Asset Ratings and Operational Ratings - The relationship between different energy certificate types for UK buildings

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Submitted to the University of Cambridge in partial fulfilment of the requirements for the Degree of Master of Studies in Interdisciplinary Design for the Built Environment

University of Cambridge

2011

Abstract

This study investigates the relationship between the Asset Ratings and Operational Ratings that are used to compare the carbon emissions of UK buildings. Asset Ratings appear on Energy Performance Certificates and are found by calculation, while the Operational Ratings used by Display Energy Certificates are based on metered data. Ideally, the Asset Rating and Operational Rating would be identical, except in cases where buildings are poorly operated. However, there are various differences between the two certificates in terms of what is included in the rating, and how they are derived. The aim of the study is investigate modifications to the Asset Rating that will allow a better comparison with the Operational Rating.

The Operational Rating benchmarks are currently under review (by others) along with the issue of what sources of energy can be classified as 'separable' and thus excluded from the Operational Rating. Modifications to the Asset Rating will be proposed to take account of unregulated energy, the different values for the carbon intensity of fuels used by each certificate, and the different methods of normalising each rating scale. The ambition is that through the refinement of both ratings, future deviations between the two would be solely attributable to poor operation.

A database of 56,000 buildings was obtained through the Freedom of Information Act. This was filtered to a set of just 99 buildings that had both Asset Ratings and Operational Ratings. The Operational Ratings were generally higher than the Asset Ratings, which is in line with the general expectation that metered data exceeds design predictions. The accompanying reports were also studied to understand the characteristics of the buildings. This process resulted in a number of recommendations for improving the content and management of the information on the certificates, to enable future studies to be more valuable and more resource efficient.

The raw energy consumption data used to calculate the Asset Ratings was modified to account for unregulated energy, different carbon intensities, and a revised normalisation of the scale. The modified Asset Ratings were compared with the Operational Ratings with the data arranged by building servicing strategy, building age, and building type. The small size of the data set meant that it was difficult to draw many conclusions. However, new buildings were shown to have lower ratings than existing buildings, and to have a better correlation between the two certificates. Naturally ventilated buildings had modified Asset Ratings that were higher than the Operational Ratings. This was thought to be due to the fact that it is easier for active systems such as air-conditioning to be poorly operated.

Graphically, the modified Asset Ratings correlated much better with the Operational Ratings. The effectiveness of the modifications was examined by looking at the number of bands between the two ratings. It was found that prior to the modifications 39 buildings had ratings that were in the same band, but that afterwards this rose to 47.

There were several buildings where the Operational Ratings were far greater than the modified Asset Ratings. These were examined and explanations were found relating to inappropriate Operational Rating benchmarks, potential sources of separable energy that are not yet classified as such, and poor operation. The findings on benchmarks and separable energy complement a parallel review of the Display Energy Certificate database by others.

The initial results of this study into the correlation between Asset Ratings and Operational Ratings are encouraging, and suggest that the proposed modifications are effective. However, the exercise should be repeated on a larger data set, which will be available if Display Energy Certificates are extended to commercial buildings, as is currently under discussion. Future studies on the database will be aided if the recommendations on information are adopted.

Declarations and Statements

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any other degree.

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by footnotes and a bibliography is appended.

The author gives consent for the thesis, if accepted, to be available for photocopying and for entering into the IDBE library, and for the title and summary to be made publicly available.

Table of Contents

Acknowledgements

I would like to thank and acknowledge Bill Bordass for all the helpful comments made during his supervision of this thesis.

Sebastian Macmillan and all of the support staff and contributors at IDBE deserve a huge amount of credit for having created such an exciting and enriching learning experience. Doing any course on one's own would be no fun at all, and so I must thank Cohort 16 for what was a great seven residential weeks.

I would also like to thank Arup for their generous financial support for the duration of the course.

Finally, I would like to thank my wife, Virginia, for shouldering an increased burden during my absences at residential weeks.

List of Figures

List of Tables

Abbreviations, Symbols and Units

AC	Air-conditioned
ADL2	Approved Document L2 of the Building Regulations
AR	Asset Rating
AR_{MOD}	Modified Asset Rating (to account for differing carbon intensities and unregulated energy)
$AR_{MOD,NORM}$	Modified and re-normalised Asset Rating
AR_{NORM}	Re-normalised Asset Rating
AR_{TYP}	Asset Rating of the Typical Building
BER	Building Emissions Rate
BIS	Department for Business, Innovation and Skills
BPF	British Property Federation
BRE	Building Research Establishment
CABE	Commission for Architecture and the Built Environment
CECED	Conseil Européen de la Construction d'Appareils Domestiques/ European Committee of Manufacturers of Domestic Equipment
CEN	Comité Européen de Normalisation
CHP	Combined Heat and Power
CIBSE	Chartered Institution of Building Services Engineers
CIP	Central Information Point
CO_2	Carbon dioxide
CRC	Carbon Reduction Commitment Energy Efficiency Scheme
DCLG	Department for Communities and Local Government
DEC	Display Energy Certificate
DSM	Dynamic Simulation Model
EC	European Community
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
ER_{TYP}	Emissions Rate of the Typical Building
EU	European Union
hr	Hour
kg	Kilogram
kW	KiloWatt
kWh	KiloWatt-hour
LZC	Low or Zero Carbon
m	Metre
MMMV	Mixed-mode mechanical ventilation
MMNV	Mixed-mode natural ventilation
MV	Mechanical Ventilation

NCM	National Calculation Methodology
NV	Natural ventilation
ODPM	Office of the Deputy Prime Minister
OR	Operational Rating
PVs	Photovoltaics
RER	Reference Emissions Rate
SBEM	Simplified Building Energy Model
SER	Standard Emissions Rate
SES	Solar Energy System
TER	Target Emissions Rate
UPRN	Unique Property Reference Number
XML	Extensible Mark-up Language

Chapter 1 Introduction

1.1 Introduction

Since 1st October 2008 it has been mandatory for public buildings in England and Wales (that are larger than 1,000m^2) to exhibit a Display Energy Certificate (DEC) in a prominent place clearly visible to the public (Department for Communities and Local Government (DCLG), 2008A).

The next day *The Guardian* (Booth, 2008A) published an article about the first 18,000 DECs. DECs are described as rating the 'energy efficiency of a building on a sliding scale where A is the best and G is the worst.' The Palace of Westminster and Bank of England were both reported as scoring a G. 'New buildings also fared badly, raising questions about the validity of sustainability claims made by architects and developers. London's City Hall scored E despite opening in 2002 and being described by its architect Foster and Partners as a "virtually non-polluting public building." ....The findings are likely to embarrass the Government......Eland House, the 10-year old head office of the DCLG, which has overseen the DEC system, scored an F.'

In a follow-up article in December 2008, *The Guardian* (Booth, 2008B) blames 'ignorance among officials, inefficient equipment and poor energy management.' The Commission for Architecture and the Built Environment (CABE) were reported as saying that 'the majority of government departments were "failing to make their new buildings and refurbishments sustainable" and that those operating them had little idea how to improve their energy efficiency.'

The *Chartered Institution of Building Services Engineers Journal* (CIBSE, 2010) reported on a Building Research Establishment (BRE) study which found that 'DECs failed to provide evidence of real energy efficiency improvements and carbon emission reductions.' 9% of data was found to be unreliable and 2% questionable.

Energy and Environmental Management (2011) reported on a later Freedom of Information Act release of data, at which point there were 40,147 buildings with DECs. It bemoaned the fact that 'there are just 142 A-rated buildings' but 6,112 G-rated buildings. It went on to say that 'The Department of Health, which really needs to save money, achieved only F and two Gs on its London buildings.'

This is just a selection of the bad press that DECs have received during the course of their short lifetime. There's been criticism of high-profile architects, embarrassment for the Government and various departments, the labelling of Government officials as ‘ignorant’, and little evidence of DECs saving energy or reducing carbon emissions.

Is this criticism deserved? One of the aims of DECs is bring about a market transformation[1] and improvement in energy standards similar to that reported for home electrical appliances (CECED, 2005), and so part of this must involve a greater public awareness of energy labelling and poorly performing buildings being perceived as unacceptable. In this respect, the criticism is not unexpected. But what of these stories fail to point out, is that a typical UK building is expected to be on the boundary between a D and an E rating (CIBSE, 2009A). This puts the low number of A-rated buildings and the performance of historical buildings such as the Palace of Westminster in perspective. There are many other factors which can affect a building’s rating. Do the press really understand the intricacies of the labelling system on which they are reporting? And, if not, are the public being misinformed?

It is probably unfair to criticise buildings for their initial DEC[2], as they have not yet had the opportunity to make any interventions that would lead to improvements. Because the life-cycle of buildings is much longer than that of domestic appliances[3], it will take much longer for any transformation to take effect, and so it is important to understand when a building is being operated well relative to its design characteristics, and when it is being operated relatively poorly.

This relationship between operational and design characteristics is the subject of the study that follows. Whereas DECs are based on the metered energy use of a building and are intended to reflect it operational characteristics, Energy Performance Certificates (EPCs) are intended to reflect the design characteristics. According to Strong (2009), ‘EPCs show only the theoretical energy performance of buildings based on standardised data and assumptions that rarely, if ever, reflect true energy performance. Only DECs give the true picture. For example, the MPs’ new office building opposite Big Ben, Portcullis House, would probably be awarded an EPC rating of A (or possibly B), but actually only achieves a DEC rating of G.’

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[1] The expectation of the British Property Federation (BPF, 2010) is that building value will begin to be affected by sustainability performance.

[2] A DEC is valid for one year and must be updated annually (DCLG, 2008A). It should be noted that the accompanying Advisory Report is valid for seven years.

[3] BRE (2010) projections indicate that, by 2050, 60% of the existing building stock will have been built prior to 2010. CECED (2005) gives the average lifetime of various household appliances: washing-machines – 13 years, refrigerators – 14 years, freezers – 17 years.

EPCs were introduced in 2008, and are only required when a building is constructed, sold or let (DCLG, 2008A). Because DECs are only required by public buildings with a useful floor area greater than 1,000m^2, the number of buildings with both an EPC and a DEC is relatively small. As this number increases, the conflicting energy ratings reported by the two certificates are likely to cause confusion, and it is easy to imagine the scornful reaction of an already sceptical press. An understanding of the reasons behind the differing ratings is vital, as scepticism about the validity of the ratings could ultimately detract from the aim of market transformation and reduced energy consumption.

Amid the dissenting voices, there have been some positive reactions. Commenting on the proposed adoption of DECs for private sectors buildings, the British Property Federation (BPF, 2010) highlighted a range of potential benefits. These included the generation of a database of building energy performance to assist in better informing policy, a means of promoting better standards of energy management, and as an aid to complying with the requirements of the Carbon Reduction Commitment Energy Efficiency Scheme (CRC). They also commented that comparison between DECs and EPCs 'would act a neat barometer of potential versus actual performance, driving improvement and promoting understanding.'

The comparison of DEC and EPC ratings forms the basis of this study, with a focus on the refinements required if the two are indeed to be used an indicator of potential versus actual performance.

1.2 Background

The key piece of European legislation relating to energy use in buildings is the Directive on the energy performance of buildings (EPBD). Directive (EC) 2002/91/EC came into force on 4th January 2003 and was amended by Directive (EU) 2010/31/EU on 18th June 2010. This amendment is referred to as the *recast* EPBD (CIBSE, 2011).

Article 7 of the EPBD[4] requires that:

> *Member States shall ensure that, when buildings are constructed, sold or rented out, an energy performance certificate is made available to the owner or by the owner to the prospective buyer or tenant, as the case might be. The validity of the certificate shall not exceed 10 years.*

[4] Article 7 of Directive (EC) 2002/91/EC, or Article 11 of Directive (EU) 2010/31/EU.

The energy performance certificate for buildings shall include reference values such as current legal standards and benchmarks in order to make it possible for consumers to compare and assess the energy performance of the building. The certificate shall be accompanied by recommendations for the cost-effective improvement of the energy performance.

Member States shall take measures to ensure that for buildings with a total useful floor area over 1,000m^2 occupied by public authorities and by institutions providing public services to a large number of persons and therefore frequently visited by these persons an energy certificate, not older than 10 years, is placed in a prominent place clearly visible to the public.

The requirements of the EPBD were transposed into national legislation in England and Wales as Statutory Instrument 2007 No. 991: *The Energy Performance of Buildings (Certificates and Inspections) (England and Wales) Regulations 2007*. This requires that *Energy Performance Certificates* expressing the *Asset Rating* are provided when buildings are constructed, sold or let. *Display Energy Certificates* expressing the *Operational Rating* are required for buildings with a total useful floor area over 1,000m^2 occupied by public authorities.

The Asset Rating is defined as 'a numerical indicator of the amount of energy estimated to meet the different needs associated with a standardised use of the building,' while the Operational Rating is defined as 'a numerical indicator of the amount of energy consumed during the occupation of a building over a period of time.'

An EPC must be provided with a Recommendations Report and is valid for ten years. A DEC must be renewed annually and be provided with an Advisory Report which remains valid for seven years. The reports are intended to provide advice to building owners and operators on how to achieve improved ratings.

The interpretation of the EPBD for England & Wales uses both the calculated Asset Rating and the measured Operational Rating. *Concerted Action EPBD* (2010) details the approach taken in the various other European Member States. Many countries use one system or the other, but several use both, and the advantages and disadvantages of each are described. In summary, using metered data is quick and cheap to implement but savings can be difficult to identify as the breakdown of energy use is unknown; calculating energy performance is more time-consuming and costly and requires detailed information, but allows the savings for various measures to be identified, and the standard calculation method allows the comparison of different buildings. No preference is expressed, save that the Member States should select the most appropriate method depending on the actual situation in the particular country.

The subject of energy benchmarking and building labelling is not new; Pérez-Lombard *et al.* (2009) carried out a comprehensive review that analyses the origin and the historic development of energy certification schemes for buildings. They also describe how building energy certification schemes for existing buildings should be implemented by the use of operational ratings with reference values (benchmarks) taken from the building stock. For new buildings, asset ratings should be used in comparison with the references values set by the regulatory standards, existing building stock and the zero energy building. This is broadly in line with the approach adopted in England and Wales.

The development of the existing certification system (and some variants that were considered) can be tracked through a range of publications written in the years preceding implementation: Bordass (2005) discusses the key issues relating to energy reporting, benchmarking and certification systems prior to the adoption of the various schemes that are now in use throughout Europe; Cohen *et al.* (2006) provides details of *EPLabel*, an early project addressing the EPBD requirements for energy labelling; Cohen *et al.* (2008) compares the methodology and content of energy certificates in the UK with the approach in Germany.

While a review of the first batch of 45,000 DECs in the UK has only just been published (Bruhns *et al.*, 2011), the prevalence of DECs is likely to increase significantly over the coming years. Whereas DECs are currently only required for public buildings with a useful floor area over 1,000m^2, Article 13 of the recast EPBD reduces the threshold to 500m^2 in 2013 and 250m^2 in 2015. The possibility of extending DECs to commercial buildings was first mooted by the Department for Business, Innovation and Skills (BIS) (2010), and has since gathered momentum with a commitment by HM Government (2011) in *The Carbon Plan* to 'extend Display Energy Certificates to commercial buildings.' This does not leave much time to implement any potential improvements to the rating system before the number of buildings with DECs reaches such high quantities that the opportunity will have been missed.

1.3 Asset Ratings and Operational Ratings - The relationship between different energy certificate types for UK buildings

This study will examine the data from a number of buildings with both EPCs and DECs and their associated Recommendations Reports and Advisory Reports, to understand the relationship between the AR and the OR.

Chapter 2 introduces the constituent information of EPCs and DECs, focussing on the derivation of the alphabetically graded scales for the AR and the OR, and the key factors affecting each. A number of important distinctions between the two systems are identified which result in differences between the AR and the OR, regardless of whether a building is well operated in a manner consistent with that envisaged during its design. These distinctions are discussed, and proposals for their correction are presented, where possible.

Chapter 3 describes the analysis of the DEC database, and the filtration process that was used to obtain a set of 99 buildings that have both ARs and ORs. While the dataset is relatively small at present, it is likely to grow quickly over the coming years. The filtration process involved the review of the Recommendations Reports and Advisory Reports that accompany EPCs and DECs, and this review led to a series of observations on the database; recommendations are presented for improvements to the constituent information and the management of this information, which will allow faster and more reliable analyses to be carried out in future. This will allow studies such as the current one to be carried out relatively quickly with a much larger (and more statistically significant) data set.

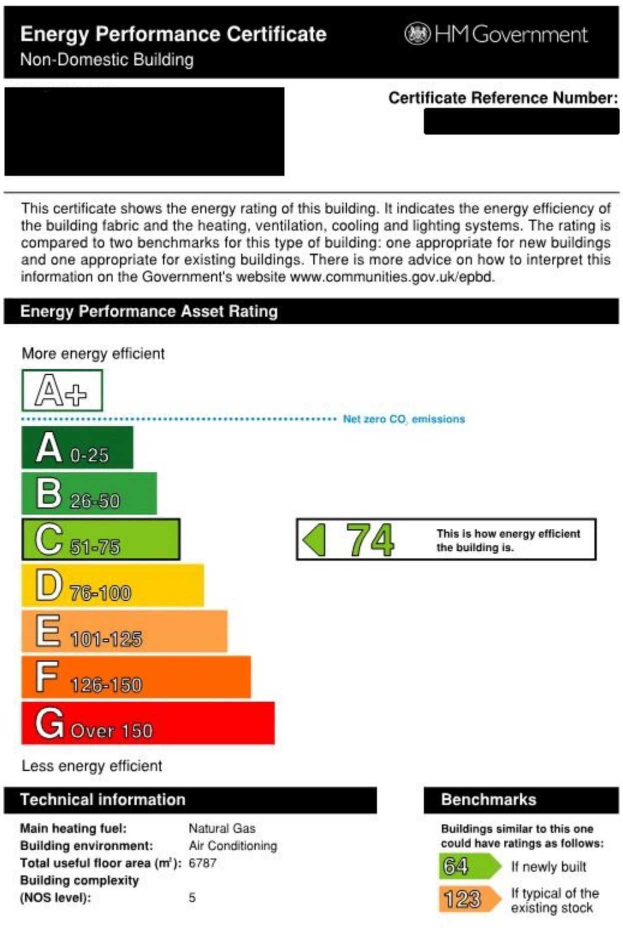
Chapter 4 presents an analysis of the differences between the AR and OR data. The various corrections are applied in succession, and their individual and cumulative effects are discussed. The data is also presented according to building type (new or existing), servicing strategy (e.g. naturally ventilated, air-conditioned, etc) and the building's benchmark category (school, general office, etc). The effectiveness of the corrections is then examined, and several buildings that have starkly different ARs and ORs are examined in more detail to determine the underlying reasons behind the divergence in their ratings.

The aim of the study is to better understand the basis of each rating system, so as to identify the elements of each that contribute to conflicting carbon ratings, even when the buildings are used as intended and well-operated. An appreciation of the reasons behind these conflicting assessments will enable identification of genuine cases of poor operation, so that appropriate action can be taken. It will also help to combat the scepticism which might otherwise undermine what should be a positive move towards reducing the carbon emissions of buildings, and help to close what Bordass *et al.* (2004) called the 'credibility gap' between predicted and actual energy use.

Chapter 2 A Comparison between Asset Ratings and Operational Ratings

2.1 Introduction

Before a meaningful analysis of the differences between the carbon emissions shown on EPCs and DECs can be undertaken, the AR and OR that each uses to express these carbon emissions must be defined, compared and contrasted in greater detail.


Energy Performance Certificate
Non-Domestic Building
HM Government
[redacted]
Certificate Reference Number:
[redacted]

This certificate shows the energy rating of this building. It indicates the energy efficiency of the building fabric and the heating, ventilation, cooling and lighting systems. The rating is compared to two benchmarks for this type of building: one appropriate for new buildings and one appropriate for existing buildings. There is more advice on how to interpret this information on the Government's website www.communities.gov.uk/epbd.

Energy Performance Asset Rating

More energy efficient
A+
Net zero CO_2 emissions
A 0-25
B 26-50
C 51-75
D 76-100
E 101-125
F 126-150
G Over 150
Less energy efficient

74 This is how energy efficient the building is.

Technical information

Main heating fuel:	Natural Gas
Building environment:	Air Conditioning
Total useful floor area (m^2):	6787
Building complexity (NOS level):	5

Benchmarks

Buildings similar to this one could have ratings as follows:
64 If newly built
123 If typical of the existing stock

Figure 2-1 - A sample Energy Performance Certificate (the building address and reference number have been blacked-out)

2.2 Asset Rating

The AR is the position of a building on the energy rating scale used on EPCs. Figure 2-1 shows a sample EPC; the building in question has a numerical AR of 74 which corresponds to a high (poor) grade C on the scale. The EPC also provides ratings to illustrate how the same building could be expected to perform ‘if newly built’ (the AR would be 64, a mid-range C) and ‘if typical of the existing stock’ (the AR would be 123, a high E). The EPC also lists the building’s floor area, main heating fuel and the building environment[5]. The fact that the building's AR is higher (worse) than the 'newly built' value means that this is most probably an existing building[6].

The AR is found by modelling the building and its systems using one of two classes of software tool: SBEM (the Simplified Building Energy Model) and its approved interfaces, or approved DSM (Dynamic Simulation Model).[7]

The AR rates the carbon dioxide (CO_2) emissions from the Actual building (these emissions are referred to as the Building Emissions Rate or BER in $kgCO_2/m^2$) in comparison to a Standard Emissions Rate (SER). The SER is found by applying a fixed improvement factor to the emissions from a Reference building whose emissions represent the Reference Emissions Rate (RER). The following equations yield the AR (DCLG, 2010A):

$$\mathbf{SER = 0.765 \times RER} \qquad \textbf{(Eqn. 2-1)}$$

$$\mathbf{AR = 50 \times BER/SER} \qquad \textbf{(Eqn. 2-2)}$$

While more detailed explanations and specifications of the definition of the Actual, Standard and Reference buildings can be found in DCLG (2010A), it is worth giving some broad definitions of these (and other relevant building types) before proceeding. Some of these definitions are also referenced by Approved Document L2A (ADL2A) of the Building Regulations (DCLG, 2010B) and can be found in Table 2-1. It is important to note the link that the National Calculation Methodology (NCM) makes between EPCs and whatever edition of ADL2 is current at the time; the Actual building will always be constructed to the minimum standards of the current edition of ADL2A.

The AR of the Typical building is shown on the EPC in Figure 2-1 as being 'typical of the existing stock,' whiled the AR of the Target building is what would be expected if the building was 'newly built.' They are found by applying the multiplier (50/SER) to the emissions rate of each, as in Eqn. 2-2.

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[5] The environment is classified as either heating with natural ventilation, heating with mechanical ventilation, mixed-mode with natural ventilation, mixed-mode with mechanical ventilation or air conditioning.

[6] Otherwise the building would be a new building that was not compliant with Building Regulations. There are some ambiguous cases that will be described in section 3.3.

[7] A list of Approved Software can be found at http://www.ukreg-accreditation.org/.

Building Name	Emissions Rate	Asset Rating	Year of Regs	Description
Actual	BER	AR	Current	The Actual building has all of the characteristics of the constructed building, but it will have fixed occupancy patterns, servicing strategies, temperature set-points etc, as defined by the NCM[8] templates.
Notional	None	N/A	Varies	Under ADL2A (2010), the Notional building is defined as one that has the same size, shape, zoning arrangements and servicing strategies as the Actual building. However, the energy performance standards of the Notional building are based on a fixed specification of fabric and services that delivers a 25% reduction in CO_2 emissions (relative to the 2006 standard based on an assumed build mix)[9]. Under ADL2A (2006), the Notional Building was based on a fixed specification to meet the minimum standards of ADL2 (2002).
Target	TER	'If newly built' AR	Current	The Target building is not defined in the manner of the other buildings. Its features are not fixed but its overall performance in terms of carbon emissions is; it is used to set the Target Emissions Rate (TER) which can be achieved in a variety of ways. Under ADL2A (2010), the TER is equal to the CO_2 emissions rate of the Notional building. Under ADL2A (2006), the TER was equal to the CO_2 emissions rate of the Notional building with a fixed improvement factor applied depending on whether the building was naturally ventilated, mechanically ventilated or air-conditioned (ODPM, 2006). It is shown on the EPC as the 'if newly built' AR.
Reference	RER	N/A	2002/ 2006	The Reference building is defined as one that has the same size, shape, zoning arrangements as the Actual building. However, it based on a fixed specification to meet the minimum specification standards of ADL2 (2002) for a mixed-mode[10] naturally ventilated building that uses gas for heating and hot water generation. It is not intended to change this definition with further revisions of ADL2.
Standard	SER	N/A	2006	The Standard Emission Rate (SER) is determined by

[8] See http://www.ncm.bre.co.uk/index.jsp for background to the NCM.

[9] The reduction will vary depending on the building type, with some sectors being required to achieve more than 25%, and others less. The aggregate across all building types should result in a 25% reduction.

[10] The building is generally naturally ventilated, but utilises mechanical cooling when the internal temperature rises above 27°C, and so is only required to prevent overheating during peaks in temperature.

Building Name	Emissions Rate	Asset Rating	Year of Regs	Description
				applying a fixed improvement factor to the emissions from a Reference building. This factor is 23.5% and is the improvement required for a heated and naturally ventilated building, compared to 28% for a mechanically ventilated or air-conditioned building, as given in ADL2A (2006).
Typical	ER_{TYP}	AR_{TYP}	Varies	The Typical building was originally defined (DCLG, 2008C) as being identical to the Reference building but built to the minimum specification standards of ADL (1995). However, it is now defined (DCLG, 2010A) as one where the CO_2 emissions rate is equal to the 2010 TER multiplied by two and divided by 0.75 (this is approximately twice the emissions rate of the 2006 TER[11]). This change in definition will be discussed is more detail in section 2.4.4.

Table 2-1 – Definitions of the building types used by the National Calculation Methodology

The A to G scale is a linear scale based on two key points defined as follows (DCLG, 2010A):

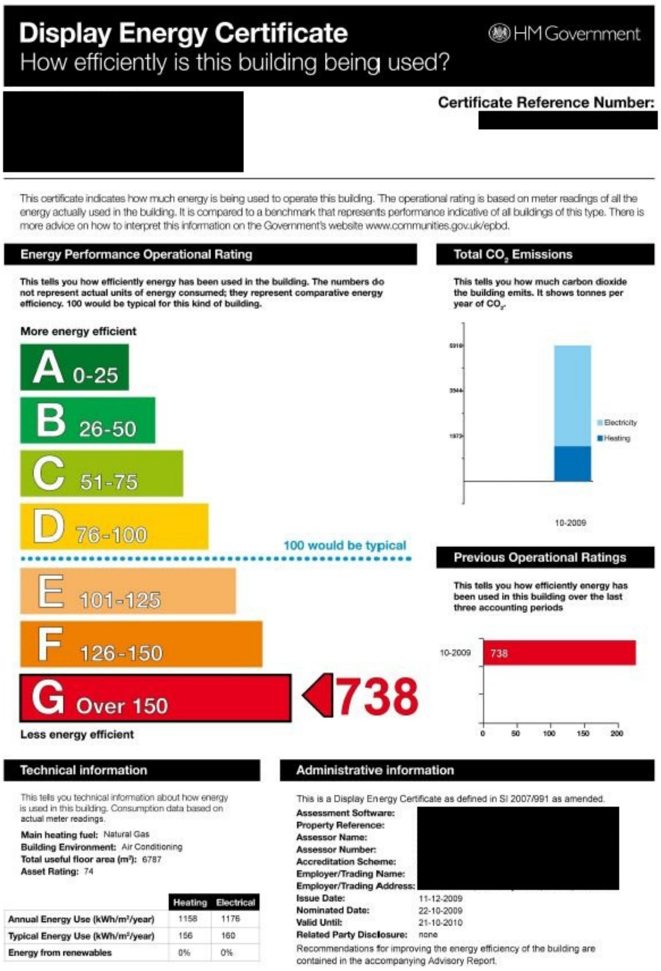
- The zero point on the scale is defined as the performance of the building that has zero net annual CO_2 emissions associated with the use of the fixed building services as defined in the Building Regulations. This is equivalent to a BER of zero.
- The border between grade B and grade C is set at the SER and given an AR of 50. This means that a gas-heated mixed-mode building that is just compliant with ADL2A (2006) would have an Asset Rating of 50. Because the scale is linear, the boundary between grades D and E corresponds to a rating of 100.

Because the emissions from the Typical building (see new definition in Table 2-1) are described as being approximately twice those of the 2006 TER, the Typical AR should have a rating that is close to the D/E boundary rating of 100. However, this will not always be the case, as will be shown in section 2.4.4.

[11] This change is likely to relate to the CEN prEN 15217 (2007) recommendation on energy performance scales, which states that the regulations reference value shall be placed at the boundary between classes B and C, and that the building stock reference value shall be placed at the boundary between classes D and E.

2.3 Operational Rating

The OR is the position of a building on the energy rating scale used on DECs. Figure 2-2 shows a sample DEC; the building in question has an OR of 738 which corresponds to a very high (poor) grade G on the scale.



Display Energy Certificate
How efficiently is this building being used?

HM Government

[redacted]

Certificate Reference Number: [redacted]

This certificate indicates how much energy is being used to operate this building. The operational rating is based on meter readings of all the energy actually used in the building. It is compared to a benchmark that represents performance indicative of all buildings of this type. There is more advice on how to interpret this information on the Government's website www.communities.gov.uk/epbd.

Energy Performance Operational Rating

This tells you how efficiently energy has been used in the building. The numbers do not represent actual units of energy consumed; they represent comparative energy efficiency. 100 would be typical for this kind of building.

More energy efficient

A 0-25
B 26-50
C 51-75
D 76-100
100 would be typical
E 101-125
F 126-150
G Over 150

738

Less energy efficient

Total CO_2 Emissions

This tells you how much carbon dioxide the building emits. It shows tonnes per year of CO_2.

5916
3944
1972
Electricity
Heating
10-2009

Previous Operational Ratings

This tells you how efficiently energy has been used in this building over the last three accounting periods

10-2009 738
0 50 100 150 200

Technical information

This tells you technical information about how energy is used in this building. Consumption data based on actual meter readings.

Main heating fuel: Natural Gas
Building Environment: Air Conditioning
Total useful floor area (m^2): 6787
Asset Rating: 74

	Heating	Electrical
Annual Energy Use (kWh/m²/year)	1158	1176
Typical Energy Use (kWh/m²/year)	156	160
Energy from renewables	0%	0%

Administrative information

This is a Display Energy Certificate as defined in SI 2007/991 as amended.

Assessment Software:
Property Reference:
Assessor Name:
Assessor Number:
Accreditation Scheme:
Employer/Trading Name:
Employer/Trading Address: [redacted]
Issue Date: 11-12-2009
Nominated Date: 22-10-2009
Valid Until: 21-10-2010
Related Party Disclosure: none

Recommendations for improving the energy efficiency of the building are contained in the accompanying Advisory Report.

Figure 2-2 - A sample Display Energy Certificate (the building address, reference number and administrative information have been blacked-out)

Like an EPC, a DEC also shows the floor area, main heating fuel and the building environment. As a DEC is renewed annually, the previous two year's ORs are shown[12]. The heating and electrical energy consumed are shown alongside the benchmarks to which they will be compared in the derivation of the OR. The percentage of energy from renewables is shown, and there is a graphical representation of the relative contribution of heating, electricity and any renewables to the carbon emissions of the building.

[12] The sample DEC is a *Year 1* DEC and so does not have any previous ORs to display.

The OR is found by entering metered data into the *ORCalc* class of software.[13]

The background to DECs and the OR scale is given in TM47 (CIBSE, 2009A). While EPCs are compared against an ADL2 (2006) compliant building with a particular servicing strategy, because the available benchmarks are understood in terms of the stock average, the OR scale is fixed by 2 points:

- zero emissions at the top of band A.
- the stock average (i.e. the benchmark for the relevant type of building) at the D/E boundary.

As with the AR, the OR scale is linear. The OR can be expressed as:

$$\textbf{OR} = 100 \times \frac{\text{Building } CO_2 \text{ emissions/building area}}{\text{Typical } CO_2 \text{ emissions per unit area}} \qquad \textbf{(Eqn. 2-3)}$$

While a grade G will have its best limit defined by the linear scale, it will have no worst limit (as illustrated in the example in Figure 2-2). In the initial phase of implementation, a building that does not have adequate data to produce an OR will be given a default G grade (of 200). It is important to distinguish between a default G rating and a G rating based on the actual energy use.

TM47 makes the point that the AR does not use the same calculation basis as the OR, so no direct correlation can be drawn between them. However, it notes that in both cases a typical building will have a numerical rating of 100[14], so there is a degree of comparability between the scaling processes. Where a building with an AR of 70 achieves an OR of 120 this might well indicate that the building is being operated inefficiently. The aim of this study is to examine whether there is any correlation between the two by analysing their relative calculation methods. By normalising one against the same parameters as the other, it is hoped to better understand the magnitude and source of the differences between the two ratings systems so that any difference between the ratings can be attributed to operation of the building alone. This is an ambitious aim, and this study represents just a step towards it.

[13] A list of Approved Software can be found at http://www.ukreg-accreditation.org/.

[14] This statement will be reflected on in section 2.4.4.

2.4 Differences between Asset Ratings and Operational Ratings

There are several key differences between the carbon emissions expressed by the AR when compared with the OR. These are:

- Non-standard use
- Unregulated energy
- Different carbon intensities
- Normalisation of each rating scale
- Separable energy use
- OR benchmarks
- Metering and scaling of renewables

2.4.1 Non-standard use

The AR of a building reflects the energy performance of that building in terms of the way it is built rather than the way it is used, and standard use is assumed (DCLG, 2008A). The AR is based on a numerical model which assumes that the building has fixed occupancy patterns, servicing strategies, temperature set-points etc, as defined by the NCM templates. The AR does not explicitly cater for the possibility that the users will use the building inefficiently by adjusting set-points or operating building services for longer or at night, for instance. The OR is based on metered data and so reflects actual usage (relative to a benchmark for the building category).

TM47 allows the OR to be corrected for extended hours of occupancy and increased occupant density, if suitable documentary evidence can be provided. As a result, this was not considered to contribute significantly to any differences with the AR.

The differences between predicted and actual energy consumption due to non-standard use cannot be corrected for, but it is hoped that this study will help to better understand the magnitude between the two, by correcting for the other sources of differences described below.

These differences are expected to be dominated by poor operation.

2.4.2 Unregulated energy

Regulated energy is defined as that used by systems integral to the function of the building that are controlled through Building Regulations (e.g. heating and cooling, lighting, water heating), while unregulated energy includes appliances, computers, catering etc (DCLG, 2009).

The AR is intended to reflect the design features of the building such as the building fabric, servicing strategy, the efficiency of the installed building services, and any Low or Zero Carbon (LZC) technologies. It focuses on the regulated energy, and it does not take account of energy used by building occupants, and so anything that is plugged in is not included in the calculation. Gas consumption due to catering, the electrical consumption of lifts, external lighting and process loads are not accounted for. The OR measures all of these things, although certain process loads (e.g. server rooms) can be excluded if these are separately metered.

It is not straightforward to correct for all of these emissions sources. Although the reports accompanying and EPC and DEC may give recommendations that highlight the presence of catering and lifts etc, the information is not detailed enough to estimate consumption so that a correction can be made. However, by using benchmarks for equipment use for the particular type of space, a partial correction can be made. The accuracy of the correction will depend on the accuracy of the equipment benchmark, and the prevalence of the other, unaccounted, sources of emissions. This correction will be described in more detail in section 4.1.

2.4.3 Different carbon intensities

The carbon intensities used in the conversion from energy consumption to CO_2 emissions are different for EPCs and DECs. The AR uses values from ADL2 (which references Table 12 of BRE, 2009A) while the OR (DCLG, 2008B) uses values from the Central Information Point (CIP). Table 2-2 compares the two sets of values and also shows the previous values used by the AR under ADL2 (2006). An AR will use either the 2006 or the 2010 values depending on when the EPC was produced. The data obtained for this study dates from May 2010, and so the 2006 values will have been used. Note that the only differences between the 2006 and CIP values are for electricity.

By using the carbon intensities from the CIP and the energy consumption data from the EPC calculation files, it will be possible to correct for the difference in carbon intensity values used.

Fuel	CIP $kgCO_2/kWh$	ADL2 (2006) $kgCO_2/kWh$	ADL2 (2010) $kgCO_2/kWh$
Anthracite	0.317	0.317	0.318
Biogas	0.025	0.025	0.018
Biomass	0.025	0.025	0.028 (pellets)/0.09 (chips)
Coal	0.291	0.291	0.301
Grid displaced electricity	0.55	0.568	0.529
Grid supplied electricity	0.55	0.422	0.517
Liquid Propane Gas	0.234	0.234	0.245

Fuel	CIP $kgCO_2/kWh$	ADL2 (2006) $kgCO_2/kWh$	ADL2 (2010) $kgCO_2/kWh$
Natural gas	0.194	0.194	0.198
Oil	0.265	0.265	0.274
Smokeless	0.392	0.392	0.347
Dual fuel (mineral and wood)	N/A	0.187	0.206
Waste	N/A	0.018	0.058

Table 2-2 - Comparison of carbon intensities used in the calculation of Asset Ratings and Operational Ratings

2.4.4 Normalisation of each rating scale

The derivations of the AR and OR scales have been previously described. The AR scale is normalised by a building compliant with ADL2 (2006), while the OR scale is normalised by the stock average. As the stock average is likely to be much worse than a building built to 2006 standards, the influence of this normalisation will be investigated.

Crucial to the normalisation of the AR scale is the definition of the Typical building. This has recently been changed in the 2010 NCM (DCLG, 2010A) from one that is identical to the Reference building but built to the minimum specification standards of ADL (1995)[15], to one where the CO_2 emissions rate is equal to the 2010 TER multiplied by two and divided by 0.75 (this is approximately twice the emissions rate of the 2006 TER). This definition (and TM47) implies that the Typical building will have a numerical rating of approximately 100, but this is not always the case. If this were true, the normalisation of the AR scale would only be an issue in explaining differences between the OR and AR for EPCs produced using the old definition[16].

As the TER now varies depending on the servicing strategy, there will now be three values for the emissions from the Typical building (ER_{TYP}), one for each servicing strategy. It is only when considering a mixed-mode building that the Typical AR (AR_{TYP}) will equal 100. This is illustrated graphically in Figure 2-3 which uses a notional scale to show the relative magnitude of the relationships between the various building types. It shows the Typical building using the earlier NCM 2008 definition as well as the current NCM 2010 definition.

[15] The previous definition was in the 2008 NCM (DCLG, 2008C).

[16] This represents all of the data set under consideration in this study, as the data was obtained prior to the implementation of ADL2 (2010).

Starting from the left of Figure 2-3, it can be seen that SER=0.765xRER and that the emissions from the Typical building are greater than the RER. If a mixed-mode building is considered, the TER under ADL2 (2006) will equal the SER (by definition). The TER under ADL2 (2010) will be 75% of the 2006 value[17], implying that the emissions of the Typical building are twice the 2006 TER. Achieving the 2010 TER would result in an AR=50 with AR_{TYP}=100. If an air-conditioned building is considered, the same relationships hold, but achieving the 2010 TER does not give an AR=50 and $AR_{TYP}\neq100$.

It should be noted that the emissions from the Typical building using the NCM 2008 definition is shown as being larger than those for a mixed-mode Typical building using the NCM 2010 definition. This is not necessarily the case: it could be the other way around or they could be almost equal. Appendix A takes the values of AR_{TYP} for the data set under consideration and divides it the 'if newly built' AR (or the AR of the 2006 TER) to test how close to the numerical value of two the results are. This gives an idea of the relative magnitudes of the emissions from a mixed-mode Typical building using both definitions. The data is scattered above and below the value two.

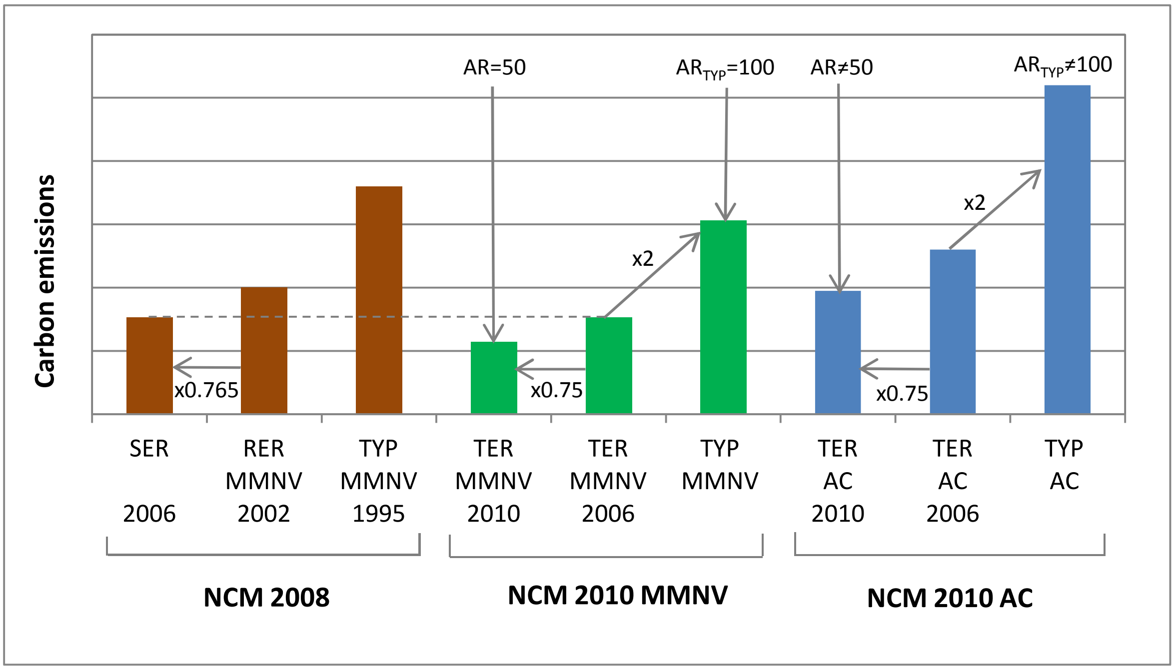


Figure 2-3 – The relationship between the emissions from various building types illustrating the effect of the change in definition of the Typical building

[17] Refer to footnote 9.

It has just been shown that AR_{TYP}=100 when the building under consideration uses a mixed-mode servicing strategy. Appendix B confirms this mathematically using the relationships between the different building types.

A revised normalisation will now be proposed. It will be implemented by taking the un-normalised carbon emissions from the EPC, and then re-normalising using the emissions of the Typical building. The analysis below presents an expression for this re-normalised AR.

Comparing the equations previously presented for the OR and AR:

$$\mathbf{OR = 100 \text{ x } \frac{Building\ CO_2\ emissions/building\ area}{Typical\ CO_2\ emissions\ per\ unit\ area}} \qquad \textbf{(Eqn. 2-4)}$$

$$\mathbf{AR = 50 \text{ x } \frac{BER}{SER} = 50 \text{ x } \frac{BER}{0.765xRER}} \qquad \textbf{(Eqn. 2-5)}$$

It can be seen that the OR has a multiplier of 100 compared with 50 for the AR, and the OR is normalised by a Typical building's emissions rate while the AR is normalised by the Standard building.

In order to compare the AR and OR on an equitable basis they should be normalised in a similar fashion. A 'normalised' AR (AR_{NORM}) will be defined in a similar form to the OR as:

$$\mathbf{AR_{NORM} = 100 \text{ x } \frac{BER}{ER_{TYP}}} \qquad \textbf{(Eqn. 2-6)}$$

The Typical Asset Rating (AR_{TYP}) is defined as:

$$\mathbf{AR_{TYP} = 50 \text{ x } \frac{ER_{TYP}}{SER}} \qquad \textbf{(Eqn. 2-7)}$$

Rearranging Eqn. 2-7 and substituting ER_{TYP} into the equation for AR_{NORM}, and using the definition of Eqn. 2-5 gives:

$$\mathbf{AR_{NORM} = 100 \text{ x } BER \text{ x } \frac{50}{SERxAR_{TYP}} = 100 \text{ x } \frac{AR}{AR_{TYP}}} \qquad \textbf{(Eqn. 2-8)}$$

This expression will be used to correct for the difference between the normalisation of the rating scales. It should be noted that the revised normalisation will have no impact when applied to a mixed-mode naturally ventilated building that is exactly compliant with ADL2A (2006). This is described in more detail in Appendix B.

2.4.5 Separable energy use

One major source of discrepancies which warrants attention is that of separable energy use. This could also contribute to situations where the OR is much greater than the AR. Separating out certain energy uses is an optional part of the approved OR methodology which can increase the relevance of the OR if a building has certain specified 'process' energy uses which are not captured by the building's benchmark category. The benchmark data and details of the allowable separable energy uses can be found in TM46 (CIBSE, 2008). The categories are:

- regional server room
- trading floor
- bakery oven
- sports floodlighting
- furnace, heat treatment of forming process
- blast chilling or freezing

Where a building has a separable energy use but this has not been metered separately, then this difference cannot be accounted for. However, by examining the EPC, DEC and accompanying reports it can often be identified that a separable energy use is likely to be present, and so the differences between the AR and OR can be (at least partially) attributed to this. There is currently some debate (Bruhns *et al.*, 2011) as to whether the allowable separable energy uses should be expanded.

2.4.6 Operational Rating benchmarks

The OR is obtained using a benchmark for the relevant type of building. If the benchmark used is unsuitable then the OR rating will be affected. The OR benchmarks are currently being examined to identify benchmark categories that require further refinement (Bruhns *et al.*, 2011). This issue will be examined in more detail in Chapter 4.

2.4.7 Metering and scaling of renewables

The amount of renewables in the data set under consideration is relatively minor. If the renewables were more significant, there would be another potential source of discrepancies. This can arise due to the scaling of renewables in the calculation of the AR.

One example is where a Combined Heat and Power (CHP) system is selected to meet the base heating load of a building. The kW rating of the CHP system will be entered into the calculation software, but the Actual building can have a different base heating load than the designed building. The result would be that the CHP operates either more or less than it would in reality, which would lead to a misleading level of carbon savings.

Another potential source of discrepancies is where renewables are installed but not separately metered, meaning that the resulting carbon savings cannot be accounted for in the calculation of the OR.

2.5 Accounting for the differences between Asset Ratings and Operational Ratings

While it is difficult to correct the CO_2 emissions predicted by an AR to account for all the differences between the two scales, it is possible to correct for certain differences.

The xml files that accompany an EPC contain a more detailed breakdown of energy usage. The process that follows will attempt to correct the AR so that it includes unregulated energy and the energy use will be converted to CO_2 using a common set of carbon intensities. This modified AR (AR_{MOD}) will then be scaled so that it is compared to the OR on a more equitable basis. In theory, any deviation between this modified and re-normalised AR ($AR_{MOD,NORM}$) and the OR should be attributed solely to non-standard use, unmetered separable energy use or unsuitable OR benchmarks[18].

The Recommendations Reports will be examined for evidence of unmetered separable energy, and the study by Bruhns *et al.* (2011) gives details of benchmarks requiring further refinement. This should make it possible to identify buildings where unmetered separable energy or unsuitable benchmarks are contributing to differences between the $AR_{MOD,NORM}$ and the OR.

The various differences between ARs and ORs and the potential for correction are summarised in Table 2-3 below. These corrections will be applied in Chapter 4 once the DEC database has been examined in more detail.

Difference	Potential for correction
Non-standard use	No correction.
Unregulated energy	Partial correction of AR using equipment benchmarks.
Different carbon intensities	Full correction of AR by applying carbon intensities from CIP database to EPC energy consumption.
Normalisation of each rating scale	Full correction of AR.

[18] And the fact that the correction for unregulated energy use is only a partial one.

Difference	Potential for correction
Separable energy use	Separable energy uses not metered cannot be corrected for.
Operational Rating benchmarks	No correction as part of this study, but subject to ongoing refinement.
Metering and scaling of renewables	No correction but not significant for this data set.

Table 2-3 – Differences between Asset Ratings and Operational Ratings and potential for correction

Chapter 3 Examination of the database

3.1 Introduction

Following a Freedom of Information request to the DCLG in the early part of 2010, a data file consisting of 56,481 entries from the DEC database was received on 13th May 2010. The file contained the following data on each entry:

- Building Address
- Current and previous Operational Ratings
- Current and previous Carbon Dioxide Emissions
- Main Heating Fuel
- Building Environment
- Total useful floor area (m^2)
- Asset Rating
- Annual Energy Use (kWh/m^2) – Heating
- Annual Energy Use (kWh/m^2) – Electrical
- Typical Energy Use (kWh/m^2) – Heating
- Typical Energy Use (kWh/m^2) – Electrical
- Energy from Renewables

The key elements for the initial data filtration that follows are the OR and the AR.

3.2 Data filtration process

1,572 entries were found to have both an AR and an OR, and these entries were examined for erroneous data.

Instead of a blank entry indicating no AR, many (1,331) had a '0' AR indicating zero energy emissions on the corresponding EPC. Due to the difficulty in achieving zero emissions without the use of LZC technologies, entries which had a '0' AR but had no renewables recorded on their DEC were omitted from the study. There were 1,315 such erroneous entries, leaving 257 remaining entries.

A further level of filtration was carried out on the remaining 257 records. Following Bruhns *et al.* (2011), entries were omitted on the basis that they were not typical of wider performance. These criteria are shown in Table 3-1 along with the number of occurrences of each.

Identifier	No. of occurrences
Floor area < $50m^2$	0
OR < 5	62
OR > 1000	5
Annual heating energy = 0	8
Grid supplied electricity is main heating fuel	13
No metered data (OR = 0, 200, 9999)	19
Total	97

Table 3-1 – Data filtration identifiers and frequency of occurrence

One DEC referenced an AR of 200; this is the default rating for the DEC when there is no data available and this found to be an erroneous indication that there was no EPC.

The result of this further stage of filtration was that there were now just 149 entries that had both ARs and ORs that were valid.

Using the postcode search function in the Landmark database[19], EPCs and their associated Recommendations Reports and xml data files were downloaded, along with the DECs and their associated Advisory Reports.

3.3 Examination of the database entries

The EPCs, Recommendations Reports, xml files, DECs and Advisory Reports were examined for all 149 entries. Information was tabulated on the main heating fuel and building environment reported by each set of documents, and the recommendations of both sets of accompanying reports were examined to deduce whether the building in question was new, existing, or an extension to an existing building. Where the recommendations were not conclusive, the value for air permeability of the building was also examined to help with this process. A minimum standard for air permeability of 10 $m^3/(hr.m^2)$ at 50 Pascals was introduced by ADL2 (2006). Any building with a value of 10 or below in the xml file was assumed to be new.

A further check on whether a building was new or existing was carried out by comparing the AR with the 'if newly built' AR. The expectation would be that a new building would have an AR better than, or as good as, the 'if newly built' AR, as otherwise it would not comply with Building Regulations.

[19] https://www.ndepcregister.com/

There was one building that was judged to have been existing whose AR was better than the ‘if newly built’ AR. On examination, this was because an extension had been built which included biomass boilers.

There were fifteen buildings that were judged to have been new whose AR was worse than the ‘if newly built’ AR. However, these were examined in further detail and the buildings were confirmed as being new (this included internet searches for dates of construction). The reason for the AR being worse than the ‘if newly built’ value varied. The reasons were:

- Any building whose design or construction commenced prior to the introduction of ADL2 (2006) but was completed afterwards would be considered as new, but could have an AR that was worse than the ‘if newly built’ AR. Where the design had commenced, these buildings would not have needed to comply due to transitional arrangements. Where construction had commenced, these buildings would be compliant with the current edition when the design had been carried out (ADL2 (2002)).
- Any building that was completed just prior to the introduction of ADL2 (2006) could have the characteristics of a new building and could have an AR that was worse than the ‘if newly built’ AR. These buildings would be compliant with ADL2 (2002).
- A new naturally ventilated building that is just compliant with ADL2 can have an AR that is marginally worse that the ‘if newly built’ AR. This because the RER for a mixed-mode naturally ventilated building will be higher than the BER for a naturally ventilated building that is just compliant with ADL2 due to the use of some mechanical cooling.

The conclusion is that a comparison between the AR and the ‘if newly built’ AR is not entirely reliable in determining whether a building is new or existing.

A further examination of the data set was carried out, and 45 of the 149 entries were discounted for the following reasons:

- EPC not found in database despite an AR appearing on the DEC.
- DEC examined does not have an AR (error in database provided by DCLG).
- AR relates to another building on a campus or a part of a tenancy.

The first two reasons were most prevalent. This exercise reduced the number of valid entries to 104.

3.4 Observations on the database entries

With the potential extension of DECs to commercial buildings, the number of database entries has the potential to increase many fold. The manual examination of the database that has been carried out as part of this study would be very time-consuming as the number of entries increases over time. In order to make future studies of the DEC database feasible and more useful, the recommendations and observations that follow should be considered for incorporation into the DEC process at the earliest opportunity. In some cases there are no recommendations accompanying particular observations; the intention is to highlight elements of the process that might warrant further investigation in the future. In order that a massive opportunity is not missed to extract maximum benefit for little additional effort, careful consideration must be given now to the potential uses of this data in the future, such as providing an evidence base for the effectiveness of energy policy interventions, or gaining a closer understanding of the gaps between predicted and actual energy use.

3.4.1 Unique Property Reference Number (UPRN)

UPRNs are used to identify buildings on the Landmark database. Various discrepancies were found where EPCs and DECs for the same building had different UPRNs, which suggests that the management of the address database needs to be improved. A method of linking the UPRN of a tenancy to the whole building (or campus) should be implemented.

Recommendation: Improve the management of the address database by implementing a graphical tree topology that allows the relationship between tenancies, buildings and campuses to be more easily linked. The importance of checking the address database for existing UPRNs when adding a building certificate should be reiterated to assessors. An initiative to correct instances where there are multiple UPRNs for a single building should be implemented during the annual renewal of DECs.

3.4.2 Cross-referencing between EPCs and DECs

Currently DECs show the AR, but EPCs do not show the OR. It was found that some DECs showed an AR for which an EPC could not be found. It is also possible that there are DECs that do not show an AR where one exists.

Recommendation: Implement a more explicit link between EPCs and DECs by requiring EPCs to include the OR where a DEC is also available.

3.4.3 Building type

It is only through the process of deduction by the time-consuming analysis of Recommendations and Advisory Reports that it can be determined whether a building is new, existing or an extension. Comparison between the AR and 'if newly built' AR is not always accurate. This is detrimental to carrying out analyses of the data and should be explicitly included as a piece of information on both EPCs and DECs.

Some Advisory Reports provide very useful entries under Building Description (e.g. 'brick/brick cavity wall construction, mainly built 1936-1938 except for first floor offices (North) c. 1979') whereas others sometimes contain no text whatsoever.

Recommendation: Include an additional piece of information relating to building type ('new at time of certificate production', or 'existing') on both EPCs and DECs. For new buildings, the year of construction should be included. Communicate the importance of improved building descriptions on the accompanying reports to assessors, and include a review of these descriptions in the Quality Assurance process.

3.4.4 Area

There were examples of buildings with both EPCs and DECs where the areas were marginally different, but were close enough to suggest that this was not justified. For example, if there were a tenancy arrangement for part of a building that had its own EPC, the area on the EPC for the remainder of the building would be expected to be different from the area on the DEC for the whole building. This difference would be significant whereas some of the areas differences found were relatively small, which indicated different measurement results.

However, there were also many examples of buildings with exactly the same area, which is encouraging.

Any discrepancies could be removed if the two certificates were better cross-referenced as suggested earlier.

3.4.5 Building environment

Both EPCs and DECs have the following categories for the servicing strategy of the building environment:

- natural ventilation (NV),

- mixed-mode natural ventilation (MMNV),
- mixed-mode mechanical ventilation (MMMV),
- mechanical ventilation (MV),
- air-conditioning (AC).

Over 10% of the 104 entries with both EPCs and DECs were found to have different strategies depending on whether the EPC or DEC is consulted. Some examples are buildings that are AC under the EPC, but MMMV, MV and even NV on the DEC. As the DEC benchmarks are the same regardless of servicing strategy, the incorrect selection of the servicing strategy on the DEC is not thought to indicate anything other than carelessness (which itself should be of some concern). The analysis that follows in Chapter 4 will use the description on the EPC to determine the building environment, on the assumption that the process of modelling the building for an EPC will mean that more attention is paid to determining the servicing strategy correctly than for a DEC, which could be considered as more of a data collection exercise.

It is also possible that where buildings have multiple strategies, different assessors have made different assessments of which is more prevalent.

Recommendation: Communicate the importance of the correct selection of building environment to assessors and include a review of these in the Quality Assurance process.

3.4.6 Main heating fuel

There are several examples where the EPC states that the main heating fuel is biomass, oil or electricity while the DEC states gas. The main heating fuel is defined as the heating fuel that provides the majority of the load, in instances where there is more than one fuel.

The difference between the EPC and DEC could be explained by the EPC predicting that one fuel would provide the majority of the load, but operational factors resulting in a differing mixture of fuels for the DEC. However, the DEC Advisory Report allows for all fuels to be listed and there are examples of biomass appearing on the EPC as the main heating fuel, but not being mentioned in the Advisory Report at all. Perhaps biomass is being used but is not being metered or recorded, or perhaps this is a firm example of the frequent anecdotes about biomass boilers being installed for regulatory compliance but never actually being operated?

Recommendation: Both certificates should list all heating fuels and the proportion of the total load that each meets (or is predicted to meet).

3.4.7 Renewable energy

While the DEC details the energy from renewables, the EPC does not. However, by examining the xml files and reading the Recommendations Reports, references to renewables were found; these sometimes contradicted the information on the DEC and in its Advisory Report. Some examples are:

- Photovoltaics (PVs), SES (Solar Energy System) and wind in EPC xml file but not mentioned in the Advisory Report.
- SES in EPC xml file but solar water panel and small CHP mentioned in the Advisory Report.
- No renewables in EPC xml file but PVs mentioned in the Advisory Report.
- PVs in EPC xml file with 'solar array' mentioned in Recommendations Report as being inactive.
- Biomass and PVs in EPC xml file but only PVs mentioned in the Advisory Report.
- No renewables in EPC xml file but Advisory Report mentions 'solar panels.'
- PVs and wind in EPC xml file but only wind is mentioned in the Advisory Report.
- No renewables in EPC xml file but renewables are noted on the DEC.
- Biomass, CHP and SES in EPC xml file while biomass, PVs and solar are mentioned in the Advisory Report.
- Wind in EPC xml file but not mentioned in the Advisory Report.

Some of these discrepancies could possibly be explained by the potential time lag in the production of the relevant certificates and reports (an EPC and Recommendation Report is only required on construction sale or let, while a DEC is required each year and the Advisory Report is valid for seven years) alongside retro-fitting of new technologies after an EPC has been produced.

Another explanation might be that the renewables do not appear in the DEC as there is no means of metering their contribution. However, in this case one would expect that one of the Advisory Report recommendations would be to implement metering.

Recommendation: Both certificates should list the renewable technologies and contributions so that the predicted and actual performance can be better understood.

3.4.8 Separable energy uses

Separable energy uses were not found in many of the DEC Advisory Reports examined. Elements of energy consumption that might be considered as separable energy uses that were not subject to metering were mentioned in several Advisory Reports and these will be referred to later in the study.

Recommendation: Separable energy uses that have been accounted for should be listed on the DEC. Atypical energy use should also be noted.

3.4.9 Advisory Reports

Advisory Reports were sometimes missing even when the *Year 1* DEC was found. These are often very different from the Recommendations Report. Notwithstanding the differences between EPCs and DECs, the recommendations should follow similar lines in places.

3.5 Implementation of recommendations

The analysis that follows in Chapter 4 involves a detailed study of the records of approximately 100 buildings that have both an AR and an OR from a database of over 56,000 buildings. While the data that will be presented leads to some interesting observations, a larger data set would provide more certainty of the trends displayed. With the reduction in the size threshold of buildings that will require a DEC being implemented by the recast EPBD, and the expected DEC rollout to commercial buildings, the number of buildings with both carbon ratings is likely to increase greatly. However, unless the recommendations above are implemented, it will be impractical to repeat this study due to the resources required for manual examination of the data.

Chapter 4 Accounting for the differences between Asset Ratings and Operational Ratings

This chapter will present the AR and OR data and attempt to account for some of the differences between the two systems.

Various corrections that can be made to account for the differences between ARs and ORs were discussed in Chapter 2. Of these, the methods of correcting the AR for different values of carbon intensities and the different normalisation of each scale have already been presented. The correction to the carbon emissions of the AR to account for unregulated energy will now be considered.

4.1 Correction for unregulated energy

The xml data file details all of the predicted energy consumption data for the Actual, Notional, Typical and Reference buildings. This includes the cooling, heating, auxiliary, lighting and equipment consumption in kWh/m^2 alongside the energy consumption by fuel. The emissions due to equipment are included in the xml data file, but as it is unregulated energy it is not included within the carbon emissions used to calculate the AR. It is used to generate an associated cooling load which impacts on the carbon emissions of mechanically cooled buildings, but does not otherwise contribute to the AR.

In order to correct for unregulated energy, this equipment consumption will be included within the carbon emissions. This is a far from perfect means of allowing for unregulated energy. It relies on the accuracy of the benchmark figures for equipment use, and does not make any allowance for lifts, catering etc. It would be extremely difficult to correct for such items as the documents that accompany the EPC and DEC do not provide much information on the presence and extent of lifts and other sources of unregulated energy. CIBSE (2009B) advocate the inclusion of lifts, security and feature lighting in future editions of ADL2 from 2013 onwards, which would presumably works its way through to EPCs (via the NCM) to help reduce this difference between ARs and ORs.

As a further check on the xml data, the kWh/m^{2}used by cooling, auxiliary energy and lighting were added together and compared with the total kWh/m^2 attributed to 'grid supplied electricity'. A manual calculation of the AR was then undertaken using the emissions from the various sources and the appropriate carbon intensities, and this was compared with the value on the certificate. Where fossil fuels were used for heating and hot water generation, the manual and actual ARs were expected to be equal. Where this was not the case, the magnitude of difference in grid supplied electricity was examined. In some cases the difference was found to be a multiple of the equipment energy use. This was further investigated and of the 104 entries it was found that there were 14 entries where the equipment energy had been included in the grid supplied electricity and 16 entries where twice the magnitude of the equipment had been included. By examining the software used for each EPC it was found that those entries that included a single multiple of the equipment energy were all created using TAS (versions 9.1.x and 9.1.3), and those that included a double multiple were all created using IES (versions 5.9.0.1, 5.9.2, 6.0, 6.0.2, 6.0.3 and 6.0.5).

This suggests that the guidance on what should be classified as 'grid supplied electricity' in the xml file is not entirely clear, and has been applied incorrectly by both TAS and IES.

There were five records where the difference between the manual AR calculation and that on the EPC could not be explained by equipment use. In two cases it was not clear what the origin of the difference was. In three cases, LZC technologies were present, and it may be that the way that the CO_2 displaced is calculated is not as intended. The three records had the following LZC technologies:

- CHP and SES
- District heating (of unknown carbon intensity)
- Biomass and PVs

These five records were excluded from the exercise as the energy breakdown within the xml file could not be relied upon for the proposed correction process. Following the exclusion of these five records, the original database of 56,481 entries stood at just 99. While the small number of valid records will reduce the statistical significance of the exercise, it is hoped that some of the lessons learned in the analysis can be fed back into the EPC and DEC generation process so that similar studies can be carried out relatively easily in the future when the number of buildings with both ARs and ORs has increased dramatically. The indicative findings from the analysis of the 99 valid records are presented below.

Recommendation: Clarify the definition of 'grid supplied electricity' in the EPC output xml file, and the method of accounting for LZC technologies, with the providers of Approved Software. Include the carbon intensity of any district heating in the xml file.

4.2 Analysis of buildings with both Asset Ratings and Operational Ratings

4.2.1 Asset Rating and Operational Rating

Figure 4-1 shows the ARs and ORs for the 99 database entries that had both an EPC and a DEC. A straight line with AR=OR is plotted; this represents the line that the data should follow if:

- the buildings were used in the standard patterns that are input to the calculation methodology,
- the two ratings systems measured exactly the same sources of carbon, using the same carbon intensities and the same normalisation scale,
- all separable energy uses were accounted for,
- appropriate OR benchmarks were used,
- and renewable energy sources were appropriately sized and metered.

This will be referred to as the *line of equal emissions.* Errors by Energy Assessors are not considered, on the assumption that the various Quality Assurance schemes reduce these to acceptable levels.

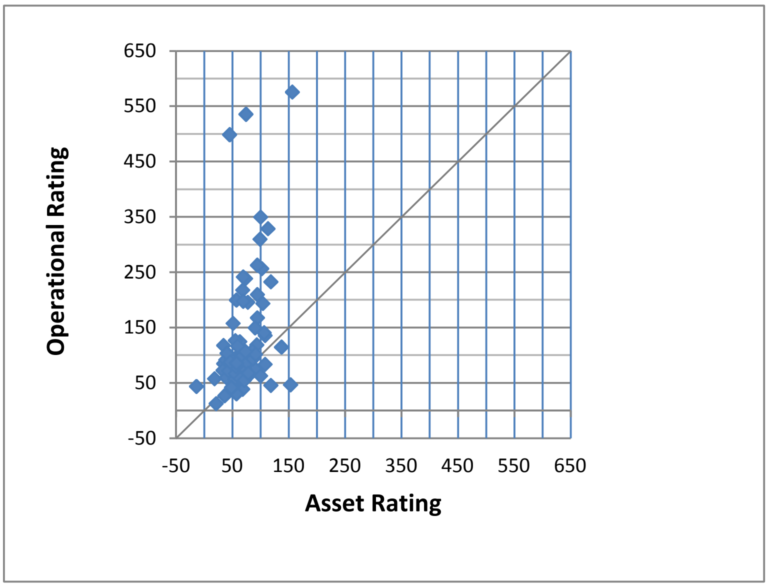


Figure 4-1 - Variation of Operational Rating with Asset Rating

To the uninformed, a building that appears above this line could be considered to be operated in a more carbon intensive way than its design predicted, while a building appearing below the line could indicate that it is being operated in a less carbon intensive way than predicted by the design. Due to the various factors previously discussed, this is not necessarily the case. However, by modifying the raw EPC data we will attempt to get nearer to the point where this is true, so that the remaining differences can be identified.

Referring to Figure 4-1, there are a number of cases where the OR is greater than 150, which could indicate that these buildings:

- are operated poorly or in a non-standard way,
- have design characteristics that are much worse than typical,
- have separable energy uses that are not separately metered and so cannot be deducted from the OR, or have process loads that are not allowed as separables,
- have inappropriate OR benchmarks.

The potential reasons for these high variations will be discussed later.

Figure 4-2 shows the same data as Figure 4-1 but it focuses on the majority of the data whose OR is less than 225. While there are a number of outlying points where the OR is significantly greater than the AR, the majority of the data is clustered around the line of equal emissions. The tendency is for the OR to be greater than the AR, which is in line with the general expectation that design predictions are usually exceeded in practice. 60% of the data have both an AR and an OR that lie between 25 and 100 on each scale. This range corresponds to ratings of B, C and D. 39% have both an AR and an OR that lie between 50 and 100 corresponding to ratings of C and D.

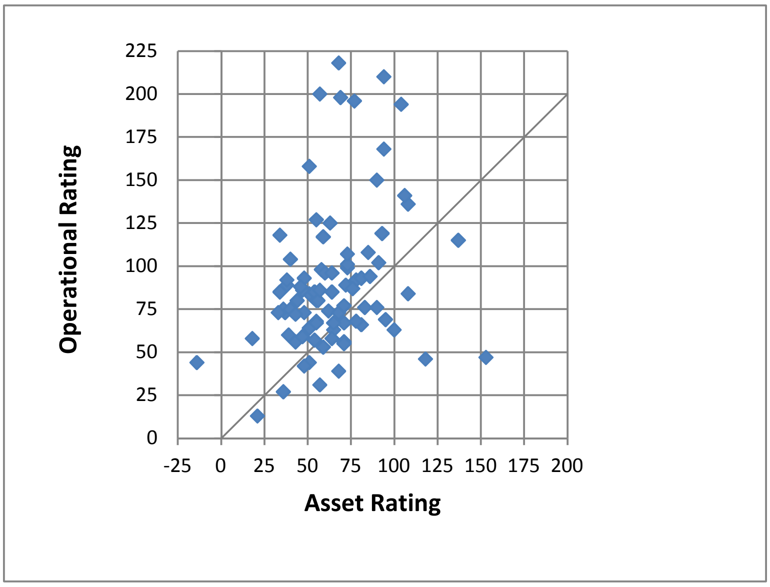


Figure 4-2 - Variation of Operational Rating with Asset Rating with focus on data where OR<225

Figure 4-3 repeats the data of Figure 4-2 but also compares it with the corresponding AR_{TYP} for each building. If the building is better than typical, then AR is less than AR_{TYP} and AR_{TYP} will lie to the right of AR. If the building is worse than typical, then AR is greater than AR_{TYP} and AR_{TYP} will lie to the left of AR. It can be seen from Figure 4-3 that the majority of values for AR_{TYP} are to the right of the corresponding AR, indicating that the performance of the data set is generally better than typical.

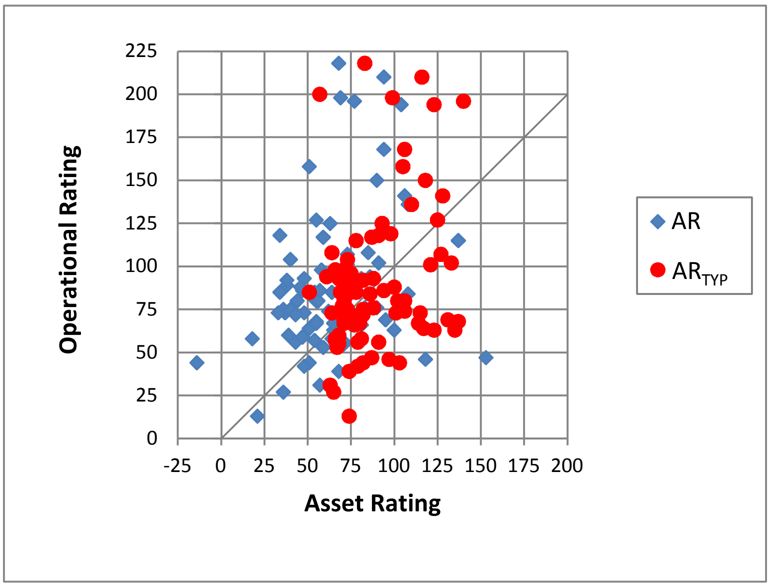


Figure 4-3 - Variation of Operational Rating with Asset Rating and Typical Asset Rating

4.2.2 Correction for unregulated energy

The first step in correcting the AR to account for unregulated energy is to plot the un-normalised

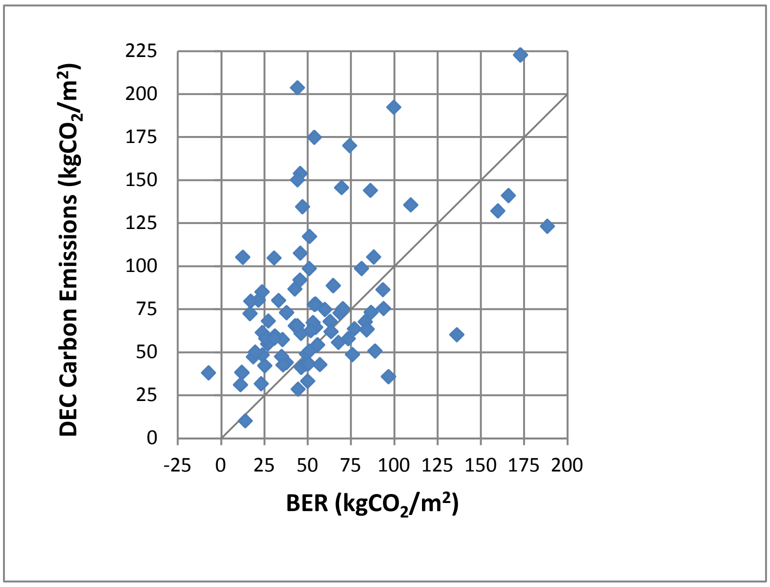


Figure 4-4 - Variation of DEC carbon emissions with BER

carbon emissions from the DEC and the EPC. These un-normalised emissions will be corrected before being re-normalised. Figure 4-4 shows how the DEC carbon emissions compare with the EPC carbon emissions (or BER). There is a similar pattern to Figure 4-2 with the DEC carbon emissions exceeding the design predictions for the BER. The data is less clustered as a result of being un-normalised.

The next step is to apply the correction for unregulated energy to the BER. The correction is not perfect as little as known about the extent of lifts, catering, external lighting and server rooms etc. However, by using the equipment loads that the NCM uses to generate a cooling load, a significant proportion of the unregulated energy can be accounted for. Figure 4-5 shows the revised data; compared with Figure 4-4 the effect is to shift the data set to the right as a result of the increase in BER shown on the x-axis.

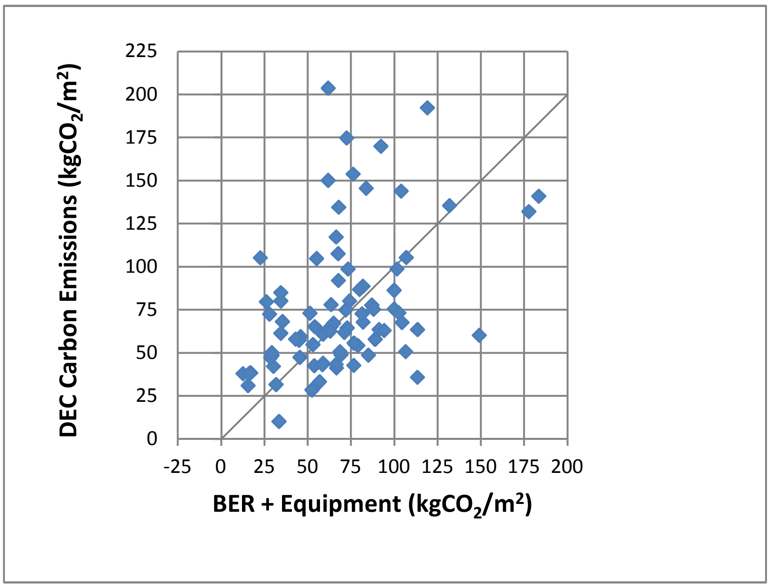


Figure 4-5 - Variation of DEC carbon emissions with BER adjusted to include emissions due to equipment

4.2.3 Correction for carbon intensities

The next step is to apply the correction for the different carbon intensities of fuel used by the two systems. The values from the CIP database used to calculate the OR will be applied to the sum of the BER and equipment energy consumption instead of the ADL2 values dictated by the NCM. Figure 4-6 shows these results. As the data set was obtained prior to the implementation of ADL2 (2010), the carbon intensities used to calculated the BER will be those from ADL2 (2006). Referring to Table 2-2, the only difference between the ADL2 (2006) and CIP database are for electricity. Grid displaced electricity is $0.55kgCO_2/kWh$ in the CIP database and $0.568kgCO_2/kWh$

under ADL2 (2006). This is a relatively minor difference and will only apply to buildings with CHP, wind turbine or PV installations, which do not contribute significantly to the data set[20]. The difference in carbon intensities of grid displaced electricity was not corrected.

The more significant difference is between the 0.422kgCO_2/kWh used for grid supplied electricity under ADL2 (2006) compared with 0.55kgCO_2/kWh in the CIP database. The effect of this will be to once more shift the data set to the right due to the higher carbon intensity used, with buildings that use proportionally more electricity than other fuels shifting by a more significant amount. Because ADL2 (2010) uses a value of 0.517kgCO_2/kWh, this difference will become less significant in the future.

Recommendation: Over time, the lodged EPCs will use different values for carbon intensities depending on the values used by the NCM when the EPC was produced. The values used should be included in the EPC output xml file to aid future analyses, rather than having to use deduction based on the date of lodgement.

It is interesting to note that the majority of the data has now crossed the line of equal emissions, which is contrary to the general expectation that design predictions underestimate actual emissions. The implication is that the gap between the two can be closed by comparing the

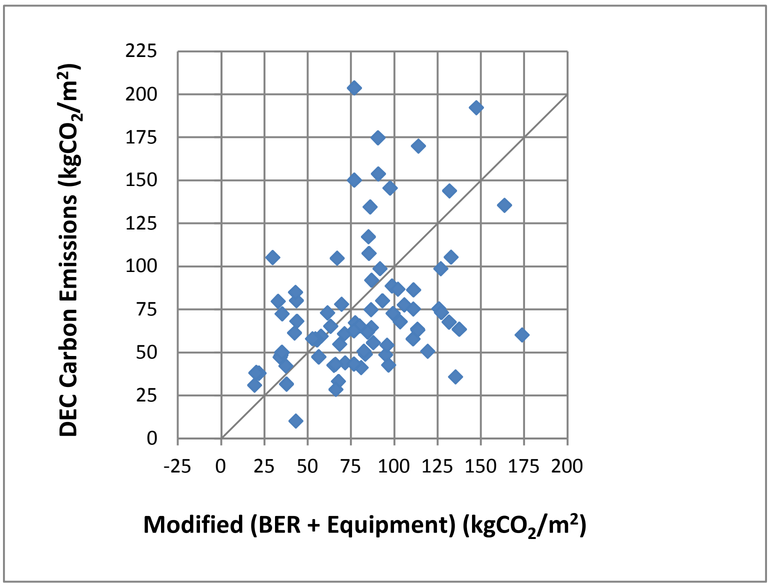


Figure 4-6 - Variation of DEC carbon emissions with BER adjusted to include emissions due to equipment and then modified for carbon intensity factors from the CIP database

[20] Only five buildings in the data set had CHP, three had wind turbines, and four had PVs.

carbon emissions on a more equitable basis by including emissions due to unregulated energy and using the same values for carbon intensities.

4.2.4 Analysis of data by building environment

Figure 4-7 shows the same data as Figure 4-6 but the data is given different symbols to indicate the building environment category shown on the EPC[21]. The small size of the data set (99 entries) means that it is difficult to draw any firm conclusions. This is especially the case for the 12 mechanically ventilated and four mixed-mode buildings. The 31 air-conditioned buildings display no particular pattern at all with some lying above, and others below, the line of equal emissions.

The 52 naturally ventilated buildings exhibited more uniform behaviour. They were generally clustered along the line of equal emissions but tended to be below it, perhaps indicating that naturally ventilated buildings perform better in terms of carbon emissions than predicted.

One explanation could be that air-conditioned buildings have a greater potential to be used in a non-standard way (e.g. poor commissioning leading to greater emissions that expected, systems left running out-of-hours, heating and cooling fighting each other) whereas it could be argued that naturally ventilated buildings are less likely to be used in a non-standard way (e.g. there is

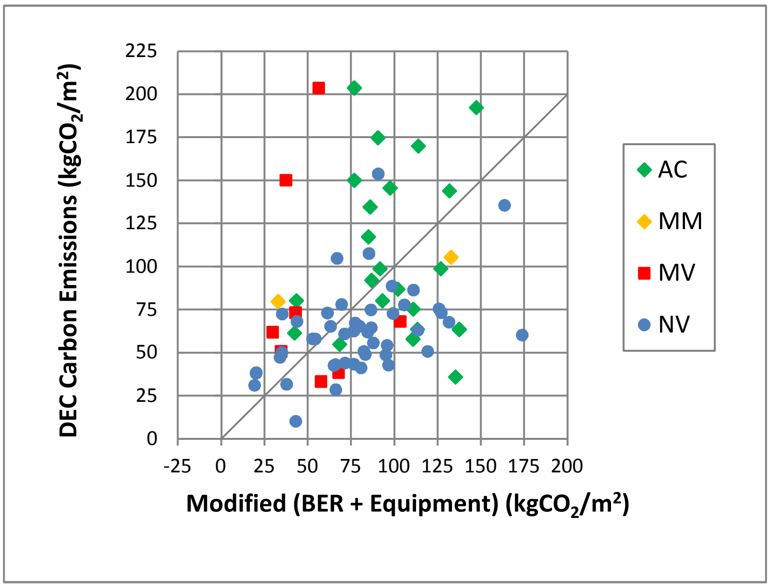


Figure 4-7 - Variation of DEC carbon emissions with modified BER (including equipment) by building environment

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[21] The reasons behind this were set out in section 3.4.5.

potential for excessive heating energy if a space is over-ventilated, but draughts are likely to lead to people making an intervention to reduce the ventilation rate). Whatever the reason, the large percentage of naturally ventilated buildings in the data set (52%) means that they dominate the data set and its trends.

4.2.5 Analysis of data by building age

Figure 4-8 shows the same data as Figure 4-6 but the data is given different symbols to indicate whether the buildings are new or existing.

Again, the data set is small but the indications are that new buildings tend to have lower emissions on both scales, and are clustered around the line of equal emissions. Existing buildings have higher emissions, and there was more evidence of metered emissions exceeding predicted emissions. This could be interpreted as new buildings demonstrating a better correlation between design predictions and metered data. Existing building constituted 72% of the data set.

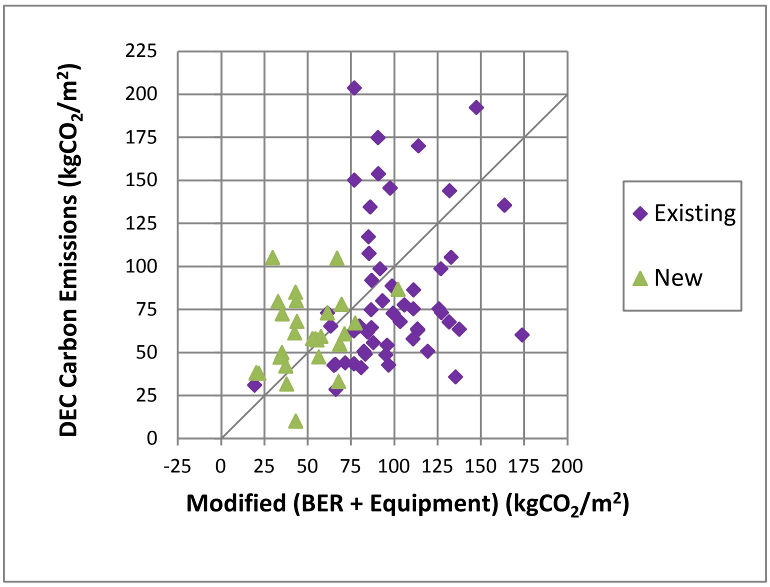

Figure 4-8 - Variation of DEC carbon emissions with modified BER (including equipment) by building age

4.2.6 Analysis of data by building benchmark category

Figure 4-9 shows the same data as Figure 4-6 but the data is given different symbols to indicate the building benchmark category used in the DEC rating. There are no particular trends by benchmark category, mainly due to the small size of the data set. 'General office' can be seen to dominate, representing 49% of the data set.

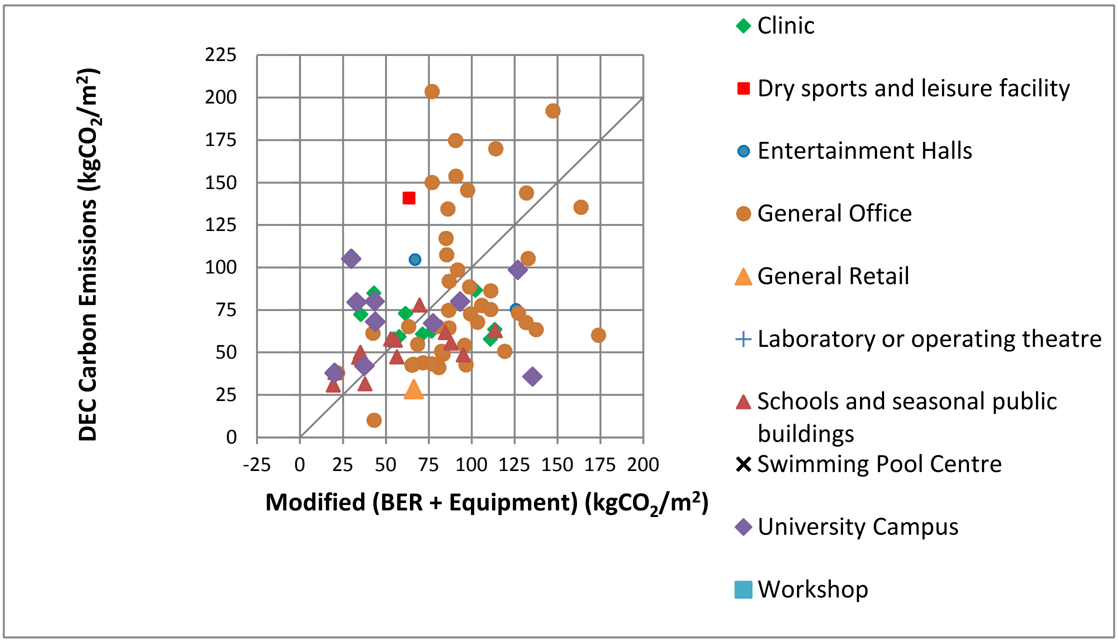

Figure 4-9 - Variation of DEC carbon emissions with modified BER (including equipment) by building benchmark category

4.2.7 Correction for differences in the normalisation of each rating scale

Before re-normalising the modified BER (including equipment), the unmodified AR (i.e. the data from Figure 4-2) will be shown alongside its re-normalised set, AR_{NORM} (where AR_{NORM} = $100xAR/AR_{TYP}$). This is to show the effect of the re-normalisation in isolation from the other corrections. Finding AR_{NORM} involves multiplying the AR by $100/AR_{TYP}$. Referring back to Figure 4-3, AR_{NORM} will shift to the right or left of AR depending on whether AR_{TYP} is less than or greater than 100 (i.e. depending on whether the multiplier $100/AR_{TYP}$ is greater than or less than 1). Figure 4-10 shows that the re-normalisation (on its own) has had a relatively small effect on the majority of the data.

Figure 4-11 shows the variation of the unmodified AR (i.e. the data from Figure 4-2) against the modified AR (i.e. the BER modified for carbon intensities and equipment from Figure 4-6 normalised in the standard way by multiplying by 50/SER[22]). This is to show the effect of the corrections in isolation from the re-normalisation. The effect is that the range of the AR is squeezed more tightly in the x-direction, improving the correlation between design predictions and metered data.

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[22] The SER has also been corrected for unregulated energy and different carbon intensities.

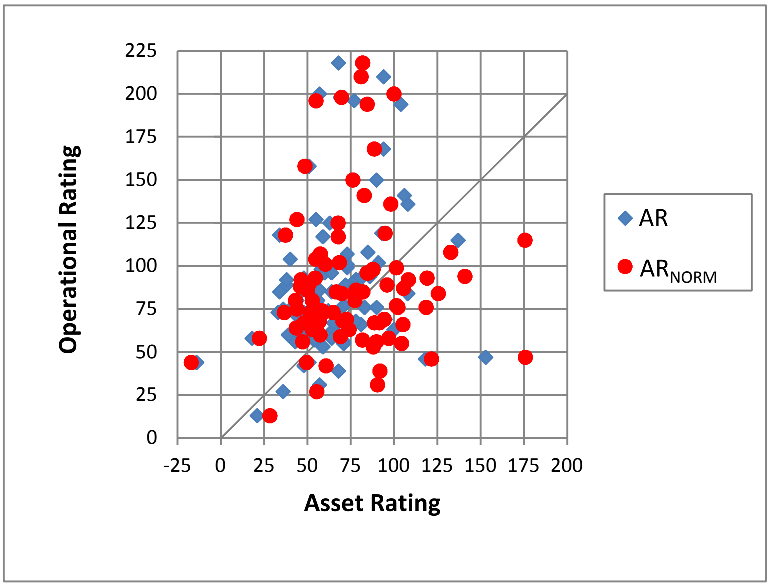

Figure 4-10 - Variation of Operational Rating with Asset Rating and re-normalised Asset Rating

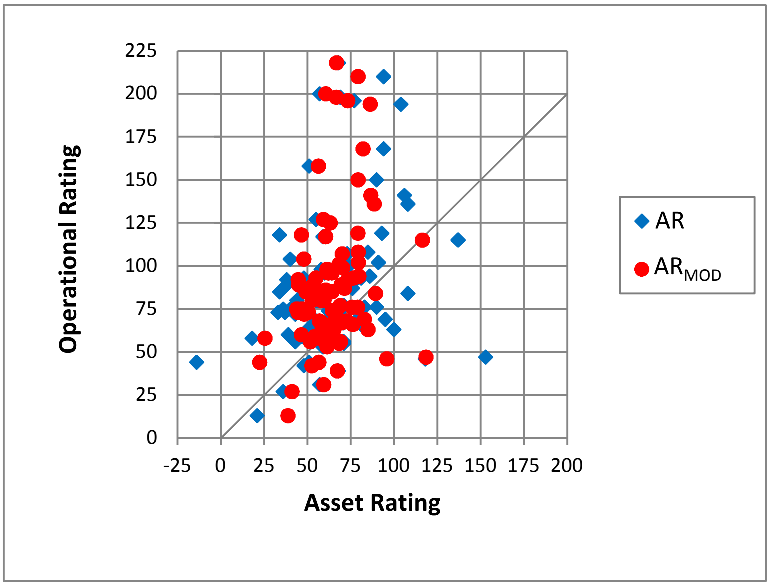

Figure 4-11 - Variation of Operational Rating with Asset Rating and modified Asset Rating

Figure 4-12 shows the variation of the unmodified AR (i.e. the data from Figure 4-2) against the AR modified for carbon intensities and to include equipment, and re-normalised. The cumulative effect is that the data is squeezed more tightly in the x-direction and shifts to the right along the x-axis. The general impression from a visual inspection is that the process has improved the correlation between design predictions and metered data.

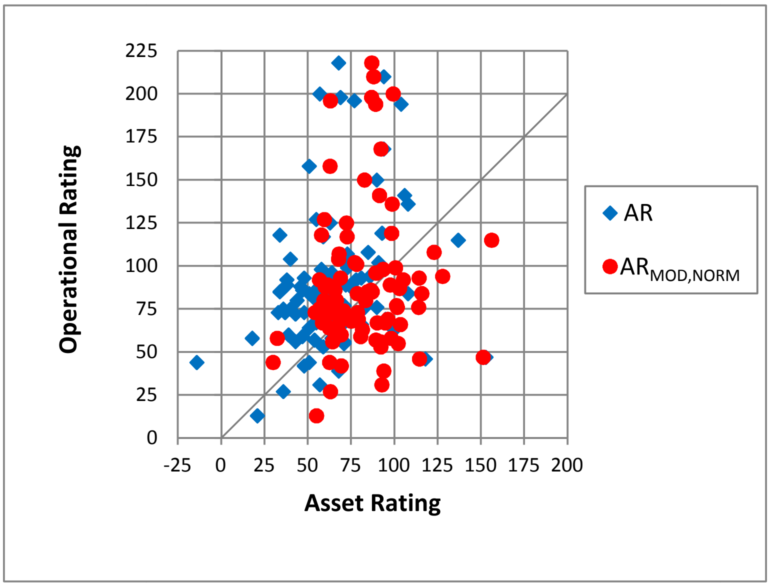

Figure 4-12 - Variation of Operational Rating with Asset Rating and modified and re-normalised Asset Rating

4.3 Effectiveness of the corrections to the Asset Rating

In order to judge the effectiveness of the corrections and re-normalisation, the extent of the correlation between the OR and AR will be examined. This will be done by quantifying the difference between the OR and AR in terms of the number of OR rating bands between them.

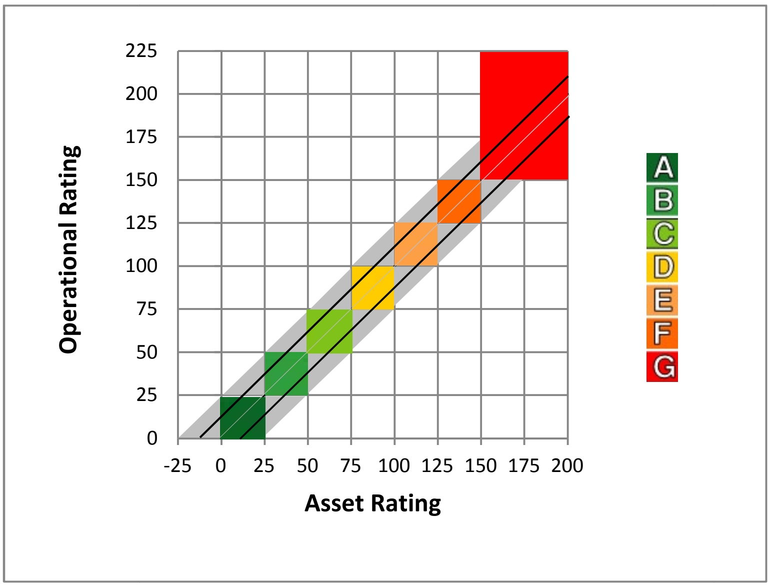

Figure 4-13 - Graphical representation of OR and AR alphabetical rating against numerical values

Figure 4-13 shows a range of coloured areas that represent the various alphabetical OR and AR ratings. It also shows the line of equal emissions which always lies within the coloured areas. When there are small differences between the OR and AR and the numerical values are towards the middle of the range for a particular alphabetical rating, then a building can still achieve the same alphabetical rating on each scale. However, when the numerical values are near the upper or lower limits of the range for a particular alphabetical rating, even small differences between the OR and AR can result in a different alphabetical rating. The range of numerical ratings at which this is most likely to occur are highlighted in grey in Figure 4-13.

Rather than quantifying the difference between the OR and AR in terms of alphabetical bands, 25 unit bands were chosen to take account of the fact that two buildings can have very similar numerical ratings but very different alphabetical ratings if they lie near the border of a particular rating (i.e. to avoid misrepresenting the magnitude of difference between the OR and AR ratings when these lie within the grey areas of Figure 4-13). This results in a band around the line of equal emissions with 25 units the upper and lower limits in each direction (represented by the dark lines parallel to the line of equal emissions in Figure 4-13).

Figure 4-14 shows that prior to any corrections being applied, 39 buildings had ORs and ARs that were within 25 units of each other (a zero band difference), 29 were within 50 units of each other (a single band difference), and 31 were more than 50 units apart (a two or more band difference). After the corrections were applied, the number of buildings in the same band increased to 47, which indicates a better correlation between design predictions and measured data.

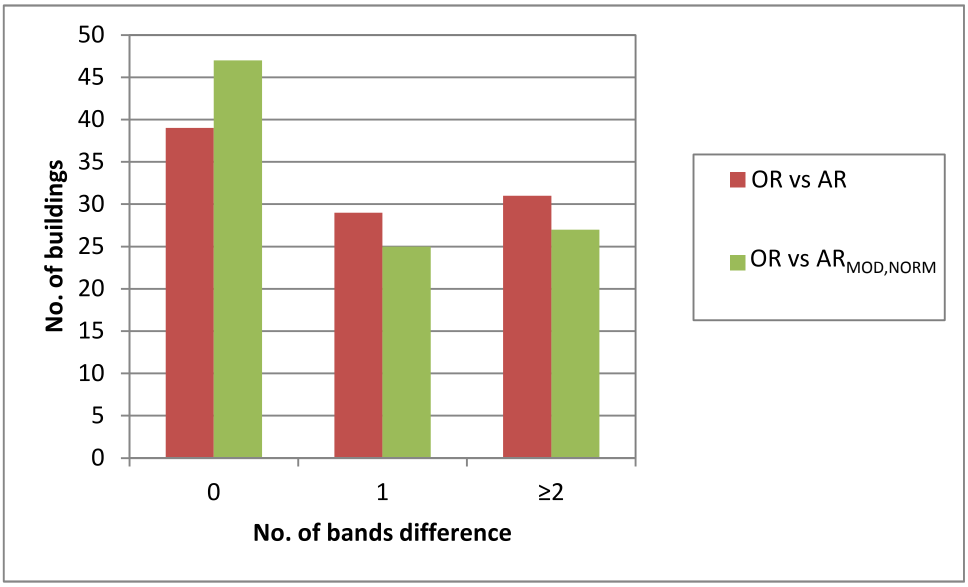

Figure 4-14 - Number of 25 unit bands between OR and AR before and after corrections

The number of buildings with a single band difference between them reduced to 25 and the number with a two or more band difference reduced to 27. The general trend was for the correction process to reduce the number of bands between the OR and AR rating. Although the number of buildings that are now in the same band increased by only 8, this is a significant proportion of the 99 building data set.

Figure 4-15 shows that of the buildings that were now in the same band, the sum of the difference between the numerical ratings of the OR and AR reduced from 1,172 prior to the correction to 509 afterwards. Those that now had a single band between them saw a slight increase in the difference in the numerical ratings from 569 to 886. This is likely to be due to buildings with a genuine difference between the OR and AR having this difference reduced from two bands to a single band, thus leading to an apparent reduction in the correlation between the two scales at this level.

Overall, the difference in the numerical ratings reduced from 5,971 to 5,677, which represents a reduction of about 5%. While this does not seem significant, this is due to the large differences that exist for genuine reasons between buildings with 2 or more bands between them. This can be illustrated by referring back to the six buildings in Figure 4-1 with an OR greater than 300; between them they have a numerical difference between their OR and AR of 2013. The shift of bands for buildings whose different ratings have been corrected demonstrates an improved correlation between the two systems.

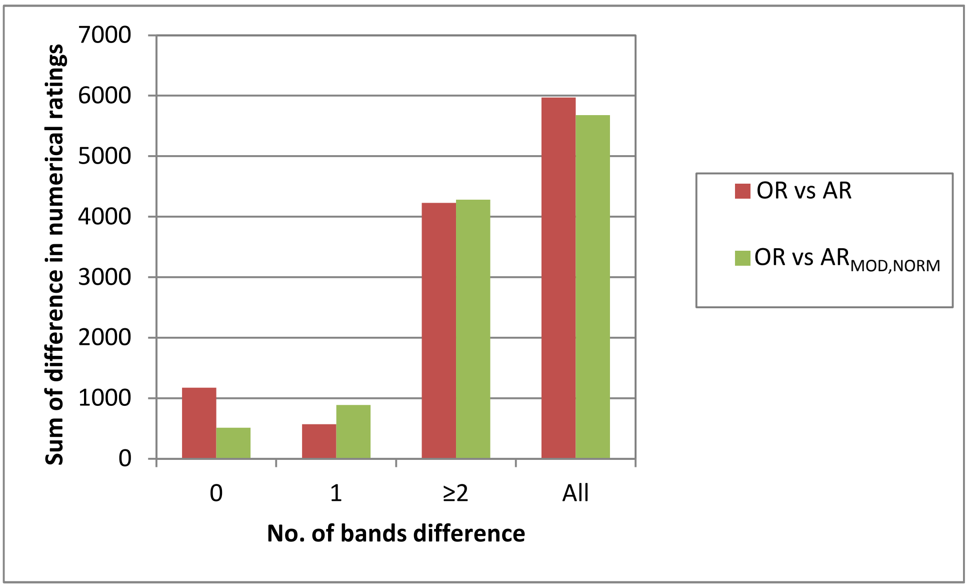

Figure 4-15 - Sum of difference in numerical ratings between OR and AR for all buildings in each band

Prior to the corrective procedures, 60% of the data had both an AR and an OR between 25 and 100 on each scale (i.e. B, C and D), while 39% had both an AR and an OR between 50 and 100 (i.e. C and D). Following the procedures, the numbers were 52% and 45% respectively. This is a numerical indication of the observation that the range of AR values has been reduced.

4.4 Outlying points

The data in Figure 4-1 is repeated in Figure 4-16. *Outlying p*oints, representing buildings with an OR greater than 150 whose AR is less than 150, are highlighted in grey. The potential reasons to explain the high OR of these buildings relative to their AR were described in section 4.2.1. The Advisory Reports of the 19 buildings highlighted in Figure 4-16 will be investigated in more detail to find which of the reasons are behind these large variations, and comments on these can be found in Table 4-1.

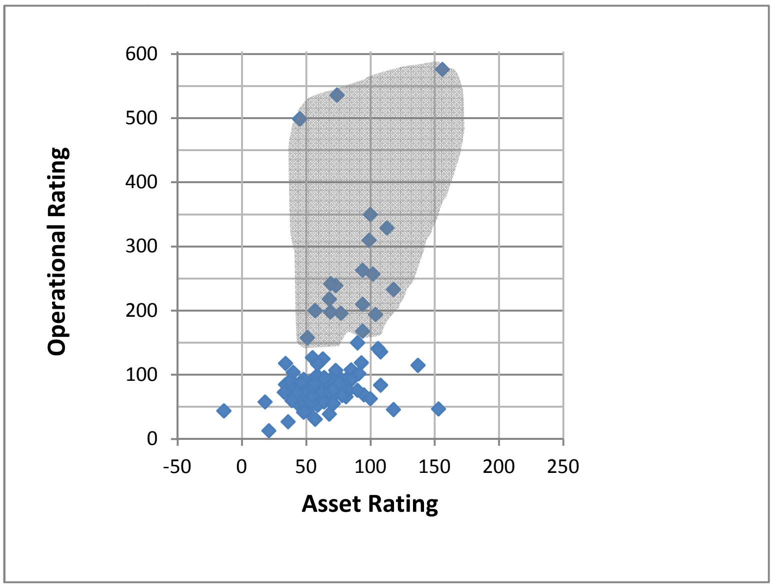

Figure 4-16 - Variation of Operational Rating with Asset Rating with outlying points (OR>150) highlighted

4.4.1 Suitability of OR benchmarks and application of separable energy uses

Bruhns *et al.* (2011) have carried out the most comprehensive study on the DEC database to date. Two of the issues that they concluded as requiring action are relevant to this examination of outlying points.

The first relates to benchmarks, and they recommended collecting current statistical data on actual consumption, due to the fact that many of the benchmarks were based on old data from the 1980s and 1990s, sometimes with small samples and, as a consequence, relatively poor statistical quality. They also recommended further work on the extent to which new separable energy uses could be included in the DEC process, describing the current list as being 'constrained both by their definition and by their restriction to certain benchmark categories.' They made several additional comments on particular benchmark categories that are of relevance to the buildings in Table 4-1.

The benchmarks for the Laboratory (and Operating Theatre) and Workshop category were considered too stringent. Median ratings of the Laboratory and Operating Theatres category were found to be between 25% and 30% above the benchmark which implied the need to take account of process loads. 41% of the sample was G rated and evidence was found of the significant influence of process loads and high usage ventilation systems. The authors recommended allowing major electrical laboratory equipment as a separable in this category.

Bruhns *et al.* (2011) also found that 55% of Workshops had grades F or G. This, along with the rising distribution curve, made it likely that many buildings in this category had major electrical process loads, which should be considered as being separable. The Sorting Office building type (part of the Workshop category) in particular appeared to have a high electrical load, suggesting the need to allow electrical separables. The Sorting Office was also identified as one of the building types that should be examined with a view to creating its own benchmark category.

Another building type identified for examination as a potential new benchmark category was Courts, which is currently a building type in the General Office category.

4.4.2 Examination of individual outlying points with OR greater than 150

Table 4-1 indicates that the high OR of each of the 19 buildings has been contributed to by a combination of poor building operation, issues with separable energy use, process loads or the benchmark itself. The prevalence of these outlying points would be reduced to a large extent by the implementation of better sub-metering, and the recommendations of Bruhns *et al.* (2011) regarding benchmarks and separable energy uses. This would then allow those buildings that are being poorly operated to be more easily identified.

Study Ref.	AR	OR	Building operational issues	Process loads/Separables/Category issues
76	102	576	Existing building with several recommendations regarding building operational performance. These indicate that building operation is likely to have contributed to the high OR.	Refer to findings of Bruhns *et al.* (2011) regarding Sorting Office buildings.

Study Ref.	AR	OR	Building operational issues	Process loads/Separables/Category issues
2	69	536	No indication of general building performance due to missing Advisory Report.	Refer to findings of Bruhns *et al.* (2011) regarding Laboratory buildings.
123	52	499	Advisory Report states that 'the current metering provisions do not enable production of a specific and reasonably accurate Operational Rating for this building. It is recommended that meters be installed and a regime of recording data be put in place.' This statement seems to call into question the accuracy of the OR.	Advisory Report states that there is 'no accurate means of discounting or measuring separable energy use of shared services or energy intensive areas such as data server rooms.' This would have contributed to the high OR.
35	83	350	No indication of building operational performance due to missing Advisory Report.	Refer to findings of Bruhns *et al.* (2011) regarding Laboratory buildings.
50	83	329	Existing building with several recommendations regarding building operational performance. These indicate that building operation is likely to have contributed to the high OR.	None.
54	85	310	Existing building with several recommendations regarding building operational performance. These indicate that building operation is likely to have contributed to the high OR. Advisory Report states that 'the current metering provisions do not enable production of a specific and reasonably accurate Operational Rating for this building. It is recommended that meters be installed and a regime of recording data be put in place.' This statement seems to call into question the accuracy of the OR.	None.
68	79	263	Existing building but few recommendations regarding building operational performance.	Refer to findings of Bruhns *et al.* (2011) regarding Court Room buildings.
17	86	257	Existing building with several recommendations regarding building operational performance. These indicate that building operation is likely to have contributed to the high OR.	None.
150	67	242	Existing building with several recommendations regarding building operational performance. These indicate that building operation is likely	Advisory Report states that there is 'no accurate means of discounting or measuring separable energy use of energy intensive areas such as

Study Ref.	AR	OR	Building operational issues	Process loads/Separables/Category issues
			to have contributed to the high OR.	data rooms.' This would have contributed to the high OR. Building houses specialist Government security services which may entail process loads not typical of the benchmark category which would contribute to the high OR.
36	67	239	No indication of building operational performance due to missing Advisory Report.	Refer to findings of Bruhns *et al.* (2011) regarding Laboratory buildings.
37	88	233	No indication of building operational performance due to missing Advisory Report.	Refer to findings of Bruhns *et al.* (2011) regarding Laboratory buildings.
64	66	218	Existing building but few recommendations regarding building operational performance.	Data Centre listed as discounted separable energy use. Loading Bay mentioned which would constitute a process load and contribute to the high OR. PVs present but no metered data available, which would reduce the OR. Building houses specialist Government security services which may entail process loads not typical of the benchmark category which would contribute to the high OR.
71	79	210	Existing building but few recommendations regarding building operational performance.	Advisory Report recommends 'installing additional sub metering in accordance with CIBSE TM39 to areas of higher energy use (e.g. server rooms, kitchen facilities, etc) to allow the calculation of a more accurate Operational Rating.' This would have contributed to the high OR.
7	60	200	No indication of building operational performance due to missing Advisory Report.	None.

Study Ref.	AR	OR	Building operational issues	Process loads/Separables/Category issues
96	66	198	No indication of building operational performance due to missing Advisory Report.	Refer to findings of Bruhns *et al.* (2011) regarding Laboratory buildings.
79	73	196	Existing building with several recommendations regarding building operational performance. These indicate that building operation is likely to have contributed to the high OR.	None.
19	86	194	Existing building with several recommendations regarding building operational performance. These indicate that building operation is likely to have contributed to the high OR.	None.
33	82	168	Existing building with several recommendations regarding building operational performance. These indicate that building operation is likely to have contributed to the high OR.	None.
131	56	158	Existing building with several recommendations regarding building operational performance. These indicate that building operation is likely to have contributed to the high OR.	Advisory Report states that there is 'no accurate means of discounting or measuring separable energy use of shared services or energy intensive areas such as data server rooms.' This would have contributed to the high OR.

Table 4-1 – Outlying data points where OR>150 and AR<150

4.5 Conclusions

Figure 4-17 shows the modified and re-normalised AR data of Figure 4-12. The outlying points are highlighted and the *band of equal emissions* is shown. The benchmark categories have also been shown (and the dominant General Office category has been further broken down by building environment) and these can be cross-referenced with Bruhns *et al.* (2011) to determine whether the OR benchmark requires refinement.

Apart from the outlying points, any buildings that are not within the band of equal emissions have an OR and modified AR that deviate by at least one numerical band. The benchmark categories have not been identified as being in need of serious refinement. As a result, having carried out a series of corrections, the remaining reasons for the deviation in OR and AR are:

- Non-standard use or poor operation
- Presence of sources of unregulated energy not previously accounted for

- Minor elements of separable energy use or process loads

There are indications that the AR will take further sources of unregulated energy into account in the future (section 4.2.2), and that the applicability of separable energy uses will widen (section 4.4.1). When this occurs, it will be possible to attribute the remaining differences between the OR and AR to poor (or non-standard) building operation.

This would represent a positive step whereby the design and actual ratings could be compared to highlight buildings that are poorly operated, without there being any excuses such as unfair benchmarks or dissimilar ratings systems to hide behind.

It is acknowledged that the data set involved in this study is relatively small. As such, the preceding work should be considered as *initial observations* rather than conclusive evidence. It is hoped that by following the recommendations of section 3.4 that such an analysis could be completed with relative ease on a larger data set (once the DEC extension to commercial buildings has occurred) to allow more definitive evidence to be gathered.

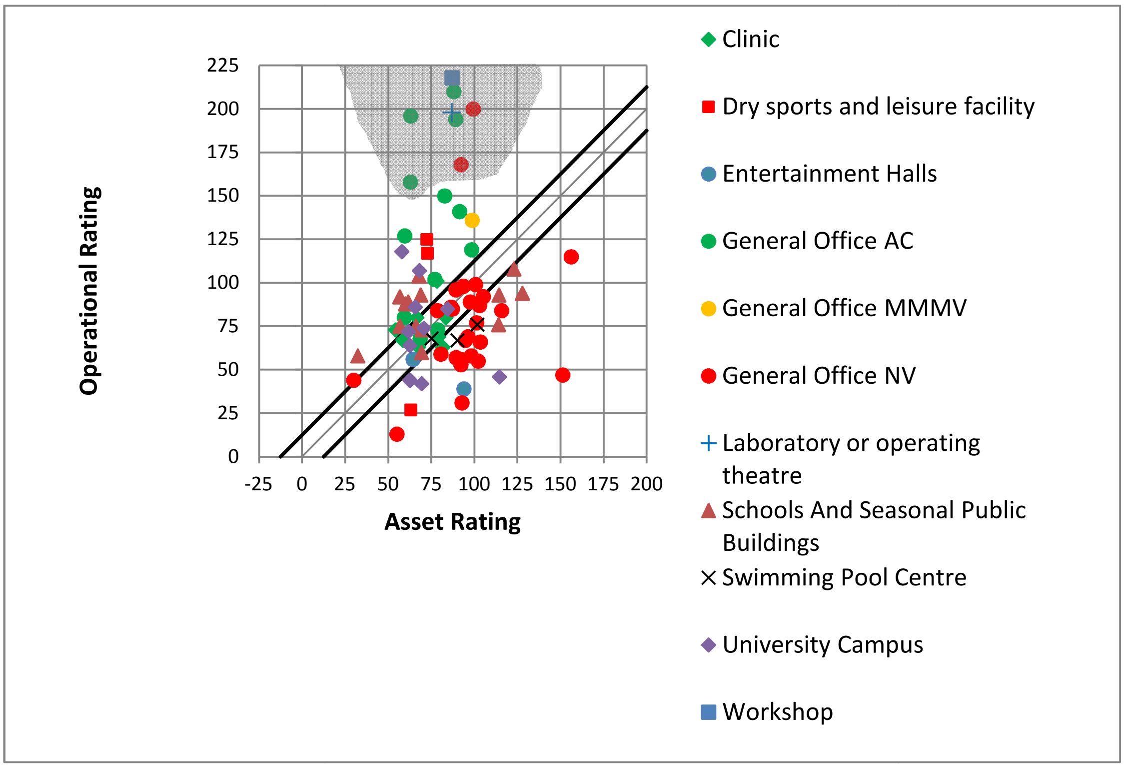

Figure 4-17 - Variation of Operational Rating with Asset Rating and modified and re-normalised Asset Rating by building benchmark category with outlying points (OR>150) highlighted

Chapter 5 Conclusions

5.1 Introduction

A study has been carried out into the relationship between the calculated AR that EPCs use to express a building's carbon emissions, and the OR based on metered data that is used on DECs. The aims of the study were to:

- understand the basis of the OR and AR rating scales, so that criticism of DECs and EPCs can be put in perspective.
- understand the reasons why buildings can receive very different ORs and ARs.
- close the gap between the OR and AR by proposing and investigating a number of corrections to the AR outputs.
- move towards a position where the difference between the OR and AR clearly identifies cases of poor building operation.
- learn lessons from the analysis of the data that can be used to improve the DEC and EPC information, before the anticipated increase in the number of buildings that have both certificates, so as to enable meaningful analyses to be carried out efficiently in the future.

5.2 Differences between the AR and the OR

There are several key differences between the carbon emissions expressed by the AR when compared with the OR. These are due to:

- Non-standard use
- Unregulated energy
- Different carbon intensities
- Normalisation of each rating scale
- Separable energy use
- OR benchmarks
- Metering and scaling of renewable

Non-standard use (and the more widespread poor operation) would ideally be the only difference between the AR and the OR, but the other differences make the contribution of poor operation difficult to identify.

A partial correction was proposed to deal with the fact that the AR does not account for unregulated energy, which involved the use of NCM equipment loads that are generally only used to generate a cooling load in air-conditioned buildings. Elements such as lifts, catering and escalators cannot be corrected for at this point, but may be included in future versions of the NCM.

The difference in carbon intensities used by the AR compared with the OR was corrected by applying the carbon intensities from the CIP database to the energy consumption information from the EPC output file.

The AR is calculated by taking the carbon emissions and normalising with the emissions from a building that is just compliant with the Building Regulations. However, the OR is normalised with respect to a building that is representative of the stock average. A revised normalisation procedure for the AR was proposed so that it could be compared more equitably with the OR. It was found that the revised normalisation would have no impact on a mixed-mode naturally ventilated building that is exactly compliant with ADL2.

The issue of what is an appropriate separable energy use and the suitability of the OR benchmarks has been investigated by others (Bruhns *et al.,* 2011). The Recommendations Reports and Advisory Reports that accompany EPCs and DECs were examined in detail for evidence of un-metered separable energy, or sources of energy use that might be categorised as separable in the future.

Differences due to the metering and scaling of renewables were not considered significant for the data set under examination.

If all of the differences above could be successfully corrected, any difference between AR and OR could be used to identify buildings whose operation required improvement.

5.3 Examination of the database

In order to make the corrections described above, a database obtained following a Freedom of Information request was examined. This originally consisted of 56,481 buildings. Of these, 1,572 were found to have both ORs and ARs, but many of the AR values of zero incorrectly indicated zero emissions where, in fact, an AR did not exist. There were other factors which invalidated a number of records. After a filtration process was undertaken, the number of buildings with a valid OR and AR was reduced to just 99.

The Advisory Reports and Recommendations Reports were manually interrogated to gain a better understanding of the characteristics of the buildings under examination. This was a particularly time-consuming activity, but it provided some very useful information. The following recommendations were made as a method of improving the information that DECs and EPCs provide, and to make future studies easier. This will be all the more important as the size of the database increases over time.

The following recommendations were made[23]:

- Improve the management of the address database by implementing a graphical tree topology that allows the relationship between tenancies, buildings and campuses to be more easily linked. The importance of checking the address database for existing UPRNs when adding a building certificate should be reiterated to assessors. An initiative to correct instances where there are multiple UPRNs for a single building should be implemented during the annual renewal of DECs.
- Implement a more explicit link between EPCs and DECs by requiring EPCs to include the OR where a DEC is also available.
- Include an additional piece of information relating to building type (‘new at time of certificate production’, or ‘existing’) on both EPCs and DECs. For new buildings, the year of construction should be included. Communicate the importance of improved building descriptions on the accompanying reports to assessors, and include a review of these descriptions in the Quality Assurance process.
- Communicate the importance of the correct selection of building environment to assessors and include a review of these in the Quality Assurance process.
- Both certificates should list all heating fuels and the proportion of the total load that each meets (or is predicted to meet).
- Both certificates should list the renewable technologies and contributions so that the predicted and actual performance can be better understood.
- Separable energy uses that have been accounted for should be listed on the DEC. Atypical energy use should also be noted.
- Clarify the definition of ‘grid supplied electricity’ in the EPC output xml file, and the method of accounting for LZC technologies, with the providers of Approved Software. Include the carbon intensity of any district heating in the xml file.
- Over time, the lodged EPCs will use different values for carbon intensities depending on the values used by the NCM when the EPC was produced. The values used should be included in the EPC output xml file to aid future analyses, rather than having to use deduction based on the date of lodgement.

5.4 Analysis of data

The OR and AR for all 99 buildings that had both a DEC and an EPC were plotted. There were 19 buildings where the OR is greater than 150 and where the AR is less than 150, but the remainder were scattered around the line of equal emissions (where AR=OR). The tendency was for the OR to be greater than the AR, which is line with the general expectation that design predictions are usually exceeded in practice. By comparing the AR with AR_{TYP} it was found that, for the buildings in question, performance was generally better than typical.

[23] These recommendations first appeared on page 24 and onwards.

The un-normalised DEC emissions were then plotted against the un-normalised EPC emissions (or BER). The pattern was similar to that when normalised. The partial correction for unregulated energy was applied, and the effect was to increase the modified BER, shifting that data so that it was scattered more evenly around the line of equal emissions.

The correction for different carbon intensities was then applied. As the data set used the carbon intensities from ADL2 (2006) to generate the BER, the main difference in carbon intensities was between the value of 0.422kgCO_2/kWh from ADL2 (2006) and 0.55kgCO_2/kWh in the CIP database for grid supplied electricity. The effect was to further increase the modified BER, with buildings that use proportionally more electricity than other fuels increasing by a more significant amount. The majority of the data crossed the line of equal emissions, which is contrary to the general expectation that design predictions underestimate actual emissions. The implication is that the gap between the two can be closed by comparing the carbon emissions on a more equitable basis by including emissions due to unregulated energy and using the same values for carbon intensities.

The modified BER (partially corrected for unregulated energy and corrected for different carbon intensities) was then examined under the categories of building environment, age and benchmark category to investigate whether any patterns were apparent in the relatively small data set.

When the data was examined by building category, there was no clear pattern. Naturally ventilated buildings, which represented 52% of the data, were generally clustered around the line of equal emissions but tended to have a modified AR that was greater than the OR. This may indicate that naturally ventilated buildings perform better in terms of carbon emissions than predicted. The large number of naturally ventilated buildings dominates the data set compared to the other categories.

When the data was examined by building age, existing buildings, which represented 72% of the data, had higher emissions on both scales. There were also several instances of existing buildings with an OR greater than 150 and an AR less than 150. The new buildings were clustered more closely around the line of equal emissions, which may indicate that new buildings demonstrate a better correlation between design predictions and metered data.

The data was also examined by building benchmark category. The small size of the data set meant that no conclusions could be drawn about a particular category. The largest single category was ‘General Office’, which represented 49% of the data. Even this category showed large scatter which meant that no conclusions could be made. This should not have been unexpected given that the category is comprised of existing and new buildings with various building environments, and these subsets have already been shown to exhibit a large amount of scatter themselves.

In order to show the effect of the modifications in isolation from the revised normalisation, the original AR values were normalised using the revised procedure, and this was shown to have a relatively small effect. Then, the modified BER was normalised in the standard fashion. The effect was that the range of AR values was reduced, improving the correlation between design predictions and metered data. Finally, the modified BER was normalised using the revised procedure. The result was that the range of values AR of was reduced, and that the modified and re-normalised AR was generally greater than before, resulting in the data being more centred around the line of equal emissions. Prior to the corrective procedures, 60% of the data had both an AR and an OR between 25 and 100 on each scales (i.e. B, C and D), while 39% had both an AR and an OR between 50 and 100 (i.e. C and D). Following the procedures, the numbers were 52% and 45% respectively. This is a numerical indication of the observation that the range of AR values was reduced. These initial findings, on what is a limited data set, indicate that the process has improved the correlation between design predictions and metered data.

An attempt to quantify the effectiveness of the corrective procedure was made by identifying the number of 25 unit bands that existed between the OR and AR, before and after the corrections. Prior to any corrections being applied, 39 buildings had ORs and ARs that were within 25 units of each other (a zero band difference), while afterwards this increased to 47 indicating an improvement in the correlation between the two ratings.

Finally, o*utlying p*oints (representing buildings with an OR greater than 150 whose AR is less than 150) were examined in detail. Their Advisory Reports were studied, and alongside a review of the DEC database by Bruhns *et al.* (2011), the reasons for the high metered data compared with the design predictions were attributed to a combination of:

- benchmarks that required refinement
- the presence of process loads not allowed as separable energy or unmetered separable energy
- non-standard use or poor operation

There is also likely to have been a contribution to the emissions of many buildings from unregulated energy sources that are not accounted for by the partial correction that was applied. As the NCM evolves, it is expected that theses additional sources will eventually be included. This development, the refinement of the OR benchmarks and definition of separable energy over time, along with the proposed corrections to the AR, should result in the gap between the OR and the AR closing, to the point where any deviations can be attributed to poor operation, allowing appropriate action to be taken.

Appendix A – Definition of the Typical building

In the building definitions of Table 2-1, a change in the definition of the Typical building was described. It was originally defined as being identical to the Reference building but built to the minimum specification standards of ADL (1995). However, it is now defined as one where the CO_2 emissions rate is equal to the 2010 TER multiplied by two and divided by 0.75 (this is approximately twice the emissions rate of the 2006 TER).

The implications of this change in definition need to be examined as the value of AR_{TYP} is important to the normalisation process described. However, the change in definition will not have an effect on the current study as the data set was obtained prior to the implementation of ADL2 (2010), i.e. it uses the original definition.

Figure A-1 shows the ratio between AR_{TYP} and the 'if newly built' AR (i.e. the ADL2A (2006) TER, as the data set in question which was obtained prior to the introduction of ADL2 (2010)). It can be seen that the majority of the data is clustered around the value two, which appears to justify the new definition of the Typical building which implies that AR_{TYP} is approximately twice the ADL2 (2006) AR. However, a building that has its EPC updated will have a revised AR_{TYP} because few of the values were exactly equal to two. This is due to the fact that the Typical building had (by its original definition) a mixed-mode natural ventilation servicing strategy, whereas the 'if newly built' AR is based on the strategy that is actually used. Under the revised definition, the Typical building will also be based on the actual servicing strategy.

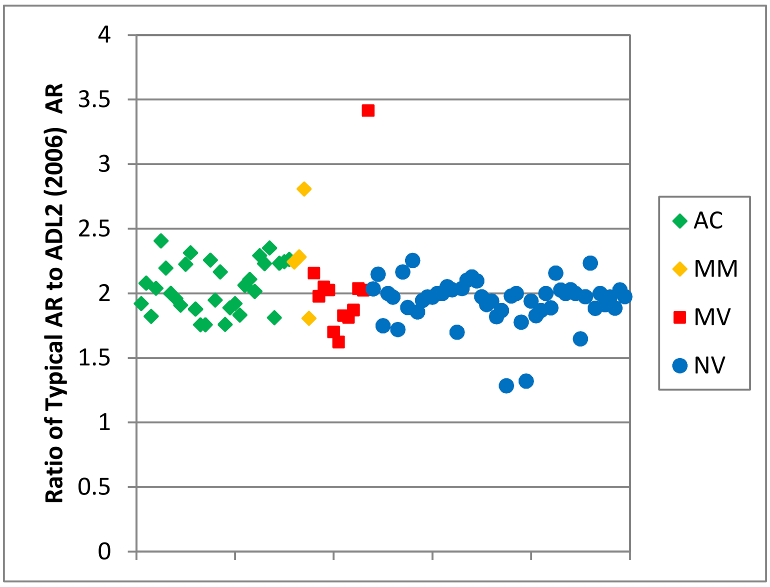

Figure A-1 - Ratio of Typical AR to 'if newly built' AR categorised by building environment

Appendix B – Revised normalisation of the AR scale for mixed-mode buildings

The following expressions (from Eqn. 2-6 and 2-8) were proposed as an alternative means of normalising the AR scale:

$$\mathbf{AR_{NORM} = 100 \times \frac{BER}{ER_{TYP}} = 100 \times \frac{AR}{AR_{TYP}}} \qquad \textbf{(Eqn.B-1)}$$

This can be compared with the standard definition of the AR (Eqn. 2-5):

$$\mathbf{AR = 50 \times \frac{BER}{SER} = 50 \times \frac{BER}{0.765xRER}} \qquad \textbf{(Eqn.B-2)}$$

The Standard building (see definition in Table 2-1) uses mixed-mode natural ventilation as a servicing strategy. The definition of the Typical building implies that:

$$\mathbf{SER=TER_{2006,MMNV}} \qquad \textbf{(Eqn.B-3)}$$

As noted in the definition of the Typical building in Table 2-1, the emissions rate from the Typical building (ER_{TYP}) can be expressed as:

$$\mathbf{ER_{TYP} = 2 \times \frac{TER_{2010}}{0.75} \approx 2xTER_{2006}} \qquad \textbf{(Eqn.B- 4)}$$

Combining Eqn. B-3 and B-4 gives:

$$\mathbf{SER=0.5xER_{TYP}} \qquad \textbf{(Eqn.B-5)}$$

Substituting this into Eqn. B-2 gives:

$$\mathbf{AR = 100 \times \frac{BER}{ER_{TYP}}} \qquad \textbf{(Eqn.B-6)}$$

Comparing this to Eqn. B-1 gives the result that AR = AR_{NORM}, which means that the revised normalisation will have no impact on a mixed-mode naturally ventilated building that is exactly compliant with the ADL2 (2006) TER.

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