COLLEGE BRIEF
November 2009

Accommodation

1. Rooms
   Character and comfort

2. Sustainability
   Fabric and systems
   a. Photovoltaic panels
   b. Fresh air intake and outlets
   c. Extract air and heat exchange
   d. Fabric upgrades
      - air tightness
      - insulation
   e. Under/floor heating
   f. Ground-source heat boreholes

3. Facade
   Renewal of fabric

Compliance with Building, Fire and other Regulations

Complete new services installations

Refurbish and enhance facades and character of court and of rooms

Reduce energy use and carbon emissions in line with global targets
Trinity College

- Largest college in Cambridge
- 600 undergraduates
- 300 graduates
- 180 fellows

New Court:
- At the ‘heart’ of the College
- Level access from road and rest of college
- Accommodates majority of undergraduates as well as central tutorial offices

...and (**most importantly**)  
- Fellows’ Car Parking
Opportunities for provision of significantly sustainable student accommodation?
Option 1: Demolish and new build?
Option 2: sustainable energy source.
Option : Make New Court sustainable

“At present 45% of the UK’s energy is consumed heating air and water in existing buildings, and 85% of today’s buildings will form 70% of the building stock in 2050. If we are to get anywhere near meeting the CO2 emissions reduction targets (80% reduction in emissions relative to 1990 to be achieved by 2050), then all existing buildings will need a major retrofit to ensure the improved efficiency of energy use.”

Professor Michael Kelly. (ex Trinity College)
Designed by William Wilkins. 1821

'graeco-palladian'

'gothic'
Condition of existing exteriors
Condition of existing interiors
Condition of existing facilities
Proposed Strategy

Photovoltaics
A PV array mounted on the South-facing roof over Garret Hostel Lane will produce 14,000kWh electricity, saving 7,280 kg carbon, per year.

Air-Tightness
Penetrations around windows and through external and internal walls sealed, windows draught-stripped, new membranes to roof. To achieve draught-sealing to 3.0m3/h/m2@50Pa

Insulation
Improvement of the thermal performance of roof, ground floor and external walls, using vapour-permeable insulation to achieve maximum thermal performance without risk to the existing fabric.

Mechanical Ventilation with Heat Recovery
Supply fresh tempered air to student rooms and extract air from the gyps, showers and wcs, re-purposing the otherwise redundant chimney flues.

Underfloor heating with Ground Source Heat Pump
The improved thermal performance will allow an underfloor heating system to be fed by a ground source heat pump from a borehole array within the courtyard.
This installation will provide up to 97% of the annual heating load.
Proposed strategy: mechanical ventilation
Risks of irreversible damage to significance and fabric of a heritage asset

- Risk to character and significance
- Risk to fabric
Architectural character/significance: exterior
### Hierarchy/significance of interiors

<table>
<thead>
<tr>
<th>Room Category, Prevalence and Significance</th>
<th>Approach</th>
<th>Typical Room Appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grand Rooms</td>
<td>To preserve and repair the existing fabric and, only where necessary, to renew or adjust this to accommodate fabric upgrade. Some of these rooms have four external walls and an insulated lining would be added to each of these. To maintain the existing arrangement and details, this would be installed across the full extent of each wall, allowing a reinstatement/like-for-like replacement of the existing cornice, picture rail (where present) and skirting details. Joinery pieces and the fireplace are to be refurbished and re-installed.</td>
<td>![Image of Grand Room]</td>
</tr>
<tr>
<td>Rare</td>
<td>HIGH (Archway Rooms)</td>
<td>![Image of Archway Room]</td>
</tr>
<tr>
<td>(5 rooms)</td>
<td>N/A (New Seminar Room)</td>
<td>![Image of New Seminar Room]</td>
</tr>
<tr>
<td>Standard - formal</td>
<td>A lining would be added to accommodate insulation to external walls only. A similar lining element would accommodate the main service risers to internal walls - as shown on plan. Fitted furniture is envisaged as a distinct, subordinate, and removable timber intervention. This would be separate from the background wall/lining and its maximum height keyed to door surround height.</td>
<td>![Image of Standard Room]</td>
</tr>
<tr>
<td>1/10 MODERATE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard - normal / informal</td>
<td>An insulated lining would be added to accommodate insulation to external walls only. A similar lining element would accommodate the main service risers to internal walls - as shown on plan. Fitted furniture is envisaged as a distinct, subordinate, and removable timber intervention. This would be separate from the background wall/lining and its maximum height keyed to door surround height.</td>
<td>![Image of Normal Room]</td>
</tr>
<tr>
<td>1/4 MODERATE (LOW - generally slightly lower significance than 'Standard - formal')</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attic Rooms</td>
<td>The existing sloped ceiling is to be lined-out to provide the additional insulation depth required - the junction detail between sloped ceiling and adjacent walls is to be maintained. Fitted furniture is envisaged as a distinct, subordinate, and removable timber intervention separate from the background wall/lining.</td>
<td>![Image of Attic Room]</td>
</tr>
<tr>
<td>1/4 LOW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back rooms</td>
<td>An insulated lining is to be added only to the outside walls. A similar lining would accommodate the main service risers to internal walls - as shown on plan. Fitted furniture is envisaged as a distinct, subordinate, and removable timber intervention. This would be separate from the background wall/lining and it's maximum height keyed to door surround height.</td>
<td>![Image of Back Room]</td>
</tr>
<tr>
<td>1/3 LOW</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Design approach
Design approach:
Maquettes and model details
Design approach: Mock-Up Room
Design approach: model
Design approach:

Windows and shutters
Design approach: services distribution
Risks of irreversible damage to significance and fabric of a heritage asset

- Risk to character and significance
- Risk to fabric
Review of relevant research
Climate Change and the Historic Environment

May Cassar

Review of relevant research
Review of relevant precedents
Understanding existing fabric performance

• In-situ U-value measurements
• Hygrothermal gradient monitoring
• Thermal imaging
• Air pressure testing
• On site weather data collections
• Material property testing
Air-tightness and thermal imaging.

Air-tightness

Archimetrics/NBT figure: 11.0 m³/h/m²@50Pa. (7.1 ac/h@50Pa.)

Project proposal 3.0 m³/h/m²@50Pa.

For reference:
- Building Regs (new buildings): 10.0 m³/h/m²@50Pa.
- Passivhaus Standards: 1.5 m³/h/m²@50Pa. (0.6ac/h@50Pa.)

Apart from the windows, the front of Staircase II displays a relatively consistent temperature where the facade is not covered in vegetation (fig. 7), apart from the areas which would be expected to be cooler such as the parapet and other external decorations.

Ingress was in evidence around most extractors units.

To the rear of Staircase II, there is substantially more visible, with warmth from radiators commonly visible through the wall (illustrated in figs 8 and 9). Together with a paternoster route to the rear of the ground floor kitchen (fig 10). The radiators were visible in all the staircases adjoining the rear

A further difference between these two rooms should be noted. In room 6, the area above the picture rail on the exterior wall is colder than the area below (shown in fig 24). In room 4A, it would be noted on the same location (Fig. 23).

The third floor, all rooms had floor coverings. Figures 26 show ingress in Room 8 at floor level where the floor has carpet and underlay onto the floorboards. This compares to Room 7A, where there is a layer of hardboard above the boards (Fig. 27).
For 8 walls measured

Range of measured U-values (ISO 9869) = 0.59 – 0.78 W/m²K

Average measured U-value = 0.69 W/m²K

Standard U-value calculated for walls (ISO 6946) = 0.94 W/m²K

25% difference between measured/calculated U-values

Project proposal = 0.25 W/m²°C.

For comparison:

a. Building Regulations. (Limiting Value for new buildings): 0.35 W/m²°C.
b. Passivhaus Standards (target): 0.15 W/m²°C.
Interstitial Hygrothermal Gradient Monitoring - IHGM

![Graph showing hygrothermal section with temperature and dew point margins for each layer.

- Project: New Court
- Site: Trinity College, Cambridge CB2 1TQ
- Client: Trinity College
- Document authors: Cameron Scott & Caroline Rye
- ArchiMetrics Limited

The following graphs plot hygrothermal responses through wall sections for both the monitored walls as a series of monthly averages from January 2013 to December 2013. The Hygrothermal Sections provide plots of temperature and dewpoint (calculated as the temperature drop required to cause the measured %RH to condense) through the wall sections on a monthly basis.

**Control Wall - Hygrothermal Sections**

![Figure showing hygrothermal section with temperature and dew point margins for each layer.]

- **Archimetrics**
- **Hygrothermal section**

![Graph showing temperature and dew point margins for each layer.]

- **Layer 1**
  - Minimum: 7.4°C
  - Maximum: 17.0°C
  - Average: 12.3°C
- **Layer 2**
  - Minimum: 5.8°C
  - Maximum: 11.2°C
  - Average: 8.1°C
- **Layer 3**
  - Minimum: 4.9°C
  - Maximum: 7.2°C
  - Average: 6.0°C
- **Layer 4**
  - Minimum: 2.9°C
  - Maximum: 4.6°C
  - Average: 3.7°C
- **Average**
  - Minimum: 5.2°C
  - Maximum: 10.2°C
  - Average: 7.5°C

![Image of IHGM equipment setup on a wall.]
## Materials property testing

<table>
<thead>
<tr>
<th>Room ID</th>
<th>Sample Depth mm (from Int Face)</th>
<th>Material</th>
<th>Dry Density kg/m³</th>
<th>Material moisture content % by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>E3 Inner</td>
<td>1</td>
<td>70 brick (painted)</td>
<td>1370</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>232 mortar</td>
<td>1600</td>
<td>1.25%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>434 brick</td>
<td>1683</td>
<td>0.25%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>635 brick</td>
<td>1764</td>
<td>0.00%</td>
</tr>
<tr>
<td>E3 Outer</td>
<td>1</td>
<td>50 mortar</td>
<td>1300</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>230 brick</td>
<td>1638</td>
<td>1.53%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>380 brick</td>
<td>1556</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>540 brick</td>
<td>1412</td>
<td>0.00%</td>
</tr>
<tr>
<td>E6</td>
<td>1</td>
<td>82 Timber (batten)</td>
<td>700</td>
<td>7.4%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>260 mortar</td>
<td>1679</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>430 mortar</td>
<td>1571</td>
<td>4.55%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>665 limestone</td>
<td>1920</td>
<td>0.00%</td>
</tr>
<tr>
<td>E61</td>
<td>1</td>
<td>50 brick</td>
<td>1477</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>220 mortar</td>
<td>1400</td>
<td>1.43%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>387 brick (painted)</td>
<td>1520</td>
<td>2.63%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>550 brick</td>
<td>1600</td>
<td>0.00%</td>
</tr>
<tr>
<td>E66</td>
<td>1</td>
<td>50 mortar</td>
<td>2170</td>
<td>0.46%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>50 brick (painted)</td>
<td>1667</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>217 brick (painted)</td>
<td>2026</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>540 brick</td>
<td>1537</td>
<td>0.46%</td>
</tr>
<tr>
<td>E80</td>
<td>1</td>
<td>50 mortar</td>
<td>2305</td>
<td>1.14%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>382 brick (painted)</td>
<td>1600</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>310 mortar</td>
<td>1890</td>
<td>1.06%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>445 brick</td>
<td>1618</td>
<td>0.00%</td>
</tr>
<tr>
<td>E3</td>
<td>1</td>
<td>80 brick</td>
<td>1863</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>245 brick</td>
<td>1600</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>415 brick</td>
<td>1309</td>
<td>1.39%</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>575 mortar</td>
<td>1520</td>
<td>0.93%</td>
</tr>
</tbody>
</table>
Standard approaches to condensation analysis using the vapour diffusion or Glaser method (EN ISO 13788:2002 [2]) ignore the moisture capacitance of building materials. Most brick types have a high moisture capacity. If thick walls become saturated they can store large volumes of water all year round, leading to high vapour pressures inside the wall that drive moisture inwards for significant portions of the year.

Figures 2.1(a) and 2.1(b) compare a winter temperature and vapour pressure profile for a rendered façade with low rain exposure (east-facing) and an un-rendered façade with high rain exposure (south-facing). For the former case the winter vapour-pressure gradient shown by the light blue line acts from inside to out (right to left). For the latter case the vapour pressure gradient acts from the centre of the wall into the room due to the high moisture content stored in the wall.

Figure 2.1(a) A rendered façade with low rain exposure during typical winter conditions. Stored moisture in the wall is relatively low and the vapour pressure gradient (shown by the light blue line) acts from inside to out.

Figure 2.1(b) A un-rendered façade with high rain exposure during typical winter conditions. Stored moisture in the wall leads to peak vapour pressure in the centre of the wall, driving moisture inwards.
The risk is mould growth
Vapour Open v Vapour Closed

Fig. 4.1(a) Case 5B – 150mm Phenolic Foam insulation with vapour control layer. Temperature and humidity isopleth showing one year of hourly simulation data for conditions at the inner face of the original brickwork.

Fig. 4.1(b) Case 5C – 100mm Pavadentro breathable insulation. Temperature and humidity isopleth showing one year of hourly simulation data for conditions at the inner face of the original brickwork.
2050 climate predictions

Meteonorm - Typical year
- Extreme rainfall

Prometheus - Med emissions

Prometheus - High emissions
Proposed Strategy

**Photovoltaics**
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Improvement of the thermal performance of roof, ground floor and external walls, using vapour-permeable insulation to achieve maximum thermal performance without risk to the existing fabric.

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Supply fresh tempered air to student rooms and extract air from the gyps, showers and wcs, re-purposing the otherwise redundant chimney flues.

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The improved thermal performance will allow an underfloor heating system to be fed by a ground source heat pump from a borehole array within the courtyard. This installation will provide up to 97% of the annual heating load.
Project Team:
The importance of having the right expertise

- Track record and credibility of the team
- Credibility of the approach to the project
- Collaborative approach to delivering a pathfinder project
- Supportive College Client with long term goals
Project team: the Council’s perspective

- Trust and confidence in the College and its team
- Long engagement in the process
- Support for the council team in the form of funding for external, independent advice – so the innovative approaches could be objectively assessed
- A desire to encourage innovation particularly around carbon reduction and heritage assets
Managing the planning process

Three questions:

1. What are the heritage values of the existing building and what are their relative significances? Including continuity of building use for optimum purpose, collegiality etc.

2. To what extent will the proposals harm, or benefit, these values? What are the harms and to what values do they apply? What heritage benefits arise from the proposals (replacement of defective render, refurbishing and re-purposing of shutters etc)?

3. Are any harms outweighed or balanced by heritage or other benefits? What other benefits would arise from the proposals? Environmental sustainability, research and monitoring, knowledge transfer etc.
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   - What are the harms and to what values do they apply?
   - What heritage benefits arise from the proposals (replacement of defective render, refurbishing and re-purposing of shutters etc)?

3. Are any harms outweighed or balanced by heritage or other benefits?
   - What other benefits would arise from the proposals?
   - Environmental sustainability, research and monitoring, knowledge transfer etc.
Managing the planning process: Responses

“...such listed buildings, of which there are many in central Cambridge, must evolve if they are to remain in viable use and not become museums...”

Cambridge City Council Planning Committee
Managing the planning process: Responses

“...The Government is committed to give more power to councils and communities to make their own decisions on planning issues, and believes planning decisions should be made at the local level wherever possible. The Secretary of State has carefully considered the impact of the proposal, and the key policy issues which this case raises. In his opinion, the proposals do not: involve a conflict with national policies on important matters; or raise significant architectural and urban design issues...”

Secretary of State.
...Authenticity lies in whatever most truthfully reflects and embodies the values attached to the place. It can therefore relate to...function, as well as fabric...

...Retaining the authenticity of a place is not always achieved by retaining as much of the existing fabric as is technically possible....

...A desire to retain authenticity tends to suggest that any deliberate change to a significant place should be distinguishable, that is, its extent should be discernible through inspection... In repair and restoration, a subtle difference between new and existing..is more likely to retain the coherence of the whole than jarring contrast....
Keys to success: Client

• Client supports and sponsors the approach
• Time and funding to undertake the research and develop a compelling and evidenced narrative
• Investment in mock-ups, models and extensive testing along the way – window sample and student room mock ups
Keys to success: Council

- Financial support for the Council to obtain independent, objective expert advice
- Leadership and working with officers in persuading key stakeholders and committee to have confidence in the approach
- A desire to find a pathfinding solution that was win-win in terms of heritage issues, sustainability and collaborative working in a Cambridge context
Outcome

• Heating load reduced by 75%
• Reduction in carbon emissions 88%
• Ongoing monitoring shows no risk to the structure
• Preservation and enhancement of heritage character
• Upgrade of comfort and facilities
• POE shows rooms popular with students
Outcome: Monitoring the fabric

Control panel

Test panel
Outcome: 3-step reduction of carbon emissions

Existing carbon emissions.

60% reduction in demand
- insulate, double-glaze, reduce air leakage, improve use of daylight.

43% increase in system efficiency
- more efficient heating, lighting, ventilation and control systems.

55% reduction of the carbon in the energy supply
- pv generation, ground source heat pump.

Future carbon emissions

Outcome:

1. 60% reduction in demand
2. 43% increase in system efficiency
3. 55% reduction of the carbon in the energy supply
New Court Satisfaction Survey: All Occupants

Q15 Comparing with other available College rooms, would you recommend a fellow student to reside in a room in New Court?

Answered: 29   Skipped: 0

Bar Chart:
- Yes: 80%
- No: 20%