building performance congress

# Energy Performance of Non-Domestic Buildings: Closing the Credibility Gap

***Bill Bordass, William Bordass Associates***
***Robert Cohen, Energy for Sustainable Development Ltd***
***John Field, Target Energy Services Ltd***

## Abstract

Recital 16 of the Energy Performance of Buildings Directive (EPBD) requires the energy certificate to describe a building's actual energy-performance situation to the extent possible. If we wish to achieve the rapid reductions in energy use and $CO_2$ emissions that the EPBD anticipates, it is vital that this clause is taken seriously. It provides a fantastic opportunity to report actual energy use clearly, to grade it against a clear description of the building in use, and to relate it transparently to expectations at the design stage. This will at last begin to close the feedback loop, reduce the credibility gaps that so often occur between design expectations of energy efficiency and actual fuel consumption outcomes, and consequently lead to more rapid improvements in building energy performance.

Credibility gaps arise not so much because predictive techniques are "wrong", but because the assumptions often used are not well enough informed by what really happens in practice, because few people who design buildings go on to monitor their performance. While some differences are legitimate (e.g. the building is used more, or has more things in it), surveys nearly always reveal avoidable waste - which can arise from poor briefing, design, construction and commissioning, and not just bad training, bad maintenance and bad management. A widespread problem is control systems which just do not work, or have poor management and user interfaces, resulting in equipment defaulting to ON unnecessarily.

To achieve genuine step-change improvements, procuring clients, design and building teams, users and managers will all need to engage much more closely with achieved performance. Better transparency between intentions and outcomes will release drivers towards better assumptions, better predictions, better design, better implementation, and better management of both the procurement and the product. We discuss how certification might be developed to help identify and close the credibility gaps, and present an idea for an energy certificate which takes these issues into account.

## Introduction

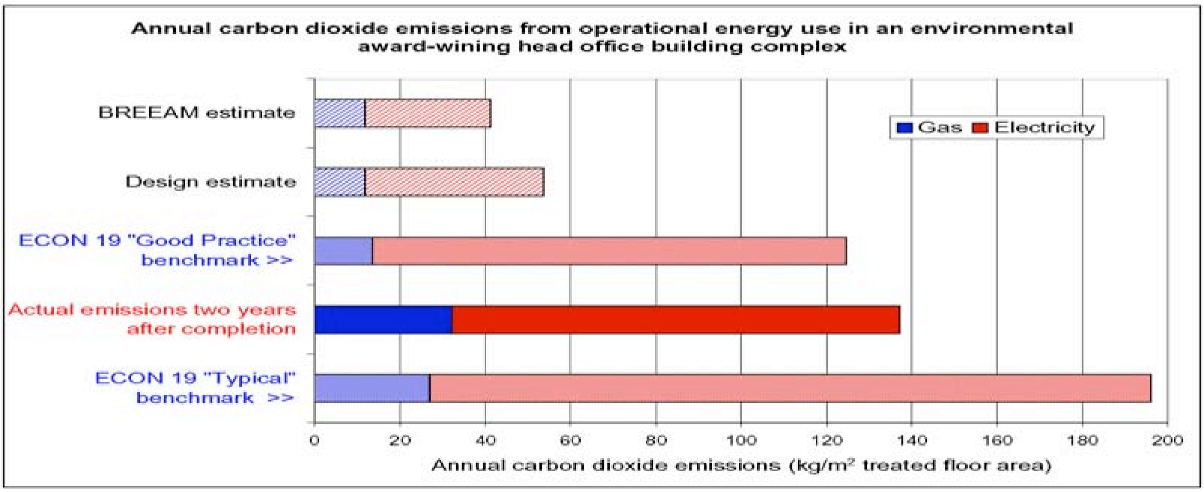
**Nondomestic buildings in the UK**
Nondomestic buildings (commercial and public) account for about one-sixth of the UK's entire $CO_2$ emissions and one-third of the building-related ones. Their proportion of energy (particularly electricity) consumption has also been growing. This paper considers some reasons why these buildings often use much more energy than they could, and suggests ways of improving the situation. It concentrates on operational energy use, and on savings that can be made on the demand side before calling upon external sources of delivered energy (however low in carbon these may be).

**Nondomestic buildings often waste energy**
Many nondomestic buildings are major energy-wasters (Bordass, 2001a). New buildings are not necessarily better, with energy use often proving to be much higher than their designers anticipated. Norford et al (1994) note the need for considerable caution about what constitutes a low-energy building. Annual $CO_2$ emissions of two - and sometimes even three - times design expectations are far from unusual, a massive credibility gap.

**An example**
Figure 1 shows data from an energy survey of an environmental award-winning office some two years after its completion (Curwell et al, 1999). The gas and electricity consumption (per $m^2$ of treated floor area) is converted into $CO_2$ emissions using the published UK factors at the time and compared with:
- the estimates made by the designers;
- the estimates for the BREEAM (BRE Environmental Assessment Method) certificate; and
- typical and good practice UK benchmarks adapted from Energy Consumption Guide 19 (Action Energy, 2003) "ECON 19" for an office of a similar type and use.

The $CO_2$ factors used throughout figure 1 are those published in the 1998 edition of ECON 19.

**Figure 1. Differences between actual $CO_2$ emissions and predictions at the design stage**




*In the example shown in figure 1 above:*
- *The design predictions did not include the electricity consumed by the equipment and HVAC systems in the computer and communications rooms. The ECON 19 benchmarks do.*
- *The requirements for flexibility and reserve capacity in the air conditioning for the computer and communications rooms, together with the use of the same chilled water system for top-cooling of the offices in occasional hot periods, had led to a design which had relatively high 24-hour loads for fans and pumps.*
- *The amount of electricity drawn by office equipment when not in use was high, partly owing to the security system adopted which did not allow networked equipment to be switched off.*
- *The HVAC plant was not operating optimally: the managers had this under investigation but had not yet found a solution.*

*This draws attention to important issues that significantly affect achieved energy performance but need more recognition in briefing, design and management – and in certification.*

## Why the credibility gap?

**There are many reasons**
When faced with the credibility gap – and most people neither seem to know nor care about it (Bordass 2003) – the instant reaction of the occupier may be that the designers got it wrong, while the designers complain that the occupier has never bothered to understand the building, is using it in unexpected ways and doesn't operate, maintain and manage it properly. There is often some truth on both sides, but there can be many more reasons.

**Slippage during initial estimation**
For example the designers may often have:
1. Only estimated the energy use of the typical spaces (e.g. only the office space in an office building), and left out everything else, circulation areas, support spaces, car parks and so on.

2. Only reported the energy used by normal building services (heating, hot water, cooling, ventilation and lighting), not by anything else.
3. Assumed the building is empty at night with most systems off. Often they aren't, see figure 2.
4. Assumed near-perfect control and a close match of supply to demand.

In comparing design options, the above simplifications may be practical and legitimate, but in effect the designers are not predicting the actual energy use but some strange optimal energy use (a bit like the thermodynamic efficiency limit for a heat engine). Then the credibility gap really opens up when designers go on to claim how good their building will be by making direct comparisons between the total primary energy use or $CO_2$ emissions for this subset, with the totals in benchmarks such as ECON 19 (Action Energy, 2003) which are based on actual energy performance data and take into account all energy uses in the completed and operating building.

**Slippage during design development**

In addition, what was actually specified to be built may have deviated from the design assumptions at the time the options were appraised and the estimates of energy use first made. For instance:

5. Client requirements may have changed, affecting the design and its energy use.
6. The insulation, ventilation, solar and daylight characteristics of the envelope may have changed.
7. The heat storage characteristics of the fabric may have changed.
8. The building services and the controls may have been altered.

But were their affects on the predicted energy use re-calculated, particularly if to do this would have meant having to pay people who had been thought to have completed their tasks (e.g. thermal modellers and BREEAM environmental certifiers), to come back and have another look?

**Slippage during construction and commissioning**

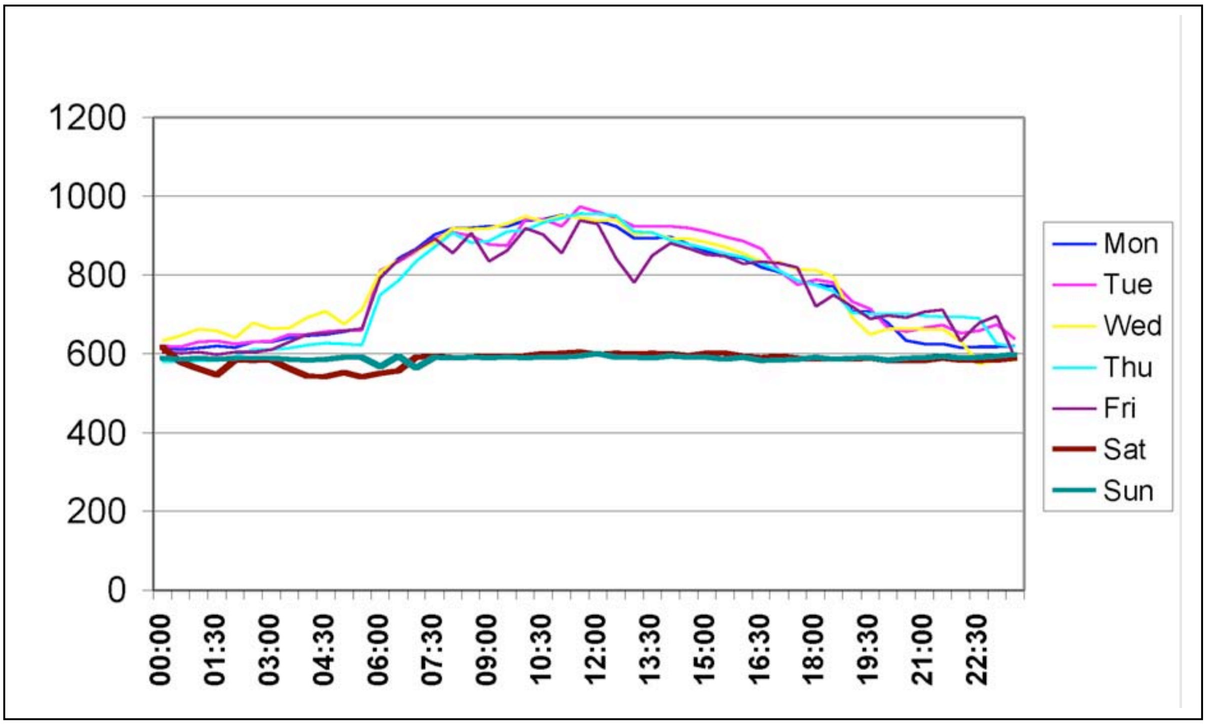
The building may not be constructed as intended:

9. If tenders were high, cost savings may have been necessary. Cost cuts often affect thermal characteristics, building services and controls – things that aren't generally seen although they can be felt. Solar and glare control devices often suffer too. Increasingly such negotiations are between clients, project managers, contractors and suppliers and not under full control of the design team – who may sometimes not be involved at all, or only in commenting on the outcome.
10. Elements which include contractor-design (and often cost negotiations too) may not end up as anticipated. For example, it is not unusual for structures to cut into zones which had been intended for insulation, and to make air sealing measures very difficult to install; and for cladding systems not to be of the intended thermal integrity, especially at interfaces with foundations, eaves and other types of wall construction.
11. Building services equipment may have been substituted for that originally specified.
12. Build quality may not have been up to standard, e.g. with degraded insulation and airtightness.
13. Commissioning may not have been thorough. It is not uncommon to find energy-saving devices such as variable speed drives, heat recovery and "free cooling", and plant sequencing systems working very poorly, if at all.
14. Services and controls may not work exactly as intended.

**Once completed**

15. The building may not be occupied quite as envisaged.
16. The fitout may change the building and its energy systems substantially and clash with some of the design intentions and installed systems.
17. The systems may never be fine-tuned to suit changing occupancies and seasons.
18. Operators and users may find it difficult to understand the control systems and to operate them effectively; and the systems may not always have been usable or manageable in the first place.
19. Maintenance and energy management may not be up to standard.
20. Systems and equipment may default-to-on unnecessarily; or because it is the only way to keep the level of complaints down, see figure 2. A similar example is shown in figure 19.2 of CIBSE Guide F (2004).
21. There may be emergent properties and unintended consequences, for example control systems which irritate the occupants and are therefore by-passed.
22. In rented – and particularly multi-tenanted - buildings, the split of responsibilities between landlord, tenants and building managers often inhibits investment and exacerbates the wasteful operation of systems.

**Figure 2. Half-hourly electricity demand profile in an office building**




*The extreme but nevertheless real illustration in figure 2 above shows the average electricity demand (in kW) every half hour for a week in October 2001 for an air-conditioned office building in London. There is very little use out of normal Monday-Friday working hours, but the base load at night and the weekend is still about two-thirds of the daytime peak. This baseload might have been largely ignored in design calculations. About half of it is accounted for by computer installations (including their dedicated air-conditioning systems) and other 24-hour loads such as security lighting (these may be legitimate business requirement, though much avoidable waste can often be found here). The other half is from the air-conditioning which ran permanently during the heating season to avoid complaints of discomfort at the perimeter. Was this a design issue affecting the intrinsic efficiency of the building, or an inappropriate management response? In summer the monitored baseload is approximately halved, while the peak is slightly higher, particularly for pre-cooling on Monday morning.*

## Making things better

**Improving the process**

Ordinary people might reasonably expect designers and builders to be experts on the performance of the buildings they create. This is not normally so: those who produce buildings work on projects. These projects are about producing buildings. Having produced one, designers and builders go on to the next - as do the project managers and the procurement wings of major construction clients. By and large, the providers do not stay around to see how well the buildings they have produced actually work. Consequently, large differences between energy performance expectations and outcomes can occur virtually unnoticed, while designers continue to repeat flawed prescriptions. Designers may also fail to realise when they have a success on their hands which they should be replicating: instead they may attempt to gild the lily and create “solutions” which are more complicated than necessary. “Keep it simple and do it well” is often the most reliable formula for success.

**Achieving virtuous circles**

Good briefing, good design and good management can deliver buildings which are simultaneously comfortable, productive, economic and energy-efficient, but these are still rare.

## Certification and transparency

**What is an energy certificate for?**
A certificate is not an end in itself, but a means to improvement. It should:
1. Encourage people to commission, design and build better buildings in order to get a better grade.
2. Help occupiers to select and demand better buildings when they are looking for space.
3. Stimulate owners and landlords to compete to offer buildings of good energy performance.
4. Provoke and assist the undertaking of investment and management measures to improve the energy performance of occupied buildings.

**Triggers for certification**
In relation to the requirements of the EPBD, the Energy Performance of Buildings Directive (OJEC, 2003):
- Attributes 1 to 3 above are aimed at the point of completion, sale or rental – Article 7.1 of the EPBD. These need calculated predictions of energy performance and grades that can be compared on a reasonably uniform basis.
- Attribute 4 also relates to the requirements of Article 7.3 for the display of energy certificates for large (over 1000 $m^2$) public buildings (including buildings frequently visited by the public) in operation (with the trigger being the type of building they are and not their construction, sale or rental). This can make use of actual consumption.
- For buildings certified on predictions only, we would also recommend re-certification after say three years, taking actual performance into account - including modifications made during fit-out.
- Actual energy performance can also be taken into account when buildings in use are re-certified.

In all certification exercises, we must remember that a critical part of the activity is not calculating the grade, but making improvements in energy and carbon efficiency - identifying the cost-effective energy-saving measures and providing motivation for putting them into effect.

**Practicality, consistency and correctness**
A suitable certification system will need to be:
- Practical, with methods to suit the nature of the building being assessed and the skills and experience of those doing the assessment; at a time and cost which suits governments and the marketplace, and avoids accusations of "gold plating".
- Consistent, with certificates as compatible as practically possible between countries and sectors.
- Technically robust, so that certificates can be meaningful even if some precision needs to be sacrificed in the cause of practicality.

**Two complementary approaches**
For occupied buildings, for which records of energy use are available, how do we deal most effectively with the EPBD's requirement in Article 16 to "describe the actual energy-performance situation to the extent possible"?
- Those accustomed to thermal modelling tend to wish to use the empirical results to re-calibrate their models. However, to provide a model-based certificate can require a large overhead of data collection, particularly where design data is not available. In practice, many recommendations can be made without any modelling at all, though computers can help to manage the calculations.
- Many of those accustomed to doing energy surveys tend to feel that models do not always describe what actually happens very well – particularly in the more complex buildings, and would prefer a more direct route.

We see the routes using calculated and actual energy as complementary. What one should use at any time is the most efficient and effective for the task in hand.

**Using tree diagrams**
Another paper at this conference (Cohen, Bordass and Field, 2004) shows how 'tree diagrams' (CIBSE, 1999) can be used to help to grade the energy performance of buildings in operation, make comparisons with benchmarks; develop appropriate energy-saving measures, and determine their impact. The same vocabulary can also be used to summarise design expectations and to relate them to performance in use.

**Design freedom?**
In order not to inhibit innovation, designers often prefer to work to an energy target for the whole building, rather than to have innovation inhibited by too many prescriptive requirements. The intention is admirable, but how far can design data be trusted, given the credibility gaps that can occur? The tree diagram notation offers a common basis to report both:

- design assumptions and predictions; and
- data collected from buildings in use.

This potentially allows discipline and transparency to be improved while flexibility is retained.

**An example**
Figure 3 shows a tree diagram illustrating the elements of electricity consumption by fans in an air-conditioned building, and comparing design expectations with in-use outcomes. The figures here are whole-building averages, but the same approach can be used at any scale, as discussed below.

**Figure 3. Tree diagram for fan energy consumption**

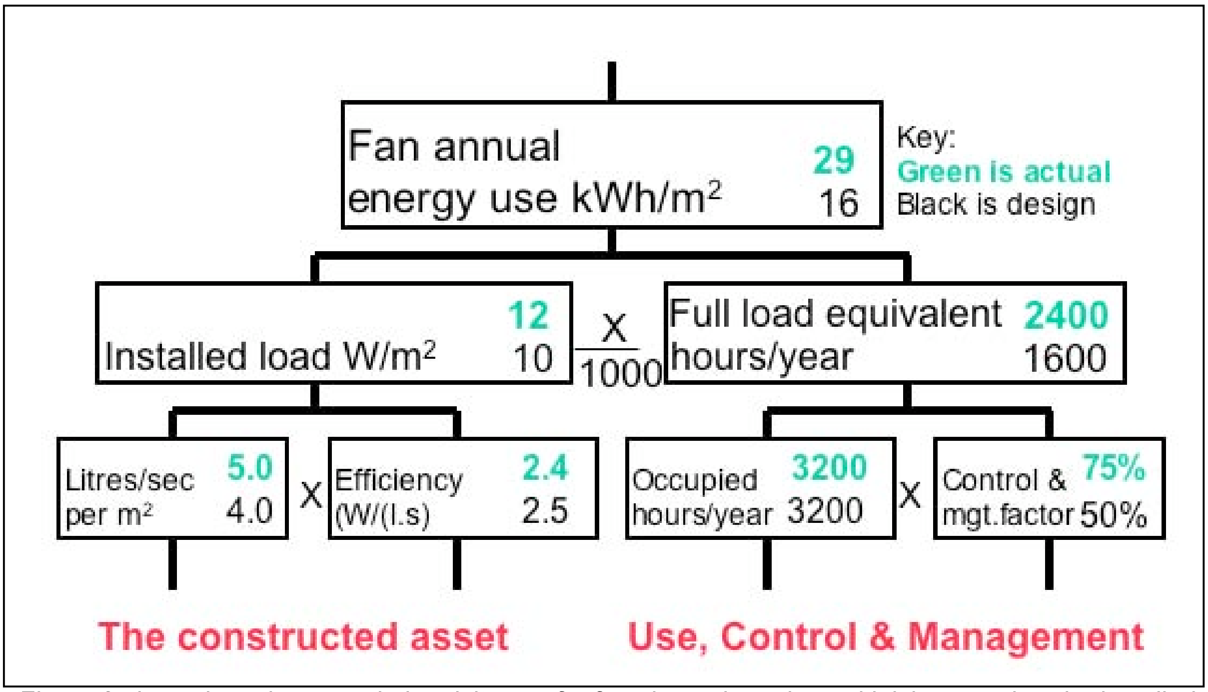



*Figure 3 shows how the annual electricity use for fans is made up by multiplying together the installed load for the ventilation system on the left by the equivalent full load hours of operation on the right. In turn, the load can be broken down into:*

- *a service standard and an efficiency on the left, representing the characteristics of the constructed asset*
- *occupancy hours and a control & management factor on the right, representing how the building is used, controlled and managed.*

*In this example the actual energy use by the fans is significantly higher than the design estimates. The main reasons for this are:*

- *A higher ventilation rate. This may be the result of a new requirement (e.g. higher occupancy densities or internal gain levels – these can also be examined); and*
- *An increased control and management factor for the same occupancy hours. How much is this a problem for the design, the installation, the control, the management or the use of the building?*

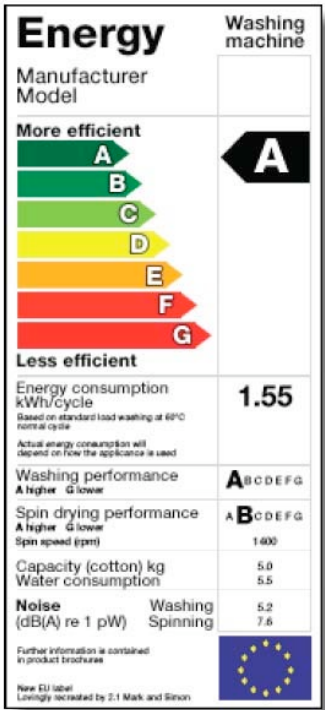
**The power of tree diagrams**
This relatively obvious tree diagram description can be put to quite powerful uses. It can:

- Split out energy by end use at whatever scale suits the task in hand, from the whole building down to one specific piece of plant, room, zone or end-use.

- Permit benchmarking at a whole range of levels (e.g. annual energy use for fans, typical annual full-load running hours, typical installed power density and specific fan power, and so on).
- Allow the efficiency of any building, system or energy end-use to be summarised in terms of its "AGT factor" – how actual (A) performance relates to Good Practice (G) and Typical (T) levels.

Tree diagrams were also used to harmonise the empirical energy use benchmarks in ECON 19 with industry standards and rules of thumb for engineering systems; and this approach also underpins the system of "tailored benchmarks" for non-standard offices (see www.actionenergy.org.uk).

**Using tree diagrams for transparency**
Essentially each value in each box in a tree diagram can be regarded as a useful value for the building, system, subsystem or end-use concerned, and capable of comparison with other data (as in figure 3), or with relevant benchmarks. The boxes can be completed however the value is determined e.g. by measurement, estimation or calculation. Tree diagrams therefore offer the potential for use as a practical language for a whole variety of comparisons. Indeed, they have already been applied in this way using CIBSE TM22 workbooks to summarise the results of design energy calculations and to compare these with energy survey and facilities management data. A standard classification system might also be developed to allow databases to be constructed which could potentially accommodate energy use information from any source, for example as part of an on-line certification exercise.




## Developing the energy performance certificate

**The form of the certificate**
It is clear that both professionals and the public like the idea of a certificate with a headline indicator of similar appearance to the familiar EU energy efficiency label used on domestic appliances, as illustrated alongside.

In addition to the energy efficiency A-G grade, the example shows:
- How much energy is used per wash cycle. Normally, but not always, an energy-efficient small machine will use less energy than a larger machine of the same grade.
- Additional information on performance, also on an A to G scale – in this example the washing and drying performance.
- Background information on context, here the spin speed.
- Further information on features, here load capacity in kg.
- Further information on performance, here water consumption and noise levels. Here engineering values rather than grades are shown *(though the actual values in this example from www.saveenergy.co.uk seem unlikely, and the units of water consumption are not given).*

**A certificate for buildings**
We have discussed the possible first page of a certificate for buildings with industry representatives in the UK, our colleagues in two EU research projects (Europrosper & Green Effect) and other contacts. Generally, those consulted have thought that the front page of a nondomestic building energy certificate should show a similar amount of information to the appliance certificate. A few people also thought the front page should include the main energy- and $CO_2$-saving measures proposed.

However, a strong recent opinion, with which we agree, is that the certificate should show both:
- a standardised "Asset Rating", which takes into account the potential of the building for energy efficiency with standard patterns of use for its type; and
- an "Operational Rating" based on the efficiency of the building's performance in use, and which takes into account its actual occupation, management and fuel consumption.

The Asset Rating can be calculated first as a "design rating" and then confirmed upon the completion of the building in relation to what actually exists and how good its installation, commissioning and control potential appears to be. Following experience in use, the Asset Rating could also be updated based on the evidence of the Operational Rating.

**A possible format for the first page of a certificate**

Figure 4 is an example of a possible first page. The headline grading shows:

- The familiar A to G scale (we suggest it might be extended to H for buildings with very poor energy efficiency and A*, A**, A*** etc. for buildings with very low energy use or $CO_2$ emissions).
- Twin "sliders", one for the Asset (or Design) Rating and the other for the Operational Rating.

**Taking account of the credibility gaps**

Credibility gaps are exposed – first by correcting the Asset Rating first for build quality and then in the light of actual energy performance (where this uncovers shortcomings in intrinsic efficiency); secondly by comparing the Asset and Operational Ratings; and thirdly by a sub-rating for management. In this particular example, although the $CO_2$ emissions are more than in the Asset Rating owing to a higher intensity of use, an excellent level of management has led to a better Operational Rating. Sadly – at least at present – the opposite normally prevails.

**Both ratings do not always have to be shown**

While the certificate would be to a standard format, it will not always be possible to show both Asset and Operational Ratings: sometimes one of them will be blank. In particular:

- For a newly-completed or refurbished building, no actual energy performance data will be available, and so only the Asset Rating is capable of being shown.
- For space on the market, although past data on actual energy performance may be available, it may not be relevant to how the building will perform for a new occupant.
- For occupied buildings obliged to display a certificate under EPBD Article 7.3, the Operational Rating is paramount. However, ideally an Asset Rating would be calculated at the same time.

**Other detail proposed on the first page**

- Above the scales, showing the type of certificate, the building type (here an office but it could include sub-types or mixed uses), and whether the certificate is for the whole building, a part of it (e.g. an individual tenancy), or perhaps even for Landlord's Services only.
- Below the scales, there are the quantitative performance indicators and further information:
- On the methods and units used. In particular, the UK is likely to use $CO_2$ for final comparisons, while many other EU countries will want to use primary energy. Different countries and sometimes sectors are likely to use different methods and floor area definitions.
- Then on key numbers, for example occupancy levels – which are critical inputs to models and critical outputs from in-use assessments.
- Finally on the energy efficiency grades for subsystems and management.
- There is also space for an indicator of internal environmental quality.

Some people think the first page needs to be simpler. If so, some detail could go on later pages, which will need to show the recommended savings measures (unless they are on Page 1) and supporting input and output data on both the design, its performance in use, and to identify the specific methods and assumptions used in making the assessments.

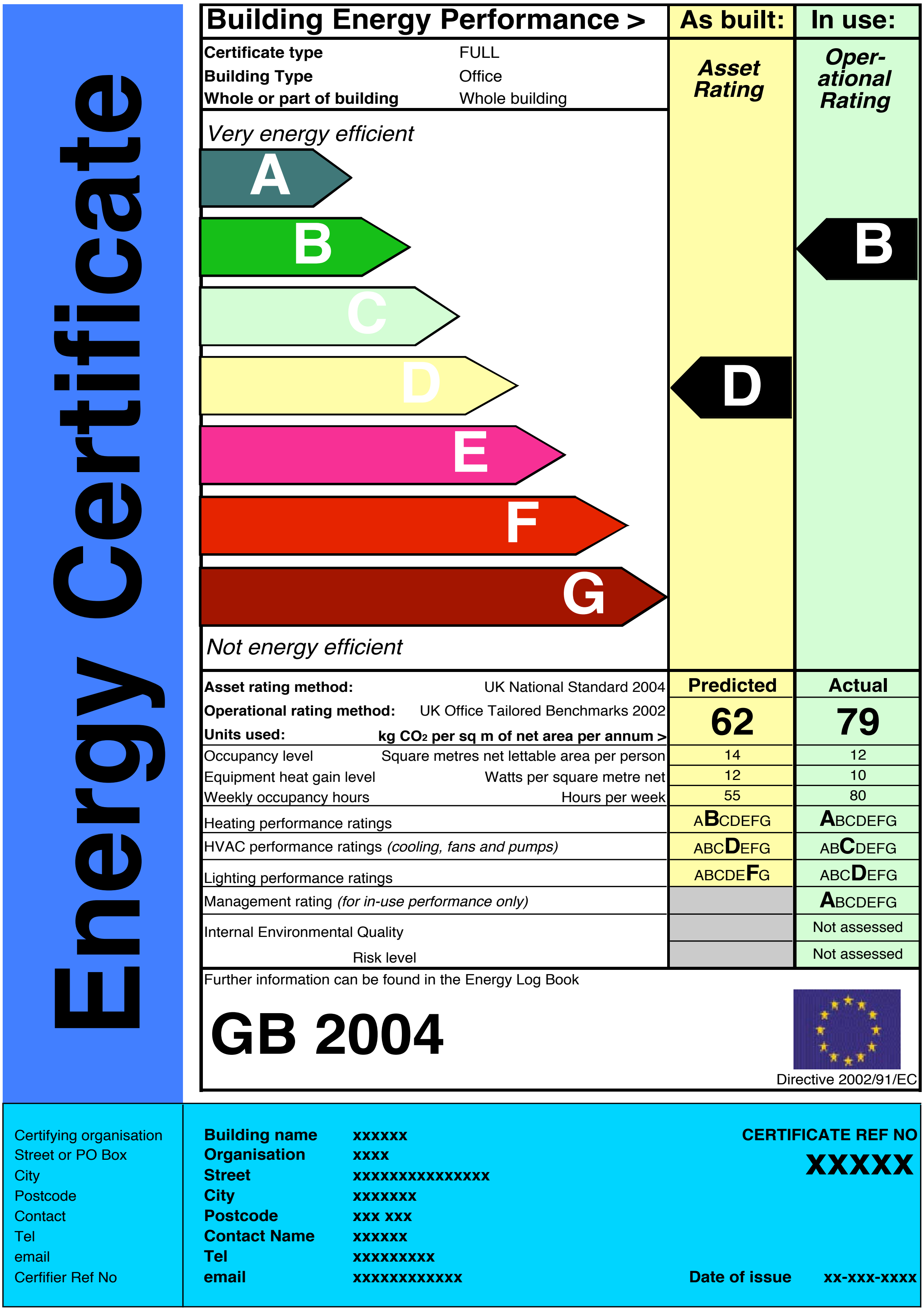
## Conclusions

If we are serious about reducing $CO_2$ emissions from nondomestic buildings, then it is vital to use the EPBD to address achieved performance and to close the credibility gaps. Major opportunities lie in:

1. bringing into use newly-completed, newly-refurbished and newly-occupied buildings;
2. fitouts - these may be trapped by Building Regulations in the UK, but not necessarily elsewhere;
3. improving the management of existing buildings (including newly-occupied ones, for example by re-certifying them some three years after occupation, taking account of actual energy use); and
4. helping to close the feedback loop into procurement, design, construction and handover so that the supply side learns how to achieve true performance improvements in practice, and building operators learn to make better use of the latent potential of a building and its systems.

We hope that the design of the certificate finally chosen, together with the underlying procedures, will enable these objectives to be achieved in an efficient and cost-effective way, and stimulate rapid reductions in energy use and $CO_2$ emissions by taking account of how buildings actually work and are used and managed.

Figure 4. A possible first page of an energy certificate, showing both Asset and Operational Ratings



Energy Certificate

| Building Energy Performance > | | As built: | In use: |
|---|---|---|---|
| **Certificate type** | FULL | *Asset Rating* | *Oper-ational Rating* |
| **Building Type** | Office | | |
| **Whole or part of building** | Whole building | | |

*Very energy efficient*

A
B
C
D
E
F
G

*Not energy efficient*

As built (Asset Rating): D
In use (Operational Rating): B

| | | Predicted | Actual |
|---|---|---|---|
| **Asset rating method:** | UK National Standard 2004 | | |
| **Operational rating method:** | UK Office Tailored Benchmarks 2002 | 62 | 79 |
| **Units used:** | **kg $CO_2$ per sq m of net area per annum >** | | |
| Occupancy level | Square metres net lettable area per person | 14 | 12 |
| Equipment heat gain level | Watts per square metre net | 12 | 10 |
| Weekly occupancy hours | Hours per week | 55 | 80 |
| Heating performance ratings | | A**B**CDEFG | **A**BCDEFG |
| HVAC performance ratings *(cooling, fans and pumps)* | | ABC**D**EFG | AB**C**DEFG |
| Lighting performance ratings | | ABCDE**F**G | ABC**D**EFG |
| Management rating *(for in-use performance only)* | | | **A**BCDEFG |
| Internal Environmental Quality | | | Not assessed |
| | Risk level | | Not assessed |

Further information can be found in the Energy Log Book

**GB 2004**

Directive 2002/91/EC

| | | | |
|---|---|---|---|
| Certifying organisation | **Building name** | xxxxxx | **CERTIFICATE REF NO** |
| Street or PO Box | **Organisation** | xxxx | **XXXXX** |
| City | **Street** | xxxxxxxxxxxxxxx | |
| Postcode | **City** | xxxxxxx | |
| Contact | **Postcode** | xxx xxx | |
| Tel | **Contact Name** | xxxxxx | |
| email | **Tel** | xxxxxxxxx | |
| Cerfifier Ref No | **email** | xxxxxxxxxxxx | **Date of issue** xx-xxx-xxxx |

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