# WHAT COLOUR is YOUR BUILDING?

## Measuring and reducing the energy and carbon footprint of buildings

David H. Clark


# Appendix D
## Operating energy rating methodology

www.whatcolourisyourbuilding.com

# Appendix D: Operating energy rating methodology

*The measure of success is not whether you have a tough problem to deal with, but whether it is the same problem you had last year.*

John Foster Dulles, U.S. Secretary of State (1953-59).

Contents

This appendix describes how, in the author's opinion, the Display Energy Certificate (DEC) methodology in the UK could be adapted to better motivate landlords and tenants to reduce energy consumption and $CO_2e$ emissions in commercial office buildings.

The principles outlined in this appendix can be applied, with suitable adjustments, to benchmark energy performance in any country. If primary energy is the preferred unit of energy then simply substitute this for $kgCO_2e$, using the appropriate conversion factors (refer to Appendix C – Energy consumption data).





Published by RIBA Publishing, 15 Bonhill Street, London EC2P 2EA
www.ribaenterprises.com

Issue 1.0: 30 June 2013

# D1. OVERVIEW OF PROPOSED RATING TOOL

This section provides an overview of the proposed energy performance rating methodology. Sections D2 to D4 provide more details to justify the proposed approach.

## D1.1 Calculation methodology

The calculation methodology used in DECs is a good starting point as it is very simple.

$$\text{Rating Score} = \frac{\text{energy consumption}}{\text{energy benchmark}} \times 100\%$$

The key components to define are therefore:

- energy consumption – what to include, what to leave out
- energy benchmark – to reflect building use, area, occupancy density and hours of use
- rating scale – where to set the top, median and bottom scores, and the number of steps in-between.

A separate rating for landlords and tenants is also proposed.

## D1.2 Energy consumption

The annual energy consumption is determined from utility meters (or fuel delivery dockets for solid/liquid fuels) for the landlord, tenant or whole building. At the design stage, energy modelling should use a methodology to estimate the metered energy consumption over 12 months. One of the most robust methodologies is described in the NABERS energy guides to energy estimation for buildings and tenancies, as these are regularly updated to calibrate modelling with measured performance.[1] This is very different to the UK Energy Performance Certificate (EPC) modelling which does not attempt to estimate actual consumption.[2]

The total energy consumption is then converted to a consistent energy unit of $kgCO_2e$. The UK emission factors (EF) are set out in Chapter 1 while factors for other countries are listed in Appendix B.

$$\text{Energy consumption } (kgCO_2e) = \text{Electricity (kWh)} \times EF + \text{Gas (kWh)} \times EF + \ldots\ldots$$

Large unusual energy consuming items (known as seperables in the DEC methodology) are often excluded from energy ratings. For example, a large server room providing IT services to an organisation (including computers in other buildings) would have a worse rating than a building which outsources the IT (and associated energy consumption) to an external data centre. The total building energy consumption ($kgCO_2e$) should always be reported on a rating certificate, but separables can be excluded from the calculation of the rating score, provided they are separately metered and the owner is taking steps to reduce their energy consumption.

The CIBSE guide *Operational Ratings and Display Energy Certificates – TM47:2008* provides guidance on how to exclude allowable separable 'process' energy loads from the energy consumption in the DEC rating calculation. These include regional server rooms, trading floors and bakery ovens.

## D1.3 Energy benchmarks

The energy benchmark represents the typical energy consumption of a building type (office, retail, etc.). These are based on the median of measured energy consumption in a wide range of buildings.[3] The median gives a slightly lower number than the average because a 100 $m^2$ building counts the same as a 10,000 $m^2$ building in the determination of the benchmark. Statisticians can argue over which is most appropriate – however the key aim is to motivate people to save energy.

In this book the typical benchmark for offices, using the $CO_2e$ emission factors in Chapter 1, has been set at 100 $kgCO_2e/m^2$ of oGIA. This is 20% higher than the current DEC benchmark of 81 $kgCO_2e/m^2$, but is lower than the benchmarks for most air conditioned office building benchmarks from ECON 19.[4]

The occupied gross internal area (oGIA) used in this appendix is the standard GIA (excluding car parking and untreated spaces) reduced to reflect the percentage of the net lettable area (NLA) of the building that is not occupied by tenants. The current DEC system does not make this adjustment, which is why an empty building can get an A rating.

$$\text{Occupied Gross Internal Area (oGIA)} = \text{GIA} \times \frac{\text{Occupied NLA}}{\text{Total NLA}}$$

The benchmark also needs to be adjusted to reflect the intensity of use of a building. The typical benchmark is based on:

- Occupancy density: 1 workspace per 12 $m^2$ of NLA (roughly 1 per 15 $m^2$ of GIA).
- Hours of use: 50 hours per week (2,600 hours per year).

Figures D.1 and D.2 show proposed factors to adjust the office energy benchmark for occupancy density and extended hours of use. The hours factor for the whole building is very similar to the current DEC factor for offices and would apply when 25% or more of the workspaces are occupied during extended hours. The main issue with occupancy density is agreeing a simple but robust method of measuring this. The derivation of the factors is described in Section D.2

The charts also show separate factors for landlord and tenancy benchmarks, which are discussed in Section D1.6.

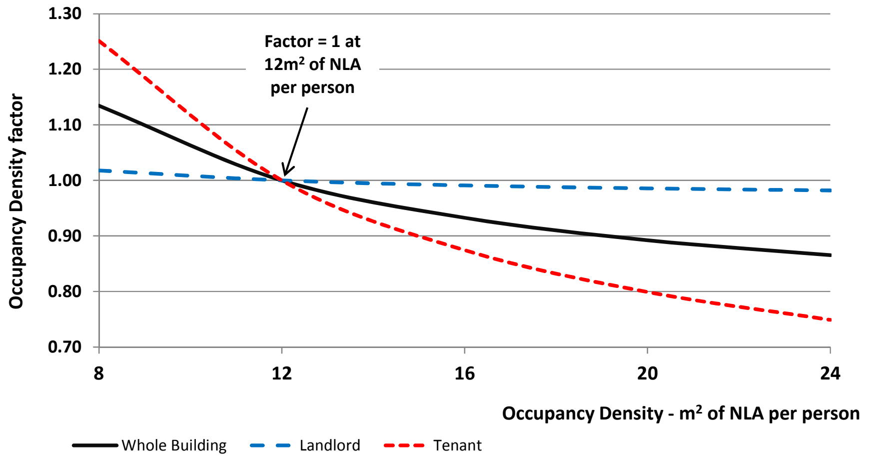



**Fig D.1** **Benchmark adjustment factor for occupancy density**

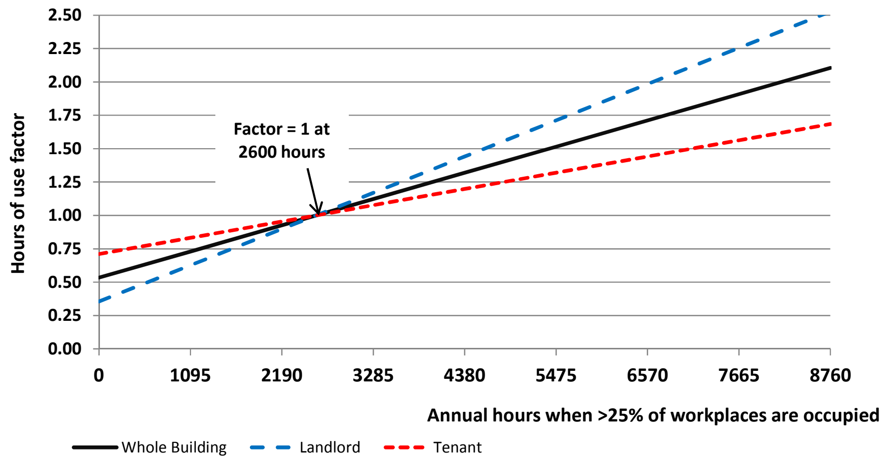



**Fig D.2** **Benchmark adjustment factor for hours of use**

The energy benchmark for an office building is:

Energy benchmark ($kgCO_2e$) = 100 $kgCO_2e/m^2$ x oGIA ($m^2$) x Occupancy factor x Hours factor

The default occupancy and hours factors should be 1, unless sufficient evidence can be provided to justify using alternative factors. This keeps the cost of undertaking ratings to a minimum for most buildings, as only owners or occupants who need a better rating will pursue the cost of gathering the data to use a different occupancy or hours factor.

*Note: The rules regarding adjustment of benchmarks and exclusion of seperables for official rating tools need to be far more robust and detailed than explained here. This appendix aims to highlight the key principles – it is not an official rating tool.*

## D1.4 Rating scale

The rating score is calculated by dividing the energy consumption by the energy benchmark. The challenge lies in representing this score so that it is easy to understand, and encourages building owners and occupants to want to make improvements.

Figure 2.6 in Chapter 2 showed that the DEC rating scale in 2012 was particularly tough. In Australia, the NABERS rating scale originally stopped at 5 stars (equivalent to a DEC rating of 'C'), but there was a big gap between 5 stars and zero carbon, so in 2011 a sixth star was added, with the addition of more likely in the future. The US Energy Star top score of 100 falls well short of zero carbon.

A rating scale should ideally reflect a low carbon aspiration, the typical performance of the building stock, and provide enough increments (or steps) to allow differentiation in the market place. The NABERS rating tool initially only used whole stars, but half stars were quickly introduced to recognise and reward incremental improvement.

The current DEC scale of 0 to 150 places the median (100) at the two third point in the scale on the D/E boundary. This means a lot of buildings must get a 'G' rating, because the median isn't in the middle.

Figure D.3 shows a potential alternative rating scale to reflect the diversity of energy performance in the building sector. This ranges from a score of 0 to 175 and consequently puts the median (100) closer to the middle of the scale. The scale also splits the ratings into sub-steps (similar to the half star concept) to provide more differentiation between buildings, particularly at the lower end where the majority of commercial offices will reside. The impact at the top end of the scale is relatively small – an 'A' rating is still very challenging to achieve.

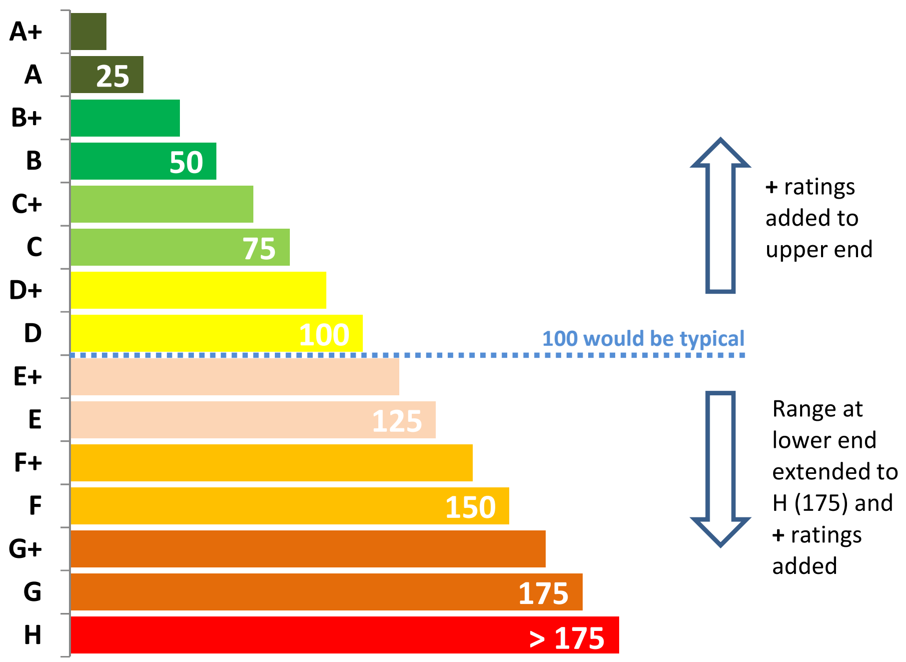



**Fig D.3 A possible alternative energy rating scale for commercial buildings**

The primary purpose of energy rating tools is to make energy visible to building owners and occupants, to motivate them to take action. If they don't do this, then they are just a framed certificate on a wall gathering dust. The rating scale therefore needs to engage with the maximum number of people (occupants and building owners).

Figure D.4 shows the annual energy consumption of 138 large commercial office buildings in London.[5] Over 50% of these buildings would achieve the lowest rating using the current DEC rating scale. In comparison, only 24% would achieve the lowest rating ('H') using the benchmark and extended rating scale proposed in this book. If over half the commercial offices receive the lowest rating under the current system, then this provides little differentiation or motivation to occupiers and building owners to act. The proposed rating scale in this appendix shows 27% of offices achieving a 'D' rating or better and 6% receiving a 'B' rating, which seems more reasonable for commercial offices compared to 17% and 2% respectively for the current DEC rating system. An 'A' rating is very difficult to achieve in either scale.

Section D4 gives examples of the use of energy labels for fridges, boilers and cars, which all have a similar appearance to building energy ratings in the UK. These have evolved to reflect the range in energy efficiency of each product and show that there is no precedent for sticking rigidly to an 'A' to 'G' scale:

- The fridge scale now starts at 'D' and goes up to 'A+++'.
- The boiler energy scale has been scrapped because energy efficiency legislation means that all new boilers get an 'A' rating.
- The car emissions scale ranges from 'A' (<100 g/km) to 'M' (>255 g/km) to reflect the wide diversity of type, size and performance of vehicles.

Building energy labels are also similar in appearance to consumer product labels in other countries such as Australia (star ratings) and the US (Energy Star label). This creates a public understanding of what constitutes good performance.

Finally, in the author's opinion, it would be better if an EPC (design) and a DEC (operational) certificate actually looked different – very few people can currently tell them apart visually.[6]

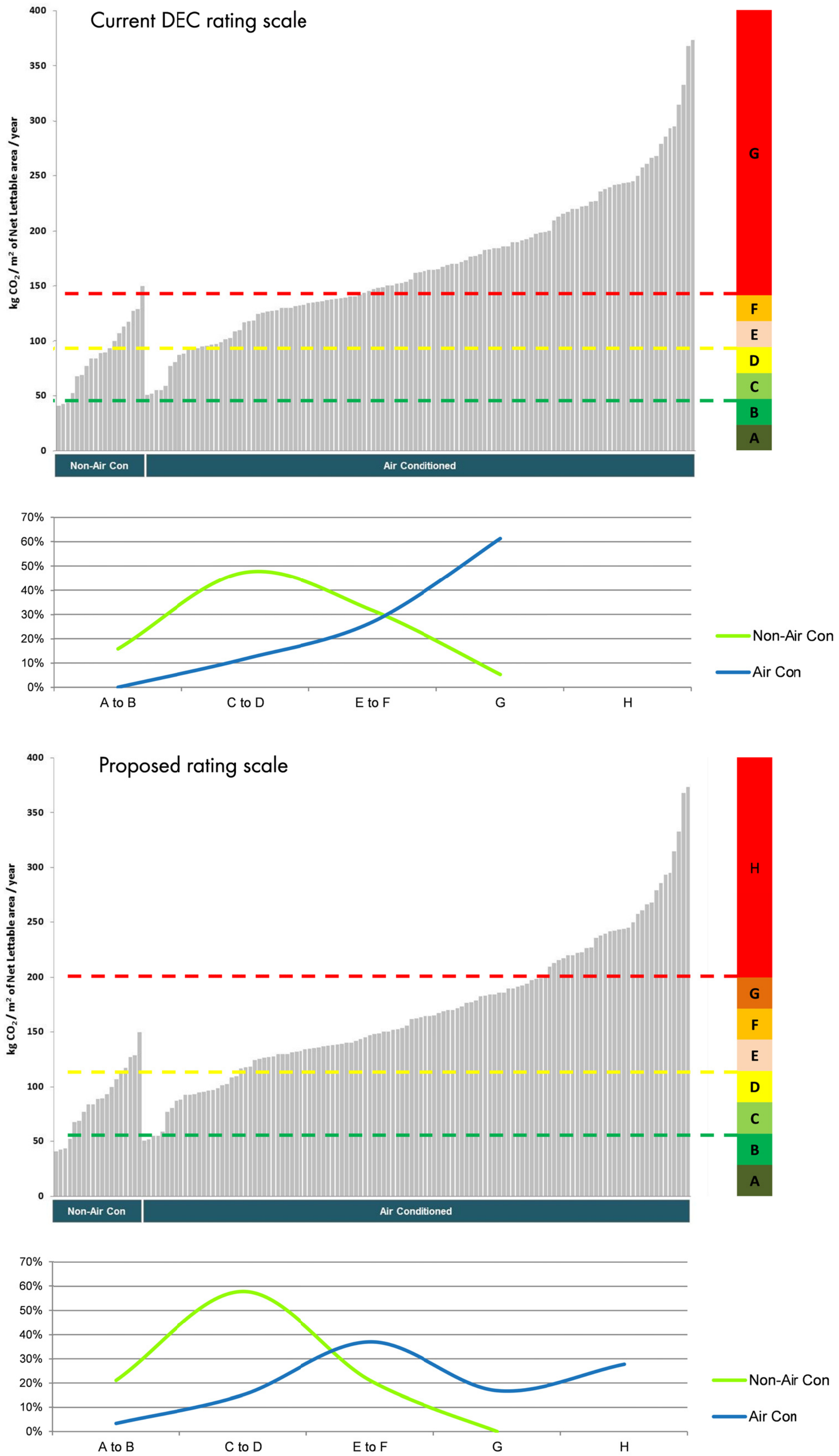



**Fig D.4** **Current DEC scale and proposed rating scale applied to 138 commercial office buildings in London with rating distribution curves (energy charts from Jones Lang LaSalle / Better Buildings Partnership, 2012)**

## D1.5 Example calculation for Building X

Building X (refer to Appendix M) is a 10-storey office building with 10,000 $m^2$ of GIA, an occupancy density of 1 workplace per 12 $m^2$ of NLA, and an occupancy greater than 25% for 60 hours per week for 50 weeks of the year. The building was 95% leased and consumed 1,500 MWh of electricity and 750 MWh of natural gas over a 12 month period.

Step 1 – convert the energy consumption to $kgCO_2e$
**Energy Consumption** = 1,500,000 x 0.6 + 750,000 x 0.2 = **1,050 $tCO_2e$** (105 $kgCO_2e/m^2$ of GIA).
There are no deductions from the total for allowable seperables in this building.

Step 2 – calculate energy benchmark
**Standard benchmark:** For offices this is **100 $kgCO_2e/m^2$ of GIA**
**Area:** The total net lettable area is 8,000 $m^2$. The occupied area over 12 months was 7,600 $m^2$ so the oGIA = (7,600 / 8,000) x 10,000 = **9,500 $m^2$**
**Occupancy:** The occupancy density factor for 1 per 12 $m^2$ of NLA from Figure D.1 is **1.0**
**Hours:** The extended hours of use = 60 hours x 50 weeks = 3000 hours per year. From Figure D.2 the hours factor is **1.07** (refer to Appendix D3.1 for calculation formula)
**Adjusted energy benchmark** = 100 x 1.07 x 1.0 = **107 $kgCO_2e/m^2$ of oGIA**
*Note: if hours of use or occupancy are not known then default values of 1.0 are used for both.*

**Total building energy benchmark** = 107 x 9,500 $m^2$ = **1,018 $tCO_2e$**
*If the building had other uses (e.g. retail on ground floor), the benchmark would be built up by following the process above for the area of each use and then adding the total energy benchmark for each to give a total $tCO_2e$ benchmark for the whole building.*

Step 3 – calculate the rating score
**Rating score** = [1050 / 1018] x 100 = **103**
On the scale in Figure D.3 this would have an 'E+' rating. Without the adjustment for unoccupied floor area the score would have been 98 (a 'D' rating).

## D1.6 Landlord and tenant benchmarks in offices

Unlike most other building types which have a single owner-occupier (e.g. public buildings, houses, industrial, hospitals, etc.), in commercial buildings, such as offices and shopping centres, there are usually two parties – the landlord and the tenant. Each controls different aspects of energy use and each should therefore have separate benchmarks to assess their own performance in reducing energy consumption. Poor energy management by the landlord can drag the rating of a building down, despite what the tenants might be doing to save energy. Conversely, a landlord with an efficient building can receive a poor rating because the tenants leave computers and lights on overnight.

Energy benchmarking should therefore follow the 'polluter pays principle', or, as we are talking about energy labels, the 'polluter displays principle'.

In many buildings the tenants have their own electricity meters, with supply contracts directly with utility companies, so compiling whole building energy consumption in a multi-tenanted building might not be possible without legislation requiring energy disclosure by all tenants.

Recognising this as long ago as 1999, the Australian NABERS rating scheme has three versions – base building (for landlords), tenants and whole building – with the majority of ratings undertaken for base buildings. This is because many landlords wanted to demonstrate the energy performance of their building to tenants either to attract or retain them. Since 2010 it is mandatory for landlords with buildings over 2,000 $m^2$ to provide a NABERS Energy rating.[7]

In 2012, there were no official separate benchmarks for landlords or tenants in the UK and a number of organisations support the development of these.[8] Currently landlords use Energy Performance Certificates (EPCs) which are based on computer modelling, while tenants use DECs which include a proportion of the landlord's energy.

The benchmarking of operational energy in office buildings needs to recognise two fundamental issues:

- a landlord's asset is floor area, a tenant's asset is people; and
- the energy performance rating should reside with the party who provides the services and controls the energy.

In a typical commercial office building, with an occupancy of 1 person per 12 $m^2$ of NLA and with the landlord providing all the Heating, Ventilation and Cooling (HVAC), then the 100 $kgCO_2e/m^2$ benchmark is split roughly equally between the two parties (refer to Section D2). Converting the tenancy benchmark into $kgCO_2e$ per person then gives:

| | |
|---|---|
| Landlord benchmark: | 50 $kgCO_2e$ / $m^2$ of oGIA |
| Tenant benchmark: | 750 $kgCO_2e$ / person |

The intention here is to illustrate the principle of benchmarking landlord and tenant energy separately. Further research is required to determine if this simple 50:50 split is appropriate – which will of course require more energy consumption data from real buildings to be made available.

The hours of use factors in Figure D.2 can be applied to both of these benchmarks. The occupancy factor for landlords in Figure D.1 is fairly negligible, and given the difficulty a landlord would have in measuring how many people the tenants employ in the building, this factor can be practically ignored when considering landlord ratings. The occupancy density factor is not required for the tenancy benchmark, as it is already based on people. Most tenants know (or should know) how many people they employ and how often they work.

| | |
|---|---|
| Landlord benchmark: | 50 $kgCO_2e/m^2$ x oGIA x Hours Factor |
| Tenant benchmark: | 750 $kgCO_2e$/person x no. of people x Hours Factor |

However, as always with energy benchmarking, it is not as simple as setting a landlord and tenant benchmark. Some landlords don't provide any heating, cooling or ventilation to tenant spaces, while others may provide a mix of different services, often in the same building. Section D3 proposes a method of adjusting the landlord and tenant benchmarks based on the HVAC services that each is responsible for.

## D2. POTENTIAL LANDLORD AND TENANT BENCHMARKS

Table D.1 shows how the proposed office energy benchmark of 100 $kgCO_2e/m^2$ of oGIA in Chapter 2 is assumed to be split in a typical building with gas boilers and electric chillers.

| | Electricity | Gas | Total |
|---|---|---|---|
| $kWh/m^2$ | 140 | 80 | 220 |
| Emissions factor | 0.6 | 0.2 | |
| **$kgCO_2e/m^2$** | **84** | **16** | **100** |

**Table D.1 Assumed energy split in the benchmark office**

Determining an appropriate split between tenant light and power and the landlord's base building services requires a detailed review of sub-metered energy consumption in a wide range of buildings. This is not available to the author. The average of the energy use indices in ECON19 for the eight office benchmarks (refer to Appendix C) is summarised in Table D.2 and suggests an average 48:52 tenant to landlord split.

| | Tenant | Landlord |
|---|---|---|
| Nat vent cellular (good) | 48% | 52% |
| Nat vent cellular (typical) | 43% | 57% |
| Nat vent open plan (good) | 56% | 44% |
| Nat vent open plan (typical) | 52% | 48% |
| **Average nat vent** | **50%** | **50%** |
| Air con standard (good) | 43% | 57% |
| Air con standard (typical) | 38% | 62% |
| Air con prestige (good) | 55% | 45% |
| Air con prestige (typical) | 49% | 51% |
| **Average air con** | **46%** | **54%** |

**Table D.2 Tenant / landlord energy consumption split from ECON19**

The only Cundall office where the landlord provided all HVAC services was London, which had a split of 45:55 (refer to Appendix C). In a BBP paper,[9] the breakdown of energy use of British Land's office portfolio in 2010-11 was given as:

- Occupier (tenancy lighting & small power) = 50%
- Landlord influenced (shared services) = 36%
- Landlord controlled (common areas) = 14%

While more research is clearly required, the office energy benchmark could be reasonably assumed to be split equally between landlord and tenant with each receiving 50 $kgCO_2e/m^2$ of oGIA. Table D.3 shows the breakdown by electricity and gas.

| | Tenant electricity | Landlord electricity | Landlord gas |
|---|---|---|---|
| Proportion of electricity | 60% | 40% | - |
| Energy ($kWh/m^2$) | 83 | 57 | 80 |
| **$kgCO_2e/m^2$** | **50** | **34** | **16** |

**Table D.3 Assumed tenant and landlord split for energy benchmarking**

The breakdown by energy end use will vary in every building. For discussion purposes – and to illustrate the work required to develop adjustment factors for landlord and tenancy ratings based on services provided – the assumed breakdown of the office benchmark is shown in Table D.4.

| Energy end use | $kgCO_2e/m^2$ |
|---|---|
| Heating & DHW (gas) | 16 |
| Cooling | 10 |
| Ventilation fans | 10 |
| Pumps & controls | 8 |
| Other (lift, common area lighting, etc.) | 6 |
| **TOTAL - Base building services** | **50** |
| | |
| Tenancy lighting | 18 |
| Tenant small power (personal) * | 17 |
| Tenant small power (shared) * | 15 |
| **TOTAL - Tenancy** | **50** |
| | |
| **TOTAL – Whole building** | **100** |

* Small Power (personal) refers to personal computers and equipment while Small Power (shared) refers to tenancy items that do not vary directly with staff numbers (e.g. servers, fridges, etc). This is used in the derivation of the hours of use adjustment factor in Section D.3.

**Table D.4 Assumed breakdown of office energy benchmark by energy use**

These benchmarks are acceptable if the landlord provides all the heating, ventilation and cooling (HVAC) services in the building. This might occur in large commercial offices with central heating and cooling, but in many offices the tenants are responsible for providing the heating and cooling energy. For example, the use of VRF systems (heat pumps) connected directly to the tenancy electricity meter would distort the landlord or tenant ratings if they were not adjusted to reflect this. It should be possible to develop a rating methodology which makes some adjustment based on which party provides which services to the different areas of the building.

Table D.5 shows how the landlord benchmark is adjusted for an example building where the landlord provides the ventilation, with the heating and cooling from a VRF system connected to the tenant's electricity meter. The ventilation system provides tempered air (heating only) to the tenants, so an assumption that 30% of the heating is provided by the landlord has been made. The reception foyer is also cooled, together with some of the common areas, so an assumption that 5% of the cooling is provided by the landlord has been made. In this example the landlord benchmark is reduced to 21.7 $kgCO_2e/m^2$, while the tenant benchmark is increased to 77.3 $kgCO_2e/m^2$.

| Services | Base building benchmark ($kgCO_2e/m^2$) | Services provided by landlord | Services provided by tenant | Landlord energy benchmark ($kgCO_2e/m^2$) | Energy to add to tenant benchmark ($kgCO_2e/m^2$) |
|---|---|---|---|---|---|
| Heating | 15 | 30% | 70% | 4.5 | 10.5 |
| DHW | 1 | 100% | 0% | 1 | 0 |
| Cooling | 10 | 5% | 95% | 0.5 | 9.5 |
| Ventilation | 10 | 100% | 0% | 10 | 0 |
| Pumps and controls | 8 | 30% | 70% | 2.4 | 5.6 |
| Common area | 6 | 100% | 0% | 6 | 0 |
| **TOTAL** | **50** | | | **24.4** | **25.6** |

**Table D.5 Example of simplified landlord / tenant benchmark adjustment based on HVAC services**

In a naturally ventilated building, the cooling and ventilation benchmarks should stay with the landlord, because they are providing a building which doesn't require fans and cooling to provide comfort.

More research is required to determine an appropriate method of allocating the energy benchmark to landlords and tenants, to ensure that it is simple (e.g. a drop-down menu in a rating tool), and to close any loopholes that could be exploited to improve ratings without reducing energy.

# D3. CALCULATION OF PROPOSED ADJUSTMENT FACTORS

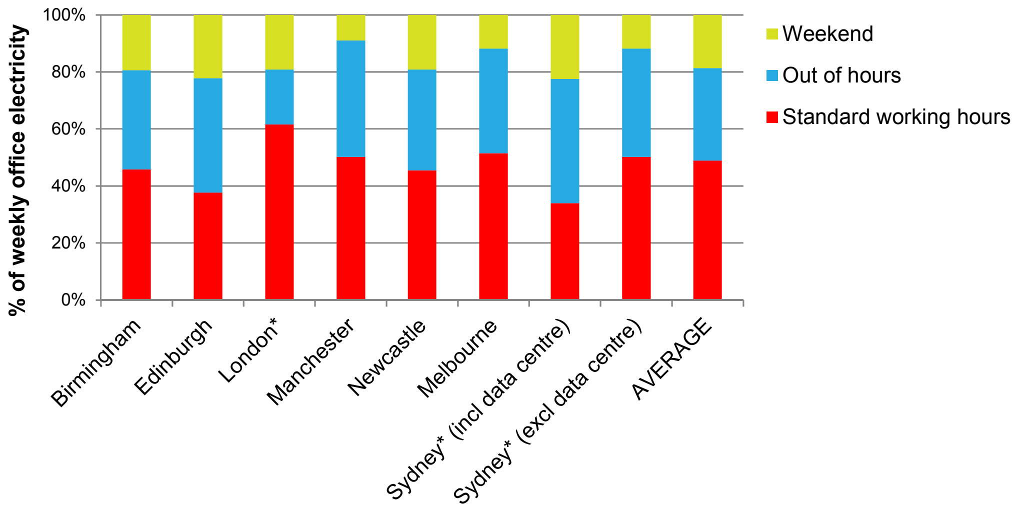
## D3.1 Hours of use adjustment factor

There are 8,760 hours in a year. The office benchmark is based on a building being occupied for 10 hours per day (8am to 6pm), 5 days per week, which is 2,600 hours per year (30% of the year).

The development of an hours of use adjustment factor needs to recognise that buildings consume energy when they are unoccupied (evenings and weekends), and that this vacant hours energy consumption is already included in the office benchmark. Vacant hours are the hours outside standard working hours when the building is either empty or lightly occupied. If a building is occupied by more than 25% of the occupants for extended hours, then this should be recognised and the energy benchmark increased accordingly.

Determining the energy consumption profile is relatively easy if the building has smart meters or a BMS metering system. Published energy data is 'as rare as hen's teeth' however.

In November 2009, Cundall undertook a simple 'time of energy use' study in seven offices to obtain an understanding of when energy was being consumed. The tenancy electricity meters were read at the start and end of each normal working day for one week, starting and finishing on Monday morning. The energy use during each working day, overnight and during the weekend was then calculated. Figure D.5 shows the split by time of use for each office.




* Does not include air conditioning systems which are provided by the Landlord.

**Fig D.5 Time of tenancy electricity use study in Cundall offices in November 2009**

All the offices turned lights off at night and most people switched off their computers. Despite this, the vacant hours energy use averaged 50% of the total weekly tenancy energy consumption (with a minimum of 38% and a maximum of 62%). This is probably not unusual – you can check it in your own office by doing the same exercise yourself over a week.

Lots of equipment is left switched on for 8,760 hours each year, including fridges and IT servers. Also, if one or two people (or the cleaners) stay back late, or come in early and turn all of the lights on, then the vacant hours energy consumption is increased. It was estimated that the IT servers accounted for up to 40% of the total tenancy electricity consumption (light and power) in a typical office.

Data from Cundall's landlord in Newcastle suggests that around 25% of base building electrical energy use occurs during the night tariff period. There is less vacant hours energy use for the base building services because there is less equipment required to run 24/7 (such as large IT servers) and the BMS should be able to shut down HVAC systems most of the time when not required.

Figure D.6 shows a suggested typical split in energy use between working hours and vacant hours for a standard 50 hour per week office workplace, based on the findings of the (albeit very limited) Cundall office energy study. Further research is required on typical vacant hours energy use in a range of office buildings.

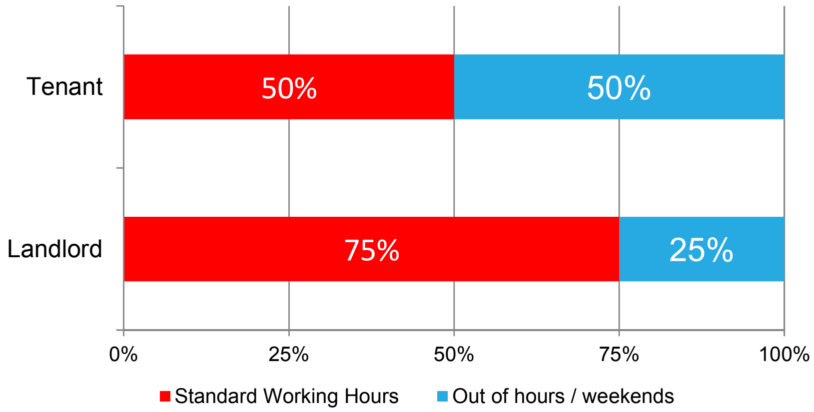



**Fig D.6 Proportion of energy use during standard and vacant hours in typical offices (estimated)**

Section D2 suggested a 50:50 split between landlord and tenancy energy for typical office buildings. Table D.6 shows how the vacant hours energy split for landlord and tenants is applied to this to adjust the office benchmarks for different hours of use.

The hours of use adjustment factors in Figure D.2 are then derived from this table. For example, the factor for a whole building occupied for 8,760 hours per year is 211/100 = 2.1. The formula to calculate the factors shown in Figure D.2 are:

Hours of Use Factor = A + [B x occupied hours / 8,760]

where A and B are:

| | A | B |
|---|---|---|
| Whole Building | 0.53 | 1.57 |
| Base Building | 0.36 | 2.17 |
| Tenancy | 0.71 | 0.97 |

| | Hours | Days | Weeks | | Hours | | |
|---|---|---|---|---|---|---|---|
| Standard hours | 10 | 5 | 52 | | **2600** | | |
| Maximum hours | 24 | 365 | | | **8760** | | |
| | | | | | | | |
| | **Landlord electricity** | **Landlord gas** | **Tenant electricity** | | **Whole building** | **Landlord** | **Tenant** |
| Energy split | 40% | 100% | 60% | | | | |
| $kWh/m^2$ | 57 | 80 | 83 | | 220 | 137 | 83 |
| **$kgCO_2e/m^2$** | **34** | **16** | **50** | | **100** | **50** | **50** |
| | | | | | | | |
| **Vacant hours energy use** | **25%** | **25%** | **50%** | | | | |
| Energy in std. hrs | 25 | 12 | 25 | | 62 | 37 | 25 |
| Energy in vacant hrs | 8 | 4 | 25 | | 38 | 12 | 25 |
| | | | | | | | |
| Energy per std. hour | 0.009789 | 0.004615 | 0.009628 | | | | |
| Energy per vacant hour | 0.001377 | 0.000649 | 0.004064 | | | | |
| **Energy for 8,760 hours** | **86** | **40** | **84** | | **211** | **126** | **84** |
| | | | | | | | |
| **Hours** | | **$kgCO_2e/m^2$** | | | | **$kgCO_2e/m^2$** | |
| 0 | 12 | 6 | 36 | | **53** | 18 | 36 |
| 1095 | 21 | 10 | 42 | | **73** | 31 | 42 |
| 2190 | 30 | 14 | 48 | | **93** | 45 | 48 |
| 3285 | 40 | 19 | 54 | | **112** | 58 | 54 |
| 4380 | 49 | 23 | 60 | | **132** | 72 | 60 |
| 5475 | 58 | 27 | 66 | | **152** | 86 | 66 |
| 6570 | 67 | 32 | 72 | | **171** | 99 | 72 |
| 7665 | 77 | 36 | 78 | | **191** | 113 | 78 |
| 8760 | 86 | 40 | 84 | | **211** | 126 | 84 |

**Table D.6** **Calculation of vacant hours energy use in offices**

The CIBSE guide *Operational Ratings and Display Energy Certificates – TM47:2008* provides guidance on how to adjust the DEC rating based on hours of use. If the occupier can demonstrate that the occupancy exceeds 25% of the usual maximum occupancy for more than 2,040 hours per year, the office benchmark can be increased using the formula:

Benchmark = 75.5 $kgCO_2/m^2$ + {0.009844 x [(Hours > 25% occupancy) – 2,040]}.

If the office is occupied for 8,760 hours (i.e. 24/7), the DEC benchmark is 141.7 $kgCO_2/m^2$. This is equivalent to an hours of use factor of 1.9, which is similar to the result using the methodology described above.

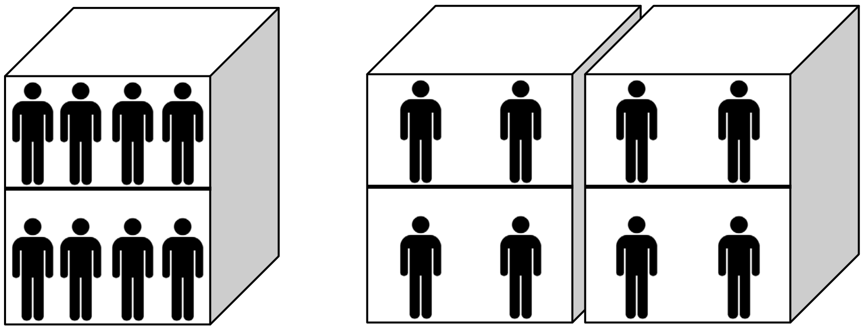
## D3.2 Occupancy density adjustment factor

Buildings don't use energy – it is people using buildings that use energy. As the number of people occupying a building increases, the total energy consumed should increase (more air conditioning, ventilation, computers and equipment) and consequently the energy rating gets worse. However, by increasing the occupancy density, the total energy consumed per person reduces because the building space is being used more intensely or efficiently. This is illustrated in the following example.

Building A has a GIA of 15,000 $m^2$ and is fully occupied by Company P. They have 1,000 occupants with an occupancy density of 1 per $10m^2$. The building has total emissions of 1,500 $tCO_2e$.

If the company decided to move half of its staff into Building B, which is identical to Building A, and to give everyone twice as much room, (an occupancy density of 1 per 20 $m^2$) then the energy consumption of Building A would clearly reduce – but not by half. This is because the whole floor space still needs to be lit, ventilated, heated and cooled.

Table D.7 shows what happens to the total energy consumption of Company P and the energy benchmarks for the buildings, if Building A's total consumption is assumed to reduce by one third when half the staff move into Building B. Building B has identical energy consumption to Building A.



| | Building A | | Building A | Building B |
|---|---|---|---|---|
| Floor area ($m^2$ – GIA) | 15,000 | | 15,000 | 15,000 |
| No. of occupants | 1000 | | 500 | 500 |
| Occupancy density ($m^2$/p) | 10 | | 20 | 20 |
| | | | | |
| **Total $kgCO_2e/m^2$** | **100** | | **67** | **67** |
| Energy per $m^2$ reduction | | | 33% | 33% |
| | | | | |
| **Total $tCO_2e$** | **1500** | | **2000** | |
| Energy increase | | | 33% | |

**Table D.7** **Illustration of how occupancy density can influence building energy benchmarking for a hypothetical example**

A densely occupied building, all other things being equal (hours, energy efficiency, etc.) will have a worse energy rating score, based on floor area only, compared to an identical building with half the people. If there is no adjustment factor for occupancy, companies making efficient use of their buildings will be penalised in comparison to less intensively used buildings. As Table D.7 shows, the total energy consumption of Company P increases if building space is used less intensively. The energy bills and rental costs will also increase.

Although this is a theoretical example, real energy data tends to support the principle, although the differences are not nearly as pronounced as in the hypothetical example described. Figures D.7 and D.8 show annual energy consumption (in $kgCO_2/m^2$ of NLA) for the year 2010/11 in 97 commercial properties in London (from the same data source used in Figure D.4). It is difficult to draw any firm correlation between decreasing occupancy density and decreasing energy consumption, particularly as there is so much variation in energy performance for buildings with the same occupancy density. The trend line in Figure D.7 can be crudely interpreted to suggest a 0.5% decrease in energy consumption for each $m^2$ of NLA provided per person above $10m^2$. Applying this to the hypothetical example above would suggest a 5% reduction, which is far less than the 33% calculated in Table D.7.

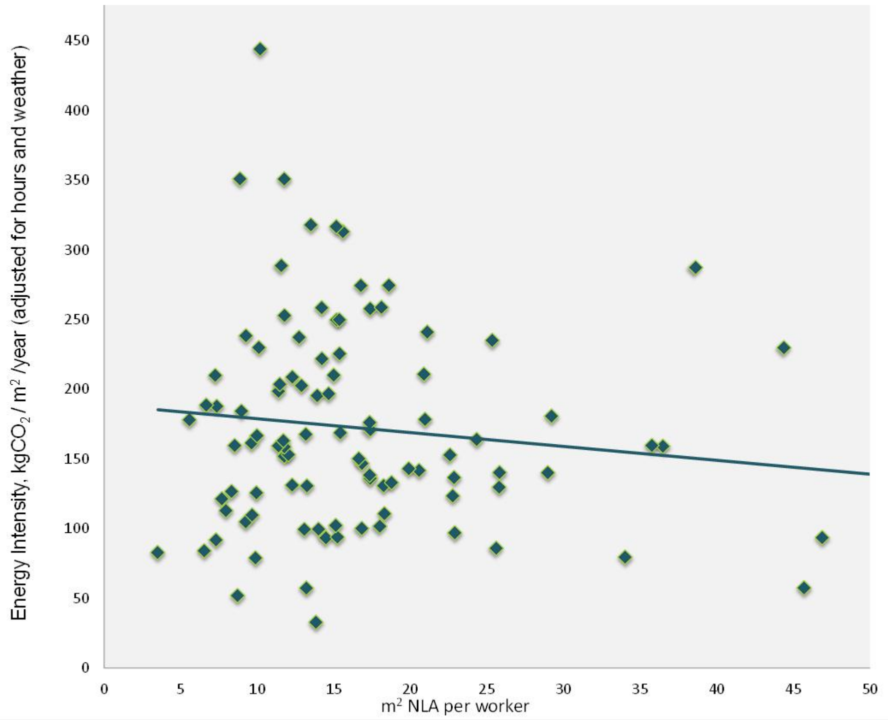



**Fig D.7** **Energy consumption compared to worker density in 97 commercial offices in London in 2010/11 (source: Jones Lang LaSalle / Better Building Partnership, 2012)**

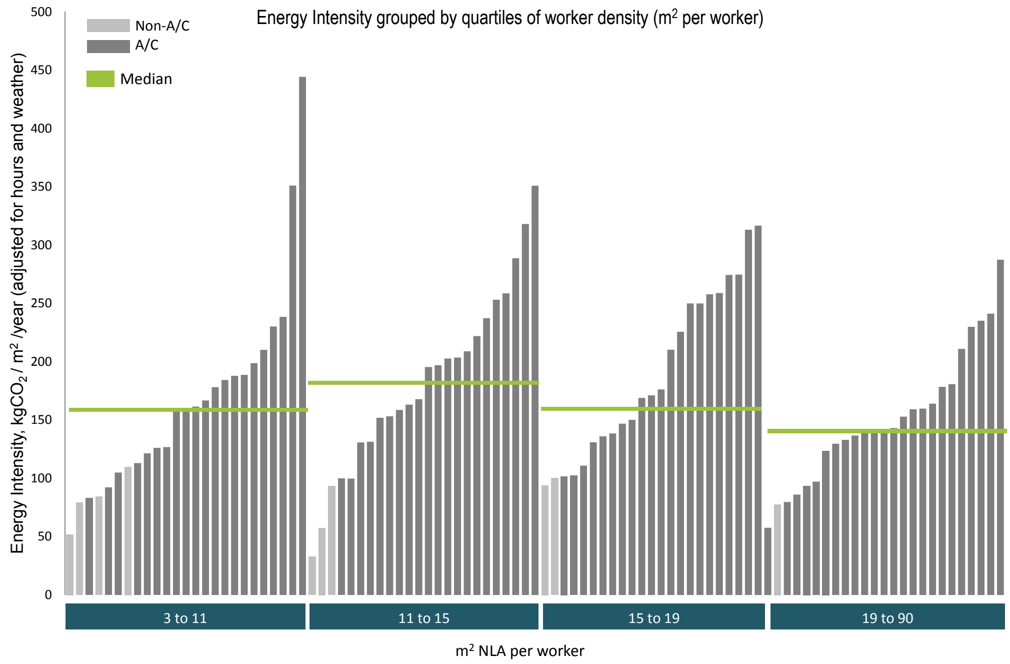



**Fig D.8** **Energy consumption grouped by occupancy density in 97 commercial offices in London in 2010/11 (source: Jones Lang LaSalle / Better Building Partnership, 2012)**

To make ratings fairer, the occupancy density of a building should be considered (both the NABERS and Energy Star energy rating systems do so). The challenge is finding a simple way of measuring people in buildings that the industry can agree on, and defining the adjustment factor. Options for measurement of occupancy density include:

- Counting workstations and computers – this approach is used in NABERS tenancy and whole building ratings (base building ratings don't consider occupancy as this is outside the landlord's control).
- Company payroll to determine the Full Time Equivalent (FTE) employees working from the office – easy for tenants to obtain, although it doesn't measure how often the people use the building.
- Security access systems – the system can record how many hours each year each occupant uses the building, but relatively few buildings have such systems.

The adjustment factor curves shown in Figure D.1 were based on a number of assumptions made by the author regarding how energy-consuming items in a building might be influenced by occupancy density. Table D.8 shows how Figure D.1 was derived and includes, for each item, an estimate of how much of the energy benchmark is directly proportional to changes in occupancy density:

- 100% of small power for computers and monitors – assume one PC per person.
- 30% of small power for printers, fridges, servers, etc. – some items can't be cut in half.
- 20% of lighting energy – the whole tenancy area still needs to be lit (note: if task lighting is adopted then occupancy density will have a bigger impact).

- 10% of landlord services – note that heating and cooling are opposites (a higher occupancy leads to more heat produced by people and requires less heating in winter but requires more cooling in summer).

| | $kgCO_2e$ /m² | Variation | Energy influenced by density ratio ($kgCO_2e/m^2$) | NLA | 8 | 12 | 16 | 20 | 24 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | GIA | 10 | 15 | 20 | 25 | 30 |
| | | | | *Ratio* | *1.50* | *1.00* | *0.75* | *0.60* | *0.50* |
| Heating & DHW (gas) | 16 | -10% | -1.6 | | 15.2 | 16.0 | 16.4 | 16.6 | 16.8 |
| Cooling | 10 | 10% | 1.0 | | 10.5 | 10.0 | 9.8 | 9.6 | 9.5 |
| Ventilation fans | 10 | 10% | 1.0 | | 10.5 | 10.0 | 9.8 | 9.6 | 9.5 |
| Pumps and controls | 8 | 10% | 0.8 | | 8.4 | 8.0 | 7.8 | 7.7 | 7.6 |
| Other (lift, common areas, etc) | 6 | 10% | 0.6 | | 6.3 | 6.0 | 5.9 | 5.8 | 5.7 |
| **TOTAL - Base building services** | **50** | **4%** | **1.8** | | **51** | **50** | **50** | **49** | **49** |
| | | | | ***Factor*** | ***1.02*** | ***1.00*** | ***0.99*** | ***0.99*** | ***0.98*** |
| | | | | | | | | | |
| Tenancy lighting | 18 | 20% | 3.6 | | 19.8 | 18.0 | 17.1 | 16.6 | 16.2 |
| Tenant small power (personal) | 17 | 100% | 17.0 | | 25.5 | 17.0 | 12.8 | 10.2 | 8.5 |
| Tenant small power (shared) | 15 | 30% | 4.5 | | 17.3 | 15.0 | 13.9 | 13.2 | 12.8 |
| **TOTAL - Tenancy** | **50** | **50%** | **25.1** | | **63** | **50** | **44** | **40** | **37** |
| | | | | ***Factor*** | ***1.25*** | ***1.00*** | ***0.87*** | ***0.80*** | ***0.75*** |
| | | | | | | | | | |
| **TOTAL – Whole building** | **100** | **27%** | **27** | | **113** | **100** | **93** | **89** | **87** |
| | | | | ***Factor*** | ***1.13*** | ***1.00*** | ***0.93*** | ***0.89*** | ***0.87*** |

**Table D.8 Estimate of occupancy density adjustment factor**

Table D.8 shows, based on the assumptions made, that the base building energy benchmark is not significantly influenced by occupancy density, while the influence on tenants (the occupants) is more significant. For the whole building the factor is a 0.9% decrease in energy consumption for each m² of NLA above the base assumption of 12m² per person. This is not dissimilar to Figure D.7. The main difference occurs for higher density offices. In Figure D.1, the factor increases while the BBP/JLL data in Figure D.8 shows a decrease.

All other things being equal, more people means more energy, however further research is required to prove a statistical relationship between occupancy density and energy consumption and to develop more robust adjustment factors than those shown in Table D.8 and Figure D.1.

## OCCUPANCY DENSITY IN OFFICES

The average occupancy density of 1 person per 15 $m^2$ of GIA (1 per 12 $m^2$ of NIA) assumed in the benchmarks is based on the *BCO Occupier Density Study Summary Report* of 249 UK properties in June 2009, published by the British Council of Offices in June 2009.

The key findings were as follows:

- The arithmetic mean of all properties was 11.8 $m^2$ per workplace NIA with a median value of 10.6 $m^2$.
- The mean for city centres (including London) was 12.0 $m^2$ per workplace NIA. The mean for properties outside city centres was 10.6 $m^2$.
- Utilisation of workspaces (the number of spaces occupied by people at any time) can vary, is often less than 100% and in some cases is around 50% to 60%.
- Approximately 77% of properties have an effective density of 8 to 13 $m^2$ per workspace NIA.
- All sectors had a density of 9.9 to 11.9 $m^2$ with the exception of insurance (13 $m^2$), manufacturing (16 $m^2$) and legal (20 $m^2$).
- Workspace densities on different floors in a building can vary significantly and be as high as 6 $m^2$ per workplace NIA.
- The report also recommended that occupancy density should be expressed as:

$$\text{Effective Density} = \frac{\text{Floor Area (NIA)}}{\text{maximum occupancy (i.e. no. of workspaces)}}$$

*Note: A factor of 1.25 was used to convert NIA to GIA for benchmarking purposes in this book.*

## D3.3 Other adjustment factors

The UK's Display Energy Certificate (DEC) uses Heating Degree Days to adjust the heating component of the energy benchmark, to reflect whether it was a mild or cold year. The software uses the building postcode to obtain the appropriate local degree days for the region in which the building is located over the 12 month rating period.[10] Cooling degree days are not included in the DEC methodology, but would be appropriate for energy benchmarking in hotter climates.

Adjustment for heating and cooling degree days hasn't been described in this appendix. The approach used in DECs can be used.

## D4. PRECEDENT FOR A DIFFERENT ENERGY RATING SCALE

Energy labels provide a simple, graphical way of communicating the energy or carbon efficiency of the products we purchase, including buildings. The EU has the A to G (green to red) scale, the US has *Energy Star* and Australia uses star ratings.

In section D1.4 an alternative rating scale to the current DEC scale was proposed, extending to H and introducing half steps. The precedent for different or changing scales can be seen by considering ratings for fridges, boilers and cars in the UK – refer to Figure D.9.

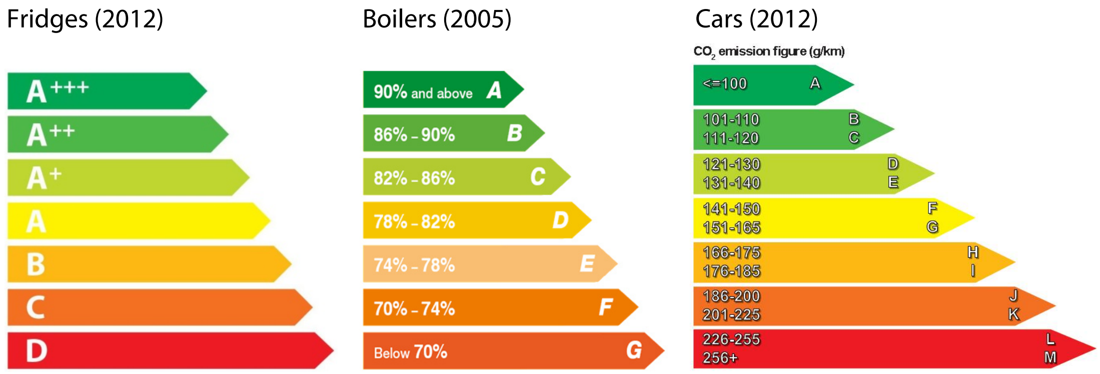



**Fig D.9** **Energy labels for different consumer goods in the UK**

### Fridges

An A to G energy rating for fridges (and other household appliances) was first introduced in the EU in 1995. In 2003 two new ratings, A+ and A++, were added to incentivise fridge manufacturers who had already achieved A ratings to go further. In 2011 an A+++ rating was added and the E to G end of the scale was removed for electric fridges, reflecting the improvement in energy efficiency performance and legislation since the scheme was introduced.[11]

At some stage the EU might have to 'bite the bullet' and recalibrate the scale, otherwise we'll end up with a scale from A to A++++++. Australia faced a similar problem in 2000, and again in 2010, when most new fridges were achieving 4 or 5 stars. The scales were simply reset (in 2010 a 4 star fridge became a 2 star) and manufacturers got on with the task of striving for higher star ratings again.

### Gas boilers

Gas boilers in the UK are rated according to their efficiency in converting fuel to heat as a percentage. This rating is called SEDBUK (Seasonal Efficiency of Domestic Boilers in the UK). When the scheme was first introduced in 2005, the ratings used an A to G scale. Nearly all new gas condensing boilers had an A rating (>90% efficient) while old boilers with pilot lights typically had a G rating (<70% efficient). Faced with the challenge of all new boilers having a similar rating, and with efficiencies reaching their practical limits, in 2009 the SEDBUK scheme was changed. The A to G scale was abolished, the calculation methodology was adjusted, and only the percentage efficiency was displayed.[12] An A-rated 90% efficient boiler under the 2005 scheme has an 88% efficiency rating under the 2009 scheme.

## Cars

The Fuel Economy label was introduced in the UK in 2005 and displays the $CO_2$ emissions (expressed as $gCO_2$/km), fuel economy (mpg and litres/100km) and fuel costs (for 12,000 miles) for new cars. The label was intended to be familiar to consumers as it uses similar coding to appliance energy ratings such as fridges. The scale uses the green to red bands, but ranges from A (<100 g/km) to M (>255 g/km) to reflect the diversity of cars on the market.

Figure D.10 shows the ratings of cars available in the UK in April 2011.[13] The shaded area indicates where at least 75% of the cars fall within that range (e.g. 83% of hatchbacks are within the B to G range). Table D.8 shows the approximate conversion of mpg to p/km for petrol and diesel vehicles.[14]

| | Hatchback | Saloon | Estate | SUV |
|---|---|---|---|---|
| <=100 A | 3% | 0% | 1% | 0% |
| 101–110 B<br>111–120 C | 26% | 5% | 11% | 0% |
| 121–130 D<br>131–140 E | 43% | 28% | 34% | 7% |
| 141–150 F<br>151–160 G | 14% | 19% | 22% | 13% |
| 101–110 H<br>111–120 I | 9% | 21% | 19% | 24% |
| 101–110 J<br>111–120 K | 4% | 14% | 10% | 36% |
| 101–110 L<br>111–120 M | 1% | 11% | 3% | 19% |

**Fig D.10 Proportion of car types available in the UK in each fuel economy rating band in 2011**

| mpg | litres/100km | Petrol | Diesel |
|---|---|---|---|
| | | g/km | g/km |
| 20 | 14.1 | 328 | 374 |
| 30 | 9.4 | 218 | 250 |
| 40 | 7.1 | 164 | 187 |
| 50 | 5.6 | 131 | 150 |
| 60 | 4.7 | 109 | 125 |
| 70 | 4.0 | 94 | 107 |
| 80 | 3.5 | 82 | 94 |

**Table D.9 Approximate conversion factors for mpg to g/km**

Since 2001, Vehicle Excise Duty (road tax) has been linked to vehicle $CO_2$ emissions, and company car tax rates followed suit in 2002. A new 'M' rated car in January 2013 had a first year road tax of £1,030, with a standard 12 month tax of £475 applying thereafter.[15] For an 'A' rated vehicle, both the first year and standard tax rates were zero. Perhaps it is only a matter of time before similar tax regimes are applied to building taxes, with adjustments to stamp duty and/or Uniform Business Rates based on energy ratings – refer to Chapter 10 for further discussion on this.

## Conclusion

The two messages from this quick review of other consumer rating schemes are:

- Rating scales are not static and need to be revisited over time to reflect changes in energy performance.
- The number of steps in the scale should reflect the variety in energy performance of the product.

It is therefore not necessary to stick rigidly to a standard A to G scale to rate office buildings in the UK.

## Notes

All websites were accessed on 6 May 2013 unless noted otherwise. Information papers referenced are available to download from www.wholecarbonfootprint.com.

1. The NABERS *Energy Guide to Building Energy Estimation* is a guide to using computer simulation to estimate base building or whole building energy consumption to achieve a 4 star rating or higher. Its aim is to ensure that simulations provide useful and realistic assistance to the design process. The guide is also used to estimate energy consumption for Green Star ratings. www.nabers.gov.au.

   The document provides a very clear statement on the role of energy modelling during design:

   *'Simulation is not a definitive indicator of the performance of a building, and indeed the relationship between the average performance of buildings and their simulations is very weak. Real buildings rarely reach the performance potential indicated by simulation and the gap between theoretical and actual performance is often very substantial. As a consequence, simulation should not be advanced to clients as a sole and uncaveated means of estimating building performance in operation.'*

2. Refer to section 2.6 in Chapter 2, section 6.1 in Chapter 6 and Information Paper 9 – Design energy rating data for further details.

3. The DEC benchmarks are based on CIBSE *Energy Benchmarks* TM46:2008 – further details are provided in Appendix C.

4. The UK Government Energy Efficiency Best Practice Guide *Energy use in offices* ECON 19, published in 2003, gives a range of benchmarks for different office types. These range from 34 $kgCO_2e/m^2$ for a good naturally ventilated cellular office to 218 $kgCO_2e/m^2$ for a typical air conditioned prestige office. Refer to Appendix C for details.

5. Refer to Appendix C for details on the BBP data.

6. Refer to Information Paper 9 – Design energy rating data for examples of the two certificates.

7. Refer to Commercial Building Disclosure programme at www.cbd.gov.au.

8. In March 2011 the UK Green Building Council issued a report: *Carbon Reductions in Existing Non-Domestic Buildings*, which made a recommendation that '*DECs (for occupiers and for landlords) should be introduced to non-domestic buildings via a 'mandatory soft start' in 2011/12, to take place prior to the formal display of certificates from 2012/13.*'

   Following government unwillingness to do anything about this, the Better Building Partnership released a position paper in February 2012, *Voluntary DECs and Landlord Energy Certificates*, stating that the '*membership wishes to develop a rating system that: allows for the breakdown of energy use in a building between owner and occupier; is simple to understand; is relatively inexpensive to undertake; provides an 'appropriate' range of ratings; and allows owners to compare buildings with each other, which should ultimately impact market value.*' The BBP has been developing a voluntary landlord rating system which is likely to be released in late 2013.

9. Refer to note 8.

10. *Display Energy Certificate: Software Specification* published by Communities and Local Government, 2008. Also refer to *Operational Ratings and Display Energy Certificates* – TM47:2008, CIBSE. For further information on heating degree days, refer to Information Paper 16 – Heating degree days.

11. Information on the new fridge labels was taken from www.newenergylabel.com/uk/background and www.which.co.uk/energy/saving-money/guides/energy-labels-explained/fridge-and-freezer-energy-labels/.

12. Information on SEDBUK 2005 and 2009 was from www.baxi.co.uk/sedbuk-ratings/.

13. The percentage of cars in each band is taken from the database on www.carpages.co.uk (accessed 29 April 2011) with the following number of vehicles: hatchbacks (1499), saloon (685), estate (837) & SUV (389).

14. The factor used to get an approximate conversion of mpg to g/km was: Petrol (1 mpg = 6,554 g/km) and Diesel (1 mpg = 7,486 g/km).

15. Details of the point of sale fuel economy label taken from www.dft.gov.uk/vca/fcb/point-of-sale-pos-so.asp. Information on the road tax and car database is available at http://carfueldata.direct.gov.uk/.

.