Four Years In | Four Years Out:

Two university buildings 2000-2008

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ABSTRACT: When a building is completed, it is usually seen as a final product. ***But*** *completion and handover mark only the start of a building's life. If viewed over thirty years, the initial construction budget accounts for just a fraction of the building's true costs. During its lifetime primary expenditure is actually likely to be upon personnel costs; work performance and salaries, staff retention and absenteeism. Whether a building is a success, therefore, must be seen in the context of its whole life and the comfort of its users. How can the results of lengthy and complex design processes ensure ongoing specific user comfort and performance,* ***and*** *sustain appropriate, elegant, 'future proof' buildings?*
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INTRODUCTION

In 2000 the University of Cambridge commissioned award-winning, London-based architectural practice Allies and Morrison to develop a Masterplan and design two new buildings for its arts and humanities campus on its Sidgwick site. In 2004, the two naturally ventilated buildings, The Institute of Criminology and The Faculty of English, were completed and occupied. Now, four years on, the client body, Estate Management and Building Service (EMBS) is reviewing the performance of both buildings in terms of user comfort, and comparing these findings against the original projections of the design team. The EMBS Post Occupancy Evaluation (POE) report:

- Compares actual energy performance against projected energy performance.
- Examines actual running costs against projected costs.
- Collates feedback from building users and facilities management.

This paper will critique the expected performance of these two buildings against actual performance. The approach taken by client and design team towards the life-time performance of the building will be reviewed, with hindsight. The post-occupancy feedback data will be drawn upon to assess the successes and failures of the projects in terms of performance, comfort and communication, four years after completion.

BACKGROUND

The design team was asked to respond to the university's rich historic context, while producing flexible, 'future proof' [1] energy efficient buildings. Internally, ease of control and good energy performance were given as a priority along with real user comfort: environmental, psychological and spatial. The design team needed to ensure that the users behaved in a way that made a success of the planned passive environmental strategy so, development of the designs involved extensive meetings with the buildings' users in an effort to understand how they used their current spaces, and what they wanted from their new buildings.

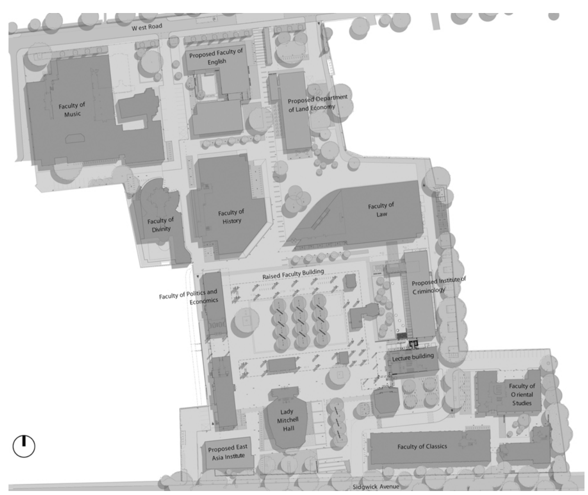

Figure 1: Allies and Morrison masterplan for the Sdigwick site 2000 (image: Allies and Morrison Architects)

The larger site was also studied in detail to establish a series of sheltered external spaces and clearly articulated 'front doors'. This masterplan study built on the positive aspects of the surrounding 1950's architecture of narrow floor plates and concrete frame construction, designed by Sir Hugh Casson (Casson Conder & Partners) (Fig. 1).

Figure 2: The Institute of Criminology from west court (image: Lovell)

Figure 3: The Faculty of English from east/ adjacent main entry (image: Lovell)

Both of the new buildings are naturally ventilated with operable windows playing a key role in environmental control. The final design of the windows, however, also had to reflect both the aspirations of the user and the aesthetic and technical objectives of the designers. The result was two very different façade fabrication systems, each specific to their building, users and immediate site.

In designing the façades the architects had to resolve a number of key issues. Together with providing enclosure they needed to incorporate operable windows, meet high performance insulation values and air leakage criteria as well as reduce excessive heat gain. The articulation of the elevations needed to reflect the internal grid while reconciling the broader contextual relationships. Both buildings have the same internal office areas and floor to ceiling heights (Fig. 4). But because each building deals with natural light and air flow in specific ways, the user groups each perceive and experience their space in quite different manners.

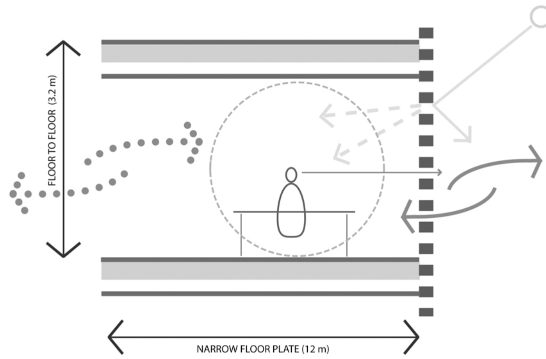

Figure 4: Diagram to show office space relationship to building envelope, environment and structure (image: Lovell)

Criminology is a relatively new discipline and a branch of the Law Faculty at Cambridge. Largely based on post-graduate field research, the department wanted to establish its own distinct identity within this purpose-made building. Although most of their work requires strict confidentiality and involves interaction with police and government security, researchers wanted the building, and the workspaces within it, to be light and open. For them, windows were a symbol of progress, of modern, open thinking and of transparency. In response, the design maximizes areas of clear glazing, which were restricted only by environmental requirements to avoid excessive heat gain in summer and to minimize heat loss in winter. The offices are heated by a perimeter trench heater within the depth of the raised floor under each fixed window, so that the glazing rises from finished floor level visually unobstructed (Fig. 2).

In contrast, the priority for members of the English Faculty was to be able to teach their largely undergraduate student body in small groups around a table. Their building is organized as a series of individual rooms arranged along corridors with the façade articulated by 'punched' openings - the window frames the world beyond for each faculty member and associated student group (Fig. 3). The offices in this building are heated by more tangible, wall-mounted panel radiators placed below each window, against which one might sit to read a book.

Whilst recognising the need for identity to be given to individual faculty buildings the Client (EMBS) was mindful of commissioning buildings that would serve future needs – even those not yet apparent. The brief for both English and Criminology was for the provision of the maximum 'flexible' space possible – more in line with commercial office 'shell and core' development. Both buildings, while identifying specific office spaces, allow for partitions to be removed or added on a 1500mm module. The relationship between window for light and ventilation, structure, heating systems, potential internal planning and control are inextricably linked (Fig.4).

ENERGY PERFORMANCE

As part of the integrated design and environmental strategy a "heavyweight concrete frame construction was implemented in both buildings to naturally modulate the temperature of internal spaces, absorbing excess heat during the daytime and releasing it at night through large areas of exposed thermal mass." [2] The high performance building envelopes (outlined earlier) were designed to reduce thermal loss above and beyond the requirements of building code and, with effective shading, allow larger glazed areas resulting in good levels of day-lighting throughout.

The outline energy performance criteria issued to the design team by the Client were based on a number of documents, specifically:

- Estate Management and Building Service, 1998. *Energy Services Design Guide and Consultants Brief for University Buildings*. University of Cambridge.
- Building Research Establishment Environmental Assessment Method (BREEAM), 2000. *Very Good* rating. [3]
- Great Britain Office of the Deputy Prime Minister, 2006. *Conservation of Fuel and Power Approved Document Part L2A*. London: NBS. [4]
- Great Britain Energy Efficiency Best Practice Programme, 2000. *Energy Consumption Guide 19: Energy Use in Offices*. Watford: BRECSU. (ECON 19) [5]

The EMBS Energy Services Design Guide outlines the following environmental design criteria: "Winter internal conditions to be 19ºC 'against' external ambient temperature of -3 ºC" i.e. the building fabric, equipment and systems should be designed to achieve and maintain 19ºC against this given external temperature. "Summer internal conditions for a naturally ventilated building are not to exceed +3 ºC above the external ambient temperature".

The ECON 19 document gives benchmark representative values for energy consumption, energy cost and Carbon Dioxide emissions for common building types, against which a building's actual performance can be compared (Fig. 5). The benchmarks offer both 'typical' [6] energy consumption patterns and 'good practice' [7] examples, and recommendation is made to improve upon 'good practice' benchmarks. This comparison is based on annual energy use per square metre of floor area and measured in kWh/m².

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	Good practice	Typical	Good practice	Typical	Good practice	Typical	Good practice	Typical
Heating and hot water – gas or oil	79	151	79	151	97	178	107	201
Cooling	0	0	1	2	14	31	21	41
Fans, pumps, controls	2	6	4	8	30	60	36	67
Humidification (where fitted)	0	0	0	0	8	18	12	23
Lighting	14	23	22	38	27	54	29	60
Office equipment	12	18	20	27	23	31	23	32
Catering, gas	0	0	0	0	0	0	7	9
Catering, electricity	2	3	3	5	5	6	13	15
Other electricity	3	4	4	5	7	8	13	15
Computer room (where appropriate)	0	0	0	0	14	18	87	105
Total gas or oil	79	151	79	151	97	178	114	210
Total electricity	33	54	54	85	128	226	234	358

Figure 5: Annual delivered energy consumption (EUI) of good practice and typical office types (kWh/m² treated floor area). Source: Energy Consumption Guide 19: Energy use in Offices pg. 20 table B – refer to average between building types 1 & 2 [9]

In the Design Team Stage D Report [8], the Environmental Engineers, Buro Happold, identified that "by keeping in the recommended comfort bands the internal temperature (of the buildings) should be allowed to swing with the external temperature over a 24 hour cycle by using the thermal mass of the building. This will ensure that the active systems are kept to a minimum". The report also stated that "maximum temperatures for offices and the libraries spaces shall not exceed 25ºC for more than 1% of the year." This statement was studied extensively using building simulation software (Fig. 6).

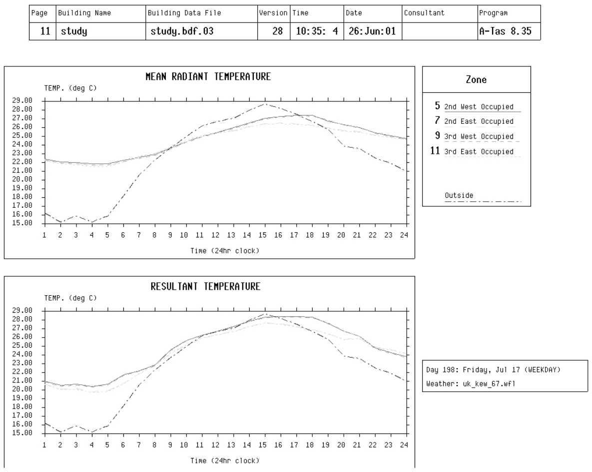

Figure 6: The Institute of Criminology TAS sample study to show internal expected temperatures (image: Buro Happold)

Actual energy data output from the last two years has shown that both buildings are consistently on target with, or close to (within 6 units), the performance indicators [9] (Fig. 7) for electricity consumption (measured in kWh/m^2). The Faculty of English records show that gas consumption for the building is 50% under the performance indicator of 150 kWh/m^2 and both buildings use 50% less water than target consumption levels (m^3/ m^2). Ongoing annual monitoring will continue to record building performance.

Space type	% of average higher education campus	Electrical target (kWh/year)	Fossil target (kWh/year)
Teaching	25	22	151
Research	20	105	150
Lecture hall	5	108	412
Office	30	36	95
Library	10	50	150
Catering	2.5	650	1100
Recreational	7.5	150	360
Total academic	100 of academic (75% of total)	75	185
Residential	100 of residential (25% of total)	85	240

Figure 7: Annual target consumption figures (typical higher education campus) for representative space types. Source: Energy Consumption Guide 54: Energy Efficiency in Further & Higher Education. pg. 7 table 2. [9]

COMFORT & CONTROL

Computer based Building Management Systems (BMS) were specified to control and monitor the internal environments including heating, artificial lighting and, where applicable, air conditioning [10]. Local control for radiators and trench heaters are 'capped' based on overall design temperature guidelines and overhead lighting is sensor controlled. The BMS systems are monitored and controlled from an off-site central university facility where data can be collected and assessed.

Post Occupancy Evaluation (POE) in the form of building user feedback has shown that there have been no negative reports regarding solar heat gain or glare for either building, both of which were a concern for the design team with the predominantly east/ west facing facades (Fig. 8). The buildings were designed to enable individual control of blinds and operable windows and also benefit from very high performance envelope specification.

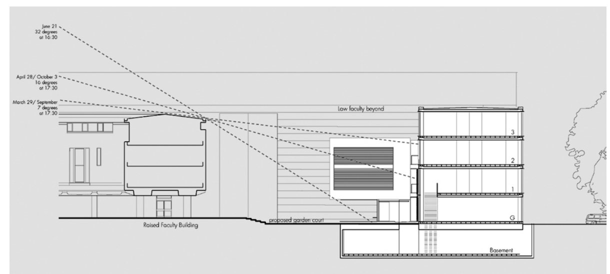

Figure 8: The Institute of Criminology section showing extent of solar exposure on west facade (image: Allies and Morrison Architects)

However, Criminology has had a number of issues arising related to space heating. On analysis these seem to be as a result of the following:

- Criminology has subdivided office space on the first, second and third floors to a far greater extent than expected at the briefing stage [11]. In some cases these additional sub-divisions have caused a sensor located in one room to also control an adjacent room in which the users may have conflicting comfort thresholds.
- There have been post-commissioning technical problems with the variable speed pumps that drive the hot water in the heating system, this has led to operational problems.
- The thermostatic radiator value (TRV) control and sensors on trench heaters are actually located in the trench itself therefore they may be automatically switching off too soon, before the rest of the room has reached thermostat temperature level. [12]

The Faculty of English have not moved any partitions and have panel radiators (discussed earlier) with easily accessible controls below each window. No concerns or comfort issues have been raised.

METERING

Existing buildings on the Sidgwick site built prior to 2000 were either unmetered or insufficiently metered, so there was no way to accurately calculate building energy and utility performance. With changes in budgeting and responsibilities of the collective users within each building; gas, electricity and water metering were installed for both English and Criminology. In 2008, as a result of Government legislation [13], industry guidelines (CIBSE) and university policy, metering strategies were reviewed by EMBS and a more complex system of sub-metering is now proposed for all new buildings (Fig. 9).

Currently meter data for electricity use is lumped together as one figure with no direct way to identify electricity use for lighting versus cooling versus 'plug-in' (computers etc.). Sub-meter will break down 'building' loads from 'process' loads (plug-in computers etc.) and allow identification of increased peak loads and energy usage monitoring over time, throughout the day and year.

LOADS

The comparison of energy use and loads between existing buildings on the Sidgwick site is not practical. The buildings are an eclectic group in scale, construction and systems. They range from a Victorian villa to a series of naturally ventilated (but poorly constructed, in terms of performance) post war buildings, to James Sterling's History Faculty and Norman Foster's Law Faculty (fully air-conditioned).

What is apparent though, is that with the completion of the Faculty of English and the Institute of Criminology there has been a return to narrow floor plates utilising daylight and natural ventilation and more thermally massive structures – combined with far superior building technology and materials application e.g. low-e double glazed units, sufficient shading, better U-Value performance etc.

As the buildings become more effectively timetabled throughout the calendar year and if research awards expand, the I.T equipment loads will increase in turn having an impact on heat gains in the buildings. It is not possible to anticipate this potential increase, but worth noting when considering the potential effect it may have on building performance.

COMMUNICATION: DESIGNING/ OPERATING

The design of an institutional building has to go a through rigid, and often complex, sign-off processes at each stage of design development. A key aspect of communication was to present material at an appropriate format and level of detail throughout this process. However generally there is a gap between design process and building management communication.

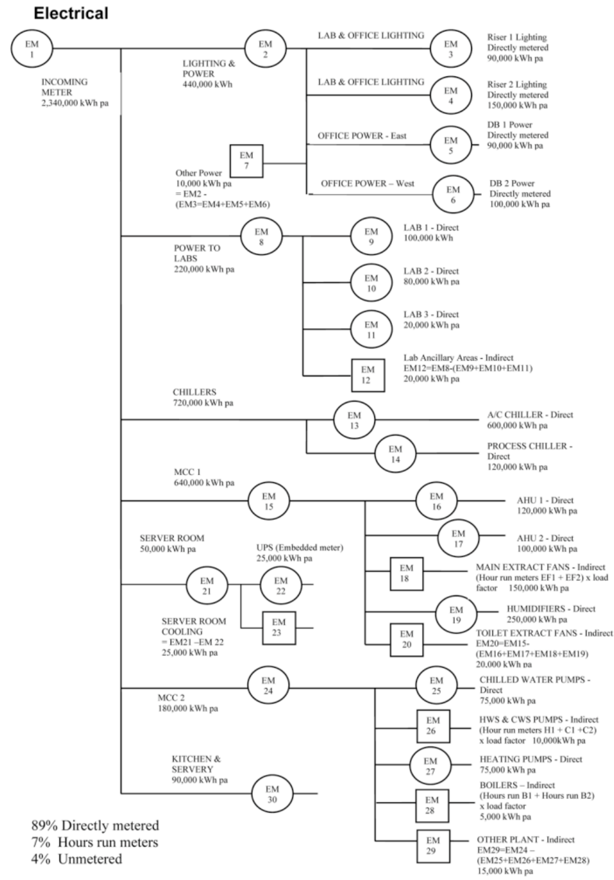

Figure 9: 'Electrical' extract from EMBS draft design Guidance for Sub-Metering compiled with reference to The Carbon Trust, 'Good Practice Guide 348: Building Log Books and CIBSE guides' TM31 & TM22 (image: EMBS)

Communication, together with clarity of process, was vital in terms of enabling successful design progress, systems integration, and maintenance and user education. Where this stumbled in the design process, or where gaps occurred, is invariably where problems have arisen with the day to day use of the buildings. Likewise where the right parties were brought together at key moments, resolution was most comprehensive.

In theory an institutional facility has perhaps the greatest potential to achieve maximum energy performance through specification, management, user education and long term owner occupation. However this requires the simplest (often most complex to design!) strategy in terms of clarity – documents must not be cumbersome or buried in service areas of the building. Key information such as the 'simple energy do's and don'ts' listed in the building log books for these buildings could be issued to building users annually/seasonally (via email) together with clear diagrams (desktop 'pop-ups'?) of how and when to open and close windows to enable the optimum performance of the natural ventilation strategy.

CONCLUSION

The need for the Masterplan for the Sidgwick site grew out of balancing university space needs with quality of built environment and the need for clearly defined orientation and way-finding for users – at the scale of the building these needs are not so different. Users, Clients and Institutions need quality *and* flexibility; day to day operation must be integral and intuitive to the spatial configuration, as with the Faculty of English heating strategy.

Over the life of a building responsibility must be shared between the initial briefing, the design team, the contractors, the commissioning team, and the client and building users. Successful and well integrated passive design requires not only a proactive client and design team but also engaged building users given succinct and clear instructions to simple operating methods that then are supported by sophisticated building management systems now commonly specified for buildings of this type.

In formal terms, detailed attention to the relationship between building grids, structural and environmental strategies, site and concept approach, right through to manufacture and assembly of materials, all play a part in distilling complex issues of modern construction into "models of clarity, tact and architectural intelligence" [14]. However, user behaviours and their influence over the design and day to day operation are, and continue to be, an active determinant in the energy performance of buildings, pre and post occupation.

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client:
Estate Management and Building Service University of Cambridge
design team:
architect: Allies and Morrison Architects
structural engineer: WhitbyBird Engineers
environmental engineer: Buro Happold
quantity surveyor: Atkins Faithful & Gould
landscape architect: J & L Gibbons
key dates:
2000 masterplan commissioned
2002 start on site
2004 building occupation
2008 post occupancy evaluation

REFERENCES

1. Future proof: To allow for flexibility in the building design and realisation, anticipating future building program uses and user needs and in doing so, avoiding obsolescence.
2. Excerpt from Buro Happold Criminology Building Log Book dated 10 March 2006.
3. BREEAM is the UK equivalent of LEED assessment in USA. Note: A formal BREEAM submission was not made for either project but the Design Team completed an informal full assessment based on the 'Very Good' rating.
4. Building Regulation Document Part L2A came into effect in 2002, English and Criminology were not required to meet this code since the Building Regulation submission was made before this date, however the Client and Design Team chose to meet this more stringent code in the interests of building performance and energy conservation.
5. Since these buildings were completed EMBS refers to a more current kWh/m² multiplier factor than the one in outlined in ECON 19 to give carbon emissions in tonnes of CO^2. The Guidelines to the Department for Environment, Food and Rural Affairs (DEFRA - UK) Greenhouse Gas Conversion Factors for Company Reporting (June 2008) are updated annually relating more specifically to energy data.
6. Consistent with median values of data collected in mid-1990's for Department of the Environment, Transport and Regions (DETR) from a broad range of occupied office buildings (in the UK).
7. Examples in which significantly lower energy consumption has been achieved using widely available and well proven energy-efficient features and management practices, These examples fall in the lower quartile of the data collected.
8. From the Royal Institute of British Architects Works Stages, Stage D: Design Development.
9. To calculate 'performance indicator' against which EMBS measure actual energy/ utilities performance and in order to take in to account the specific patterns, occupancy and scheduling of the higher education sector they now refer to Great Britain Energy Efficiency Best Practice Programme, 1997. *Energy Consumption Guide 54: Energy Efficiency in Further & Higher Education*. Watford: BRECSU, rather than previously referred to Great Britain Energy Efficiency Best Practice Programme, 2000. *Energy Consumption Guide 19: Energy use in Offices*. Watford: BRECSU.
10. Larger seminar and lecture spaces at Criminology and a drama studio in English occupy the basement areas and are conditioned primarily with displacement air systems.
11. This is related to research confidentially requirements and somewhat to a change in the internal politics of the Faculty.
12. BMS boiler flow system is controlled by outside air temperature, the TRV controls flow & the BMS controls temperature: based on external ambient temperature – capped off site at 19ºC.
13. Great Britain Office of the Deputy Prime Minister, 2006. *Conservation of Fuel and Power Approved Document L2A*. London: NBS.
14. Stamp, Gavin. 2004. Taming the Zoo. *Building Design,* 8 Oct. p. 12-17