IBPSA-ENGLAND BSO12

First Building Simulation and Optimization Conference
Loughborough, UK
10-11 September 2012

COMPARISON OF EPC, DEC AND DYNAMIC THERMAL SIMULATION RESULTS AT BIRMINGHAM AIRPORT

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ABSTRACT

In the United Kingdom (UK) Energy Performance Certificates (EPC) are intended to indicate the energy efficiency potential of a building for owner/occupiers and Display Energy Certificates (DEC) provide a performance rating for an operational facility based upon metered data. This study uses dynamic thermal simulation (DTS) to evaluate the difference between the EPC and DEC results for the new International Pier at Birmingham Airport in the UK and to test the impact of EPC recommendations. The Pier building achieved an EPC rating of ‘B’ but the operational DEC rating of ‘F’ was much lower than anticipated. Differences between EPC, actual performance and simulation data have been analysed to identify the critical pieces of information that influence the disparate ratings. Conclusions consider the role of EPCs in designing this type of building and informing energy efficient operation.

INTRODUCTION

Energy Performance Certificates (EPCs) and Display Energy Certificates both form part of the final implementation of the European Directive 2002/91/EC in England and Wales (Department for Communities and Local Government, 2008a). These two regulatory systems essentially have the same aim which is to “...promote the improvement of the energy performance of buildings...” (Department for Communities and Local Government, 2008a, p.3). They were first introduced towards the end of 2008 and are now a well established part of the UK government’s carbon reduction strategy.

Although both certificates form part of the same strategy and have similar intentions they use different calculation methodologies which results in an Asset Rating in the case of EPCs and an Operational Rating for the DECs. Despite using different calculation methodologies and the DECs accounting for energy consumption from more end-uses, the final ratings are presented in one of seven A-G bands (with EPCs having an additional A+ rating for zero carbon facilities). This can cause some confusion for building operators when the same building receives entirely different ratings for its EPC and DEC.

This paper describes a case study of the new International Pier building at Birmingham airport. An EPC was produced for the building when designed and built in 2009. The EPC recorded an Asset Rating score of 47 meaning that it was in the ‘B’ rating band. This rating was in agreement with Birmingham airport’s development policy; they have been introducing energy conservation measures across their building stock for the past decade. It was therefore disconcerting for the airport operators when the 2011 DEC Operational Rating was calculated as 127 placing it in the ‘F’ band despite 22.75% of the building’s energy use being provided from renewable sources. Given the different calculation methodologies used for EPCs and DECs it would be reasonable to expect some difference between the ratings. Subjectively however, it was the extent of the difference that caused concern for the airport operators.

It is the aim of this paper to resolve the difference between these two ratings and to identify the sources of energy consumption that have resulted in the comparatively low operational rating. Originally, a dynamic thermal simulation model was created to meet Building Regulations Part L2A requirements (HM Government, 2006) and the outputs from this model were also used to calculate the EPC rating. The Part L2A compliance report and the data provided for the DEC assessment were made available by the airport Energy Manager for this analysis. Unfortunately, the original simulation model could not be obtained. A new calibrated dynamic thermal simulation model of the Pier has recently been produced for work outside the scope of this paper and this was also used in the analysis. This was calibrated with monitoring data from 2010.

A brief background to the EPC and DEC initiatives is described in the literature review. The next section of the paper uses the data from Birmingham Airport to illustrate the calculation procedures for both certificate schemes. The penultimate section of the paper uses metered data from the building and the calibrated simulation model to establish where the additional energy is being used in comparison to the EPC calculated consumption. Recommendation reports are issued with EPCs which suggest measures to improve the energy performance of the building. Effects of the recommendations made in the International Pier EPC report were tested using the new simulation model. Results from this exercise are also presented in the penultimate section of this paper. They were used to recalculate the DEC rating to assess what level of improvement could be achieved.

CASE STUDY BUILDING

The International Pier building was completed in 2009. It largely serves as a circulation and waiting area for departing and arriving passengers as they board and disembark their flights. It also incorporates small sales areas, lounges, toilets, light plant rooms and office space. Total floor area is 12,987m^2 (taken from drawings provided by the Airport) but this does not include the stands or air bridges which are viewed as unconditioned space in the EPC and DEC calculations. The building is served by grid electricity but also uses a gas fired Combined Heat and Power (CHP) unit. Figure 1 shows the simulation model of the as-built building used in this case study. The main terminal building is shown in the background and was included in the simulation as local shading and an attached adiabatic space.

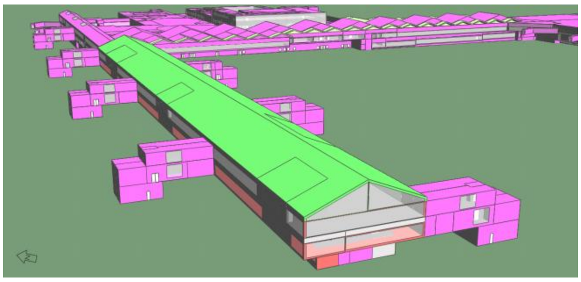

Figure 1: DTS model of the International Pier at Birmingham Airport

LITERATURE REVIEW

Given the political origin of both EPCs and DECs, there has been much written about them both. This is however largely industry commentary that has been published in trade press. Reviewed literature did not include any case studies that directly compare EPC and DEC results that have been published in academic journals or conference proceedings. As there appears to be extensive interest in the two certificate schemes it is likely that some academic work has been produced that compares them but the literature search failed to identify any documents of this nature in academic databases such as Scopus. However, many pieces have been written that present either guides or analysis of the two certificate schemes since their introduction in 2008.

The EPC and DEC calculation methods are explained in the next section using results from the Pier building to help illustrate the process. There is a requirement for an EPC when a building using energy to condition indoor space is constructed sold or let; this is also the case with existing buildings or parts of buildings that have been extensively altered or designed to be used separately (Watson, 2009). Display Energy Certificates are mandatory for all public sector buildings with a floor area greater than 1000m^2 (DCLG, 2008b) and this requirement is due to be extended across the commercial building sector (DCLG, 2010).

To part meet the requirements of the EU Directive, the National Calculation Methodology (NCM) was developed for the Department of Communities and Local Government (DCLG) in England and Wales (DCLG, 2011). Under this methodology, non-domestic buildings have to use the approved Simplified Building Energy Model (SBEM) or approved Dynamic Simulation Modelling (DSM) that incorporates the SBEM approach to assess buildings other than dwellings (Watson, 2009). It is the DSM approach that was used for the Pier EPC. It was in the first instance used for the Building Regulations Part L2A compliance. Results from this calculation were then used to compute the EPC rating as described in the next section. Significantly, the EPC only accounts for energy used by the heating, cooling ventilation and hot water systems as well as the fixed lighting; plug loads are not included in the calculation (DCLG, 2008a).

Display Energy Certificates are calculated using measured utilities data for a fixed 12 month period covering all energy consumption (DEC, 2008b) within the defined building which is then compared against a set of benchmark data divided in to specific building category types (Chartered Institute of Building Services Engineers, 2008). There are some adjustment factors relating to weather (degree days), occupancy and separated building use which can be used to adjust the benchmarks as part of the DEC calculation procedure (DCLG, 2008b). An important distinction to note at this stage is the different fuel emission factors used in these calculations.

Being based upon the NCM/SBEM calculations, the EPC scheme uses the emission factors specified by Building Regulations (HM Government, 2006) whereas the DEC references the carbon dioxide (CO_2) emission factors used to calculate the benchmarks (CIBSE, 2008). In this instance the EPC factors were based upon the 2006 data with grid electricity rated at 0.422 kgCO_2/kWh and gas at 0.194 kgCO_2/kWh; the DEC benchmark data use 0.55 kgCO_2/kWh for electricity and 0.19 kgCO_2/kWh for gas. This does have some impact when comparing results.

A study produced by the Chartered Institute of Building Services Engineers (CISBE) in 2011 reviews the suitability of the benchmarks used in the DEC calculations (Bruhns et al, 2011). This review covered 29,310 public buildings and found that a large proportion of the median DEC results were very close to the average benchmark score of 100 which lies between the D and E ratings, the intended average benchmark (CIBSE, 2011). It should be noted however that in the less common building categories such as Entertainment Halls and Workshops, the median ratings were more than 25 points away from the average 100 benchmark. It is relevant in this case that the sample included no airport terminal buildings (Bruhns et al, 2011).

In total, 94% of buildings in the DEC database were included in categories whose median rating was within one grade of the CIBSE estimated benchmark. It was also found that there is a significant trend for DEC recorded electricity consumption to be higher than the CIBSE benchmark with the inverse being true of the gas consumption which could be due to increased plug loads, improved building envelope performance and the benchmarks being largely based upon data from the 1980s and 1990s (Bruhns and Jones, 2011). In one extreme case, the median rating in the Public Waiting and Circulation category was four times higher than the DEC benchmark although there were only 9 buildings in this sample (Bruhns and Jones, 2011).

Statistical confidence in the DEC benchmarks is mirrored by the construction industry's belief that DECs offer a more robust facility rating than EPCs (Wright and Matthews, 2011). This is due to DECs being calculated using measured performance rather than being based upon the hypothetical estimates produced for EPCs. This sceptical industry view of EPCs was also supported by the early findings of a study during 2009 asserting that 79% of property professionals ignored EPC recommendations produced as part of the Advisory Reports (Willoughby, 2009). Assumptions made in EPCs have also been described as unrealistic in terms of actual performance, especially as they do not include plug-loads and, in the case of schools, local authorities are viewing DEC results as the best point of reference for building performance improvement (Kimpian and Durman, 2012).

EPC AND DEC METHODOLOGIES

This section describes EPC and DEC methodologies using the data compiled for the UK Birmingham Airport International Pier rating. Since the International Pier EPC was produced, the Building Regulations for Approved Document Part L2A have been updated (HM Government, 2010). This paper covers methodology for Approved Document Part L2A 2006 (HM Government, 2006). The Pier building's EPC Asset Rating was 47 placing it in band 'B'. The EPC Asset Rating (AR) is calculated from the formula;

$$AR = 50 \times (BER/SER) \quad (1)$$

Where BER is the Building Emission Rate and SER is the Standard Emission Rate. The EPC is graded on a scale from A+ to G, based upon the calculated asset rating. The BER and SER are calculated as part of the compliance procedure to meet Building Regulations for England and Wales. Using the SBEM methodology energy demands for heating, cooling, ventilation, lighting and hot water for the as-built building are calculated. Total energy demand is then converted to CO_2 emissions per square metre to produce the BER (Watson, 2009).

The SER is set at a 23.5% reduction against the Notional Emission Rate (NER) defined as part of the SBEM calculation as described below. Five criteria must be met to comply with the Building Regulations: 1. Achieving an acceptable building CO_2 emission rate (BER); 2. Limits on design flexibility; 3. Limiting solar effects in summer; 4. Quality of construction and commissioning; 5. Providing information (HM Government, 2006). Results calculated in 1 and 2 are used in the EPC.

Approved SBEM calculation methods are used to calculate the BER, NER and Target Emission Rate (TER). The Pier EPC was calculated using results from Integrated Environmental Solutions (IES) Virtual Environment version 6.4 SBEM approved software (IES, 2009). The BER should be calculated on as-built properties including: location, geometry, functional zones, construction properties, heating, ventilation and air conditioning (HVAC) systems, domestic hot water (DHW), air leakage, lighting, controls and low and zero carbon technologies (LZC).

A notional building (used to calculate the NER) is derived from the as built building (used to calculate the BER) in accordance with conditions defined in paragraph 22 of Approved Document L2A (HM Government, 2006). The TER is calculated from the formula:

$$TER = NER \times (1\text{-improvement factor}) \times (1\text{-LZC benchmark}) \quad (2)$$

If the BER is equal to or less than the TER the building is compliant with criteria 1. The EPC is then derived from the formula stated above. The SER is calculated from the NER in accordance with procedures specified in the National Calculation Methodology (DCLG, 2008). The International Pier results were:

$BER = 55.9kgCO_2/m^2$

$NER = 99.5kgCO_2/m^2$

$TER = 71.7kgCO_2/m^2$

The SER calculated for the EPC was $59.5kgCO_2/m^2$. This results in the final calculation of:

AR = 50 × (BER/SER)

47 = 50 × (55.9/59.5)

The DEC Operational Rating (OR) is based on actual building CO_2 emissions from metered energy consumption data. This is compared against the CIBSE building emission benchmarks for a building of that category (CIBSE, 2008). The DEC is graded on a scale from A to G, based upon the OR. DECs are valid for one year, inclusive of an advisory report valid for seven years. As discussed the airports 2011 DEC OR has been calculated at 127 placing it in band 'F'. The OR is derived from the formula;

$$OR = (\text{Building } CO_2 \text{ emissions/TADA in } m^2) \times (100/\text{Typical } CO_2 \text{ emissions per } m^2) \quad (3)$$

In this case, TADA is an acronym for the Total Area in DEC Assessment. This can sometimes be a smaller area than the total in the building. For example, the case study building DEC assessment does not include the Stands as described earlier. Building CO_2 emissions are established from annual metered consumption data, with a maximum/ minimum variation of 31 days. Standard CO_2 conversion factors for DEC are maintained by government in a Central Information Point (CIP) file, accessible by accredited energy assessors (DCLG, 2008c). Typical CO_2 emissions per square metre are published in the CIBSE energy benchmark document TM46 (CIBSE, 2008). Benchmarks are adjustable by two factors; weather and occupancy. Emission benchmarks included in the same CIBSE document are derived from two fuel sources, electricity and fossil-thermal energy (CIBSE, 2008). For the Pier building, the DEC is based on the 'Terminal' category. Benchmarks for the Terminal category are shown below in Table 1.

Table 1:

CIBSE benchmarks for Terminal buildings

	$kWh/m^2/year$	$kgCO_2/m^2/year$
Electricity	75	41.3
Fossil-thermal	200	38.0
Total	275	79.3

An adjustment to allow for the colder weather degree days of 2010/11 was made in the Pier DEC calculation resulting in an increased fossil-thermal benchmark of 223kWh/m², (equivalent to 42.37kgCO_2/m²). The International Pier related energy consumption and CO_2 emissions for 2010/11 are shown in Table 2.

Table 2:

International Pier DEC calculation data

	$kWh/m^2/year$	$kgCO_2/m^2/year$
Electricity	117	64.4
Fossil-thermal	221	41.9
Total	338	106.3

Including the adjusted fossil-thermal benchmark, this results in a DEC calculation of:

$$OR = (\text{Building } CO_2 \text{ emissions/TADA in } m^2) \times (100/\text{Typical } CO_2 \text{ emissions per } m^2)$$

$$127 = (1{,}391{,}483.9/13{,}112) \times (100/83.2)$$

It is relevant to note that the two calculation methods allow for on-site renewable electricity generation in a different way. The 2006 EPC calculation methodology uses a grid displaced CO_2 fuel emission factor of 0.568 kgCO_2/kWh as opposed to the 0.422 kgCO_2/kWh value for grid supplied electricity (HM Government, 2006). The DEC methodology removes the on-site generated electricity from renewable sources before the final CO_2 calculation, effectively giving the renewable electricity the same CO_2 fuel emission factor as grid supplied electricity, 0.55 kgCO_2/kWh (HM Government, 2010).

ANALYSIS OF RESULTS FOR THE INTERNATIONAL PIER

As emphasised in the previous section, there was considerable difference between the EPC and DEC ratings for this building. There are clear differences between the total consumption figures for both gas and electricity but the large difference between ratings is also due to some calculation and benchmarking subtleties that are not immediately clear. Within large organisations a variety of individuals have an interest in the operation of their capital assets but without any specialist building energy performance knowledge it would be very difficult to identify why there is such disparity between the two ratings.

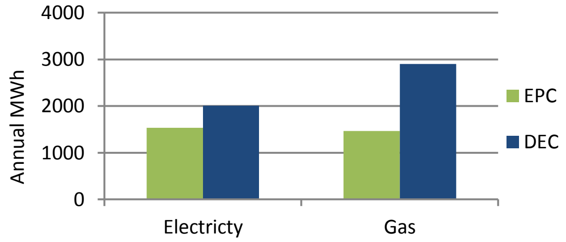

Figure 2: EPC and DEC utility consumption

Figure 2 shows the difference between the energy consumption estimated by the EPC and the energy consumed on site and recorded for the DEC at a utility level. There is of course no plug load consumption included in the EPC data.

As the two calculation methodologies differ, the CHP generated electricity has not been removed from the total electricity consumption for these results. An intuitive observation would be that as the EPC does not include for plug-loads, the difference between the two results (474MWh, 10% of the total consumption) could account for equipment and non-fixed lighting. Unfortunately, end-use monitoring data is not available for the building but the calibrated simulation model produced for this analysis suggests that this is a simplistic assumption.

Based upon the results for this case study, without any renewable generation, it would be seemingly impossible for the as-built Pier to achieve greater than the average rating for electricity. This is because the specified benchmark for Airport Terminal electricity consumption is 75 kWh/m^2/year; the EPC modelled estimate for system and fixed lighting electricity consumption alone was 123.8 kWh/m^2/year. Data provided by Birmingham Airport confirmed that the annual electricity consumption for the entire terminal in 2010 was 278 kWh/m^2. Data recorded for East Midlands Airport terminal building in 2010 was 266.5 kWh/m^2 (Parker et al, 2012). The respective gas consumption figure for Birmingham was 158 kWh/m^2 and for East Midlands it was 215 kWh/m^2. Even though the electricity CO_2 emission factor used in the DEC (0.55) calculation is much higher than the EPC (0.422 in 2006), the DEC benchmark of 41.3 kgCO_2/m^2/year is still lower than the EPC estimate of 52.24 kgCO_2/m^2/year before CHP generated electricity is removed (accounting for the CHP generation this is reduced to 32.96 kgCO_2/m^2/year).

It was however the gas consumption for 2010/11 that was much higher than the EPC estimate. Part of this could be accounted for by the relatively cold conditions during 2010. As part of this analysis a new model for the International Pier was created using the EPC input criteria. To test the theory that the colder weather had a large impact on the overall performance of the building, a surrogate weather file from a colder European city was used (Copenhagen).

Figure 3 shows the average dry-bulb temperatures from the simulation weather file for Birmingham, the actual weather for Birmingham in 2010 (British Atmospheric Data Centre, 2012) and the surrogate Copenhagen weather file. The comparison file should not be seen as conclusive and has been used in this scenario in the absence of the actual weather file for the site. It is intended that the recorded weather conditions from the site are used in future work.

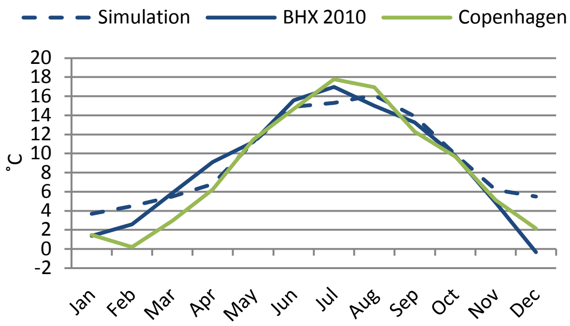

Figure 3: Comparative dry-bulb temperature for simulated and actual weather

Using the surrogate weather file does however provide comparative simulation results that are useful in this analysis. The new Pier DTS model designed to mimic the EPC results was calibrated to within 1% for total annual energy consumption. When the alternative weather file is introduced to the simulation model designed to mimic the EPC DTS it also estimates total energy consumption to within 1% of the annual total measured on site and used for the DEC calculation. Results for both calibrated versions of the model are presented in figure 4 in comparison with the EPC and DEC results (EPC versions do not include equipment consumption; CHP generated electricity has been subtracted from the DEC figures).

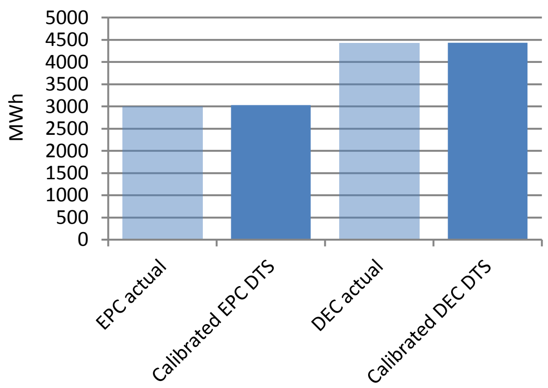

Figure 4: Final annual energy consumption from EPC, DEC and calibrated DTS models

It should be noted that the DTS results included here should be taken as indicative only. The main reason for this is that the original IES DTS model used for the EPC calculation was not available. Data used to create the new Pier DTS model was taken from the Part L2A compliance report produced by the Airport's engineering consultants; the model geometry was created using current drawings supplied by the Airport.

There are some differences between the EPC model and the new calibrated model. The most obvious is that the total floor area differs; the recorded floor area for the EPC model was 12,389m^2 as opposed to the 12,987m^2 calculated from the calibrated simulation model, an error of 4.8%. Some of this can be accounted for by an area that is now used as an executive lounge that was not included in the EPC. When the EPC was calculated the space was unoccupied and considered as an unconditioned space. The lounge is 532m^2 and its inclusion in the DEC also accounts for some increase in energy consumption.

Although there was a small difference between the recorded DEC floor area (13,112m^2) and the new DTS model, the percentage error is much lower (less than 1%). The other main difference is that the NCM thermal template values for the equipment heat gains/consumption are taken from the 2010 defaults.

Using the new calibrated DTS models, the impact of the recommendations made in the EPC report can be estimated. Recommendations made were to replace gas with biomass fuel, install a ground source heat pump, install an air source heat pump, improve floor insulation, install solar water heating and install solar photovoltaic panels. For the purpose of this case study the recommendations added to the DTS models were: replace all gas with biomass fuel; an additional 100mm of floor insulation; 175m^2 solar water heating; and a 350m^2 (50kW) photovoltaic array (the same size system has recently been installed on the main terminal building). The other heat sources were considered to be alternatives to the biomass option so have been omitted from this exercise. Revised ratings are shown below:

EPC:

AR = 50 × (BER/SER)

33 = 50 × (39.6/59.5)

EPC band: B

DEC:

OR = (Building CO_2 emissions/building area in m^2) × (100/Typical CO_2 emissions per m^2)

99 = (1,068,808/12,987) × (100/83.2)

DEC band: D

Introducing the EPC recommendations does have some impact on the EPC Asset Rating but it does not move the building into the higher ‘A’ band. There is a slightly more pronounced effect on the DEC result with the operational score improving to 99 and the building moving two bands up the scale to a D rating although this is marginal as it is only 2 points from being in the ‘E’ rated band. The advantage of using DTS is emphasised by these results as the interaction between the recommended improvement means that building performance is not improved as much as might be expected. This is largely due to the increased floor insulation and solar thermal system reducing demand on the biomass Combined Heat and Power (CHP) unit. Although the CHP unit consumes less biomass in this scenario, it in turn produces less electricity which has a much higher fuel emission factor than biomass, 0.55 kgCO_2/kWh as opposed to 0.025 kgCO_2/kWh.

CONCLUSION

From the evidence compiled in this paper it appears that the main reasons for the large difference between the Pier EPC and DEC ratings were the relatively low electricity benchmark used in the DEC calculation methodology and the colder weather for the DEC monitoring period. It also suggests that the EPC underestimates the operational energy used in the building and the omission of plug-load consumption leads to some confusion. At the very least, a simple estimate of the plug-loads could be included in the EPC report. In this instance, final plug-load annual consumption from equipment and non-fixed lighting were similar to those estimated in the NCM methodology. The tendency for EPCs to estimate lower total CO_2 emissions was also partly due to the lower fuel emission factors although this has been addressed in the updated 2010 Building Regulations through the introduction of a grid supplied electricity factor of 0.517 kgCO_2/kWh (HM Government, 2010).

The DEC Airport Terminal electricity benchmark contributes greatly to the Pier’s low DEC rating. As described in the literature review, CIBSE are working to ensure that the benchmarks used for DEC calculations are both accurate and representative of average building types. It is no surprise however that the most accurate current benchmarks are for building categories with the broadest and highest resolution of data. It could be argued that should DECs be made compulsory for all commercial buildings that the range of data for this type of building will improve and benchmarks can be adjusted accordingly. The two examples of overall airport terminal electricity consumption noted in the previous section suggest that a more reasonable electricity benchmark for this type of building would be in the region of 200 kWh/m^2/year. This is however an extremely small sample and more data need to be collected for this to be representative of the building stock in this category. The small sample does however indicate that the fossil fuel benchmarks are reasonable.

DISCUSSION

Further work is required to investigate how much allowance is created in the DEC assessment for colder weather in monitoring years. It was not possible to evaluate this with the data available for this paper. Although there was some adjustment for the monitoring period, the additional gas consumption also largely contributed to the low DEC rating. Based upon the recommendations in the EPC report, the test simulations indicate that the EPC would not be improved to an A rating and that the revised DEC rating would be improved to a D rating. Although there are some reservations about the effectiveness of EPCs in promoting energy efficiency, recommendations made in this case would significantly reduce the building's carbon footprint. However, they would not necessarily improve the efficiency of the building and rely on low or zero carbon technologies to reduce CO_2 emissions.

Anecdotal feedback provided by the Airport Energy Manager confirmed that at the corporate board level the disparity between the two ratings raised questions over the operation and design of the building. In the worst case scenario, this could prejudice decisions to invest in energy efficient buildings in the future. From an economic perspective, the airport energy budget is the second largest after staff costs and reducing building energy consumption is a priority for the airport operators. They also have a commitment to reduce their carbon footprint and this perceived poor DEC rating caused further discontent regarding the quality and design of the facility. It is possible that the reason for this is the use of the same A-G rating scale which may lead non-building professionals to assume the rating systems are complementary.

The obvious difference between these two rating systems is that plug-loads are not included in the EPC calculations. In spite of this, it would be reasonable to argue that if a building is designed for a specific purpose then certain plug-loads should be included in any estimate of its operational performance. As already stated, the equipment loads specified in the NCM calculations that inform the EPC rating were very similar to those estimated by the calibrated DTS model. Using the same alphabetic rating system would then be more coherent and a lower DEC rating would intuitively indicate inefficient operation of the facility.

ACKNOWLEDGEMENT

The authors wish to acknowledge the staff of Birmingham Airport and particularly Kevin Turnbull who made this work possible.

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