

Abdulaziz Aljahdali
P132783

Table of Content

1.Introduction	3
2.Findings	4-6
2.1. Energy Consumption Worldwide	4
2.2. Energy Retrofitting Method of Building Envelops	4
2.3. Characteristics of Benchmark Building	5
2.4. Listed Buildings Classification	6
2.4.1. England and Wales / 3 grades of classification	7
3.Data Collected	8-9
4.Discussion of Results	10-13
U Value and its calculations	14-20
5.Propose	21-22
6.Conclusion	23
7.References	24
7.Appendix	25-29

1.Introduction

In December 2017, a survey taken place in the University of Wales Trinity St. David (UWTSD) has been conducted, precisely at the Lampeter campus. This survey aimed to upgrade the student accommodation and improve the sustainability condition of the building. Lampeter has been graded as Grade II of a listed building. Final year students of the Faculty of Architectural technology course at UWTSD in Swansea campus were assigned to proposed to restore the Lampeter accommodation to make it more sustainable without any modification of the original structure and the overall outside shell of the building. This report ultimate goal is to provide a solution of improving the windows of the building.

2. Findings

2.1. Energy Consumption Worldwide

Today, energy crisis have grown a serious concern in many industries as it also has a significant impact on a country's economic growth. Having a high demand on energy consumption while at insufficient energy resources can seriously harm many lives including the future generation, not to mention the 'toxic' environmental pollution including excessive waste of resources issues that have not been acknowledged seriously. Taking this into account, according to (IEA, 2015), buildings (including housing and commercial) use roughly 40% of the total yearly energy in most countries across the globe. In addition, it also makes approximately 26% of greenhouse gas emissions on yearly, according to EPA, (2013). Furthermore, according to Mithraratne (2007), approximately 50% of the greenhouse gas releases in the UK are due to the energy consumed in buildings. In comparison to Australia, a total of 25% of energy used by both households and also buildings, which means that, Australia is accountable for 20% of releasing the greenhouse gas, says Department of Industry (2013). DWA (2008) states that as a result for poor thermal performance, Australian use about 40% of its energy on buildings, precisely for the purpose of heating and cooling. Therefore, it is important to implement sustainable design principles to ensure the effectiveness when utilising construction materials in order to enhance the thermal performance of both new and existing buildings, as claimed by Lyons and Reardon (2013). The reason is that, thermal performance of buildings defines the amount of energy consume by the building, to be exact for heating and cooling purpose as it affect the energy efficiency greatly.

Right before the oil crisis happened back in 1973, CRES (2000) stated that the energy competence of envelope building components was barely taken as a core element in designing and constructing a building. As an outcome, majority of the existing houses that aged more than 40 years, are built without a thought of how efficient its energy will be. Note that partial of these existing buildings are now significant part of cultural heritage, which means maintenance work is required although some of these buildings have zero value of cultural heritage. To enhance the energy efficiency of these old buildings, razing it down and substitute it with new buildings may appear to solve the problem. Nevertheless, when considering the amount of time and energy needed for this practice is neither economical nor efficient. Therefore, one of the best ways to preserve the value of these heritage buildings is to use retrofitting method to improve the efficiency of its energy performance. Energy retrofitting of old buildings is a corrective process that can help in achieving huge energy saving as well as improving the energy efficiency.

2.2. Energy Retrofitting Strategy for Building Envelopes

The uses of energy in terms of heating and cooling are generally controlled by how good is the quality of the building envelopes. Building envelopes are the structural barriers that separate the interior and the exterior environment of the building. Building envelopes can be in many forms including external walls, external doors, windows, roof, ground and the internal walls that unattached conditioned spaces from non-condition spaces. The fundamental issue here is the energy loss generated by the building envelopes. Building envelopes are known by its heat loss through these processes: transmission of heat or electricity, convection and radiation. Hence, it is crucial to improve the thermal performance of building envelopes. Besides, there are several different methods of retrofitting that can be used to support this case, namely: energy retrofitting of external walls, roofs and ceilings, floors, and windows.

2.3. Characteristics of Benchmark Building

In this research, an old building known as Lampeter Campus in Swansea has been chosen to be the case of this study for the purpose of modelling and simulation. Figure 1. Below shows the floor plan of the case study building.

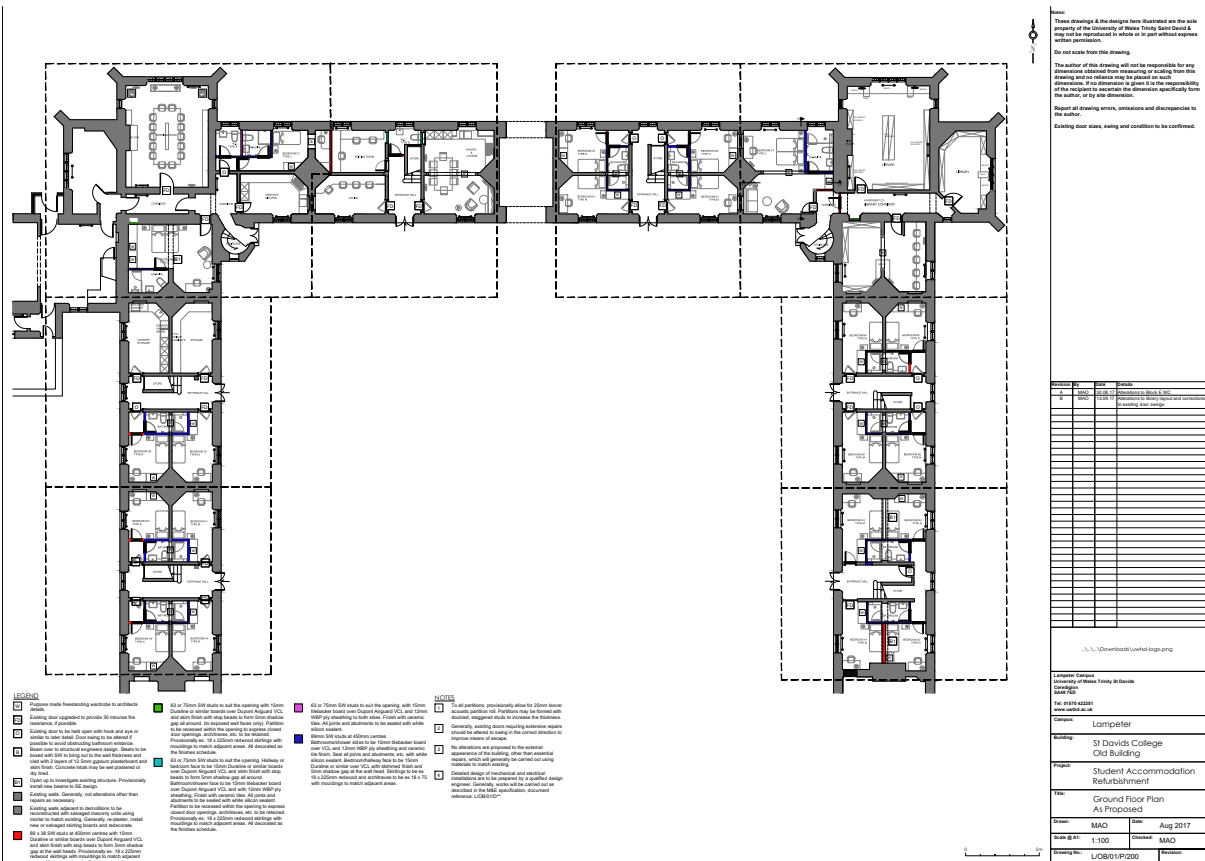


Figure 1. Floor Plan of Lampeter building

Lampeter Campus is multi-floors-story building that occupies numbers of bedrooms, living room, room for leisure, including offices and also kitchens. Total opening area of the building is in the inner court. In Figure 2 (see page 6) shown a 3-Dimensional model and orientation of Lampeter building.

In this study, software called FirstRate 5 has been used for modelling and estimating the energy consumption of Lampeter building in heating and cooling annually. The software allows users and also the thermal performance surveyors to create energy ratings for Lampeter building by outlining the floor plan. FirstRate 5 also practices the exact fundamental calculation engine designed by CSIRO or better known as Commonwealth Scientific and Industrial Research Organisation. Step one involved modelling, where climate data have been presented to the software by significant area, materials and climate data. Thenceforth, as illustrated in Figure 1 and Figure 2 floor plan has been sketched using Revit and imported to adoptable format to the software. However, due to the insufficient information, after modelling the entire building to run the test the software could not come with accurate results.

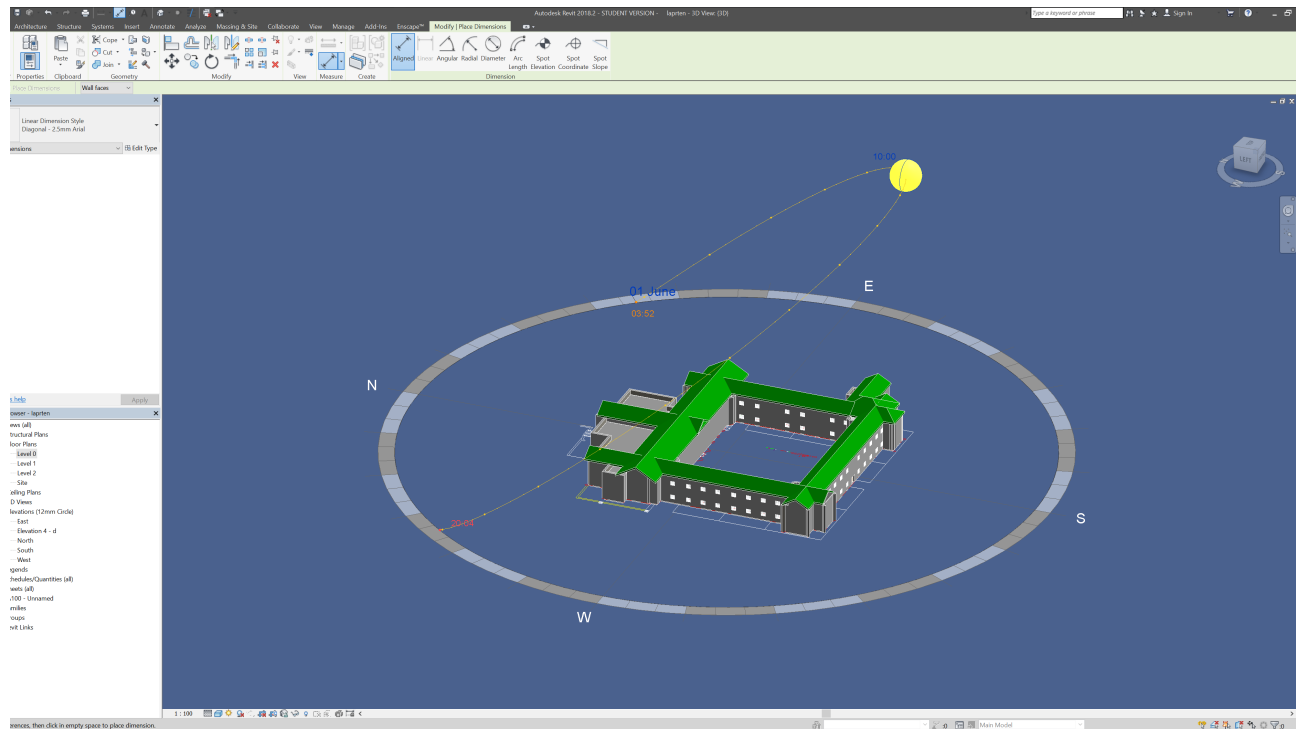


Figure 2. 3-Dimensional model and orientation of Lampeter

2.4. Listed Buildings Classification

A listed building in the United Kingdom is referring to as a registered building in the Statutory List. It is important to note that these are particularly significant reflections of architectural and historical concern. These buildings are protected from destruction or any modification work to maintain its value of heritage. With regards to repairing, maintenance or even a small alteration works are needed, prior approval from local planning authorities is highly required. Its is considered to be one of its necessity that all listed buildings are to be built by the man's hand with a firm structure and persisting in its own original form. Unless they are religious buildings, they are exempted as it only requires the operating organisation to permit its operations. Interestingly, majority of the listed buildings are well-known across the globe mainly because it has become tourist attractions. Most listed buildings become attractions to human-being as they are typically rich with history, landmarks of architectural works, bridges, monuments, sculptures, and memoirs of war, landmarks and miles are also listed. Any surviving buildings that are built back in the 1700-1840 are generally registered. After World War II, all buildings that aged over 30 years old and are exceptionally significant can also be listed.

2.4.1. England and Wales / 3 grades of classification:

Grade I: Buildings with special historical and architectural interest, sometimes of international importance

*Grade II *:* Important buildings, especially architectural styles

Grade II: They are distinct buildings, of National interest and of special interest, in most of them private buildings and residential housing and others.

If the alterations works cannot be proceeded due to issue such as problem getting approval from the local council, it is the responsibility of the owners of these buildings to keep the building in its best conditions. If, somehow these alteration or repair works are made without arrangement with the local council, it is likely that the building's owner can be judged for not complying with all the mandatory processes. In this case, these buildings may have the possibility that its structure changes, if that is what the owner wanted. However, the owner are required to appeal the eviction of his/her building from the record, though this is quite unfamiliar in the United Kingdom.

3. Data Collected

These data are collected during the survey conducted on the 12th of December 2017. The survey took place in Lampeter campus UWTSD Swansea by a class of Architectural Technology students from UWTSD, Swansea. **(Figure 3)**



Figure 3. Lampeter Campus

The observation was made on the listed building on site, and this report aim to offer a proposition for sustainable windows, conservation and sustainable refurbishment for this building.

Listed on Grade II: Gates and boundary wall to St. David's University College, Lampeter, Ceredigion (along the SW of station terrace and the E side of College Street).

Listed Date: 10 February 2012

Last Emended: 10 February 2012

Grade: II

Source: Cadw

Source ID: 87646

Building Class: Education

Location: Along the SW of station terrace and the E side of College Street

County: Ceredigion

Town: Lampeter

Community: Lampeter (Llanbedr Pont Steffan)

Built-up Area: Lampeter

Traditional County: Cardiganshire

3.1. History of the Building

The Boundary walls and gateways are possibly contemporary with the original early 19th Century construction of the college but may belong to the later 19th Century phase of college additions. The gates are probably later replacements.

Source: www.britishlistedbuildings.co.uk/wales

4. Discussion of Results

4.1. Report of the Survey

A thorough survey has been conducted to identify all the required work that needs to be done. In this report, restoration of all old windows will be the main focus. See Figure 4. Figure 4 illustrates an example of Lampeter windows to show any possible situation that might come up in the process of restoring and installing the secondary windows. It also shows the thicknesses of profiles that can be used to prevent any alteration of the original design of the building from its external view. The next step was to get access to electronic documents from the local council. The reason for this step is to identify the grade of the Lampeter building that was registered under the Local Listed Buildings.



Figure 4.
Lampeter Window

Based on the survey, a laser scan has been used as a device to capture water infiltration measurements and the different temperature scales, see Figure 5, Figure 6 and Figure 7. It has been identified that these windows do not require the objectives for a sustainable building, with a single glass panel the energy loss are visible by the colour negative temperature as seen in Figure 5, Figure 6 and Figure 7 as well as the cracks and that have to be improved as the passive design technique suggested. From this research, it can be seen that the south-facing windows have a larger wear and worsening as they have a greater exposure to the sun. This may be one of the reason that leads to a major gap in temperature from day until night. Moreover, the material used tends to break and deteriorate easily. As for the inner courtyard and west-facing side, it shows number of signs of deterioration and this lifts up the needs to improvement. Nevertheless, there is no necessity or requirement for conservation work, which significantly helps in costs reduction.

With regards to the method and restoration process, it is vital to initiate the existing windows so that when the interior of the new windows are secure, the old materials are ready to get fixed without any risks or anything that would increase the costs. In order to begin the work, all planning works need to be prepared in advance in order adapt Lampeter building's windows efficiently and effectively. A good planning is required to avoid any risks towards the materials and the safety of the worker.

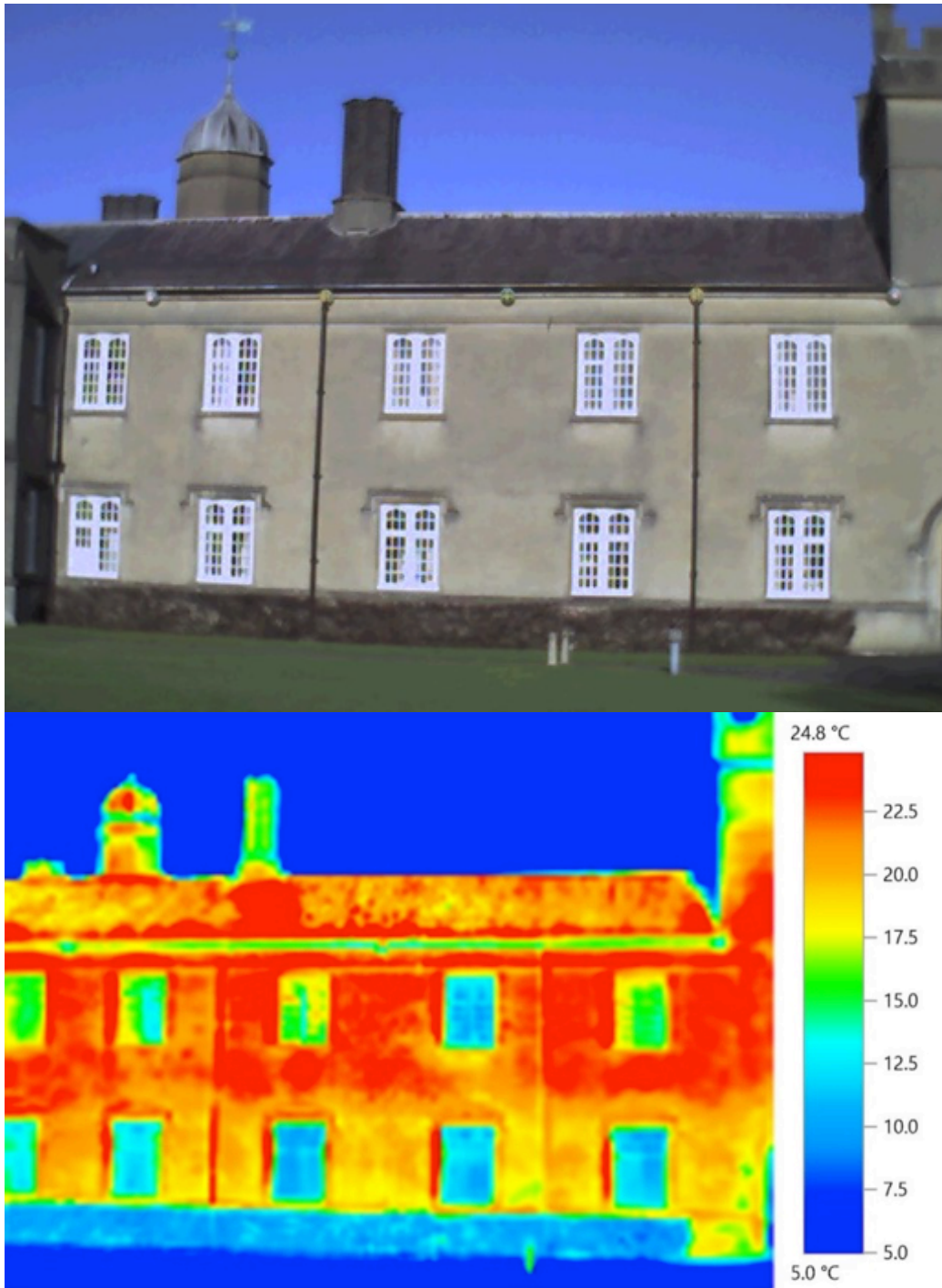


Figure 5. South Facade

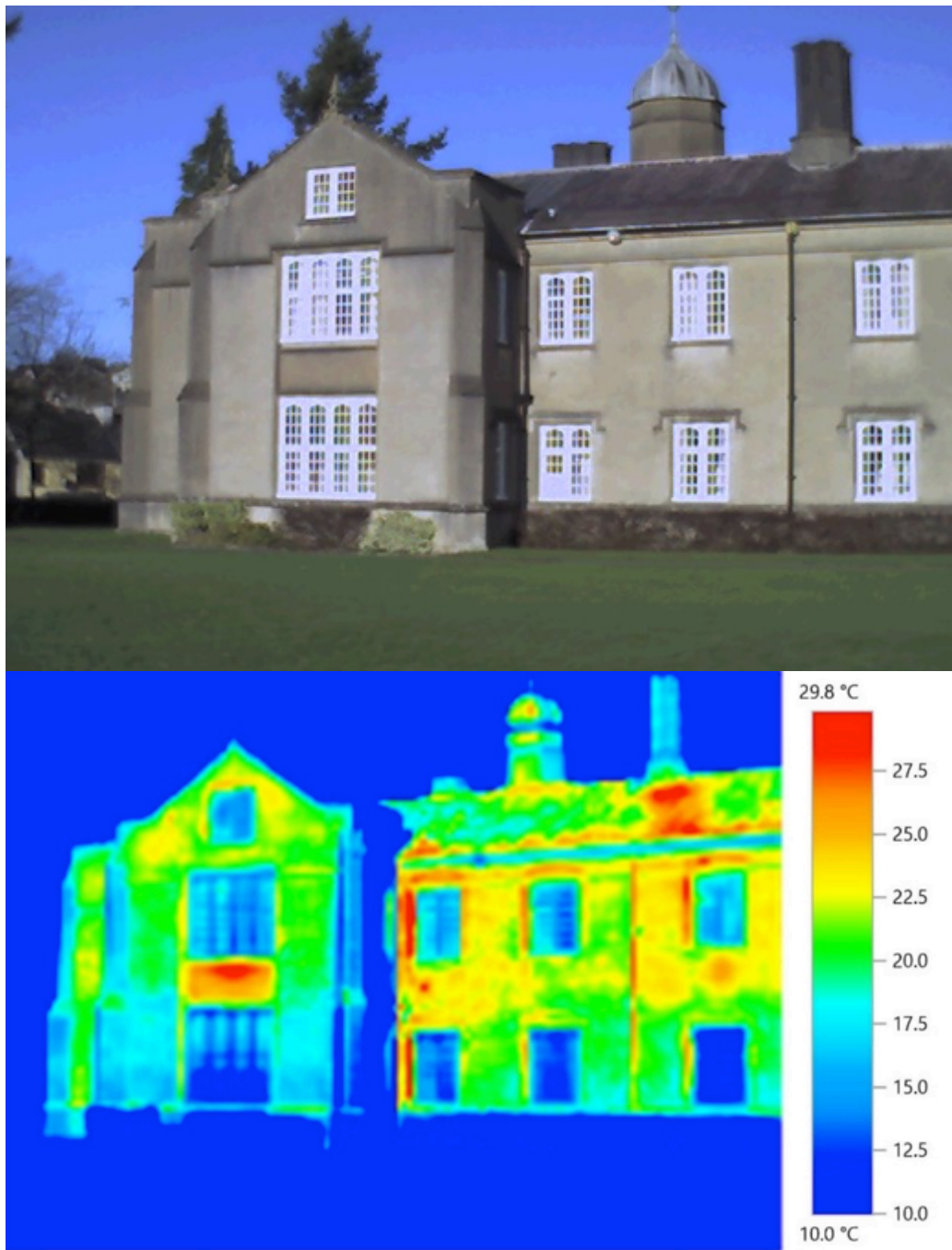


Figure 6. South Left Corner to West Facade

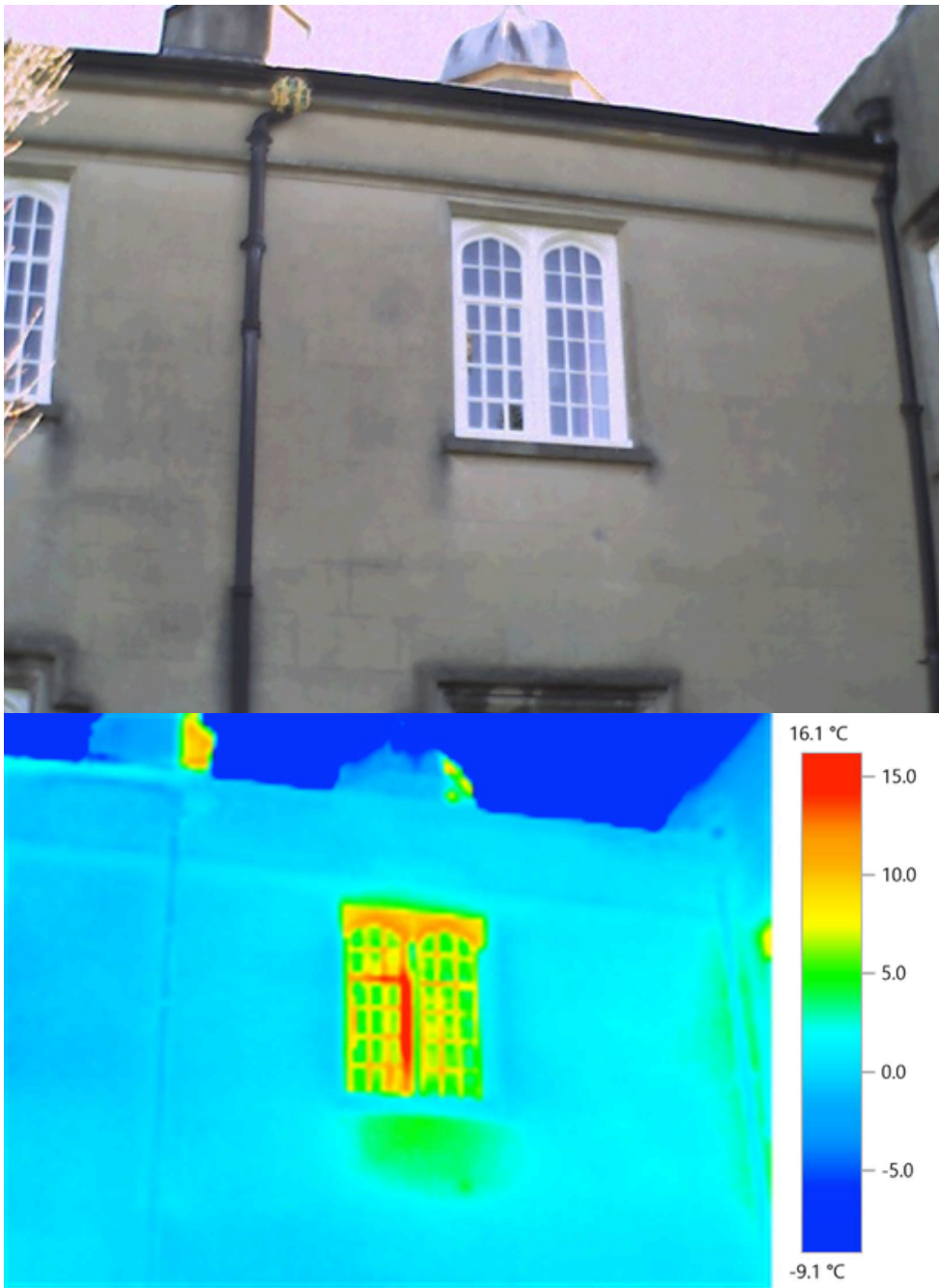


Figure 7. West Facade Level 1 Window

The term 'U-Value' and its calculations

The term 'U-value' can be defined as the amount of heat lost per square meter of a building component. These usually involve mediums such as wall, roof, floor, windows etc. The U-value functions as the resistance of these significant building parts to heat passing from a warmer to a cooler surrounding. It is important to note that as the U-value increases, it is most likely for the thermal performance of the building (in this case, Lampeter) to be defective. This is an obvious fact by just considering how much heat is leaving across each square meter of internal surface.

To calculate the U-value, it is important to have an in-depth knowledge of the building components such as the wall thickness, materials or any insulation used. As for instance, a Victorian property that has a classic solid wall (9" brickwork) has a U-value of 2.1 W/m²K.

As a matter of fact, the lowest (close to zero) U-value will reflect how efficient the insulating material is. Furthermore, at the present time, building regulations specify that for each new building, its elements must follow the maximum U-values as follows:

2010-2013 Building Regulations U-Values

Wall: 0.3 W/m²K
Roof: 0.15 W/m²K
Floor: 0.25 W/m²K
Windows – 1.6 W/m²K

Building regulations

According to Building Regulations Part L (1A), windows are obliged to have a U-value at minimum 2W/m². Additionally, walls must not have more than 0.3W/m²K and triple glazed windows of 0.6W/m²K. Hence, after comparing all these materials, it clearly shows that windows have the highest U-value, meaning that it is the weak spot in insulation work.

Putting things in perspective will help to see the bigger picture. Below are some U-values:

- Single glazed: 4.8W/m²K
- Single glazed with curtain: 3.6W/m²K
- Secondary glazing: 2.9 - 3.4W/m²K
- Double glazed (building regs): 2W/m²K

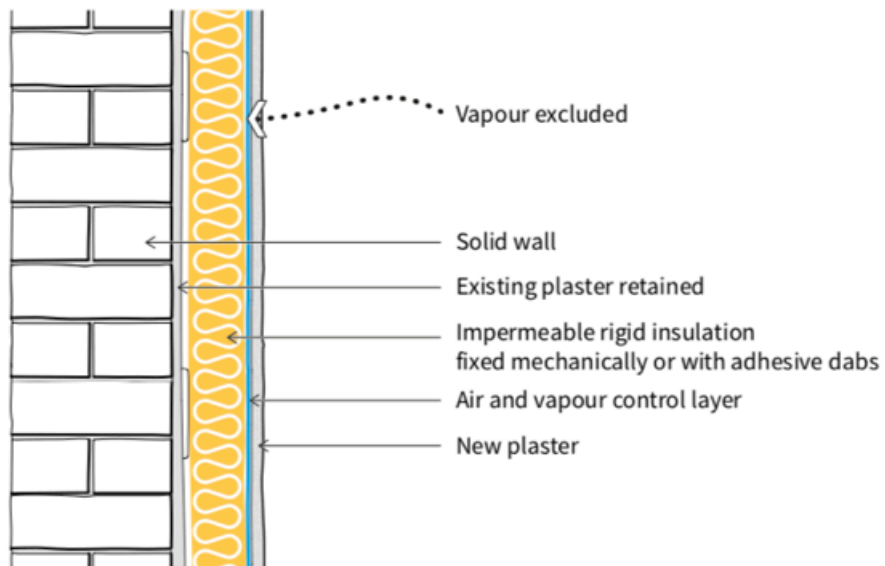


Figure 8: Internal insulation for solid wall

The R-value is calculated by using the following formula:

$$R = l/\lambda$$

l is the thickness of the material in meters

λ is the thermal conductivity (TC) in W/mK

In order to add insulation, the two R-values need to be added together. See below calculation:

80mm Polyisocyanurate insulation

tC of 0.022

$$R\text{-value} = 0.08/0.022 = 3.63 \text{ m}^2\text{K/W}$$

So the R-value of both is 3.81 m²K/W

But for rooms, adding inner and outer surfaces of each element is required. These resistances are known as R_{si} and R_{so} separately with common but these calculations are complex so the use of software is necessary.

$$U = \frac{1}{R\text{-Value}} + \begin{matrix} \text{Convection Heat Losses} \\ + \\ \text{Radiation Heat Losses} \end{matrix}$$

$$U = 1 / [R_{si} + R_1 + R_2 + \dots + R_{so}]$$

In practice this is a very complex calculation, so it is best to use U-Value calculation software.

Units are in Watts per meter squared Kelvin (W/m²K).

As a guideline, an un-insulated cavity wall has a U-Value of about 1.6 W/m²K, while a solid wall has a U-Value of roughly 2 W/m²K

In order to understand the difference between the insulation, these steps are compulsory. Basically, compare the old room and the new room with recommendation mentioned above. Not to forget, include the outside and inside temperature is required.

Calculations are as follows:

Heat Loss (W) = Area (m²) x U-value (W/m².K) x [Room Design Temp - External Design Temp] (K)

So,

Old heat loss= 12m² x 1.62m²K/W x (20-12) = 155.52k

New heat loss= 12m² x 0.392m²K/W x (20-12) = 37.63k

(More the 4x the efficiency with just 80mm EPS board insulation)

This calculation is for the room labeled in red in the floor plan in page 19, Figure 9. The solution below is for the wall of the selected room.

- Add 100mm EPS board on the internal surface (inside the room)
- The result will reflect the U-Value of 0.261 W/m².K

Note:

- The current wall without insulation is 0.962 W/m².K as shown in Appendix on page 26-29
- This upgrade for the wall will meet the regulation for Refurbishment building of Wales/ England regulation for Refurbishment building of 0.3/0.55 W/m².K

Wales

	Domestic			Non-domestic			
	New Build	Existing Buildings		New Build	Existing Buildings		
	Best Starting Point (Fabric Only)	Extension	Refurbishment	Best Starting Point (Fabric Only)	Extension (Domestic in Character)	Extension (Other Buildings)	Refurbishment
Wall	0.16	0.21	0.30 / 0.55 *	0.22	0.21	0.26	0.30 / 0.55 *
Floor	0.11	0.18	0.25	0.18	0.18	0.22	0.25
Pitched Roof - Ceiling Level	0.11	0.15	0.16	0.14	0.15	0.15	0.16
Pitched Roof - Rafter Level	0.11	0.15	0.18	0.14	0.15	0.18	0.18
Flat Roof	0.11	0.15	0.18	0.14	0.15	0.18	0.18

Table 1. Wales Refurbishment Building Regulation

Grade II*: particularly important buildings of more than special interest

If the candidate is able to meet certain conditions, for example stating that the building does not have a special architectural value or historical interest, permission for listed buildings is normally granted upon a 'like-for-like' basis. Note that it is most likely involving buildings with Grade II.

Conversely, for listed buildings that are claimed to have special architectural and historical values, it is essential for the candidate to reinstate and re-use only existing materials as much as they could. In order to do so, it may involve actions such as scarfing timber, releasing sashes, installing new draught-proofing as well as re-glazing glasses (by using the existing glass if possible) and repairing works will be required in order to maintain the value of the listed building. Furthermore, initial colour of the building if faded need to be preserved. However, in such cases where repairing work is impossible, any replacement materials will need to copy the existing designs. As of the glaze windows, secondary double-glazing is highly recommended. Of course, upgrading a single glazed is the easiest solution, however, it appears to be not as competence like the primary double-glazing. U-value will be approximately 2.8 to 3.0W/m².

Weakness of our solution:

1. Condensation - because it is not in a secure unit, the gap between the window and the secondary glass allow air in between, as it has similar level of humidity as its surrounding air
2. Total efficiency - the insulation performance is not as good as double-glazing, meaning shortage of any vacuum between the sheets of glass. There will be some heat loss because there is insufficient contact fastening around the mating side.

Truth is, secondary glazing will never perform an efficient thermal work as good as the double or triple glazing. However, it is considered to be doing its work decent enough if installed carefully.

Solutions to address:

1. Packets of silica gel can be put in the air gap. Gradually, it will be saturated. However, swiftly lose the absorbed moisture if heated. For instance, this could take place in a cooling oven or even close to a fireplace. It will only does it work if the next step is followed;
2. It is important to seal the secondary glazing securely around the side of the window. A normal standard draught-proof strip will work just fine because it holds the small surface tightly.
3. If the seal is properly done, the silica gel should keep compression down. However for this to work, another step required is to swap the sachets and dry-heating the originals regularly.
4. Otherwise, it can be done by reverting to the classic old-style solutions can do this. One of the alternatives is to use thick, floor-length curtains drawn at evening. Lined fabric is also suitable as an insulator as it is not see-through. Worse come to worst, this is the very options but worry not, it works just fine.

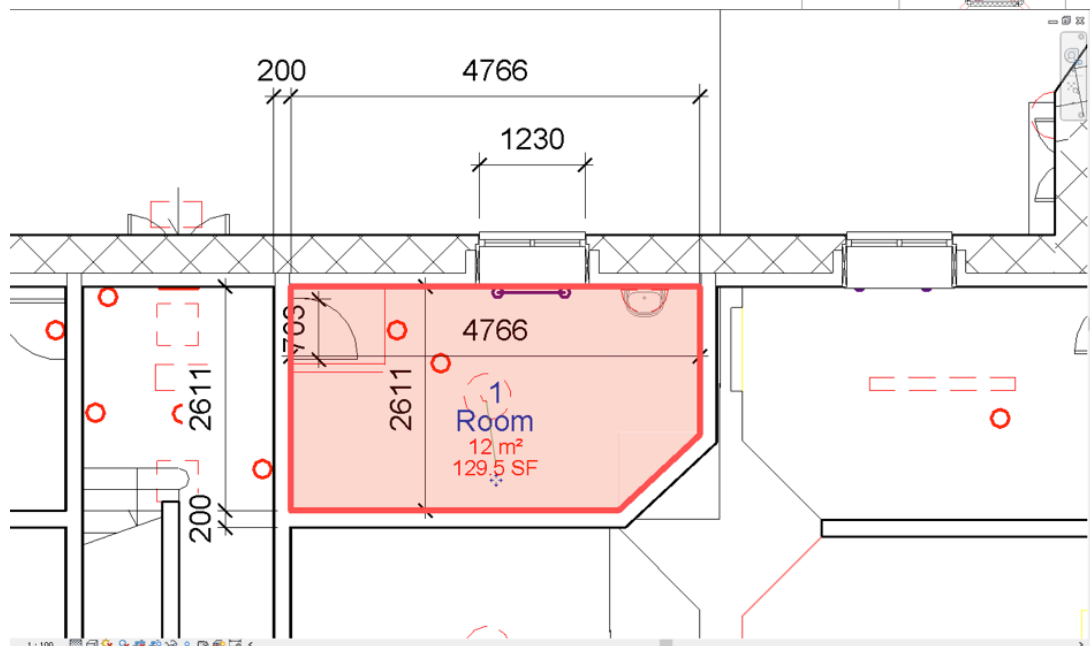


Figure 9. Floor Plan

Assuming the floor, roof and door are meeting the building regulation

Assumption of the current room

Surface	Area	U-Value W/m2.K	Thermal loss w/k
Roof	12m ²	0.15	1.8
Wall	12m2	0.962	11.55
Window	1.23m2	5	6.15
Door	1.89	1.8	3.4
Floor	12m2	0.25	3
Total			25.9 BTU

Table 2. Assumption of current room

With new windows and insulated wall

Surface	Area	U-Value W/m ² .K	Thermal loss w/k
Roof	12m ²	0.15	1.8
Wall	12m ²	0.261	3.13
Window	1.23m ²	2.8	6.15
Door	1.89	1.8	3.4
Floor	12m ²	0.25	3
Total			17.48BT U

Table 3. With new window and insulated wall

Room dimension are as shown in figure(the pic with red room)
 $2.6 \times 4.7 \times 2.4 = 29.32$

So the total heat loss though the fabric are:

- a. Current room: 25.9
- b. New room: 17.9

To calculate the heat loss due to air change: (Room volume) x (air change) x
 (temperature difference)

- a. Current room: $25.9 \times 0.02 \times 8 = 4.144 + 25.9 = 30 \text{ BTU/h}$
- b. New room: $25.9 \times 0.02 \times 8 = 4.144 + 17.48 = 21.62 \text{ BTU/h}$

As the number are showing by just adding a secondary window and adding internal insulation of 100mm, the room can be more efficient by 1.4 times.

5. Propose

Making the Lampeter campus more energy efficient several factors should be looked at, such as the overall material of the building for example the windows, doors, wall, roof and floor. Examining these parts of the building will lead to better understanding and solutions, furthermore, it could lead to where the building needs to be fixed or replaced if needed. Because the building can't be energy affected if for example, have a well insulated wall but the windows leaking the hot air out, therefore a combination of solutions such as applying the strategies of passive design, active design or hybrid system will give better efficient results.

With that been said, using the passive design strategy for this case will be more suitable since it will cost less and be subtle for existing buildings and one of the key factors of the passive design is to keep the energy losses to a minimum so the building will not consume more energy.

Looking at the results of the survey done, the windows leak a great deal of ambient energy, therefore it needed to be treated. One of the alternatives is to use internal blinds as it helps to improve the window performance. As a matter of heat loss, heavy and coated curtains may be a good option to reduce the heat loss. Furthermore, the use of double glazing with double profile will only be effective when the existing frame supports the new features of the new windows. However, in the case of windows in the Lampeter building, it is impossible to eliminate the original windows to replace it with a new one. In this case, another option is to propose a secondary glazing and the placement of an independent UPVC frame as double glazing has the capability to provide the preferred function in a sustainable way. See Figure 10 and Figure 10.1.



Figure 10. Frame System for Secondary Windows

The internal double glazed window with fixing the shoulders and window sill, offers the exact insulation values, energy losses reduction, lower the noise and dust entry, assuring the equivalent current light input across the old window. The window's design should be circumspect and projected together with outlining that it cannot be viewed from the outside of the old window to ensure that the original design or the building will not be effected. In addition, supplementary security procedure can be added in a reasonable way in existing windows. Not to forget, the new secondary window also comes with additional safety procedures.



Figure 10.1. Frame System for Secondary Windows



Local: Windows Company at
Lampeter - J & P Home
Improvements

*Double-Glazing Installer in
Lampeter, Wales*

Address: Unit 1-5, Lampeter
Industrial Estate, Tregaron Rd,
Lampeter SA48 8LT

6. Conclusion

As time goes by it become more difficult to maintain historical building such as Lampeter campus, because of the use of better and newer material as well as new more advance technics that for example benefits the the building to maintain its heat as mentioned above.

For Lampeter campus's window, wood frame are easy to replace, However in our case those replacement have to be carefully put as the wooden frame and iron windows tend to get damaged over time by corrosion and need to be dealt with with it carefully because the iron spike are what keeping the windows sticking to that wall and the might effect the surrounded wall, is been mention earlier maintenance are need for those type of building, Therefore regular inspection should be in place to detect the causes may accrue to the building and preventing it form causing and permanent damage and therefore replacing the original parts of the building wont be needed. In most cases, humidity are the reason for causing the damage, but most of the material such as copper, stone, glass and wood can be recycled, for instead, glass can be reused, there metal material can be melted and used as a new material. And luckily, most historical building build with such material.

As this report aim to provide a sustainable solution for retrofitting, The wood beam frame of the widows is one of the best solution to repair the damaged windows. Important factory should be in mind to preventing the widows of a damage over time is the tightness. also, choosing suitable choice of windows frame paint can make the windows water proof to some degree and ultraviolet attacks. As the sun hitting the south facade the most, its windows needs more maintenance, repair and the use of unsuitable material used before can show deterioration.

As the windows on the south facade got exposed to the sun light more and got significant difference in temperatural at day and night, so the metal tend to show more sign of wear than the rest of the buildings facade but the also the west and in the middle garden side wall shows some deterioration and needs to be dealt with, however it doesn't need as much maintenance as the south facade.

As mentioned above, to decrease the thermal losses of the building the building should have a well insulated envelope, such as roof, walls and floor. Along with, widows and film glass on them and widows moisture control.

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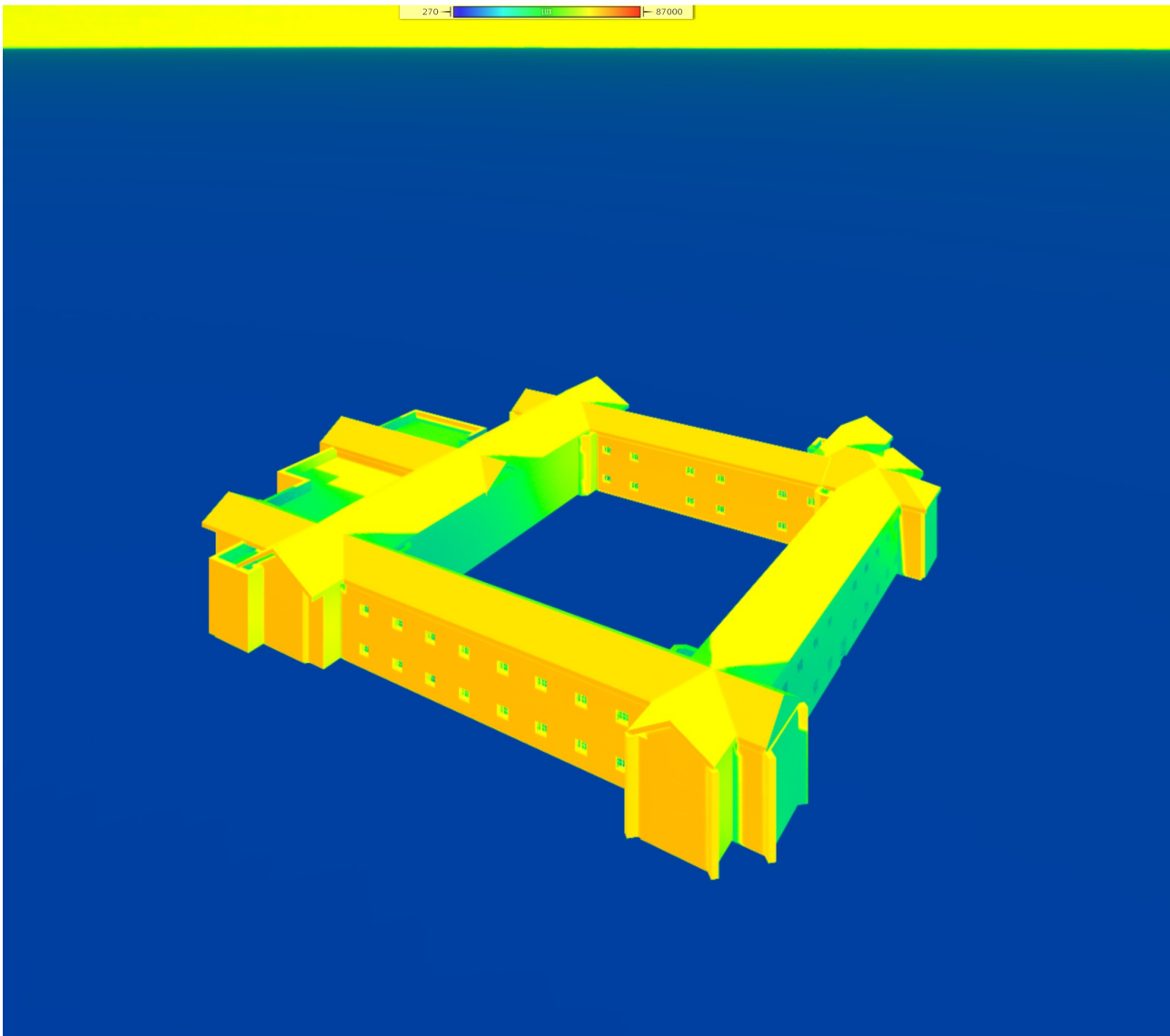
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8. Appendix



Heat map of external wall of Lampeter Building, UWTSD.



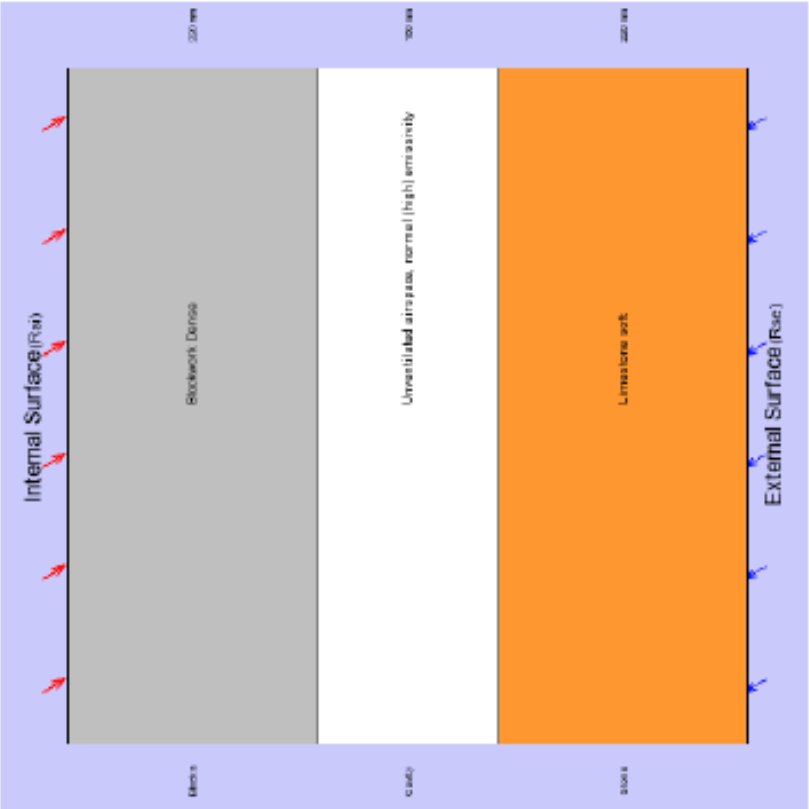
U-Value Calculator

Thermal transmittance (U-value) according to BS EN ISO 6946 2007

Project		Reference	
lampeter campus wall without insulation			
		Building Use Domestic	
		Build Type Refurbishment	
Element Type:		Max U-Value $U = 1/R_T = 0.30 \text{ W/m}^2\text{K}$	
External Wall			
Material	Thermal Cond. (W/mK)	%	Thickness (mm)
Internal Surface (Rsi)			Resistance (m²K/W)
Blockwork Dense	0.4400	100	220
Unventilated airspace, normal (high) emissivity	0.1800	100	160
Limestone soft	1.1000	100	220
External Surface (Rse)			0.0400
Total thickness: 600.0 600.0 mm (actual)			
Total resistance: $RT = R_{si} + R + R_{se} = 1.050 \text{ m}^2\text{K/W}$			
U-Value (uncorrected): $U = 1/R_T = 0.952 \text{ W/m}^2\text{K}$			
Total ΔU: 0.010			
U-Value (corrected): $U = 1/R_T + \Delta U = 0.962 \text{ W/m}^2\text{K}$ ✕			

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U-Value Calculator

Thermal transmittance (U-value) according to BS EN ISO 6946 2007

Project		Reference	
lampeter campus wall with insulation		Building Use (Domestic)	
		Build Type (Refurbishment)	
Element Type:		Max U-Value $U = 1/RT = 0.30 \text{ W/m}^2\text{K}$	
(External Wall)			
Material	Thermal Cond. (W/mK)	%	Resistance (m²K/W)
Internal Surface (Rsi)			0.1300
EPS Board	0.0400	100	3.0000
Blockwork Dense	0.4400	100	0.5000
Unventilated airspace, normal (high) emissivity	0.1800	100	0.1800
Limestone hard	1.7000	100	0.1294
External Surface (Rse)			0.0400
Total thickness: 720.0 mm (actual) Total resistance: $RT = Rsi + R + Rse = 3.979 \text{ m}^2\text{K/W}$ U-Value (uncorrected): $U = 1/RT = 0.251 \text{ W/m}^2\text{K}$ Total ΔU: 0.010 U-Value (corrected): $U = 1/RT + ΔU = 0.261 \text{ W/m}^2\text{K}$ ✓			

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