
Window	Window	0.7425	10	21	11.139	14.266	25.406	2.705
				Totals	87.601 watts	148.881 watt	236.48178 watts	

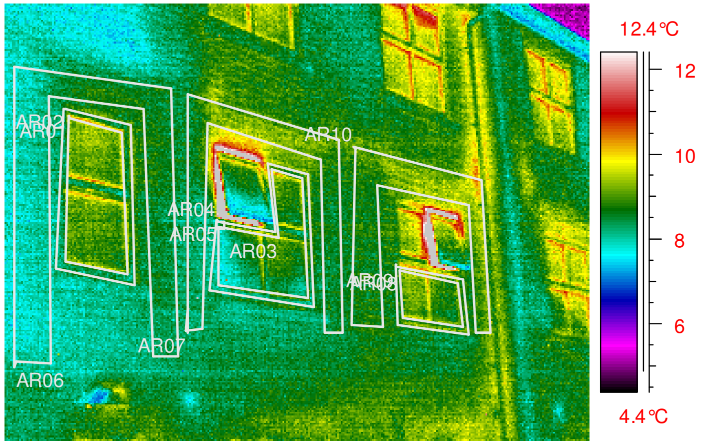


LabelValue
IR : max19.8℃
IR : min4.7℃
AR01 : avg9.2℃
AR02 : avg9.0℃
AR03 : avg8.7℃
AR04 : avg8.3℃
AR05 : avg8.7℃
AR06 : avg8.3℃
AR08 : avg9.1℃
AR09 : avg9.1℃
AR07 : avg8.8℃
AR10 : avg9.0℃

Cost per kWh	**£0.0740**
Boiler Efficiency	**80%**
Total heat loss from this room	0.236481777 kW
Cost of heating the room per hour:	£0.0219
Cost of heating the room per day	£0.5250
Cost of heating the room per calendar month	£15.97
Cost of heating the room per year	£191.62

F16 Bedroom 5

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	6.965	9	24	76.462	134.614	211.076	1.876
Window	Window	0.7425	9	21	7.722	9.105	16.827	1.723
				Totals	84.184 watts	143.719 watt	227.90369 watts	



LabelValue
IR : max19.8℃
IR : min4.7℃
AR01 : avg9.2℃
AR02 : avg9.0℃
AR03 : avg8.7℃
AR04 : avg8.3℃
AR05 : avg8.7℃
AR06 : avg8.3℃
AR08 : avg9.1℃
AR09 : avg9.1℃
AR07 : avg8.8℃
AR10 : avg9.0℃

Cost per kWh **£0.0740**

Boiler Efficiency **80%**

Total heat loss from this room 0.227903688 kW

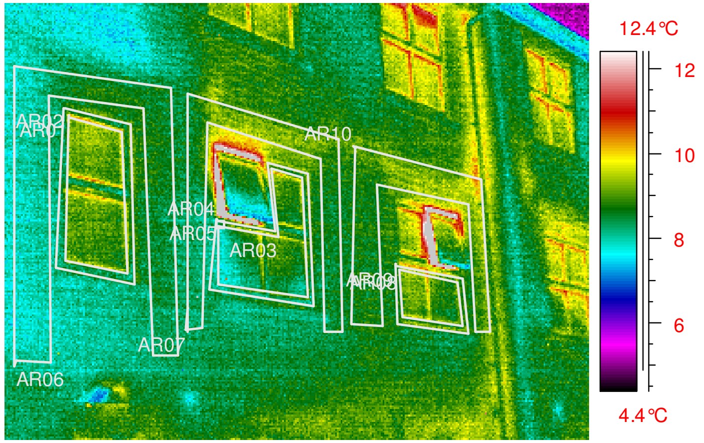
Cost of heating the room per hour: £0.0211

Cost of heating the room per day £0.5059

Cost of heating the room per calendar month £15.39

Cost of heating the room per year £184.67

F17 Bedroom 6		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Window	0.7425	9	16	7.722	10.156	17.879	2.954
Brick Wall	Wall	6.965	9	20	76.462	140.080	216.542	2.559
				Totals	84.184 watts	150.236 watt	234.42036 watts	



LabelValue
IR : max19.8°C
IR : min4.7°C
AR01 : avg9.2°C
AR02 : avg9.0°C
AR03 : avg8.7°C
AR04 : avg8.3°C
AR05 : avg8.7°C
AR06 : avg8.3°C
AR08 : avg9.1°C
AR09 : avg9.1°C
AR07 : avg8.8°C
AR10 : avg9.0°C

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.234420357 kW

Cost of heating the room per hour: £0.0217

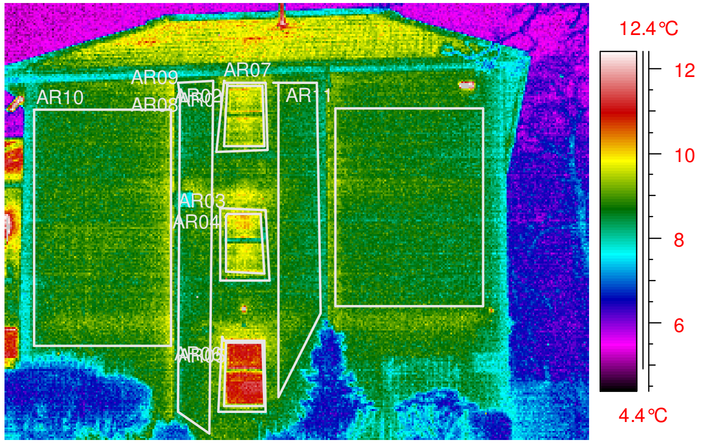
Cost of heating the room per day £0.5204

Cost of heating the room per calendar month £15.83

Cost of heating the room per year £189.95

F19 Bedroom 7

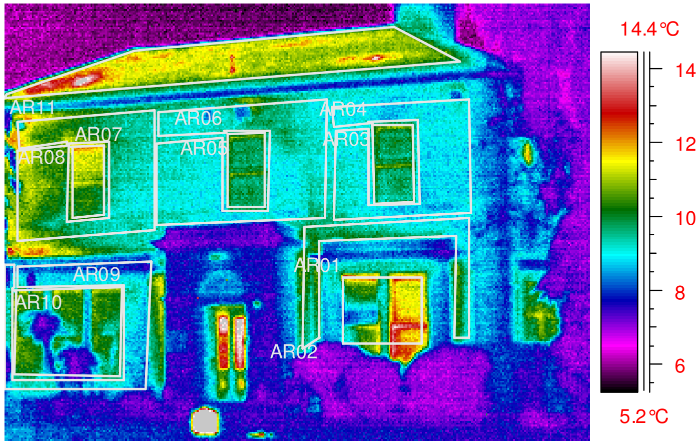
		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	9.244	12	24	237.632	498.972	736.603	5.439
Window	Window	2.756	15	21	106.808	246.849	353.656	12.643
				Totals	344.44 watts	745.820 watt	1090.2595 watts	



LabelValue
IR : max20.4℃
IR : min4.7℃
AR01 : avg9.5℃
AR02 : avg9.4℃
AR03 : avg9.5℃
AR04 : avg9.4℃
AR05 : avg10.7℃
AR06 : avg10.4℃
AR07 : avg8.7℃
AR08 : avg7.4℃
AR09 : avg8.7℃
AR10 : avg8.9℃
AR11 : avg8.7℃

Cost per kWh	**£0.0740**	
Boiler Efficiency	**80%**	
Total heat loss from this room	1.09025955	kW
Cost of heating the room per hour:	£0.1008	
Cost of heating the room per day	£2.4204	
Cost of heating the room per calendar month	£73.62	
Cost of heating the room per year	£883.44	

F2 Bedroom 12		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Window	1.485	11	19	29.185	44.058	73.243	4.859
Brick Wall	Wall	13.515	11	24	280.369	551.935	832.304	4.065
				Totals	309.55 watts	595.992 watt	905.54669 watts	



Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.905546694 kW

Cost of heating the room per hour: £0.0838

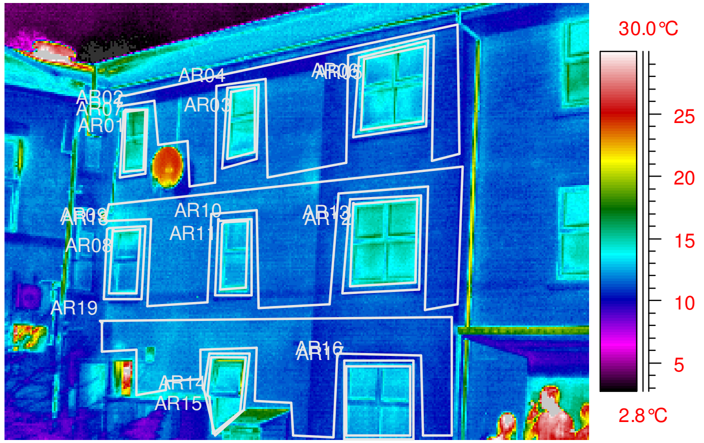
Cost of heating the room per day £2.0103

Cost of heating the room per calendar month £61.15

Cost of heating the room per year £733.76

F21A Bedroom

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)		U Value
Window	Window	2.756	13	21	80.210		139.754		219.964		7.158
Brick Wall	Wall	6.965	12	24	179.046		375.956		555.002		5.439
				Totals	259.26	watts	515.71	watt	774.96603	watts	



Cost per kWh **£0.0740**

Boiler Efficiency **80%**

Total heat loss from this room 0.774966027 kW

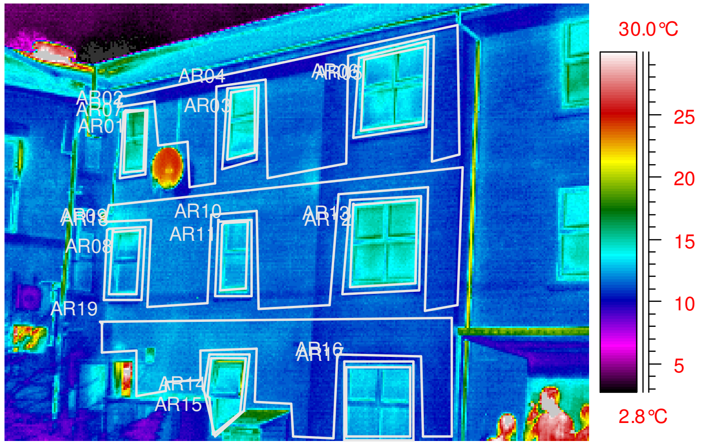
Cost of heating the room per hour: £0.0717

Cost of heating the room per day £1.7204

Cost of heating the room per calendar month £52.33

Cost of heating the room per year £627.95

F21B Bedroom		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Window	2.756	13	21	80.210	139.754	219.964	7.158
Brick Wall	Wall	6.965	12	24	179.046	375.956	555.002	5.439
				Totals	259.26 watts	515.71 watt	774.96603 watts	



Cost per kWh **£0.0740**

Boiler Efficiency **80%**

Total heat loss from this room 0.774966027 kW

Cost of heating the room per hour: £0.0717

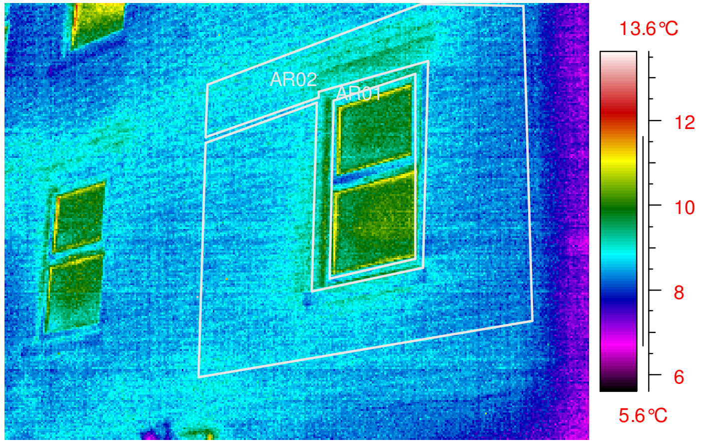
Cost of heating the room per day £1.7204

Cost of heating the room per calendar month £52.33

Cost of heating the room per year £627.95

F3 Bedroom 11

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C		Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)		U Value
Brick Wall	Wall	20	9	22		219.561		393.184		612.745		2.165
Window	Window	1.1	10	21		16.502		21.135		37.638		2.705
					Totals	236.06	watts	414.32	watt	650.38323	watts	



LabelValue
IR : max14.5℃
IR : min6.3℃
AR01 : avg9.8℃
AR02 : avg8.6℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.650383233 kW

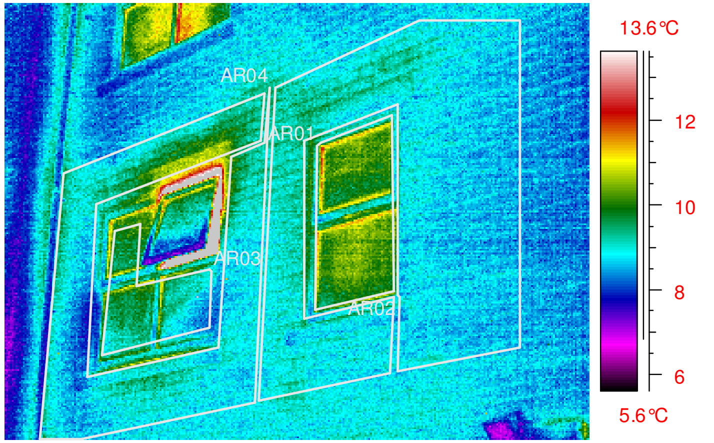
Cost of heating the room per hour: £0.0602

Cost of heating the room per day £1.4439

Cost of heating the room per calendar month £43.92

Cost of heating the room per year £527.01

F4 Bedroom 10		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	East Wall	9.75	11	22	202.264	413.670	615.934	4.804
Window	East Window	0.7525	11	19	14.789	22.326	37.115	4.859
Brick Wall	South Wall	14.257	10	22	225.769	430.544	656.313	3.372
Window	South Window	0.55	12	19	13.394	23.034	36.428	6.864
				Totals	456.22 watts	889.573 watt	1345.7899 watts	



LabelValue
IR : max23.1℃
IR : min6.6℃
AR01 : avg10.2℃
AR02 : avg8.8℃
AR03 : avg9.4℃
AR04 : avg9.0℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 1.345789858 kW

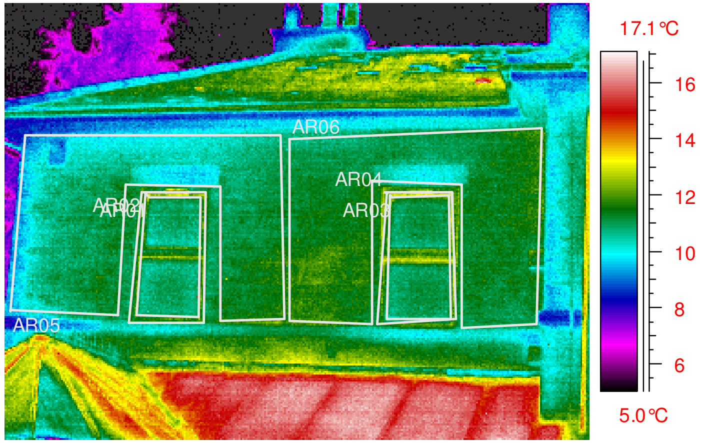
Cost of heating the room per hour: £0.1245

Cost of heating the room per day £2.9877

Cost of heating the room per calendar month £90.87

Cost of heating the room per year £1,090.49

F5 Bedroom 9		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Window	0.7525	11	19	14.789	22.326	37.115	4.859
Brick Wall	Wall	14.2575	11	22	295.773	604.913	900.685	4.804
				Totals	310.56 watts	627.238 watt	937.79994 watts	



LabelValue
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IR : min4.1℃
AR01 : avg11.0℃
AR02 : avg11.2℃
AR03 : avg11.3℃
AR04 : avg11.4℃
AR05 : avg10.7℃
AR06 : avg11.3℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.937799941 kW

Cost of heating the room per hour: £0.0867

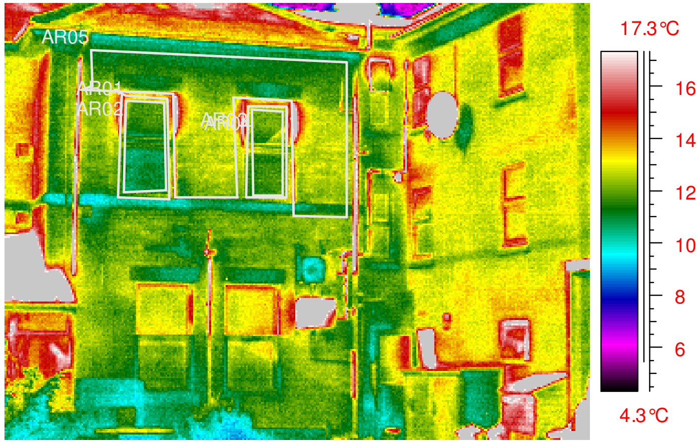
Cost of heating the room per day £2.0819

Cost of heating the room per calendar month £63.32

Cost of heating the room per year £759.90

F6 Bartle Room

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Window	1.485	12	21	36.165	56.189	92.354	5.338
Brick Wall	Wall	13.515	10	24	214.019	397.393	611.412	2.891
				Totals	250.18 watts	453.581 watt	703.76548 watts	



LabelValue
IR : max60.8℃
IR : min5.2℃
AR01 : avg11.3℃
AR02 : avg11.7℃
AR03 : avg12.1℃
AR04 : avg12.0℃
AR05 : avg12.3℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.703765475 kW

Cost of heating the room per hour: £0.0651

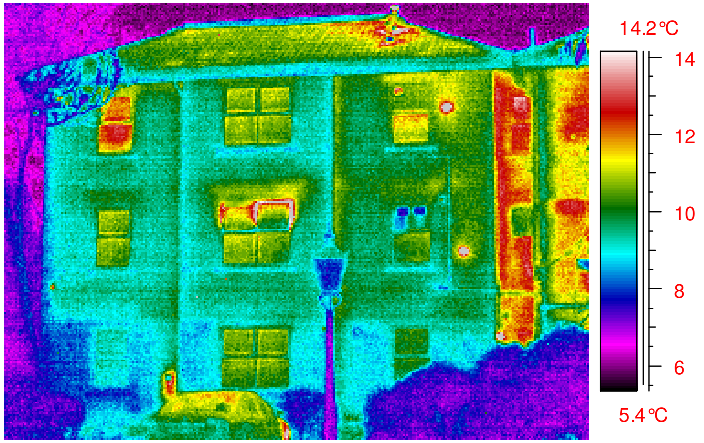
Cost of heating the room per day £1.5624

Cost of heating the room per calendar month £47.52

Cost of heating the room per year £570.26

F8&9 Nurse Station/Sluice

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Window	1.485	9	21	15.444	18.210	33.655	1.723
Brick Wall	Wall	10.515	10	24	166.512	309.181	475.693	2.891
				Totals	181.96 watts	327.392 watt	509.34814 watts	



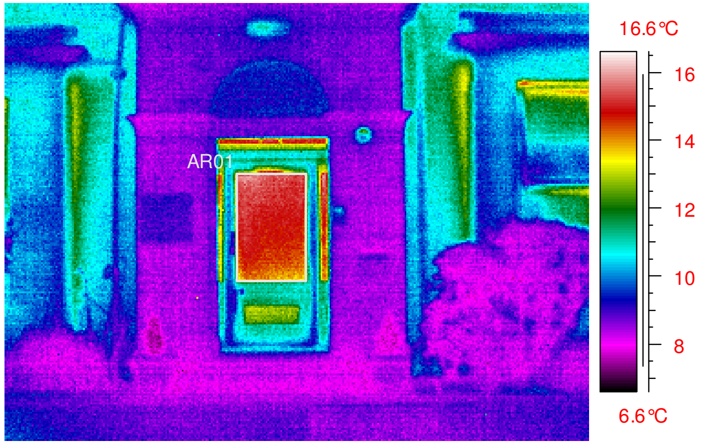
LabelValue
IR : max55.5℃
IR : min5.4℃

Cost per kWh	**£0.0740**
Boiler Efficiency	**80%**
Total heat loss from this room	0.509348138 kW
Cost of heating the room per hour:	£0.0471
Cost of heating the room per day	£1.1308
Cost of heating the room per calendar month	£34.39
Cost of heating the room per year	£412.72

G1 Entrance Lobby

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Door	Door	0.78	15	17	31.908	155.196	187.104	39.004

Totals 31.908 watts 155.196 watt 187.10369 watts



LabelValue
IR : max16.1℃
IR : min6.9℃
AR01 : avg14.8℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.187103687 kW

Cost of heating the room per hour: £0.0173

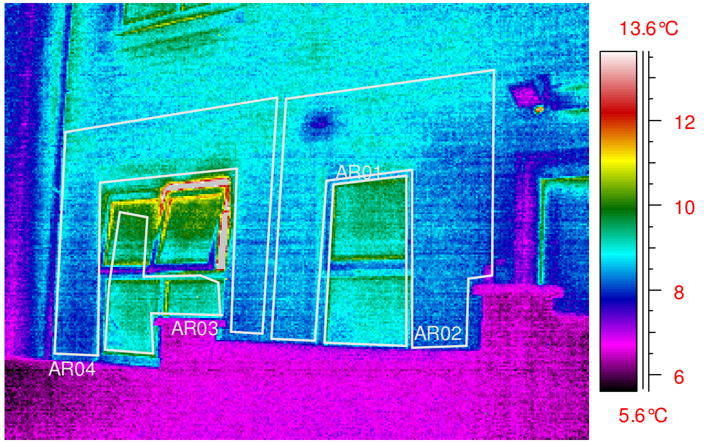
Cost of heating the room per day £0.4154

Cost of heating the room per calendar month £12.63

Cost of heating the room per year £151.61

G12 Consulting Room 1

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	5.4214	9	25	59.516	104.049	163.566	1.759
Window	Window	2.1306	9	20	22.159	26.511	48.670	1.880
				Totals	81.675 watts	130.561 watt	212.23595 watts	



Cost per kWh **£0.0740**

Boiler Efficiency **80%**

Total heat loss from this room 0.212235949 kW

Cost of heating the room per hour: £0.0196

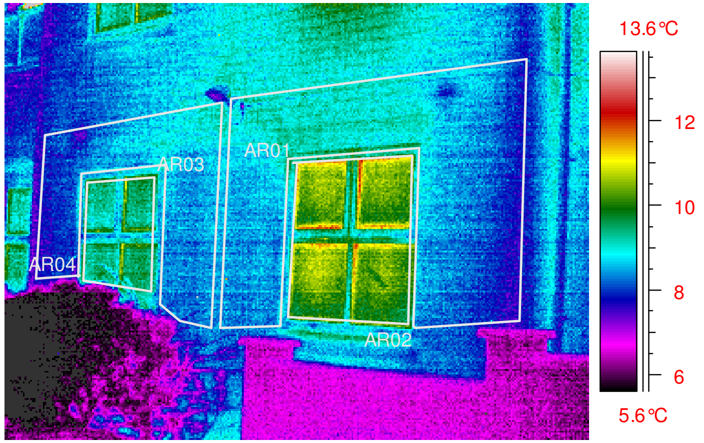
Cost of heating the room per day £0.4712

Cost of heating the room per calendar month £14.33

Cost of heating the room per year £171.97

G13 Consulting Room 2

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	5.4214	8	25	33.460	55.902	89.362	0.934
Window	Window	2.1306	10	20	31.964	41.888	73.852	2.975
				Totals	65.424 watts	97.7904 watt	163.21409 watts	



LabelValue
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IR : min4.4℃
AR01 : avg10.3℃
AR02 : avg8.5℃
AR03 : avg9.4℃
AR04 : avg8.4℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.163214092 kW

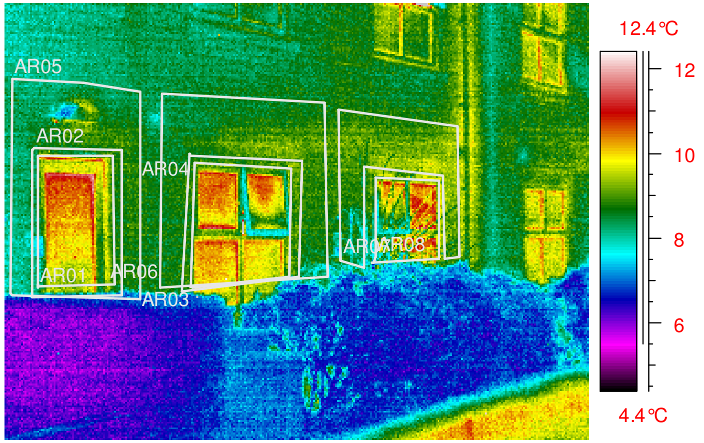
Cost of heating the room per hour: £0.0151

Cost of heating the room per day £0.3623

Cost of heating the room per calendar month £11.02

Cost of heating the room per year £132.25

G14 Hospital Manager		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	5.4214	8	23	33.460	56.341	89.801	1.058
Window	Window	2.1306	9	20	22.159	26.511	48.670	1.880
				Totals	55.619 watts	82.8524 watt	138.47111 watts	



LabelValue
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AR02 : avg9.5℃
AR03 : avg9.7℃
AR04 : avg9.5℃
AR05 : avg9.0℃
AR06 : avg9.1℃
AR08 : avg9.5℃
AR07 : avg9.0℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.138471107 kW

Cost of heating the room per hour: £0.0128

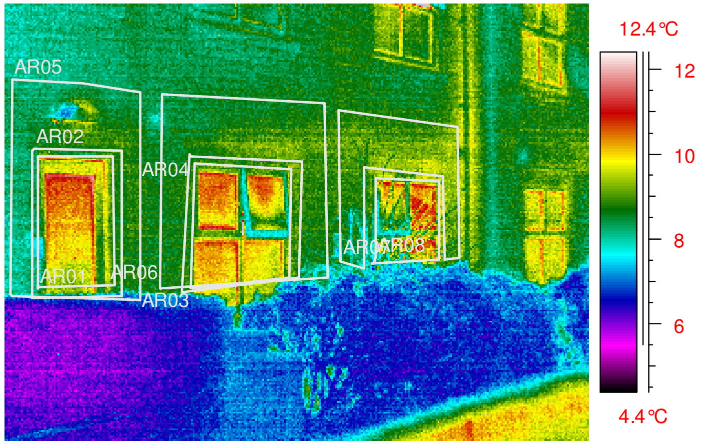
Cost of heating the room per day £0.3074

Cost of heating the room per calendar month £9.35

Cost of heating the room per year £112.20

G15 Therapy Service

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Window	2.1306	10	20	31.964	41.888	73.852	2.975
Brick Wall	Wall	5.4214	9	23	59.516	105.616	165.133	2.011
				Totals	91.480 watts	147.504 watt	238.98458 watts	



LabelValue
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AR02 : avg9.5℃
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AR04 : avg9.5℃
AR05 : avg9.0℃
AR06 : avg9.1℃
AR08 : avg9.5℃
AR07 : avg9.0℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.238984581 kW

Cost of heating the room per hour: £0.0221

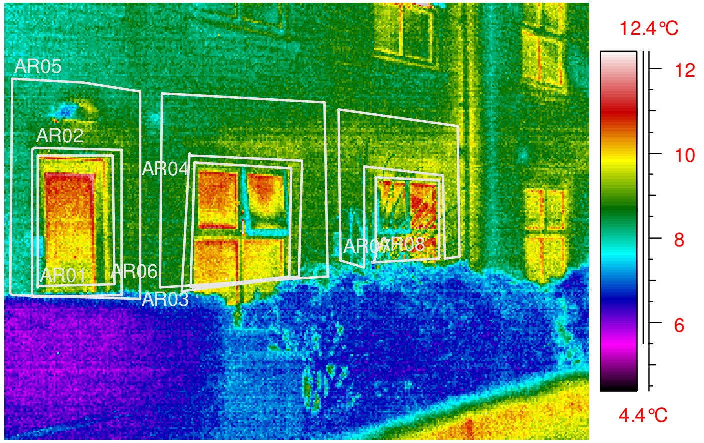
Cost of heating the room per day £0.5305

Cost of heating the room per calendar month £16.14

Cost of heating the room per year £193.65

G16 Marketing Office

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Window	2.1306	10	20	31.964	41.888	73.852	2.975
Brick Wall	Wall	5.4214	10	23	85.851	161.399	247.250	3.113
				Totals	117.82 watts	203.287 watt	321.10238 watts	



LabelValue
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AR01 : avg9.8℃
AR02 : avg9.5℃
AR03 : avg9.7℃
AR04 : avg9.5℃
AR05 : avg9.0℃
AR06 : avg9.1℃
AR08 : avg9.5℃
AR07 : avg9.0℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.321102381 kW

Cost of heating the room per hour: £0.0297

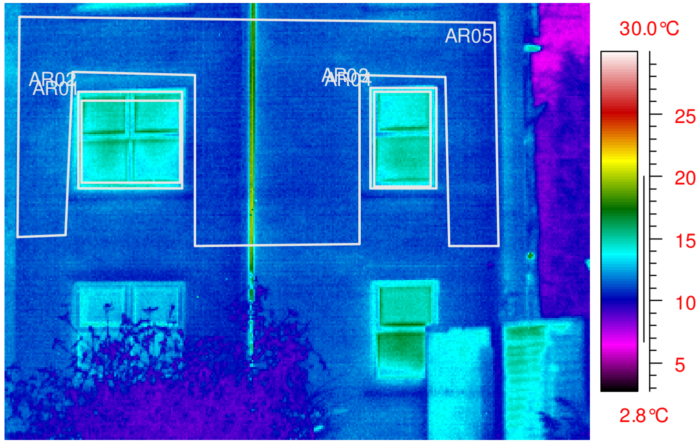
Cost of heating the room per day £0.7128

Cost of heating the room per calendar month £21.68

Cost of heating the room per year £260.19

G18 Assisted Bath

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	10.1124	12	25	259.955	534.634	794.589	5.021
Window	Window	2.8676	13	21	83.458	145.413	228.871	7.158
				Totals	343.41 watts	680.047 watt	1023.4597 watts	



LabelValue
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IR : min6.4℃
AR01 : avg14.5℃
AR02 : avg14.4℃
AR03 : avg14.2℃
AR04 : avg14.4℃
AR05 : avg11.5℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 1.023459722 kW

Cost of heating the room per hour: £0.0947

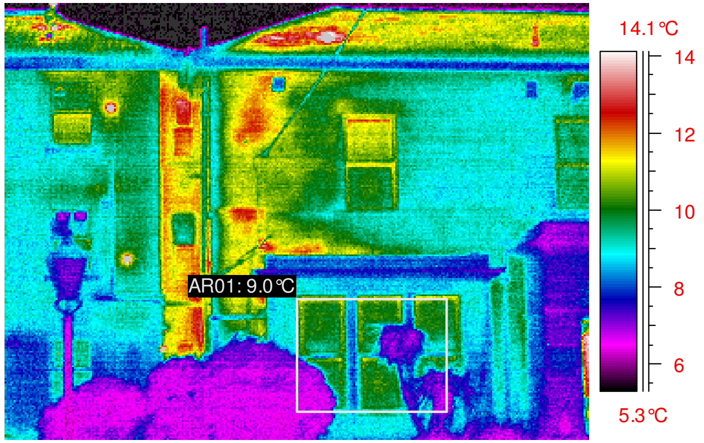
Cost of heating the room per day £2.2721

Cost of heating the room per calendar month £69.11

Cost of heating the room per year £829.31

G2 Reception

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Windows	2.97	9	21	30.889	36.421	67.310	1.723
Brick Wall	Wall	12.03	11	20	249.563	538.017	787.580	5.872
				Totals	280.45 watts	574.438 watt	854.88969 watts	



LabelValue
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IR : min4.6℃
AR01 : avg9.0℃

Cost per kWh **£0.0740**

Boiler Efficiency **80%**

Total heat loss from this room 0.854889694 kW

Cost of heating the room per hour: £0.0791

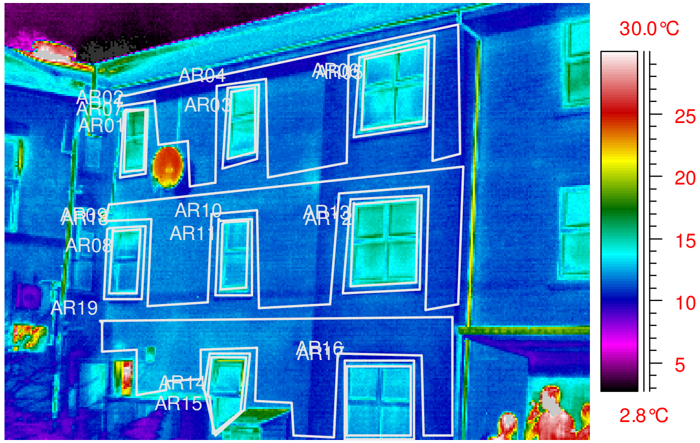
Cost of heating the room per day £1.8979

Cost of heating the room per calendar month £57.73

Cost of heating the room per year £692.72

G21 Hospital Director

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C		Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)		U Value
Brick Wall	Wall	3.983	12	25		102.389		210.578		312.967		5.021
Window	Window	0.737	14	21		24.987		49.618		74.605		9.505
					Totals	127.38	watts	260.196	watt	387.57212	watts	



Cost per kWh **£0.0740**

Boiler Efficiency **80%**

Total heat loss from this room 0.387572123 kW

Cost of heating the room per hour: £0.0359

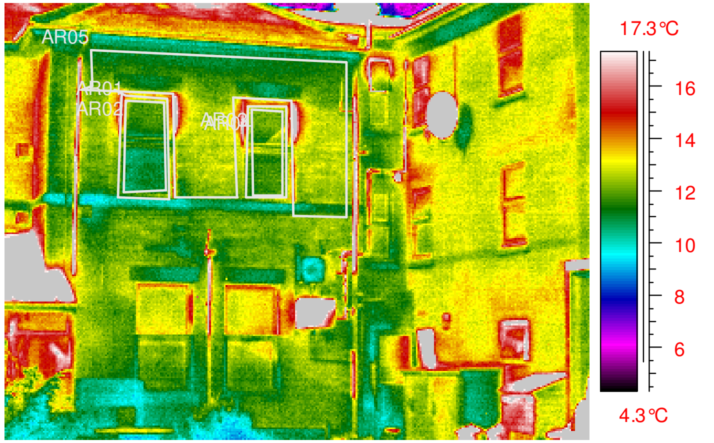
Cost of heating the room per day £0.8604

Cost of heating the room per calendar month £26.17

Cost of heating the room per year £314.05

G27 Dining Room

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	10.02	12	25	257.580	529.749	787.328	5.021
Window	Window	1.98	13	21	57.625	100.404	158.029	7.158
				Totals	315.21 watts	630.152 watt	945.35757 watts	



Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.945357571 kW

Cost of heating the room per hour: £0.0874

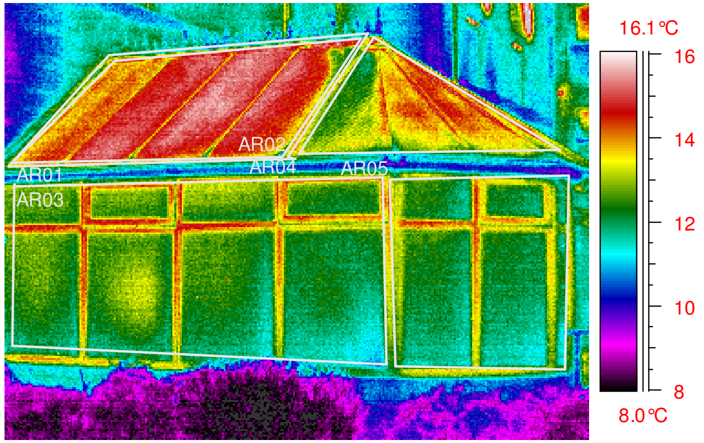
Cost of heating the room per day £2.0987

Cost of heating the room per calendar month £63.84

Cost of heating the room per year £766.02

G30 Conservatory

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
PentRoof	Glass Roof	14.875	14	18	504.321	1,852.644	2,356.965	20.713
Window	Glass Wall	24.5	13	19	713.041	1,426.512	2,139.553	9.544
Brick Wall	Lower Wall	10.5	11	24	217.823	428.806	646.629	4.065
				Totals	1435.2 watts	3707.96 watt	5143.1477 watts	



LabelValue
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IR : min7.4℃
AR01 : avg14.6℃
AR02 : avg14.4℃
AR03 : avg12.6℃
AR04 : avg13.5℃
AR05 : avg12.4℃

Cost per kWh **£0.0740**

Boiler Efficiency **80%**

Total heat loss from this room 5.143147725 kW

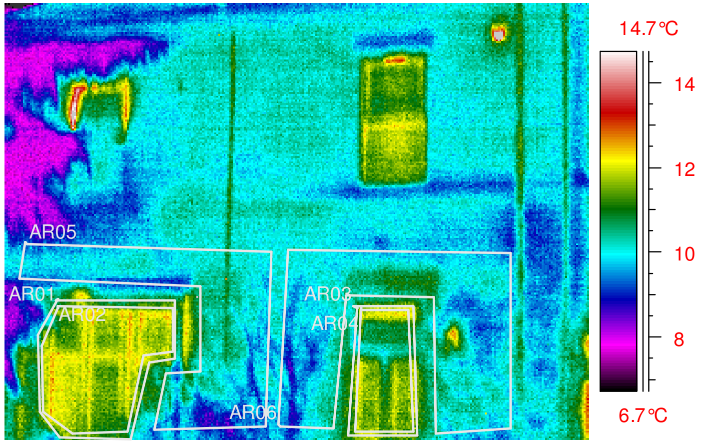
Cost of heating the room per hour: £0.4757

Cost of heating the room per day £11.4178

Cost of heating the room per calendar month £347.29

Cost of heating the room per year £4,167.49

G31 Multi Function Space		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C		Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)		U Value
Door	Door	3.3	11	19		64.856		97.906		162.761		4.859
Brick Wall	Wall	11.7	10	22		185.277		353.326		538.603		3.372
					Totals	250.13	watts	451.231	watt	701.36435	watts	



LabelValue
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IR : min4.9℃
AR01 : avg11.8℃
AR02 : avg11.7℃
AR03 : avg11.4℃
AR04 : avg11.4℃
AR05 : avg9.9℃
AR06 : avg10.0℃

Cost per kWh **£0.0740**

Boiler Efficiency **80%**

Total heat loss from this room 0.70136435 kW

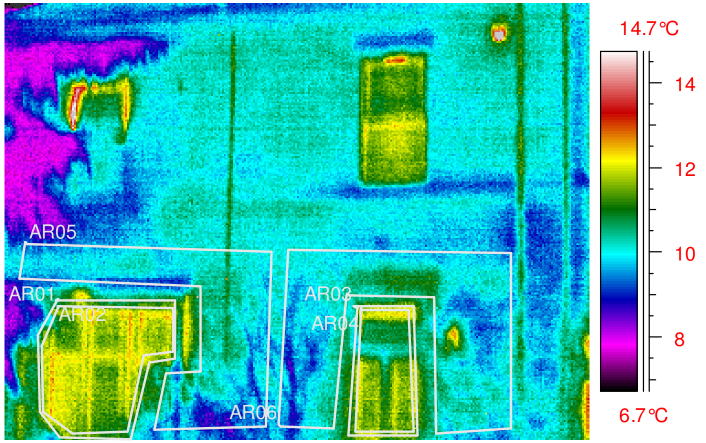
Cost of heating the room per hour: £0.0649

Cost of heating the room per day £1.5570

Cost of heating the room per calendar month £47.36

Cost of heating the room per year £568.32

G32 Multi Function Space		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Window	1.98	12	19	48.220	82.921	131.141	6.864
Brick Wall	Wall	13.02	10	22	206.180	393.188	599.368	3.372
				Totals	254.40 watts	476.109 watt	730.50952 watts	



LabelValue
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AR02 : avg11.7℃
AR03 : avg11.4℃
AR04 : avg11.4℃
AR05 : avg9.9℃
AR06 : avg10.0℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.730509516 kW

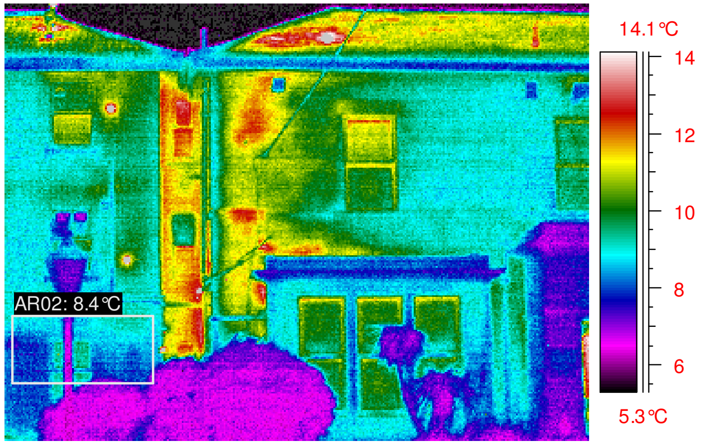
Cost of heating the room per hour: £0.0676

Cost of heating the room per day £1.6217

Cost of heating the room per calendar month £49.33

Cost of heating the room per year £591.93

G6 Changing Room		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	3.983	9	23	43.726	77.594	121.320	2.011
Window	Window	0.737	10	20	11.057	14.490	25.546	2.975
				Totals	54.782 watts	92.0839 watt	146.86611 watts	



LabelValue
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IR : min4.6℃
AR01 : avg9.0℃
AR02 : avg8.4℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.146866113 kW

Cost of heating the room per hour: £0.0136

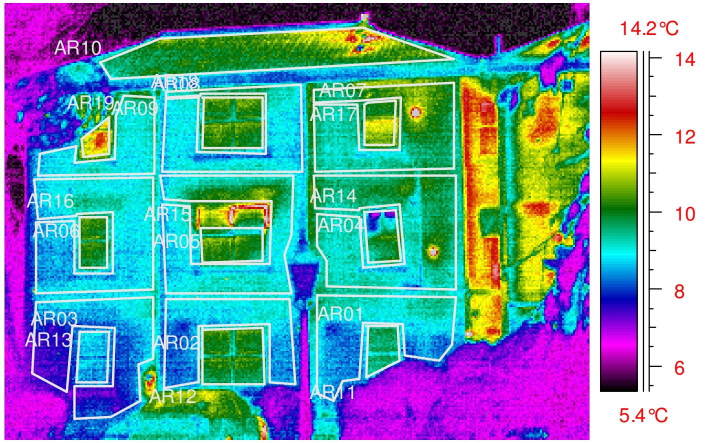
Cost of heating the room per day £0.3260

Cost of heating the room per calendar month £9.92

Cost of heating the room per year £119.01

G7 Waiting Area

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)		U Value
Window	Window	2.1306	10	20	31.964		41.888		73.852		2.975
Brick Wall	Wall	2.5894	9	23	28.427		50.445		78.872		2.011
				Totals	60.390	watts	92.3333	watt	152.72351	watts	



Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.152723512 kW

Cost of heating the room per hour: £0.0141

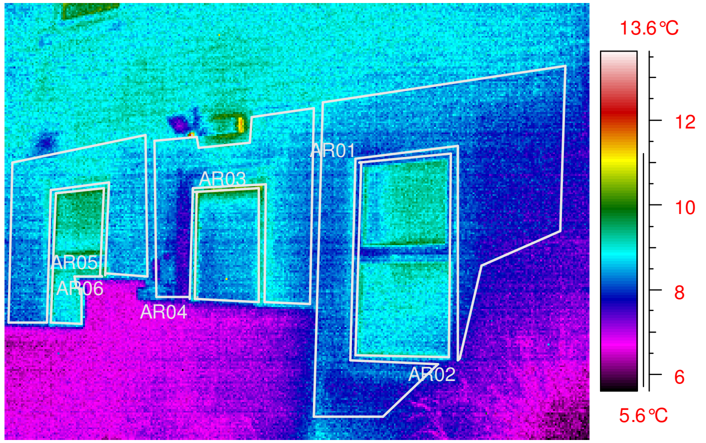
Cost of heating the room per day £0.3390

Cost of heating the room per calendar month £10.31

Cost of heating the room per year £123.75

G9 Pantry

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	West Wall	3.983	8	22	24.582	41.588	66.171	1.134
Brick Wall	North Wall	3.983	8	22	24.582	41.588	66.171	1.134
Window	West Window	0.737	9	21	7.665	9.038	16.703	1.723
Window	North Window	0.737	9	21	7.665	9.038	16.703	1.723
				Totals	64.495 watts	101.252 watt	165.7472 watts	



Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.165747198 kW

Cost of heating the room per hour: £0.0153

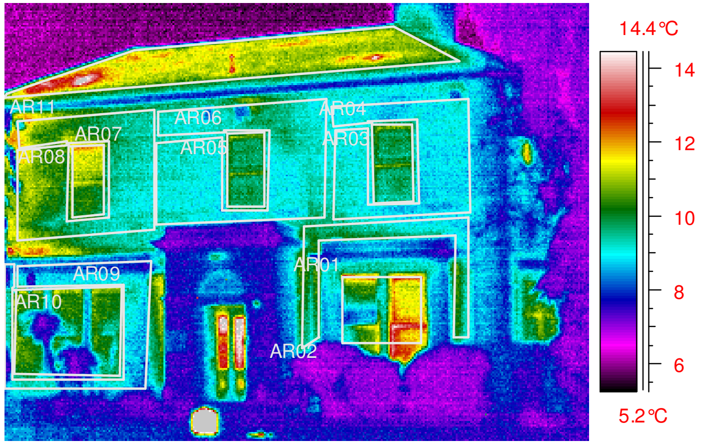
Cost of heating the room per day £0.3680

Cost of heating the room per calendar month £11.19

Cost of heating the room per year £134.30

SE1 Roof Space

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C		Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
PentRoof	Roof Void West	79.8	11	13		1,620.603	6,516.213	8,136.816	24.570
					Totals	1620.6 watts	6516.21 watt	8136.8159 watts	



LabelValue
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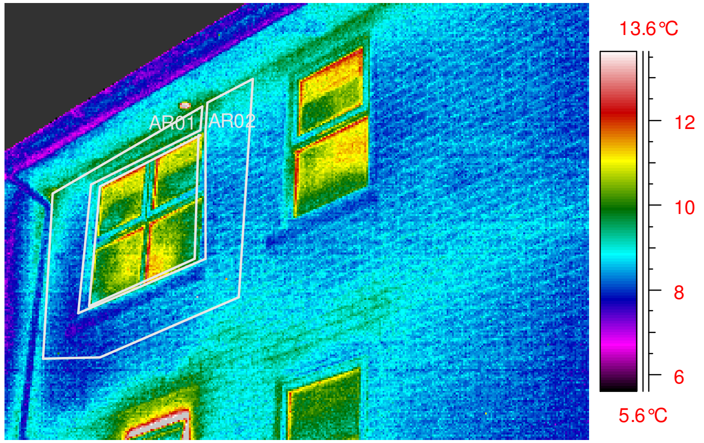
AR01 : avg10.7℃
AR02 : avg9.6℃
AR03 : avg9.9℃
AR04 : avg9.0℃
AR05 : avg9.9℃
AR06 : avg9.2℃
AR07 : avg10.8℃
AR08 : avg10.0℃
AR09 : avg9.5℃
AR10 : avg8.8℃
AR11 : avg11.2℃

Cost per kWh	**£0.0740**
Boiler Efficiency	**80%**
Total heat loss from this room	8.136815889 kW
Cost of heating the room per hour:	£0.7527
Cost of heating the room per day	£18.0637
Cost of heating the room per calendar month	£549.44
Cost of heating the room per year	£6,593.26

SE11 Bedroom 14		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Window	2.028	10	21	30.424	38.966	69.390	2.705
Brick Wall	Wall	5.58	9	24	61.257	107.846	169.103	1.876
				Totals	91.682 watts	146.812 watt	238.49388 watts	



LabelValue
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IR : min2.9℃
AR01 : avg10.3℃
AR02 : avg8.6℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.238493879 kW

Cost of heating the room per hour: £0.0221

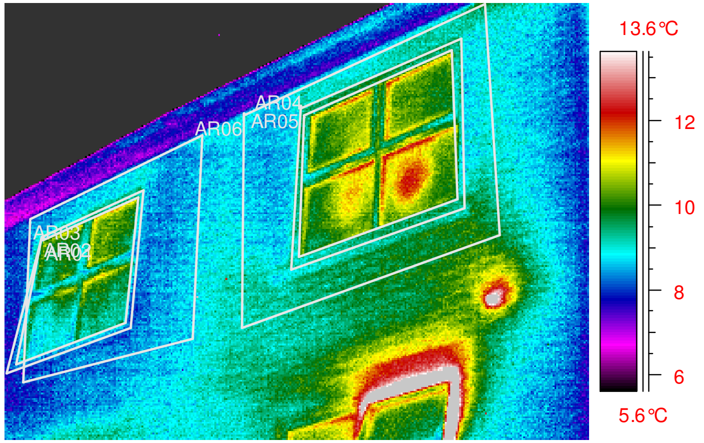
Cost of heating the room per day £0.5295

Cost of heating the room per calendar month £16.10

Cost of heating the room per year £193.25

SE12 Bedroom 15

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	5.58	10	24	88.363	164.073	252.436	2.891
Window	Window	2.028	10	21	30.424	38.966	69.390	2.705
				Totals	118.79 watts	203.039 watt	321.82681 watts	



LabelValue
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AR02 : avg9.5℃
AR03 : avg9.0℃
AR04 : avg10.5℃
AR05 : avg10.3℃
AR06 : avg9.7℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.321826806 kW

Cost of heating the room per hour: £0.0298

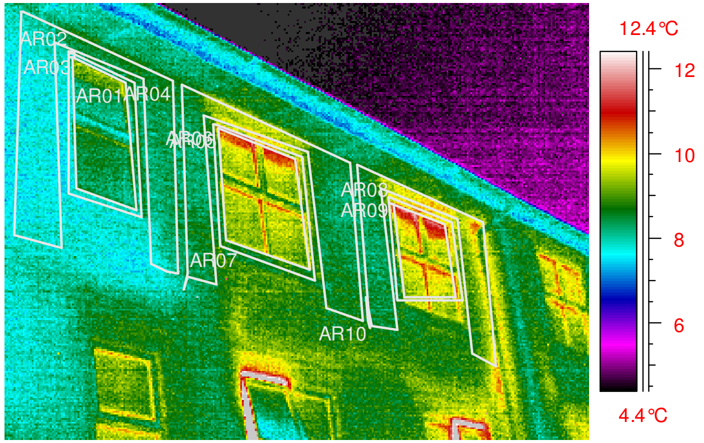
Cost of heating the room per day £0.7145

Cost of heating the room per calendar month £21.73

Cost of heating the room per year £260.78

SE13 Bedroom 16

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	5.58	8	22	34.439	58.263	92.702	1.134
Window	Window	2.028	9	24	21.092	24.065	45.157	1.379
				Totals	55.531 watts	82.3288 watt	137.85938 watts	



LabelValue
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AR02 : avg8.2℃
AR03 : avg8.4℃
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AR05 : avg9.7℃
AR06 : avg9.5℃
AR07 : avg8.6℃
AR08 : avg10.0℃
AR09 : avg9.9℃
AR10 : avg9.0℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.137859377 kW

Cost of heating the room per hour: £0.0128

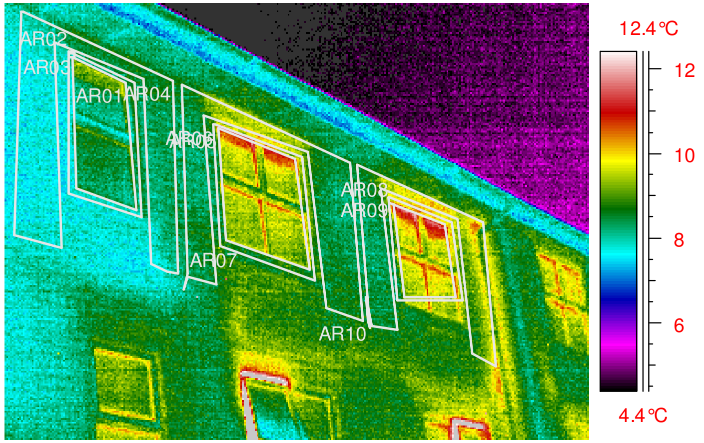
Cost of heating the room per day £0.3060

Cost of heating the room per calendar month £9.31

Cost of heating the room per year £111.71

SE14 Bedroom 17

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	5.58	9	24	61.257	107.846	169.103	1.876
Window	Window	2.028	10	21	30.424	38.966	69.390	2.705
				Totals	91.682 watts	146.812 watt	238.49388 watts	



LabelValue
IR : max20.0℃
IR : min3.2℃
AR01 : avg8.5℃
AR02 : avg8.2℃
AR03 : avg8.4℃
AR04 : avg8.0℃
AR05 : avg9.7℃
AR06 : avg9.5℃
AR07 : avg8.6℃
AR08 : avg10.0℃
AR09 : avg9.9℃
AR10 : avg9.0℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.238493879 kW

Cost of heating the room per hour: £0.0221

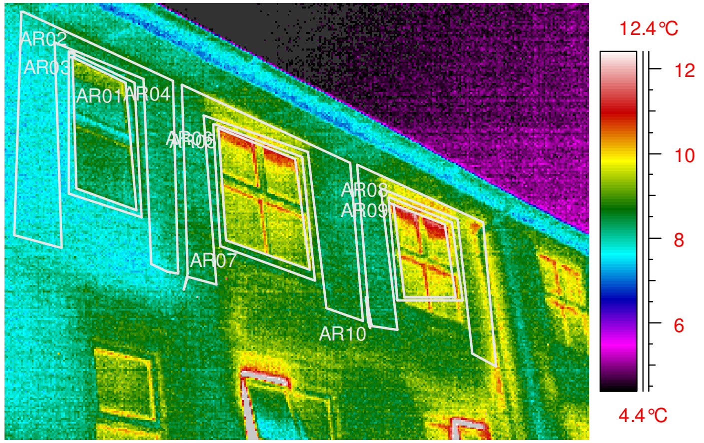
Cost of heating the room per day £0.5295

Cost of heating the room per calendar month £16.10

Cost of heating the room per year £193.25

SE15 Bedroom 18

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Window	2.028	10	21	30.424	38.966	69.390	2.705
Brick Wall	Wall	5.58	9	24	61.257	107.846	169.103	1.876
				Totals	91.682 watts	146.812 watt	238.49388 watts	



LabelValue
IR : max20.0℃
IR : min3.2℃
AR01 : avg8.5℃
AR02 : avg8.2℃
AR03 : avg8.4℃
AR04 : avg8.0℃
AR05 : avg9.7℃
AR06 : avg9.5℃
AR07 : avg8.6℃
AR08 : avg10.0℃
AR09 : avg9.9℃
AR10 : avg9.0℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.238493879 kW

Cost of heating the room per hour: £0.0221

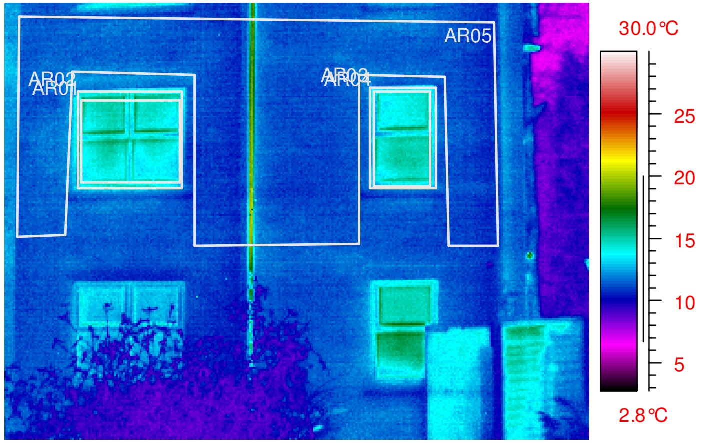
Cost of heating the room per day £0.5295

Cost of heating the room per calendar month £16.10

Cost of heating the room per year £193.25

SE18 Group Room

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	Wall	9.257	12	24	237.966	499.673	737.639	5.439
Window	Window	2.743	14	21	92.998	184.670	277.669	9.505
				Totals	330.96 watts	684.344 watt	1015.3078 watts	



LabelValue
IR : max20.5℃
IR : min6.4℃
AR01 : avg14.5℃
AR02 : avg14.4℃
AR03 : avg14.2℃
AR04 : avg14.4℃
AR05 : avg11.5℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 1.015307803 kW

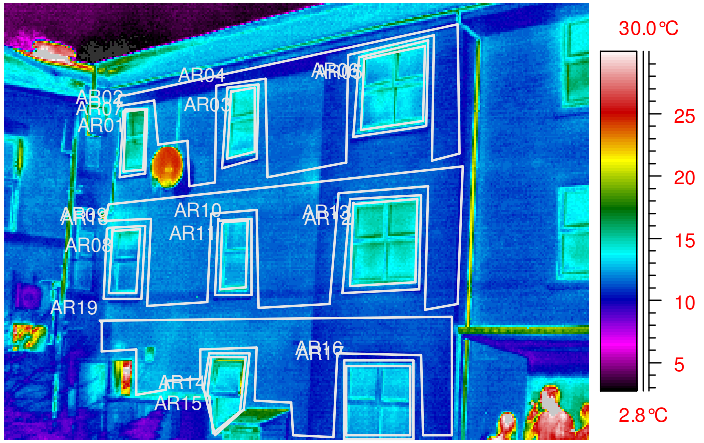
Cost of heating the room per hour: £0.0939

Cost of heating the room per day £2.2540

Cost of heating the room per calendar month £68.56

Cost of heating the room per year £822.70

SE19 ATP Office		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Window	2.028	13	21	59.022	102.838	161.860	7.158
Brick Wall	Wall	5.58	12	24	143.443	301.197	444.639	5.439
				Totals	202.47 watts	404.034 watt	606.49941 watts	



Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.606499411 kW

Cost of heating the room per hour: £0.0561

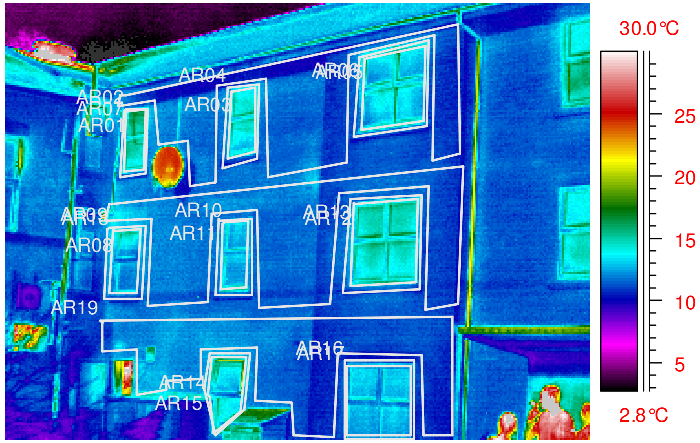
Cost of heating the room per day £1.3464

Cost of heating the room per calendar month £40.95

Cost of heating the room per year £491.45

SE20 Bedroom

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)		U Value
Window	Window	2.028	13	21	59.022		102.838		161.860		7.158
Brick Wall	Wall	5.58	12	24	143.443		301.197		444.639		5.439
				Totals	202.47	watts	404.034	watt	606.49941	watts	



Cost per kWh **£0.0740**

Boiler Efficiency **80%**

Total heat loss from this room 0.606499411 kW

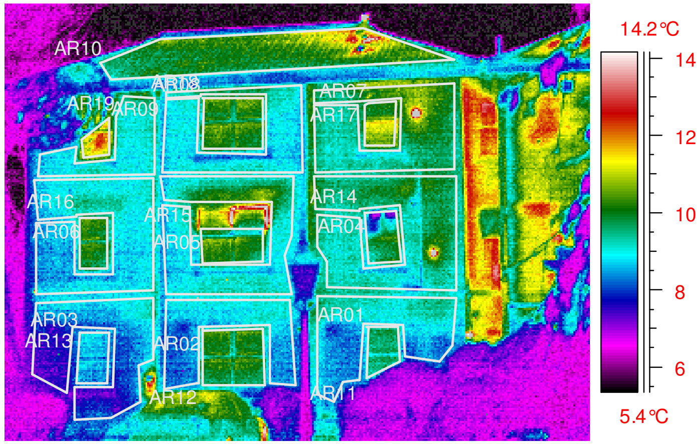
Cost of heating the room per hour: £0.0561

Cost of heating the room per day £1.3464

Cost of heating the room per calendar month £40.95

Cost of heating the room per year £491.45

SE8 Medical Secretary		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Window	Window	1.485	10	21	22.278	28.533	50.811	2.705
Brick Wall	Wall	10.515	9	24	115.434	203.226	318.660	1.876
				Totals	137.71 watts	231.759 watt	369.47103 watts	



Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.369471032 kW

Cost of heating the room per hour: £0.0342

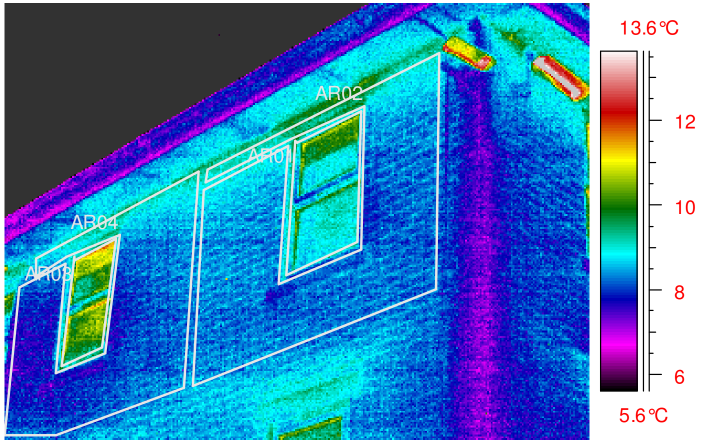
Cost of heating the room per day £0.8202

Cost of heating the room per calendar month £24.95

Cost of heating the room per year £299.38

SE9 Bedroom 13

		Area sq m	Outside Surface Temperature 'C	Intside Surface Temperature 'C	Radiant Heat Loss (watts)	Convective Heat Loss (watts)	Total Heat Loss (watts)	U Value
Brick Wall	North Wall	6.965	8	24	42.987	72.083	115.070	0.992
Window	West Window	0.715	10	21	10.727	13.738	24.465	2.705
Brick Wall	West Wall	6.965	9	24	76.462	134.614	211.076	1.876
Window	North Window	0.715	9	21	7.436	8.768	16.204	1.723
				Totals	137.61 watts	229.203 watt	366.81499 watts	



LabelValue
IR : max15.3℃
IR : min2.6℃
AR01 : avg9.2℃
AR02 : avg8.4℃
AR03 : avg10.1℃
AR04 : avg8.2℃

Cost per kWh £0.0740

Boiler Efficiency 80%

Total heat loss from this room 0.366814986 kW

Cost of heating the room per hour: £0.0339

Cost of heating the room per day £0.8143

Cost of heating the room per calendar month £24.77

Cost of heating the room per year £297.23

Total radiant loss 10,015.732	watts	Total convective loss 192,678.853	watts

Total heat loss from the building	33.364062831	kW
Cost of heating the building per hour:	£3.09	
Cost of heating the building per day	£74.07	
Cost of heating the building per calendar month	£2,252.91	
Cost of heating the building per year	£27,034.90	

Annual Heat Losses by Room

This report is based on expected ambient conditions throughout year.

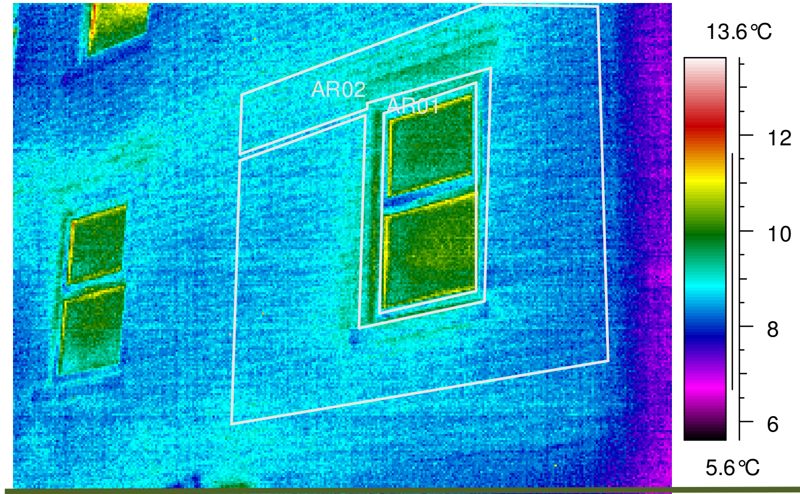
Building Details

	Priory Hospital
Location:	Rosemary Lane
	Preston
	PR4 0HB
Date:	10/02/2011
Cost per kWh	**£0.0740**
Boiler Efficiency	**80%**

Potential cost savings report

Ron Frend

Room or Area Name: **F10 Asst Ward Manager**



LabelValue
IR : max14.5℃
IR : min6.3℃
AR01 : avg9.8℃
AR02 : avg8.6℃

For this room:

potential savings are up to **2051** kwH per year

Potential annual cost savings are **£189.70**

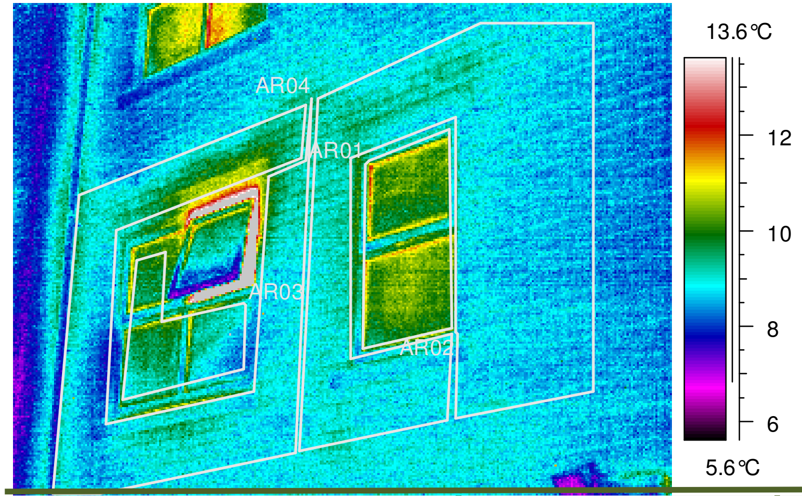
- Significant Heat Loss
- Heat is being lost
- Some Heat is being lost at this position
- Slight heat loss at this position
- Minimal heat is being lost at this position
- No measureable heat loss at this position

North Window **0.7425** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **222.55236** kwHours = **£20.586**	Actual U-value **2.705** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-82.68883** kwH per year Potential annual cost savings are **-£7.65**
North Wall **6.9375** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **1841.7275** kwHours = **£170.360**	Actual U-value **1.876** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1108.1163** kwH per year Potential annual cost savings are **£102.50**
West Window **0.7425** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **222.55236** kwHours = **£20.586**	Actual U-value **2.705** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-82.68883** kwH per year Potential annual cost savings are **-£7.65**
West Wall **6.9375** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **1841.7275** kwHours = **£170.360**	Actual U-value **1.876** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1108.1163** kwH per year Potential annual cost savings are **£102.50**

Potential cost savings report

Ron Frend

Room or Area Name: **F11 Store Room**



LabelValue
IR : max23.1°C
IR : min6.6°C
AR01 : avg10.2°C
AR02 : avg8.8°C
AR03 : avg9.4°C
AR04 : avg9.0°C

For this room:

potential savings are up to **853.3** kwH per year

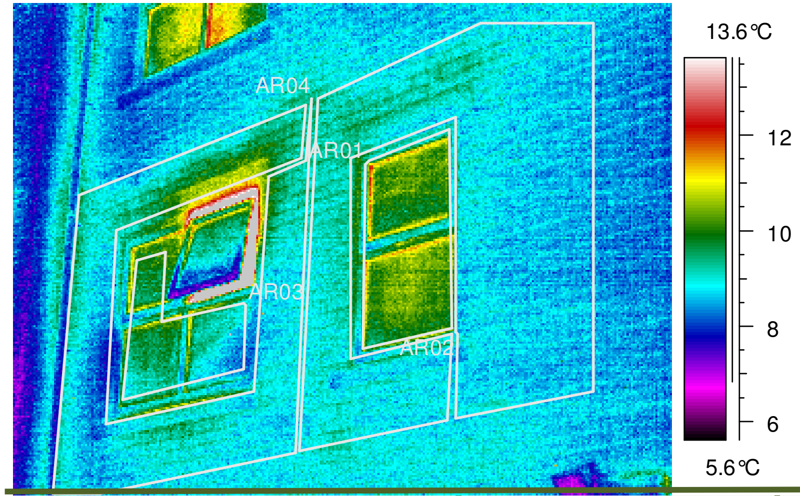
Potential annual cost savings are **£78.93**

- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **5.86** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **1555.679** kwHours = **£143.900**	Actual U-value **1.876** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **936.00883**kwH per year Potential annual cost savings are **£86.58**
Window **0.7425** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **222.55236** kwHours = **£20.586**	Actual U-value **2.705** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-82.68883**kwH per year Potential annual cost savings are **-£7.65**

Potential cost savings report

Room or Area Name: **F13 Bedroom 2**



LabelValue
IR : max23.1℃
IR : min6.6℃
AR01 : avg10.2℃
AR02 : avg8.8℃
AR03 : avg9.4℃
AR04 : avg9.0℃

For this room:

potential savings are up to **954.2** kwH per year

Potential annual cost savings are **£88.26**

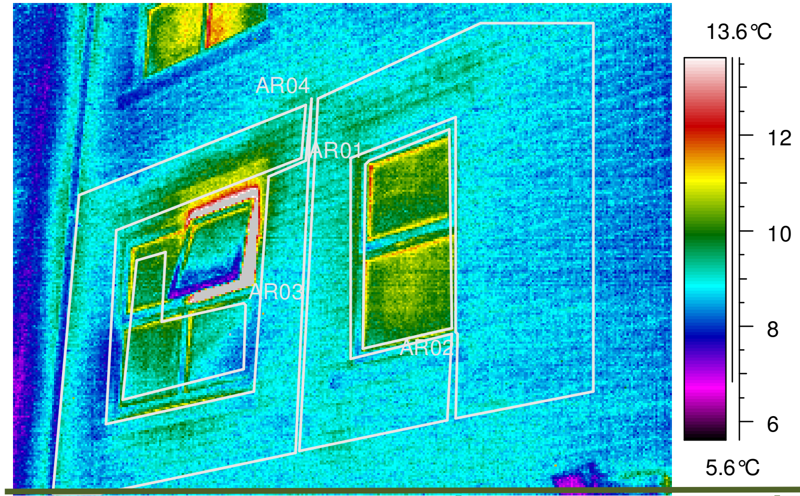
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **6.965** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **1849.0280** kwHours = **£171.035**	Actual U-value **1.876** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1112.5088**wH per year Potential annual cost savings are **£102.91**
Window **0.7425** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **147.40830** kwHours = **£13.635**	Actual U-value **1.723** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-158.3470**wH per year Potential annual cost savings are **-£14.65**

Potential cost savings report

Ron Frend

Room or Area Name: **F14 Bedroom 3**



LabelValue
IR : max23.1℃
IR : min6.6℃
AR01 : avg10.2℃
AR02 : avg8.8℃
AR03 : avg9.4℃
AR04 : avg9.0℃

For this room:
potential savings are up to **885.2** kwH per year
Potential annual cost savings are **£81.88**

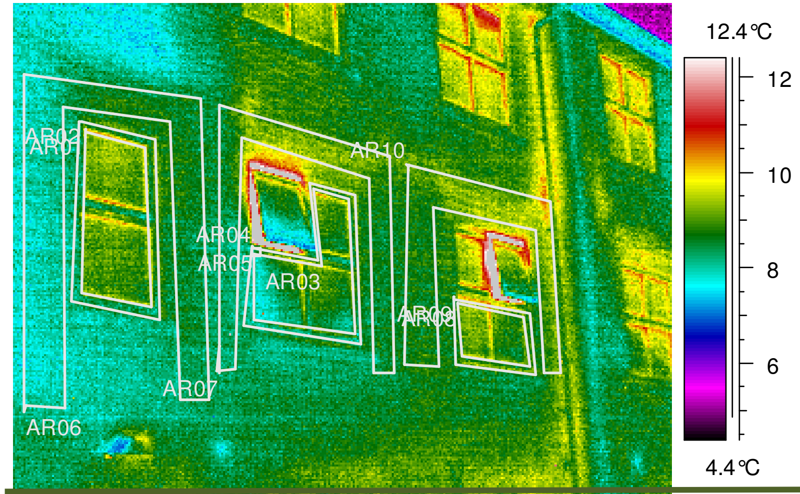
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **6.965** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **1849.0280** kwHours = **£171.035**	Actual U-value **1.876** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1112.5088**kwH per year Potential annual cost savings are **£102.91**
Window **2.041** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **611.75673** kwHours = **£56.587**	Actual U-value **2.705** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-227.2968**kwH per year Potential annual cost savings are **-£21.02**

Potential cost savings report

Ron Frend

Room or Area Name: **F15 Bedroom 4**



LabelValue
IR : max19.8°C
IR : min4.7°C
AR01 : avg9.2°C
AR02 : avg9.0°C
AR03 : avg8.7°C
AR04 : avg8.3°C
AR05 : avg8.7°C
AR06 : avg8.3°C
AR08 : avg9.1°C
AR09 : avg9.1°C
AR07 : avg8.8°C
AR10 : avg9.0°C

For this room:

potential savings are up to **1030** kwH per year

Potential annual cost savings are **£95.26**

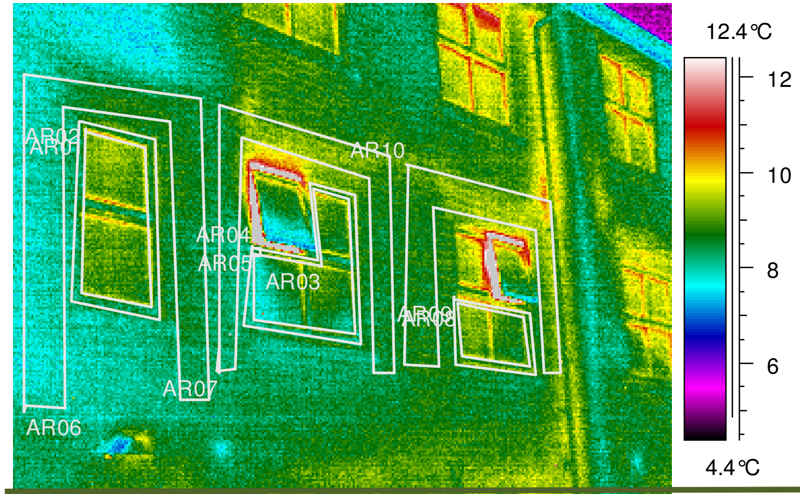
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **6.965** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **1849.0280** kwHours = **£171.035**	Actual U-value **1.876** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1112.5088**wH per year Potential annual cost savings are **£102.91**
Window **0.7425** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **222.55236** kwHours = **£20.586**	Actual U-value **2.705** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-82.68883**kwH per year Potential annual cost savings are **-£7.65**

Potential cost savings report

Ron Frend

Room or Area Name: **F16 Bedroom 5**



LabelValue
IR : max19.8℃
IR : min4.7℃
AR01 : avg9.2℃
AR02 : avg9.0℃
AR03 : avg8.7℃
AR04 : avg8.3℃
AR05 : avg8.7℃
AR06 : avg8.3℃
AR08 : avg9.1℃
AR09 : avg9.1℃
AR07 : avg8.8℃
AR10 : avg9.0℃

For this room:

potential savings are up to **954.2** kwH per year

Potential annual cost savings are **£88.26**

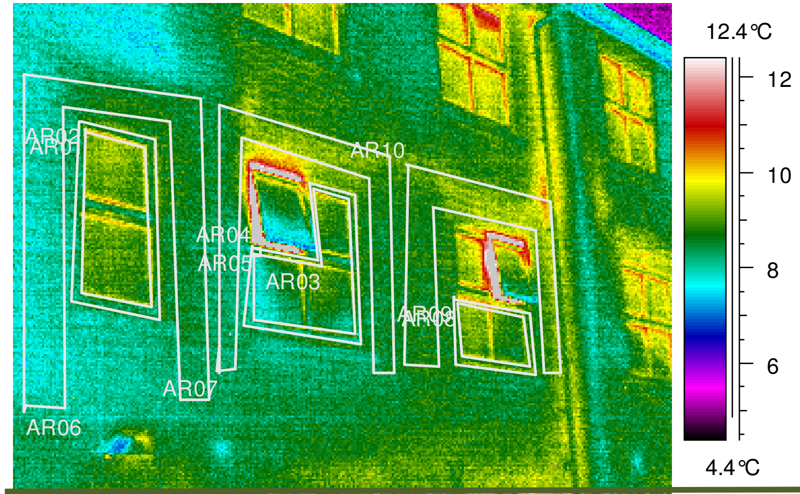
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **6.965** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **1849.0280** kwHours = **£171.035**	Actual U-value **1.876** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1112.5088**kwH per year Potential annual cost savings are **£102.91**
Window **0.7425** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **147.40830** kwHours = **£13.635**	Actual U-value **1.723** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-158.3470**kwH per year Potential annual cost savings are **-£14.65**

Potential cost savings report

Ron Frend

Room or Area Name: **F17 Bedroom 6**



LabelValue
IR : max19.8℃
IR : min4.7℃
AR01 : avg9.2℃
AR02 : avg9.0℃
AR03 : avg8.7℃
AR04 : avg8.3℃
AR05 : avg8.7℃
AR06 : avg8.3℃
AR08 : avg9.1℃
AR09 : avg9.1℃
AR07 : avg8.8℃
AR10 : avg9.0℃

For this room:

potential savings are up to **1289** kwH per year

Potential annual cost savings are **£119.27**

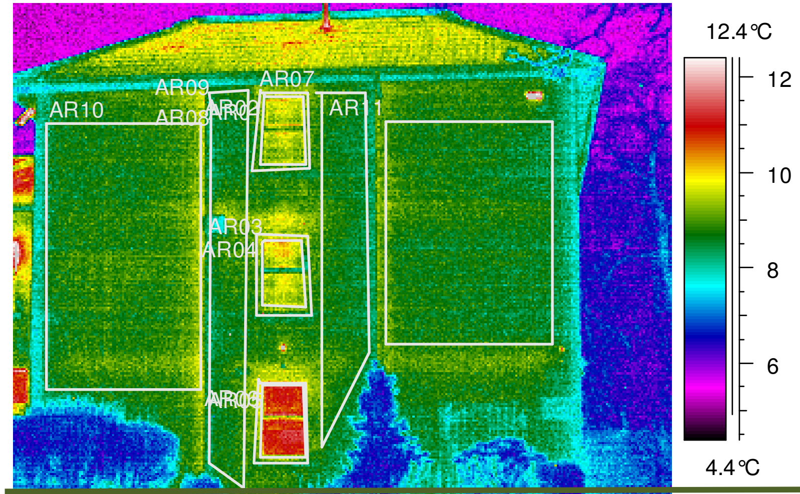
- **Significant Heat Loss** (white)
- **Heat is being lost** (red)
- **Some Heat is being lost at this position** (yellow)
- **Slight heat loss at this position** (green)
- **Minimal heat is being lost at this position** (blue)
- **No measureable heat loss at this position** (black)

Window **0.7425** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **16** 'C	Annual Heat Loss from this Window **156.61632** kwHours = **£14.487**	Actual U-value **2.954** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-41.81809** kwH per year Potential annual cost savings are **-£3.87**
Wall **6.965** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **20** 'C	Annual Heat Loss from this Brick Wall **1896.9060** kwHours = **£175.464**	Actual U-value **2.559** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1331.2243** kwH per year Potential annual cost savings are **£123.14**

Potential cost savings report

Ron Frend

Room or Area Name: **F19 Bedroom 7**



LabelValue
IR : max20.4°C
IR : min4.7°C
AR01 : avg9.5°C
AR02 : avg9.4°C
AR03 : avg9.5°C
AR04 : avg9.4°C
AR05 : avg10.7°C
AR06 : avg10.4°C
AR07 : avg8.7°C
AR08 : avg7.4°C
AR09 : avg8.7°C
AR10 : avg8.9°C
AR11 : avg8.7°C

For this room:

potential savings are up to **7454** kwH per year

Potential annual cost savings are **£689.48**

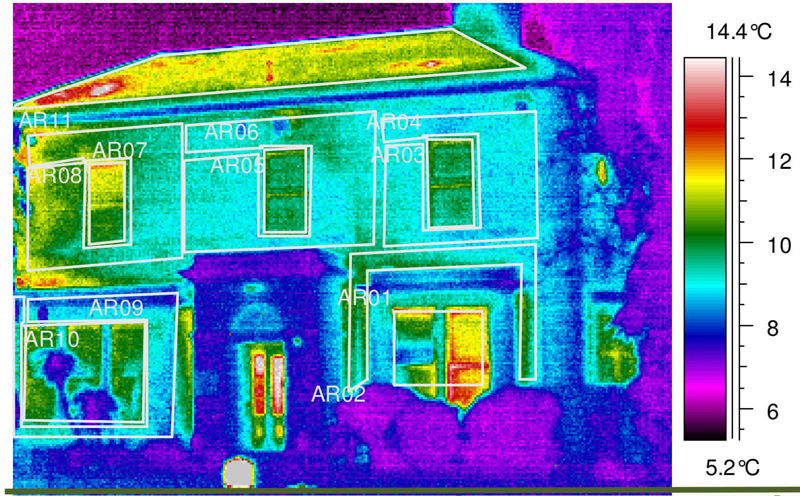
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **9.244** sq. m. Test Data: Outside Temperature: **12** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **6452.643** kwHours = **£596.869**	Actual U-value **5.439** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **5479.2027** kwH per year Potential annual cost savings are **£506.83**
Window **2.756** sq. m. Test Data: Outside Temperature: **15** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **3098.0307** kwHours = **£286.568**	Actual U-value **12.643** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1974.5834** kwH per year Potential annual cost savings are **£182.65**

Potential cost savings report

Ron Frend

Room or Area Name: **F2 Bedroom 12**



For this room:

potential savings are up to **5984** kwH per year

Potential annual cost savings are **£553.50**

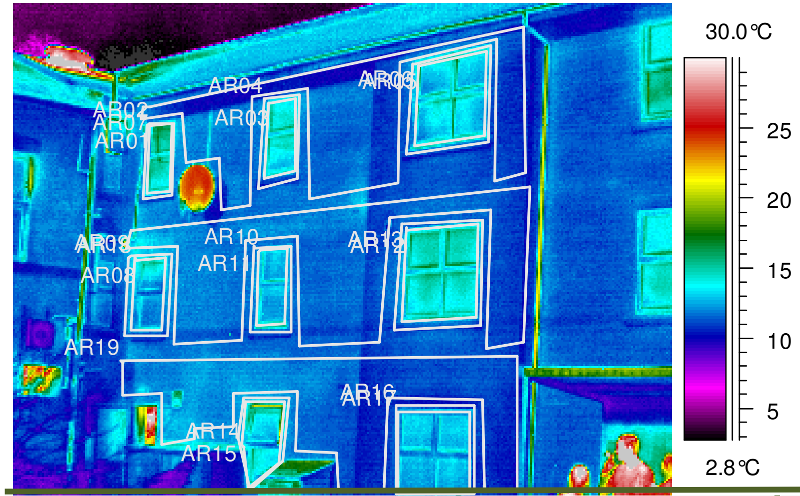
- Significant Heat Loss
- Heat is being lost
- Some Heat is being lost at this position
- Slight heat loss at this position
- Minimal heat is being lost at this position
- No measureable heat loss at this position

Window **1.485** sq. m. Test Data: Outside Temperature: **11** 'C Inside Temperature: **19** 'C	Annual Heat Loss from this Window **641.6056** kwHours = **£59.349**	Actual U-value **4.859** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **118.00829**wH per year Potential annual cost savings are **£10.92**
Wall **13.515** sq. m. Test Data: Outside Temperature: **11** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **7290.9834** kwHours = **£674.416**	Actual U-value **4.065** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **5865.7999**wH per year Potential annual cost savings are **£542.59**

Potential cost savings report

Ron Frend

Room or Area Name: **F21A Bedroom**



For this room:

potential savings are up to **4928** kwH per year

Potential annual cost savings are **£455.84**

- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Window 2.756 sq. m. Test Data: Outside Temperature: **13** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **1926.8830** kwHours = **£178.237**	Actual U-value **7.158** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **799.61881** kwH per year Potential annual cost savings are **£73.96**
Wall 6.965 sq. m. Test Data: Outside Temperature: **12** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **4861.8194** kwHours = **£449.718**	Actual U-value **5.439** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **4128.3694** kwH per year Potential annual cost savings are **£381.87**

Potential cost savings report

Ron Frend

Room or Area Name: **F21B Bedroom**

For this room:

potential savings are up to **4928** kwH per year

Potential annual cost savings are **£455.84**

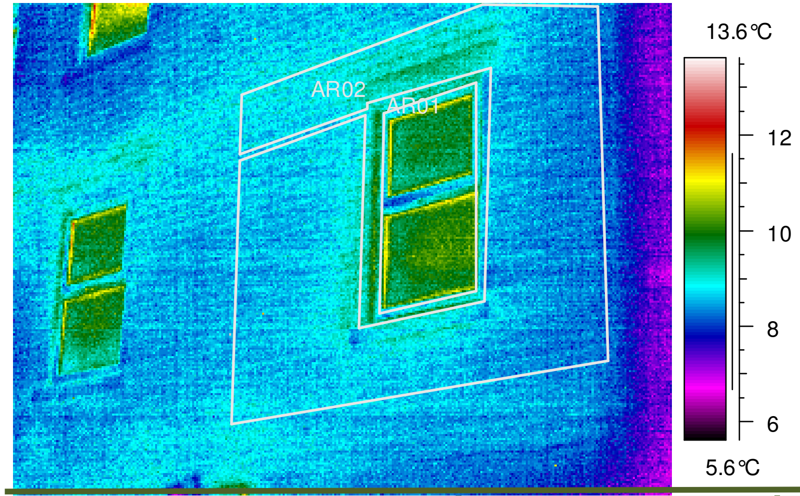
- ⬜ **Significant Heat Loss**
- 🟥 **Heat is being lost**
- 🟨 **Some Heat is being lost at this position**
- 🟩 **Slight heat loss at this position**
- 🟦 **Minimal heat is being lost at this position**
- ⬛ **No measureable heat loss at this position**

Window **2.756** sq. m. Test Data: Outside Temperature: **13** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **1926.8830** kwHours = **£178.237**	Actual U-value **7.158** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **799.61881** kwH per year Potential annual cost savings are **£73.96**
Wall **6.965** sq. m. Test Data: Outside Temperature: **12** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **4861.8194** kwHours = **£449.718**	Actual U-value **5.439** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **4128.3694** kwH per year Potential annual cost savings are **£381.87**

Potential cost savings report

Ron Frend

Room or Area Name: **F3 Bedroom 11**



LabelValue
IR : max14.5℃
IR : min6.3℃
AR01 : avg9.8℃
AR02 : avg8.6℃

For this room:

potential savings are up to **3376** kwH per year

Potential annual cost savings are **£312.23**

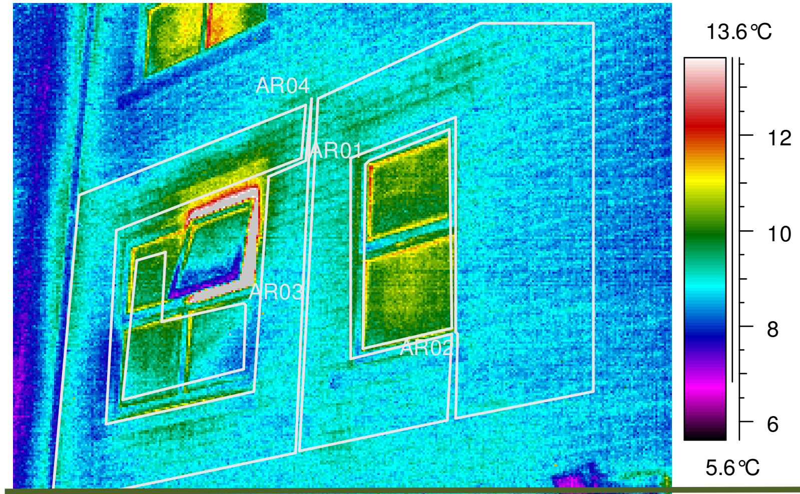
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **20** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **22** 'C	Annual Heat Loss from this Brick Wall **5367.6499** kwHours = **£496.508**	Actual U-value **2.165** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **3498.0147** kwH per year Potential annual cost savings are **£323.57**
Window **1.1** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **329.70720** kwHours = **£30.498**	Actual U-value **2.705** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-122.502** kwH per year Potential annual cost savings are **-£11.33**

Potential cost savings report

Ron Frend

Room or Area Name: **F4 Bedroom 10**



LabelValue
IR : max23.1℃
IR : min6.6℃
AR01 : avg10.2℃
AR02 : avg8.8℃
AR03 : avg9.4℃
AR04 : avg9.0℃

For this room:

potential savings are up to **9091** kwH per year

Potential annual cost savings are **£840.92**

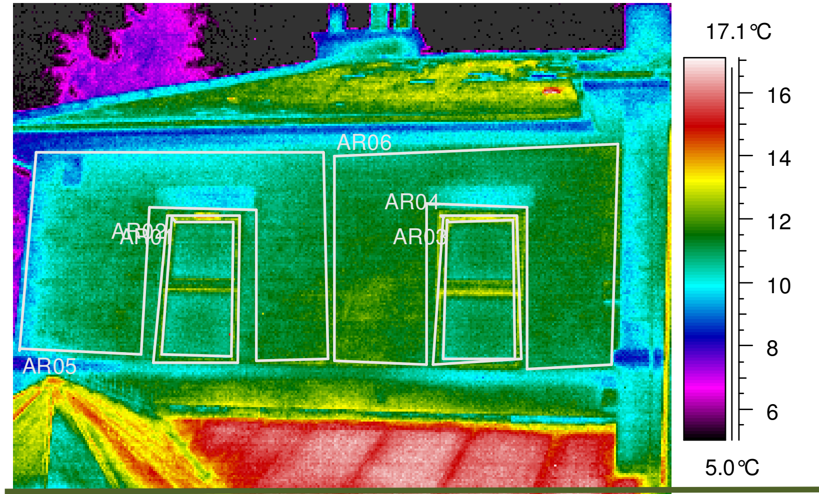
- **Significant Heat Loss** (white)
- **Heat is being lost** (red)
- **Some Heat is being lost at this position** (yellow)
- **Slight heat loss at this position** (green)
- **Minimal heat is being lost at this position** (blue)
- **No measureable heat loss at this position** (black)

East Wall **9.75** sq. m. Test Data: Outside Temperature: **11** 'C Inside Temperature: **22** 'C	Annual Heat Loss from this Brick Wall **5395.5841** kwHours = **£499.092**	Actual U-value **4.804** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **4487.0012** kwH per year Potential annual cost savings are **£415.05**
East Window **0.7525** sq. m. Test Data: Outside Temperature: **11** 'C Inside Temperature: **19** 'C	Annual Heat Loss from this Window **325.12338** kwHours = **£30.074**	Actual U-value **4.859** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **59.798812** kwH per year Potential annual cost savings are **£5.53**
South Wall **14.257** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **22** 'C	Annual Heat Loss from this Brick Wall **5749.3016** kwHours = **£531.810**	Actual U-value **3.372** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **4418.6263** kwH per year Potential annual cost savings are **£408.72**
South Window **0.55** sq. m. Test Data: Outside Temperature: **12** 'C Inside Temperature: **19** 'C	Annual Heat Loss from this Window **319.11013** kwHours = **£29.518**	Actual U-value **6.864** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **125.56606** kwH per year Potential annual cost savings are **£11.61**

Potential cost savings report

Ron Frend

Room or Area Name: **F5 Bedroom 9**



LabelValue
IR : max17.3°C
IR : min4.1°C
AR01 : avg11.0°C
AR02 : avg11.2°C
AR03 : avg11.3°C
AR04 : avg11.4°C
AR05 : avg10.7°C
AR06 : avg11.3°C

For this room:

potential savings are up to **6621** kwH per year

Potential annual cost savings are **£612.46**

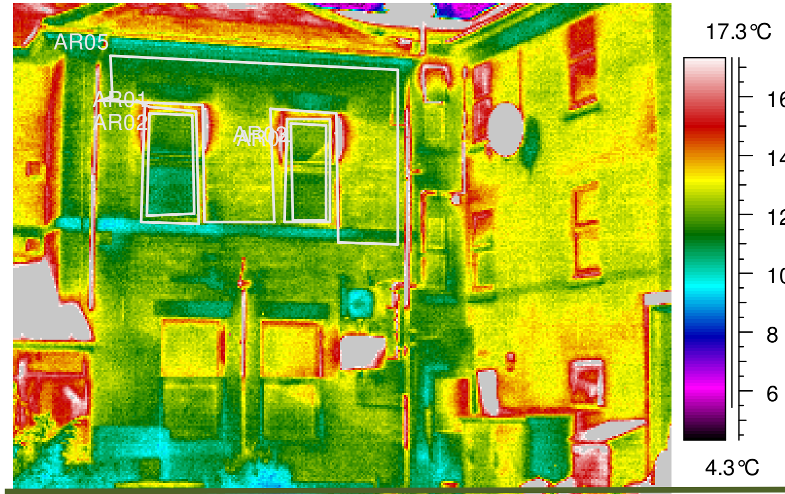
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Window **0.7525** sq. m. Test Data: Outside Temperature: **11** 'C Inside Temperature: **19** 'C	Annual Heat Loss from this Window **325.12338** kwHours = **£30.074**	Actual U-value **4.859** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **59.798812** kwH per year Potential annual cost savings are **£5.53**
Wall **14.2575** sq. m. Test Data: Outside Temperature: **11** 'C Inside Temperature: **22** 'C	Annual Heat Loss from this Brick Wall **7890.0041** kwHours = **£729.825**	Actual U-value **4.804** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **6561.3764** kwH per year Potential annual cost savings are **£606.93**

Potential cost savings report

Ron Frend

Room or Area Name: **F6 Bartle Room**



LabelValue
IR : max60.8°C
IR : min5.2°C
AR01 : avg11.3°C
AR02 : avg11.7°C
AR03 : avg12.1°C
AR04 : avg12.0°C
AR05 : avg12.3°C

For this room:

potential savings are up to **4129** kwH per year

Potential annual cost savings are **£381.97**

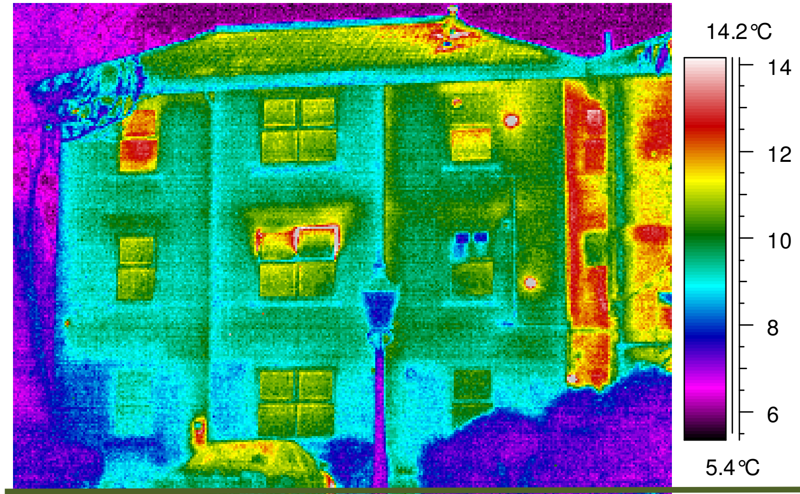
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Window **1.485** sq. m. Test Data: Outside Temperature: **12** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **809.01859** kwHours = **£74.834**	Actual U-value **5.338** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **200.59284**wH per year Potential annual cost savings are **£18.55**
Wall **13.515** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **5355.967** kwHours = **£495.427**	Actual U-value **2.891** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **3928.7982**wH per year Potential annual cost savings are **£363.41**

Potential cost savings report

Ron Frend

Room or Area Name: **F8&9 Nurse Station/Sluice**



For this room:

potential savings are up to **2740** kwH per year

Potential annual cost savings are **£253.45**

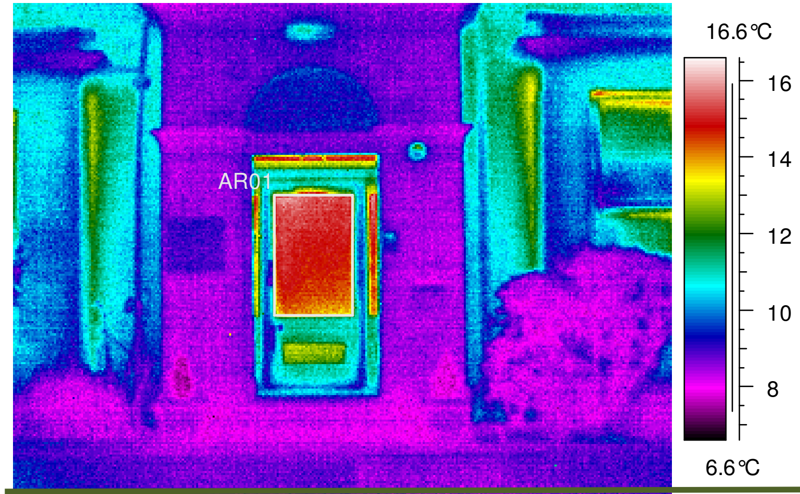
- Significant Heat Loss
- Heat is being lost
- Some Heat is being lost at this position
- Slight heat loss at this position
- Minimal heat is being lost at this position
- No measureable heat loss at this position

Window **1.485** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **294.81661** kwHours = **£27.271**	Actual U-value **1.723** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-316.6941** kwH per year Potential annual cost savings are **-£29.29**
Wall **10.515** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **4167.0731** kwHours = **£385.454**	Actual U-value **2.891** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **3056.7009** kwH per year Potential annual cost savings are **£282.74**

Potential cost savings report

Ron Frend

Room or Area Name: **G1 Entrance Lobby**



LabelValue
IR : max16.1℃
IR : min6.9℃
AR01 : avg14.8℃

For this room:

potential savings are up to **1397** kwH per year

Potential annual cost savings are **£129.27**

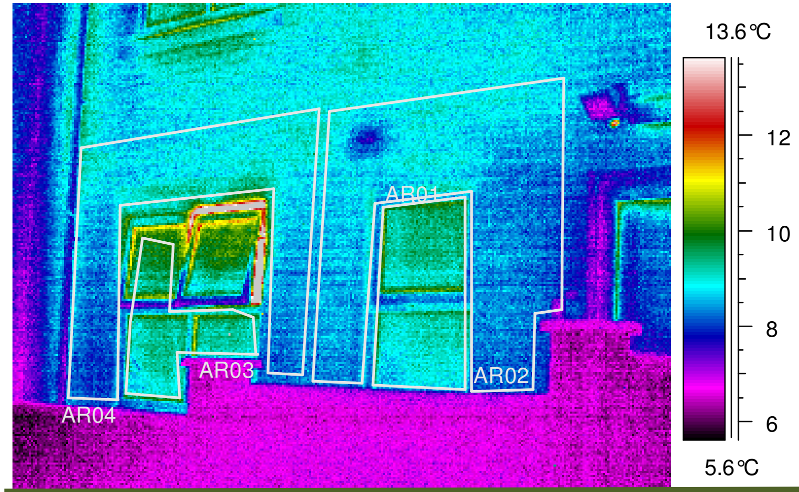
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Door **0.78** sq. m. Test Data: Outside Temperature: **15** 'C Inside Temperature: **17** 'C	Annual Heat Loss from this Door **1639.0283** kwHours = **£151.610**	Actual U-value **39.004** Target U-value **3.5** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1397.4606**kwH per year Potential annual cost savings are **£129.27**

Potential cost savings report

Ron Frend

Room or Area Name: **G12 Consulting Room 1**



For this room:

potential savings are up to **436.9** kwH per year

Potential annual cost savings are **£40.41**

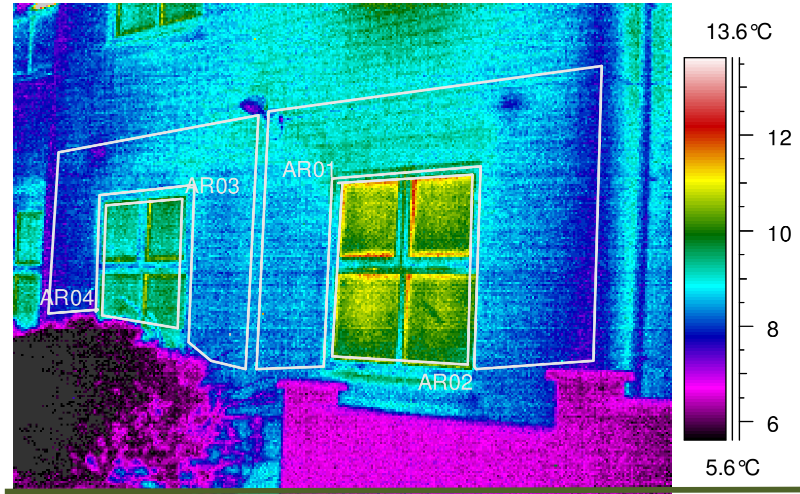
- Significant Heat Loss
- Heat is being lost
- Some Heat is being lost at this position
- Slight heat loss at this position
- Minimal heat is being lost at this position
- No measureable heat loss at this position

Wall **5.4214** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **25** 'C	Annual Heat Loss from this Brick Wall **1432.8367** kwHours = **£132.537**	Actual U-value **1.759** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **826.30260** kwH per year Potential annual cost savings are **£76.43**
Window **2.1306** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **20** 'C	Annual Heat Loss from this Window **426.35023** kwHours = **£39.437**	Actual U-value **1.880** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-389.4218** kwH per year Potential annual cost savings are **-£36.02**

Potential cost savings report

Ron Frend

Room or Area Name: **G13 Consulting Room 2**



LabelValue
IR : max17.8℃
IR : min4.4℃
AR01 : avg10.3℃
AR02 : avg8.5℃
AR03 : avg9.4℃
AR04 : avg8.4℃

For this room:
potential savings are up to **8.128** kwH per year
Potential annual cost savings are **£0.75**

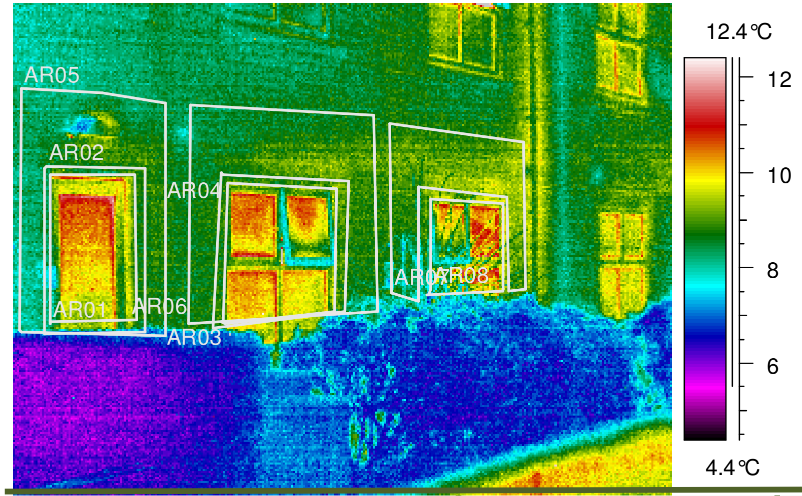
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **5.4214** sq. m. Test Data: Outside Temperature: **8** 'C Inside Temperature: **25** 'C	Annual Heat Loss from this Brick Wall **782.81283** kwHours = **£72.410**	Actual U-value **0.934** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **175.48241** kwH per year Potential annual cost savings are **£16.23**
Window **2.1306** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **20** 'C	Annual Heat Loss from this Window **646.94261** kwHours = **£59.842**	Actual U-value **2.975** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-167.3541** kwH per year Potential annual cost savings are **-£15.48**

Potential cost savings report

Ron Frend

Room or Area Name: **G14 Hospital Manager**



For this room:

potential savings are up to **-144** kwH per year

Potential annual cost savings are **-£13.28**

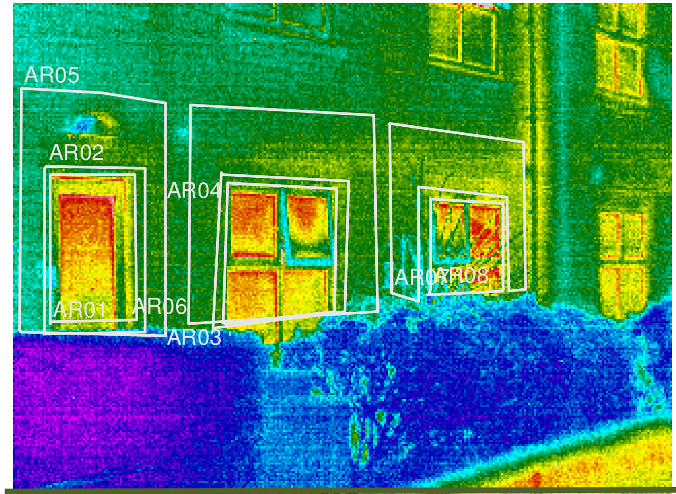
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

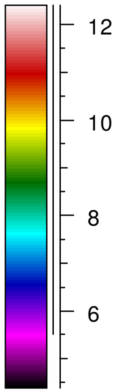
Wall **5.4214** sq. m. Test Data: Outside Temperature: **8** 'C Inside Temperature: **23** 'C	Annual Heat Loss from this Brick Wall **786.65667** kwHours = **£72.766**	Actual U-value **1.058** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **245.8143** kwH per year Potential annual cost savings are **£22.74**
Window **2.1306** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **20** 'C	Annual Heat Loss from this Window **426.35023** kwHours = **£39.437**	Actual U-value **1.880** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-389.4218** kwH per year Potential annual cost savings are **-£36.02**

Potential cost savings report

Ron Frend

Room or Area Name: **G15 Therapy Service**





LabelValue
IR : max18.0°C
IR : min5.0°C
AR01 : avg9.8°C
AR02 : avg9.5°C
AR03 : avg9.7°C
AR04 : avg9.5°C
AR05 : avg9.0°C
AR06 : avg9.1°C
AR08 : avg9.5°C
AR07 : avg9.0°C

For this room:

potential savings are up to **739.2** kwH per year

Potential annual cost savings are **£68.37**

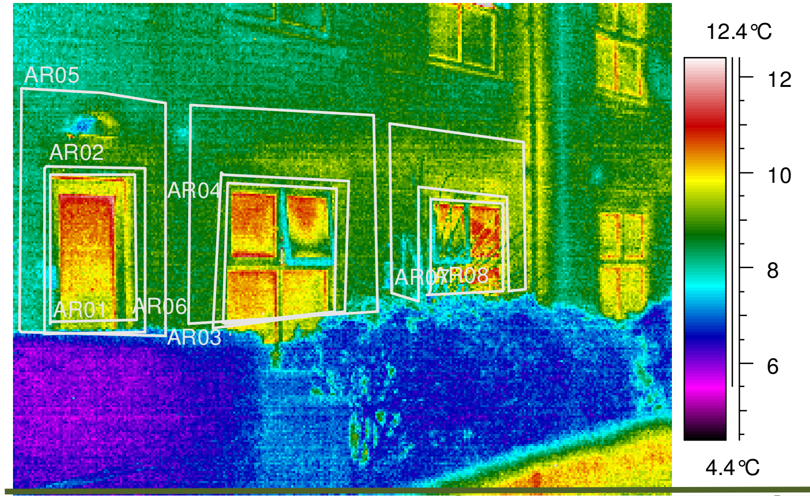
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Window **2.1306** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **20** 'C	Annual Heat Loss from this Window **646.94261** kwHours = **£59.842**	Actual U-value **2.975** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-167.3541** kwH per year Potential annual cost savings are **-£15.48**
Wall **5.4214** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **23** 'C	Annual Heat Loss from this Brick Wall **1446.5623** kwHours = **£133.807**	Actual U-value **2.011** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **906.51629** kwH per year Potential annual cost savings are **£83.85**

Potential cost savings report

Ron Frend

Room or Area Name: **G16 Marketing Office**



LabelValue
IR : max18.0℃
IR : min5.0℃
AR01 : avg9.8℃
AR02 : avg9.5℃
AR03 : avg9.7℃
AR04 : avg9.5℃
AR05 : avg9.0℃
AR06 : avg9.1℃
AR08 : avg9.5℃
AR07 : avg9.0℃

For this room:

potential savings are up to **1459** kwH per year

Potential annual cost savings are **£134.99**

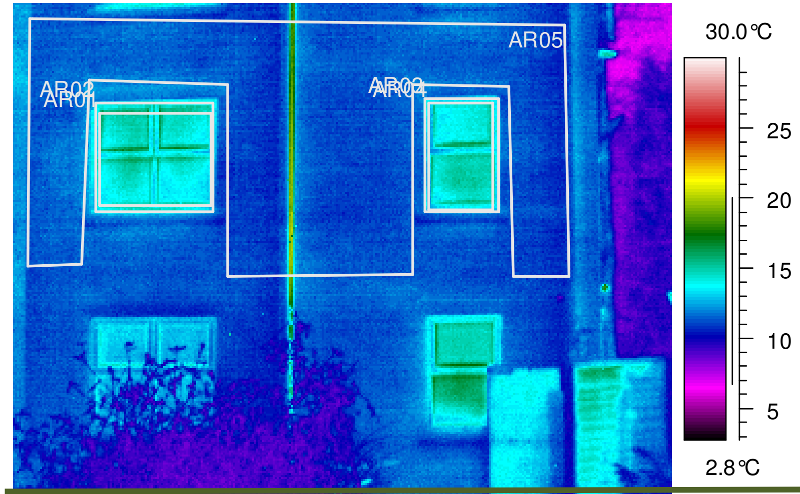
- Significant Heat Loss
- Heat is being lost
- Some Heat is being lost at this position
- Slight heat loss at this position
- Minimal heat is being lost at this position
- No measureable heat loss at this position

Window **2.1306** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **20** 'C	Annual Heat Loss from this Window **646.94261** kwHours = **£59.842**	Actual U-value **2.975** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-167.3541** kwH per year Potential annual cost savings are **-£15.48**
Wall **5.4214** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **23** 'C	Annual Heat Loss from this Brick Wall **2165.9142** kwHours = **£200.347**	Actual U-value **3.113** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1626.6645** kwH per year Potential annual cost savings are **£150.47**

Potential cost savings report

Ron Frend

Room or Area Name: **G18 Assisted Bath**



LabelValue
IR : max20.5℃
IR : min6.4℃
AR01 : avg14.5℃
AR02 : avg14.4℃
AR03 : avg14.2℃
AR04 : avg14.4℃
AR05 : avg11.5℃

For this room:

potential savings are up to **6666** kwH per year

Potential annual cost savings are **£616.58**

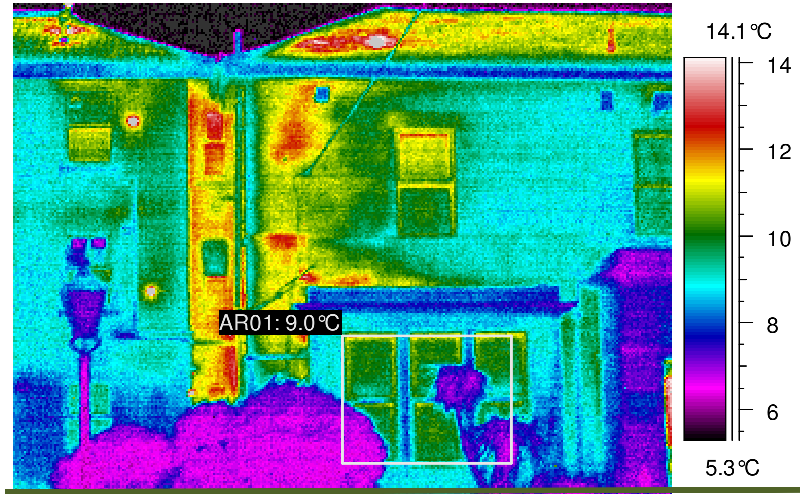
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall 10.1124 sq. m. Test Data: Outside Temperature: **12** 'C Inside Temperature: **25** 'C	Annual Heat Loss from this Brick Wall **6960.598** kwHours = **£643.855**	Actual U-value **5.021** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **5833.7015** kwH per year Potential annual cost savings are **£539.62**
Window 2.8676 sq. m. Test Data: Outside Temperature: **13** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **2004.9092** kwHours = **£185.454**	Actual U-value **7.158** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **831.99815** kwH per year Potential annual cost savings are **£76.96**

Potential cost savings report

Ron Frend

Room or Area Name: **G2 Reception**



LabelValue
IR : max56.8°C
IR : min4.6°C
AR01 : avg9.0°C

For this room:
potential savings are up to **5292** kwH per year
Potential annual cost savings are **£489.54**

- Significant Heat Loss
- Heat is being lost
- Some Heat is being lost at this position
- Slight heat loss at this position
- Minimal heat is being lost at this position
- No measureable heat loss at this position

Windows 2.97 sq. m. Test Data: Outside Temperature: 9 'C Inside Temperature: 21 'C	Annual Heat Loss from this Window 589.63321 kwHours = £54.541	Actual U-value 1.723 Target U-value 3.3 as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to -633.3882 kwH per year Potential annual cost savings are -£58.59
Wall 12.03 sq. m. Test Data: Outside Temperature: 11 'C Inside Temperature: 20 'C	Annual Heat Loss from this Brick Wall 6899.2005 kwHours = £638.176	Actual U-value 5.872 Target U-value 0.7 as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to 5925.685 kwH per year Potential annual cost savings are £548.13

Potential cost savings report

Ron Frend

Room or Area Name: **G21 Hospital Director**

For this room:

potential savings are up to **2650** kwH per year

Potential annual cost savings are **£245.16**

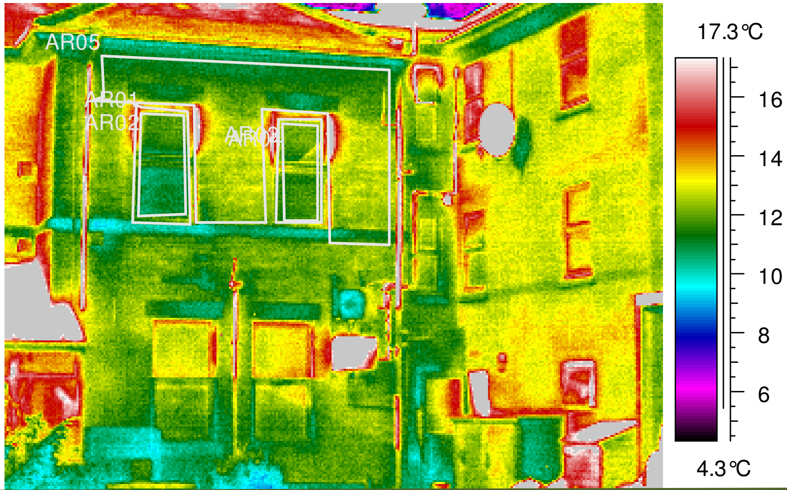
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **3.983** sq. m. Test Data: Outside Temperature: **12** 'C Inside Temperature: **25** 'C	Annual Heat Loss from this Brick Wall **2741.5907** kwHours = **£253.597**	Actual U-value **5.021** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **2297.7367** kwH per year Potential annual cost savings are **£212.54**
Window **0.737** sq. m. Test Data: Outside Temperature: **14** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **653.54111** kwHours = **£60.453**	Actual U-value **9.505** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **352.60236** kwH per year Potential annual cost savings are **£32.62**

Potential cost savings report

Ron Frend

Room or Area Name: **G27 Dining Room**



For this room:

potential savings are up to **6355** kwH per year

Potential annual cost savings are **£587.83**

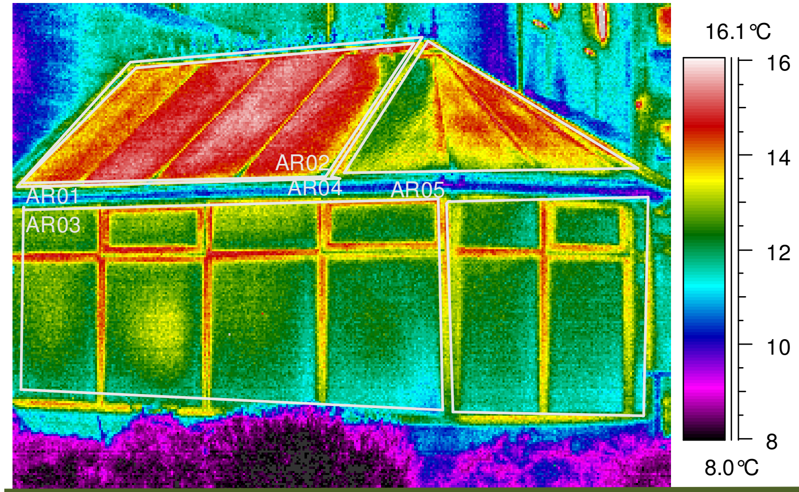
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **10.02** sq. m. Test Data: Outside Temperature: **12** 'C Inside Temperature: **25** 'C	Annual Heat Loss from this Brick Wall **6896.9969** kwHours = **£637.972**	Actual U-value **5.021** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **5780.3972**kwH per year Potential annual cost savings are **£534.69**
Window **1.98** sq. m. Test Data: Outside Temperature: **13** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **1384.3354** kwHours = **£128.051**	Actual U-value **7.158** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **574.47215**kwH per year Potential annual cost savings are **£53.14**

Potential cost savings report

Ron Frend

Room or Area Name: **G30 Conservatory**



LabelValue
IR : max17.3°C
IR : min7.4°C
AR01 : avg14.6°C
AR02 : avg14.4°C
AR03 : avg12.6°C
AR04 : avg13.5°C
AR05 : avg12.4°C

For this room:

potential savings are up to **34835** kwH per year

Potential annual cost savings are **£3,222.22**

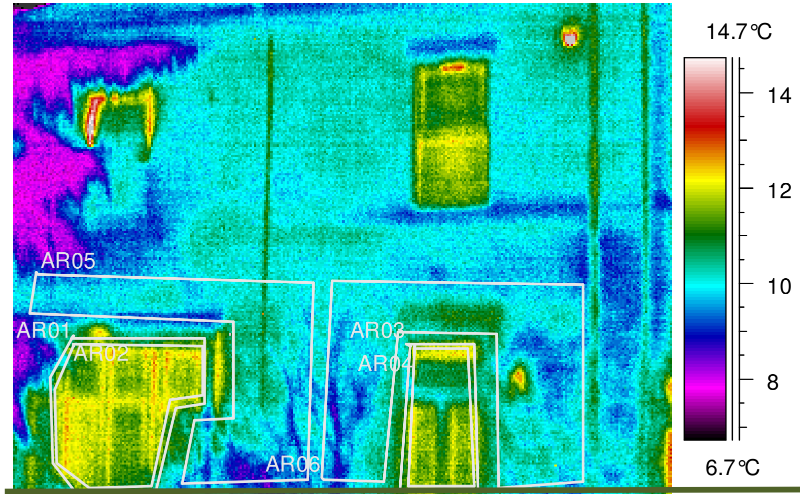
- **Significant Heat Loss** (white)
- **Heat is being lost** (red)
- **Some Heat is being lost at this position** (yellow)
- **Slight heat loss at this position** (green)
- **Minimal heat is being lost at this position** (blue)
- **No measureable heat loss at this position** (black)

Glass Roof **14.875** sq. m. Test Data: Outside Temperature: **14** 'C Inside Temperature: **18** 'C	Annual Heat Loss from this PentRoof **20647.018** kwHours = **£1,909.849**	Actual U-value **20.713** Target U-value **0.35** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **20139.636**wH per year Potential annual cost savings are **£1,862.92**
Glass Wall **24.5** sq. m. Test Data: Outside Temperature: **13** 'C Inside Temperature: **19** 'C	Annual Heat Loss from this Window **18742.485** kwHours = **£1,733.680**	Actual U-value **9.544** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **10137.942**wH per year Potential annual cost savings are **£937.76**
Lower Wall **10.5** sq. m. Test Data: Outside Temperature: **11** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **5664.4710** kwHours = **£523.964**	Actual U-value **4.065** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **4557.2252**wH per year Potential annual cost savings are **£421.54**

Potential cost savings report

Ron Frend

Room or Area Name: **G31 Multi Function Space**



LabelValue
IR : max17.7℃
IR : min4.9℃
AR01 : avg11.8℃
AR02 : avg11.7℃
AR03 : avg11.4℃
AR04 : avg11.4℃
AR05 : avg9.9℃
AR06 : avg10.0℃

For this room:

potential savings are up to **3818** kwH per year

Potential annual cost savings are **£353.15**

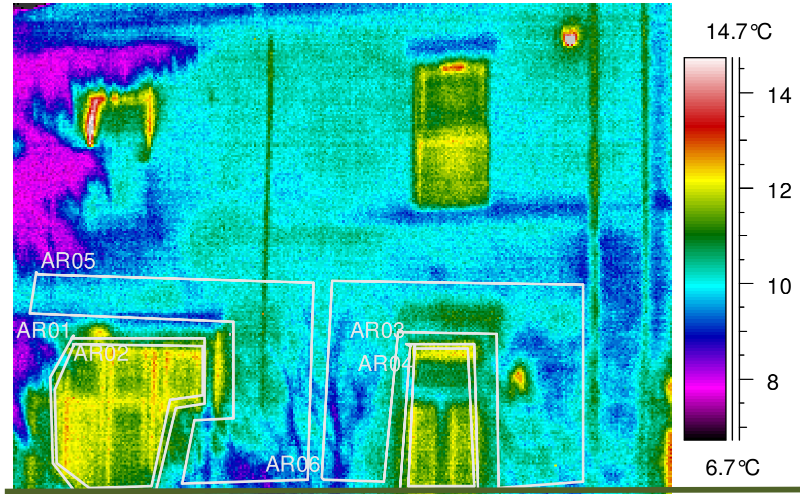
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Door **3.3** sq. m. Test Data: Outside Temperature: **11** 'C Inside Temperature: **19** 'C	Annual Heat Loss from this Door **1425.7902** kwHours = **£131.886**	Actual U-value **4.859** Target U-value **3.5** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **191.72248**wH per year Potential annual cost savings are **£17.73**
Wall **11.7** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **22** 'C	Annual Heat Loss from this Brick Wall **4718.1615** kwHours = **£436.430**	Actual U-value **3.372** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **3626.1435**wH per year Potential annual cost savings are **£335.42**

Potential cost savings report

Ron Frend

Room or Area Name: **G32 Multi Function Space**



LabelValue
IR : max17.7℃
IR : min4.9℃
AR01 : avg11.8℃
AR02 : avg11.7℃
AR03 : avg11.4℃
AR04 : avg11.4℃
AR05 : avg9.9℃
AR06 : avg10.0℃

For this room:

potential savings are up to **4487** kwH per year

Potential annual cost savings are **£415.07**

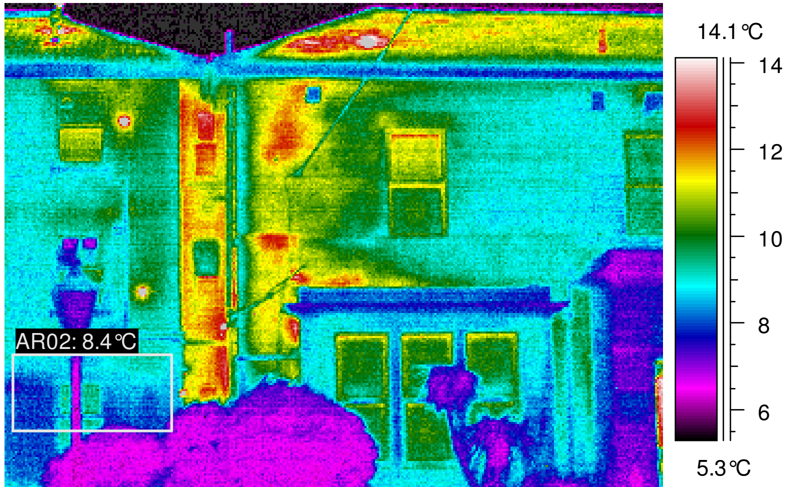
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Window **1.98** sq. m. Test Data: Outside Temperature: **12** 'C Inside Temperature: **19** 'C	Annual Heat Loss from this Window **1148.7965** kwHours = **£106.264**	Actual U-value **6.864** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **452.03782**wH per year Potential annual cost savings are **£41.81**
Wall **13.02** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **22** 'C	Annual Heat Loss from this Brick Wall **5250.4669** kwHours = **£485.668**	Actual U-value **3.372** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **4035.2469**wH per year Potential annual cost savings are **£373.26**

Potential cost savings report

Ron Frend

Room or Area Name: **G6 Changing Room**



LabelValue
IR : max56.8℃
IR : min4.6℃
AR01 : avg9.0℃
AR02 : avg8.4℃

For this room:

potential savings are up to **608.1** kwH per year

Potential annual cost savings are **£56.25**

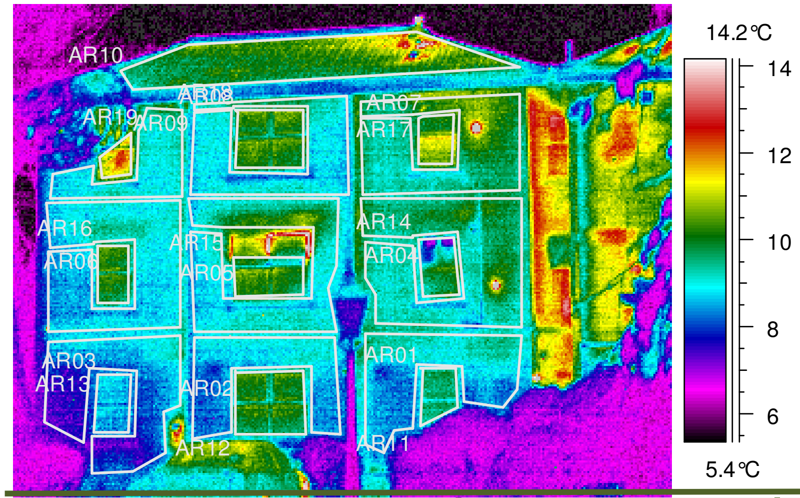
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **3.983** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **23** 'C	Annual Heat Loss from this Brick Wall **1062.762** kwHours = **£98.305**	Actual U-value **2.011** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **666.00036**kwH per year Potential annual cost savings are **£61.61**
Window **0.737** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **20** 'C	Annual Heat Loss from this Window **223.78518** kwHours = **£20.700**	Actual U-value **2.975** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-57.88977**kwH per year Potential annual cost savings are **-£5.35**

Potential cost savings report

Ron Frend

Room or Area Name: **G7 Waiting Area**



For this room:

potential savings are up to **265.6** kwH per year

Potential annual cost savings are **£24.57**

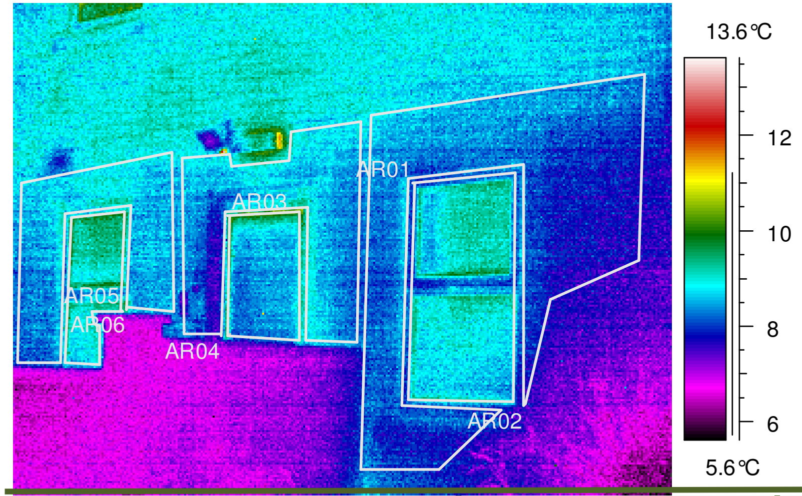
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Window **2.1306** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **20** 'C	Annual Heat Loss from this Window **646.94261** kwHours = **£59.842**	Actual U-value **2.975** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-167.3541**kwH per year Potential annual cost savings are **-£15.48**
Wall **2.5894** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **23** 'C	Annual Heat Loss from this Brick Wall **690.91535** kwHours = **£63.910**	Actual U-value **2.011** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **432.97548**kwH per year Potential annual cost savings are **£40.05**

Potential cost savings report

Ron Frend

Room or Area Name: **G9 Pantry**



For this room:

potential savings are up to **99.12** kwH per year

Potential annual cost savings are **£9.17**

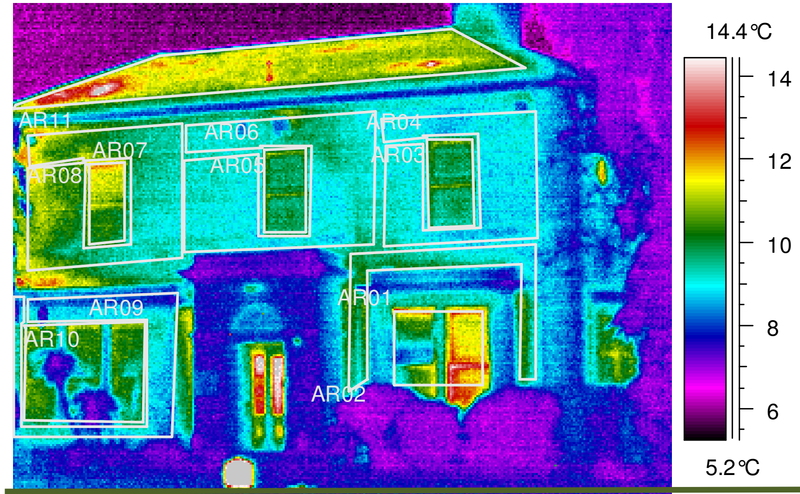
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

West Wall **3.983** sq. m. Test Data: Outside Temperature: **8** 'C Inside Temperature: **22** 'C	Annual Heat Loss from this Brick Wall **579.65634** kwHours = **£53.618**	Actual U-value **1.134** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **206.73344** kwH per year Potential annual cost savings are **£19.12**
North Wall **3.983** sq. m. Test Data: Outside Temperature: **8** 'C Inside Temperature: **22** 'C	Annual Heat Loss from this Brick Wall **579.65634** kwHours = **£53.618**	Actual U-value **1.134** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **206.73344** kwH per year Potential annual cost savings are **£19.12**
West Window **0.737** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **146.31639** kwHours = **£13.534**	Actual U-value **1.723** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-157.1741** kwH per year Potential annual cost savings are **-£14.54**
North Window **0.737** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **146.31639** kwHours = **£13.534**	Actual U-value **1.723** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-157.1741** kwH per year Potential annual cost savings are **-£14.54**

Potential cost savings report

Ron Frend

Room or Area Name: **SE1 Roof Space**



LabelValue
IR : max17.5°C
IR : min5.0°C
AR01 : avg10.7°C
AR02 : avg9.6°C
AR03 : avg9.9°C
AR04 : avg9.0°C
AR05 : avg9.9°C
AR06 : avg9.2°C
AR07 : avg10.8°C
AR08 : avg10.0°C
AR09 : avg9.5°C
AR10 : avg8.8°C
AR11 : avg11.2°C

For this room:

potential savings are up to **69762** kwH per year

Potential annual cost savings are **£6,453.01**

- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Roof Void West **79.8** sq. m.
Test Data:
Outside Temperature: **11** 'C
Inside Temperature: **13** 'C

Annual Heat Loss from this PentRoof
71278.507 kwHours
= **£6,593.262**

Actual U-value **24.570**
Target U-value **0.35**
as per Building Regulations approved Documents ADL 12

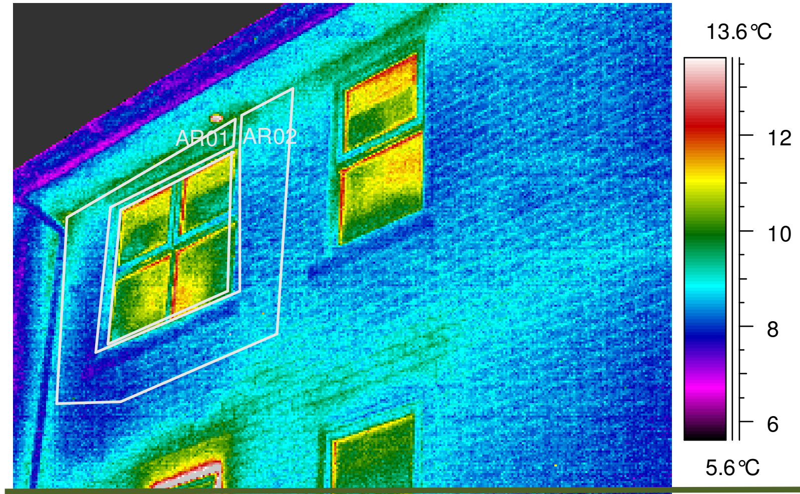
If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to..................

potential savings are up to **69762.308**wH per year
Potential annual cost savings are **£6,453.01**

Potential cost savings report

Ron Frend

Room or Area Name: **SE11 Bedroom 14**



LabelValue
IR : max16.8℃
IR : min2.9℃
AR01 : avg10.3℃
AR02 : avg8.6℃

For this room:
potential savings are up to **665.4** kwH per year
Potential annual cost savings are **£61.55**

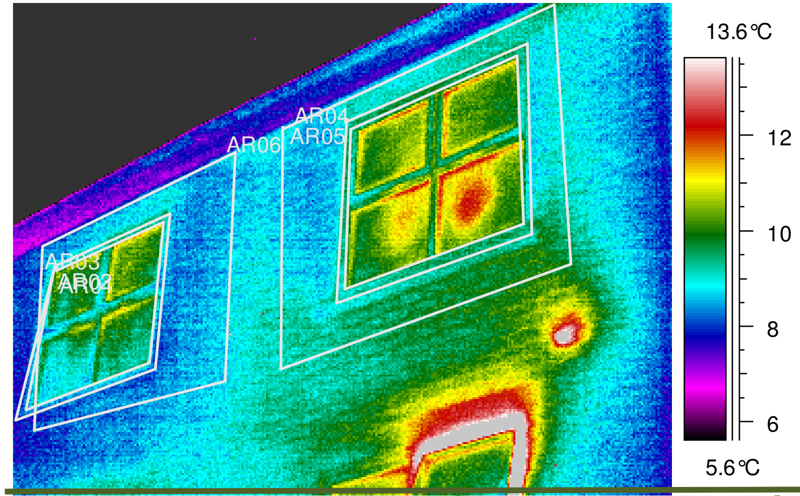
- Significant Heat Loss
- Heat is being lost
- Some Heat is being lost at this position
- Slight heat loss at this position
- Minimal heat is being lost at this position
- No measureable heat loss at this position

Window **2.028** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **607.86019** kwHours = **£56.227**	Actual U-value **2.705** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-225.8491**kwH per year Potential annual cost savings are **-£20.89**
Wall **5.58** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **1481.3462** kwHours = **£137.025**	Actual U-value **1.876** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **891.28486**kwH per year Potential annual cost savings are **£82.44**

Potential cost savings report

Ron Frend

Room or Area Name: **SE12 Bedroom 15**



LabelValue
IR : max21.9℃
IR : min3.3℃
AR01 : avg9.6℃
AR02 : avg9.5℃
AR03 : avg9.0℃
AR04 : avg10.5℃
AR05 : avg10.3℃
AR06 : avg9.7℃

For this room:

potential savings are up to **1396** kwH per year

Potential annual cost savings are **£129.15**

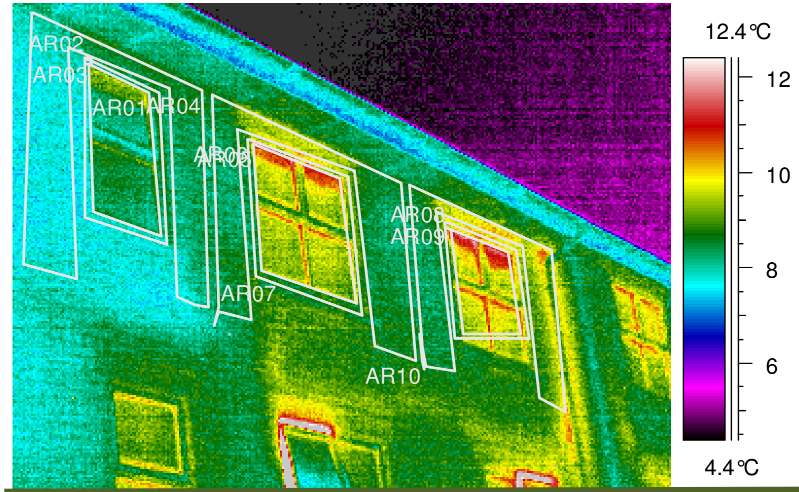
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **5.58** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **2211.3426** kwHours = **£204.549**	Actual U-value **2.891** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1622.1009** kwH per year Potential annual cost savings are **£150.04**
Window **2.028** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **607.86019** kwHours = **£56.227**	Actual U-value **2.705** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-225.8491** kwH per year Potential annual cost savings are **-£20.89**

Potential cost savings report

Ron Frend

Room or Area Name: **SE13 Bedroom 16**



LabelValue
IR : max20.0°C
IR : min3.2°C
AR01 : avg8.5°C
AR02 : avg8.2°C
AR03 : avg8.4°C
AR04 : avg8.0°C
AR05 : avg9.7°C
AR06 : avg9.5°C
AR07 : avg8.6°C
AR08 : avg10.0°C
AR09 : avg9.9°C
AR10 : avg9.0°C

For this room:

potential savings are up to **-326** kwH per year

Potential annual cost savings are **-£30.14**

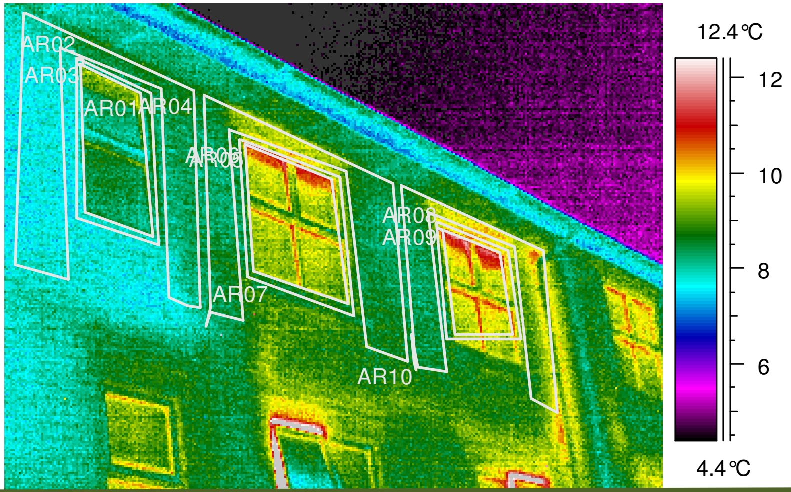
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **5.58** sq. m. Test Data: Outside Temperature: **8** 'C Inside Temperature: **22** 'C	Annual Heat Loss from this Brick Wall **812.0719** kwHours = **£75.117**	Actual U-value **1.134** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **289.62405** kwH per year Potential annual cost savings are **£26.79**
Window **2.028** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Window **395.57624** kwHours = **£36.591**	Actual U-value **1.379** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-615.4136** kwH per year Potential annual cost savings are **-£56.93**

Potential cost savings report

Ron Frend

Room or Area Name: **SE14 Bedroom 17**



LabelValue
IR : max20.0℃
IR : min3.2℃
AR01 : avg8.5℃
AR02 : avg8.2℃
AR03 : avg8.4℃
AR04 : avg8.0℃
AR05 : avg9.7℃
AR06 : avg9.5℃
AR07 : avg8.6℃
AR08 : avg10.0℃
AR09 : avg9.9℃
AR10 : avg9.0℃

For this room:

potential savings are up to **665.4** kwH per year

Potential annual cost savings are **£61.55**

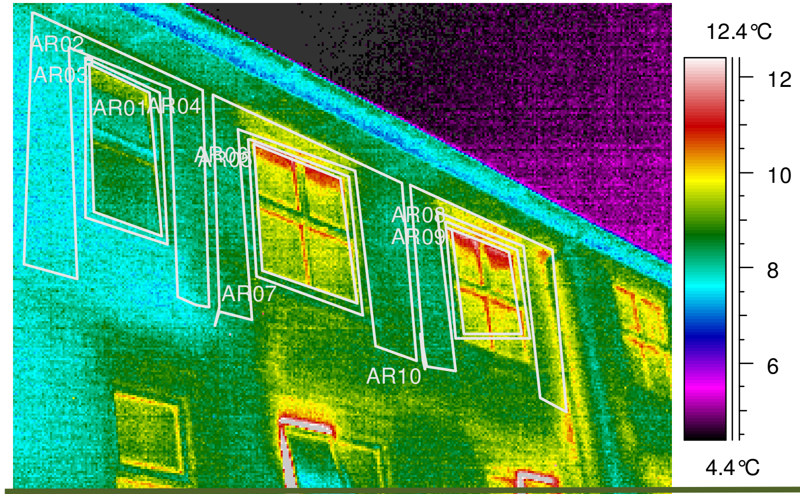
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **5.58** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **1481.3462** kwHours = **£137.025**	Actual U-value **1.876** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **891.28486**kwH per year Potential annual cost savings are **£82.44**
Window **2.028** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **607.86019** kwHours = **£56.227**	Actual U-value **2.705** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-225.8491**kwH per year Potential annual cost savings are **-£20.89**

Potential cost savings report

Ron Frend

Room or Area Name: **SE15 Bedroom 18**



LabelValue
IR : max20.0℃
IR : min3.2℃
AR01 : avg8.5℃
AR02 : avg8.2℃
AR03 : avg8.4℃
AR04 : avg8.0℃
AR05 : avg9.7℃
AR06 : avg9.5℃
AR07 : avg8.6℃
AR08 : avg10.0℃
AR09 : avg9.9℃
AR10 : avg9.0℃

For this room:

potential savings are up to **665.4** kwH per year

Potential annual cost savings are **£61.55**

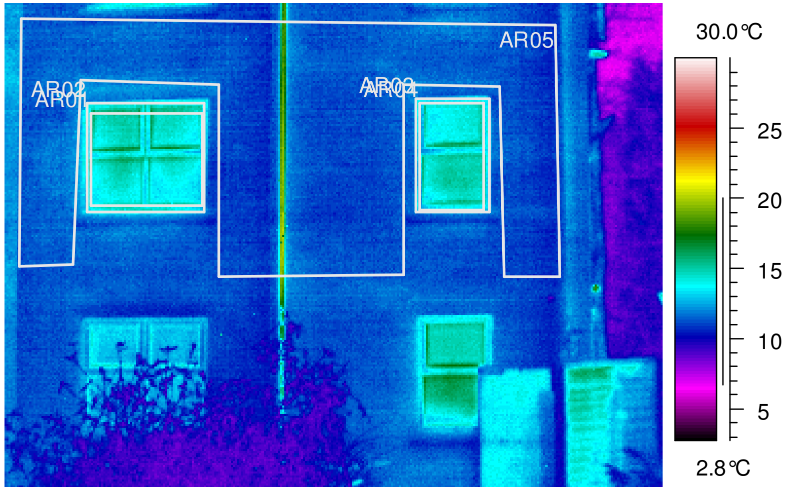
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Window **2.028** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **607.86019** kwHours = **£56.227**	Actual U-value **2.705** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-225.8491** kwH per year Potential annual cost savings are **-£20.89**
Wall **5.58** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **1481.3462** kwHours = **£137.025**	Actual U-value **1.876** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **891.28486** kwH per year Potential annual cost savings are **£82.44**

Potential cost savings report

Ron Frend

Room or Area Name: **SE18 Group Room**



LabelValue
IR : max20.5℃
IR : min6.4℃
AR01 : avg14.5℃
AR02 : avg14.4℃
AR03 : avg14.2℃
AR04 : avg14.4℃
AR05 : avg11.5℃

For this room:

potential savings are up to **6799** kwH per year

Potential annual cost savings are **£628.93**

- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Wall **9.257** sq. m. Test Data: Outside Temperature: **12** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **6461.7174** kwHours = **£597.709**	Actual U-value **5.439** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **5486.9082**wH per year Potential annual cost savings are **£507.54**
Window **2.743** sq. m. Test Data: Outside Temperature: **14** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **2432.3789** kwHours = **£224.995**	Actual U-value **9.505** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1312.3314**wH per year Potential annual cost savings are **£121.39**

Potential cost savings report

Room or Area Name: **SE19 ATP Office**

For this room:

potential savings are up to **3896** kwH per year

Potential annual cost savings are **£360.36**

Significant Heat Loss

Heat is being lost

Some Heat is being lost at this position

Slight heat loss at this position

Minimal heat is being lost at this position

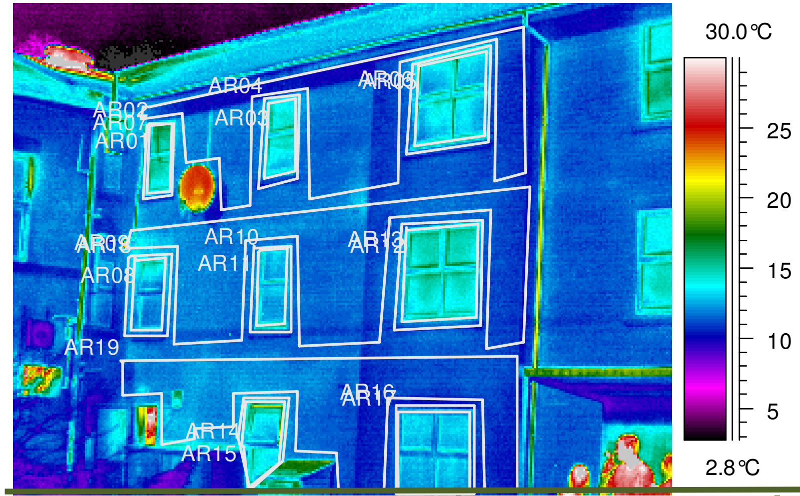
No measureable heat loss at this position

Window **2.028** sq. m. Test Data: Outside Temperature: **13** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **1417.8950** kwHours = **£131.155**	Actual U-value **7.158** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **588.39875** kwH per year Potential annual cost savings are **£54.43**
Wall **5.58** sq. m. Test Data: Outside Temperature: **12** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **3895.0398** kwHours = **£360.291**	Actual U-value **5.439** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **3307.4373** kwH per year Potential annual cost savings are **£305.94**

Potential cost savings report

Ron Frend

Room or Area Name: **SE20 Bedroom**



For this room:

potential savings are up to **3896** kwH per year

Potential annual cost savings are **£360.36**

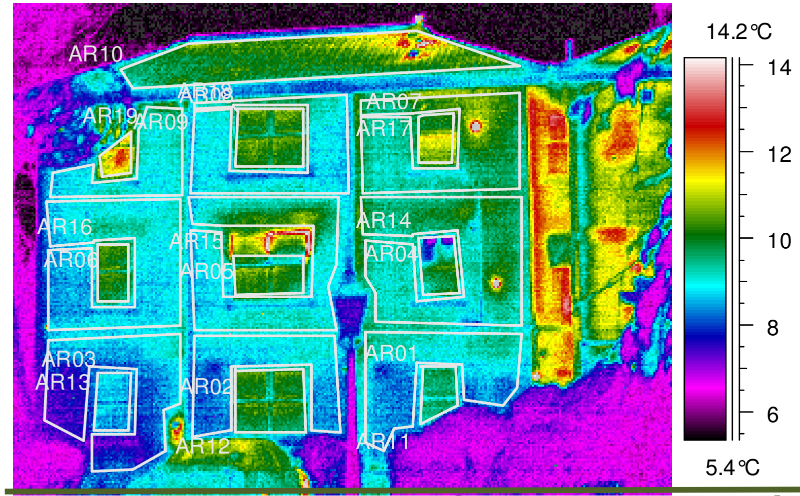
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Window **2.028** sq. m. Test Data: Outside Temperature: **13** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **1417.8950** kwHours = **£131.155**	Actual U-value **7.158** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **588.39875** kwH per year Potential annual cost savings are **£54.43**
Wall **5.58** sq. m. Test Data: Outside Temperature: **12** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **3895.0398** kwHours = **£360.291**	Actual U-value **5.439** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **3307.4373** kwH per year Potential annual cost savings are **£305.94**

Potential cost savings report

Ron Frend

Room or Area Name: **SE8 Medical Secretary**



For this room:

potential savings are up to **1514** kwH per year

Potential annual cost savings are **£140.06**

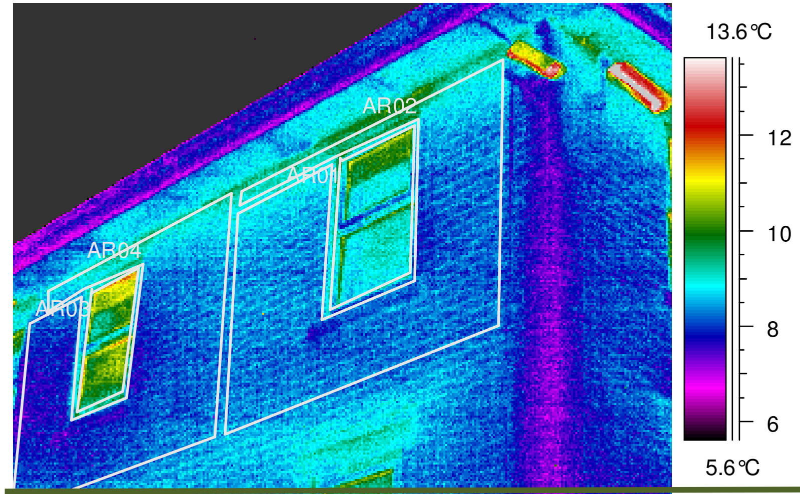
- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

Window **1.485** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **445.10473** kwHours = **£41.172**	Actual U-value **2.705** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-165.3777**kwH per year Potential annual cost savings are **-£15.30**
Wall **10.515** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **2791.4615** kwHours = **£258.210**	Actual U-value **1.876** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1679.5449**kwH per year Potential annual cost savings are **£155.36**

Potential cost savings report

Ron Frend

Room or Area Name: **SE9 Bedroom 13**



LabelValue
IR : max15.3℃
IR : min2.6℃
AR01 : avg9.2℃
AR02 : avg8.4℃
AR03 : avg10.1℃
AR04 : avg8.2℃

For this room:

potential savings are up to **1151** kwH per year

Potential annual cost savings are **£106.46**

- **Significant Heat Loss**
- **Heat is being lost**
- **Some Heat is being lost at this position**
- **Slight heat loss at this position**
- **Minimal heat is being lost at this position**
- **No measureable heat loss at this position**

North Wall **6.965** sq. m. Test Data: Outside Temperature: **8** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **1008.0129** kwHours = **£93.241**	Actual U-value **0.992** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **270.47057** kwH per year Potential annual cost savings are **£25.02**
West Window **0.715** sq. m. Test Data: Outside Temperature: **10** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **214.30968** kwHours = **£19.824**	Actual U-value **2.705** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-79.62628** kwH per year Potential annual cost savings are **-£7.37**
West Wall **6.965** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **24** 'C	Annual Heat Loss from this Brick Wall **1849.0280** kwHours = **£171.035**	Actual U-value **1.876** Target U-value **0.7** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **1112.5088** kwH per year Potential annual cost savings are **£102.91**
North Window **0.715** sq. m. Test Data: Outside Temperature: **9** 'C Inside Temperature: **21** 'C	Annual Heat Loss from this Window **141.94874** kwHours = **£13.130**	Actual U-value **1.723** Target U-value **3.3** as per Building Regulations approved Documents ADL 12	If you improve the U-Value to that required in Building Regs approved documents BR ADL1 and 2 you will save up to.................. potential savings are up to **-152.4823** kwH per year Potential annual cost savings are **-£14.10**

Potential cost savings report

Ron Frend

Actual Total radiant loss	10,015.732	watts
Actual Total convective loss	23,348.331	watts

Actual heat loss from the building	33.36406283	kW
Cost of heating the building per year	£27,034.90	

If all items in this report have their U-VALUES improved to existing Building Regulations MINIMUM requirements there would be an annual cost saving of: **£20,010.15**

Annual Averaged Heat Loss Component Report

Please note: This report estimates the costs associated with heat losses over a 12 month period based on averaged ambient data.

Priory Hospital

Rosemary Lane

Preston

Lancashire

PR4 0HB

Date of Survey:

10/02/2011

Cost per kWhour: 0.074

Annual Average Conditions

Wind Speed m/s: 3.500

Boiler Efficiency **80%**

Cost per kWh **£0.0740**

Brick Wall

			Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)	
Total heat loss from this component	16.88949858	kW	Totals 5737.2	watts	11152.3	watt	16889.499	watts
Cost of heating per calendar month	£1,140.46							
Cost of heating per year	£13,685.56							

Door

			Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)	
Total heat loss from this component	0.349865128	kW	Totals 96.764	watts	253.102	watt	349.86513	watts
Cost of heating per calendar month	£23.62							
Cost of heating per year	£283.50							

PentRoof

			Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)	
Total heat loss from this component	10.49378136	kW	Totals 2124.9	watts	8368.86	watt	10493.781	watts
Cost of heating per calendar month	£708.59							
Cost of heating per year	£8,503.11							

Window

			Radiant Heat Loss (watts)		Convective Heat Loss (watts)		Total Heat Loss (watts)	
Total heat loss from this component	5.630917765	kW	Totals 2056.9	watts	3574.03	watt	5630.9178	watts
Cost of heating per calendar month	£380.23							
Cost of heating per year	£4,562.73							

Total radiant loss 10,015.732 watts Total convective loss 192,678.853 watts

Total heat loss from the building	33.364062831	kW
Cost of heating the building per hour:	£3.09	
Cost of heating the building per day	£74.07	
Cost of heating the building per calendar month	£2,252.91	
Cost of heating the building per year	£27,034.90	