THE PROBE PROJECT: TECHNICAL LESSONS FROM PROBE 2

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The Probe series of published post-occupancy surveys in CIBSE's Journal *Building Services* has reviewed building services, energy performance, management, and occupant satisfaction in buildings of technical interest. Findings from Probe 1 were reported at the National Conference in 1997. Since then Probe 2 has added eight new buildings, which are compared with the original findings. The good news is better occupant satisfaction and energy efficiency, particularly in the naturally ventilated and mixed mode buildings. The bad news is the persistence of chronic problems, e.g. poor functionality and user interfaces for controls; over-complicated systems which occupants and management find difficult to use; and widespread energy wastage. Air infiltration, anecdotally a problem in Probe 1, was also investigated by pressure tests in Probe 2. It was high in most of the buildings, with two notable exceptions.

The new results confirm the need for better briefing; clearer communication; closer examination of the demands buildings will make on their occupants and management; more robust and sometimes simpler solutions with downside risks considered and minimised; intrinsically efficient systems with more usable controls; better industry support to occupiers after handover; and better feedback with cradle-to-grave benchmarking. These will help the industry to improve current practice, tackle recurrent problems, respond more effectively to the Egan and Kyoto agendas, understand and communicate with its customers, and lead to better occupant satisfaction, productivity and all-round performance.

INTRODUCTION

Over the past four years, in a unique collaboration between a publisher, researchers and government, post-occupancy surveys have been carried out on sixteen recently-completed buildings, and the results published in the CIBSE's Journal Building Services (BSJ). The PROBE (Post-Occupancy Review of Buildings and their Engineering) exercise has contributed to the wider agenda of improving the performance of the building industry and its products through monitoring, benchmarking and continuous improvement.

BSJ's editor routinely selects buildings for review that are likely to be of particular interest to services engineers. Selected ones were revisited by the Probe team, typically 2-3 years after they were first occupied. Many included relatively novel design and technical features, e.g. superinsulation, displacement ventilation, chilled beams, ice storage, advanced control systems, automated natural ventilation, and mixed mode designs.

Findings from the first eight buildings were outlined in a paper to the 1997 CIBSE Annual Conference [1]. Another eight buildings have now been surveyed, representing a wider range of building types and including mixed-mode (MM) systems, in which natural and mechanical ventilation and cooling systems operate together. The paper is a update from Probe 2, outlining the similarities, areas of success and difficulty, and what the industry, its customers and collaborators might do to achieve better all-round performance.

The Probe 1 survey process has been described elsewhere [2]. Probe 2 added surveys of water consumption, pressure tests for air leakage by BRE and BSRIA, and began to pilot the spreadsheet version of the Energy Assessment Method developed by Target Energy Services and recently published as CIBSE's TM 22 [3].

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TABLE 1 THE BUILDINGS STUDIED, WITH DATE OF PUBLICATION

PROBE 1 *(TFA = treated floor area)*

NAME	*ABBREVIATION*	*FUNCTION*	*SERVICING*	*TFA m^2*	*DATE*
Tanfield House	*TAN*	Very deep plan administrative centre	AC	19800	Sep 95
1 Aldermanbury Square	*ALD*	Narrow plan speculative office	AC	7000	Dec 95
Cheltenham & Gloucester Bldg Society	*C&G*	Deep plan headquarters	AC	17400	Feb 96
de Montfort University, Queens Building	*DMQ*	University engineering department	ANV	8400	Apr 96
Cable & Wireless Training College	*C&W*	Residential training centre	ANV (part)	11400	Jun 96
Woodhouse Medical Centre	*WMC*	Doctors' and Dentists' surgeries	NV	640	Aug 96
HFS Gardner House	*HFS*	Headquarters office	AC	3800	Oct 96
Anglia Polytechnic University	*APU*	Learning Resource Centre	ANV	5650	Dec 96
PROBE 2					
John Cabot City Technology College	*Cabot*	Secondary School	NV/ANV	8800	Oct 97
Rotherham Magistrates Courts	*RMC*	Courtrooms and offices	MM	4350	Dec-97
Charities Aid Foundation	*CAF*	Principal office (pre-let)	MM	3700	Feb-98
Elizabeth Fry Building	*FRY*	University teaching	MM	3130	Apr-98
Marston Books Office	*MBO*	Principal office (pre-let)	NV/(ANV)	960	Aug-98
Marston Books Warehouse	*MBW*	Warehouse (pre-let)	NV	5030	Aug-98
Co-operative Retail Services	*CRS*	Deep plan head office	AC/(MM)	17300	Oct-98
The Portland Building	*POR*	University teaching	ANV/MM	6000	Jan-99

HVAC: AC=Air Conditioned; NV=Naturally ventilated; ANV=Advanced Natural ventilation;
MM=Mixed Mode (HVAC type bracketed if it is a minor part of the building or has a minor influence)

Table 1 lists the buildings studied. Probe 1 included:

- Four predominantly air-conditioned (AC) offices for financial services companies, representative of completions in the early 1990s.

- Three educational buildings with "advanced" natural ventilation (ANV), often designed using computer or salt bath models and incorporating stack effect and motorised openings. At C&W, this applied to the classrooms only: its residential and sports facilities were more conventional.

- The naturally-ventilated (NV) Woodhouse Medical Centre, with doctors' and dentists' surgeries, had some mixed mode (MM) characteristics with its heat recovery background mechanical ventilation (but this was no longer in use) and added comfort cooling in two rooms.

Probe 2 added:

- Another deep plan head office, CRS, an atrium design with exposed ceilings, uplighting, chilled beams and constant-volume displacement ventilation. Like Tanfield it had MM aspirations with openable windows, but - as at TAN *(Tanfield House - for abbreviations see the italics in Table 1)* - management discouraged their operation and it essentially operated as an AC building.

- Marston Books, a NV office of low-energy design incorporating an innovative window system and attached to a much larger NV warehouse. This was surveyed as two separate buildings.

- A predominantly NV school, Cabot, including some ANV, with motorised louvres to ventilate the hall and street, plus passive ventilation shafts from bulkhead ducts some ground floor rooms.

- Probe 2 also introduced three MM buildings (four with POR - see below). The first three had "complementary" natural and mechanical ventilation and cooling systems operating concurrently in their main areas (for MM definitions see reference [4]). RMC had displacement-ventilated courtrooms and public areas with additional NV and ANV, plus NV offices with added comfort cooling. CAF had floor supply, exposed ceilings and openable windows. Elizabeth Fry was the most innovative for the UK, a thermally massive building which used Termodeck ventilated floorslabs and was sufficiently well insulated to dispense with perimeter heating. Its lecture rooms also used Termodeck with an air quality-controlled variable volume system.

- The Portland Building, while predominantly NV, took a catholic approach to servicing and so is classified as zoned mixed-mode. Its atrium and library have ANV, the main lecture room is AC, other large lecture and seminar rooms are naturally-ventilated and comfort-cooled; and offices with openable windows onto the atrium also have mechanical supply ventilation.

ENERGY AND TECHNICAL PERFORMANCE UPDATE

The energy performance of the Probe 1 buildings and related issues were discussed in reference [2]. Here we highlight similarities and differences in Probe 2. Figure 1 shows annual CO_2 emissions by end use for the whole dataset, calculated from the delivered gas and electricity consumption in the table, using factors of 0.20 kg/kWh for gas and 0.52 for electricity. It also includes benchmarks from ECON 19 [5] for Good Practice (GP) and Typical (TYP) offices: Type 1 (naturally-ventilated, cellular), Type 2 (naturally-ventilated, open plan), and Type 4 (prestige air-conditioned: head office type with computer suite and restaurant). The building data are sorted by increasing emissions for building services, i.e: up to the right hand end of the white bar for lighting. Further to the right is energy consumption by occupier's equipment (e.g: office equipment, restaurants, and AC computer and communications rooms). Probe 2 adds the highest energy user (CRS) to the dataset, four buildings at the low end (though none quite as low as Probe 1's WMC), and three in the middle.

Probe 2 energy analysis was often frustrated by poor gas bill data, often based almost entirely on estimated readings: an unfortunate consequence of the liberalisation of the UK fuel markets. *Should the Regulator consider asking for more precise fuel billing, together with routine annual energy reporting to customers?*

The air-conditioned office in Probe 2

CRS's high consumption fits the pattern of the AC head offices in Probe 1, but with the extra coming more from the occupier's equipment than the normal building services. Indeed, emissions from CRS's heating, hot water, cooling, fans and pumps were smaller than any other Probe AC office and similar to ECON 19 Type 4 Good Practice levels. This to some extent justified the efficiency of its displacement ventilation and heat recovery, but the building was also prone to overheating (see below), and would have benefited from longer AC running hours, which would have increased consumption. Sadly, other end uses were high:

- The electrode boiler humidifiers ran more than they needed to, as in most AC Probe 1 offices. *More guidance is required on the need for and efficient specification and use of humidifiers.*

- Lighting energy use was high, owing to uplighting with a high installed power density; metal halide lamps with slow response times; and automatic lighting controls which the occupiers did not entirely understand, so most lights were on all day and many unnecessarily at night. *It is still not easy to specify good lighting controls: careful attention is required to ensure functionality.*

- Many PCs were left on overnight, often with power-saving facilities disabled. *This is a worrying trend as people use PCs and networks more; and a habit which is sometimes encouraged by IT staff. Occasionally there are good reasons, but often it is the path of least resistance.*

- The large 1300 m^2 computer suite was relatively lightly occupied, but was nevertheless a high energy user. Its AC system is included in the figures. As usual, neither the suite nor its AC was submetered. *To improve building energy performance, these areas need AC which works very efficiently over a wide range of loads, plus effective metering and energy management,*

Overnight use of PCs and lighting, together with heat gains into the floor void, both from the ballasts installed there and from transmission of stored radiation and convection gains into the soffit also led to overheating at CRS generally, and preheated the incoming displacement air by an unexpectedly large amount.

The mixed-mode buildings

The MM buildings in Probe 2 had encouragingly lower energy consumption. Occupant satisfaction was also very high in two of them (RMC and FRY). CAF makes an interesting comparison with Probe 1's AC HFS. Although both were very similar in size, usage and equipment levels, the MM CAF's emissions were less than half the AC HFS's; and both had considerable scope for reductions. HFS did suffer from extended HVAC operating hours to overcome an air infiltration problem, but CAF had leakage problems too. However, the unusually comfortable and well-managed Best Practice Cased Study of One Bridewell Street [6, 7] still remains the benchmark for AC offices. *AC buildings must not be demonised, but they do need making much more energy efficient: good examples are still far too rare.*

The MM Elizabeth Fry Building makes a breakthrough, with lower emissions than Probe's low-energy NV and ANV academic buildings, and exceptionally good comfort and occupant satisfaction in its offices. Its high insulation and use of thermal mass, heat recovery and night ventilation for cooling gave exceptionally low heating energy consumption (but only after considerable post-occupancy attention to control and management) and eliminated refrigeration altogether. However, it is a relatively straightforward building, and not directly comparable with open-planned AC head offices with intensive use and comprehensive support services. FRY nevertheless sets a benchmark for future buildings; and lighting and fan energy use are both capable of further improvement: the designers were aiming to halve them next time. *The mixed mode approach looks promising in terms of delivering both energy efficiency and occupant satisfaction.* See also references [7 to 9].

The Portland building also illustrates how a zoned ANV/MM university teaching building can have a similar energy profile to a NV or ANV one. However, both here and at Cabot, Probe found that the comfort cooling systems in their lecture, seminar and meeting rooms were running constantly year-round, without even effective arrangements for time switching. It appeared that design emphasis on the passive elements of these buildings might have caused the active systems in relatively small areas to be taken too much for granted. Many Probe buildings also had electric water heating, but none of them had time switches (except RMC which had retrofitted them) or flow regulation (except Cabot with self-closing taps). *In design and specification, it is important to take account of everything, and not overlook simple opportunities for improving energy performance. Relatively small things can also have a disproportionate influence in an otherwise energy-efficient building.*

The need to count everything and review priorities is particularly important when it comes to air (and to a lesser extent water) transport systems. Some low-energy buildings have expensive (to build and sometimes to maintain) ventilation towers, to avoid a small fan. In other buildings whose designers have aimed for energy efficiency (and sometimes even in different parts of the same one), the significance of fan energy (in the UK with a high CO_2 overhead of electricity production), sometimes appears to have been overlooked. An example is the MM Rotherham Magistrates' Courts in which fan energy consumption was estimated to be 39 kWh/m^2, causing some 20 kg/m^2 of CO_2 emissions. This building had initially been designed to extract passive solar gains from the sunspaces via a plate heat exchanger to preheat the courtrooms. Dynamic simulation indicated that this would save 5 kWh/m^2 per year of gas (equivalent to 1 kg/m^2 of carbon dioxide). So a 5% reduction in fan energy consumption would have saved as much as the entire solar contribution, while in fact the design of the system had to recover the heat had increased ventilation rates fan power. Admittedly, the system had had to be simplified to achieve tender cost reductions, but *prevention can be better than cure!*

The naturally-ventilated buildings

The lowest energy user in Probe 2 was Marston Books Warehouse, in spite of its two-shift operation. However, this consumption level is not unusual for a new warehouse, and MBW is less intensively serviced - with lower illuminance and heating standards - than the other buildings. Unusually for a warehouse, the building was reasonably airtight (8.9 m^3/hour at 50 Pa per m^2 of envelope area), even though the designers had taken no special measures to ensure this. Unfortunately, the connected office building was less fortunate, with three times the infiltration rate, and major leakage at the junction between its brick walls and the lightweight cladding of its roof; and also where it connected to the lightweight upper level cladding of the warehouse. *In British buildings, these junctions are notorious for air leakage; and airtightness generally requires much more thorough attention in design, specification and on site.*

High air leakage occurred in all Probe 2 buildings except MBW and particularly FRY - the only building to have taken the problem really seriously, in detailing, specification, site quality control, and its own pressure test. Even here, the Probe re-test found major leakage around the rooflights and entrance doors, and a 20% deterioration overall. An important point for building services engineers is the leakage that can occur through engineered ventilation openings: this was most extreme through the motorised and manually-controlled dampers used in the street and the main halls at Cabot, and the occupier finally had to block them up (in the main hall too, in order to reduce noise breakout). Even then, measured leakage was similar to MBO. *Note that openings engineered for summertime heat removal also have to function in winter. Dampers do not usually close tight enough.* Sadly, nor did MBO's motorised windows, though windows usually shut much tighter than dampers.

Some NV buildings make good use of daylight and need little electric lighting. Cabot was a case in point, confirming its design strategy. However, school lighting consumption is generally modest in relation to offices, owing to better daylight, lower artificial illuminance standards, shorter occupancy hours, and teacher control. Sadly, although the classroom light switches were arranged to suit daylight availability, when teachers needed the lighting, they usually switched everything on at once.

MBO was designed for good natural lighting, but in practice its lighting energy consumption was only just below the ECON 19 typical level. This was largely a consequence of difficulties with the automatic daylight-linked and occupancy-sensed controls which were too coarsely zoned, with poor user interfaces. Manual controls might well have worked much better in this small, friendly office which had good management and well-motivated staff. Another issue which arose both here and at Cabot were the high maintenance and support costs for lighting controls and BMSs, particularly in small buildings and with tight educational budgets. These could readily exceed the value of any likely energy savings, while poorly-implemented and supported systems could actually raise energy consumption. *Design for simplicity, usability & manageability remain the watchwords.*

IMPROVING THE PROCESS See also reference [10]

Here we re-visit the conclusions from Probe 1 [1], in relation to the various stages of a project.

For briefing

Probe 1 saw the need for more strategic briefing, greater clarity of discussion, and assessment of options and solutions for usability, robustness and manageability. In Probe 2 it was still clear that many buildings and systems demanded more than their occupiers had been prepared to give. *It is important that people "own" the right problems: clients (and designers) may not appreciate the management overheads of systems proposed.*

Figure 2 can assist discussions. Buildings can be more or less demanding (usually through technological complexity), and have higher or lower management input, leading to four main types:

Type A — A complex building with well-resourced management. This suits organisations for which this enhances their corporate image; and who regard the extra management as investment in their staff satisfaction and productivity and improving their business, as at Tanfield. These are however rare.

Type B — This suits most occupiers better: simpler, less demanding buildings which don't get in the way. This is easiest to do at a more domestic scale - as at WMC, MBO and the offices at Elizabeth Fry - but it also has wider lessons in examining briefing requirements and design responses.

Type C — This is the hole that many buildings fall into, in Probe particularly the educational ANV buildings, where no extra resources had been allocated for management and fine tuning of innovative systems. The administration - if not the maintenance staff - appeared to have felt that new buildings should be able to look after themselves. Even the now-excellent Elizabeth Fry did not perform optimally until independent monitoring had clearly identified a need for attention; and the University Estates Department and the design team then rose to the occasion.

Type D — This is rare, exemplified perhaps by people in houses or offices they have designed themselves, where high levels of insight and commitment can sometimes make systems which are thoughtful, imaginative but not necessarily user-friendly perform extremely well - but only in the hands of their originators or similar enthusiasts.

For design

Probe 1 saw the need for regular review of designs against strategic objectives for the building and the needs of occupants, or possible occupants. It encouraged designers to seek simpler, more robust, intrinsically efficient solutions; to balance any predicted gains in physical conditions against possible losses in occupant tolerance; and to seek to improve usability and "forgiveness". *Keep things simple and do them well. Less can be more!*

Probe 2 reinforces this agenda. It has found the highest forgiveness in the simpler NV buildings such as Marston Books and Woodhouse Medical Centre; in good MM buildings which can provide the best of both worlds; and in Type A AC buildings with competent, efficient and responsive management. Conversely, automatic controls cause major irritation if they swing into action inappropriately and occupants are helpless. Examples included capricious and intrusive lighting control systems; and ANV windows which opened in response to temperature sensors, but could also sometimes admit noise, draughts, fumes and insects - of which the BMS was inevitably not aware - so causing aggravation. *Provide local user over-rides where you can.*

Probe 2 has also shown how easily designs can lose touch with the individual components of energy consumption. Cradle-to-grave benchmarking using a common language in briefing, design, regulation, specification, acceptance and into occupancy can help to resolve this [11], for example making clear the trade-offs which are occurring in seeking to change to a less expensive but less energy-efficient luminaire; or when a contractor proposes a different AHU which may need a bigger fan motor; or by making assumptions on running hours more realistic. The way has been paved by CIBSE TM 22. *Get to the roots of energy consumption!*

For construction

Probe 1 concluded that not enough could be taken for granted, from airtightness to controllability; important points now for the Movement for Innovation. It suggested better and more appropriate specifications, standards, procedures and benchmarks, with means of confirming compliance, and demonstrating to clients that any added costs were highly affordable in better performance and fewer nasty surprises. *Attention to detail is essential.*

Just one example. Probe 2 confirms that unwanted air infiltration remains a chronic problem. This had major adverse effects on HVAC design and performance, for example:

- Systems have to be routinely oversized to cope with the risk, adding to their costs.
- Comfort conditions are threatened, and hence occupant satisfaction and productivity.
- The energy implications can be very much greater than the added ventilation heat loss, as the hours and seasons of operation of plant also have to be increased.

We now need to engage our clients and colleagues to make sure that it happens! Buildings like FRY show how a reliable fabric can bring radical savings on the services. *Baselines also need challenging generally: features which are essential to good performance often seem to be regarded as if they were optional extras.*

At and beyond handover

Probe 1 noted that the commendable ambition to get things "right first time" could have the unintended consequence of stopping clients and designers making sensible plans to nurse a building - particularly a complex and innovative one - through its infancy. When one is building a prototype for an uncertain use, emergent properties ensure that only in hindsight can all problems be identified. Few buildings are also operationally complete when they are physically complete (computer hardware and software is a good analogy), but the traditional concept of practical completion still assumes that they are. After that, shuffled responsibilities during the defects liability period often seem to hinder, not resolve teething problems, which can then get worse as confidence is lost. *We need better after-sales service to support our clients and provide valuable insights and feedback for ourselves and for the industry, together with a re-assessment of the legal and contractual meaning of practical completion. Why shouldn't some buildings need the equivalent of sea trials?*

Designers, builders and occupiers must recognize that innovative (or at least unfamiliar) techniques such as MM and ANV may well require management input and fine tuning to fulfil their potential, particularly at the early stages when problems with both technical (and particularly control) performance, occupant understanding, and unintended consequences can easily occur. Where innovation runs ahead of the knowledge base, it is especially important to set objectives and benchmarks, to undertake appropriate monitoring (including metering), and to seek and take account of feedback (including post-occupancy surveys). *Learn on the job, and tell others!*

Probe 2 included one excellent example of the value of sea trials activities. At the Elizabeth Fry Building, monitoring for BRECSU revealed that all was not well with the controls, leading to energy wastage and some loss of comfort. The client and the design team addressed this problem and found that the stand-alone controls initially provided (at client request) did not provide sufficient information to permit the management to gain an understanding of how the building actually responded to control action, and to "drive" it satisfactorily. A BMS was retrofitted, and the information gained also showed that a simpler control strategy than the designers had anticipated could deliver excellent results. Sadly, this level of attention is rare, though the investment has now made the building more comfortable, cheaper to run and easier to manage. *Less can be more!*

For facilities management

Probe 1 identified the importance of matching the building to the management skills likely to be available and regarded as affordable by the occupier. This has proved so important that we have now brought discussion of manageability into the briefing section above. *Don't procure what you can't manage; and make sure that the appropriate management systems are then in place.*

When outsourcing contracts

Probe 1 identified that routine activities like maintenance, cleaning and security were important monitoring and feedback mechanisms, which could reinforce policies of continuous improvement. In outsourcing, it was important to maintain this feedback - both formal and informal - in support of the facilities management task, and for contracts to be drafted and managed accordingly. *Don't outsource your feedback loops!*

Probe 2 showed that there were still problems in this respect. Outsourced FM and maintenance contracts seldom seemed to undertake proactive sea-trials activities - they had probably not been asked to. They were more likely to maintain the status quo for the building services, so chronic problems persisted. They were also seldom invited to undertake energy management. Indeed energy management was rare in all the Probe buildings.

CONCLUSIONS

Probe 2, like Probe 1, has revealed a world of interesting and imaginative buildings, but in which some aspects have not lived up to expectations. Partly this is a consequence of the human condition and the second law of thermodynamics, but it also adds to a general feeling (as expressed in the Egan report [12]) that our buildings - with notable exceptions - are not as good as they could easily be. Where Probe buildings did perform well, this was often the result not of major innovations, but of good communications and relatively simple, thoughtful solutions, implemented and followed through with attention to detail. Good performance is now tantalisingly within our grasp, but it requires changes in what clients ask for and how the industry goes about things; with means of adding and consolidating value in straightforward and effective ways. It also needs clearer recognition of the implications of design proposals for management involvement and vigilance; matching the demands of the building to the resources of the occupiers, rather than creating obstacle courses for them.

Today we ask more of our buildings: we want them to be quick, flexible, cost-effective, environmentally-efficient, and to raise staff morale and organisational performance. Some of these objectives may be fundamentally opposed, viz the project management maxim: *"Do you want it quick, cheap, or good? Choose any two!"* In fact conflicts can often be resolved by good briefing, good design, good execution and good management (Probe has examples of good all-rounders) but the attention to detail and checking of the means (the buildings) against the ends (client requirements) can require more care than the market is presently prepared to pay for, in spite of the demonstrable value that can be added for business, for people and for the environment.

“How very little, since things were made, things have altered in the building trade.” [13]. But in hindsight this slow evolution did confer a degree of robustness and stability. Now things are changing faster, we need to remember that specific and sometimes unexpected shortcomings are inevitable in any prototype (viz: Murphy’s Law which dogs all R&D). It is not easy to innovate reliably in things which people want to take for granted: most building occupants are looking for solutions and convenience, not leading edge technology which to deliver performance may demand a lot of time and money from a committed and enthusiastic user. Effective use of post-occupancy assessments by the industry could help to make the required innovation more rapidly usable.

However, many problems revealed by Probe can be anticipated: they fall into regular patterns, e.g. excessive air leakage; control and interface problems; essential features regarded as unaffordable; systems too complicated, unresponsive, or inefficient, and so defaulting to ON; little attention to energy benchmarking; and anticipated management skills absent. The industry appears slow to recognise - or certainly to deal with - these chronic problems, partly because features that add value for the user are not always valued in the marketplace. Hence, for example, making controls really effective and usable can require considerable extra effort - at least at present when off-the shelf specifications and solutions are not readily available. Few people are prepared to pay for this effort, particularly if they have not been advised at an early stage that they need to make an allowance for it. Indeed, one problem with cost planning for buildings is that it often looks back to historical precedents which may not adequately represent today’s physical, performance, service and regulatory requirements.

Probe has also found that the very people who are prepared to sanction investment in more energy efficient designs nevertheless baulk at committing resources to managing the buildings in order to deliver this energy efficiency. There are two battles to be won:

- For new work, to seek inherently robust, “fit and forget” energy-efficient designs, e.g. airtight, low heating demand, efficient heating plant, low specific fan power and installed lighting capacity, good controls, and so on … and attempting to keep management requirements to a minimum.
- For all buildings, ensuring effective monitoring and management.

POSSIBLE NEXT STEPS

What might we do to make things better? Here are a few ideas.

- Strive to avoid commonly-occurring problems as outlined above, for example uncontrolled air infiltration; poor intrinsic efficiency and demand-responsiveness of systems; ineffective, unfriendly and intrusive controls; and insufficient support after handover.
- Improve communication with our clients and colleagues, to ensure better agreement on ends and more effective ownership of problems. For example, services engineers themselves cannot do much about envelope airtightness; planning for sea trials needs the agreement and understanding of other team members and the client - and perhaps even different forms of contract; and downstream issues such as manageability require input from an occupier and user perspective.

- Routinely collect information on technical performance and occupant satisfaction, in order to understand where we are going, what we need to do, and the problems to be avoided.

- Develop industry benchmarks against which performance can be requested in briefing and regulation, and reviewed during design, construction, commissioning, completion, handover and operation, in a process of regular reality-checking throughout a project. At present there is often too wide a gap between the language used by specialists and the issues which investor and user clients - and often other building team members - can engage with readily.

- Institutions - both jointly and severally - should aim to promote standards and benchmarks not just at the basic minimum level, but also good practice (which CIBSE might perhaps require members to adopt) and advanced practice (for which CIBSE might encourage members to compete in order to push forward the established frontiers).

- A culture of continuous improvement, which becomes embedded where possible in standards and - where standards do not exist or are not appropriate - provides sufficient resources to deal with the issues effectively. This should include maintaining a rolling agenda of items requiring performance improvement, and encourage means of making this happen … and reviewing the results.

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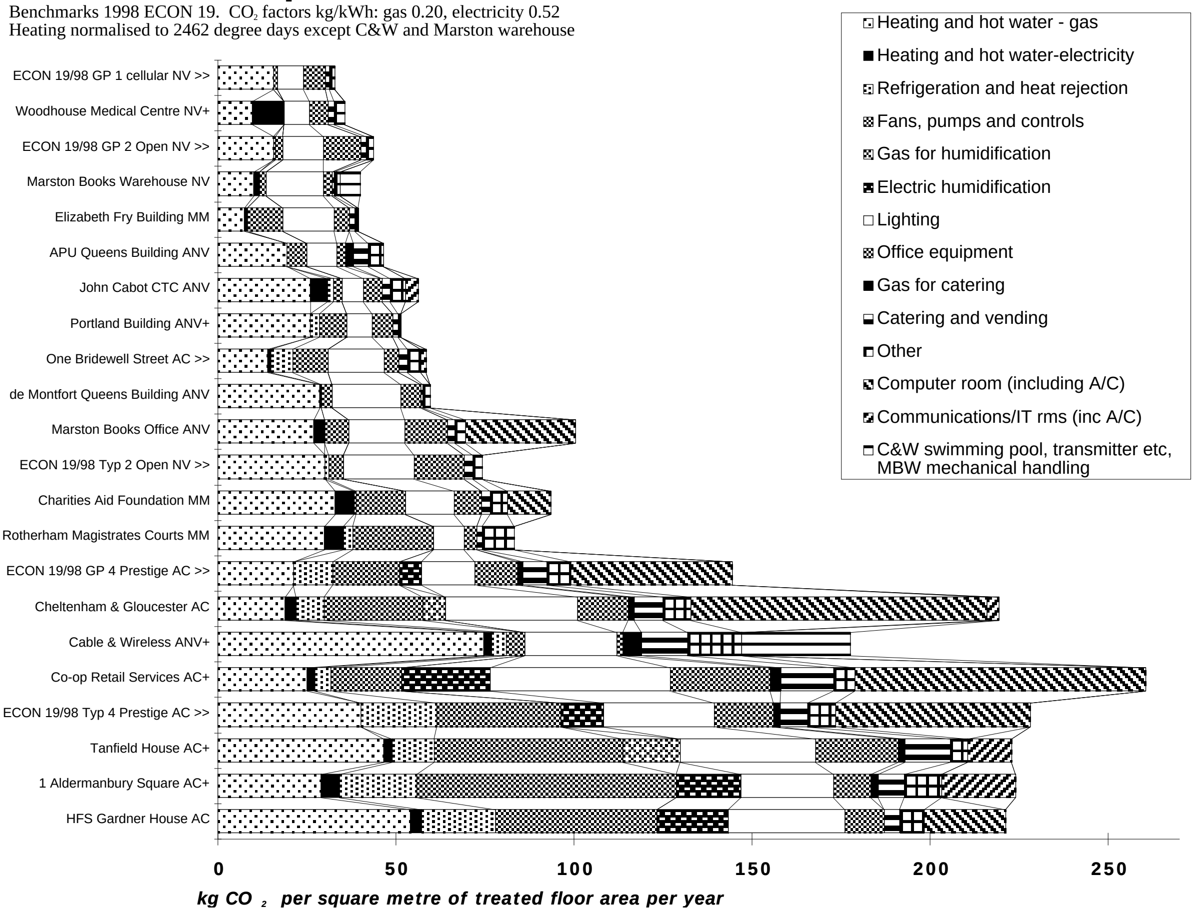
FIGURE 1: Annual CO_2 emissions

Benchmarks 1998 ECON 19. CO_2 factors kg/kWh: gas 0.20, electricity 0.52
Heating normalised to 2462 degree days except C&W and Marston warehouse



ENERGY DATA FROM WHICH FIGURE 1 HAS BEEN CALCULATED (with kg/kWh factors for CO2 0.52 for electricity and 0.20 for gas)

Estimated breakdown of annual energy consumption (kWh/m² of treated floor area by fuel)

With energy benchmarks from the 1998 edition of Energy Consumption Guide 19 (ECON 19)

Normalised heating & hot water for graphs corrected to 2462 degree days (15.5°C base) per year (not C&W and Marston Warehouse). Simple correction used unless in bold.	1 Aldermanbury Square AC+	HFS Gardner House AC	Tanfield House AC+	Co-op Retail Services AC+	ECON 19/98 Typ 4 Prestige AC >>	Cheltenham & Gloucester AC	ECON 19/98 GP 4 Prestige AC >>	Rotherham Magistrates Courts MM	Cable & Wireless ANV+	Charities Aid Foundation MM	One Bridewell Street AC >>	Marston Books Office ANV	Elizabeth Fry Building MM	ECON 19/98 Typ 2 Open NV >>	de Montfort Queens Building ANV	Marston Books Warehouse NV	Portland Building ANV+	Woodhouse Medical Centre NV+	John Cabot CTC ANV	ECON 19/98 GP 2 Open NV >>	APU Queens Building ANV	ECON 19/98 GP 1 cellular NV >>
GAS:																						
Total actual gas	117	253	331	118		101		142	400	151	53	113	35		127		100		98		115	
Heating and hot water gas	106	253	242	103		61		142	374	151	53	113	35		127		100		98		104	
Heating+HWS gas (normalised)	145	**271**	233	**125**	201	95	107	150	374	165	**70**	135	37	151	**143**	51	130	49	**130**	79	**97**	79
Gas for catering	11	0	9	15	9	8	7		26												11	
Gas for humidification			80			32																
ELECTRICITY:																						
Heating and hot water - electricity	10	6	5	5		6		10	4	11	2	6	2		1	3	0	17	9			
Refrigeration and heat rejection	42	40	23	9	41	15	21	5	8	1	12		0	2			5		3	1		
Fans, pumps and controls	140	87	102	38	67	53	36	44	10	27	19	13	19	8	6	3	15		5	4	11	2
Electric humidification	35	38		48	23		12															
Lighting	50	63	73	97	60	71	29	17	50	26	30	30	28	38	37	31	14	14	12	22	16	14
Office equipment	20	21	45	54	32	28	23	7	3	15	8	23	8	27	11	5	11	10	10	20	5	12
Catering and vending	14	8	24	29	15	16	13	3	25	5	5	4	3	5	1	1	3	3	4	3	8	2
Other	20	13	10	11	15	15	13	17	29	9	7	6	2	5	4	3	2	6	8	4	8	3
Computer room (including A/C)	No	44	No	157	105	160	87	No	No	23.7	No	60	No	No	No	No	No	No	No	No	No	No
Communications/IT rms (inc A/C)	40		24	Incl	Incl	6	Incl				3								7			
C&W swimming pool, transmitter etc, MBW mechanical handling									59							11						
Total gas	**156**	**271**	**322**	**140**	**210**	**135**	**114**	**150**	**400**	**165**	**70**	**135**	**37**	**151**	**143**	**51**	**130**	**49**	**130**	**79**	**108**	**79**
Total electricity	**371**	**321**	**305**	**448**	**358**	**370**	**234**	**103**	**188**	**117**	**86**	**142**	**62**	**85**	**60**	**58**	**49**	**50**	**58**	**54**	**48**	**33**
Electricity for building services	277	235	203	196	191	146	98	76	72	65	63	49	49	48	44	38	34	31	29	27	27	16
CO2 for building services (sort category for bars in fig 1)	**173**	**176**	**168**	**127**	**140**	**101**	**72**	**69**	**112**	**67**	**47**	**53**	**33**	**55**	**51**	**30**	**44**	**26**	**41**	**30**	**33**	**24**

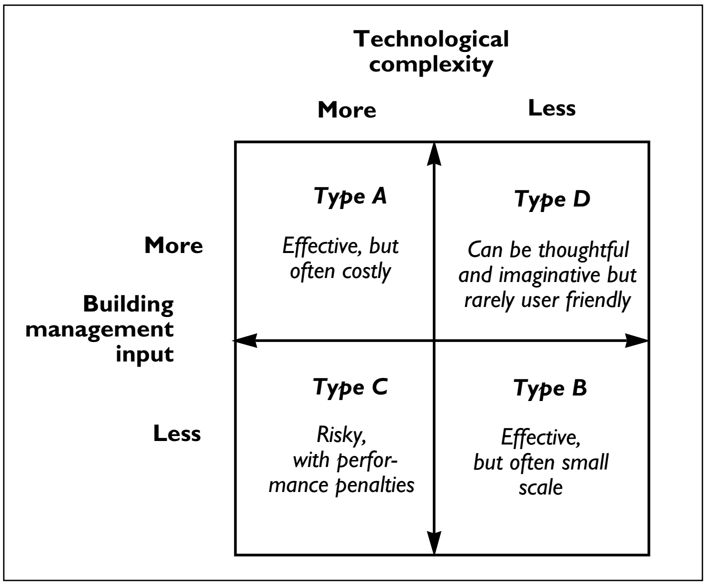


Figure 2 Briefing strategies