A comparative study of the energy certification schemes implemented in the UK and ASHRAE building energy labelling programme

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Abstract

Following inception of the Energy Performance of Buildings Directive (EPBD) in the EU, energy certification schemes have gained prominence in the UK in recent years. Introduction of building Energy Quotient (bEQ), ASHRAE's new building energy labelling programme, provides an opportunity to compare these schemes and explore improvement opportunities. ASHRAE's bEQ broadly follows the same principles that underpin the energy certification schemes implemented in the UK. However, greater consistency in baselines defined for the 'As Designed' and 'In Operation' schemes, attention to key determinants of energy use based on building type, and an integrated approach to operational rating & indoor environmental quality are among the key contributions of bEQ that can help improve building energy certification programmes.

Keywords Building Energy Certification, building Energy Quotient (bEQ), EPBD, EPC, DEC

1.0 Introduction

The concept of energy certification for buildings emerged following the drastic increase in oil prices in early 1990s and the necessity to improve energy efficiency of buildings that account for 20-40% of total energy use in developed countries [1]. In 2002, the Energy Performance of Building Directive mandated the implementation of energy certification schemes in the EU member states in response to concerns regarding energy security and climate change [2].

Following inception of the EPBD, two types of energy certification have been implemented in England and Wales in recent years. Energy Performance Certificates (EPC) are required when new buildings are constructed, and existing buildings are sold or rent out. EPC is meant to reflect the potential energy performance of a building under standardised conditions and, therefore, the rating included on the certificate is called *asset rating*. Display Energy Certificates (DEC), mandatory for public buildings above 500 m^2, are based on actual operating conditions and measured energy use. Therefore, a DEC represents the *operational rating* of a building.

The introduction of these certification schemes has led to greater awareness of energy efficiency in buildings. Furthermore, a large amount of data has been collated to produce these certificates that provide invaluable information about energy performance of national building stock and key determinants of energy use [3, 4].

However, the following issues have hindered these schemes in achieving their full potential and caused some confusion in the market:

- The EPBD is more focused on calculated energy performance. Article 7 of this Directive only asks for *publicising* the energy certificates for public buildings. A display energy certificate based on *measured* performance is therefore not essential under EPBD. A number of European countries have opted for energy certification solely based on calculated performance [5].
- As calculated vs. measured energy performance of a building is not directly addressed by EPBD, where countries opted for inclusion of measured performance in their certification schemes, these two types of certification were not always developed in tandem. For example, the baselines defined, energy end-uses included in the analysis, and source-site conversion factors used in the EPC and DEC schemes in England and Wales are not consistent.
- An unintended consequence of this disjointed approach to energy certification has been disillusionment among some field practitioners and their clients who wish to be able to compare operational rating of their buildings with asset rating to explore the effect of actual operating conditions and building management on energy performance. Yet the abovementioned methodological issues often compound the problem.
- Finally, the building certification schemes implemented in the UK are predominantly focused on energy. The standard thermal conditions and ventilation rates assumed in EPC calculations allow for minimum acceptable conditions defined in design codes. In operation, thermal comfort and indoor air quality are partly addressed by CIBSE TM44 [6], the protocol governing inspection of air-conditioning systems in accordance with Article 9 of EPBD. However, this protocol is not applicable to all buildings, and is somewhat disjointed from EPCs and DECs. Its enforcement has also not been great so far.

  The ever-increasing awareness of energy performance gap has led to calls for energy performance contracts in the industry that are welcome. However, the downside is, in the absence of an integrated framework to assess operational energy performance along with indoor environmental quality, energy savings might be achieved at the expense of occupants' wellbeing.

ASHRAE building Energy Quotient (bEQ) is a new energy-labelling programme that broadly follows the principles of energy certification in the EU. However, it is not primarily designed to respond to regulatory requirements and is market oriented. It comprises two ratings: 'As Designed' & 'In Operation'. The 'As Designed' rating is designed to neutralise the effect of occupant behaviour and operating conditions. It can therefore compare energy efficiency of different buildings of the same type under identical operating conditions, and help prospective tenants and buyers in choosing the most energy efficient property [7]. The 'In Operation' rating, on the other hand, reflects the energy performance of buildings under actual operating conditions, and is designed to help building users improve their buildings' performance [8]. While these objectives are almost identical to that of EPCs and DECs, the bEQ ratings are more streamlined to facilitate comparison of the performance in use with the as-built status.

Figure 1 shows a sample bEQ certificate that is issued by ASHRAE after reviewing the work submitted by approved professionals. Both 'As Designed' and 'In Operation' ratings are presented on the same certificate. Figure 2 shows the bEQ Dashboard, and provides additional information about the 'As Designed' & 'In Operation' rating systems.

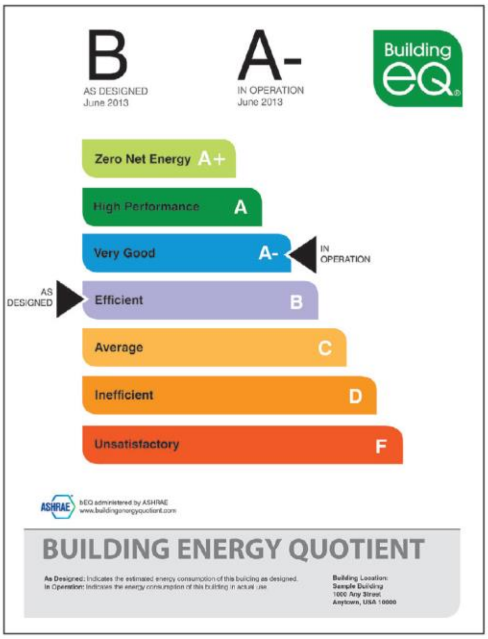

Figure 1 - Sample building Energy Quotient (bEQ) indicating the grades and classifications used [9]

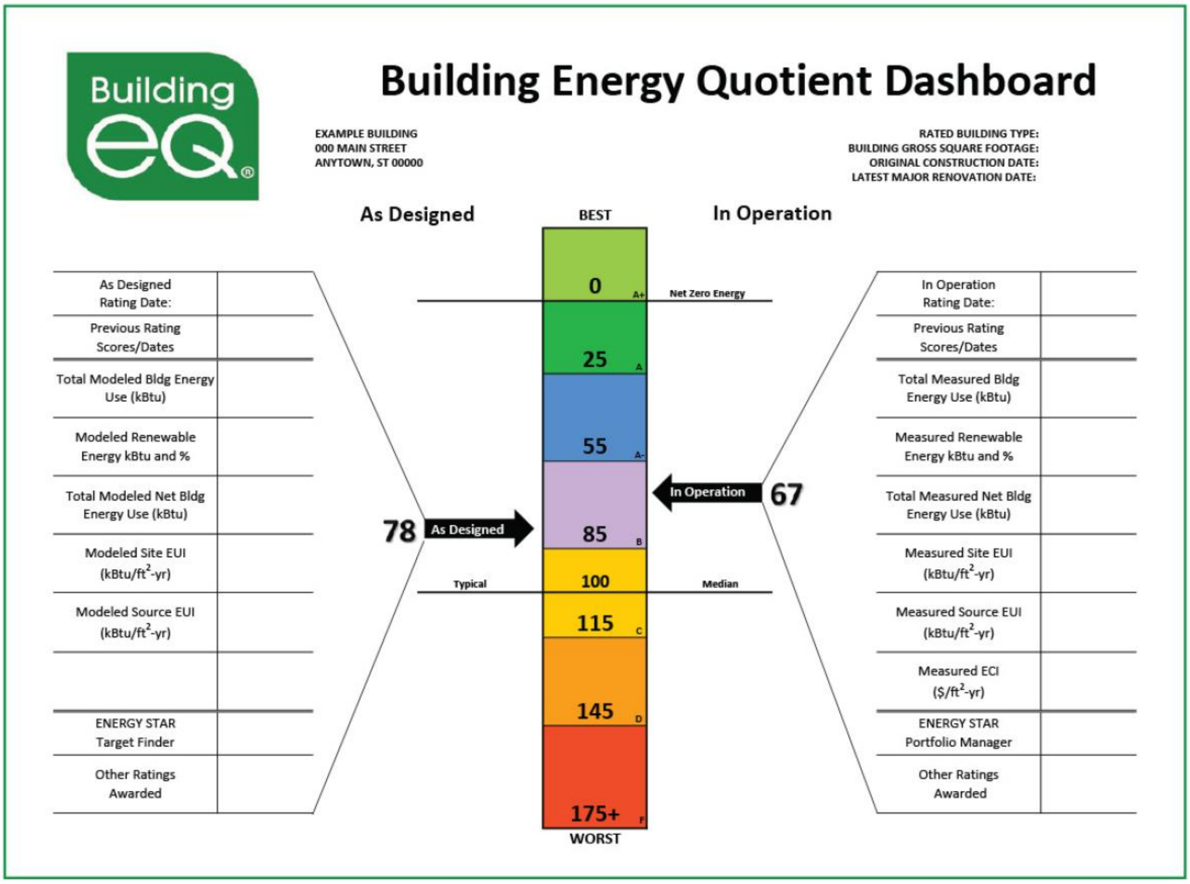

Figure 2 – bEQ Dashboard indicating the rating system and scale used [9]

Table 1 compares the fundamental characteristics of EPCs and DECs with the bEQ. A comparative study of ASHARE bEQ and the existing certification schemes in the UK can help identify improvement opportunities for building energy certification programmes.

Table 1 – Comparison between energy certification schemes in England and Wales, and ASHRAE bEQ [7, 8, 10 and 11]

Characteristic	EPC	bEQ (As Designed)	DEC	bEQ (In Operation)
Principle objective	Asset rating	Asset rating (for prospective tenants & buyers)	Operational rating	Operational rating (for portfolio managers and building users)
Principle driver	Regulations	Market	Regulations (public buildings only), Market for other buildings	Market
Metric used for total performance	kg $CO_2/m^2/yr$.	$kBtu/ft^2/yr$. (source energy)	kg $CO_2/m^2/yr$.	$kBtu/ft^2/yr$. (source energy)
Reference values	CO_2 emissions defined by self-reference method (Reference building emissions defined by the Building Regulations 2002 subject to average 23.5% improvement)	Median Source Energy Use Intensity (EUI) or ENERGY STAR Target Finder	As defined in CIBSE TM46 (supposed to be the CO_2 emissions of the median of national building stock for every building type)	Median Source EUI or ENERGY STAR Portfolio Manager
Source –site ratio[1]	Elec.: 0.422 kg CO_2/kWh Gas: 0.194 kg CO_2/kWh[2]	Elec.: 3.34 kBtu/kBtu Gas: 1.047 kBtu/kBtu	Elec.: 0.55 kg CO_2/kWh Gas: 0.19 kg CO_2/kWh	Elec.: 3.34 kBtu/kBtu Gas: 1.047 kBtu/kBtu
Rating	(As-built CO_2 emissions based on modelling / Reference value) × 50	(As-built Source EUI based on modelling / Reference value) ×100	(Measured CO_2 emissions / Reference value) × 100	(Measured Source EUI / Reference value) × 100
Energy end-uses not included in the rating	Equipment load	None	None	None
Energy classification bands	A+ to G (A+ indicating net exporter of energy)	A+ to F (A+ indicating zero net energy)	A to G	A+ to F (A+ indicating zero net energy)
Administration	Various certification bodies approved by the Government	ASHRAE	Various certification bodies approved by the Government	ASHRAE
Quality Assurance (QA)	Sampling (minimum 2%)	100% (certificate issued by ASHRAE after review)	100% (certificate issued by ASHRAE after review)	Sampling (minimum 2%)

[1] Source-site ratio is a multiplier that converts onsite building energy use to primary energy/CO_2 emissions. It includes the effects of losses in generation and distribution of energy nationwide.
[2] As of October 2010, 0.517 kg CO_2/kWh for electricity and 0.198 kg CO_2/kWh for gas [12].

2.0 Methodology

The aim of this study is to compare ASHRAE's new energy labelling schemes with the energy certification schemes implemented in England and Wales, and explore the lessons that could be learned from the ASHRAE schemes to improve the methodologies underpinning EPCs and DECs.

To this end, a case study approach was used to compare the bEQ labelling system with EPC and DEC. Five secondary schools constructed post-2006 in England were subject to long-term monitoring by the authors. In addition to detail operational data, the energy performance certificates lodged with the national register were also available. Table 2 provides background information about these buildings.

Table 2 – Background information about the case study buildings

Parameter	Building A	Building B	Building C	Building D	Building E
Building Type	Academy	Sixth Form	Academy	Secondary School	Secondary School
Completion year	2008	2010	2009	2010	2007
Total useful floor area (m^2)	10,418	2,843	10,172	14,610	10,490
Occupants number	1,250	350	1,200	2,000	1,200
Number of PCs and laptops	514	223	602	512	540
Number of walk-in refrigerators	2	1	2	2	2
Open on weekends	N	N	N	N	N
Energy used for cooking	Y	Y	Y	Y	Y
Degree days (HDD18ºC, CDD18ºC)[3]	HDD: 3,146 CDD: 67	HDD: 3,146 CDD: 67	HDD: 3,381 CDD: 37	HDD: 2,786 CDD: 157	HDD: 2,786 CDD: 157
% Heated	100%	90%	100%	100%	100%
% Cooled	10%	30%	20%	10%	50%

This paper compares the following four specific aspects of the energy certification schemes:

- Methods used for Asset Rating
- Methods used for Operational Rating
- Link between operational rating and indoor environmental quality
- Data visualisation techniques

The following subsections explain the methods used to compare these aspects of energy labelling between ASHRAE bEQ and EPC/DECs.

[3] The methodology for accounting for weather in ENERGY STAR Portfolio Manager is based on deviation of heating and cooling degree-days from a base temperature of 65 ºF (18ºC) [13].

2.1 As Designed bEQ vs. EPC

Depending on building type, the reference values for 'As Designed' bEQ are either based on median source EUIs, which are provided in the bEQ spreadsheet for each ASHRAE climate zone, or could be defined by using ENERGY STAR Target Finder. The ENRGY STAR Target Finder is a tool that can be used during design stages to predict building energy use based on a number of building characteristics and the measured energy use of existing buildings with similar characteristics. The median of the statistical distribution of energy performances of existing buildings with similar characteristics must be used as the reference value for 'As Designed' bEQ.

At the time of writing this paper, neither the median EUIs nor the inputs for ENERGY STAR Target Finder were yet defined for schools as the 'As-Designed' bEQ was still under development for certain building categories. The standard thermal modelling inputs required to calculate energy performance under standard occupancy and operating conditions were also not yet defined for schools. Consequently, it was not possible to determine the 'As Designed' bEQ for the case study buildings.

The approach taken to compare the 'As Designed' bEQ with the EPC scheme for this study is as follows:

- A comparison between bEQ standard modelling inputs required to calculate energy performance for a given building, and the EPC standard assumptions for building categories that are already developed for 'As Designed' bEQ,
- A presentation of EPC results against measured energy use for the case study buildings, and a demonstration as to how these results would have been different if the principles used in 'As Designed' bEQ had been adopted. The effects of two major differences between 'As Designed' bEQ and EPC have been investigated: inclusion of equipment load in the rating system, and use of identical source-site ratios for the modelled & measured performances.

2.2 In Operation bEQ vs. DEC

Contrary to 'As Designed' bEQ, the 'In Operation' scheme is well developed for all building categories. The reference values defined for the 'In Operation' scheme follow the general principle outlined for 'As Designed' bEQ: depending on building type, the reference values for 'In Operation' bEQ are either based on median source EUIs, which are provided in the bEQ spreadsheet for each ASHRAE climate zone, or could be defined by using ENERGY STAR Portfolio Manager. ENERGY STAR Portfolio Manager essentially uses the same methodology as ENERGY STAR Target Finder; the difference being the Target Finder is often used to set design targets for projects based on measured energy use of buildings with similar characteristics (i.e. target % better than the median of existing building stock). It is, thus, customary to use ENERGY STAR Target Finder for design projects and ENERGY STAR Portfolio Manager for performance review.

ENERGY STAR Portfolio Manager must be used to define the reference values for schools in bEQ. The source of data used in ENERGY STAR programme to establish the peer building population in the United States is data from the Department of Energy , Energy Information Administration's Commercial Building Energy Consumption Survey (CBECS). Under the CBECS programme, the measured performance and a large number of energy-related building characteristics are collated for thousands of buildings at regular intervals. The first CBECS survey was conducted in 1979. The 10^{th} and most recent survey is now being conducted to provide data for calendar year 2012 [14].

The ENERGY STAR methodology is based on performing regression analysis on CBECS data to identify key energy use determinants for each building type. Table 3 includes the key determinants of energy use in schools identified by ENERGY STAR based on 2003 CBECS data for 353 schools across the United States [15].

The regression equation derived from this analysis is used to calculate a reference value for schools' energy use based on their energy-related characteristics. This regression equation has a coefficient of determination (R^2) value of 0.26, indicating it could explain 26% of the variance in source EUI for schools [15]. Given that the total useful floor area is by far the most dominant factor in determining energy use of a building and is already included in EUI by definition, this means this regression analysis can explain almost a third of energy use variance *after* accounting for area. Computing the R^2 value based on energy use rather than EUI for offices has revealed that the resultant regression equation can explain almost 80% of the variations in source energy use of offices [16]. This is remarkable given the relatively few parameters involved in the final regression analysis.

The DEC scheme in the United Kingdom is essentially based on median energy use intensities of different building types converted to CO_2 emissions. However, a number of corrections are applied to the median values to tailor for building context. A list of these corrections is provided in Table 3 against energy-related characteristics considered for schools in ENERGY STAR.

Table 3 – Building characteristics tailored for in ENERGY STAR vs. corrections applied to benchmarks in the DEC scheme [11, 15].

Building characteristics tailored for in ENERGY STAR in calculating the reference EUI (applicable to K12 Schools in the US)	**Corrections applied to the DEC scheme against ENERGY STAR energy-related characteristics used for schools**
Total useful floor area (in addition to inclusion in EUI)	Included in the metric only (kg CO_2/m²/yr.)
Computers per 1000 ft²	Number of computers will not change the benchmark
Walk-in Refrigeration Units per 1000 ft²	**Mixed use with 'Restaurant' building category allowed for schools**
Cooking?	**Mixed use with 'Restaurant' building category allowed for schools**
Open Weekends?	**Allowed under 'occupancy adjustment'**
High School?	No distinction between primary and secondary schools in defining the benchmarks
Heating Degree Days	**Included in the calculation procedure**
Cooling Degree Days	Not included in the calculation procedure

The approach taken to compare the 'In Operation' bEQ with the DEC scheme for this study is as follows:

- The ENERGY STAR reference values for 'In Operation' bEQ are calculated for all case study buildings based on the inputs listed in Table 2. The parameters involved in the regression equation used for schools are presented in Table 4 [15].
- Calculating ENERGY STAR source energy as a reference value for the case studies implies a hypothetical assumption that there are identical buildings to

the case study buildings with the same energy use located in the geographical locations in the US that have the closest weather conditions possible to their UK counterparts. For example, Seattle might be considered a good location to host London based case studies D & E given the similarities in weather conditions reflected in Table 5 and Figure 3. The 'In Operation' bEQ ratings for the case study buildings are calculated accordingly. The DEC ratings are also presented.

Table 4 - Parameters involved in calculating ENERGY STAR reference values[4]

Parameter	Reference Centring Value[5]	Coefficients
Constant	n/a	131.9
High School	n/a	4.377
C_Ln(HDD) × Percent Heated	7.716	8.974
C_Ln(CDD) × Percent Cooled	5.045	6.389
C_Ln (Square Feet)	10.2	-19.26
Open Weekends (yes/no)	n/a	18.43
C_Number of Walk-in Refrigerators per 1000ft2	0.0109	574.7
Presence of Cooking (yes/no)	n/a	24.2
C_Number of Computers per 1000 ft2	1.742	9.568
C_Square Feet	47310	0
C_CDD × Percent Cooled	1316	0
High School × C_Square Feet	n/a	0.00021
High School × C_CDD * Percent Cooled	n/a	0.0285
High School × C_Ln(CDD) * Percent Cooled	n/a	-11.75

$$Source\ Energy\left(\frac{kBtu}{ft^2}\right) = \sum_{i=1}^{n} Centred\ variable_i \times Coefficient_i$$

Where:

$$Centred\ variable = Actual\ variable\ (Table\ 2) - Reference\ Centring\ Value\ (if\ applicable)$$
$$n{:}\ number\ of\ parameters\ in\ Table\ 4$$

Table 5 – Comparison between London weather conditions & Seattle [17, 18]

Weather Station	HDD18ºC	CDD18ºC	Heating Design Temperature (99.6%, ºC)	Cooling Design Temperature (Dry-Bulb, ºC)	Cooling Design Temperature (Wet-Bulb, ºC)
London Heathrow Airport	2,786	157	-4	26	18
Seattle Tacoma International Airport	2.738	204	-8	28	17

[4] C denotes centred value.
[5] Reference centring value is the observed mean of the total sample (353 schools across the US).

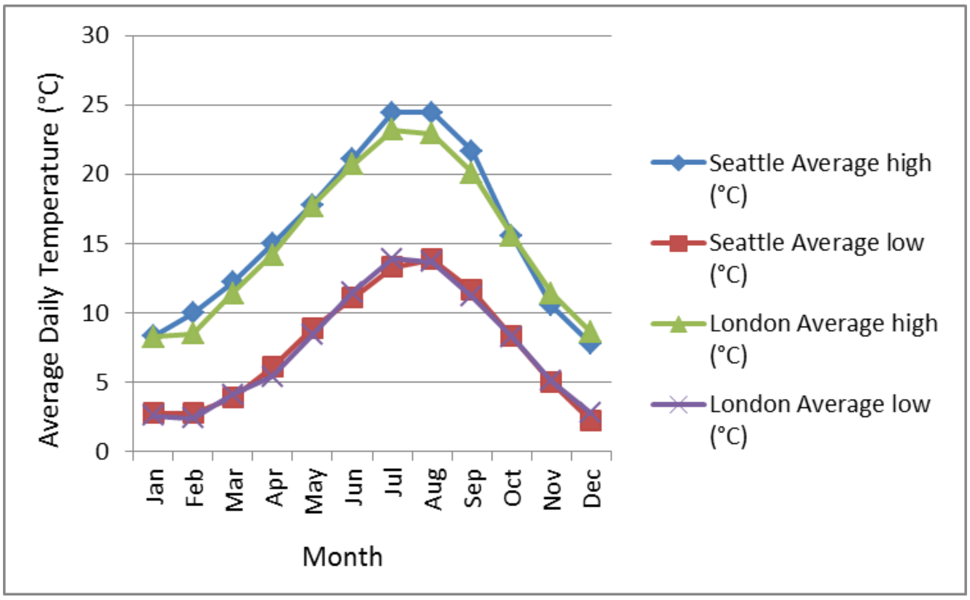

Figure 3 – London vs. Seattle long-term high and low temperatures [19, 20]

- The variables included in the regression equation for schools are centred. The centred variable is equal to the difference between actual value and the observed mean. The observed mean is based on total sample before filters are applied to allow for building characteristics. This means that the reference EUI derived from the ENERGY STAR is not comparable to the reference EUI derived from measured energy use in the UK as the ENERGY STAR sample represents the climate of US with extreme heating and cooling degree-days. However, it is reasonable to compare the sensitivity of reference EUIs to correction factors listed in Table 3. For example, one can assess the sensitivity of reference EUI to the number of computers, which is not tailored for under the DEC scheme and is perceived to be influential in higher than expected energy use of modern school buildings [21]. This relative change in EUI could provide an indication of the likely impact of the ever-increasing use of computers and laptops in UK schools on total source energy use.

This is in effect a comparison between the benchmarking engines underpinning the ‘In Operation’ bEQ and DEC schemes.

2.3 Energy Assessment & Indoor Environmental Quality

The ‘In Operation’ bEQ calculation spreadsheet includes a form for assessing the building Indoor Environmental Quality (IEQ). There is provision to include the outcomes of occupant survey, thermal comfort studies, lighting survey, and indoor air quality review. While carrying out occupant survey and measurement of all parameters related to the IEQ are not mandatory, the approved professional responsible for the assessment must confirm whether the design intents and functional systems meet the minimum requirements prescribed in building codes and national standards.

The DEC scheme does not include an assessment of IEQ. An assessment of indoor air quality in two case studies with close energy performance levels is provided to highlight the significance of taking into account the IEQ in energy assessments.

2.4 Data Visualisation Techniques

It is useful to compare data visualisation techniques used in these schemes and how the outcomes of energy assessments are communicated with building users. The ways the trends of energy use and CO_2 emissions in consecutive years are presented to building users in bEQ and DEC schemes along with their implications are briefly reviewed.

3.0 Analysis

The methods explained above were applied to the case study buildings to explore the similarities and contrasts of the existing certification schemes in England & Wales and ASHRAE bEQ.

3.1 Comparison of Standard Conditions & Normalisation of EPCs

Table 6 compares a number of standardised conditions used in the energy certification schemes to neutralise the effect of occupant behaviour and operating conditions. The standardised conditions for office and retail sectors are presented. It is notable that the equipment load and operation hours assumed for Bank/financial offices in 'As Designed' bEQ are significantly higher than those used for their counterparts in the EPC scheme. Ever increasing use of ICT equipment and the extended hours of operation have often been cited as major reasons for discrepancy between measured performance and energy use calculated under standardised conditions in the UK [22]. It appears that ASHRAE 'As Designed' bEQ is more perceptive of the operation of modern specialist offices.

Table 6 – Standardised conditions used in asset rating calculations [23, 24]

Scheme	Activity type	Equipment Load (W/m^2)	Occupant Density (m^2/p)	Ventilation rate (l/s/p)	Heating Set Point/Setback (ºC)	Cooling Set Point/Setback (ºC)	Heating Hours (week days)
EPC	General Office	11.77	9.0	10.0	22/12	24.0 (setback n/a)	05:00-19:00
	Office (financial/ professional services)	**12.18**	10.5	10.0	22/12	24.0 (setback n/a)	**06:00-18:00**
	Retail (Dept. store sales)	5.20	8.6	10.0	20/12	23.0 (setback n/a)	07:00-18:00
As Designed bEQ	General Office	10.76	13.9	10.6	21.1/12.8	23.9/32.8	06:00-22:00
	Bank/Financial Office	**28.95**	9.3	7.1	21.1/12.8	23.9/32.8	**06:00-22:00**
	Retail	3.23	9.3	11.8	21.1/12.8	23.9/32.8	06:00-21:00

Figure 4 illustrates how, following the 'As Designed' bEQ principles, the calculated total performance and EPC ratings change when equipment load is included in the calculations, and source-site ratios identical to those used for operational rating are adopted.

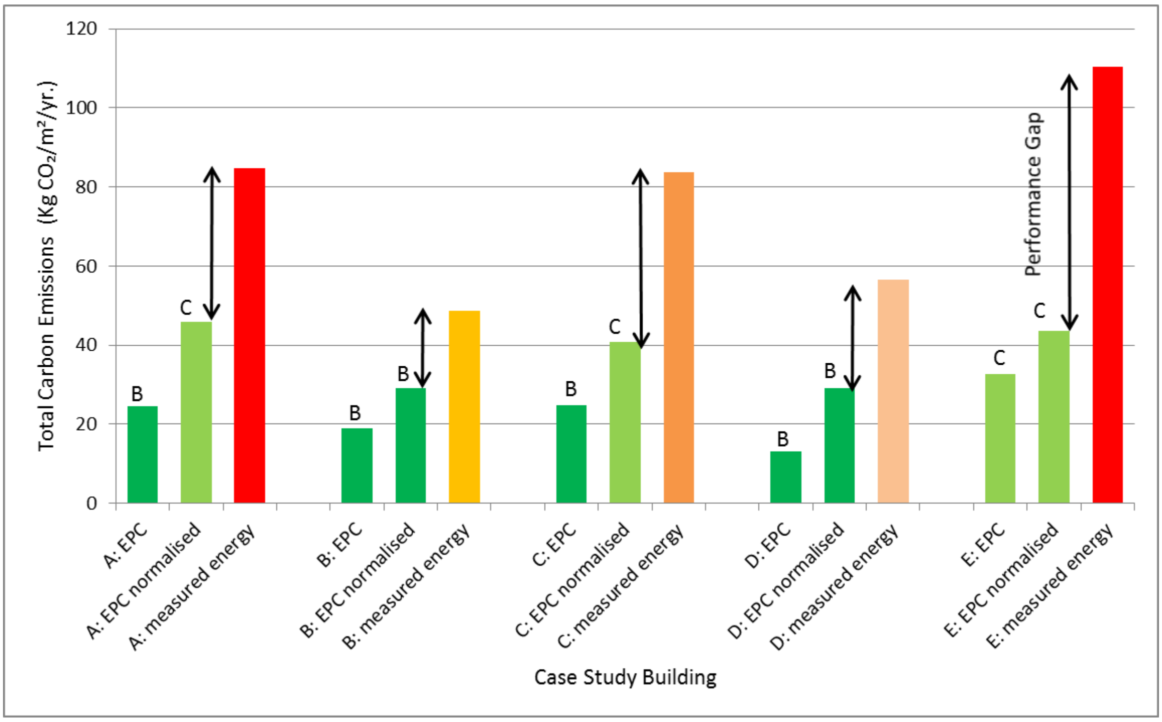

Figure 4 – Normalisation of EPC results based on As Designed bEQ principles[6]

On two occasions change of source-site ratios have changed the original EPC rating bands from B to C. A large proportion of heating in Building A was intended to be provided by ground source heat pumps and, therefore, the calculations are very sensitive to increases in carbon intensity of electricity. Furthermore, the design strategy for heating in Building C was based on use of biomass boilers with extremely low kWh to carbon emissions conversion factors. Consequently, electricity was the determinant factor in carbon intensity of the source energy, and 30% increase from 0.422 kg CO_2/kWh assumed in the initial calculations to 0.55 effectively changed the asset rating band. Asset and operational ratings are often not generated simultaneously and the source-site ratios related to the national grid may well change at the interim. However, it is reasonable to expect any change in the value of source-site ratios are reflected across the board in the calculation engines underpinning both asset & operational ratings. This has not been the case since inception of EPC and DEC schemes (See Table 1).

Figure 4 also shows normalising total performances derived from EPC calculations based on standard equipment load and using source-site ratios identical to operational rating precede any attempt to determine energy performance gap that may have caused by operational issues.

3.2 In Operation bEQ vs. DEC

Figure 5 shows the reference values used in the DEC and 'In Operation' bEQ and the ratings achieved when measured energy uses presented in Figure 4 are used to calculate the energy quotients.

[6] Note: A-E in the legend denote case study buildings; B-C on the graph denote EPC ratings.

As discussed before, higher source EUIs achieved in the US climate cannot be used to compare energy efficiency levels in the UK and US. The difference in EUIs, to some extent, is a result of buildings located in extreme weather conditions being represented in the observed mean used to calculate the centred variables for ENERGY STAR regression analysis. It should also be noted that the energy determinants of schools in the UK would not necessarily be identical to the US schools and will have to be identified by a statistical analysis of the UK building stocks and their energy related characteristics. However, relative changes in EUIs derived from sensitivity analysis could be *indicative* of adjustments required in reference values and the limitations of the existing benchmarks used in the UK.

To illustrate this point, the 'In Operation' bEQ reference values calculated based on actual number of personal computers and the reference values calculated assuming the case studies have the same personal computers as ENERGY STAR median building (2.11 PC per 1000 ft² [25]) are shown in Figure 6. The case study schools were procured under the Building Schools for the Future (BSF) programme with high number of ICT equipment that are not effectively represented in the current benchmarks underpinning the DEC scheme. There is no mechanism within DEC to correct school benchmarks for ICT equipment. The ENERGY STAR benchmarking engine that underpins the 'In Operation' bEQ, however, tailors its benchmarks for the number of computers. Figure 5 reveals using actual number of computers in benchmarking process for the case study buildings could increase the In 'Operation' bEQ reference values by 36% compared to schools with identical conditions except for number of computers that are fixed at ENERGY STAR median level. This finding has far-reaching consequences for the benchmarking schemes in the UK that will be discussed in section 4.

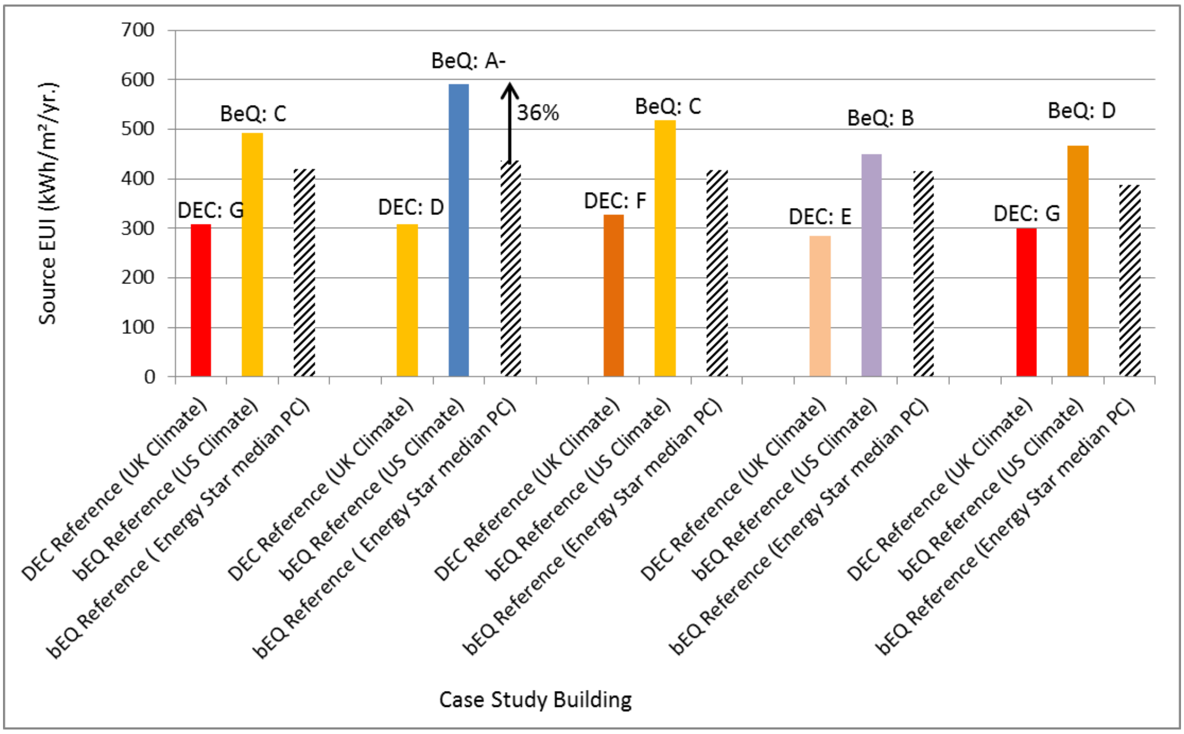

Figure 5 –Source EUI reference values used in DEC & 'In Operation' bEQ (Buildings A-E)

3.3 Energy Assessment & Indoor Environmental Quality

Figure 6 shows the indoor air quality in typical classrooms at two buildings in the sample that have close energy performance levels. However, it appear the average CO_2 concentration in Building D is constantly higher than 1,500 ppm during peak times whereas CO_2 concentrations in Building B remain below 1,000 ppm even at full occupancy that occurred in the afternoon during measurements. In this case, Building B has both better level of energy performance and higher indoor air quality thanks to a well-procured and managed demand-controlled ventilation system that also utilises effective heat recovery. Poor energy performance of other mechanically ventilated buildings in this sample, buildings A and E, confirms that there is no one size fits all solution to energy performance and IEQ. However, an integrated approach to energy and IEQ can lead to major environmental improvements for building users. Adjustments in the traffic light control system that prompts teachers to operate windows when indoor CO_2 concentration increase led to lower average CO_2 concentrations in Building D. Adopting an integrated approach to energy performance and IEQ, similar to 'In Operation' bEQ, can make best use of DEC assessors expertise and bring huge environmental improvements.

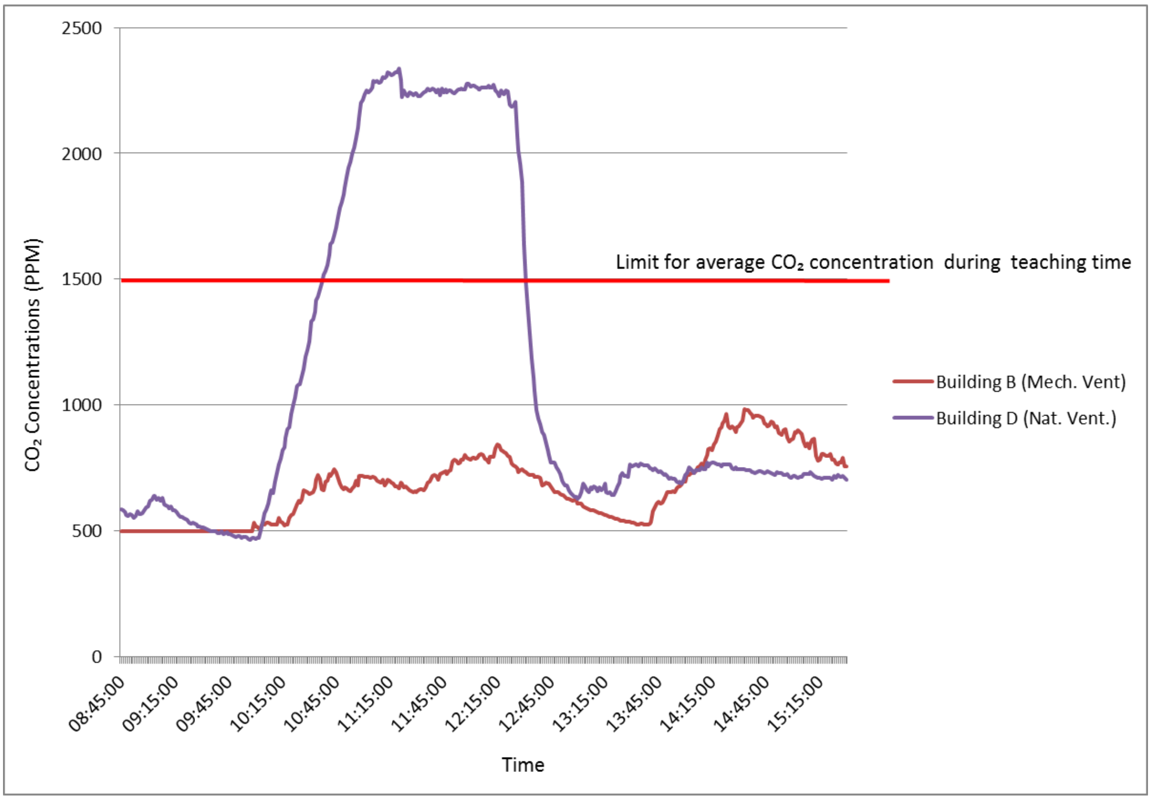

Figure 6 – Indoor air quality in typical classrooms at Buildings B and D, Winter 2012 (peak CO_2 concentrations occurred at 100% nominal occupancy capacity.)

3.4 Data Visualisation Techniques

Figures 7 and 8 show how CO_2 emissions and energy performance trends are communicated with building users under DEC and 'In Operation' bEQ schemes. Display energy certificates include a graph that reports total CO_2 emissions for the previous three years when data is available. This is an effective way to communicate the trend of building emissions with building users and people visiting public buildings. The 'In Operation' bEQ tool, on the other hand, produces graphs that relate gas and electricity use to mean daily temperatures up to the past four years when data is available. These graphs are presented to the clients in the recommendation reports that are appended to the certificate. This presentation format might be beyond the simplicity intended for DECs that are meant to be easily understood by public. However, it is notable that DEC advisory reports do not include any graphic information. Presenting data in a format similar to what is produced by the bEQ tool will enable building managers understand the trends and forecast energy use of their premises under different weather conditions.

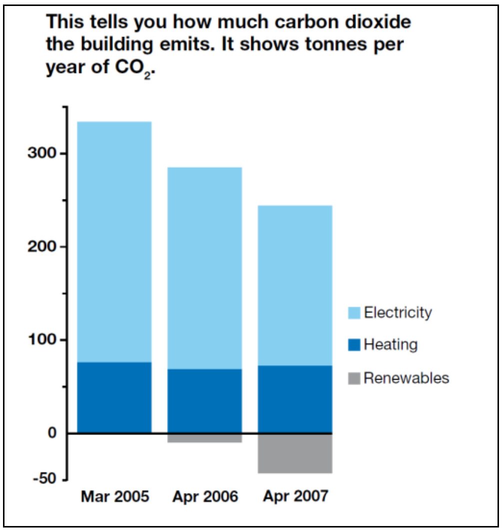

Figure 7 – Typical illustration of the trend of energy use: DEC scheme

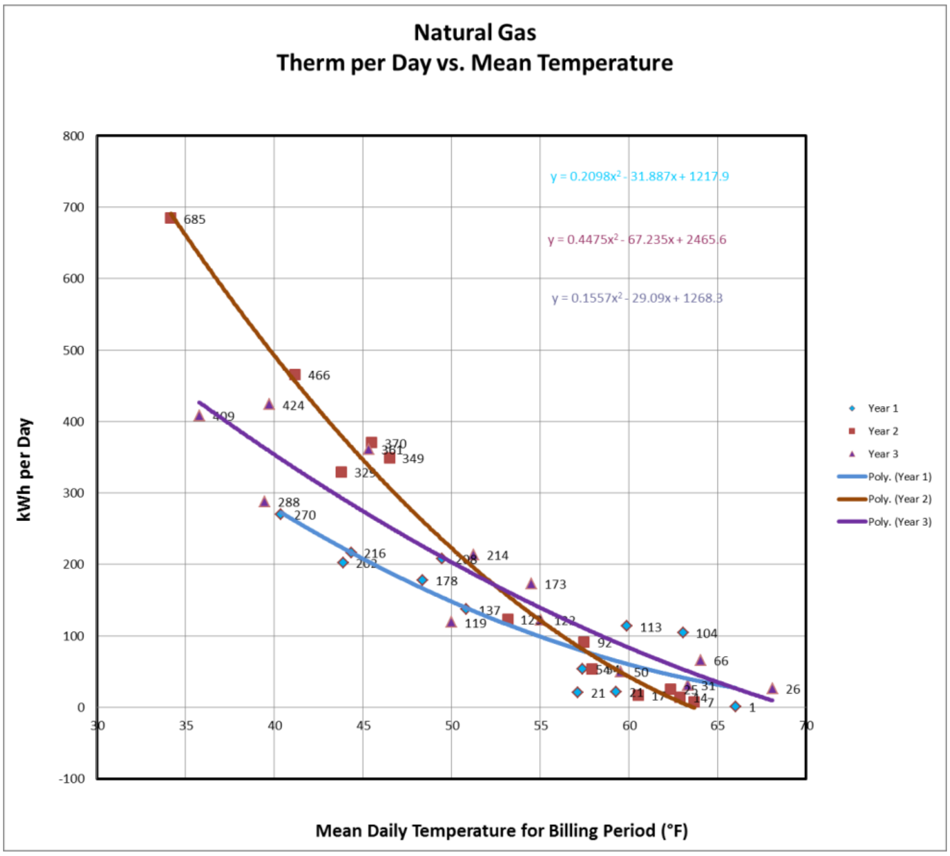

Figure 8 – bEQ regression analysis on past 3 years' energy use for Building E

4.0 Discussion

The comparative study presented in this paper can inform the following topics related to energy labelling.

4.1 Asset Rating vs. Operational Rating

The self-reference method used to define the reference values in the EPC scheme is not directly comparable to the statistical method used to derive reference EUIs for the DEC scheme. The baselines defined for these schemes are, thus, not entirely consistent. The use of ENERGY STAR Target Finder & Portfolio Manager in the bEQ schemes, on the other hand, sets reference values that are derived using the same methodology. Other factors that could impede comparison between asset and operational ratings in the UK are the exclusion of equipment load from EPC ratings and different source-site ratios used in the analysis. Therefore, it is important to normalise the effect of these factors before any attempt is made to compare the outcomes of EPC calculations with DECs. It is also important to avoid comparing the dimensionless ratings and use the total performance figures instead.

The difference between total energy performances, including the equipment load and normalised for source-site ratios, could then point to actual operating conditions and building management issues that must be further explored using frameworks such as the one proposed by CIBSE TM54 [26]. This technical memorandum provides a framework to assess the effect of operating conditions that might be different than the standardised conditions used for asset rating. These include occupants' density, operating hours, ventilation rates, temperature set points, actual equipment load and control issues related to occupants' behaviour (e.g. opening windows).

4.2 Possible scenarios for the future of energy benchmarking in the UK

Gathering accurate information about energy-related building characteristics for large samples of different types of buildings is expensive and technically complex. Yet the success of the ENERGY STAR programme, and the CBECS database that underpins it, in attributing significant part of the variations in source energy use of different building types to relatively few building characteristics, shows the value of having robust data for benchmarking.

The case studies presented in this paper show how energy benchmarks could be adjusted to allow for ever-increasing use of ICT equipment in buildings. Such adjustments are crucial if the DEC scheme is to be extended to private sector and applicable to equipment-intensive offices and other building types.

There is no extensive and well-administered programme of data gathering comparable to CBECS in the UK yet. However, given the existing policy landscape and industry trends, there are two alternative options to develop robust energy benchmarks. These methods can go beyond simple median EUIs and tailor for other energy-related building characteristics:

- **Statistical approach:**
  As the DEC scheme is mandatory for public buildings above 500 m² with strict quality assurance requirements, it is an ideal platform to gather large amount of good quality data on a regular basis. A number of energy-related building characteristics are already included in the lodgement files stored in the national register. It is important to include the building characteristics that are most likely to affect energy use in the DEC inputs. It is also important to strike

the right balance between inclusion of the most relevant factors and simplicity of the scheme. Some data points such as building age, commissioning, and refurbishment history could be gathered for all buildings. Other data points could be defined based on building type learning the lessons from programmes such as CBECS, ENERGY STAR and others. There are few data points for every building type and therefore it is envisaged that adding these extra data points will not have drastic impact on certification costs. There is also room to trade off new data points with less important factors already included in the scheme. A well-structured DEC scheme could be used to develop robust energy benchmarks aside performing its normal regulatory role under the EPBD.

- **Normative approach:** in the absence of large datasets, normative bottom-up methods could be used to tailor for some aspects of building context. For example, in 2002 the principles of CIBSE TM22 Energy Assessment and Reporting Method were used to develop a prototype *tailored benchmarking* tool for offices that was compatible with the Energy Consumption Guide 19 [27, 28]. New work has been done on schools using the same principles [29]. This approach could be followed in parallel with the statistical approach and could be very helpful until robust large-scale data is available for regression analysis.

4.3 Prospects for ASHRAE bEQ

A major challenge for bEQ, as a voluntary energy certification programme, is to find its market. The fact that ENERGY STAR, the benchmarking engine underpinning a number of bEQ's building categories, is also one of its major competitors is certainly a threat. However, detailed classification of energy performance levels in bEQ might be more appealing to commercial clients seeking green credentials who are keen to differentiate themselves from their competitors (see Figure 4).

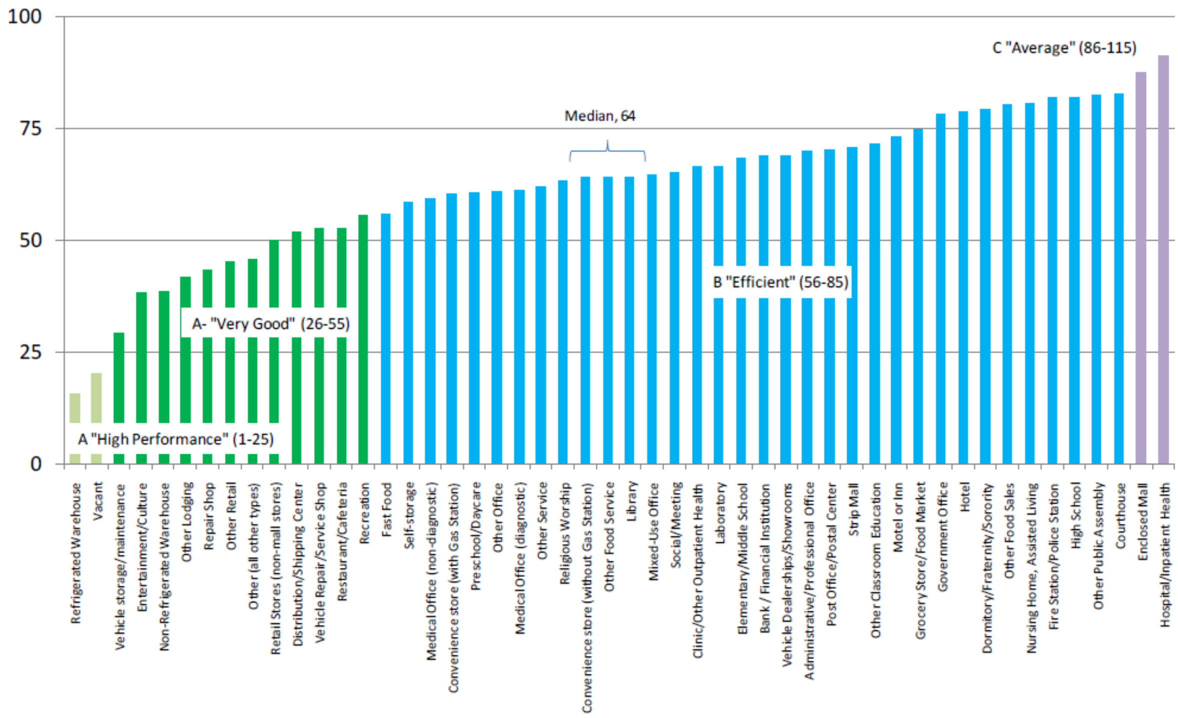

Figure 4 – The bEQ differentiates 50 ENERGY STAR rated buildings into four performance levels [30]

The way asset rating and operational rating are compared against each other in this system might also make it attractive to the sustainability rating systems such as LEED that are increasingly geared towards verification of energy performance. bEQ's attention to IEQ makes it possible to be used as a single platform for verification of energy and thermal comfort that have separate credits under LEED NC [31].

5.0 Conclusion

A comparison between the new ASHRAE building energy-labelling programme and the energy certification schemes implemented for non-domestic buildings in the UK identified a number of improvement opportunities. Notably it was established that it is necessary to normalise the energy performances derived from asset ratings for equipment load and source-site ratios before any attempt is made to determine the root causes of energy performance gap by comparing asset ratings with operational ratings.

It is also important to follow an integrated approach to operational energy performance and indoor environmental quality to ensure energy efficiency has not been achieved at the expense of environmental conditions.

The ENERGY STAR benchmarking system underpins the reference values used for a number of building categories in ASHRAE energy labelling programme. Sensitivity analysis on the effect of number of computers on reference values derived from ENERGY SAR regression equation for schools revealed that increasing the number of computers from Energy Star median level to actual numbers in the case study buildings lead to 8-36% increase in reference values. This highlights the significance of being able to tailor energy benchmarks based on building context.

The main challenge for the UK certification schemes appears to be the necessity to develop robust energy benchmarks that go beyond simple median EUIs and the existing correction factors applied. It is suggested that the DEC scheme is an ideal platform to gather the necessary data, identify key determinants of energy use in different sectors, and develop the capability to adjust benchmarks accordingly. Lessons learned from the CBECS and ENERGY STAR programmes in the United States could be used to equip the DEC platform with necessary data points to collate the most relevant energy-related building characteristics without comprising the simplicity and cost-effectiveness of the scheme.

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