Operational Rating vs Asset Rating vs Detailed Ssimulation

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Abstract

It is widely acknowledged that carbon dioxide emission is one of the primary causes of global warming. The Kyoto protocol, to which the European Union (EU) is a signatory, has an objective to reduce emissions of six key greenhouses gasses. This objective is unlikely to be met without the introduction of more primary legislation. Throughout the EU, the building stock is responsible for around 45% of all carbon emissions and this sector is clearly a primary target for legislative actions. This has led to the introduction of the Energy Performance of Building Directive (EPBD).

The EPBD requires several different measures to achieve prudent and rational use of energy resources and to reduce the environmental impact of the energy use in buildings. The three main components for implementation of the Directive are: calculation methodology, energy certificate and inspections of boilers and air-conditioning. This paper is concerned with energy certificates of buildings.

The principal categories for the energy certificate scheme are Asset rating, based on calculated energy use and Operational rating, based on metered energy. The Asset rating is determined by modelling the building under a defined set of standard conditions of occupancy, climate, environment and use. Asset rating includes energy use of heating, cooling, hot water, ventilation and lighting for non-domestic buildings. It will apply to both new and existing buildings. In the case of existing buildings, the calculation methodology for Asset rating will have to take into account that design data is unlikely to be available in existing buildings. In contrast, the Operational rating, will be based on metered energy. The metered energy consumption includes energy uses for all purposes. These intrinsic differences opened a debate about if these two ratings are at all comparable, and if so under which circumstances.

This paper, as part of the UK research project “Carbon reduction in buildings”, investigates the issues surrounding the application of Asset rating on existing buildings and its compatibility with Operational Rating, but also with detailed simulation software. The case study is a typical narrow plan office building hosting University estate built in early 1970 with treated floor area of 1280m^2 on 4 flours. The methodology used for the Asset rating is UK national calculation methodology SBEM, while the detailed simulation program used is DesignBuilder. In absence of a UK national methodology for Operation rating, EPLabel software has been applied, although the building energy consumption has been compared with UK design guide for office buildings. The significant differences in results (for gas 207kWh/m^2 vs 276kWh/m^2 vs 164kWh/m^2) suggest that great care and understanding must in employed while producing and interpreting building energy certification.

Introduction

Promoting energy efficiency in buildings in the European Union has gained prominence with the adoption of the Directive on Energy Performance of Buildings (EPBD) in 2002. The EPBD requires several different measures to achieve prudent and rational use of energy resources and to reduce the environmental impact of the energy use in buildings. The three main components for implementation of the Directive are:

1. calculation methodology,
2. energy certificate and
3. inspections of boilers and air-conditioning.

The calculation methodology is used to determine the data for energy certificate of buildings and it allows for different levels of complexity:

1. simplified hourly or monthly calculation or
2. detailed calculations.

The principal categories for energy certificate scheme are:

1. Asset rating, based on calculated energy use under standardized occupancy conditions and
2. Operational rating, based on metered energy.

Long before EPBD, ever since 1993, various EU documents were clearly indicating the importance of the energy reduction in building sector. Over the last decade building energy performance standardization and legislation is in many EU member states considered to be an attractive strategy for increasing the energy efficiency of new and existing buildings in both domestic and non-domestic building sectors since energy regulation and energy certification are two main mechanisms to control the energy consumption in buildings.

The calculation methodology for Asset rating has to be based on the characteristics of a building and its installed equipment assuming standard conditions for occupancy, climate , environment and use. Operational rating is based on metered energy consumption which includes energy uses for all purposes and in actual conditions. Some authors, like in (Roulet, 2006), suggest that Asset and Operational ratings should not be compared at all. However, if they are to if not increase then at least inform on building sector energy efficiency, at least these two mechanisms must complement each other.

Energy certification of buildings requires a method that is applicable to both new and existing buildings and should treat them in an equivalent way. However a design data is unlikely to be available in the case of existing buildings. A methodology for providing "missing" data in order to calculate energy use for heating and cooling, ventilation, domestic hot water and lighting might be of at least equal importance as calculation engine itself.

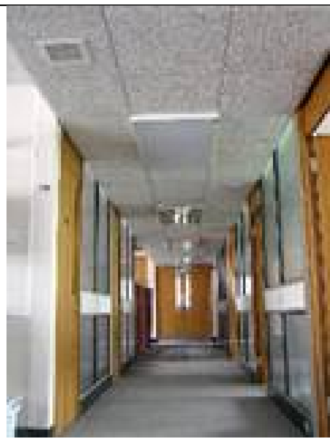
This paper investigates the issues surrounding the application of Asset rating on existing buildings and its compatibility with Operational Rating, but also with detailed simulation software. The presented research is part of UK Carbon reduction in buildings, CaRB, research project, http://www.carb.org.uk/.

The case study

The Building

The case study, Southgate House, is a typical narrow plan office building leased by De Montfort University and hosting the University Estates Department. It is built in early 1970 with floor area of 1280m^2 on 4 flours. The example building is one of the first buildings to be surveyed in Leicester for the CaRB project. Surveying is the essential part of CaRB project since good quality data on buildings and the energy they use is vital to understanding and reducing carbon emissions. The building images are presented in Figure 1.

Figure 1 Southgate building outside and inside corridor view

The building is five stories high. Typical stories are 11m wide and 27m long with 3m between floor levels. The ground floor is largely open to the air, being a car park, with a small untreated entrance lobby, plus an electricity substation. Above the ground floor are four floors of office space, heated by hot water radiators and cooled by air. The air-conditioning system is Variable Refrigerant Flow, VRF, system. Two LTHW boilers using natural gas are used for the heating and hot water. Also heat recovery ventilators are used, one per floor. Since there was no available information on their type, it was assumed with certain level of confidence that they are plate type heat exchangers. Northern and southern facades are concrete without insulation. All external walls at ground level are concrete without insulation. Western and eastern facades are concrete with internal insulation. Twenty windows of 1.2m width and 1.8m high are mounted at west and east façade. The windows are single glazed with aluminum frame.

Southgate's building metered energy consumption for 2004 together with the UK design guide for offices, ECON 19, is presented in Table 1

Table 1 Building metered energy consumption and ECON Guide benchmarks

	Building metered energy use	**ECON 19 "Typical" building benchmark**	**ECON 19 "Good practice" building benchmark**
Gas	247.72kWh/m^2/year	178 kWh/m^2/year	97 kWh/m^2/year
Electricity	111.69kWh/m^2/year	226 kWh/m^2/year	128 kWh/m^2/year

According to the CIBSE energy benchmarks for office buildings, the Southgate building is as almost good as "good practice" category for electricity consumption and worse than "typical practice" for gas consumption (*, 2000).

Building Operational Rating

In the UK the Operational Rating is indroduced by Display Energy Certificates (DECs) scheme. A DEC is always accompanied by an Advisory Report that lists cost effective measures to improve the energy rating of the building. Display Energy Certificates are only required for buildings that are occupied by a public authority or an institution providing a public service to a large number of persons with a total useful area greater than 1000m^2. Display Energy Certificates are valid for one year. The accompanying Advisory Report is valid for 7 years. The requirement for Display Energy Certificates comes into effect from 1 October 2008. In the longer term, the UK Government has announced its intention to consult on whether this requirement should be extended to include private sector buildings occupied by commercial organisations where large numbers of members of the public regularly visit the building. Such an extension would be subject to separate legislation.

In the absence of national method, the EPLabel on-line web tool using UK national sets of parameters, (*, 2007), have been used to produce the Operational rating for the Case Study building. The results are presented in Figures 2 and 3.

Figure 2 EPLabel on-line tool results

Measured Energy Rating (MER)

Electricity

Delivered Energy Carriers	Supplied kWh/yr	Specials kWh/yr	Weather Correction kWh/yr	Supplied at Regional Climate kWh/yr	Ex Specials at Regional Climate kWh/yr	Energy Weighting Factor kg CO2/kWh	Total Weighted Energy kg CO2/m2/yr	Ex Specials kg CO2/m2/yr	Good kg CO2/m2/yr	Typical kg CO2/m2/yr
Grid electricity	*167175*	*0*	*0*	*167175*	*167175*	*0.568*	*74.184*	*74.184*		

Fuel/Thermal

Delivered Energy Carriers	Supplied kWh/yr	Specials kWh/yr	Weather Correction kWh/yr	Supplied at Regional Climate kWh/yr	Ex Specials at Regional Climate kWh/yr	Energy Weighting Factor kg CO2/kWh	Total Weighted Energy kg CO2/m2/yr	Ex Specialskg CO2/m2/yr	Good kg CO2/m2/yr	Typical kg CO2/m2/yr
Natural gas	*265781*	*0*	*0*	*265781*	*265781*	*0.194*	*40.282*	*40.282*		
Overall Total							**114.466**	**114.466**	**72.359**	**144.718**
MER Grade							D	(R = 0.79)		
MER Grade Ex Specials								D	(R = 0.79)	

Building Energy Use (BEU)

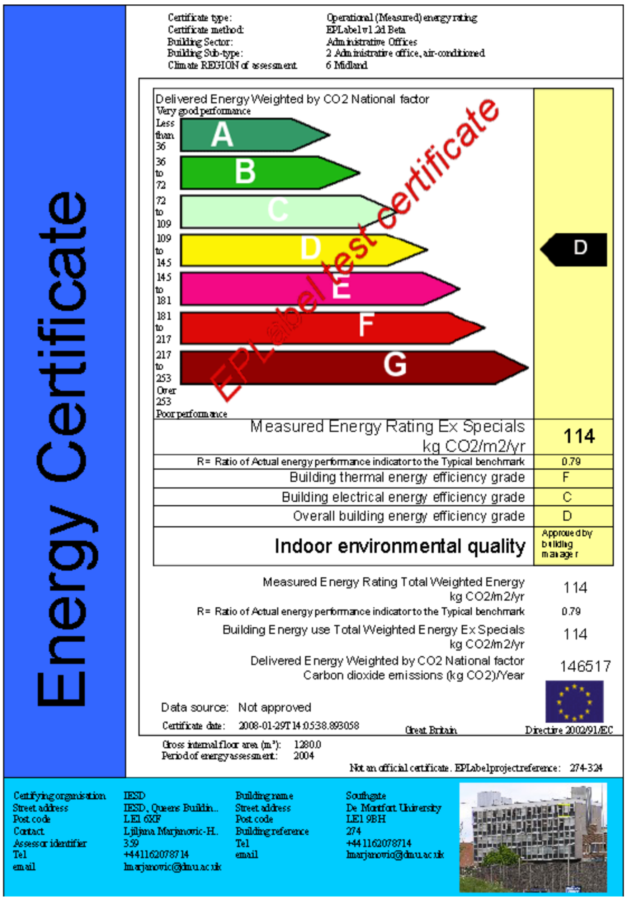
Electricity

All Energy Carriers	Supplied kWh/yr	Specials kWh/yr	Weather Correction kWh/yr	Supplied at Regional Climate kWh/yr	Ex Specials at Regional Climate kWh/yr	Energy Weighting Factor kg CO2/kWh	Total Weighted Energy ex Specials kg CO2/m2/yr	Good kg CO2/m2/yr	Typical kg CO2/m2/yr
Grid electricity	*167175*	*0*	*0*	*167175*	*167175*	*0.568*	*74.184*		
Total Electricity							*74.184*	*57.652*	*115.304*
BEU Electricity Grade							C	(R = 0.64)	

Fuel/Thermal

All Energy Carriers	Supplied kWh/yr	Specials kWh/yr	Weather Correction kWh/yr	Supplied at Regional Climate kWh/yr	Ex Specials at Regional Climate kWh/yr	Energy Weighting Factor kg CO2/kWh	Total Weighted Energy ex Specials kg CO2/m2/yr	Good kg CO2/m2/yr	Typical kg CO2/m2/yr
Natural gas	*265781*	*0*	*0*	*265781*	*265781*	*0.194*	*40.282*		
Total Fuel/Thermal							*40.282*	*14.707*	*29.414*
BEU Thermal Grade							F	(R = 1.37)	
Overall Total							**114.466**	**72.359**	**144.718**
BEU Grade							D	(R = 0.79)	

Figure 3 EPLabel Operational Rating certificate



If the results from the ECON 19 and EPLabel are compared it can been seen that both methods have indicated that the buidling gas consumption is “worse” than it’s electrical energy consumption. The overall Operation Rating of D can be considered a good result for at least 35 years old building bult in time when prcatically no buidling regulation covering non-domestic building stock in the UK has existed.

Building Asset Rating

The UK National Calculation Method (NCM) for the EPBD is defined by the department for Communities and Local Government (CLG). The procedure for demonstrating compliance with the Building Regulations for buildings other than dwellings is by calculating the annual energy use for a proposed building and comparing it with the energy use of a comparable 'notional' building. Both calculations make use of standard sets of data for different activity areas and call on common databases of construction and service elements. A similar process is used to produce an 'asset rating' in accordance with the EPBD. The NCM therefore comprises the underlying method plus the standard data sets. The implementation for the Asset Rating Certificates also comes into effect by October 2008.

The NCM allows the actual calculation to be carried out either by an approved simulation software, or by a new simplified tool based on a set of CEN standards. That tool has been developed for CLG by BRE and is called SBEM **-** Simplified Building Energy Model. It is accompanied by a basic user interface **-** iSBEM**.** SBEM is a computer program that provides an analysis of a building's energy consumption. SBEM calculates monthly energy use and carbon dioxide emissions of a building given a description of the building geometry, construction, use and HVAC and lighting equipment. It was originally based on the Dutch methodology NEN 2916:1998 (Energy Performance of Non-Residential Buildings) and has since been modified to comply with the emerging CEN Standards.

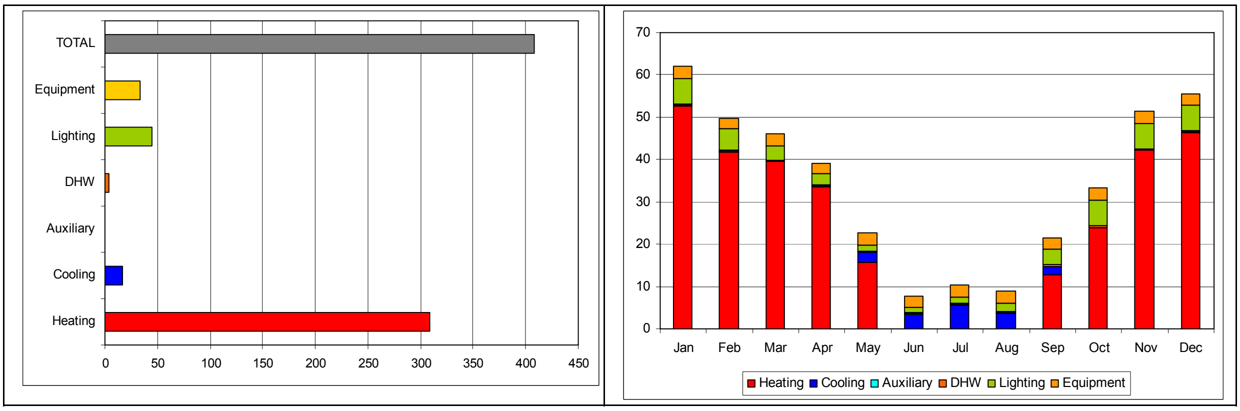
As already mentioned, for the existing building the issue of available design data is very important. Table 2 gives the listing of construction and glazing characteristics for the Southgate building according to SBEM database.

Table 2 Building fabrics characteristics based on SBEM

PROJECT DATABASE				
Name	**Generally used in walls that connect the zone to:**	**Construction from the library**		**U-value**
		Category	**Library**	**[W/m^{2}K]**
Walls				
External wall N/S	Exterior	Solid (masonry) wall	Solid concrete wall, uninsulated	1.7
External wall W/E	Exterior	Solid (masonry) wall	Cast concrete wall, internal insulation	0.83
Internal wall ground	Unheated adjoining space	Curtain wall	Curtain wall, pre-1981	2.3
Internal wall	Conditioned adjoining space	Curtain wall	Curtain wall, pre-1981	2.3
Roofs				
Roof	Exterior	Flat roof	Flat roof, pre-1981	1.8
Floors				
Floor	Underground	Solid ground floor	Solid ground floor, uninsulated	0.53
Floor ext.	Exterior	Solid ground floor	Solid ground floor, uninsulated	0.53
Floor internal 1	Unheated adjoining space	Solid ground floor	Uninsulated floor	1
Floor internal and ceiling	Conditioned adjoining space	Solid ground floor	Uninsulated floor	1
Doors				
Door		Personnel door	Uninsulated personnel door	3
Garage door		Vehicle access door	Vehicle access door, pre 1995	
Glazing				
Glazing		4 mm single glazing (clear glass)	Metal frame, thermal break, conventional glazing spacer, Aluminium window frame	5.264

In order to apply SBEM calculation engine, the building had to be zoned. Following SMEB zoning guidelines, each floor from 1st to 3rd was divided into two zones, west and east, while the fourth floor remained one single zone. SBEM HVAC systems Template dos not recognize the combination of systems existing in the Southgate building: boiler radiation heating system and VRF cooling system. To only way around this was to apply SBEM twice: first time as if the building has only radiator heating system and second time as if the building has only VRF system. The combined output is presented in Figure 4.

Figure 4 Buildings Energy end uses, SBEM results



The solution existing in the Case Study building, where the building is retrofitted with the air-conditioning system decades after it is built, is not un-common, especially for the heavily glazed buildings such as Southgate House. Considering the current limitation of SBEM that the building can have only one central system, it is difficult to see how this building can be certificated. The Asset Ratings for the Southgate House assuming only radiator heating or only VRF air-conditioning system are presented in Figures 5 and 6 respectively.

Figure 5 SBEM rating for radiator heating only with VRF system and with only

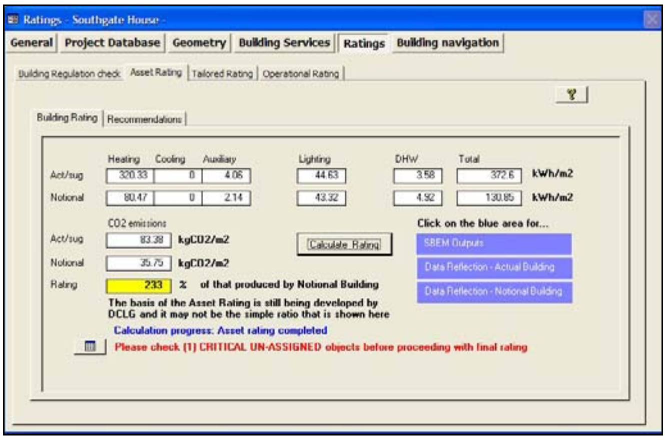
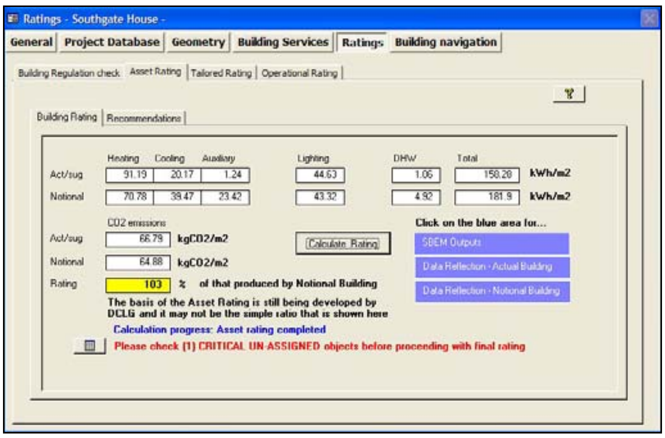


Figure 6 SBEM rating for VRF air-conditioning system only



One way to interpret these two certificates would be that the building can improve its energy efficiency in winter months when only radiator heating system is used, whilst in summer months, when the VRF system is used for cooling, is almost as energy efficient as notional building.

Detailed Simulation

The use of detailed simulation software will almost certainly be the way of providing Asset Rating for the new buildings when all of the design parameters are know. However it is of interest to explore how would detailed simulation software deal with the existing buildings when no design parameters are available. For these purposes the DesignBuilder detailed simulation software has been used. The survey information about the Southgate House translated into DesignBuilder parameters is presented in Table 3.

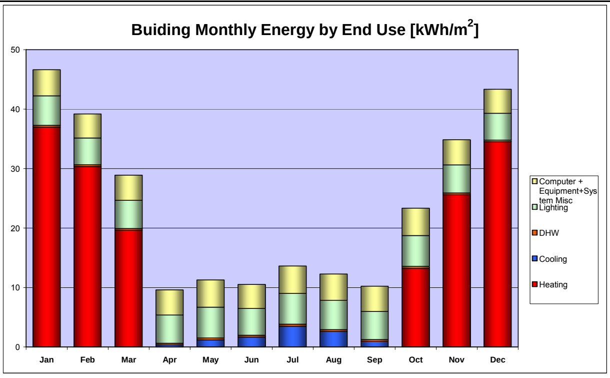
Table 3 DesignBuilder Building Fabric Inputs

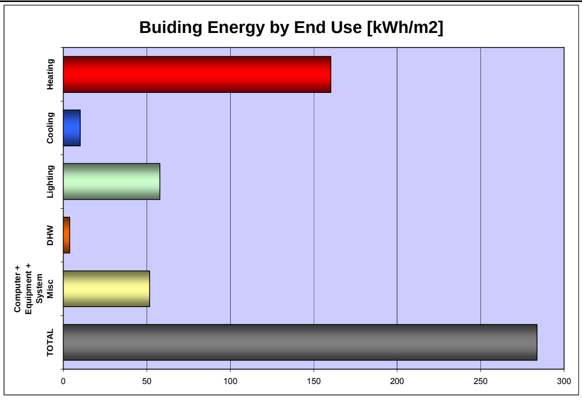
PROJECT DATABASE		
Name	**Description**	**U-value [W/m²K]**
External walls		
Southgate N/S	• Cast concrete − 200 mm	2.824
Southgate W/E	• Cast concrete − 30 mm • MW stone wool − 30 mm • Air gap − 10 mm • Gypsum plasterboard − 15 mm	0.831
Roof		
Flat roof	• Asphalt − 20 mm • Cast concrete − 200 mm	2.757
Floors		
Ground floor slab	• Concrete slab − 130 mm	3.058
Internal floor slab	• Concrete slab − 200 mm	2.652
Internal partitions		
Southgate − internal_ground	• Aerated concrete block − 200 mm	0.937
Internal partitions 1st ÷ 4th floor	• Light weight 2 x 25 mm gypsum plasterboard with 100 mm cavity	1.712
Glazing		
Single clear − 6 mm	• Total solar transmition (SHGC) − 0.81	6.121

Comparing the values in Tables 2 and 3 it can be seen that DesignBuilder is more conservative on building fabrics quality than SBEM.

The results obtained from DesignBuilder are given in Figure 7.

Figure 7 DesignBuilder results





The Asset Rating provided by DesignBuilder is presented in Table 4.

Table 4 Southgate House Asset Rating according to DesignBuilder

Summary	
Name	Southgate House
Date	30/01/2008
Building type	OFFICE
Treated Floor area	1279.34
Assessment type	4-EPBD Asset rating
Dimension	Inner
Calculation method	1-EnergyPlus
Climate base location	GBR_Finningley_IWEC
Heating degree-days	3116
Cooling degree-days	689
Output	
Actual building carbon intensity	79.95kg CO2/m2
Regulations compliant variant carbon intensity	59.31kg CO2/m2
Asset energy performance rating	1.3480
Class	**C**

Discussion

This paper investigates the issues surrounding the application of Asset rating on existing buildings and its compatibility with Operational Rating, but also with detailed simulation software as part of UK Carbon reduction in buildings, CaRB, research project. The case study is a typical narrow plan office building hosting University estate built in early 1970 with treated floor area of 1280m^2 on 4 flours. The methodology used for the Asset rating is UK national calculation methodology SBEM, while the detailed simulation program used is DesignBuilder. In absence of a UK national methodology for Operation rating, EPLabel software has been applied, although the building energy consumption has been compared with UK design guide for office buildings.

The Southgate House scored D Operational Rating using EPLabel web tool which can be considered a good result for at least 35 years old building with original boilers and retorfitted VRF air-conditiong system in the later stage of building life. Also that result is brodely speaking similar to buidling energy performance comparison with ECON 19 Guides, see Table 1.

Since SBEM gives Asset rating in percentages and not in letter scale it is difficult to compare the results for the Southgate House directly with the C Asset Rating obtained by detailed simulation software. It is possible however to compare the predicted annual carbon emission. Detailed simulation software predicted annual CO_2 emission of 80kgCO$_2$/m^2, Table 4. This result is similar when compared with the SBEM results of 83.38kgCO$_2$/m^2 and/or 66.79kgCO$_2$/m^2, Figures 5 and 6 respectively, suggesting overall annual CO_2 emission somewhere around 95kgCO$_2$/m^2. If the Asset Rating is interpret as building theoretical potential and Operational Rating as operational reality, the result would indicated that there is a room for improvement, but also that the gap should be relatively easy to close.

However, the significant differences in results can be compared when comparing energy end use breakdown, rather than it's comparison with notional building or benchmarks. The difference between detailed simulation software and SBEM prediction in Southgate House end energy use is given in Figure 7.

Figure 7 Building Energy End Use breakdown as predicted by SBEM (Figure 7a) and DesignBuilder (Figure 7b)

Figure 7a SBEM results

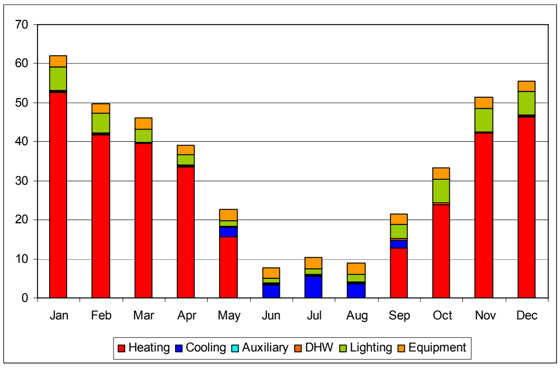
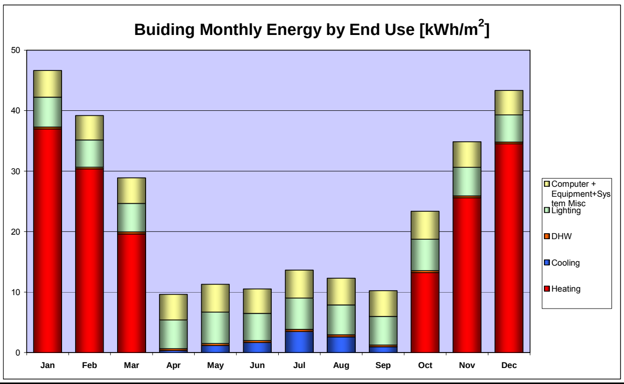


Figure 7b DesignBuilder results



Since the certificates should be accompanied with the reports and suggestions on how to improve the building performance, if the breakdown of energy end-use is not predicted or benchmarked reliably it is difficult to see how could report than point to real problems in building energy use. The modelling predictions were rather different for the annual fuel consumption too as presented in Table 5.

Table 5. Building annual energy consumption and CO_2 emission

	Metered energy consumption	**SBEM results**	**DesignBuilder results**
Gas	247.72kWh/m^2	312.2 kWh/m^2	164.06 kWh/m^2
Electricity	111.69kWh/m^2	100.1 kWh/m^2	119.72 kWh/m^2
CO_2 emission	114kgCO$_2$/m^2	≈ 95kgCO$_2$/m^2	80kgCO$_2$/m^2

When comparing different software tools it is usually of interest to comment on time intensities involved in their implementation. iSBEM, being a very basic user interface, requires a large amount of data about the building geometry to be calculated and entered manually. The calculation itself is fast. DesignBuilder is above all detailed simulation software which primary purpose is to be a design tool, whilst Asset rating is one extra feature it offers. As any established building design tool, it has user friendly interface allowing easy data input, but the execution time for Asset rating is naturally much longer than SBEM.

Conclusion

This paper investigates the issues surrounding the application of Asset rating on existing buildings and its compatibility with Operational Rating, but also with detailed simulation software as part of UK Carbon reduction in buildings, CaRB, research project. The case study is a typical narrow plan office building hosting University estate built in early 1970 with treated floor area of 1280m^2 on 4 flours. The methodology used for the Asset rating is UK national calculation methodology SBEM, while the detailed simulation program used is DesignBuilder. In absence of a UK national methodology for Operation rating, EPLabel software has been applied, although the building energy consumption has been compared with UK design guide for office buildings.

The results for the Operational Rating, D, and Asset Ratings, C, are rather consistent with the building reality and are also largely compatible between different tools used. However the values for absolute prediction between tools for both fuel break down and end energy use break down differ significantly. These significant differences suggest that great care and understanding must in employed while producing and interpreting building energy certification.

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