Passivhaus schools conference
RIBA, 11 December 2009

Building services:

avoiding unnecessary energy demand and use through careful design and operation

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Structure of the talk

1. **BACKGROUND**

2. **HOW DOES THE PH STANDARD RELATE TO UK SCHOOL ENERGY PERFORMANCE?**

3. **ELECTRICITY USE -** *the elephant in the room!*

4. **PUTTING IT ALL TOGETHER**

1

BACKGROUND

How can we get our new and refurbished schools to turn out good?

Why good buildings go bad while some are just born that way

Dr Paul Bannister, Exergy Australia Pty Ltd

ABSTRACT

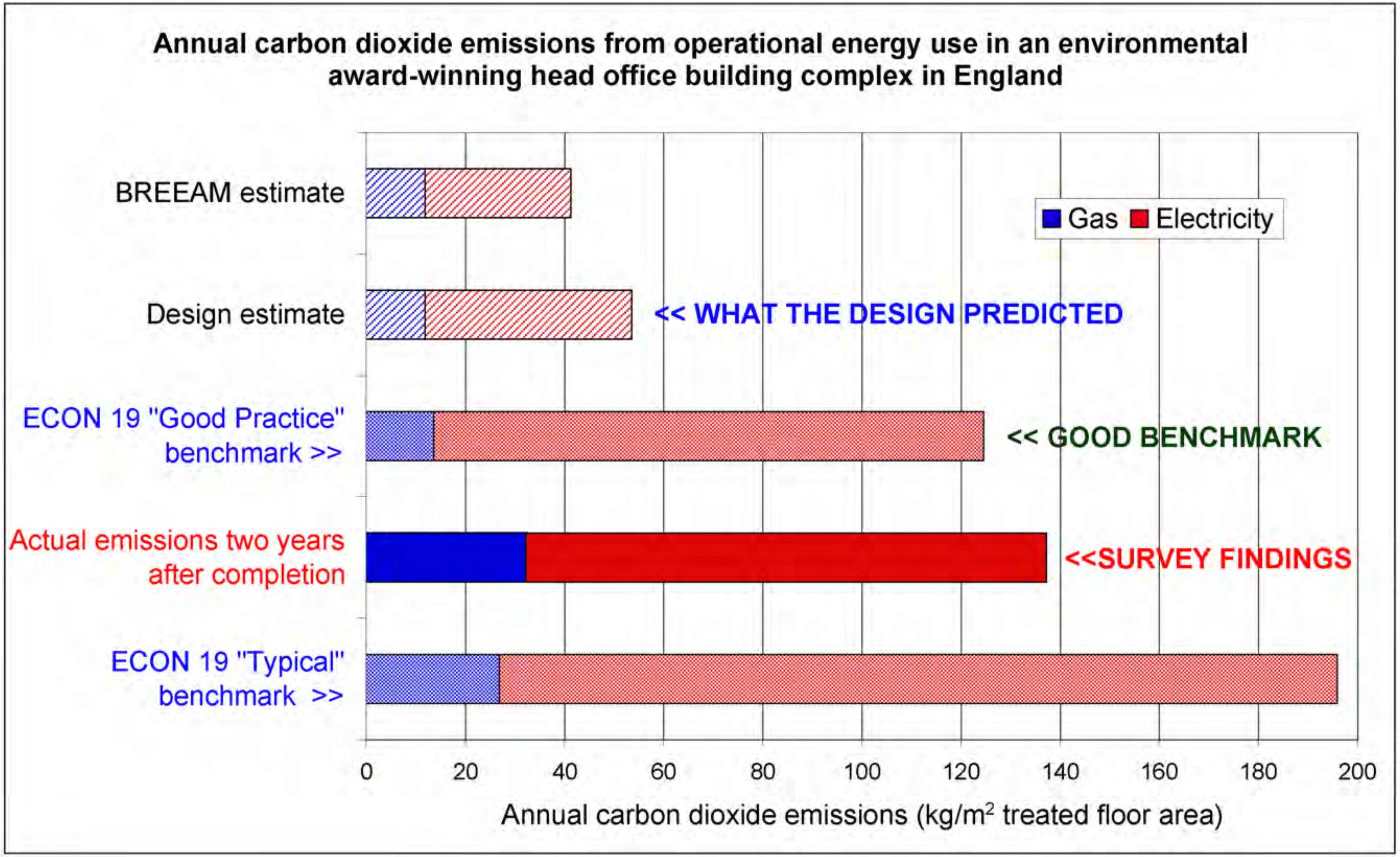
With the realisation that climate change is not going to be resolved by inaction or unrealised promises, the issue of actual building performance has become focal in today's commercial buildings sector. With this has come the genuinely problematic issue of delivering and operating buildings at levels of efficiency higher than have been achieved before.

While some argue that good design is all, those involved in operating buildings are generally aware that the issues of delivering and operating high-efficiency buildings are somewhat more complex. A building that has a good theoretical performance may not perform well in practice, while many lesser buildings may be easier to operate and improve.

In this paper, a range of issues that cause apparently well designed buildings to perform poorly are explored, with particular emphasis on the issues affecting base buildings under the Australian Building Greenhouse Rating scheme. These issues include items that can be seen as the responsibility of various participants in the supply chain, as well as many that are the product of numerous such participants. It is identified that delivering and operating high-efficiency buildings is a complex and multifaceted problem that requires a holistic rather than reductionist view of the building process. Some guidelines for more reliable delivery of efficient buildings are also provided.

SOURCE: Ecolibrium, the Journal of the Australian Institute of Refrigeration, AC and Heating, 24-32 (February 2009)

The Credibility Gap for a 1996 green building award winner. *These persist unfortunately.*



SOURCE: S Curwell et al, *The Green Building Challenge in the UK,* Building Research and Information **27** (4/5) 286-293 (1999).

What we're missing:
The evidence under our noses

"in theory, theory and practice are the same, in practice they aren't"
SANTA FE INSTITUTE for research into complex systems

"designers seldom get feedback,
and only notice problems when asked to investigate a failure"
ALASTAIR BLYTH CRISP Commission 00/02, UK

"unlike medicine, the professions in construction
have not developed a tradition of practice-based user research …
Plentiful data about design performance are out there, in the field …
Our shame is that we don't make anything like enough use of it"
FRANK DUFFY Building Research & Information, 2008

"I've seen many low-carbon designs,
but hardly any low-carbon buildings"
ANDY SHEPPARD Arup

It's the process, not just the product

Factors for success at the Elizabeth Fry Building, UEA

But only its technical features were mentioned when a Royal Commission used it an exemplar

- A good client.
- A good brief.
- A good team *(worked together before on the site).*
- Specialist support *(e.g. on insulation and airtightness).*
- A good, robust design, efficiently serviced *(mostly).*
- Enough time and money *(but to a normal budget).*
- An appropriate specification *(and not too clever).*
- A good, interested contractor *(with a traditional contract).*
- Well-built *(attention to detail, but still room for improvement).*
- Well controlled *(but only eventually, after monitoring and refit).*
- Post-handover support *(triggered by independent monitoring).*
- Management vigilance *(easier now, but needs to be sustained).*

SOURCE: W Bordass et al, *Assessing building performance in use 5*, BR&I **29** (2), 144-157 (March-April 2001), Figure 6.

2

HOW DOES THE PASSIVHAUS STANDARD RELATE TO THE IN-USE ENERGY PERFORMANCE OF UK SCHOOLS?

Implications of the Passivhaus standard

PRIMARY ENERGY FACTORS *(SAP 2005)*

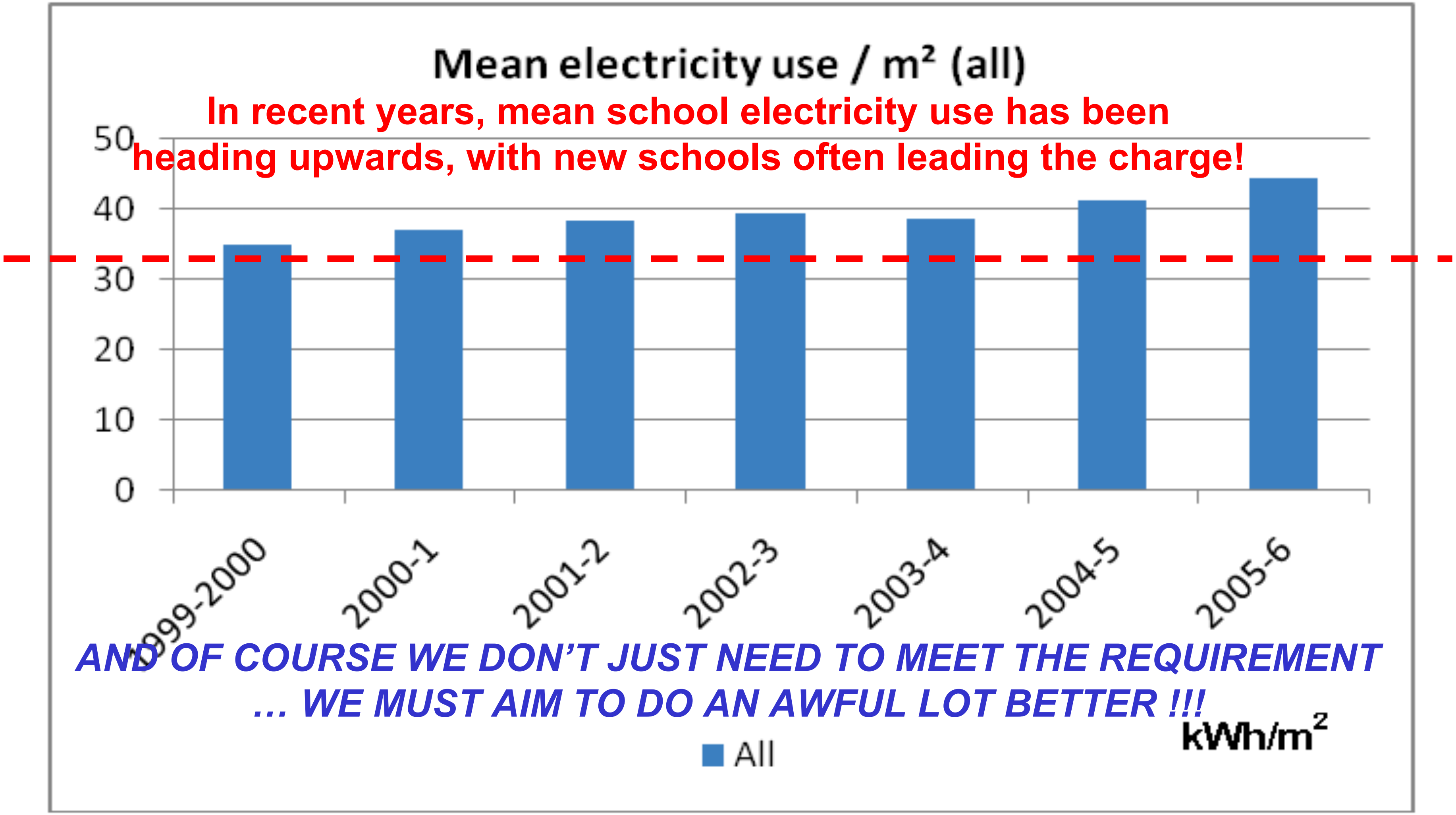
Mains Gas 1.15 Mains Electricity 2.8

PASSIVHAUS STANDARD FOR HEATING	*(kWh/m²)*
• **Required heating demand, max**	**15**
• Plus hot tap water etc, say *8 kWh/ m², including kitchen, sports*	23
• Plus boiler and system losses, say +15% *(3 kWh/m²)*	**26**
• **Conversion to primary energy, +15% *(4 kWh/m²)***	**30**
NB: system losses in most UK installations can be much higher	

PASSIVHAUS STANDARD FOR PRIMARY ENERGY	
• **Required primary energy, max, *for everything***	**120**
• Less heating requirement above *(30 kWh/m²)*	90

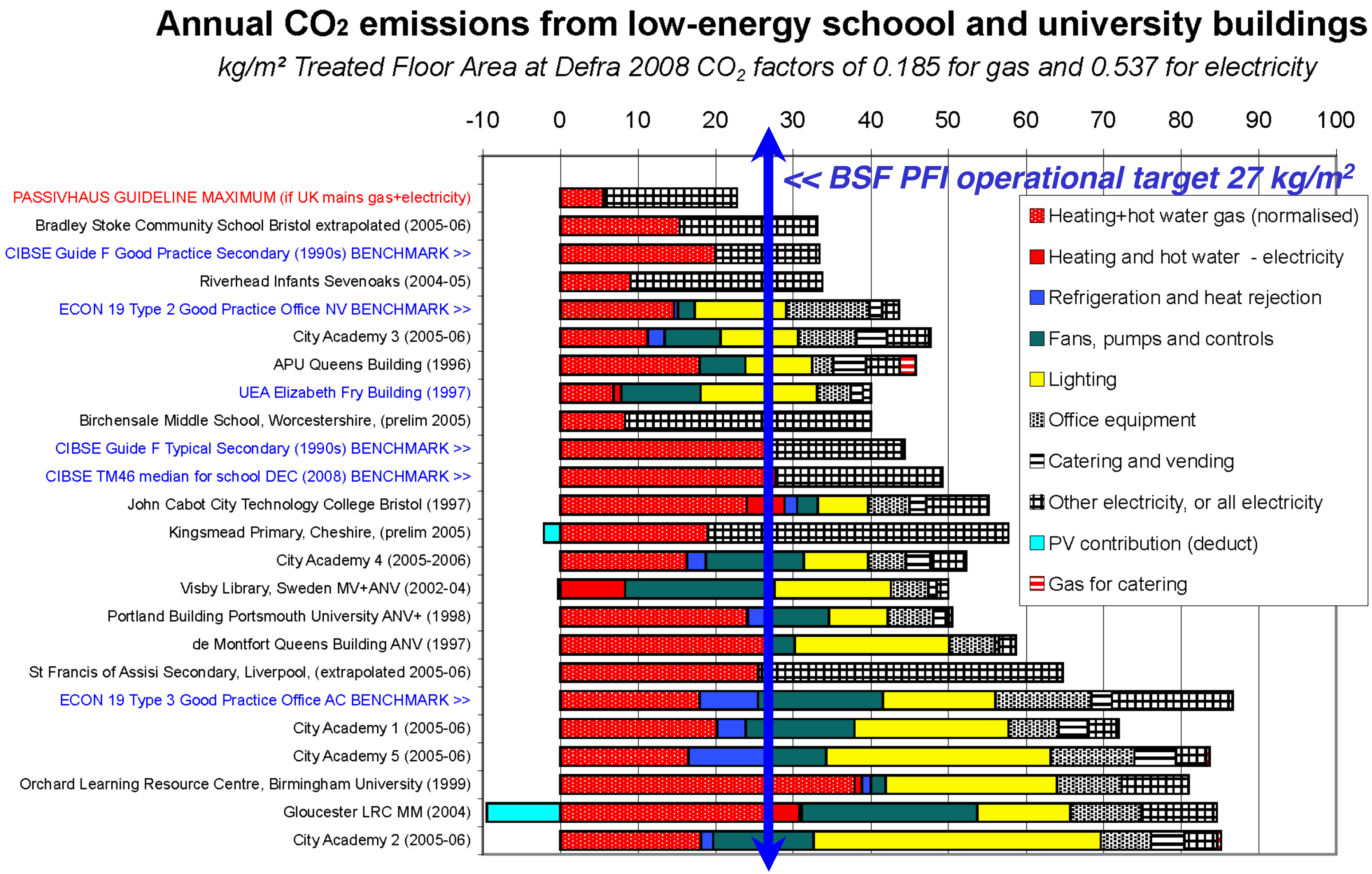
RESIDUAL PRIMARY REQUIREMENT AS UK MAINS ELECTRICITY	
• **Conversion to delivered electricity @ 2.8 factor**	**32**
• *Median school electricity consumption (DfES, 2003 data)*	*39*
• *Lower quartile school electricity consumption (DfES, 2003 data)*	*31*

How easily can you meet the PH electrical maximum *(about 32 kWh/m², 17 kg CO_2/m²)*?

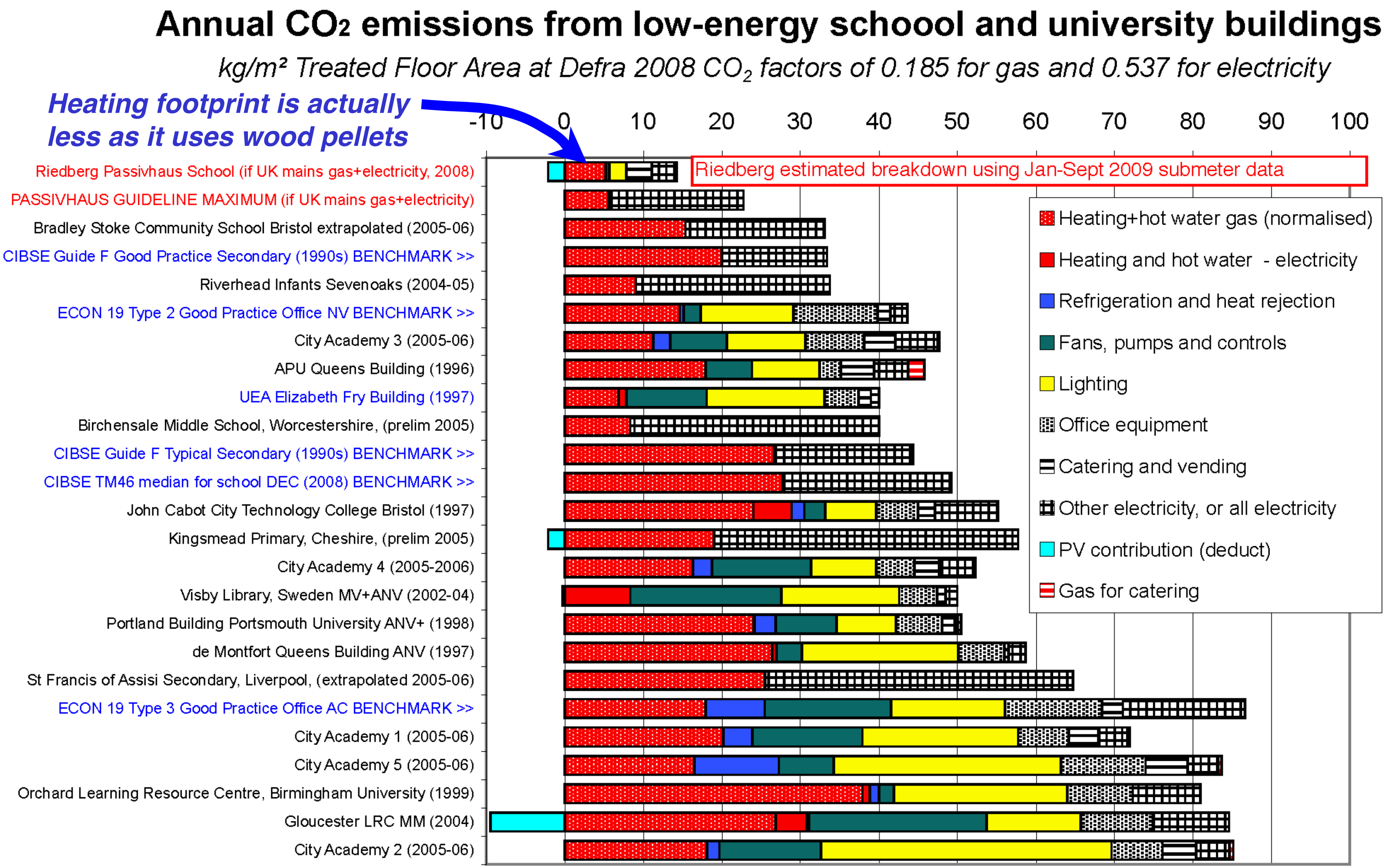


SOURCE: AECOM, *Reducing carbon emissions from existing schools,* page 16, DCSF (August 2009).

How do specific low energy designs look?



Where does Riedberg PH school fit in?



Why are new UK schools so different in performance, *and with high electricity use?*

YES, THERE IS OFTEN A LOT WE COULD IMPROVE:

- Fabric performance is less good, *both in theory and in practice.*
- Building systems are much more liberally sized.
- Building systems and controls are often too complicated.
- Unmanageable complication leads to avoidable waste.
- Poor demand-responsiveness to pattern of use, *default to ON.*

BUT … **POLICY IS ALSO MANDATING MORE INTENSIVE USE, *e.g.***

- Non-traditional space planning, *encourages default-to-on.*
- Performance standards for PFIs etc, BB 93 and BB 101 lead to services and energy mission creep.
- Interactive whiteboards undermine daylight strategies.
- Much more ICT: Ambition of one computer per student.
- Extended hours for community use.
- *"Adding features"* tick-box approach making things too complicated.
- *Schools are getting to look and use energy more like offices!*

PLUS … Dysfunctional procurement systems that make it difficult or impossible to pay proper attention to critical detail.

Are we making schools too complicated?

Technology - management interactions

		Technological complexity	
		More	Less
Building management input	More	*Type A*	*Type D*
	Less	*Type C*	*Type B*

SOURCE: W Bordass et al, *Assessing building performance in use 5*, BR&I **29** (2), 144-157 (March-April 2001), Figure 3.

Are we making schools too complicated?

Technology - management interactions

		Technological complexity	
		More	**Less**
Building management input	**More**	*Type A* Effective, but often costly	*Type D* Rare, not replicable?
		Risky with performance penalties *Type C*	Effective, but often small-scale *Type B*

Secure Type A
Seek more Type B
(and possibly Type D)
Avoid Type C.

3

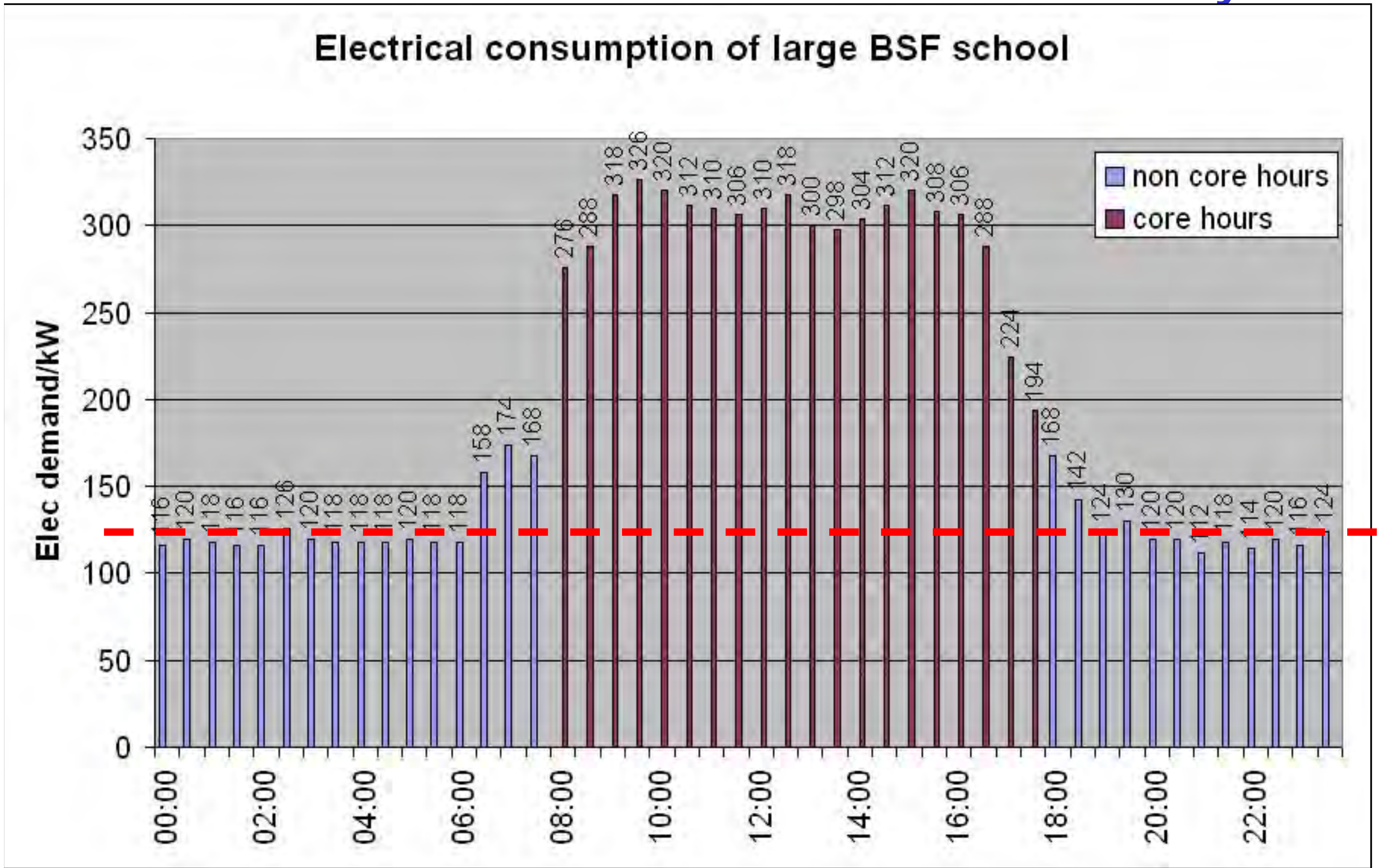
ELECTRICITY:
THE ELEPHANT IN THE ROOM

the PH allowance for electricity has at least three times the CO_2 impact of that for heat

and that's not all …

The electrical tail can often wag the dog

kWh/half hour in a BSF secondary school



120 kW baseload: ca. 7 W/m^2 or 45 kWh/m^2 p.a.

Equivalent to 60% of all lighting or 1000 PCs including screens. printers etc.

Breakdown of annual electricity use: 44% used between 0800-1800 on term time days

56% (~£75,000) of electricity used at other times: 14% term weekends, 26% term nights, 16% holidays

SOURCE: Buro Happold monitoring (October 2009)

Where is the electricity going?

THE MAJOR USERS

- Lighting,*15-30 kWh/m², but can be much more if it defaults to ON, especially in corridors, stairs etc..*
- ICT,*5-10 kWh/m²*, but has been growing rapidly.
- Fans, *highly variable* but can be *10-20 kWh/m²* and occasionally much more, *with cooling creeping in.*
- Catering kitchens, *5-10 kWh/m²,* often wasteful.
- Other things, *5-10 kWh/m²,* but can be more: external lights, lifts, security and fire protection systems *(now including sprinklers)*, electronic control systems …
- Special things, e.g. swimming pools, server rooms, laboratories, pottery kilns - *localised high consumers.*
- *So many new UK schools end up with 50-100 kWh/m², Riedberg is about 18 (incl. kitchen), less 4 for PV.*

Small changes make big differences:
if you use the multiplier effect

ENGAGE PEOPLE … AND, for example:

1. Halve the demand

    X

2. Double the efficiency

    X

3. Halve the carbon in the supplies

    and …

you're down to one-eighth of the carbon

Passivhaus is mostly about STEP 1, often by over 50%.

Too much of UK policy, is about STEP 3, e.g. Merton Rule.

WHY? When prevention is much better than cure!

Multipliers can help you make big reductions, *but they can also catch you out!*

- ***Concept:*** *An inefficient concept creates an unnecessarily energy-dependent building.* Passivhaus clearly addresses this.
- ***Building fabric:*** *Poorly specified, detailed or constructed, it creates additional loads for the building services.*
- ***Standards:*** *Thoughtlessly-applied standards (sometimes for the best of reasons) can unnecessarily increase energy requirements.*
- ***Plant and equipment:*** *Lower-efficiency plant, equipment and distribution requires more energy than necessary to do to the task.*
- ***Control systems:*** *Unsuitable controls mean that systems run unnecessarily and inefficiently. Sometimes large control overheads.*
- ***As built:*** *Not constructed, installed, controlled or commissioned as intended owing to haste, ignorance, or commercial factors.*
- ***Occupier:*** *Designers often blame the occupier for high energy use … but designers seldom design to suit the occupiers.*
- ***Managers and users:*** *Easy route can be for things to default to ON.*

"Much energy consumption comes from the compounding of unnecessary loads" … AMORY LOVINS

How things can mount up: *some simple arithmetic for lighting*

THE ASSET:

•	Illuminance standard	300 lux	*or 400?*
X	Installed efficiency	1.67 W/m^2 per 100 lux	*or 2.5?*
=	**Power density**	**5 W/m^2**	***or 10?***

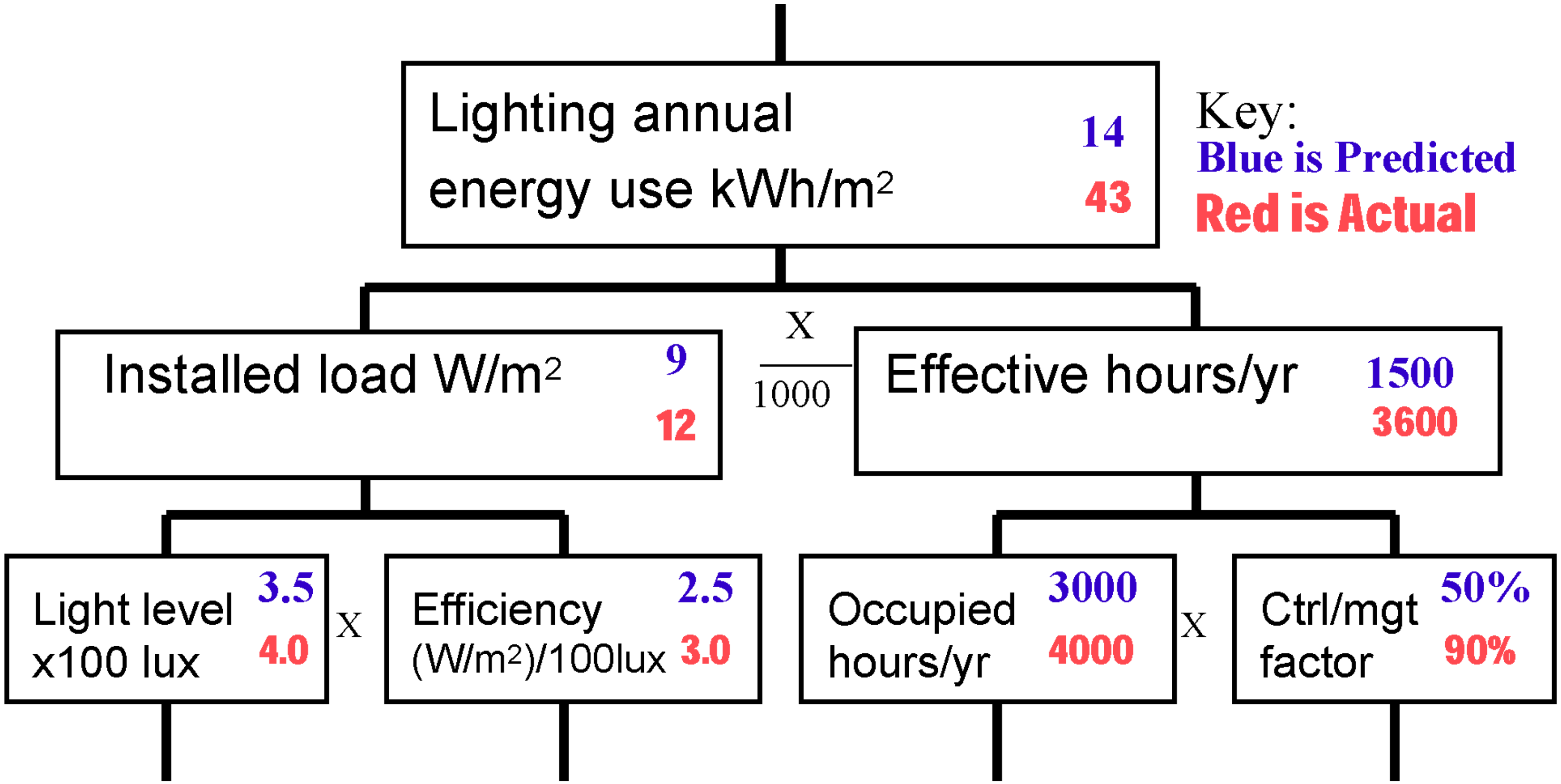
OPERATION, CONTROL AND MANAGEMENT:

•	Typical hours of usage	2000 hours per year	*or 3000?*
X	Efficiency of control	on 40% or the time	*8 AM-8 PM*
=	**Full load equiv. hours/year**	**800**	***or 3000 + ?***

THE OUTCOME *(power density **X** full load equivalent hours)*

Annual energy use	4 kWh/m^2	*or 30?*
Similar to	Riedberg PH School	*UK Academies range 15-69*

Illustrating the effect of multipliers
with CIBSE TM22 tree diagrams



© ESD/WBA/TES

The process is described in CIBSE TM22: *Energy Assessment and Reporting Method, London:* CIBSE (1999 and 2006)

"Why worry about a little fan energy?"
some simple arithmetic for school MVHR

FOR 60 m² classroom, max capacity 40 people, requires			*1.5 m² per person*
•	Ventilation standard	5 litres/sec per person	*or 8?*
THE ASSET:			
•	Ventilation standard *(per m²)*	*3.7* litres/sec per m²	*or 5.3?*
X	Specific fan power of plant	1.25 Watts/per litre/sec	*or 2?*
=	**Power density**	**4.6 W/m²** of classroom	***or 10.6?***
OPERATION, CONTROL AND MANAGEMENT:			
•	Typical hours of usage	1000 winter hours per year	*or 8760?*
X	Efficiency of control	On for these hours	*variable vol, say 33%*
=	**Full load equiv. hours/year**	**1000**	***say 3000?***
THE OUTCOME *(power density **X** full load equivalent hours)*			
Annual energy use		4.6 kWh/m²	***or 32?***

You can reduce overall fan kWh/m² by getting classroom air to do double duty on its way out *(as at Riedberg),* heating & ventilating corridors, cloakrooms etc.

4

PUTTING IT ALL TOGETHER

Fit and forget? *Or not?*

Design for usability and manageability

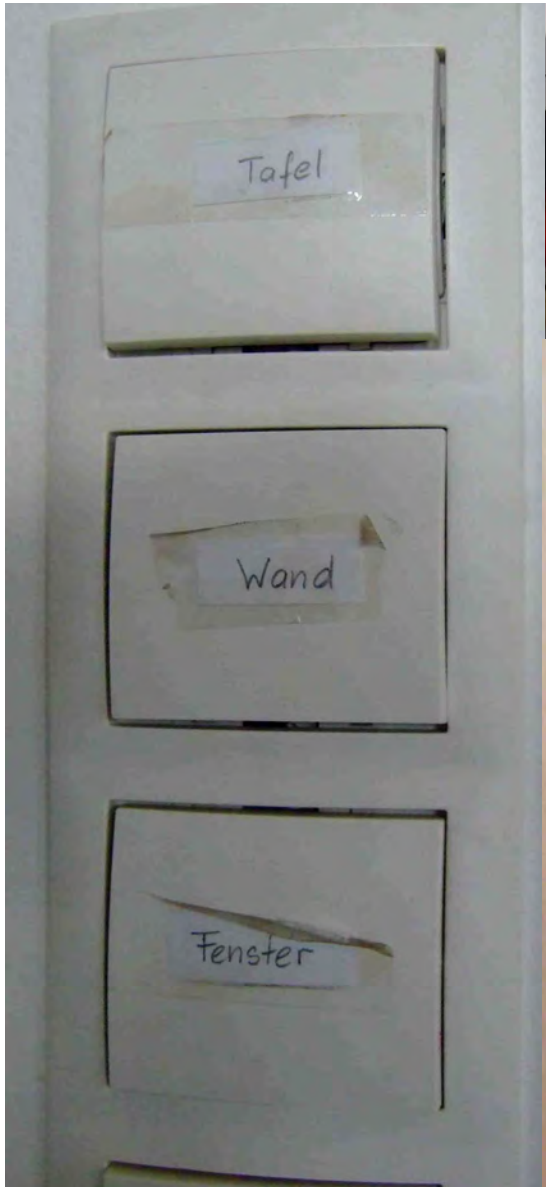
Physical variables

Context-free	**A** **Fit and forget** *Make invisible*	**B** **Implement and manage** *Make usable*	**Context-dependent**
	Make habitual **Implement and internalise** **C**	*Make acceptable* **Risk and robustness** **D**	

Behavioural variables

SOURCE: After W Bordass and A Leaman, *Design for manageability,* BR&I, **25** (3) 148-157 (May/Jun 1997)

Controls that work, *and make sense*



It ought to be simple enough, but we've a long way to go!

Squeezing things down*: Gentle engineering, simple sophistication,sense and science*

- Question requirements and standards
- Be in a position to trust the passive measures, *so you can reduce design margins.*
- Increase efficiency, *of systems not just plant*
- Minimise operating hours, *or if not use very low-powered "trickle charge" systems.*
- Design for usability, manageability, *and demand responsiveness.*
- Specify effective control and monitoring systems, *and make sure you get them, the users understand them, and you understand the users.*
- Minimise complication
- Monitor to avoid waste
- Trap unintended consequences *and clashes, both in design and use.*
- Count everything, review everything, learn and share.
- *Avoid mission creep: more is not necessarily better*

What's this? *Why we need to take account of everything, in design and in use.*

Over summer 2009, this frost thermostat *(improperly set at 17°C on installation)* energised the wall heater in a plant room of a new low-energy building, and wasted more electricity than the wind generator *(designed to offset the entire building's annual heating energy use)* created.

Improving procurement
Soft Landings may be a start

It can run alongside any procurement system, and helps to:

- Improve briefing
- Link building performance and FM to design.
- Ease transition to occupation.
- Reduce post-handover problems.
- Facilitate monitoring, POE and feedback.
- Capture learning.

It can help design and building teams to:

- Relate design targets to achieved outcomes.
- Manage expectations and review performance at intervals throughout a project, and on into use.
- Allocate responsibilities, *including client responsibilities.*
- Improve relationships with clients and users.

Developed by UBT and BSRIA with the originator Mark Way and an industry group. Published July 2009. Now being progressed both in detail, and specifically with a team of leading players involved in schools.

PFS plans pilot projects in 2010

SOURCE: published July 2009, downloadable from www.usablebuidings.co.uk and www.softlandings.org.uk

Getting it right: *Robust buildings*

- Get the brief right, *based on practical insight.*
- Get the standards right: *avoid mission creep.*
- Get the fabric right: *passive measures.*
- Get the services right: *gentle engineering.*
- Get the other things right: *ICT, catering etc..*
- Get the controls right; *and their user interfaces.*
- Get it built right; *with a suitable procurement path.*
- Get it finished right: *commissioning, operator and user engagement, handover, aftercare.*
- Get it operated and used right*, information, training, monitoring and review, troubleshooting and fine tuning.*
- Keep it up to the mark, *monitoring, feedback and continuous improvement.*
- Don't make it too difficult and expensive to look after.

Don’t procure what you can’t afford to manage

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