Meeting the current and future UK challenges for sustainable building designs – Case studies

Mei J. Ren [1] Matthew Cotton [1] Kate Brown [1] Garry Palmer [1]

[1] Advanced Design Group, Faber Maunsell, UK

ABSTRACT

This paper uses two case studies to illustrate the process of building design with due regard to sustainable construction and how the recent changes in legislations affect the way buildings are designed in the UK. Two real case studies cover housing and commercial office sectors. These case studies indicate that a performance based design approach exploiting building simulation offers a building with an improved indoor comfort, lower carbon emissions and added value to the client. Finally, this paper offers some insight into future developments of the UK legislations.

KEYWORD

Zero carbon, Part L compliance, energy benchmark, EPBD, renewable energy.

INTRODUCTION

Since the Energy Performance of Building Directives (EPBD) was published in 2003, the Building Regulations in the UK has undergone fundamental changes in recent years. Part L of the Building Regulations deals with “Conservation of Fuel and Power in buildings”. Faber Maunsell was commissioned by the UK government to carry out a comprehensive study of carbon and energy performance of building stocks in the UK. With input from various industry practitioners, Faber Maunsell published Building Regulation Part L consultation paper (ODPM, 2004), on behalf of Office of the Deputy Prime Minister (now renamed as the Department of Community and Local Government). The proposed new approach was to promote a holistic whole building performance based method to address buildings’ overall carbon performance.

A BRIEF REVIEW OF THE CHANGING UK LEGISLATIONS

Building Regulations

Part L 2002 of the Building Regulations allows three ways to demonstrate compliance of building design.

- Elemental method - primarily a “prescriptive” code with minimum U values and glazing areas being specified for building elements
- Whole Building method - applicable to certain types of buildings
- Carbon Emission method - a “performance based approach”. However, the method was not often chosen by the industry as a way to demonstrate compliance to Part L because of its complexity.

Recent studies show that there is a poor correlation between U values and overall carbon emissions (ODPM, 2004). The aim of the new Part L (2006), which took effect in April 2006, is to use legislation to reduce overall carbon emissions of the building industry. It uses a performance based approach to encourage a holistic design process. The concept is similar to the “Carbon emission” method of the old Part L but offers a simpler and more standardised calculation methodology, i.e. National Calculation Methodology. This is the only method to demonstrate compliance to Part L Criterion 1: Carbon Performance.

Demonstrating building design compliance to energy conservation of Part L 2006 is by means of showing that the overall carbon emissions of the proposed building are lower than a notional building of same size and shape designed to meet elemental method of Part L 2002 by an improvement factor, which is approximately 25%, depending on the type of the building. The improvement factor will likely to be further increased in the next revision of the Part L, possibly in three to five years time, in order to tighten the regulation even further.

Planning policies

Apart from the Building Regulations, government planning policies have a crucial role in driving sustainability to the main stream of building design. Increasingly regional and local authorities’ planning policies require sustainability statement to be submitted by the design team to support their planning applications for a proposed development. Within the Sustainability Statement, the following must be demonstrated:

1. To address energy efficiency measures so as to improve carbon performance beyond the minimum Part L requirement;
2. To demonstrate the use of on site renewable technologies and to indicate their feasibility;
3. To demonstrate that the development can achieve a "very good" BREEAM rating.

BREEAM stands for Building Research Establishment Environmental Assessment Methodology. It is one of the earliest methods of assessing environmental related sustainability of a proposed development. It covers areas of Carbon emission, Materials, Public transport, Ecology, Health and wellbeing, and Management. BREEAM has many versions for different building types and applications, including BREEAM for offices, Ecohomes for homes, be-spoke BREEAM for hotels and laboratories, etc.

Back in 2003, the Great London Authority (GLA) introduced its renewable energy policy. It requires that a proposed development must demonstrate that a renewable system on site contributes to 10% of the final site electricity demand. At present, a growing number of local authorities are asking for the renewable contributions from 10% to 20%, including Manchester, London, Sefton, and Leicester, etc. Renewable energy technologies include wind turbines, photovoltaic, solar thermal, absorption cooling using waste heat, ground source heat pumps, biomass heating and biomass Combined and Heat Power (CHP). Many local authorities encourage the use of CHP to provide community heating across developments.

Energy performance certification

The UK government is committed to implementing the Energy Performance of Building Directives, which was agreed within European countries in 2003. The UK government has set July 2007 as the deadline for the residential sector, when the Home Information Pack will be implemented with a declaration of carbon and energy performance of the dwelling. For public buildings, "Asset rating" will have to be displayed for a new built and also with "Operational rating" updated every year from April 2008.

At present, the detailed assessment methodology for "Asset rating" and "Operational rating" has not yet been fully developed and published by the government. The current anticipation is that the buildings will be assessed and benchmarked against a reference mixed mode building of a similar size. The following Figure 1 shows rating scales and an example building is benchmarked against the rating.

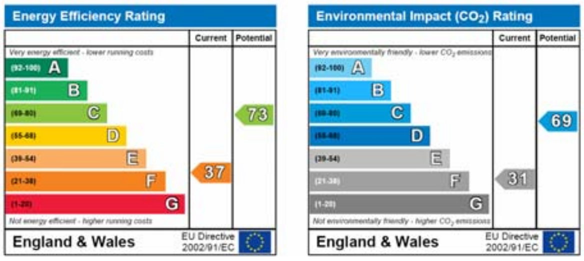

Figure 1, Energy Certifications

Code for sustainable homes

The UK's Code for Sustainable Homes was launched in December 2006 and is a direct replacement of the 'Ecohomes' assessment method for new domestic buildings in England. The key principle behind the code is a 'star rating' from one to six stars which will be used to demonstrate the environmental performance of all new homes.

The code contains a set of sustainable design principles across nine key categories including energy, water, materials, waste, etc. The crucial areas will have mandatory minimum targets (energy, water, materials, waste, and surface water, with the largest weighting given to energy/carbon). In order to achieve the best code level 6, each dwelling on the site must be 'zero carbon' (DCLG, 2007) and achieve the minimum fabric thermal performance.

The UK government recently introduced a new incentive for home buyers by offering stamp duty relief for "zero carbon" homes. This requires that the dwellings must not be connected to the mains gas supply in order to qualify for stamp duty relief (BN26).

The following sections use two recent project examples to indicate how the new legislations impact on the design and how designers adopt computer simulation to demonstrate the code compliance and in the meantime, advise the design team to maximise the sustainability within the site and the client's cost constraints.

CASE STUDY 1 – HOUSING

The UK housing sector is experiencing fast growing demand. The average house prices in the U.K. have tripled since the Labour government took office in 1997. About 180,000 homes were completed last year. The government has announced that it wanted to build 2 million new homes by 2016 and 3 million new homes by 2020, with construction 240,000 homes a year.

Energy use in existing housing represents 27% of the UK's CO2 emissions. The UK government has proposed plans to reduce carbon emissions from new homes to ***zero*** by 2016.

Definition of a ‘Zero Carbon’ dwelling (DCLG,2007) - **“Where net carbon emissions from ALL energy used in the dwelling is zero”.**

This includes the energy consumed in the operation of:

- Space heating
- Space cooling
- Hot water systems
- Ventilation
- All internal lighting
- Cooking
- All electrical appliances (TV’s, fridge’s etc)

Faber Maunsell has been commissioned to investigate and advise on a number of exemplar projects in order to set performance brief for private developers to build zero carbon homes. One of the examples was to assist the Northwest Development Agency working with English Partnerships to develop a brownfield site located in the north of England.

A key requirement is for the site to be developed to meet the Carbon Challenge. The Carbon challenge calls on developers to achieve the highest level (level 6) of the new Code for Sustainable Homes (DCLG, 2007) to demonstrate that zero carbon homes are economically viable on a commercial scale. These standards are likely to be adopted for all new dwellings by 2016.

The three key principles for developing a low energy / low carbon building development are (in order):

1. Reduce energy demands of individual buildings (adopt ‘passive’ design principles).
2. Meet outstanding energy demands using efficient technologies.
3. Supply energy for buildings from low or zero carbon technologies (LZC’s).

Where possible, developers should follow these simple yet effective steps in order to meet the minimum of code level 6 for all dwellings. Throughout the project, assessment has been carried out to investigate a range of design parameters.

Figure 3 indicates energy consumptions of a typical 3 bed (3 storey) home built to the 2006 standard, which may be compared to that shown in Figure 3 with significantly reduced space heating load.

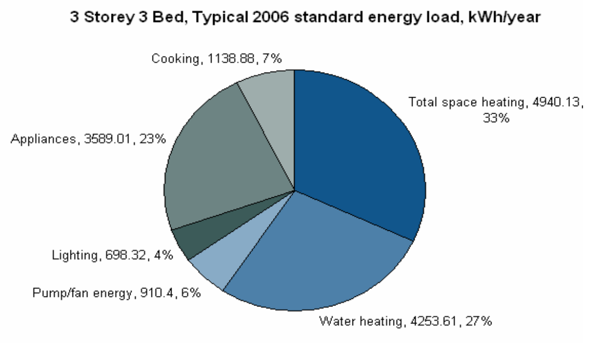

Figure 2: Predicted annual energy demand for a standard Part L compliant 3 bed house

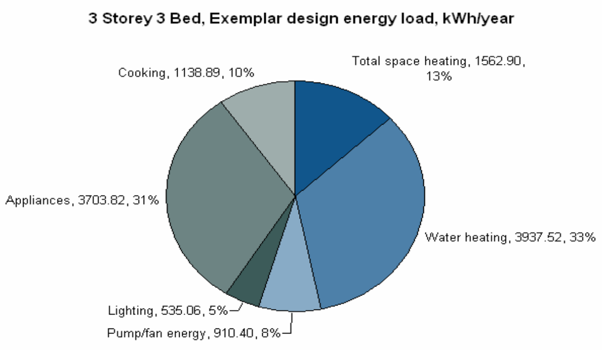

Figure 3: Predicted annual energy demand for an exemplar 3 bed house

As can be seen in Figure 2, there is a huge potential to reduce space heating energy consumption in homes. To illustrate the impact of passive design principles on dwelling energy demand, Figure 3 indicates the annual predicted energy consumed by a house that is built to the ‘Passivhaus’ (Passive House Institute) standard required to meet Code level 6 (zero carbon). The ‘exemplar’ home has an energy demand approximately 25% less than the equivalent ‘compliant’ home.

Standard Assessment Procedure software (SAP) has been used to carry out a series of parametric studies, including orientations, glass ratios, building element U values, and services strategy to assess code compliance and carbon performance. SAP is an empirical computer model and was initially developed based on Building Research Establishment Domestic Energy Model (BREDEM), which provides a framework for the calculation of energy use in dwellings. It has been recently updated to align with the changes in legislations and new technologies in the domestic sector.

In order to minimise energy demand for a dwelling, the following are the key recommendations:

- Whenever possible, orient longest building elevation to the south,

- Heat loss parameter (HLP) must be less than 0.8W/m2K required to achieve Code level 6. U value of windows must be less than 0.8 W/m2K and air leakage less than 1m3/m2/hr @50Pa.
- Adopt passive natural or whole house ventilation with heat recovery,
- Maximise daylight in rooms with high daylight occupancy such as lounge,
- 75% of the internal light fittings should be dedicated and energy efficient,
- Select energy efficient White Goods
- Use shading on the south to block high angle summer sun,
- Wherever possible, adopt cross ventilation with open accommodation,
- Specify high thermal mass materials that can reduce peak summer temperatures.

By adopting the aforementioned recommendations, energy load will be dramatically reduced. The second step is to use energy efficient systems to meet the outstanding demand, i.e. water heating, lighting, cooking and appliances, etc. The third step is to adopt renewable energy technologies to offset carbon generated by the development. A number of systems have been considered, including:

- High efficiency condensing boilers with solar hot water
- Wind turbines
- Photovoltaic (roof mounted)
- Biomass heating (community heating)
- Biomass CHP (community heating)
- Fuel cells (tri-generation)

The following formula have been used to calculate the renewable contribution required in order to provide a development carbon neutral, i.e. carbon emission rates produced by the development must be offset by the total carbon savings offered by the renewables.

Qelec * 0.568 = C space heating + C water heating + C lighting + C fans+pumps + C appliances+ cooking

Note:
Qelec is electricity generated by renewables (kWh/year);
0.568 is carbon emission conversion factor of electricity generated by renewables (kg CO2/kWh);
C space heating, C water heating, C lighting, C fans+pumps, C appliances+ cooking are CO2 emission rates (kg CO2/year)

Results of the assessment show that for a large scale housing development, the following two options may be potentially the most viable solutions to achieve zero carbon:

1. For the site with potentials of wind energy, a large scale wind turbine can be installed. This would allow all the dwellings of the development to use electric heating and electric hot water generation.

   For a development with 300 homes, a large turbine with a 2MW rating is required to generate the amount of electricity and offset the carbons produced by electric heating, hot water and lighting and appliances. Installation of such a large turbine usually requires a planning permission and consideration of the potential impact of noise and vibration from turbine blades, mechanical components and any linked structures. Therefore, this energy option is site dependent and is not universally applicable to each development.

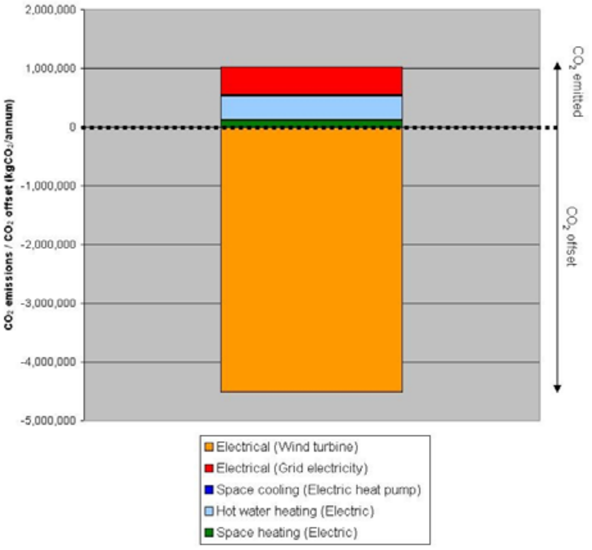

Figure 4: Annual carbon predictions for the development, with wind turbines

Biomass CHP energy centre with PV array could potentially be adopted for many large scale development, where there is no shortage in biomass fuel supply in the relevant regions. For a 300 homes development, such a biomass CHP plant using either woodchips or pellets would be 400kW in order to offset the carbons. The plant would require 60m2 and 4m high fuel storage space, and an overall 300m2 to locate CHP plant and backup boiler. In order to reduce peak demand on CHP and boilers, a buffer-tank is recommended.

In order to offset carbon emission further to net zero, additional renewable energy generation is required. Photovoltaic panels mounted on dwelling roof would be the best option. It has been calculated that 6m2 PV array per dwelling facing south orientation (assumes mono crystalline silicon panels) is required.

With biomass heating, careful considerations of fuel supply and storage must be designed into the operation of the buildings. In summary, woody biomass fuel such as thinnings and trimmings from woodlands, untreated wood products, energy crops such as rotation coppice, etc, should have sufficient supply in the UK. A key benefit of woody fuel is that the energy expended in growing them is much less than that released when they are burnt.

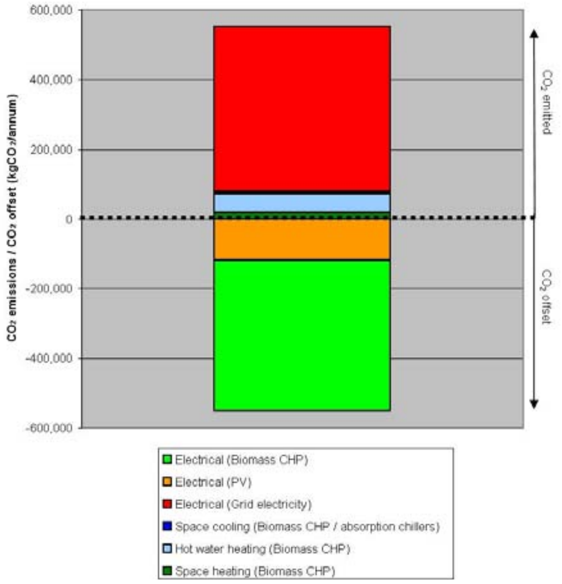

Figure 5: Annual carbon predictions for the development, with biomass CHP and PV

One of the interesting findings is that if a biomass CHP is used, there would be less incentive to reduce heat loss and improve fabric insulation to a “Passivhaus” (Passive House Institute) standard, because the CHP unit will produce substantial waste heat. CHP size is often restrained by the heat demand of a development.

In conclusion, the recommended design solutions in this case study can be commercially viable and can also offer an affordable and user friendly home environment with minimal environmental impact.

CASE STUDY 2 – COMMERCIAL OFFICE

A large proportion of commercial offices in the UK have been designed to BCO (British Council for Offices) standard. The BCO (2005) embraces some elements of sustainability issues, such as BREEAM Very Good or Excellent ratings. Most speculative office developments are fully sealed buildings serviced with 4 pipe fan coils to provide heating and cooling, and also using perimeter radiators or trench heating to offset fabric heat loss. In recent years, more and more buildings are adopting chilled beams to service a speculative office. Apart from low maintenance compared to a fan coil system, chilled beams often result in energy savings of approximately 10-20% due to less fan power required and additional benefit of radiant effect in reducing cooling demand.

Some headquarter type of office buildings have been designed with low carbon solutions. These buildings often involve the client and end user’s detailed project brief for the design team to work upon and their commitment to deliver a sustainable office building. A typical example is to use mixed mode strategy (Arnold, 1998)(CIBSE, 2000). This case study presents an example of a project where building simulation has been utilised to identify energy savings for the client in procuring a highly energy efficient building versus a standard speculative office development.

The following image indicates the 3D model of the proposed building using IES (IES Ltd). This building with 10,500m2 net floor area, is used as an example to compare the running costs, energy performance, and code compliance.

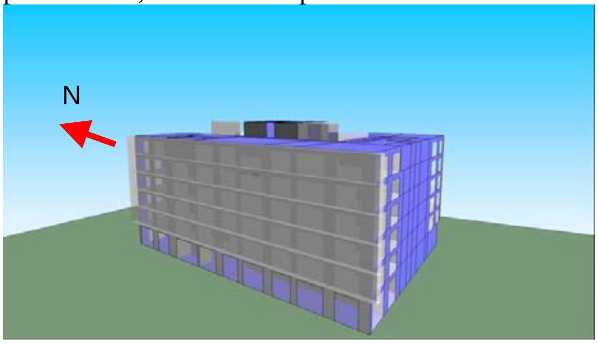

Figure 6: 3D model of building

Two types of building design have been modelled and assessed:

- Fully sealed, standard speculative building serviced with fan coils, referred to as “standard” case. Throughout the façade, a soft coated low E glass is assumed, with shading coefficient of approximately 65%.
- Mixed mode system with night cooling, ventilated double skin façade on the west orientation due to traffic noise, active chilled beam, referred to as “mixed mode” case. The middle glazing panel of 1m high is assumed to be openable by 350mm controlled by temperatures. In this case, the window opening strategy is:
  - ➢ When the internal temperature is above 21°C AND the external temperature is above 12°C, windows are open;
  - ➢ Windows will be closed at 24°C / 25°C internal temperature, and the

chilled beams then operate to meet the cooling load.

- At night, windows will be open when the internal temperature exceeds 20°C.

The mixed mode system uses natural ventilation whenever possible. At peak heating and peak cooling seasons, the windows/vents are closed and the mechanical ventilation and comfort cooling systems are used to meet the ventilation and cooling load of the perimeter office spaces. During the transitional seasons, which could be many months for the UK temperate climate, windows are open to provide ventilation and cooling.

Figure 7 shows that for a typical day in summer, depending on prevailing wind condition, excessive ventilation will sometimes occur in the corner room where windows are located on the two adjacent facades. For a standard perimeter room of 6m wide, sufficient ventilation can be achieved. However, for the rooms with double skin façade, when the internal windows are open, it is unlikely that natural ventilation can provide sufficient fresh air to the office perimeter zone due to reduced wind pressure as the driving force. In most cases, mechanical ventilation is required to supplement the fresh air supply to the office with the double skin façade.

As it currently stands, the client is not prepared to install solar shading within the double skin cavity for the building. It is estimated that with the solar shading such as blinds, cooling demands can be reduced upto 25% or more.

Modelling studies have been separated to two categories to compare performance of the "standard" case versus mixed mode design:

1. Energy benchmarking - compare with industry standard;
2. Part L - carbon performance

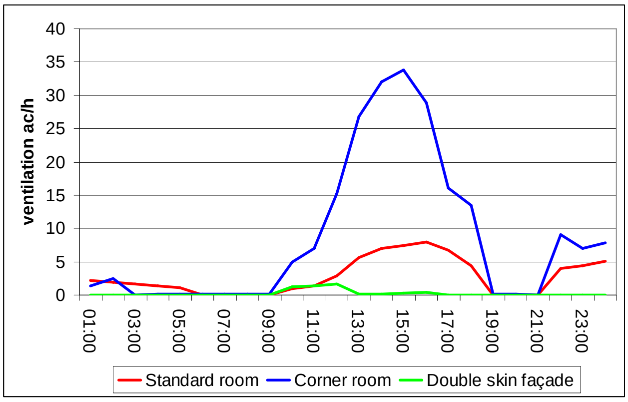

Figure 7, Mixed mode – ventilation rate

Energy benchmarking

Based on the agreed internal load with the client, it is estimated that a cost saving of up to £25,000 would result from using the mixed mode strategy, assuming a gas price of 2.5 p/kWh and an electricity price of 8 p/kWh. The annual cost savings increase with the constantly rising electricity cost. The following graphs (Figure 8 and Figure 9) indicate the energy breakdown of the two cases against ECON 19 (Best practice programme, 2000) "Good Practice" Prestigious regional headquarter.

In absence of real data of Computer room/IT load, Other electricity, Catering (gas), Catering (electricity) for the new building, data from ECON 19 were used.

It is noted that the predicted running cost of Case 1 standard building design is only marginally lower than the ECON 19 Good Practice benchmarking. Fan energy is higher than "Good Practice". This is because the projected occupancy advised by the client and used for the energy modelling for both Case 1 and Case 2 is 6 m2 per person; this is higher than the industry average occupancy density, i.e. 8 to 10 m2 per person occupancy density.

The mixed mode system can offer upto 26% CO2 reduction in services systems (reducing carbon emission rates of service systems from 49 kg CO2/m2/year to 36 CO2/m2/year including heating, cooling, fans and pumps, and lighting), or an overall 11% CO2 reduction in total energy consumption of the building.

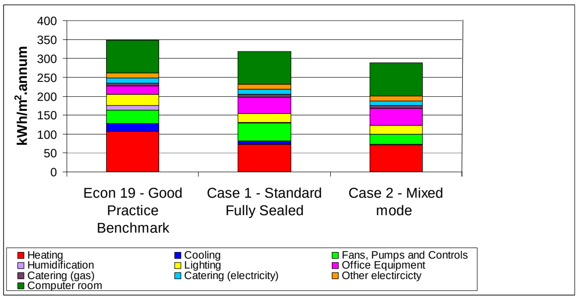

Figure 8, Energy consumption comparisons

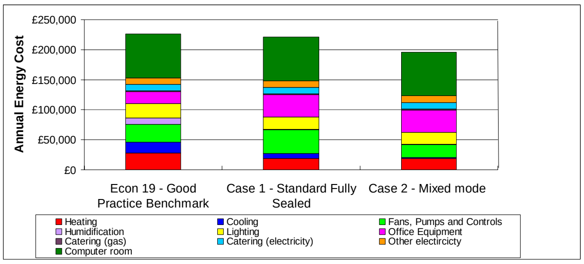

Figure 9, Running cost comparisons

Part L 2006

Whilst for energy benchmarking, the building simulation and analysis was based on the anticipated building operational profile for energy prediction, Part L model uses pre-determined operational profiles stipulated by National Calculation Methodology (NCM).

This concept works in most cases for applications where the anticipated internal loads in the proposed building are similar to the fixed internal load profiles of the selected building types. At present, limited building types have been developed including offices, educational buildings, schools, telephone exchange, retail, healthcare, hotel, airport, warehouse, prison, and laboratory, etc.

The main aim of the new Part L methodology is to drive mainstream building energy efficiency. For the buildings where the internal loads differ significantly from the fixed profile, Part L does not necessarily lead to an energy efficient building. For instance, for a studio space, the internal load of the space according to Part L NCM is 40-50W/m2, but the real load for the studio space could be in the range of 100-200W/m2. In this case, design of the real building should focus on adopting the most energy efficient way to reduce cooling load, and building fabric may have limited impact on the proposed building's carbon performance. However, the benefit of adopting low energy cooling system is not correctly accounted for in the Part L model because it will predict a much lower cooling load. Therefore, in some cases, the Part L model could differ from the real building operational performance significantly. Currently, these teething problems and difficulties are recognised by the government and more building profiles will be revised, refined and extended.

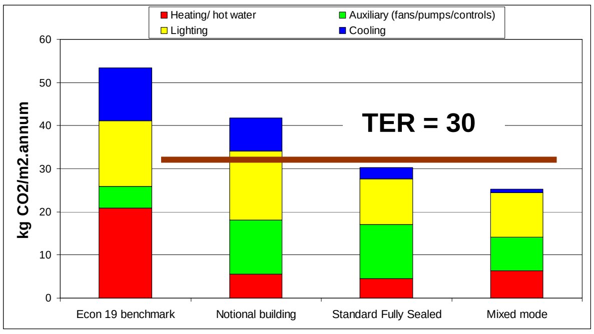

Figure 10, Part L results

Part L 2006 uses an average of 25% CO2 reduction in the notional building as the minimum standard, i.e. Target Emission Rate (TER) (DCLG, 2006). Part L may be revised again in five years time when a further 25% reduction is required. Therefore, some of our clients have set the environmental target to be future "Part L proof". In addition, some local authorities request a building planning application to demonstrate 25% improvement over Part L 2006 (Manchester, 2007). Currently in the UK, targets set by planning policy tend to lead the way ahead of the building regulations.

Figure 10 indicates that the standard fully sealed case just meets the Part L minimum requirement. The mixed mode building can achieve 10% improvement beyond the Part L standard. This could potentially increase to 15% when the heating load is reduced by refining the control temperatures of the window openings particularly in the early morning hours due to night cooling operation. However, without using renewable and low carbon technology, mixed mode systems with energy efficiency measures alone could not provide a total of 25% improvement over Part L standard. Opportunities of reducing carbon emissions further are examined as below:

1. Lighting energy consumption contributes to one of the largest proportions of building carbon emissions. The proposed building has been incorporated with efficient lighting fittings and daylight control. It would be difficult to significantly reduce carbon emissions of lighting system further, unless LED is used for offices;
2. Cooling energy consumption is reduced to minimum by using mixed mode strategy;
3. Fan power is almost cut by 40% using mixed mode compared to the notional building;
4. There is little scope to reduce heating energy further. Efficient heat receovery unit has been used in AHU to reduce fresh air load. In order to reduce heat loss, possible solutions are to increase insulation levels, using triple glazing, and reduce air leakage.

As explained above, it is difficult to design an office building which is future "Part L proof", i.e. 25% improvement over Part L 2006 without adopting low carbon or renewable systems. By using ground source heat pumps or biomass CHP, in conjunction with the aforementioned energy efficiency measures, the building can achieve an overall 25% beyond Part L 2006 minimum standard. With any renewable system, caution must be given to its suitability for a scheme. For instance, in order to maximise economical viability for a ground source heat pump system, heating and cooling load should be ideally balanced throughout the year and ground source, e.g. ground water/aquifer or soils are not affected by abundant heat or "coolth" accumulated over years of operation.

In terms of room temperature, the Part L NCM uses pre-fixed set points, i.e. 22oC ± 2 oC dead band. Such fixed setpoints would potentially limit the opportunity for natural ventilation. For instance, if the building owner is prepared to adjust cooling setpoint higher to 26oC, the reduction in carbon emissions due to this effect is not taken into account in the Part L assessment. The intention is to set a common ground to compare the performance of building envelope and HVAC plant. In the future, operational rating will need to be updated every year and the impact of room setpoints, plant part load efficiency, etc on the building operational performance will be reflected on Energy Certificate.

In conclusion, Part L 2006 arrived with a good step forward taking the mainstream building towards sustainable low carbon design. There are still many teething problems to be resolved, in particular, with regards to the pre-fixed building profiles with fixed air load stipulated by National Calculation Methodology.

CONCLUSIONS

This paper uses two project examples, a housing development and a commercial office building, to illustrate the recent changes in the UK legislations and how designs of such buildings can meet the challenges brought by the legislations.

In housing sector, the zero carbon policy will bring more and more well insulated homes with biomass boilers, biomass CHP as well as turbines and PV.

In the commercial sector, planning policies, building regulations and other policies are all having major impact on the design of buildings. By adopting energy efficiency measures, it is reasonably easy to meet the Part L 2006 requirement. However, it can be very difficult to achieve a further 25% improvement over the Part L standard by adopting energy efficiency measures alone. Low carbon and renewable systems are likely required to reduce the carbon emissions further. It is anticipated that gradually these technologies will become the industry norm, moving the mainstream buildings towards substantial CO2 reductions.

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