Tailored energy benchmarks for offices and schools, and their wider potential

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Abstract

Energy benchmarks are too often poorly-matched to the characteristics of the buildings being benchmarked. Procedures that focus on CO_2 emissions can also distance people from the physical realities of energy use by source and end use.

In 2002, CIBSE TM22 principles were used to demonstrate a prototype “tailored benchmarking” approach for offices. This helped to shape the initial placeholder benchmarks for Display Energy Certificates for public buildings in England & Wales.

In 2013, a pilot study by the authors examined how tailored benchmarks might be implemented for schools, using empirical evidence from a variety of sources to calibrate the model.

The paper outlines the principles of tailored benchmarks, their application to offices and schools, and the opportunities for a powerful, integrated benchmarking system to suit most non-domestic buildings.

Keywords Benchmark, energy certificate, performance gap, TM 22, TM 46.

1.0 Types of benchmarking

Widely-used methods for energy benchmarking non-domestic buildings include:

- Statistical, within peer groups. Performance indicators are calculated, normalised if necessary, and placed in rank order. Performance is often reported by percentile, as in EnergyStar Portfolio Manager [i] in the USA, or grouped into quartile or decile. Administrators tend to be most familiar with this approach, which is widely used in other areas, e.g. to compare financial products. Some think it is the only way to do benchmarking.
- Over time, usually by-year, either using performance scores from the above; or by self-referencing, by direct comparison with previous values. For self-referencing to be valuable, it needs to take some account of external variables (typically degree-days for weather variations) and of internal ones (e.g. changes in use and equipment).
- By comparing performance (normalised if necessary) with numerical standards. Most UK energy consumption guides (ECONs) produced in the 1990s used this approach. Separate benchmarks for annual fuel and electricity consumption were often based on stock statistics, with Typical performance at median and Good Practice (GP) at lower quartile values. GP values were sometimes derived in other ways. For example ECON 19 for offices [ii] produced more exacting GP values, based on information from case studies of buildings that used readily available energy efficient techniques, technologies and management. The approach also allowed individual end-uses to be benchmarked. Some guides included benchmarks for Poor, New or Advanced Practice.

Most benchmarking identifies where you are but not why: ideally benchmarking would be more action-oriented. There is also an urgent need for benchmarking to become more transparent between design and in-use performance; and to take better account of the activities and equipment in a building and its intensity of use.

2.0 The Energy Assessment and Reporting Method

In the early 1990s, the European Union (EU) began to consider mandatory energy performance labelling for non-domestic buildings. To help underpin its application in the UK, the British government commissioned research into an Energy Assessment and Reporting Methodology, EARM. EARM principles were embodied in a codified Office Assessment Method (OAM), which was trialled in the Probe [iii] series of post-occupancy evaluations in *Building Services – the CIBSE Journal.* This was then developed into CIBSE TM 22 [iv], which included Excel calculation software.

TM 22 uses methods of successive approximation to refine estimates of where energy goes in a building, working from the top-down (i.e. breaking down overall annual energy use by fuel, including half-hourly and sub-meter data where available) and the bottom-up (building up from individual spaces and energy end-uses); and reconciling the two approaches. By starting simple and adding detail, the surveyor can obtain preliminary results quickly and drill deeper only where necessary, depending on the significance of the issue, the time available, and the budget and motivation of their client.

Some conclusions from EARM were reported in a 1997 paper [v], which introduced “tree diagrams” that illustrate how overall energy use can be built up from (and/or broken down into) its components. They provide a powerful means of communicating and benchmarking energy performance at many different levels.

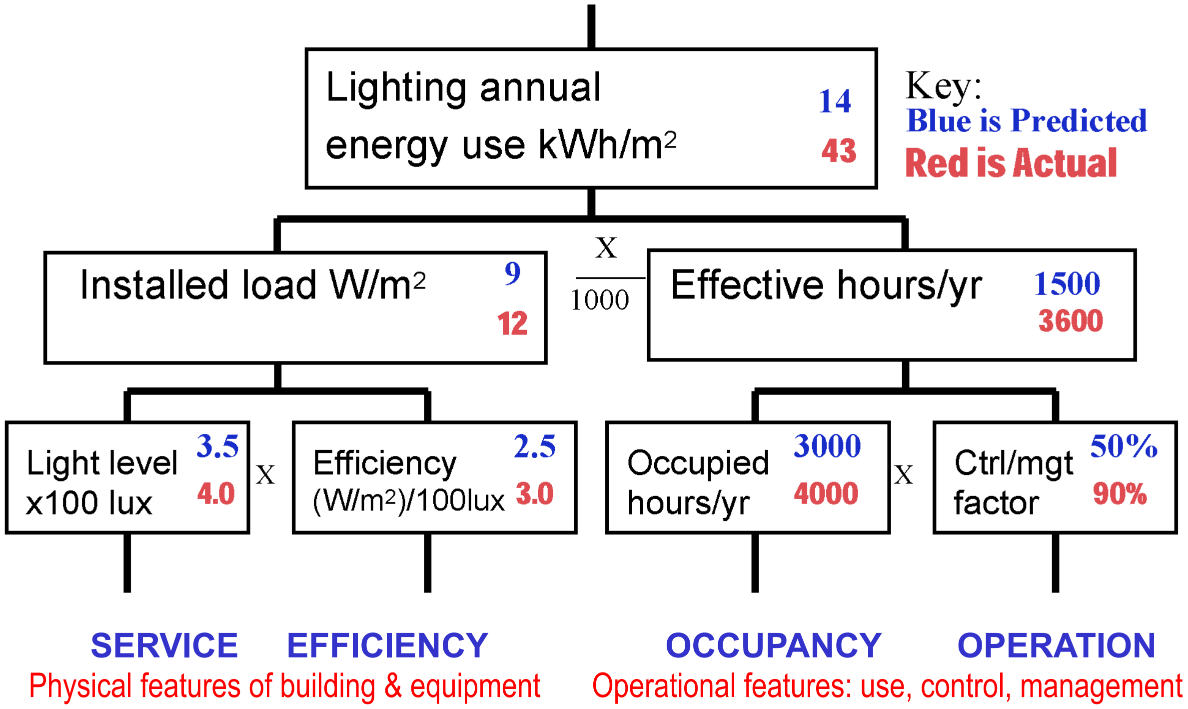


Figure 1 – Tree diagram description of the components of building energy use

Figure 1 illustrates the use of a tree diagram to summarise design predictions and actual outcomes for annual energy use of lighting in an office building surveyed.

- At the top, annual energy use for lighting was three times the design estimate.

- At the second level, this is seen to result from an installed load 33% above the design estimate; and effective full-load annual hours of operation 140% higher.
- At the bottom level on the left, the higher load is seen to be the consequence of both a higher illuminance level and a lower efficiency of the lighting installation.
- At the bottom right, the building was occupied for longer than anticipated (a legitimate issue); but the control and management regime kept the lights on at the equivalent of full output for 90% of the occupied period, not the 50% predicted. This was largely because, in the open plan areas, automatic switching distracted the occupants, so all lights were over-ridden ON during core occupancy hours.

The values on the left hand side of Figure 1 (or its equivalent) represent the qualities of the Asset, which derive partly from client requirements and occupier equipment; and partly from the design of the building and its systems. The values on the right represent use and operation. While hours of occupancy are clearly an occupier requirement, responsibilities for poor *control and management factors* can be difficult to identify uniquely. Designers often blame managers and users for wasteful operation of engineering systems, while in fact the installation is impossible to control in the manner they envisaged, with deep-seated problems, including poor usability.

Tree diagrams can be constructed on the same principles as Figure 1 for all energy sources in a building and all end-uses, e.g. fans, pumps and office equipment.

- Sometimes one end use will require information for several sources of energy: for example heating may have fuel, renewable and electrical components.
- The metrics at the bottom left will differ by end use: for example ventilation plant duty in litres/second and efficiency in Watts per litre/second.
- Sometimes not all the boxes will be filled: for example, for electronic office equipment: a W/m^2 figure at the middle level may be sufficient: this should be a typical in-use value; not a nameplate value. Sometimes the energy requirement of an end-use may be metered directly, for example chiller plant or a server room.
- For buildings in use, it may be difficult to estimate the control and management factor directly for some end-uses, but the calculation can be done top-down. For the end-use concerned: 1). calculate the equivalent annual full-load running hours, by dividing annual energy use by the installed load; 2). divide this by annual occupancy hours to obtain the control and management factor.

Each box in the tree diagram may also be used to express benchmarks. Some values already exist in some client standards (e.g. design heat gains from office equipment in W/m^2), engineering specifications, and regulatory procedures (e.g. for specific fan power and lighting efficiency). Equivalent full-load running hours and the control & management factors are much less widely reported, but can be highly revealing. The same tree diagram approach can also be used to show average actual power density in use on the left side and actual hours of use on the right.

The TM22 approach was used to prepare the second (1998) edition of *Energy Consumption Guide 19* for offices, ECON 19 [vi]. This included not only Typical and Good Practice benchmarks for annual electricity and heating fuel consumption for four examples of naturally-ventilated and air-conditioned buildings, but histograms and tables for ten energy end-uses. Behind this lay a simple “benchmark generator” spreadsheet model including tree diagram values that had been reconciled with bulk and case study data. The tree diagram benchmark elements for lighting, fans and office equipment were also reported in the publication.

3.0 Display Energy Certificates and the associated benchmarks

In the event, the EU's anticipated requirements for energy labelling did not arrive until December 2002, with the Energy Performance of Buildings Directive, EBPD [vii]. Amongst other things, the EPBD required energy certificates to be displayed in public buildings and buildings frequently visited by the public of more than 1000 m^2 usable floor area.

In response, in mid-2006, the British government decided to implement Display Energy Certificates (DECs) for public buildings in England and Wales, using an Operational Rating based on actual metered energy use, renewed every year. *[Northern Ireland also adopted the system, as did the Irish Republic. Scotland chose to display an Energy Performance Certificate, based on calculated not actual performance].*

The EPBD required energy certificates to include an indicator of energy performance, together with suitable benchmarks. In late 2006 DCLG, the Ministry responsible, asked CIBSE to review existing benchmarks and make recommendations for DECs.

A benchmark is a point of reference for measurement: the better the reference, the more meaningful the measurement. The review for CIBSE [viii] identified severe limitations with the available benchmarks for non-domestic buildings, as collated in Section 20 of CIBSE Guide F:

- Most were based on information 10-20 years old from the government's Energy Efficiency Best Practice programme (EEBPp), which had researched and produced a wide range of Energy Consumption Guides in the 1990s.
- They had been prepared by different teams, with little consistency of approach.
- Few gave much information on where the energy was going, making them of little help in identifying potential improvement measures.
- They could reinforce the status quo, for example giving elevated benchmarks to air conditioned buildings. Whether or not these were deserved required careful examination, in the light of the policy requirement for rapid reductions in energy use and greenhouse gas emissions.

The benchmarking process proposed for DECs had three main components:

- A drill-down strategy, with a simple entry level, based on annual fuel/heat and electricity use per m^2, including a headline comparison in units of CO_2 emissions.
- A limited set of benchmark categories (29 were finally chosen) for fuel/heat and for electricity, based on lightly-used examples of a limited range of building types, with the option to combine up to five categories to represent mixed-use buildings.
- Mandatory adjustments, e.g. for weather, applied to the benchmarks.
- Optional adjustments, for use where people felt the entry level did not take proper account of the nature of their building, e.g. if it contained "special" items like data centres or regional server rooms, or had long occupancy hours.

Such optional adjustments would only be permitted if they had been examined rigorously using accredited procedures, e.g. with the "special" items sub-metered and accompanied by a report on their energy efficiency and potential for improvement.

DCLG accepted CIBSE's recommendations. During 2007, initial "placeholder" benchmarks were developed. These were published in TM 46 [ix], with the procedure documented in TM 47 [x]. In anticipation of extending DECs, TM 46 covered all non-domestic building types, not just the mandated public sector buildings. However, it was recognised that 1) the benchmarks for public buildings would be reviewed and reconsidered in the light of initial results and 2) much more work on benchmarking was required for the private sector.

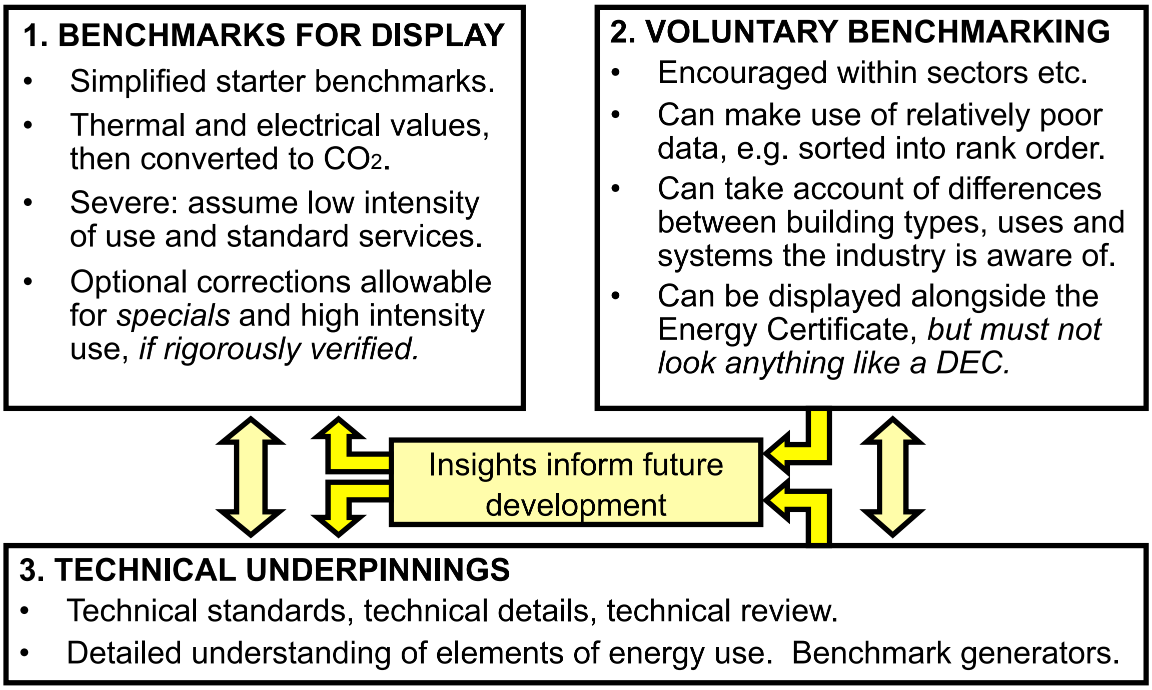
The TM 46/47 procedure signalled a switch towards tailored benchmarking in several respects, in particular the treatment of “specials” and the ability to create composite benchmarks for mixed-use buildings. Instead of normalising a building’s energy use to compare with fixed benchmarks, the benchmarks are adjusted for weather and occupancy. The approach has several advantages: a consistent system, particularly when making updates; avoiding confusion between absolute and normalised data; and integration with other systems including carbon accounting, carbon trading and portfolio aggregation, that need to take account of absolute, not normalised data. One disadvantage is that different buildings can be compared with each other only on the basis of a dimensionless performance indicator - their numerical DEC rating.

It was recognised that the more intensively-used examples of a building type (which also tend to be more common in the private sector) were likely to get poorer grades when DECs were first introduced. For example, “specials” might not be metered; and no robust, low-cost method to account for high densities of occupation could be devised that did not open the system to major risks of misuse by the unscrupulous.

To overcome such problems, additional voluntary sector benchmarks were expected to provide some comfort. For example, a building’s performance might look poor on an absolute scale, but better in comparison with its peers. DCLG’s published guidance [xi] therefore allowed additional information to be displayed alongside a DEC: this could, for example, show how a building related to its peer group; or take account of variables, like occupancy levels, that were too difficult or expensive for the DEC process to collect and verify. *[The Low Carbon Workplace has since developed a benchmark for offices based on occupancy, but it is costly to implement unless the building has good access control and occupancy monitoring systems. The Better Buildings Partnership is considering an “investment-grade” operational energy rating for landlord’s energy services in rented offices].*

4.0 Strategy for support and development of benchmarks

For the longer term, the CIBSE review identified a need to develop a more integrated approach, that would make closer connections between benchmarking annual energy use at the headline level and the finer technical details of interest to services engineers and building managers. The principles are illustrated in figure 2, which was used in presentations of the 2007 review.



1. BENCHMARKS FOR DISPLAY

- Simplified starter benchmarks.
- Thermal and electrical values, then converted to CO_2.
- Severe: assume low intensity of use and standard services.
- Optional corrections allowable for *specials* and high intensity use, *if rigorously verified.*

2. VOLUNTARY BENCHMARKING

- Encouraged within sectors etc.
- Can make use of relatively poor data, e.g. sorted into rank order.
- Can take account of differences between building types, uses and systems the industry is aware of.
- Can be displayed alongside the Energy Certificate, *but must not look anything like a DEC.*

3. TECHNICAL UNDERPINNINGS

- Technical standards, technical details, technical review.
- Detailed understanding of elements of energy use. Benchmark generators.

Figure 2 – Strategy for the support and development of benchmarks

Figure 2 shows:

- 1. At the top left, statutory benchmarks for DECs. As discussed, these were designed to be rigorous, but somewhat simple and brutal, at least to start with.
- 2. At the top right, voluntary benchmarks, often based on ranking within peer groups. Sector insights would be invaluable when determining appropriate classifications and metrics to go with the grain of industry practices.
- 3. At the bottom, the technical underpinnings, for example using EARM principles and other insights (e.g. on the performance and promise of a particular energy-saving technique or technology), to help support statutory and voluntary reporting and benchmarking.
- In the middle; and forming part of the technical underpinnings, a mechanism for using the insights from all three types of activity to inform future development, including impartial advice to government on the evolution of the DEC system.

At the time of CIBSE's review of the benchmarks for DCLG, DECs were expected to become a vital policy instrument, given the national importance of energy and carbon saving; and with non-domestic buildings responsible for a reported 18% of UK carbon emissions [xii] and offering potential for rapid, low-cost savings by engaging management.

Unfortunately, the global and national economic situation then changed for the worse and government cut its budgets. In 2010, the new government instigated many more cuts, including all funding to the Carbon Trust; a “one in, two out” policy for legislation; it also showed increasing hostility to EU Directives. DECs suffered badly, in spite of representing a fundamental indicator and potential motivator of energy saving in non-domestic buildings. In 2011, a report by industry stakeholders [xiii] identified DECs as the focal point onto which many independent policy measures could converge, including smart metering, mandatory energy audits, the CRC Energy Efficiency Scheme and verification of designed performance. In spite of this, DECs were not mandated for private sector buildings. And despite a newly available rich dataset of operational energy data from the DEC records for public buildings, there has been no investment in refining the benchmarks, nor in better benchmarking in general.

5.0 Tree diagrams and tailored benchmarking

Tailored benchmarking based on tree diagrams creates a rich language for communicating energy performance and could help to anchor a common reporting and benchmarking framework. For example, tree diagrams allow one to:

- Talk not just about overall annual fuel, electricity and CO_2 benchmarks, but their components, for example the W/m^2 of any installation and its typical hours of full-load operation. This can bring revelations: in one award-winning building, the claimed gas consumption equated to 50 equivalent full-load running hours per year of the plant: to know that a typical value was 1000 would have provided a valuable reality check. In the event, the in-use figure was about 1250 hours.
- Create benchmarks for winter and summer peak and night loads, e.g. what is a realistic W/m^2 electrical baseload in an office?
- Do calculations, e.g. *What if we halved the installed load of the lighting?* This would have very different effects depending on hours of operation.
- Benchmark at any scale, e.g. for a room, a zone, a building, or a set of buildings.
- Mix up the scales, using a fine grain for some items and a coarser grain for others. All that is necessary is to avoid omissions or double-counting.
- The algebra also allows benchmarks to be adjusted for the actual schedule of accommodation of a building, the equipment installed, and the hours of use.
- With consistent conventions, compare anything with anything else, for example one building with benchmarks or with another, and design with in-use data.
- Make comparisons across sectors. For many purposes, classification by sector may be unnecessary: the tailoring process takes account of the variations.

In 2001-2, principles from CIBSE TM22 were used to demonstrate a prototype “tailored benchmarking” approach that might supersede ECON 19 for offices.

Most benchmarking only tells you how you relate to peers and statistical distributions. Tailored benchmarking can tell you where you stand in relation to good, typical or poor practice for a building with identical activities to yours; it can also tell you why; and help you to understand what you can do about it and what the consequences might be. Tree diagram values can be populated from a wide range of sources, providing transparency between results – ranging from simple estimates and rules of thumb to the outputs of sophisticated monitoring and modelling.

In 2002-04, Europrosper, an EC research project, embedded office tailored benchmarks in proof of concept software for prototype DECs, with considerable success. A small amount of data (building size, servicing type, and annual energy use), could produce initial estimates of energy end-use breakdowns, the potential for making savings, and how much this might cost. These could then be fine-tuned as necessary by the assessor.

The approach was promising, but no funding was available at the time to extend it to other sectors. As a result, a simpler approach had to be adopted for DECs, as outlined in Section 3. Nevertheless, the DEC system was able to use some of the insights gained to include a limited amount of benchmark tailoring, with the expectation that more would follow. If this were now to happen, it would help all sectors gain confidence in the applicability of DECs to their particular circumstances.

6.0 ECON 19 tailored benchmarks for offices

The 2002 prototype spreadsheet for offices [xiv] generated tailored benchmarks from simple schedules of accommodation, servicing systems, occupation and use. Backward-compatibility to the benchmark generator used to underpin ECON 19 allowed a single set of algorithms to reproduce the typical and best practice benchmarks for the four iconic Types of office in the printed 1998 version to within two percentage points. A tree diagram approach was used for reporting, but the calculation algorithms for most end uses were more complex than figure 1 might imply. For example, the fabric and ventilation components of the heating requirement were calculated separately, as were warm-ups for each occupancy period. For lighting, the contribution of daylight was reduced as operating hours were extended. There were also calculations for the contribution of night and weekend loads to the overall annual hours run. No allowance was made for internal gains affecting heating and cooling loads; but such refinements could be added later.

The major variables defining the office space were:

- Four types of office area: cellular, open plan, call centre, and dealing room, measured by nett lettable area (NLA) and/or percentage of total NLA.
- Circulation/support space within the NLA and common parts outside it.

For each area above, the user could input:

- Workstation densities.
- Weekday, Saturday and Sunday occupancy hours and percentage occupancy.
- Percentage of the area with good daylight.
- Naturally-ventilated, air-conditioned or mixed-mode HVAC systems.

In terms of servicing, users could select the percentage of heating, hot water and humidification (if any) provided by electricity and cooling by chilled water.

The method also took explicit account of “special” areas and items found in offices that can significantly affect energy consumption, specifically:

- Catering - both for central kitchens and for local/vending facilities.
- Communications rooms, server rooms and data centres.
- Lifts/elevators, with the storey height of the building influencing the consumption index.

- User-defined special areas, e.g. car parking (surface, a parking structure or a basement), storage areas, residential, shops, sports facilities and laboratories.
- User-defined special end-uses, e.g. floodlights and fountains.

Four alternative methods were provided to calculate the energy use of “specials”:

1. Standard benchmarks where they existed, e.g. for a catering kitchen.
2. Based on component analysis, e.g. energy use per hot meal **x** number of meals.
3. Load density **x** area **x** hours, for a machine room, plus air conditioning allowance.
4. Incorporating sub-metered data for the item concerned.

Europrosper’s EU partners liked the system, but made the following suggestions:

- Include more comprehensive area descriptions, to allow for mixed uses.
- Allow more choice of HVAC systems, separating ventilation and cooling.
- Include correction of heating and cooling requirement in relation to internal gains.
- Only allow benchmarks to be increased for air-conditioning in noisy city centres or where there were high occupancy densities.
- In spite of their cold and dry winter climate, the Swedish partners regarded humidification as completely unnecessary in an office, and recommended that no benchmark allowance was made for it.

The approach developed for offices provided a foundation for piloting tailored benchmarks for schools in 2013. It was also used successfully in 2002 for estimating energy use of sports centres at the design stage, using rules of thumb agreed with leading designers.

7.0 Tailored benchmarks for schools

In 2013, with EPSRC funding, some of the authors undertook a pilot study of the applicability of tailored benchmarking to school buildings. Measured energy performance data was available from multiple sources, including:

- DEC data to 2012 for 6,686 primary schools and 1,045 secondary schools.
- More detailed analysis of the latest DEC data for all schools in Wales.
- 21 new secondary schools completed under the Building Schools for the Future (BSF) programme.
- A report to the Education Funding Agency [xv].
- A thesis with case-studies of five new City Academies (secondary schools) [xvi].
- Case studies of four secondary schools from the Building Performance Evaluation programme sponsored by the Technology Strategy Board.

The data analysis identified:

- Median energy use for heating from DECs of 125 kWh/m^2 per year for primary schools and 124 kWh/m^2 for secondary schools (both normalised to 2021 degree-days to a 15.5°C base) in relation to a TM 46 benchmark of 150 kWh/m^2.
- Median electricity use from DECs of 44 kWh/m^2 for primary schools and 51 kWh/m^2 for secondary schools, against a TM 46 benchmark of 40.
- Welsh schools using 7% more heat and 18% less electricity on average.
- Disappointingly, the new BSF secondary schools used as much energy for heating as the existing stock and much more electricity, median 76 kWh/m^2.

The data were used to create a tree diagram model to estimate all energy end uses for each activity taking place in a school, at three different levels of performance:

1. TYP, typical for the existing stock, consistent with the medians of the bulk data.
2. SNB, Standard New Build, consistent with the performance of new schools being designed today to satisfy current standards and requirements.
3. ANP, Advanced/Best New Practice, representing what might be considered technically feasible and cost effective using available technology, if taking a life cycle view.

The allowances were calculated on the basis of the activities accommodated in the building and its intensity of use *(i.e. what a building does),* not its technical characteristics *(what a building is).* The difference between the two approaches is illustrated by comparing the 'absolute' reference used by DECs (which start with the same basic benchmark however a building is serviced) with the 'relative' basis used in recent years for Building Regulations Part L compliance, albeit under standardised conditions of use (activities) and occupancy (density and hours).

- Part L requires the proposed building to perform better than a "notional" building, identical to the building proposed in shape and form, with the same servicing systems as in the proposal, but at prescribed minimum levels of fabric and plant efficiency. This can have the perverse effect of making it easier to obtain compliance by adding services (provided these are relatively efficient), than by having a lower-energy building that uses fewer services.
- The EPC uses a similar calculation, but for this purpose the predicted performance of the building is evaluated against a fixed reference specification.

As a result, some new buildings can be approved for construction that have EPC ratings that are worse than the 'relative' benchmarking philosophy adopted in the building regulations compliance calculations might be seen to imply.

In order to prepare tailored benchmarks for a school, the input characteristics that might be requires from a non-technical user include:

- Gross internal floor area (GIA) and Numbers of pupils on the Roll.
- Number of classrooms and of science, IT or DT labs or teaching spaces.
- Typical hours of use of spaces including out of hours use by the wider community.
- IT infrastructure: cloud or local servers.
- Uses of the main hall, e.g. assembly, dining, dry sports.
- Catering facilities and services provided on site and off site.
- Wet sports facilities.
- External lighting, including car parks and floodlights for sports pitches.
- The presence of separable, special or other energy uses.

To avoid over-burdening respondents, it was decided to seek inputs in three stages:

- **Tier 1**: Quick start, using the basic inputs shown in Table 1 to infer a schedule of accommodation based on school specifications from Building Bulletins BB98 [xvii] and BB99 [xviii] and to create an initial benchmark, displayed on a graph. An example is shown in Figure 3 below.
- **Tier 2**: What the building does. This requires more detailed inputs to refine the inferred schedule of accommodation and energy use and revise the benchmarks.
- **Tier 3**: What the building is, to identify its current state and the services actually present, to allow building-specific improvement measures to be identified. Being more appropriate for use by experts, this part of the model was not developed in the pilot stage.

ASPECT	INPUT REQUIRED FOR TIER 1 – QUICK START
School type	Primary, secondary or special. Is there an additional sixth form?
Capacity	Maximum number of pupils. Current number of pupils enrolled.
Size	Gross internal floor area.
Energy	Current annual consumption: Electricity (kWh) and Gas (kWh).
Usage	Number of terms per year (3 or 4). Term dates. Number of days per half term.

ASPECT	INPUT REQUIRED FOR TIER 2
Ventilation	Does traffic or other high outdoor noise source preclude openable windows?
Accommodation	Option to override default area values and identify any out of hours use.
Catering	Hot meals prepared on site, or reheated? Are meals prepared for eating offsite?
ICT	Do ICT rooms contain laptop or desktop computers? Total number of desktop computers? Is there an onsite server? Total number of interactive whiteboards, inkjet printers, laser printers and photocopiers.
Lifts/elevators	Maximum number of storeys? Are there wheelchair users in the building?
External	Presence of playing field floodlights and car park lighting.
Special items	Identify presence of Kiln rooms, Manufacturing workshops, Recording studios, CCTV, Sports facilities, Swimming pools. Ask about any other high-energy activities or equipment.

Table 1 Input data requested for school benchmarking in Tiers 1 and 2

Tailored benchmarking can create realistic energy budgets, for example appropriate ventilation rates can be included in the underlying algorithms, so that low energy use is not achieved at the expense of poor indoor air quality. *[It is of interest that the EPBD did mention safeguarding indoor climate conditions: the Europrosper project therefore developed a very simple occupant satisfaction questionnaire, for use in conjunction with DECs. However, no European government took this up].*

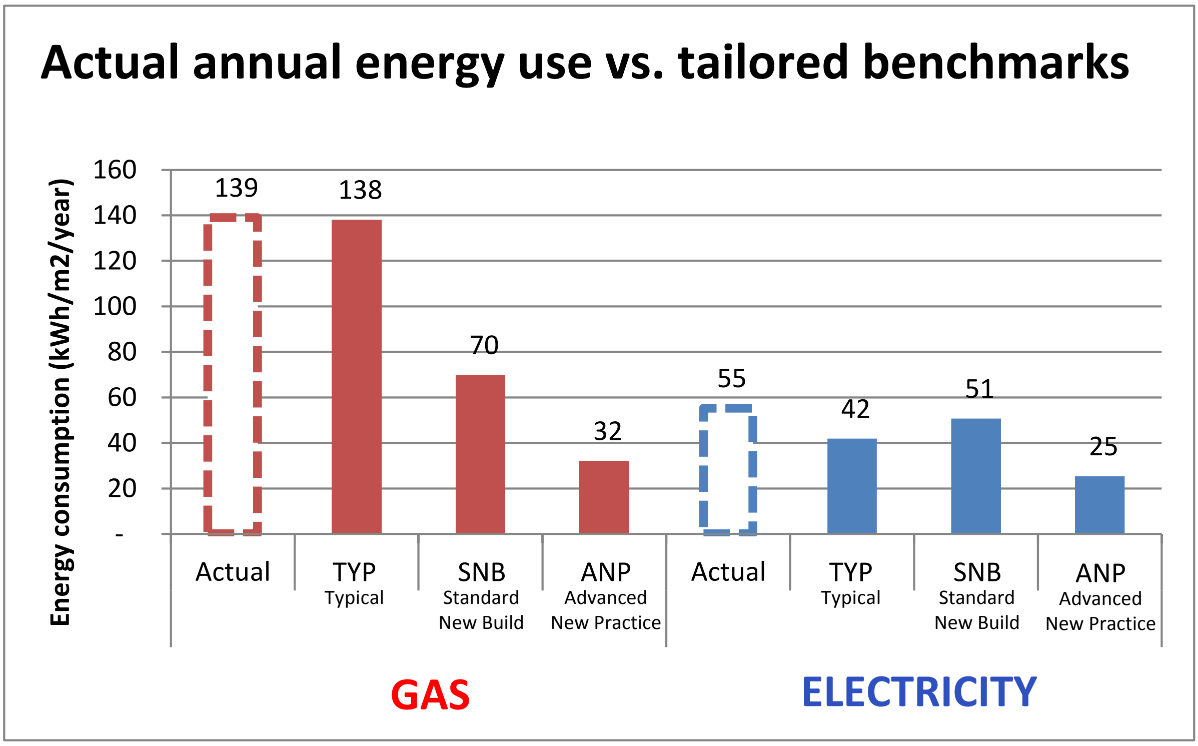


Figure 3 Benchmark comparison graphic produced by Quick Start

8.0 Conclusions

Tree diagrams and tailored benchmarking offer the potential to revolutionise the way we communicate and benchmark energy performance, with a universal system that can cover all sectors. They can take better account of context, addressing stakeholder concerns about their relevance. They can improve transparency between design intentions, individual outcomes and bulk data. Most importantly, they can be action-oriented, sharpening the focus on understanding and improving in-use performance for a wide range of participants: from those responsible for procuring, designing, constructing, equipping, operating or improving the buildings concerned to policymakers seeking to understand what is going on and what changes to policy might be required. The common language could also help to bring together what are currently a disparate set of buildings and energy policy measures.

Tailored benchmarking can be used in several different ways, as shown by examples in the paper. It can both produce absolute standards that might be considered reasonable for typical, new and advanced buildings containing particular activities; and can help to create targets for a specific building that take sensible account of its context and potential, given its existing fabric, services and equipment.

The universal availability of computing power allows a simple and relevant user experience to be supported by a large number of calculations, which however can use the common language of tree diagrams to communicate their results. It also permits the incorporation into benchmarking systems of automatically recorded data, both from main and sub-meters.

Dilemmas associated with the application of tailored benchmarks to DECs include, for example:

- The balance between asking for more data to enable better tailoring, the level of accuracy required, and the extra cost and effort. Is it better to retain something similar to the existing DEC system as a low-cost entry level, with tailored benchmarks as an optional next step for motivated clients and expert assessors?
- Repeatability and the audit trail required for QA. This in turn raises questions about whether variables (e.g. occupancy hours) should be continuous or in notches.
- Judging which end uses are allowable (e.g. humidification in offices) and how to compare (say) offices with onsite and offsite servers and cloud computing.
- The extent to which allowances should be made for HVAC systems that are sometimes essential, for example mechanical ventilation or air conditioning in noisy external environments.
- Accounting for intensity of use, e.g. workstation density, bedroom occupancy in hotels, restaurant covers in catering, footfall in retail. Many intensity factors are difficult and costly to measure reliably and can be commercially confidential.

We do not think these create insuperable barriers to constructing an effective benchmarking system that can suit all sectors. However, it is important that efforts are focused and coordinated. The authors see an urgent need for an independent Technical Platform for understanding, communicating and benchmarking building energy performance that is firmly based in the evidence and is able to learn from, support and challenge industry, government, the professions and academe.

References

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i See *The new Energy Star Portfolio Manager,* viewed 1 Dec 2013. www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/use-portfolio-manager/new-energy-star-portfolio-manager.

ii Energy Consumption Guide 19, *Energy efficiency in offices,* London: HMSO for Energy Efficiency Office, 1991.

iii All the Probe studies and review articles can be downloaded from the CIBSE website at www.cibse.org/index.cfm?go=page.view&item=2481 .

iv Technical Memorandum TM 22, *Energy assessment and reporting methodology: the office assessment method,* CIBSE, 1999.

v Field J, Soper J, Jones P, Bordass W & Grigg P, *Energy performance of occupied non domestic-buildings: Assessment by analysing end-use energy consumptions,* Building Services Engineering Research & Technology 1997, 18 (1), 39-46.

vi Energy Consumption Guide 19: *Energy use in offices,* Energy Efficiency Best Practice programme, 1998. This was reprinted (with occasional small modifications) by the Carbon Trust until 2012. The 2000 edition can be downloaded from CIBSE www.cibse.org/pdfs/ECG019.pdf

vii *Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the Energy Performance of Buildings,* Official Journal of the European Communities, 4 Jan 2003, L1, 65-71.

viii Bordass B & Field J, *Energy and* CO_2 *emissions benchmarks for non-domestic buildings,* unpublished report to CIBSE and DCLG, Jan 2007.

ix Technical Memorandum TM 46, *Energy benchmarks,* CIBSE, 2008.

x Technical Memorandum TM 47, *Operational ratings and Display Energy Certificates,* CIBSE, 2009.

xi Department of Communities & Local Government, London, *Improving the energy efficiency of our buildings: a guide to Display Energy Certificates and advisory reports for public buildings,* May 2008, 31.

xii Carbon Trust, *Building the future, today: Transforming the economic and carbon performance of the buildings we work in,* Report CTC 765, November 2009.

xiii UK Green Building Council, *Carbon Reductions in Existing Non-Domestic Buildings,* Task Group report on Display Energy Certificates and the Carbon Reduction Commitment Energy Efficiency Scheme, March 2011, 20.

xiv William Bordass Associates, *Tailored energy consumption benchmarks for offices,* Unpublished reports 2001-2. See also Boonstra C, Cohen R, Bordass B, Field J and Clocquet R, *Europrosper: experiences in energy labelling of existing buildings,* Proceedings of the Sustainable Building Conference, Tokyo, Paper 11-033, 2005

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xv Priority School Building Programme: Baseline designs for Energy Efficiency, unpublished report to the Educational Funding Agency, London, November 2012.

xvi Pegg, I, *Assessing the role of post-occupancy evaluation in the design environment – a case study approach*, EngD Thesis, Brunel University, London Oct 2007. See also Pegg, I, Cripps A, and Kolokotroni M, LB-07-001, *Post-Occupancy Performance of Five Low-Energy Schools in the UK.* ASHRAE transactions 113.2, 2007, 3-13.

xvii Building Bulletin 98, *Briefing Framework for Secondary School Projects,* London: Department for Education and Skills, 2004.

xviii Building Bulletin 99 (2nd Edition), *Briefing Framework for Primary School Projects,* London: Department for Education and Skills, 2004.