Onto the Radar:

How energy performance certification and benchmarking might work for nondomestic buildings in operation, using actual energy consumption

Preface

The Usable Buildings Trust's mission is to improve the performance of buildings by understanding how they actually work, using this knowledge to improve client requirements, industry practices, regulation, product development; and the related investment and management processes.

Scientists are now clear that the world needs to reduce its carbon dioxide emissions. Energy use in buildings accounts for a lot of these - 50% in the UK. But building energy performance is not yet seriously on the radar of most organisations[1]. Design estimates can also be much less than in-use outcomes. To improve, we need to make performance visible and to close these credibility gaps.

The EC's Energy Performance of Buildings Directive is encouraging this visibility by requiring buildings to have energy performance certificates, starting in 2006. So far most of the effort has been put into predicting the energy use of new construction and empty property on the market - the "Asset Rating". The "Operational Rating" - which takes account of actual energy use of an occupied building - has received less attention. UBT is therefore keen to consider how Operational Ratings might be brought into service quickly and to greatest effect whilst minimising all unnecessary effort.

This paper examines some of the issues, and explores ways in which statutory requirements and voluntary enhancements might be combined in non-domestic buildings. Grounded in work in the UK - in particular a study for the Sustainability Forum in January-March 2005 - it attempts to take a broader view and incorporates the comments of many people in the UK and in Europe[2].

The stepwise approach we outline would allow people to progress from very easy entry levels (e.g. just reporting their energy use systematically), through simple benchmarking, to more customised assessments. Such an approach could help statutory systems for energy certification of buildings in use to get going quickly without heavy resourcing and training implications: first encouraging people to get a few facts straight and then to progress to more detailed levels of assessment and improvement, either through their own motivations or under pressure from stakeholders.

We suspect that the more detailed levels of assessment would not form part of the initial statutory implementation of Operational Ratings, certainly for most building sectors in most countries. However, the strategy outlined would permit such systems to be developed in parallel on a voluntary basis; and some sectors are already beginning to express interest in these ideas.

Ideally, standard conventions would underpin these detailed implementations, allowing them to be strategically integrated, and so able to exchange information (e.g. for mixed use buildings) and perhaps even to converge eventually into a single harmonised system. Once a more sophisticated system had become properly bedded-in technically in a sector, and had gained the confidence of major players, it could seek to become accredited as a more insightful way of meeting the statutory requirement. Eventually such approaches might even become part of an integrated statutory system.

To turn these ideas into practical systems, there is much devil in the detail. However, this need not get in the way. If we know where we want to go, a unifying strategy could allow rapid initial action, with progressive improvements being incorporated as they become available. UBT hopes this paper can assist not just the debate, but reducing the contribution of buildings to climate change.

CONTENTS

1	**Reporting energy performance**	**2**
2	**Grading energy performance**	**3**
3	**Moving forward**	**4**
4	**Making operational ratings work for nondomestic buildings**	**4**
5	**Approaches to benchmarking energy performance and CO_2 emissions**	**5**
6	**A graduated response to the benchmarking process**	**6**
7	**Conclusions**	**8**
Appendices		
A	**The devil in the detail**	**9**
B	**What's in a benchmark?**	**12**
C	**Transparency between expectations and outcomes using tree diagrams**	**13**

1 W Bordass, *Flying Blind: Everything you wanted to know about energy in commercial buildings but were afraid to ask,* Association for Conservation for Energy and EEASOX (2001). Downloadable from www.usablebuildings.co.uk

2 Through the EPLabel project (www.eplabel.org) under the Intelligent Energy for Europe research programme. This started in January 2005 and involves nineteen countries in developing a common platform for operational ratings.

How energy performance certification and benchmarking might work for buildings in operation, using actual energy consumption *a discussion paper by Bill Bordass*

1 Reporting energy performance

1.1 ENERGY PERFORMANCE CERTIFICATION

At the end of 2002, the EC announced its Energy Performance of Buildings Directive, EPBD[2]. Amongst other things, this requires buildings to be provided with energy certificates at the point of completion, sale or rental, and for open display in public buildings over 1000 m^2 floor area[3]. The certificates - which are for information only - are required to include reference values such as current legal standards and benchmarks and may include an indicator of CO_2 emissions. They must also be accompanied by recommendations for the cost-effective improvement of energy performance.

1.2 CALCULATED OR MEASURED ENERGY PERFORMANCE?

The EPBD needs to be transposed into national law 4 January 2006, with a 3-year phase-in period, subject to EC approval of member states' programmes. For new, refurbished and empty buildings, the energy performance will need to be based on theoretical calculations. For buildings in use, there is the opportunity to base the certificate on actual fuel consumption. Indeed, the EPBD requires the certificate to "describe the actual energy-performance situation of the building to the extent possible"

1.3 THE PROPOSED UK APPROACH

In 2004, the UK consultation suggested an approach with three routes into energy certification[4]:

1. *For new designs or building works*, a *Design Rating (DR)* is calculated. A suitable DR will mean that the design accords with Building Regulations AD Part L. When the work is complete, approval depends on re-calculation based on what was actually built, and produces an *Asset Rating (AR)*. BRE is developing a National Calculation Method (NCM) for ARs.
2. *For existing buildings on the market,* an AR is also required, but most are unlikely to have good quality design data ready to hand. BRE is therefore developing methods of generating input data for the NCM by inference from a quick survey of features.
3. *For buildings in use for which fuel consumption data is available,* an *Operational Rating (OR)* can potentially be calculated from the actual annual fuel consumption.

1.4 THE PROPOSED CEN APPROACH

In its draft standards to underpin the EPBD[5], CEN (the European Committee for Standardisation) has accepted the idea of DRs, ARs and ORs.

- The DR and AR are based on calculations of the energy used for heating, cooling, ventilation, hot water and lighting using standardised input data related to climate and occupancy[6]. These are most relevant to people wishing to compare buildings on the market.
- The OR measures the in-use performance. It includes all fuel and energy used for all purposes, and so takes account of all differences between calculated and realised attributes. It is of particular relevance to building management. It can also provide useful feedback.to owners, occupiers and designers; and help to validate models used to calculate the AR.

1.5 ENERGY PERFORMANCE

CEN defines *Energy Performance* as the annual consumption by the building of all fuels, district heating and cooling, electricity etc. (the generic ISO term is "energywares"), under the appropriate conventions - each separately measured and where necessary combined into a single number using an appropriate weighting system. The UK is likely to use CO_2 weightings (e.g. in kg CO_2/kWh for each energyware), but other countries may well adopt other factors (e.g. primary energy ratios) to take account of their national or regional energy economies and the appropriate policy drivers.

1.6 ENERGY PERFORMANCE INDICATOR

The Energy Performance may be converted into an *Energy Performance Indicator (EPI,* either for each energyware or for the weighted total), by dividing it by a measure of extent of the building. This will normally be floor area (to agreed definitions). Other denominators (e.g numbers of hotel bedrooms, children in a school, or annual person-hours of occupancy) might also be used.

---

2 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, L1/65-71 (4 January 2003).

3 The precise wording is *Public authority buildings and buildings frequently visited by the public,* though initial application is likely to be for public authority buildings over 1000 m^2, frequently visited by the public.

4 *Proposals for amending Part L of the Building Regulations and Implementing the Energy Performance of Buildings Directive*, Office of the Deputy Prime Minister (July 2004).

5 CEN/TC89, prEN Drafts 15203, 15217 and the Umbrella Document, available from BSI, consultation closes Jul-05.

6 Where AR is completely inappropriate (e.g.for a 24-hour facility), a *Tailored Rating (TR)* may be calculated instead.

2 Grading energy performance

2.1 REFERENCE VALUES AND BENCHMARKS

In order to judge if a building's energy performance (or energy performance indicator) represents good energy efficiency or not, the EPI needs to be compared with something to calculate a *Grade:*

- *Asset Ratings,* being based on calculation for a subset of end uses, can be compared with other calculated values. A common approach used in modelling is to establish a *reference building* -similar to the actual building but with standard technical characteristics (e.g. a deemed-to-satisfy specification for building regulations). The ratio between the building's energy performance and the reference value can then be used to produce a Grade. For regulatory purposes, any building with energy performance better than a target level passes.
- *Operational Ratings,* being based on the (weighted) energy a building actually uses or the CO_2 it creates, cannot be compared with reference values in quite the same way. These are normally compared with *benchmarks,* usually derived from the measured performance of the building stock, often statistically. However, many EC countries do not have such benchmarks; and where benchmarks do exist (as in the UK), they are not always appropriate to the building under consideration. For example, benchmarks tend to have been area-based. While area is the most practical denominator for many reasons, modern commercial buildings tend to use their floorspace more intensively: for such buildings, a high energy use in relation at a historic benchmark may not necessarily mean inefficient. Section 5 outlines a strategic approach to benchmarking buildings in use which can take account of such complexities.

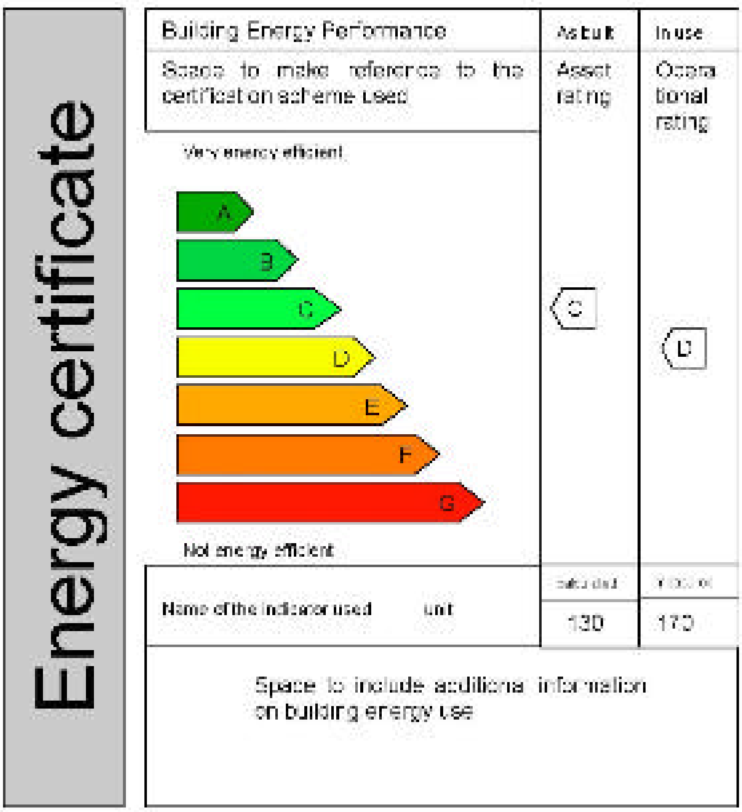
Appendix B considers general issues affecting the selection and use of benchmarks in more detail.

2.2 ASSIGNING A GRADE

The EPBD does not strictly require a grade, merely reference values against which a building's energy performance may be compared. However, CEN proposes calculating a ratio, C:

- For *Asset Ratings,* C puts the statutory requirement as the denominator, so if C is less than 1 the building passes. However, many existing buildings will have C much greater than 1.
- For *Operational Ratings,* a similar scale is suggested, but with a second calibration point - a C-value of 2 for the Typical benchmark based on the performance of the building stock.

CEN proposes converting C into a letter grade (CEN calls it "class"), as for electrical appliances. A C of less than 0.5 would rate a building Class A; between 0.5 and 1 Class B; and so on up to Class G if C is 3 or more. Other scales are possible. When a building is completed, sold or rented, it will have an Asset Rating only, while for public display in buildings in use, an Operational Rating will normally be required. Where both Asset and Operational Ratings are available or required, CEN proposes a two-column certificate, see below. Otherwise only the relevant column will be shown.



3 Moving forward

3.1 Much of the activity throughout the EU to date has been on the calculation of Asset Ratings. Operational Ratings have received less attention, with some countries starting their implementation with ARs only. However, other countries have recognised that rapid reductions in CO_2 emissions are essential to the planet's survival as we know it; and since buildings are responsible for 40% of the EU's CO_2 emissions (and 50% of the UK's) it is vital to improve energy performance not just in theory, but very much in practice. And the most rapid improvements available are not in the construction of a building, but in how it is equipped, upgraded, used, controlled and managed. Facilities managers, dealing with fuel bills, also relate more directly to Operational Ratings.

3.2 THE MISSING LINK
To make these rapid improvements, we need to create closer matches between expectations and outcomes, so that we can close the credibility gaps which so often arise between design intent and achieved performance[7]. For example, at present it is not unusual for new, "green" buildings to use more energy and have higher CO_2 emissions not only than the design expectations but sometimes also than their predecessors. However, while bringing ARs and ORs together on the certification graphic, the current CEN proposals still see them as significantly different - ARs being theoretically calculated for a subset of energy uses, whilst ORs are in actuality, for everything. However, although differently computed, they are not from two separate worlds: the underlying components of ARs and ORs can be summarised in the same way. We therefore advocate using a common descriptive system which can underpin both, provide a degree of transparency, and so begin to bridge the credibility gap. Its effective use would lead both to better predictive measures and to more rapid and effective reductions in energy wastage and CO_2 emissions. The description could be based on tree diagrams (see Appendix C)[8] and applied on a progressive basis. One can start with a only a small amount of data; it is not necessary to know everything.

4 Making operational ratings work for nondomestic buildings

4.1 THE NEED FOR BENCHMARKING
Benchmarking can help us to understand and to reduce the energy use of a building. Done well, a greater visibility of building performance could release a wide range of drivers, helping to provide a common sense of purpose for the often poorly-connected range of players involved in developing, financing, designing, building, selling, buying, renting, using, equipping, managing and regulating buildings. Done less well, benchmarking could easily become a piece of red tape which gives false signals and ties up time and money which would be better spent on getting useful things done.

4.2 SOME DIFFICULTIES TO BE OVERCOME
Although ORs get us closer to reality, getting hold of even the simplest data can be time consuming. When doing an energy survey, it is easy to spend longer on finding out how much fuel and electricity was consumed than doing the technical work. For calculating an energy performance index, the denominator (most often building area) can also be elusive, and often not in the same units as those in which the benchmarks are given. Published benchmarks may also be unavailable, or not appropriate for your particular building and the way in which it is equipped and used (see also Appendix B). This causes many people to think it could be too difficult to calculate a rating using actual energy consumption. In this paper, we hope to demonstrate how it can be done.

4.3 GETTING SOME SIMPLE FACTS
To start to evaluate energy performance, you first need to know what the annual consumption of each energyware is, and have some background data on the building against which you can begin to evaluate it. For most buildings, this starts with four key items of data:

1 The annual consumption of electricity.
2 The annual consumption of other fuel and energy supplies (e.g. district heating), by source.
3 The type of building it is.
4 Its measure of extent (normally floor area, in appropriate units).

However, there can often be ambiguities and inconsistencies even in these facts. Some of these are being resolved as part of the Voluntary Energy and CO_2 Declaration protocol, which is soon to be tested by collecting and reporting energy data for a forthcoming (2006) RIBA book on Sustainable Architecture UK. Just reporting the energy performance in clear terms would be a significant move forward, and could be regarded as Level 0 of any energy assessment and certification procedure.

---

7 W Bordass, R Cohen and J Field, *Energy efficiency in non-domestic buildings closing the credibility gap,* International conference on improving energy efficiency in commercial buildings, Frankfurt (20-22 April 2004). Downloadable from www.europrosper.org

8 Some modellers already use tree diagrams to check on the appropriateness of their input and output data.

5 Approaches to benchmarking energy performance and CO_2 emissions

5.1 LEVELS OF BENCHMARKING

One can assess the energy performance of a building in use at five different Levels:

0 *Entry level*. Collecting data and stating a building's energy intensity. A vital stage in getting the key facts straight and making people familiar with the numbers. Several countries are proposing this as the first stage of introducing the EPBD for buildings in use.

1 *Simple* assessment of whole building performance (based on the weighted sum of all fuel and energy supplied) against fixed benchmarks, to produce some sort of grade.

2 *Corrected* for exceptions, where a building and its closest benchmark are not well matched.

3 *Customised*, with benchmarks more closely matched to the building, its equipment and use. Customised benchmarks can be iconic (with a greater range of building types), or parametric (with a variety of choices for key variables affecting energy use) the main focus here.

4 *Modelled* Where good data on the design and use of building is available, one could model its energy use and generate a benchmark, in much the same way as for an Asset Rating reference (see Section 2.1). However for most buildings in use, this data will not be readily available. In addition, the purpose of this calculation is slightly different, see Appendix B.

This paper concentrates on Levels 0 to 3. Over time, procedures used at Levels 3 and 4 are likely to converge, e.g. with more modelling in customised benchmarking, and parametric descriptions allowing better information interchange between models and what actually happens in practice.

5.2 ENTRY LEVEL 0

For most buildings, Level 0 can start with just four pieces of data (see 4.3), but even these can be difficult to find. One could require people to keep them; but in principle much of the data could be made available to them automatically (and to assessors, subject to data protection requirements):

1 *The annual consumption of electricity*. The utility supplier should have this, but because there can many estimated readings (particularly for smaller consumers) it can be difficult to get measurements a year apart. This could be solved by a combination of regulation and remote metering, leading to an *Annual Statement* of consumption, corrected to 365 days[9].

2 *The annual consumption of heating fuel*. Gas and district heating suppliers could potentially provide Annual Statements. Oil and LPG suppliers might too, though with stored fuels there will be uncertainties[10]. Solid fuels would be more difficult to deal with[11].

3 *The type of building it is*. In principle, this could be registered[12].

4 *Its measure of extent* (normally floor area, in appropriate units)[13].

These data will allow a calculation of energy intensity, probably in terms of a weighted index of annual fuel consumption (e.g. as kg CO_2 emissions or kWh primary energy per unit of floor area).

5.3 FIXED BENCHMARKS - LEVEL 1

The UK has a detailed set of benchmarks, developed in various government programmes since the 1970s and now available from the Carbon Trust[14]. Other countries have fewer, and some none. Closer examination of UK benchmarks reveals underlying inconsistencies, for example:

- most are split into fossil fuel and electricity, some aren't;
- most show typical and good practice levels, some don't, and a few show a third level;
- climate and exposure corrections may be applied in different ways, or not at all;
- benchmarks in different publications can vary, probably owing to age or sampling;
- sometimes there are inexplicable variations, for example data on ostensibly similar buildings can be very different, and some benchmarking documents have internal inconsistencies.

In summary, existing fixed benchmarks are a good starting point but could benefit from a shakedown, in both numerical values (where round figures would often be just as good) and in the range of building types covered. This would also allow countries which do not have benchmarks already to get going more quickly. More detail could be added at Level 2, as outlined below.

---

9 In the UK, OFGEM (the Office of Gas and Electricity Markets) regulates the industry. Potentially it could require energy suppliers to take readings between say a minimum of 340 and a maximum of 400 days apart, and to report the standardised 365-day consumption in an annual *Energy Supplier's Statement* or perhaps even in a box on every bill. The data could also be put on a website, which could have restricted access if there were confidentiality issues. The idea of a supplier's statement is being considered in a British Standard for fuel bills, currently being drafted.

10 e.g. with customers who shop around and those whose storage is large in relation to their needs.

11 However, these are a minority and exceptions make bad law. In the UK, gas, oil and electricity cover most buildings.

12 In the UK, commercial and some public sector property already is, at least in simple terms, on the Valuation Office database www.voa.gov.uk. Information related to sale and transfer might also be stored at the Land Registry.

13 In the UK, the Valuation Office website www.voa.gov.uk contains schedules of accommodation upon which the rating assessments are based. Usually these are room schedules of nett lettable area (NLA), but for some premises other metrics are used. For example, while hotels have their public rooms measured in NLA, bedrooms are rated by a count (e.g. numbers of single bedrooms, double bedrooms. double bedrooms with bathroom etc.).

14 Numerical values are summarised in tables in Chapter 20 of CIBSE Guide F, *Energy efficiency in Buildings* (2004).

5.4 CORRECTED BENCHMARKS - LEVEL 2

In the UK at present, more complex buildings (e.g. a secondary school with a swimming pool) tend to be given different benchmarks from the basic versions. However, while school pools can differ widely in size, there is just one benchmark. Similarly, while the ECON 19 benchmark for a "Type 4" air conditioned office[15] includes allowances for a restaurant and computer room, the other three Types of office don't. Although ECON 19 says the energy use by computer rooms is variable, many people just use the quoted value regardless. Meanwhile, some offices have swimming pools but no benchmarks for them. At Level 2 one can examine such unusual areas and energy end-uses (e.g. a pottery kiln in a school) explicitly, and take account of what is actually there, particularly if it can be sub-metered for easy verification. With Level 2 available, benchmarking could become more realistic and Level 1 benchmarks could be made simpler and fewer in number.

5.5 CUSTOMISED BENCHMARKS - LEVEL 3

Customised benchmarks contain a more detailed description of the elements of the energy use of a building and are normally computed using software. They can take account of individual areas or energy end-uses, the breakdown of energy use into its components, for example using tree diagrams (see Appendix C), the intensity of occupation and the hours or use. Such procedures can be very powerful but are at present rare, with methods available in the UK for only a few sectors[16]. However, once principles are defined and numerical values agreed, the thinking can be developed and applied more widely, as has already been illustrated for offices in Europrosper[17].

5.6 MODELLED BENCHMARKS - LEVEL 4

Another approach is mathematical modelling, similar to that used for advanced designs. In theory, building energy performance can be modelled precisely; any differences between its estimated and actual performance can be turned into a list of actions; and the effects of technical and management changes can also be modelled. In practice, the results would be subject to error owing to limitations in the power of description and modelling and the effort required to produce an OR would increase considerably. However, where an AR is already available, a comparison would bring further insights. In the long term, a detailed modelling approach could become possible where building designs had been developed using a total project model software, control systems simulated before uploading into BMS software, and where facilities management had kept the database up to date.

6 A graduated response to the benchmarking process

6.1 WHAT SHOULD THE BENCHMARKS ALLOW FOR?

Historically, benchmarks for existing buildings tend to have been derived from statistics, in the UK with "Typical" levels at the average or median of the distribution (median works best) and "Good Practice" (GP) levels at the lower quartile boundary for the type of building concerned. However:

- A median or average building does not represent a real building, but a statistical construct like a family with 2.4 children; or a building with 70% gas, 20% oil and 10% electric heating. The figures are not easy to relate to: they tell you where you are in relation to comparable buildings (but the classification is often relatively crude), but seldom what you can do about it.
- "Good Practice" is a misnomer, since most buildings tend to be wasteful. If we want to push building design, equipment, behaviour, control and management to achievable good practice standards of performance to reduce CO_2 emissions, standards need to be more exacting[18].
- We also need to encourage the pioneers to aim for more advanced standards, and to reward them for verified achievement. For instance, a member of the RIBA sustainability committee recently advocated an interest group which worked actively towards zero-carbon housing.
- The benchmarks are set in relation to representative buildings. For example, an air-conditioned office is currently allowed a considerably higher benchmark just because it is air conditioned. Is this defensible, or should the benchmarks be based on the most energy-efficient solutions available to undertake the necessary environmental control task?

It is not possible to provide solely technical answers to all these questions, see Appendix B. Social and political dimensions must also be addressed. Preferred solutions could well differ from country to country and require careful consideration by the implementing authorities. However, there ought to be a set of common principles which can underpin all different implementations and weightings.

---

15 Energy Consumption Guide 19, *Energy efficiency in offices* (2003), downloadable from the Carbon Trust.

16 The Carbon Trust's website in the UK has online benchmarking tools for hotels, offices,schools sports and the government estate. These vary in their approach and the level of detail they go to.

17 Europrosper was a research project under the EU SAVE programme in 2002-04. Amongst other things, it developed proof-of-concept software for energy certification of offices, based on actual fuel consumption data.

18 Some UK publications, e.g. ECON 19, base their GP levels on case studies of well-performing buildings which make use of simple but readily available design and management methods.

6.2 MAKING THE PROCESS RIGOROUS BUT EASY

For benchmarking to be effective, it must make performance visible and actionable and become a spur to real improvement; not a ritual bureaucratic exercise which absorbs valuable time and money which would be better spent on other things - like technical and management measures to improve energy efficiency and cut CO_2 emissions[19]. The entry level should therefore be at the lowest possible cost, subject to acceptable quality. Ideally, moves to higher levels would be driven by market need (e.g. to understand what is going on, to demonstrate proven performance, to plan improvements, or to respond to customer and stakeholder pressures) and be seen as necessary and affordable by building owners, occupiers and managers, not more red tape. If energy certification begins to interest the property market and creates a demand for higher Grades, then the extra assessment and improvement measures would become economically viable business propositions.

6.3 A POSSIBLE IMPLEMENTATION

An implementation programme with the potential to combine statutory energy assessment and certification with voluntary systems might go through the levels as follows.

0 *Level 0, basic data and calculated index of energy intensity*

Occupiers might be required to collect basic data. This could be made readily accessible if:

- building type and a measure of its extent (typically floor area) was registered centrally, (as commercial building data is already on the UK Valuation Office website); and
- if utilities (and if possible other fuel suppliers) were required to provide and if possible register statements to confirm the energy they had supplied, normalised to 365 days.

Until such systems are available, the data will need to be collected in other ways, for example using a standard format such as the VECD[20]. In principle these data could also include extra items for Level 2 and possibly Level 3 benchmarking - see Sections 6.4 and 6.5 below.

1 *Level 1, simple benchmark comparison*

Level 1 would be a simple comparison of the declared energy performance indicator with appropriate fixed benchmark(s) for the building type. If building type, area and fuel use was registered centrally, then in principle a statutory system could even issue an energy certificate and grade automatically; together with a standard checklist of energy-saving measures for the building type. While this would be crude, it would be cheap, easy to kick off without trained assessors, and get people on the first rung of the ladder of understanding and improvement. Once assessors became available, the net could be tightened, e.g. by requiring all buildings of the worst grade (say G) to be assessed within say 12 months. When reasonable market penetration at Grade G had been achieved, attention could move on to Grade F, and so on.

2 *Level 2, corrected benchmark comparison*

Level 2 would focus on the “hard” exceptions which were readily verifiable, e.g. a restaurant, data processing centre or swimming pool in an office building. An office with these energy-intensive areas would probably rate badly against Level 1 benchmarks for simple, standard offices with none of these activities. The poor rating would create an incentive for the owner or occupier to go to Level 2, e.g. bringing-in an assessor to review their grade, take account of energy use by the unusual areas and end-uses, and provide specific recommendations for cost-effective improvement to these items and to the building and its management. In reporting the grade against the simple Level 1 benchmark, the special areas and energy uses could then be deducted in order to provide a more realistic comparison. Alternatively a more sophisticated grading exercise could be undertaken at Level 3. If energy use by one or more of these end-uses was large but uncertain, then a worst case (low) estimate would have to be made until the figure had been verified by more detailed monitoring or ideally sub-metering.

3 *Level 3, customised comparison*

Level 3 would permit benchmarks to be generated which took much more account of the use of the building, including schedules of accommodation and activities, and softer factors like densities and hours of occupation. However, experience has shown that reliable soft factors can be difficult to obtain[21]; and overestimation is often used to make grades look better than they really are. A Level 3 analysis would therefore require a high level of disinterested professionalism and be most appropriate for voluntary purposes to start with. Once a method had become trusted and accredited, it might be permitted to replace the statutory requirement.

---

19 For example, experience in operation of the Danish ELO system found that annual re-certification by a consultant was too expensive and was actually absorbing budgets that their clients had set aside for implementing energy efficiency measures recommended in the previous survey. Three year intervals were thought to be more appropriate.

20 The Voluntary Energy and CO_2 Declaration, under development by the Edge for both design calculations (to be trialled for the RIBA Awards) and existing buildings (to be trialled in a RIBA Publications book on sustainable architecture).

21 For example, with most managers greatly overestimating occupancy levels and hours in their buildings.

6.4 A GRADUATED RESPONSE

Once the principles of a multi-level approach are in place, rapid development becomes possible:

- Level 0 can provide data input conventions for both statutory and voluntary purposes.
- Level 1 benchmarks can be for a limited standard range of building types, because more complex buildings will now be treated more appropriately at Levels 2 and 3. This would also allow countries and regions which are newcomers to benchmarking to get started more easily.
- Level 2 can immediately begin to take account of exceptions on their own merits, rather than making standard allowances which can easily be too mean or too generous.
- Level 3 systems can be based on common principles, but tailored to issues which the experts in a sector know to be significant. If systems are first developed and tested on a voluntary basis by, with or for stakeholders in the sector concerned (e.g. hotels, offices, or schools) then they can evolve with the support of the sector and win confidence in the marketplace.

This progressive, evolutionary approach appears preferable to systems imposed from the top down, particularly if they are inadequately resourced and so run the risk of arbitrarily distorting the market, not achieving buy-in from the sector, and possibly even being ignored or rejected by major players.

6.5 TOWARDS AN INTEGRATED SYSTEM

We have indicated how energy reporting and assessment might be approached in a series of Levels: each Level adding more detail, providing more insight and potentially superseding the Level below, but requiring more stringent verification procedures. One could introduce the Levels progressively: first by requiring solely a Level 0 declaration, then adding a simple grading system using Level 1 benchmarks with the option of Level 2 corrections. At the same time, Level 3 approaches could be developed, sector by sector, on a voluntary basis to start with. The Levels have been described separately in this report. In practice, however, once the procedures have been defined, all the available Levels could be delivered in a single integrated system with a “graduated response” progression from simple to more complex assessments. This would improve efficiency by collecting only the information essential to an efficient evaluation, allowing its adequacy to the task in hand to be evaluated continuously, and including provision for sign-off of critical data. The information collected could also go into a database to provide statistical records which could be used to drive forward the continuous improvement of the system and of the associated benchmark data.

7 Conclusions

7.1 STATUTORY IMPLEMENTATION

We have outlined a strategy for a stepwise approach to energy reporting, certification and benchmarking which allows people to progress from a very simple entry level to more sophisticated benchmarking schemes. The approach could potentially allow statutory certification systems to get started quickly without major resourcing or training requirements, whilst encouraging people to get a few facts straight and to begin to progress up the Levels - either through their own motivations or under pressure from stakeholders.

7.2 VOLUNTARY EXPANSION AND ENHANCEMENT

In parallel with the statutory exercise, we advocate the parallel development of more sophisticated Level 3 energy reporting and benchmarking schemes in some building sectors, starting perhaps with offices (where a prototype system has already been demonstrated by the Europrosper project) and the public buildings (e.g. schools, higher education, health and sports) which will be first in line to display certificates under the EPBD. There has also been some interest from the hotels sector.

7.3 LONG TERM CONVERGENCE

Ideally, standard conventions would underpin Level 3 implementations, allowing them to be strategically integrated, with the potential to exchange information and to converge eventually into a single harmonised system. Once the Level 3 systems have become properly bedded-in technically in their sectors, have gained the confidence of major players, and are suitably accredited, it would then be possible to replace the multi-level systems with an integrated approach and software.

7.4 THE DEVIL IN THE DETAIL

To turn these ideas into practical systems, there is much devil in the detail. Some of the issues which will need to be tackled are outlined in Appendix A. The details need not stop one getting started rapidly, but the initial actions need to be undertaken as part of a clear strategy which can allow progressive improvements to be incorporated as better and more robust conventions and procedures become available.

APPENDIX A - The devil in the detail

A0 INTRODUCTION

This section touches upon a number of detailed issues which will need to be confronted by any energy reporting, benchmarking and certification system for nondomestic buildings which is based on measured annual energy use. Coverage is not comprehensive, but just gives a taste of what will need to be addressed. These and some other issues have also been examined in working documents for the Europrosper and EPLabel projects, and in the scoping study reports for the Edge VECD and the Sustainability Forum's work on energy benchmarking.

A1 BUILDINGS, SITES OR PREMISES?

The EPBD refers to buildings, but buildings are not always single, free-standing items. Sometimes they are sites with several buildings, often they are divided up, sometimes they overlap and interpenetrate. A useful UK legal definition is "hereditament", a unit of inheritable property, often called a premise. A premise may be a site, a building, or a tenancy within a building (e.g. a shop unit, office suite, or apartment). Frequently a premise gets metered or at least sub-metered for some, if not all of its energy supplies. For the purpose of energy certification and benchmarking, "building" will often mean "premise". However:

- Where a premise is a site, it may often be desirable to break it down into individual buildings.
- At Level 2 or 3 benchmarking, a premise may often need to be split into smaller components.

A2 LANDLORD/TENANT SPLITS

In multi-tenanted buildings, one may need to consider benchmarking landlord and tenant services separately, because the responsibilities for energy-related investment and management are often split this way. In addition, as suggested for fuel suppliers, landlords could be asked to give each tenant an annual Statement of energy used for landlord's services and the proportion allocated to the tenant: this could accompany the annual account for the service charge. Tenants would then be able to:

- see the whole picture, which may be particularly important if they are a public sector tenant which needs to display its energy certificate; and
- challenge the landlord if the method of apportioning energy use is crude (e.g. solely on a floor area basis, which still often happens).

Buildings with a single tenant could potentially be regarded and certified as whole buildings. However, an understanding of the landlord/tenant split may still be desirable, especially where responsibilities for operation and maintenance of the landlord's services are separate.

A3 FLOOR AREA DEFINITIONS

Often the most inaccurate thing about an energy performance indicator (EPI) is the denominator - the number you divide the weighted energy by to create an index. This measure of extent is usually the floor area, but people are often sloppy about both the units and the numerical values.

- *Treated floor area, TFA,* (i.e. the area which has heating, ventilation or air conditioning services) is the metric favoured by building services engineers and tends to be used in CIBSE publications and in many Carbon Trust energy consumption guides, but seldom elsewhere. However, "conditioned area" is the metric being proposed in the CEN draft publications.
- *Net internal area NIA,* also known as net lettable area NLA. This is the most robust figure for commercial property because it is the bit tenants pay rent on[22], it forms the basis of UK commercial property taxation, and figures are often immediately available from the Valuation Office[23]. The NIA can also be seen as the productive area of a building, and hence a suitable denominator for benchmarking. For these occupied spaces, NIA is also close to TFA, though the TFA of a building as a whole would include the TFA of the common parts too.
- *Gross internal area, GIA,* otherwise known as gross floor area GFA, is widely used by design and building teams. However, the schedule produced in the early stages of design is often not updated for later changes, and so may not necessarily represent what was actually built. In addition, buildings with large untreated or lightly-treated areas (e.g.accessible attic spaces, plant rooms and basement storage and car parking) can have reported floor areas much larger than their productive areas, giving them an unjustifiably low EPI.
- *Usable area UA* is also used by space planners; and the EPBD itself talks about "useful area". However, UA is not a robust metric for energy benchmarking, because what area is deemed to be usable depends on the use to which it is going to be put.

---

22 However, in spite of its importance to tenants who often pay hundreds of pounds PA for each square metre of NLA, inaccuracies in rental agreements (usually in the landlord's favour) are widely reported.

23 Though some checks of buildings known to us have revealed that the Valuation Office (VO) data does not always describe the premises and their areas in ways that could be used directly in an energy certificate. Ideally., perhaps, the VO database (or possibly the Land Registry) would include an additional field showing the relevant area for energy certification purposes.

To start with, one will probably have to use the prevailing conventions in the existing guidance material[24]. However, as one converges towards a more universal system at Levels 2 and 3, it becomes increasingly important for the metrics to be consistent. For individual areas, GIA is probably the most consistent metric for manipulating the data, but for benchmarking purposes some parts of this GIA may need to be excluded, by convention or by arithmetic; or at least their effect on the benchmark recognised. For example, if two buildings have the same TFA and the same energy use, it makes no sense for one to obtain a lower EUI and perhaps even a better grade just because it happens to have a bigger plant room or a large area of dead storage. Similarly, if two office buildings both have the same NIA but one has a poorer net:gross area ratio than the other, it makes no sense for the less spatially efficient building to get a higher grade[25].

A4 OTHER MEASURES OF EXTENT

People often ask whether floor area is the most appropriate denominator for an EUI - wouldn't it be better based on the number of people in the building, the number of person-hours of occupancy per year, or the amount of product made or value added? The answer is probably yes in principle, but very difficult in practice; as for the most part such figures are not routinely measured, or measured with sufficient accuracy and readily verified, or easily assigned to an individual building. These metrics are also unstable, varying rapidly with changes in organisations and in the economic environment and their effects on building use. In addition, for most buildings, the principal influence on energy use is that they are there and operating: for the most part, the dependence on actual occupation and activity levels is relatively weak. We therefore recommend that the EUI is first calculated on an area basis, but that there is the opportunity to calculate and report it in other units too. However, the results could only be shown on a certificate where there were robust metrics, verified data and where the assessments were repeated regularly, say at annual intervals[26].

A5 DIFFERENT BUILDING SERVICES SYSTEMS

From time to time, there have been requests to create different benchmarks for different types of building services system, going beyond the simple classification into naturally ventilated and air conditioned into more detailed descriptions, and certainly considering ventilation, cooling and humidification systems differently. On the other hand, as discussed in section 6.1 and in Appendix B below, there is a case for saying that it is not necessary to take account of what systems are actually used - benchmarks should be based on the most efficient ways of providing and servicing space to suit the activities being undertaken.

A6 RENEWABLE ENERGY AND CHP

Renewable energy can cause difficulties with reporting conventions. A logic may need to be developed which takes systematic account of whether it is considered as reducing demand (e.g. with daylight, passive solar gain, and natural ventilation and cooling) or providing renewable supply (e.g. with solar heating panels, PVs, wind generators and water power. It could (and may well) be argued that it doesn't matter - the important thing is the amount of energy the site imports and the associated CO_2 emissions. However, faced with the choice between an energy-efficient building, and an inefficient one counterbalanced to the same CO_2 emissions level by on-site renewables, the more efficient building would tend to be the more robust and most cost-effective choice in most circumstances. Similar arguments can be applied to combined heat and power (CHP) systems.

A7 CLIMATE CORRECTIONS

Buildings in different parts of the world have different pattens of energy use. However, universal corrections of benchmarks to a standard European (or often even National) climate may not be appropriate, because buildings are adapted to the climates in which they find themselves. So buildings in windy places tend to be more airtight, in sunny places better shaded, and in cold climates better-insulated. Indeed, typical levels of energy use for heating in some cold places (e.g Sweden) can be less than in much warmer climes (e.g. parts of Southern Europe). Benchmarks - at least for some end uses - are therefore likely to have to vary with country and climate zone. Climate zones need not be specific administrative or geographic regions: they might, for example, be all places lying within a country's 2000 to 2200 heating degree-day contours.

---

24 Hospitals, for example, use heated volume rather than treated area, though we would prefer an area basis.

25 These arguments were considered in some detail by the Sustainable Energy Development Authority (now DEUS) in setting up ABGR, the Australian Building Greenhouse Rating, which rates offices buildings (separately for landlords and tenants) based on the nett lettable area.

26 This should not be much of a burden once appropriate records are in place.

A8 WEATHER CORRECTIONS

Whatever the local climate, variations in weather will cause energy consumption to change from year to year. Ideally, this should to be taken into account in some way when making benchmark comparisons[27]. Methods for correcting heating energy consumption have been widely used in some countries for many years[28] Methods for correcting cooling energy consumption are less common, only applicable to buildings with mechanical cooling, and might initially be applied in southern Europe only.

A9 CORRECT THE BUILDING OR THE BENCHMARK?

In comparing a building's energy use with a benchmark to reach a grade, you can either adjust the building's energy performance or adjust the benchmark, e.g. for weather corrections. Being a ratio, the result should be the same. Mathematically, it is easier to adjust the benchmark, as one has a single procedure which does not have to take account of features specific to the building - except perhaps knowing which fuels it is appropriate to correct. In addition, it is desirable to report a building's energy performance in raw figures, because any adjustments create scope for confusion. For example: is the reported figure adjusted or not; and, if adjusted, was the adjustment legitimate? In spite of this, it may be most practical for weather (not climate) correction to adjust the building's energy consumption and not the benchmark, as this will make year-on-year comparisons easier to undertake and to understand[29]. Where good data on the building's performance are also available, one can also make corrections using the building's actual performance curve. Where a fuel is used for heating and some other purpose, e.g. gas for cooking and hot water, or in buildings with electric heating, it can be difficult to to know what proportion of the fuel to correct for local weather unless there is a well-defined performance curve. One might even consider permitting weather correction to be applied only where a building either had good monthly data or where its heating energy use had either been submetered (or could be deduced by subtraction of submeters on all the other uses).

A11 TRIGGERS FOR RE-CERTIFICATION

The EPBD requires certificates to be valid for not more than ten years.

- *For Asset Ratings,* for which the main use is at the point of sale, rental, or completion of significant building works, the trigger will be the selling transaction or the undertaking of works. A ten-year validity seems reasonable, depending on the sensitivity of the building works trigger. In practice, we imagine that if a building were to go on the market with an elderly certificate, there could be a commercial reason for re-certifying before the ten years to improve the quality of information available to help vendor and purchaser to settle on a price.
- *For Operational Ratings,* how a building is equipped, used and managed can change rapidly, so more frequent reviews would be desirable. A UK draft proposal for public buildings suggests that an Energy Performance Index and Grade might be recalculated at annual intervals. To do this the certification activity would need to be very efficient[30]. Experience with the Danish ELO system suggested that an appropriate interval between assessors' visits was about three years. If regular reviews like this were not required, then an OR might also be triggered say three years after a change of owner or tenant, or a similar interval after undertaking of building works which required an AR to be issued.

A12 EVOLUTION OF BENCHMARKS AND GRADES WITH TIME

Should buildings be evaluated against a fixed benchmark scale, or one which evolves with time as standards and/or the stock improves? There are arguments on both sides. For example:

- A fixed scale gives a degree of clarity, but
- as standards improve, and buildings get better, there could be too much bunching at the low (good) end, as has been found for domestic appliances, where many are now A-rated and the differences between them are no longer clearly visible.
- With a customised benchmarking system, standards are likely to evolve continuously anyway.

At present we think that an evolving scale might be more practical. Having a date on a certificate will itself provide an incentive for renewal, because if property values are affected by the grades, there will be market pressures for a certificate to be reasonably up-to-date. Such evolution could either be gradual (with new information being included as it became available) or changes might be tied to the revisions of energy-related building regulations, typically at intervals of about five years.

---

27 Particularly if - as was proposed in a UK working paper for ODPM - the Operational Rating were to include a report on energy use in previous years, in order to identify how performance had been changing.

28 For example heating degree-day corrections in the UK.

29 In addition, if one is making a relatively small correction for variations in local weather rather than sometimes quite a large one to a standardised national climate, the effect of errors in weather correction becomes much less of an issue.

30 e.g. with self-assessment checked by experts from time to time, or possibly even automatic if the required data (such as building type, floor area and annual utility consumption) were registered electronically.

APPENDIX B
What's in a benchmark?

B1 HISTORICAL BACKGROUND

Traditionally, energy benchmarks have been used mostly to let people compare their building's energy performance with a peer group, to determine how well they are doing and whether they need to improve. Most UK benchmarks are expressed as Energy Use Indexes (EUIs) for fossil fuel and electricity used per square metre of floor area (definitions vary) per year at "Typical"(e.g. the median of the population of buildings concerned) and "Good Practice" (e.g. lower quartile) levels.

B2 WHAT SHOULD A BENCHMARK TAKE INTO ACCOUNT?

The buildings used to create the benchmark have usually been drawn from those most similar to the building concerned, for example with different benchmark values for:

- Schools with and without swimming pools. This makes sense, but as discussed in paras 5.4 and 6.3 the swimming pools might better be considered in their own right at Level 2.
- Multi-building sites without local sub-metering based on an aggregation of benchmark values for the building types and/or activity areas included.
- Offices with and without air-conditioning (AC). This is trickier. With a drive to cut the world's CO_2 emissions, why should an office get a considerably greater allowance because it happens to be AC? People might even want to add AC just to get a better grade! Perhaps allowances should only be made on the basis of proven need at Level 3, and then at modest levels to reflect the best buildings with the best systems and the best management only.

B3 THE PURPOSES OF EACH PROPOSED LEVEL OF BENCHMARKING

Each of the five Levels of benchmarking discussed in Sections 5 and 6 of the main report has subtly different levels of interpretation.

0 *Level 0, confirms the facts* and creates a raw EUI or CO_2 emissions index (CEI)[31]. This expresses a building's *Energy Intensity*, but has little to say about its efficiency. A high EUI may not mean inefficient if the building has a high intensity of equipment and use.

1 *Level 1, compare with simple benchmarks*. The absolute EUI or CEI figures can now be compared with fixed benchmark values for the building type. This would show that, say, a CEI of 50 kg CO_2/m^2 TFA per year on UK values was reasonably good for an office but poor for an unoccupied storage warehouse with background heating, and grade them accordingly. Should allowances for, say air-conditioning be introduced here? Maybe not. There is good reason to say that the Level 1 benchmarks should be based on buildings with relatively low use intensity and high energy efficiency. If you think you have been hard done by - prove it!

2 *Level 2, correct for readily-verifiable exceptions*. This allows for a fairer comparison, because areas and energy uses not included in the Level 1 benchmarks can be examined on their merits and the grading stripped back to the elements which are more directly comparable.

3 *Level 3, compare with customised benchmarks*. Customised benchmarks are just that - benchmarks against which the performance of the building can be compared directly. They calculate reasonable yardsticks based on what the building DOES (e.g. the building's schedule of accommodation and activities, and its levels of occupancy and equipment) and its location (e.g. degree days). They do not need to take account of what the building IS (e.g. size, structure, envelope, orientation, glazing, building services design etc.).

4 *Level 4, modelled benchmarks*. Although modelling procedures can be incorporated to a greater or lesser extent in Level 3, here we define them as conceived in a paper[32] tabled at the ODPM meeting on Operational Ratings in February 2005, in which the model is seen as estimating what the actual building ought to consume under ideal conditions. This is a very different application of benchmarking to the other levels, but clearly complementary when looking at the theoretical potential for improvement and at the likely effect of alterations.

B4 A NOTE ON LEVELS 3 AND 4 IN EUROPROSPER

In hindsight, the Europrosper proof-of-concept software[33] can be seen to be getting to Level 4 in a rudimentary way. After calculating customised benchmarks at Level 3 (using the ECON19 Tailored Benchmarking process for offices) it went on to infer the component tree diagram values (see Appendix C), hence creating a bridge to a parametric version of Level 4. Then, by allowing the assessor to over-write the inferred values with known values for the actual building and for improvements, it began to move the parametric description into something more closely resembling the actual building. There appears to be considerable scope for further convergence.

---

31 Say in kg CO_2 per m^2 of treated floor area (TFA) per year

32 S Irving, *Operational ratings under the EPBD - a proposed way forward*, Version 3a (January 2005).

33 See www.europrosper.org for papers on the approach. The software itself is being superseded by the EPLabel product.

APPENDIX C
Transparency between expectations and outcomes using tree diagrams

C1 THE CREDIBILITY GAP

It is not unusual to find major discrepancies between design predictions of a building's energy use and its actual consumption when completed. The reasons include:

- *Design assumptions* (e.g. for operating hours) which do not reflect the actual situation. Sometimes this is legitimate (e.g. the office was expected to be occupied for 5 days a week and in practice is a 7-day operation), but often we find a level of design optimism.
- *Not all end uses included* in the design estimate, which often includes normal building services only.
- *Additional uses* (both fixed and portable equipment) introduced by the occupier.
- *Fitout*. This often creates a very different building to the one envisaged at the design stage, and, if poorly integrated with the design philosophy for the shell-and-core, can easily undermine low-energy design intentions.
- *Poor build quality*, for example a lack of airtightness or a failure to reach anticipated thermal insulation standards.
- *Reduced plant efficiency.* It is not unusual for computer models to over-estimate the efficiency of plant and the accuracy with which they can follow the fluctuating loads. The plant actually installed may also differ from that originally intended.
- *Poor control.* Systems often operate wastefully owing to control shortcomings in design, specification, installation, commissioning and usability; and a lack of appreciation of occupant and management requirements and behaviour.
- *Poor energy management.* Often plant is left on completely unnecessarily, particularly in tenanted buildings, where operators' priorities tend to be for service rather than economy.

C2 IMPROVING TRANSPARENCY

Transparency of description would allow some of the above discrepancies to be removed - both improving design practice and predictions and providing incentives to management. For example, "tree diagram" descriptions[34] can help to bridge the credibility gap and "get back to the roots" of energy consumption. They provide transparency between the capacity, efficiency and use of different systems in a building (heating, ventilation, lighting, office equipment and so on), how much they are used, and how tightly they are controlled. They are also capable of application at any scale, from the whole building down to an individual system (e.g. heating), zone (e.g. a computer suite), room (e.g.a meeting room), element (e.g. lighting in a room), or item of plant or equipment.

C3 TREE DIAGRAMS AND ENERGY SURVEYS

The tree diagram approach has been used not just for benchmarking but for undertaking energy surveys and for summarising design data. CIBSE TM22 includes software in the form of a Microsoft Excel workbook which is quite lengthy but relatively quick and easy to use once initial familiarity has been obtained. The method underlies, for example, the reported energy data in the Probe series of published post-occupancy surveys in *Building Services - the CIBSE Journal*[35] . More recently, the TM22 method has been used to summarise and develop design predictions of energy consumption, helping to improve transparency between design and operational data.

C4 USING THE TREE DIAGRAM

The benchmarks in ECON 19 sought transparency between energy use statistics and design and management data by breaking out the total annual consumption first into end uses and then into tree diagram input values [9]. Figure C1 shows how the tree diagram works. Note that each of the component values (A to H) can be considered as a benchmark for that particular component[36]. Starting from the top of figure C1:

A The total annual energy consumption (yellow cell) of an individual fuel. This example shows electricity consumption per square metre of treated floor area (TFA), but the tree diagram can be used for any fuel (or combination of fuels) and measure of extent (in any required units).

B The total breaks down into a series of end-uses, including the fans shown here. The illustration shows the average for the whole building, but the same principles can be used for any part of the building, for any subsystem, or indeed for any item of plant and equipment.

---

34 First used in preliminary form in the 1991 edition of ECON 19, developed in the EARM project and formalised in CIBSE TM22 (1999): *Energy assement and reporting methodology: office assessment method.*

35 Papers can be downloaded from the Probe section of www.usablebuildings.co.uk

36 So you can have benchmarks, for example, for a ventilation rate, an illuminance level, an installed lighting power density, specific fan power, boiler or chiller capacity, and for typical annual hours of use.

In its turn **B** - the annual electricity consumption by the fans (or the equivalent for any other end use) is the product of:

C representing **the asset,** here reported in terms of installed fan power density (W/m^2)

D representing usage, control and **management,** reported as annual equivalent hours of operation at the load density C.

At the bottom left, the component representing the **asset, C** is made up of by the product of:

E The standard of provision (e.g. litres of air delivered per second per m^2 TFA for fans)

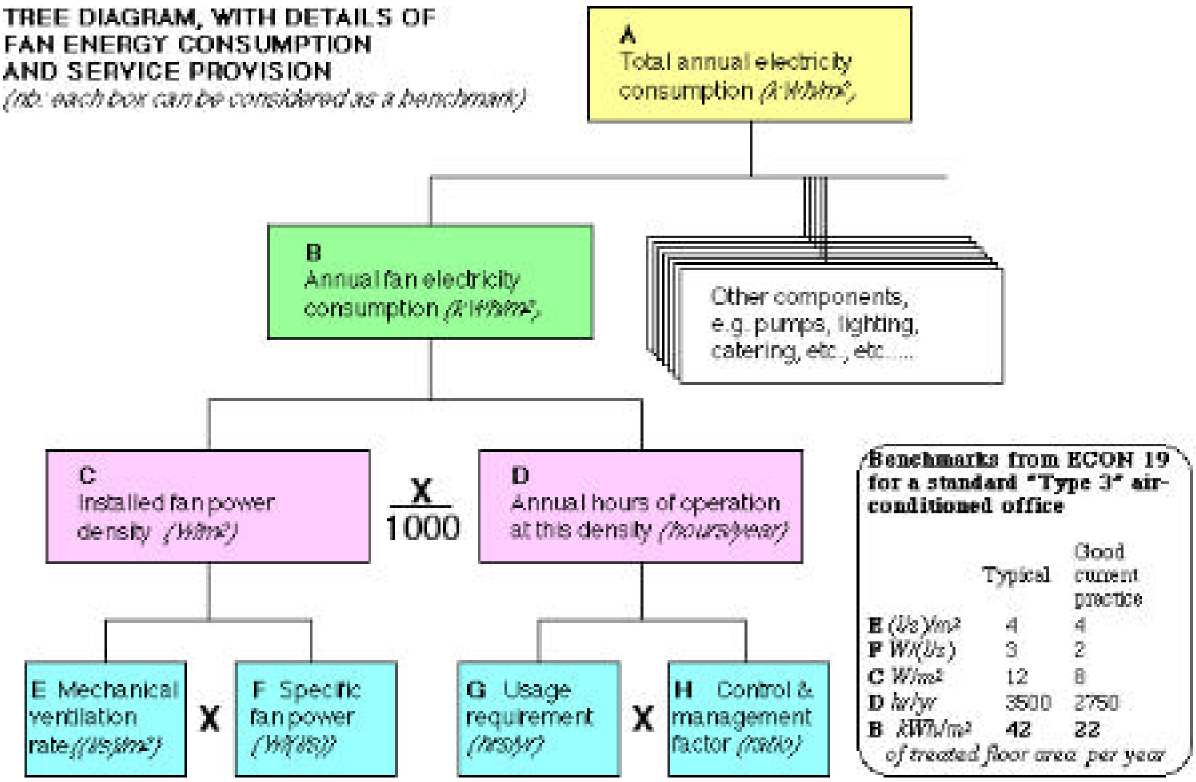
F The efficiency of provision (e.g. Watts per litre/sec of air handled for fans).

The usage, control and **management, D**, is represented by annual full-load running hours:

G The annual usage requirement (e.g. the number of occupied office hours), multiplied by

H The control and management factor (normally expressed as % utilisation[37]).

FIGURE C1: EXAMPLE OF TREE DIAGRAM DESCRIPTION FOR FANS



Some of the tree diagram components were made explicit in the 1998 version of ECON 19. For example, the bottom right corner of Figure C1 shows component values for "Typical" and "Good Practice" annual energy consumption values for fans in a "Type 3" standard air conditioned office.

C5 TREE DIAGRAMS AND BENCHMARKING

Although simple in concept, the tree diagram has proved of powerful assistance in benchmarking:

- It provides separate quantification of building-related and management-related aspects; though there are overlaps which need explaining (e.g. are long annual hours due to building use, poor control which forces systems to remain ON even when loads are small, or lazy management?)
- All of the coloured boxes may be regarded as benchmarks, giving a compact but rich description of the situation and using direct comparison to close the gap between expectations and outcomes (for example "the lighting load, estimated to be 8 W/m^2, is actually 15 W/m^2").
- The origin of the figures to be placed in each box can vary, from rough estimates to sophisticated models, and detailed monitoring data. The system therefore permits a variety of inputs - the quality of which could be graded if necessary as part of a certification system.
- Where sophisticated methods are not available or appropriate, useful estimates can also be made by applying simple arithmetic, so beginning to connect benchmarks to measures.
- It may be applied at any scale, from the whole building down to individual rooms or systems.

37 This can vary from a low percentage for a tightly-controlled and managed installation (e.g. electric lighting in a well naturally-lit building) to greater than 100% where systems run liberally (e.g. computers left on overnight).