The Learning and Skills Council

Zero Carbon FE Colleges Policy Framework

A Route to Zero Carbon FE Colleges

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24 June 2008

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Executive summary

Background

The Climate Change bill of 2007 sets challenging targets for carbon emission reductions for the UK. In the building sector, legislation is moving fast to try and meet these targets. During the compilation of this report the Government announced that by 2019 all non domestic new buildings should be built to be zero carbon. In an attempt to keep pace and even lead in this fast moving area, the Learning and Skills Council (LSC) commissioned Arup to review the Further Education sector in terms of its carbon emissions and produce recommendations from which a Policy Framework could be developed that encourages FE colleges applying to the LSC for funding to design and operate zero carbon buildings.

Original Scope

The key issues considered in this project were as follows:

1. Define zero carbon colleges with respect to relevant Government policy
2. Identify the key elements within a college which principally define its carbon emissions
3. Establish to what degree such elements need to be changed in order to define a college as zero carbon
4. Identify design, construction, operational techniques and procurement mechanisms that will achieve such changes including the identification of significant barriers to the achievement of a zero carbon college
5. Examine these techniques and mechanisms to establish the cost implications and consequently the pace at which each should be driven through the LSC capital works programme
6. Prepare a policy framework based on these studies

The key findings of the work and the recommendations that followed are summarised here, with more details on the recommendations being given in Section 9.

Key Finding: Definition of Zero Carbon FE College

To fully define a zero carbon Building, definitions are needed for the emissions that are to be included within the energy demand and the Low and Zero Carbon (LZC) supply solutions that are to be permissible to provide that energy. The emissions were considered in terms of a net annual zero carbon building balance.

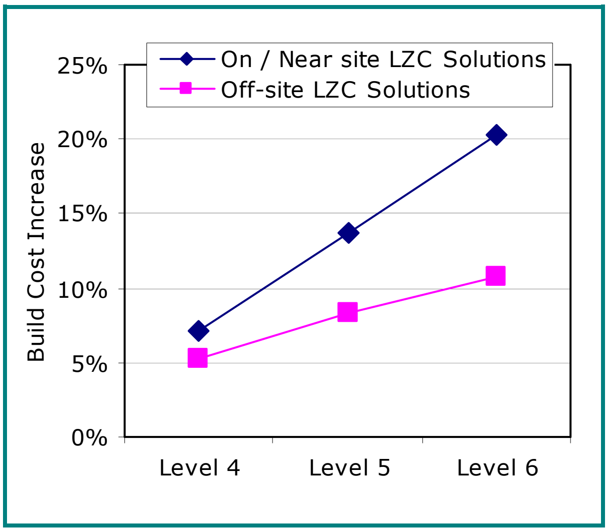
	Energy Demand	Supply Solutions
Included	Regulated Occupant In-use?	On-site Near-site Off-site
Excluded	Embodied Transport Emissions	Offsetting

Existing definitions were used as a starting point and were examined for completeness and practicality. The final definition differs from the existing in some important ways.

It is proposed that off-site energy generation is allowed and procurement models are suggested to allow this to be sufficiently regulated. In addition, a mechanism is proposed that would allow the inclusion of actual “in-use” energy figures as opposed to relying on those predicted at the design stage.

More detailed information can be found in section 3 of the report.

Key Finding: The Cost of Zero Carbon



The cost increase of a zero carbon college over a standard building has been calculated. The costs were found to be dependent on the definition of zero carbon used.

If existing definitions are used with the supply limited to on- and near-site equipment, the cost increment is of the order of 20%. This increment is split roughly evenly between the cost of minimising demand and that of decarbonising the energy supply.

If off-site energy generation systems are included in the definition then the cost decreases significantly.

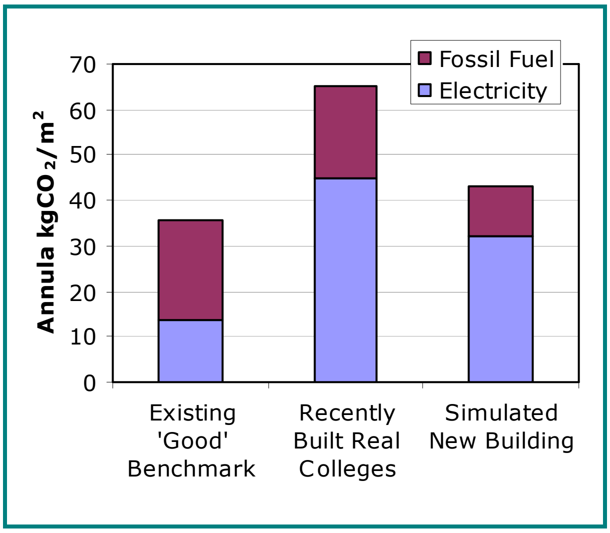
More detailed information can be found in section 7 of the report.

Key Finding: Updated Benchmarks Required

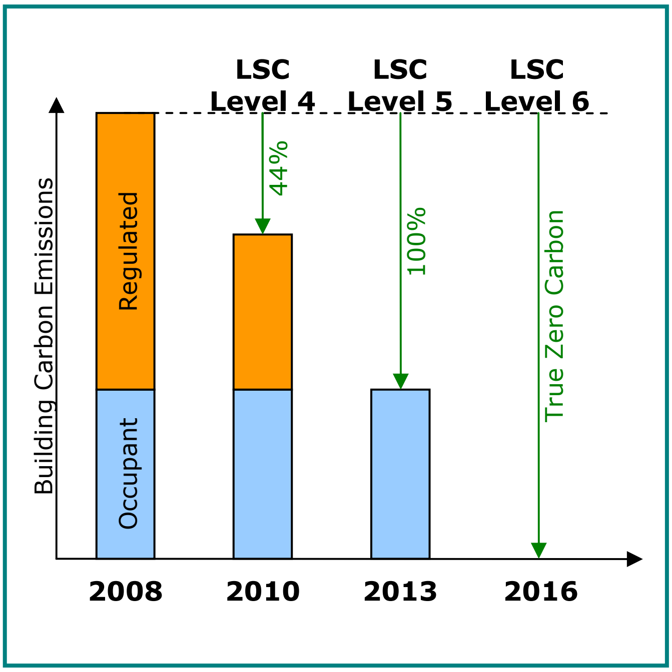
Benchmark energy consumption figures relating specifically to the FE sector have been found to be based on old information. Most existing benchmarks are derived from data collected in the mid-90's.

The benchmarks were found to have little correlation with either real-world data collected via the LSC's eMandate process or with the emissions simulated for a new college building. In particular, the balance of emissions between electricity and fossil fuels shows large discrepancies.

More detailed information can be found in sections 4 and 5 of the report.



Recommendation 1: Trajectory to Zero Carbon



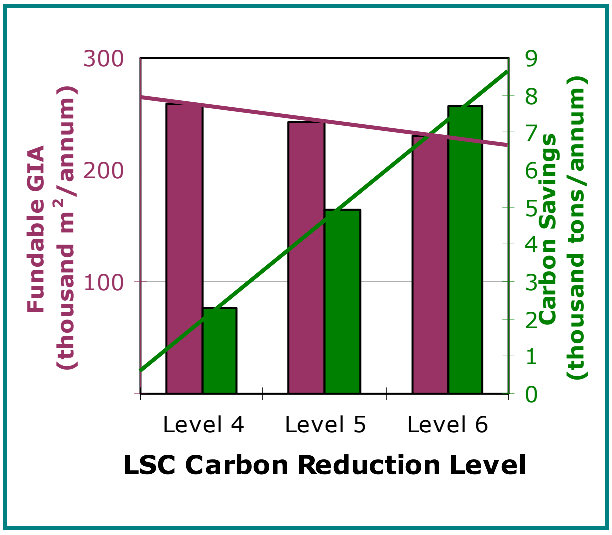
The LSC has already stated its ambition for all new college buildings to be zero carbon by 2016. It is recommended that a trajectory of gradually changing mandatory requirements is adopted in advance of this date. This will have the benefits of reducing emissions prior to 2016, gradually increasing the requirements on the design and construction sector and providing clear and foreseeable targets.

The interim carbon emissions levels are based on the levels of reductions defined within other sectors and the levels have been named to align with other sectors to promote consistency. The term 'LSC level' has been adopted to differentiate between the Code for Sustainable Homes levels which include factors other than just the carbon emissions that have been considered in this work. The interim dates are aligned with proposed amendments to the Building Regulations.

Recommendation 2: Incentivise Low Carbon Design

Prior to a level of carbon reduction being made mandatory by the trajectory, a college embarking on a new building program can choose which level to target.

In general, the cost of a building will rise as the carbon emissions fall. As the cost of buildings rise, the funding ability of the LSC's fixed budget falls (in terms of gross internal floor area (GIA) of college fundable). It was found that, despite this reduction in funding ability, the largest emissions reductions arise from the building of zero carbon (LSC level 6) colleges.



Therefore the second recommendation is that the LSC incentivise buildings at the higher LSC levels. This will maximise the emissions reductions prior to the 2016 target and has the additional benefit of further increasing the learning within the FE college design and construction industry by encouraging the building of exemplar projects.

The proposed mechanism is that of increasing the proportion of capital funding available as the LSC level increases. This would result in the LSC funding a larger proportion of the costs of reaching a higher level thereby reducing the burden on the college of funding the increased costs. The level of the funding can be adjusted to alter the amount a college must fund for an increased LSC level.

Recommendation 3: Prioritise Demand Minimisation

The capacity within the UK for the generation of Low and Zero Carbon (LZC) energy is not unlimited – in any one year there is a finite quantity available.

With the Schools, Domestic and possibly the FE College Sectors aiming for zero carbon in 2016 and the wider non-domestic sector following closely behind in 2019, the demand on the UK renewables capacity will increase dramatically.

Whilst it is important that buildings contribute to this capacity by including on-site generation where feasible, it is more important that they first reduce their energy demand down to a realistic minimum prior to looking to a low carbon energy supply to reduce their carbon emissions.

It is therefore recommended that a structure of mandatory demand minimisation techniques be incorporated into the LSC levels for carbon reduction. These techniques should encompass the building fabric, installed equipment and services and the behaviour and awareness of the occupants. To address these aspects, a set of criteria have been developed in draft form that may form the basis of a structured approach to comprehensive demand minimisation. The criteria become more stringent and numerous as higher LSC levels of emissions reduction are aimed for.

Recommendation 4: Allow Off-site LZC Generation

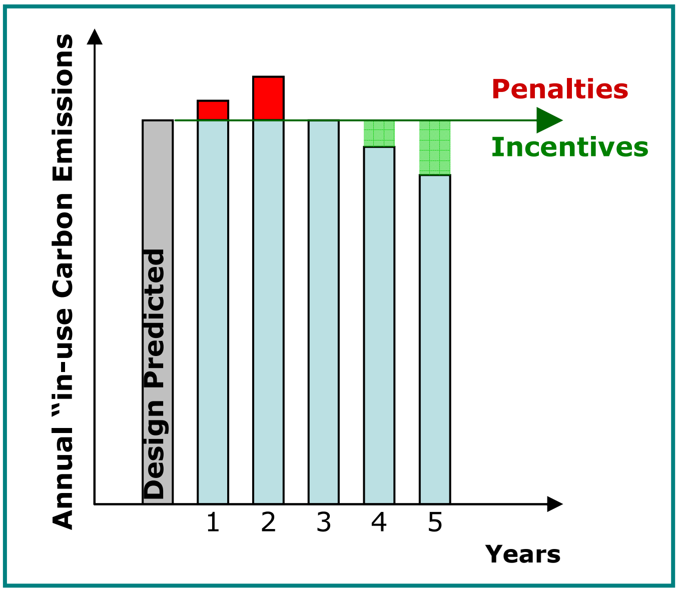
It is likely that in the case of FE colleges, and more widely among the non-domestic building sector in general, it will not be possible to generate sufficient LZC energy through on-site and near-site technology to meet the entire building's demand. This is irrespective of the extent of demand minimisation.

This study has confirmed that off-site LZC generation supplied via the National Grid will be required and it is recommended that a mechanism to robustly deliver this is set up. A number of procurement models are discussed in the report and it is those that include either the setting up of a consolidator body or entering into a partnership with an Energy Services Company on a national or regional basis that will allow the most effective procurement of off-site LZC electricity.

The detailed structure of any procurement method will have to be reached as part of a further collaborative piece of work with the LSC, addressing how the model options align to its overall strategy and remit.

It is recommended that significant emphasis is placed on the development of a structure that will result in the guaranteed and transparent additionality of off-site LZC generation capacity.

Recommendation 5: Zero Carbon 'in-use' Colleges through Annual Funding



Existing methods of evaluating the carbon emissions of a building with a view to creating a zero carbon development have relied solely on the carbon emissions predicted at the design stage using various tools. There is no guarantee that the actual in-use emissions will be the same as the predicted emissions and therefore no guarantee that a building in use is zero carbon, even if it is labelled as such. The only way to create a true zero carbon development is to monitor the energy use and carbon emissions regularly and to ensure emissions are net zero over each and every year.

It is therefore recommended that the LSC consider the use of in-use energy consumption figures to ensure the predicted reductions in carbon emissions are delivered in reality. If this approach is combined with the establishment of an energy procurement structure incorporating an active consolidator then the possibility is opened up of using a college's annual funding stream to fund the procurement of LZC energy. This would, however, need careful alignment with the preferred procurement method of direct capital funding.

Recommendation 6: Expand Scope of eMandate

The information on energy consumption collected by the LSC to date has been invaluable. It has helped identify current trends in energy use within the sector and has been used within this report to asses the accuracy of existing published benchmarks and software predictions.

The data currently collected by the LSC eMandate system breaks energy usage down by fuel type. This, along with other useful details of the colleges gives broad indications of energy usage in colleges but has limited use in identifying areas where energy savings could be made by individual colleges. It would be a natural progression for the eMandate process to assist individual colleges in targeting areas of high energy consumption.

Increasing amounts of data are generally required for more reliable evaluation and targeting of energy use. For the eMandate process one of the most useful refinements would be the collection of data relating to energy by end use. All colleges built since 2002 should have an element of sub-metering as required by Part L of the building regulations.

A second useful area of refinement relates to understanding energy use of individual college's year on year. This information would assist in generating energy targets for individual colleges and up to date benchmarks for the sector as a whole. In addition to the above it is recommended that the LSC use the eMandate data to record each colleges annual "in use" carbon balance.

Following the collection of more comprehensive data, increased analysis needs to be performed on the statistics relating to energy to ensure full use is made of the information.

1 Approach and Structure

1.1 The Scope

The Learning and Skills Council (LSC) have commissioned Arup to develop a policy framework to enable them to target and measure the carbon performance of proposed Further Education (FE) college developments and refurbishments. The aim of this policy is to define the requirements and expectations of the LSC with respect to carbon emissions of FE colleges applying for funding.

The key components of this study are as follows:

1. Define zero carbon colleges with respect to relevant Government policy
2. Identify the key elements within a college which principally define its carbon emissions
3. Establish to what degree such elements need to be changed in order to define a college as zero carbon
4. Identify design, construction, operational techniques and procurement mechanisms that will achieve such changes including the identification of significant barriers to the achievement of a zero carbon college
5. Examine these techniques and mechanisms to establish the cost implications and consequently the pace at which each should be driven through the LSC capital works programme
6. Prepare a policy framework based on these studies

1.2 Format of report

The report format is structured as follows:

Introduction

Introduction to the project and summary of the drivers for the LSC in commissioning this piece of work.

Definition of zero carbon

This section details the definition of zero carbon used for this framework. Existing definitions are considered and it is concluded that a zero carbon FE college would be required to demonstrate that its net carbon emissions produced over a year were zero. This could be achieved using low and zero carbon technologies located on-site, near-site or off-site where additionality could be demonstrated. The energy uses included in this definition are also defined and the option of targeting actual energy in use is discussed.

Existing building data gathering
Sets out the energy data gathered from existing colleges.

To be able to demonstrate that a college is zero carbon the annual energy by end use needs to be identified so that demand reduction can be addressed in the most cost effective manner and the residual energy demand can be predicted. Data collected from existing colleges was reviewed to establish a pattern of energy consumption.

Building modelling
This section summarises the conclusions of carrying out dynamic thermal modelling of five college scenarios. These scenarios were used to review the impact of improvements in fabric and air tightness as well as comparing energy use predicted at design stage with real energy usage of existing colleges. The scenarios were then used to test the method of calculating and demonstrating a zero carbon college at the design stage.

Achieving zero carbon

This section sets out the various options colleges may use to achieve low and zero carbon (LZC) college development and an outline of some of the potential energy provision models that could be used to supply energy, and possibly other utility services to colleges.

The section is intended to highlight the possible toolkit of contractual arrangements for the provision of a variety of utility services and associated business models the LSC could construct to enable colleges to achieve zero carbon.

The detail of these contractual arrangements is not intended to be the subject of this section and a more detailed study would need to be undertaken to progress a toolkit of delivery models and typical contracts that could then be rolled out nationwide.

Costing zero carbon

This section provides analysis of the costs involved in achieving levels towards zero carbon for new colleges. A number of demand reduction design limits were costed and applied to the five college scenarios. By modelling their annual energy demand with these design limits it was possible to estimate a total building carbon emissions rate for each of the scenarios. The modelled carbon reductions and any additional carbon emissions that needed to be generated from renewable energy were then costed. This cost data could then be compared to the LSC's budget over the coming years and the targets towards zero carbon identified.

Existing Mandatory Requirements

There are a number of existing regulations and assessment methods relating to the carbon emissions of new buildings and refurbishments. Some are national, some local and some voluntary leading to a mix of requirements that might be relevant to a project. These are briefly described in this section to demonstrate how the LSC policy might interact with them.

Recommendations

This section sets out recommendations for the LSC to create a Policy to achieve zero carbon colleges via the capital funding programme and using information from the LSC e-mandate system.

Appendices

Draft Assessment Criteria.
Modelling methodologies and results.
Cost calculation methodologies

1.3 Carbon Issues not considered in this framework

This project concentrates on the efficient reduction of carbon emissions directly associated with a college building; more specifically the use of energy to operate any new or refurbished college building funded by the LSC.

Carbon emissions associated with the following areas are not considered to be included in this remit:

- Transport serving the building
- Embodied energy of materials
- Logistics serving the building

This framework does not discuss sustainability issues in the broader sense. To holistically design within the natural capacity of the planet a number of other areas would need to be considered. For example, in addition to considering how a college can be designed to be zero carbon it might also be considered how the building could be:

- Self-sufficient by collecting and re-using water
- Built using sustainable materials
- Able to cope with future climate change
- A positive contribution to the community and built environment

- Sustainable in operation

Assessment tools such as BREEAM[1] provide a means of assessing the overall sustainability of a building design. Further Education colleges are currently covered by the bespoke version of the BREEAM system, soon to be replaced by a version specific to Further Education.

This framework is not a design guide and does not describe in detail the design features that would be included in a zero carbon college.

[1] Building Research Establishment Environmental Assessment Method (www.breeam.org)

Glossary

LSC	Learning and Skills Council
CLG	The Department for Communities and Local Government
FE	Further Education
UK-GBC	UK Green Building Council
CSH	The Code for Sustainable Homes
ESCo	Energy Service Company
CHP	Combined Heat and Power
ROCs	Renewables Obligation Certificates
MUSCO	Multi-Utility Services Company
DISCO	Distributed Infrastructure Services Company
LZC	Low and Zero Carbon energy (e.g. low carbon = natural gas CHP, zero carbon = wind)
TER	Target Emission Rate as defined in Approved Document Part L of the Building Regulations
BER	Building Emission Rate as defined in Approved Document Part L of the Building Regulations
CABE	Commission for Architecture and the Built Environment
BREEAM	Building Research Establishment Environmental Assessment Method
SBEM	Simplified Building Energy Model
NCM	National Calculation Method
HVAC	Heating, Ventilation and Air Conditioning
DHW	Domestic Hot Water
DSM	Dynamic Simulation Modelling
PIR	Passive Infra-red
OfGEM	Office of Gas and Electricity Markets
REGO	Renewable Energy Guarantees of Origin
JV	Joint Venture Partner
ICU	Intelligent Client Unit
GSHP	Ground Source Heat Pump
EPC	Energy Performance Certificate
EPBD	Energy Performance of Buildings Directive
DEC	Display Energy Certificate
Regulated Energy	Energy regulated by Part L of Building Regulations
Occupant Energy	Balance of energy consumed in buildings including small power etc.

2 Introduction

Through the proposed Climate Change Bill, the UK Government is establishing a long term Carbon Emissions reduction target of 60% from 1990 levels by 2050[2]. The Government has set a number of interim targets to help achieve this, such as to make the Central Government offices carbon neutral (as opposed to zero carbon) by 2012 [3], and that all new homes shall be zero carbon by 2016 [4].

Communities and Local Government (CLG) released the Code for Sustainable Homes[5] (CSH) in December 2006 to drive a step-change in sustainable home building practice and to describe how the zero carbon target might be achieved in dwellings. This was followed in December 2007 by the report "Carbon reductions in new non-domestic buildings"[6] produced by the UK Green Building Council (UK-GBC)[7] for CLG.

The UK-GBC report was commissioned by CLG to add to the understanding of whether similar targets to those set in the CSH could be set and achieved in the non-domestic sector and on what timescale. Following the recommendations made in this report, the Government announced in the March 2008 Budget that by 2019 all new non-domestic buildings should be required to be zero carbon[8].

In addition to this, in December 2007 the Secretary of State for Children, Schools and Families, announced the details of approximately 200 energy-saving projects in schools that will cost about £110m over the next three years. A typical secondary school will receive about £500,000 under the scheme to reduce carbon emissions in new school buildings. The Secretary's aim is for all new schools to be zero carbon by 2016 although specific details of what this means or exactly how it might be achieved have not been released.

The LSC is a non-departmental public body which is responsible for planning and funding Further Education (FE) and training in England other than those in universities.

The LSC expects to fund the construction and refurbishment of FE colleges by £800m/annum from now until 2011. A target has been set of having 90% of the 1993 FE building stock renewed or refurbished by 2014.

There exists, therefore, an opportunity for the LSC to dramatically influence and encourage a reduction in carbon emissions of the FE estate by developing a carbon policy which colleges must adhere to, to qualify for funding.

In particular, this study will build upon the conclusions and recommendations in the UK-GBC report on non-domestic buildings as well as considering relevant legislation, such as Part L2A[9] of the building regulations, and assessment tools such as BREEAM[10].

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[2] Climate Change Bill 2007-08 http://services.parliament.uk/bills/2007-08/climatechangehl.html

[3] In June 2006, the Prime Minister launched new targets for sustainable operations on the Government estate details can be found at (www.sustainable-development.gov.uk/government/estates/index.htm)

[4] Building a Greener Future: policy statement published by DCLG July 2007 (www.communities.gov.uk/publications/planningandbuilding/building-a-greener)

[5] The Code for Sustainable Homes launched December 2006 (www.planningportal.gov.uk/england/professionals/en/1115314116927.html)

[6] *Report of carbon reductions in new non-domestic buildings*, prepared by UK-GBC for DCLG published December 2007 (www.communities.gov.uk/publications/planningandbuilding/carbonreductions)

[7] UK Green Building Council (www.ukgbc.org)

[8] Budget statement of 12th March, Chancellor of the Exchequer Alistair Darling

[9] Building Regulations for England and Wales, Approved Document L2A: Conservation of fuel and power (New buildings other than dwellings) (2006 edition) (www.planningportal.gov.uk/uploads/br/BR_PDF_ADL2A_2006.pdf)

[10] BREEAM Further Education to be launched in 2008. Criteria will apply all further education, adult or vocational colleges.

3 Definition of a zero carbon FE college

This section details the definition of zero carbon used for this framework. Existing definitions are considered and it is concluded that a zero carbon FE college would be required to demonstrate that its net carbon emissions produced over a year were zero. This could be achieved using low and zero carbon technologies located on-site, near-site or off-site where additionality could be demonstrated. The energy uses included in this definition are also defined and the option of targeting actual energy in use is discussed.

3.1 CLG definition of a zero carbon building

The definition of 'zero carbon' within Government has been the subject of much debate recently and there are likely to be further modifications in the future. For the UK-GBC report, CLG were asked to define zero carbon prior to the work being started. The outcome of this and the discussions that lead to it are presented in Section 3 of the UK-GBC report.

As colleges fall into the category of non-domestic buildings it is suggested that the zero carbon definition used in the UK-GBC report be adapted for colleges for consistency.

The five key forms of zero carbon defined in the UK-GBC report have been duplicated below. It is the understanding and careful discussion of each of these forms, and policy instruments to regulate these, that will inform the definition of zero carbon appropriate for FE colleges:

Forms of zero carbon in order of stringency:

1. Self sustaining site (i.e. a site aiming to use no gas or electricity other than that generated on the site).
2. Annual zero carbon building balance. The building produces and exports sufficient zero carbon electricity (or possibly gas in the future) over the year to compensate for the carbon emissions resulting from all electricity and other fuels used on the site.
3. Annual zero carbon with directly connected near-site renewables.
4. Annual zero carbon with UK off-site renewables.
5. Annual zero carbon with UK or international carbon offsetting.

The current definition used by HM Treasury and the Code for Sustainable Homes (CSH), is restricted to forms 1 to 3.

In the UK-GBC report it is proposed that options 1 to 4 should be allowable for non-domestic buildings, as there may be certain circumstances or particular sites where it may be difficult or impossible for developers to achieve zero carbon with only onsite and near site low and zero carbon (LZC) technologies[11].

3.2 LSC allowable solutions

It is recommended that the LSC recognise options 1 to 4 in alignment with the recommendations in the UK-GBC report.

It is anticipated that options 2, 3 and 4 will be the most commonly adopted solutions for FE colleges. Option 1 is likely to be very difficult to achieve in reality as it is unlikely that the supply will match the demand. Options 2, 3 and 4 all require an annual zero carbon building balance with the only differences being where the LZC technologies used to achieve this are located and possibly how they are funded.

A zero carbon college adopting this strategy would still have an electricity and gas connection to the national networks however, for peak loads and on days when the LZC

[11] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, Section 3.1.2

technologies do not match the colleges demand, energy will be imported from the national grid.

On days when the on site zero carbon energy generation exceeds the colleges demand the college would then export any zero carbon electricity that it was not using from its on-site or near-site sources back to the grid.

To achieve an annual carbon building balance of zero, the quantity of carbon emitted over the year due to energy consumed from the national grid must be cancelled out by the amount of zero carbon energy exported back to the grid by technologies funded by the college.

The inclusion of option 4 (off-site LZCs) has been discussed at great length. Off-site zero carbon energy would need to be supplied via the national grid. There are currently few opportunities for providing additional LZC capacity when buying electricity from the National Grid.

Ideally off site LZC technologies would only be allowable provided an agreed method for establishing additionality could be agreed.

CLG and the UK-GBC are working hard on how to ensure additionality, however it is a very complex area. Some suggestions have been made in section 6 as to how the LSC might address this issue.

CLG also stated in the UK-GBC report that the non domestic sector "…should therefore only look at LZC solutions away from the development (and therefore connected to the grid rather than directly to the development) if it becomes obvious that the former solutions are either not delivering the required carbon savings, or are doing so at disproportionate cost" where former solutions refer to on-site and near-site technologies[12].

This encourages design teams to always consider on-site LZC energy generation first. Building on land without incorporating zero carbon energy generation capacity locks up that land as non-generating. This reduces the overall amount of land available for energy generation. Whilst this may not seem important when considering a single project it could be a serious issue when multiplied across the many future building projects proposed.

It is recommended that this approach is also adopted by the LSC and the mechanism of how this might be implemented is also discussed further in section 6.

3.3 Energy end uses to be considered in the zero carbon definition

3.3.1 Regulated Energy

Currently the Approved Document Part L2A of the building regulations requires all non domestic buildings to be designed to achieve a Building Emission Rate (BER) equal to or less than a Target Emission Rate (TER).

Compliance is demonstrated by using approved computer simulation models that predict the annual energy and hence carbon emissions for the following end uses:

- Heating
- General Lighting
- Cooling
- Auxiliary energy (pumps fans etc)

In this report CO_2 emissions from these end uses are termed "regulated" CO_2 emissions.

This is in line with the CSH definition for zero carbon that requires all regulated carbon to be net zero carbon to achieve CSH code level 5.

[12] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, Section 3.1.2

3.3.2 Occupant Energy

The CSH uses the term 'occupant energy' to describe estimated energy attributed to electrical appliances and cooking. To achieve CSH level 6, occupant energy use must be net zero carbon in addition to the regulated energy.

A comparable definition for colleges would mean that the following would be included in occupant energy:

- Small power - any electronic equipment used in the colleges (such as computers, servers, telephones etc).
- Kitchen equipment including gas.
- The use of any other fossil fuels as part of educational work such as gas for kilns, Bunsen burners etc.

Currently the Part L compliance tools are not required to predict occupant energy. In the CSH, estimates for occupant energy are calculated by relating occupant energy use to floor area of the dwelling. A draft tool for calculating occupant energy loads has been developed for colleges and can be found in appendix A.

3.3.3 Predicted vs. actual emissions

Actual energy data for a sample of colleges constructed in the last 10 years shows that they use on average 30% more energy in use than that predicted for a sample of colleges modelled at design stage using computer simulations. This is reinforced in the UK-GBC report which comments that evidence has shown discrepancies of up to 200- 300% in actual emissions versus those predicted at design stage[13]. This highlights that predicted emission figures should not be relied upon to predict real life reductions.

In recognition of this, this report considers an appropriate capital funding strategy that could be applied to encourage a zero carbon college as predicted at design stage. In addition, a method of funding colleges to operate as zero carbon 'in use' is outlined. This is discussed further in section 6.

3.4 Levels of carbon reduction

The recommendations in the UK-GBC report are that 6 levels of carbon reductions are used to provide a trajectory to zero carbon in non domestic buildings; this is consistent with the CSH approach[14].

It is recommended that the LSC only consider Levels 4, 5 and 6 with the idea that this will accelerate the trajectory to zero carbon in line with the LSC existing funding programme. Given the capability of the building industry at the current time and the aspiration of the LSC to reach carbon neutral in a short time-frame it was not deemed necessary to define levels 1 to 3.

The addition of a further category to address actual measured carbon emissions in use is also suggested. The proposed LSC carbon reduction levels are summarised below;

LSC Level 4	44% regulated carbon reduction The building emission rate (BER) is 44% less than the target emission rate (TER) as calculated by an approved Part L compliance tool
LSC Level 5	Annual zero carbon building balance - Regulated
LSC Level 6	Annual zero carbon building balance - Regulated plus Occupant
Further category	Annual zero carbon building balance - Actual Emissions

[13] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, Section 7.1.4
[14] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, Section 8.2

4 Existing building data

This section sets out the energy data gathered from existing colleges.

To be able to demonstrate that a college is zero carbon the annual energy by end use needs to be identified so that demand reduction can be addressed in the most cost effective manner and the residual energy demand can be predicted. Data collected from existing colleges was reviewed to establish a pattern of energy consumption.

4.1 Introduction

Energy Benchmarks for buildings have been available for a number of years to assess actual performance of buildings. Many of these benchmarks were collated in the 1990's or before and have not been regularly updated rendering them misleading and unhelpful.

Up to date information relating to the end use of energy consumed in buildings is essential to allow for cost effective targeting of energy reductions.

4.2 LSC eMandate Data

The LSC have records of annual electricity and fossil fuel usage for almost all existing colleges within England. This data is collected using an eMandate and became mandatory for all colleges in 2008. The information collected through the eMandate process has lead to an exemplar level of data available for the understanding of energy use within FE buildings.

The LSC eMandate Annual Report indicated that the energy consumed per square metre increased by 3.9% over the most recent two years considered. It was also noted that there were wide variations in the amount of energy being consumed with the worst estates consuming around 30% more energy than the best, indicating that although factors such as building age, curriculum etc need to be taken into account, there is scope for reducing the energy consumption. However the information currently available does not indicate which areas of end use are responsible for the increase in energy.

The collected data was split to examine the energy consumption in relation to the type of college.

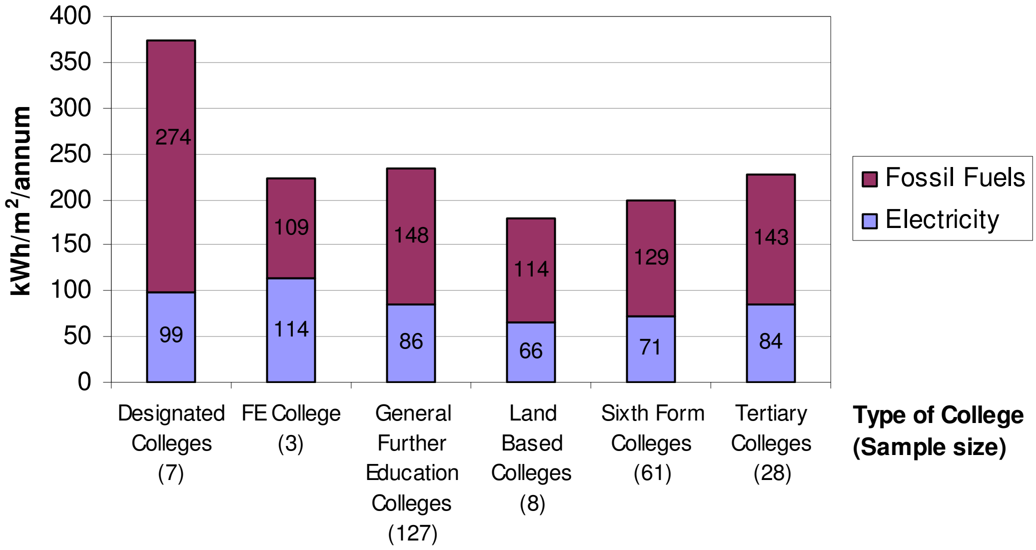


Figure 1: Comparison of energy consumption of different types of colleges

A Designated College caters for people with enhanced educational needs and as such has a very intensive and atypical use of energy. It can be seen that the Designated Colleges have a significantly larger energy use than the other types. These colleges were removed from the data for the remainder of the analysis to avoid a small specialist sample skewing the results. The average (mean) figures for the remaining dataset can be seen in Table 1.

Annual Energy Use (kWh/m^2)			
	Electricity	Fossil Fuels	Total
Average figures	82	140	222

Table 1: Average consumption figures for colleges excluding Designated Colleges from LSC eMandate data

The amount of electricity and fossil fuel used by the colleges was analysed in relation to their size, geographical area and type of location (rural, urban etc.). The results revealed some trends for which the following possible reasons have been postulated.

Observation	Possible reasons
Land Based colleges use less electricity	Land Based curriculum of rural industries demands less use of computers and high-tech equipment?
Colleges in the South use less fossil fuel	Climate gradient between regions of England result in lower heating loads in the Southern regions?
Smaller colleges use less electricity and fossil fuel	Larger colleges are less able to tightly control inefficiencies resulting from poor housekeeping practices?
Younger buildings use less fossil fuel	More recent colleges have been built to higher standards of building regulations and as such have lower heat loss?
Older buildings use less electricity	Recently built colleges are more likely to include a significant proportion of air-conditioning and include a higher density of computers and other high-tech equipment?

Table 2: Observations of trends in fuel use and postulated reasons

In addition, colleges with residential buildings showed a slightly higher use of fossil fuels (in the order of a 20% increase) but the consumption of electricity was unaffected. This is not unexpected after considering the higher demands for space heating and hot water in residential spaces.

It should be noted that, due to the tight timescales involved in this project, it was not possible to carry out a full analysis of the data to check for hidden correlations. When considering trends in the data such as those mentioned above it should be remembered that correlation does not necessarily prove cause and effect.

4.3 Existing Benchmarks Compared Against LSC eMandate Data

4.3.1 Energy use split by fuel type

There are numerous data sources referring to energy consumption in education buildings but the vast proportion of them are concerned with schools and higher education buildings. Where further education colleges are included, they are usually combined within the wider designation of ‘higher education’ (e.g. including university colleges).

However, benchmarking data relating specifically to the Further Education sector has been published by The Carbon Trust in GPG321[15].

Annual Energy Use (kWh/m^2/annum)			
	Electricity	**Fossil Fuels**	**Total**
eMandate Average	82	140	222
GPG321 Benchmarks:			
Typical Practice	45	171	216
Good Practice	32	114	145

Table 3: Comparison of eMandate averages and benchmark figures

The benchmark total energy consumption figures for colleges employing typical practice correlates well with the information gathered by the LSC eMandate process. There is, however a large discrepancy in the ratio of fossil fuels to electricity between the benchmark data and the LSC eMandate data.

The eMandate data shows there is a clear trend in the relative consumption of fossil fuels and electricity when the average age of the college buildings is considered. More recently built colleges use significantly more electricity and less fossil fuel. The figures for the total consumption show a decrease as the average age becomes lower.

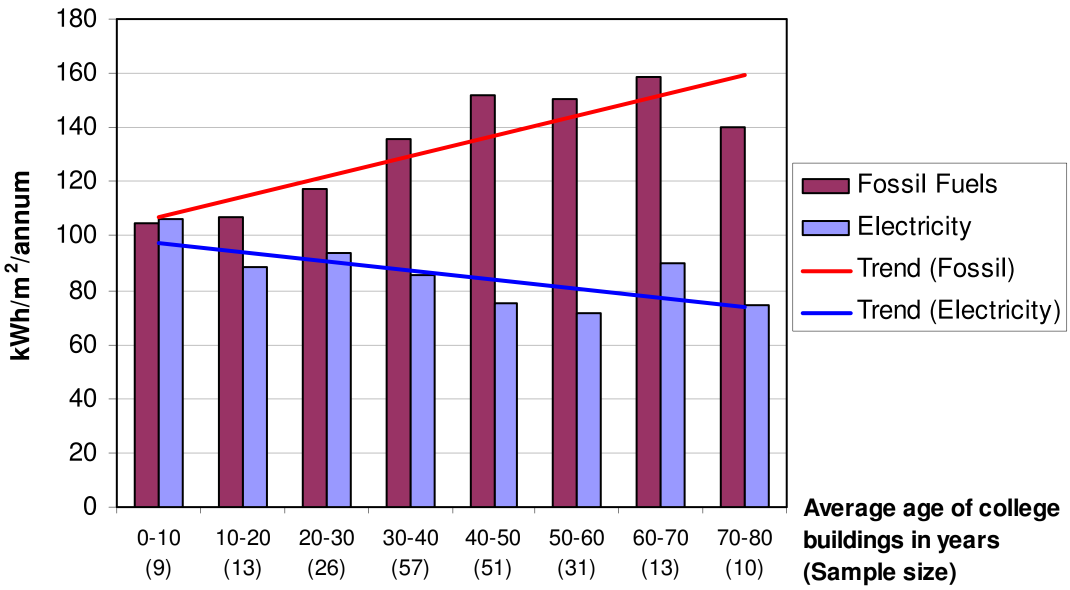


Figure 2: Variation in consumption of electricity and fossil fuels by age of buildings

It should be noted that Figure 2 does not indicate a historical trend for energy use. It indicates the differing levels of energy usage for colleges with buildings of increasing average age.

It is interesting to compare the values seen in the graph with the benchmark information from GPG321. It can be seen that the fossil fuel use in older buildings is closer to the typical practice benchmark of 171kWh/m^2/annum whereas in younger buildings it is close to the good practice value of 114 kWh/m^2/annum. This provides some confidence that, in the case of fossil fuel use, the benchmark data is still valid and relevant.

[15] *Energy Efficiency in PPP/PFI contracts for Further and Higher Education*, Action Energy (now Carbon Trust) (www.carbontrust.co.uk)

In comparison, there is a large discrepancy between the benchmark electricity use and that seen in the real data. Despite the large variation in the real data from approximately 70 to 100 kWh/m^2/annum, the level is not comparable with the benchmark levels of even the typical buildings. To exacerbate this difference, the trend with more recently built buildings is for the electricity consumption to rise, thus widening the gap even further.

The reason for this large discrepancy could be the length of time that has elapsed since the data on which the benchmarks are based was collected. This highlights the need for more recent and accurate benchmarks that could possibly come as a result of data collected in the eMandate process. Accurate benchmarks will allow the development of realistic and stretching targets for future developments.

4.3.2 Energy split by end use

Whilst information based on the fuel type is useful, it does not give any insight into the relative consumption of different end uses. As this report is primarily concerned with the minimisation of energy consumption, it is important to gain some understanding as to where the energy is being used. With this information, a more directed approach can be taken to targeting the more intensive uses. A useful comparison can also then be made between the usage profiles based on real benchmark data and those returned from the building modelling.

During the course of this work, an attempt was made to collect real data from colleges split by end use. None of the colleges contacted were able to provide such information for a number of reasons. Obviously there are a large proportion of colleges that do not have the necessary equipment installed to allow the sub-metering by end use. However, even the colleges with the equipment found other issues with the process such as a lack of resource in the facilities department to record the data or difficulties in using the equipment.

Relevant benchmark data is available from two sources:

- "*How to Conserve Energy in Further Education Colleges*" [16] (written in partnership with, amongst others, the LSC) is specific to FE colleges but only contains data on the end use, not by fuel type.
- "*Further and Higher Education Sector Overview*"[17] has data split by end use and fuel type but is not specific to FE colleges as it includes data from Higher Education establishments.

A comparison of these sources can be found in Table 4 and Figure 3. It can be seen that both sources show space heating as by far the largest user of energy in FE colleges. However, whilst the documents that include this data have only been recently published, the exact original source of the data is unclear and the information is thought to date back to the mid-90's. This would result in the benchmarks being significantly out of date and not representative of current Regulations or building practices.

[16] *How to Conserve Energy in Further Education Colleges*, R Gupta & S Chandiwala in association with Association of South East Colleges (Oct 2007)

[17] *Further and Higher Education Sector Overview*, CTV020, Carbon Trust (www.carbontrust.co.uk) (March 2007)

	Percentage Energy Use (kWh/m²/annum)			
	FE Colleges [16]	HFE Buildings [17]		
Use	**Total**	**Electricity**	**Fossil Fuels**	**Total**
Space Heating	**72%**	1%	62%	**63%**
Hot Water	**12%**	3%	2%	**5%**
Lighting	**8%**	17%	-	**17%**
Catering	**4%**	3%	2%	**5%**
Office Equipment		6%	-	**6%**
Cooling	**4%**	1%	-	**1%**
Other		3%	-	**3%**

Table 4: Comparison of benchmarks relevant to FE sector

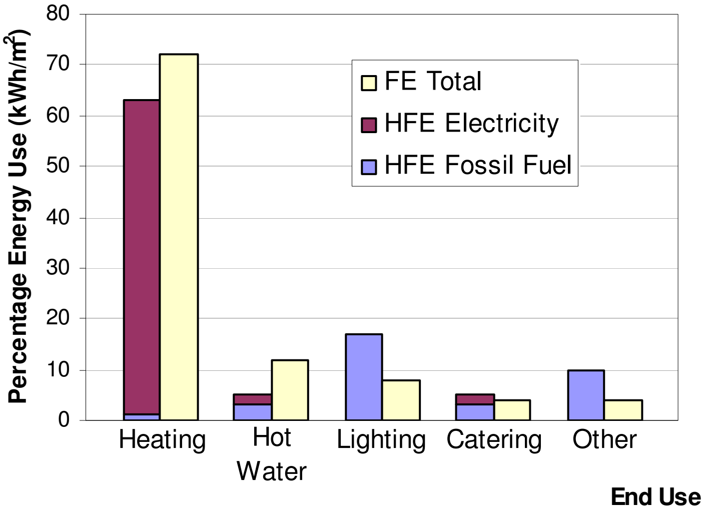


Figure 3: Comparison of benchmarks relevant to FE sector

4.4 Conclusions and recommendations

By comparing the data gathered by the LSC's eMandate process with existing benchmark data it has become evident that the benchmarks do not accurately represent current energy consumption profiles. There is a need for the benchmarks to be updated and the eMandate process is ideally placed to provide the information.

Recommendations for the development of eMandate to facilitate this are further discussed in section 9. However, initial updates to industry benchmarks could be based on the level of data gathering that is currently in place.

5 Building modelling

This section summarises the conclusions of carrying out dynamic thermal modelling of five college scenarios. These scenarios were used to review the impact of improvements in fabric and air tightness as well as comparing energy use predicted at design stage with real energy usage of existing colleges. The scenarios were then used to test the method of calculating and demonstrating a zero carbon college at the design stage.

5.1 Introduction

Building modelling is concerned with simulating and predicting the theoretical energy consumption of a building and can be used effectively as a tool to compare the effects of varying elements of the building at design stage, or to compare one design against another.

To develop the recommendations in this report a dynamic thermal simulation software package has been used to predict carbon emissions of 5 sample colleges to assist in understanding the following;

- The predicted annual carbon emissions of each of the college scenarios when designed to meet Part L2A 2006 using approved software and the impact of varying fabric improvements on each college's annual carbon emissions.
- The predicted annual carbon emissions of each college building when designed to 2002 building regulation standards to compare with real energy data from colleges built in recent years.

5.2 Methodology

The National Calculation Method (NCM) for the Energy Performance of Buildings Directive[18] (EPBD) has been defined by the CLG and incorporated into the building regulations (Part L).

Under the 2006 revision of Part L of the Building Regulations, all non domestic buildings are required to meet a Target CO_2 Emission Rate (TER). The method of demonstrating compliance is by simulating the annual energy consumption (and hence carbon emissions) of a building as designed (BER) using an approved simulation tool.

The TER is calculated by simulating the proposed building built to 2002 standards (notional building) and applying an improvement factor specified in the building regulations.

Both TER and BER calculations make use of standard sets of data for different activity areas and call on common databases of construction and service elements.

The NCM allows the actual calculation to be carried out by approved simulation software[19]. A simplified tool has been developed for the CLG by BRE and is called SBEM - Simplified Building Energy Model. It is accompanied by a basic user interface - iSBEM. There are a number of other approved interfaces in addition to iSBEM.

In addition to SBEM there are currently 3 other approved calculation engines that can be used to demonstrate compliance. These alternative calculation engines model annual energy on an hourly basis (dynamic modelling) and can be used to model more complex buildings. They are referred to as dynamic simulation models (DSM).

The UK-GBC[20] report summarises the potential issues with using SBEM and DSMs to model zero carbon buildings.

It is likely these compliance tools will be developed as the understanding of the complexities of modelling zero carbon in buildings develop and the LSC's strategy for assessing zero carbon should recognise this.

[18] www.communities.gov.uk/planningandbuilding/theenvironment/energyperformance/
[19] www.ncm.bre.co.uk/software.jsp
[20] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, section 8.1.2

Arup are currently working on a number of college designs which have had existing building simulation models created to demonstrate compliance with the building regulations. These were collected together and a selection of five college buildings was reviewed for this project.

Two studies were undertaken, study 1 looked in detail at the impact of fabric improvements and study 2 looked at the predicted annual carbon emissions of each of the college scenarios when designed to meet Part L2A 2006 using approved software.

The compliance tool used was IES VE compliance tool version 5.8.1 which is approved under the NCM and is a dynamic simulation modelling (DSM) tool.

Full details of the methodology used are available in Appendix B.

5.3 Results

The BER and TER for each college was calculated with the fabric improved to the proposed standards for LSC Levels 4 to 6 (as described in Table 22 in Appendix B). Improvements were also made to system efficiencies and lighting controls from the 2002 base level to ensure the colleges met or exceeded the TER. The results are shown in Figure 4.

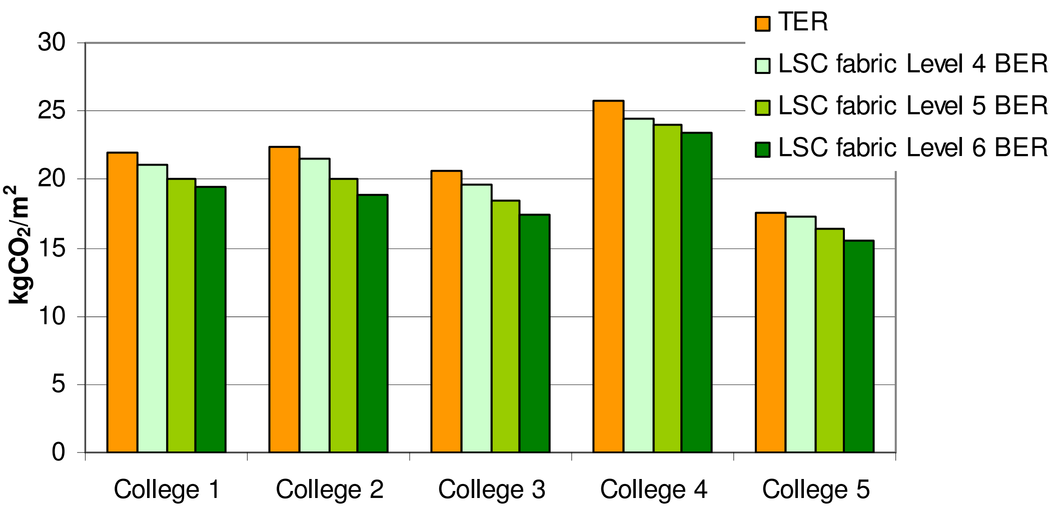


Figure 4: BER and TER for each college with improvements made to fabric and system efficiencies

The fabric improvements alone generally produced a reduction in carbon emissions of between 13 and 20% when compared to building regulations minimum standards. The notable exception was the college with a high percentage of cooling which only experienced a 3% reduction in carbon emissions.

When comparing the breakdown of CO_2 emissions by end use for college 3 and college 4 (Figure 5 & Figure 6) it can be seen that this reduced improvement in college 4 is due to cooling loads increasing as the building insulation is increased.

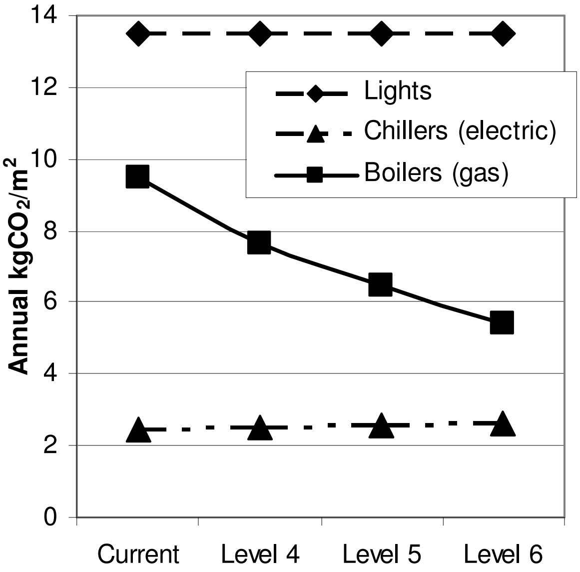


Figure 5: Detailed breakdown of CO_2 emissions for College 3 for each level of fabric improvement

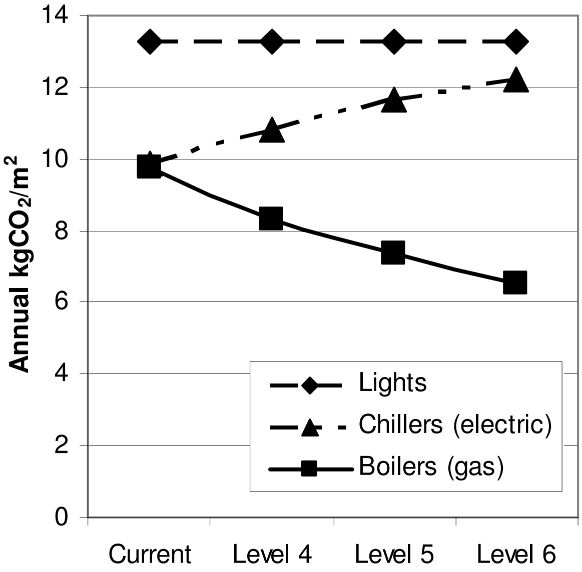


Figure 6: Detailed breakdown of CO_2 emissions for College 4 for each level of fabric improvement

College 4 has a higher proportion of air conditioned rooms (35%) than the other colleges, due the nature of the activities in the spaces. Improving the fabric insulation and air tightness actually has a detrimental effect on the carbon emissions from cooling in this case because heat is trapped in the rooms and so cooling loads in summer increase.

This highlights the importance of not being prescriptive in the solutions proposed when providing minimum energy efficiency parameters.

The Code for Sustainable Homes and the UK–GBC report both recommend heat loss parameters and cooling parameters to define limits on insulation and infiltration. These factors allow design teams to vary u-values, infiltration and thermal bridging between individual elements so long as the average meets a limiting factor. It is likely that these factors will be included the next revision of the building regulations.

It is recommended that the LSC follow CLG and building regulations lead in this area. In the meantime limiting area weighted u-values and limiting air tightness values have been included in the draft workbook in appendix A.

If it is assumed that for the example college scenarios shown in Figure 4 no further savings can be made through improvements to system efficiencies and fabric improvements, then the next consideration would be the incorporation of LZC technologies.

These can be modelled within the compliance software. To model zero carbon off-site electricity the carbon factor for electricity should be set to zero.

This study demonstrates that design teams will be able to use the approved NCM compliance tools to demonstrate that they meet the targets specified for the carbon reductions for LSC Level 4 and 5. However Part L2A currently only includes regulated energy so occupant energy and the associated LZCs to achieve LSC Level 6 compliance would need to be calculated in some other manner.

Full results for all colleges are summarised in Appendix B.

5.3.1 Occupant Energy

A suggested method for calculating predicted occupant energy is to use the existing power demands for each room type which are listed in the NCM templates in W/m^2. These values are currently used in the NCM calculation to determine cooling loads but are not currently included within the Part L rating reports as small power loads. This may be amended in the future but in the mean time a method for calculating occupant energy based on these values is described in detail in Appendix A.

This will provide consistency across all colleges and means that the LSC do not need to take responsibility for defining and updating the templates.

5.4 Predicted vs. Actual

The annual carbon emissions of the notional building for each scenario were extracted from the results. The notional building is the building designed to 2002 building regulations. In this analysis, energy from small power was included in the results. This was extracted from the IES model as this information is used in the simulation to determine cooling loads for each room. Power values and usage profiles were taken from the standard NCM small power templates for FE colleges. It should be noted that the NCM templates do not take into account unusual small power loads used for specialist curricula (such as hairdryers and catering equipment) and these should be estimated manually where they exist (see appendix A).

The average annual carbon emissions from the simulated college scenarios were compared with the average annual carbon emissions for 9 colleges built in the last 10 years from the LSC eMandate data. The results were split by fuel use. Comparing energy by end use was not possible due to end use splits not being known for the eMandate data. Using the end use splits given in published benchmark data was not relevant due to the benchmark data being out of date.

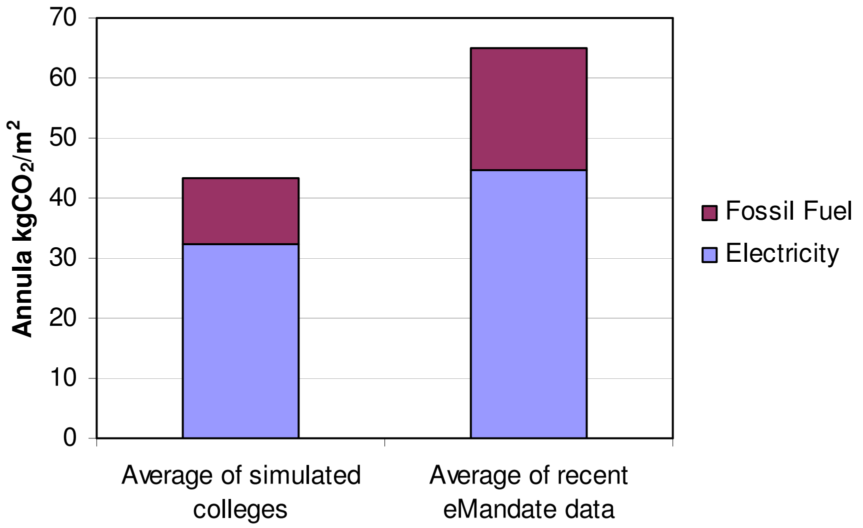


Figure 7: Comparison of simulated and actual carbon emissions split by end use

The results show that the averaged total predicted carbon emissions and the averaged eMandate data have a discrepancy of around 30%.

The UK-GBC report comments that evidence has shown in some cases discrepancies of up to 200- 300% in actual emissions versus those predicted at design stage in non domestic buildings[21].

These discrepancies highlight that predicted emission figures should not be relied upon to deliver real-life reductions and demonstrates the importance of accurate real data.

[21] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, Section 7.1.4

6 Achieving Zero Carbon

This section sets out the various options colleges may use to a achieve low or zero carbon college development and an outline of some of the potential energy provision models that could be used to supply energy, and possibly other utility services to colleges.

The section is intended to highlight the possible toolkit of contractual arrangements for the provision of a variety of utility services and associated business models the LSC could construct to enable colleges to achieve zero carbon.

The detail of these contractual arrangements is not intended to be the subject of this section and a more detailed study would need to be undertaken to progress a toolkit of delivery models and typical contracts that could then be rolled out nationwide.

6.1 Types and Extent of Work to be Addressed

The LSC Capital Funding process applies to a wide range of building works including entire new colleges, new buildings on an existing site, extensions and refurbishments on many different scales. It is clear that to effectively reduce the emissions from the further education sector, all of these types of building works will need to be addressed.

With regard to refurbishments, the UK-GBC report states that [22]:

> "Existing building stock must be tackled if we are to meet any of the Government targets for carbon reductions by 2050. Until new construction reaches zero carbon, it still represents an increase in national carbon emissions, and even after new construction has reached zero, increasing energy consumption in the existing stock (now including all the buildings that were constructed en route to zero carbon) will mean that national emissions will continue to rise."

Including refurbishments in any policy will inevitably lead to increased complexity due to the wide range of work included in this category. It will also, however, lead to a far greater reduction in emissions.

It is proposed that any refurbishments that are required to comply with Building Regulations Part L2B are of sufficient size and comprehensiveness to be included in this policy. That is to say, they are large enough to benefit from having increased requirements placed on them via the LSC funding requirements to increase the efficiency of the resultant building.

6.2 Options for Achieving Zero Carbon

When designing a low or zero carbon building or refurbishing a building there are two routes to reducing emissions: reducing the demand for energy in the building (termed demand minimisation) and reducing the carbon content of the fuel used to provide that energy (termed supply decarbonising). It is paramount that the energy demand is minimised prior to technologies being used to decarbonise the supply. If demand is not minimised, then strain will be brought to bear on the sources of low or zero carbon energy meeting that demand (this is expanded upon in section 7).

Demand minimisation and supply decarbonisation fit into a hierarchy of importance which should be used to prioritise solutions:

- Demand minimisation: Ensuring the building and services are designed in the first instance to minimise energy consumption.
- On Site Low and Zero Carbon (LZC) technologies: LZC technologies located directly on the site or integrated into the building.

[22] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, Section 1

- Near site LZC technologies: LZC technologies located near a site and connected to the site via a direct connection often termed "private wire connection". This would also include district heating systems.
- Off site LZC technologies: Zero carbon electricity purchased either directly from a utility or via a national LSC partner. If none of the previous options were available heat would need to be provided by gas and the carbon offset via investment in zero carbon offsite technologies.

On-site technologies should be considered in the first instance as building on land without incorporating generation capacity locks up that land as non-generating. This reduces the total amount of land available for energy generation. Whilst this may not seem important when considering a single project it could be a serious issue when multiplied across all future projects.

A definition of what on-site technology can be deemed to be practical and feasible will be needed to ensure consistency of approach across the projects being funded.

Whilst the possibility of retro-fitting generation technology exists it can be made impractical by design decisions that are made during design and development (for example if there are no south-facing roofs for photovoltaic cells).

6.2.1 Consideration Factors Relating to Off-site LZC Technologies

There are a number of ways of achieving off-site LZC energy but it is recommended that simply paying what are currently called "green tariffs" would not be sufficient. This is because it is difficult to audit such tariffs and the related renewable obligation certificates (ROCs) are not always retired; as such they can be controversial. Because of this, the LSC would require some sort of proof or test that the supplier is indeed providing a certain amount of electricity from renewable resources, such as the retirement of ROCs.

Since off-site LZC generation only currently applies to electricity, carbon emissions associated with heat generation for the college would still need to be accounted for to achieve the target of net zero carbon over a year. This could be achieved by combining off-site electricity generation with LZC on- or near-site heat generation. Alternatively, if this solution is not practical and feasible, additional off-site electricity could be generated to take account of the emissions resulting from heat generation.

It must be noted that this is only a short to medium term solution and would not be viable if and when carbon emissions from the UK's total building stock approach zero.

6.3 Role of Possible Partners

Before looking any further at the various models for achieving zero carbon, it is important to understand the role of a number of possible entities that may be involved with such models.

Renewable Obligation Certificates (ROC)

The Renewables Obligation requires all suppliers of electricity to hold a certain quota of Renewable Obligation Certificates (ROCs) at the end of each year to prove that they have met their renewable generation targets. The quotas are set to meet the UK renewable energy generation percentage targets and are raised each year.

If a supplier generates more than their quota they can sell them on to those that have not met their quota (auctions are held twice yearly).

Energy Partners

Many of these models include partnership arrangements, for example with what are often called Energy Services Companies (ESCos) for the provision of LZC energy.

There are many possible organisational setups for such partnerships and how they can be contracted; from the partner owning and operating a range of LZC assets, including systems for heating, cooling, and electricity, and dealing directly with colleges to them simply acting as the asset operator over a given contract period. The partners' energy strategy is influenced by its financial projections and objectives which may vary from project to project.

Intelligent Client Unit (ICU)

A more detailed study would be likely to highlight the need for an Intelligent Client Unit (ICU). This ICU would set up contracts (with expert help) and could oversee them at high level.

If these contracts relate to power retailing then OfGEM would be the regulator and the license terms of the retailer should ensure this. If not, then the ICU would need to employ (or require the suppliers to employ) a 3rd party auditor. This is perhaps a role for a consolidator or national ESCo.

If the ICU used existing mechanisms such as Renewable Obligations Certificates (ROCs) coupled to Renewable Energy Guarantees of Origin (REGOs), then they will be able to test the validity of claimed origin of that electricity.

6.4 Procurement Models

After suitable standards of demand minimisation have been met, the remaining supply can have its carbon content reduced by procuring LZC energy in a number of ways.

There are a number of models for the delivery of the carbon reductions required by the LSC Levels 4, 5 and 6. These are outlined below and discussed further in the following sections.

	Model	Characteristics	On-site	Near-site	Off-site
1.	Independent College	College owns and runs all LZC generation equipment	Y		
2.	College Partnership	College in direct partnership with ESCo to run and possibly own all or part of LZC equipment.	Y	Y	Y
3.	Consolidator Facilitating	Consolidator responds to college's requirements and assists in developing the partnerships and contractual relationships.		Y	Y
4.	Consolidator Leading	Consolidator takes a more direct technical approach to ensuring a college's energy solution fits into a national strategy.	Y	Y	Y

6.4.1 Model 1 – Independent College

Model 1 consists of LZC technology either integrated into the building or within the site boundary. It offers the first, if often costly, zero carbon solution. In this model, a partner or ESCo is not required and the LZC asset could be owned by the college.

6.4.2 Model 2 – College Partnership

6.4.2.1 On-site and/or near-site

In this model, the LZC technology asset(s) could either be building integrated or located outside the site boundary and connected directly to the site, possibly through what is often termed a 'private-wire' electrical network or a local heat network.

This model also includes a partnership with a third party. The reasoning behind this may be one of commercial risk or simply that the facilities team at the college don't have the expertise to run or maintain what could possibly be very complex systems.

The partner may simply operate the asset on a short term contract or it may operate it as a concession agreement, and in either case it could own part or all of the LZC asset(s). Alternatively, the asset(s) may be owned by the college with the third party running and maintaining it.

6.4.2.2 Off-site

ROC retirement

In this model, the college could request that the ROCs be sold with the electricity, provided by a conventional utility provider, and this would give it a current premium of approximately 4.5p/kWh on top of the normal price of electricity. Suppliers are required to hold these certificates to prove they meet their obligation as outlined earlier and therefore selling them to the college removes any possible double counting.

The sale of ROCs, however, does not guarantee that additional renewable energy will be added to the grid; it may simply raise the price of ROCs. This may have the effect of making more renewable energy schemes viable, since the price they receive for ROCs when they generate renewable energy is higher due to the increased competition for those ROCs. This should therefore indirectly increase renewable energy generation across the country as a whole.

This model differs from the others in that it would form part of the annual funding of the college and would require a long-standing commitment and strategy to incorporate it into a college's annual funding calculations.

Directly Funded Utility Provided Renewable Energy

The alternative to ROC retirement is to directly fund the utility provider to construct offsite renewable energy generation capacity, thus ensuring additional renewable energy is provided. With capital funding from the customer, suppliers who are developing renewable energy projects may be able to supply renewable electricity to that college over its lifetime at a fixed rate.

Under this funding strategy, the ROCs relating to the newly constructed equipment must be retired to ensure double counting does not occur. This is due to the fact that ROCs are designed to be an incentive to renewable energy developers to invest in renewable assets. If the assets are already funded by the college, then the income from ROCs is no longer a critical element to ensure the viability of a renewable energy scheme.

6.4.3 Model 3 – Consolidator Facilitating

This model introduces a larger scale or countrywide body that could act as either a partner, an ESCo or consolidator depending on the needs of the individual college. Its work would be overseen by the LSC's appointed Intelligent Client Unit (ICU).

This national body could negotiate with utility providers to provide renewable electricity by ROC retirement or direct funding, thus removing the need for individual colleges to undertake extensive contractual negotiations with providers.

Additionally, the body could commission its own near-site renewable energy systems directly through a private wire connection or offsite renewables remote from any college sites. To ensure no double counting, the ROCs generated by these renewables would need to be retired.

6.4.4 Model 4 – Consolidator Leading

This model has largely the same structure as model 3 but incorporates a larger role for the central consolidator. In effect, all of the above models are incorporated into a single model with one or more Joint Venture partners; either a single nationwide body, multiple regional partners or a framework of partners that would be overseen in all cases by the LSC's appointed Intelligent Client Unit (ICU).

This JV partner(s) could undertake a number of roles depending on the needs of the college from monitoring local ESCos to commissioning their own energy generation plant or simply negotiating a national price for “zero carbon” electricity supply for colleges from traditional utility providers.

The level of involvement of the JV partner(s) is adaptable to align with current or altered funding structures or with any restrictions that exist on the scope that such a body could undertake. At the end of the spectrum involving greatest involvement, the consolidator would ensure that each college’s energy supply solution aligned with an agreed national strategy for energy procurement.

This model also introduces the possibility of directly funding the construction of additional LZC generation capability and paying for that investment by the colleges allocating a proportion of their annual funding to the body that is linked to their energy consumption or carbon emissions. This is discussed further in section 6.6.

6.4.5 Summary

The range of models provides a spectrum of possibilities for the LSC to choose their level of involvement in the national energy strategy of the FE estate. In addition, the models above are not necessarily mutually exclusive; in fact it is envisaged that for the majority of colleges the most robust solution may consist of a combination of solutions. For example, a college could have a proportion of wholly-owned and run on-site generation capability (model 1) along with off-site generation supplied via a consolidator (model 3).

In addition, the models described above are not the only possibilities and each has an amount of adjustability in a number of factors that could be used to ensure it is compatible with the LSC’s wishes. In effect the options available are a continuous spectrum of increasing involvement from the independent college to a national ESCo and the models described are just imposed definitions that are useful to initially gauge attitudes to the differing approaches to energy procurement.

The organisational and contractual arrangements between the LSC and the national or regional partner again could take many forms and would need to be determined in a later phase of study and through direct negotiation with possible partners.

As mentioned above, the LSC ICU will need to oversee or subcontract the monitoring of the contracts that fall outside of OfGEM’s remit and this, again, will need to be an area of further study.

All of the above models/options could be provided on a wider basis to include other utility services such as gas, water, waste management, etc. These services could be provided by multi-utility services companies (MUSCOs) or distributed infrastructure services companies (DISCOs).

These could either be at a local scale or could be taken on by the countrywide or regional partner/consolidator (see model 4). This could form part of the college funding for utilities supplies and could be a more efficient way of outsourcing all college utility requirements.

6.5 Funding Models

The cost of these models will vary greatly depending on college location, size and design and therefore offering the college developer the opportunity to choose from these options is essential in obtaining best value. These options should, however, always adhere to the hierarchy of energy priorities laid out previously.

The funding arrangements of the LSC mean that there two possible solutions to the funding of zero carbon colleges as outlined in the following sections.

6.5.1 Capital Funding

When a college applies for funding it could be given additional capital to invest in on-site, near-site or directly attributable off-site LZC generation capability. This would offer the truest version of zero 'predicted' carbon and guarantee that additional renewable energy generation is installed in the UK (termed 'additionality'). Depending on the combination of procurement models being used on each project, the college may pass on a proportion of this capital funding to the consolidator for the body to procure generation capability on behalf of the college.

6.5.2 Annual Funding

With the exception of the independent college model which is restricted to on-site generation, the models include a mechanism where LZC off-site energy can be purchased without any capital investment. This would therefore require a college to guarantee that it will always purchase zero carbon electricity over its lifetime and therefore may require the LSC to provide the additional annual funding to achieve this.

The colleges could purchase LZC energy either directly from a utility (as in model 2), given certain contractual conditions were met around the retirement of ROCs, or it could be purchased through a central LSC commissioned partner / consolidator (as in models 3 and 4). As it is outlined above, either option would not guarantee additionality, but it could indirectly encourage it across the industry by raising the price of ROCs. However, the extent of the indirect encouragement or the magnitude of the price rise would need to be estimated.

Including offsite zero carbon in the definition of zero carbon colleges means that colleges can also be zero carbon in use without any additional capital costs. Any gap between the predicted and in-use carbon emissions can be met by buying in zero carbon electricity. This could be funded by the LSC via annual funding in addition to the current £/pupil system.

An annual funding system will also incentivise the colleges to reduce energy by providing them with annual funding slightly over the price of zero carbon offsite energy when they are meeting or improving on defined energy targets and charging them an excess levy when they are exceeding these targets (see Figure 8).

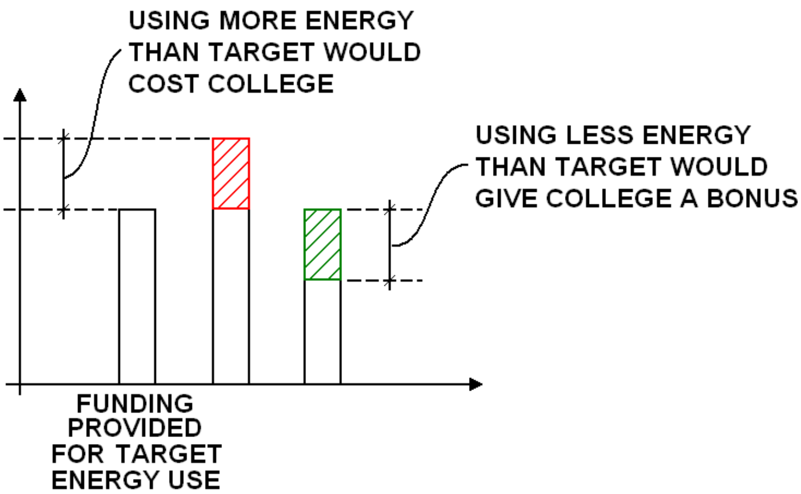


Figure 8: Use of annual funding to incentivise lower emissions

6.6 Compatibility Between Procurement and Funding Models

Both the procurement and the funding models include the possibility of using either capital or annual payment. Within the independent college procurement model it would, in all likelihood, only be possible to match the funding and procurement as indicated in the simple approach in Figure 9.

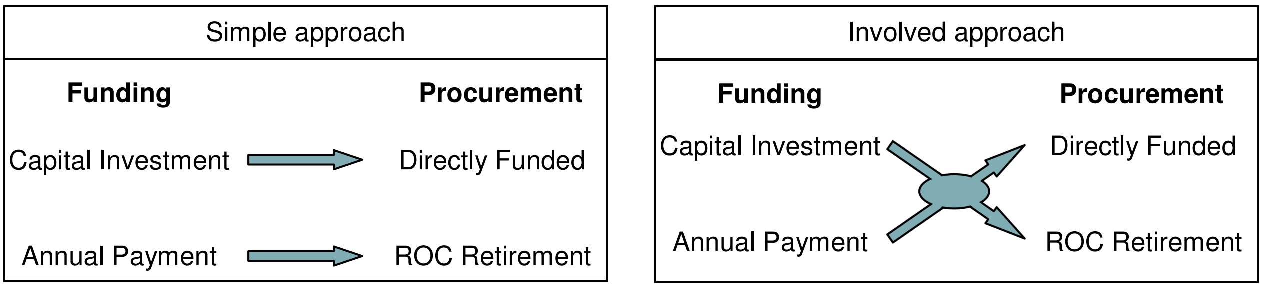


Figure 9: Increased complexity required when mixing funding and procurement periods

However, if a procurement model was chosen that includes a highly involved central body or partner, the combining funding and procurement models becomes a possibility as indicated in the involved approach in Figure 9.

The ideal case would be the combination of direct funding of additional LZC generation capability and the annual payment by colleges. In this case, the direct funding would guarantee the additionality of the LZC equipment and the annual payment would allow the use of in-use emissions in the calculation of zero carbon (thereby incentivising the college to actively manage their energy consumption).

This involved combined model would require the central body to take on the role of an ESCo, investing in equipment up-front and receiving payment for the electricity over a time.

A summary of the possible model structure is shown in Figure 10.

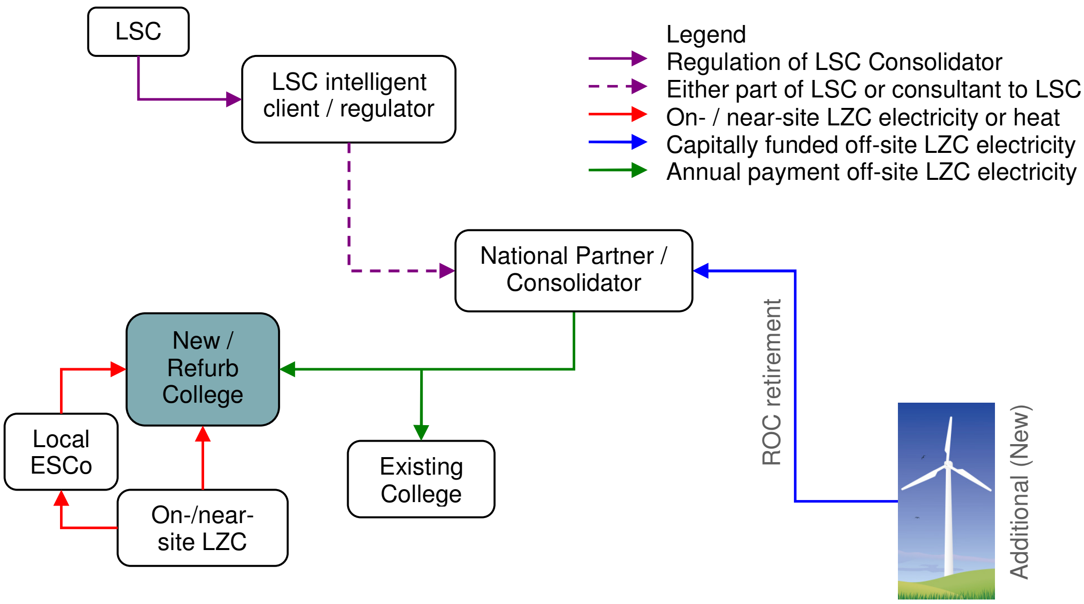


Figure 10: Procurement and funding model with an involved central partner

7 Costing zero carbon

This section provides analysis of the costs involved in achieving the proposed levels of carbon reduction for new colleges. The fabric improvements modelled in section 5 were costed and applied to the five college scenarios. The remaining emissions were used to determine the quantity of LZC technologies required to meet each of the LSC levels of carbon reduction.

This cost data could then be compared to the LSC's budget over the coming years and the targets towards zero carbon identified.

7.1 Introduction

This section of the report addresses the following;

- Capital costs of achieving the fabric improvements required for each level of carbon reduction
- Capital costs of achieving the target overall carbon emission requirements for each level including LZC technologies
- Annual costs associated with achieving zero carbon in operation

The costs have been assessed to produce possible trajectories to zero carbon and the corresponding funding requirements necessary to achieve this.

As has been detailed earlier in section 3, three levels of carbon reduction are being proposed. A fundamental factor in determining the optimum strategy for the reduction of emissions in the sector as a whole is the cost increment of constructing a building to each of these levels.

The cost calculations have been carried out entirely on the assumption that all funding applications are for new-builds as opposed to refurbishments or extensions. The wide spectrum of possibilities within refurbishments and extensions makes it very difficult to accurately quantify the costs involved, particularly within the time-frame of this study.

7.2 Methodology

As has been described previously, there are two approaches to lowering building emissions; demand reduction and supply decarbonisation. It is necessary to determine costs for each of these areas to get a complete picture of the costs involved.

The costs for demand minimisation measures were calculated using the LSC cost models for new colleges as a benchmark. The specifications were altered to improve the energy performance of the college. The cost increments were calculated using information provided by the LSC's Cost Model Working Group, more specifically with the kind assistance of Davis Langdon LLP.

These demand minimisation costs were then related to the savings in carbon emissions calculated by the dynamic simulation models described in Section 5. The remaining emissions following the demand minimisation were then reduced by the decarbonisation of the supply in a number of ways to provide comparisons between the different approaches and strategies:

- Biomass boiler with on-site photovoltaics (PV) and small-scale wind
- Ground Source Heat Pump (GSHP) with on-site solar thermal, PV, and small-scale wind
- Off-site large-scale wind power

Full details of the methodology behind the cost calculations including the sources of the base data can be found in Appendix C.

7.3 Results

7.3.1 Demand Minimisation

The results of the calculations on minimising the energy demand of the building can be seen in Table 5.

Demand Minimisation Measures	Cost (£/m^2)		
	Level 4	Level 5	Level 6
Improved U-values	£69	£108	£168
Increased air-tightness	£18	£30	£30
Thermal mass	£60	£60	£60
Improved internal lighting controls		£28	£28
Total	**£147**	**£226**	**£286**
Average percentage rise in build costs	**5.1%**	**7.8%**	**9.9%**

Table 5: Cost increments of demand minimisation measures

The UK-GBC reached similar conclusions in their report[23]. For a building with a fabric enhanced to allow carbon neutrality, they calculated a cost of £290/m^2 to £330/m^2 depending on the geometry of the building.

When the costs in the table are combined with the carbon reductions, a measure of the financial efficiency of the improvements can be reached by calculating the cost per kilogram of CO_2 saved. Discounting college 4 with its high proportion of air conditioning and therefore atypical response to the improvements, figures of £50 to £120 per kgCO_2/m^2 are reached with an average of £80 per kgCO_2/m^2. This figure can later be compared with the cost of providing LZC technologies to decarbonise the supply.

Caution should be applied to these demand minimisation methods as, to make each of the levels more comparable, the construction techniques were kept the same and the specification was increased. In reality, an alternative technique may prove to be more cost effective but in the timeframe of this study it was not possible to include this factor. It should therefore be noted that, while the cost calculations that were applied to the models are correct, they may actually represent a real-life worst case scenario.

The figures of financial efficiency determined here will be slightly higher than would be reached in real buildings because, although the increment for the increased thermal mass has been included in the cost calculations, the effect on carbon reduction was not included in the modelling. This was due to the increased complexity of incorporating such a factor in the calculation within the timescales of this project.

7.3.2 Supply Decarbonisation

The costs for the decarbonisation of the supply were calculated for each of the five colleges considered. For each of the colleges, the three LZC strategies detailed earlier were applied and the average results for the five colleges can be seen in the following table and graph.

Supply Decarbonisation Measures	Cost (£/m^2)		
	Level 4	Level 5	Level 6
Biomass + PV / Small Wind	£41	£154	£284
GSHP + Solar Thermal + PV / Small Wind	£74	£188	£321
Off-site Large Scale Wind Power	£6	£15	£25

Table 6: Cost of supply decarbonisation measures

[23] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, Section 6.4.3

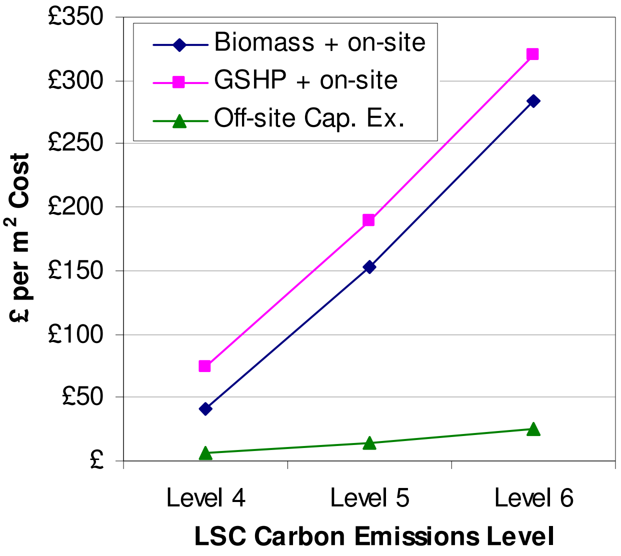


Figure 11: Cost of supply decarbonisation measures

It should be noted that these costs are indicative only and should not be taken as definitive figures. For example, the conclusion should not be drawn that the biomass or CHP solution will always be cheaper than the GSHP solution. These solutions have been applied to the IES model buildings in isolation with no information as to location, site surroundings etc. In some cases the solutions used to create these costs may not be suitable for a particular college. For instance at Level 6 the quantities of on-site LZC technologies are impractically large for some of the larger colleges, meaning that another solution would have to be found.

The financial efficiency of the measures have been calculated in the same manner as previously detailed, resulting in figures of less than £10 per $kgCO_2/m^2$:

Supply Decarbonisation Measures	Financial Efficiency (£ per $kgCO_2/m^2$)		
	Level 4	Level 5	Level 6
Biomass + PV / Small Wind	£4.93	£7.62	£8.46
GSHP + Solar Thermal + PV / Small Wind	£8.33	£9.28	£9.53
Off-site Large Scale Wind Power	£0.73	£0.73	£0.73

Table 7: Financial efficiency in £ per $kgCO_2/m^2$ for various energy supply options

It can be seen that the cost of carbon savings increased with the LSC levels. Level 4 is largely achievable by using more cost effective measures such as changing the system delivering for heat and hot water whereas at levels 5 and 6 there is a need for an increased use of more expensive LZC technologies producing electricity.

7.3.3 Annual Expenditure

If the option is taken to use the annual funding of a college to fund the carbon reductions, then the costs need to be interpreted in a different way. Using the approximate figure for the cost of ROCs stated previously of 4.5p/kWh the increases in annual funding can be calculated and are shown in Table 8.

Annual Expenditure Model	Cost Increment (£/m^2)		
	Level 4	Level 5	Level 6
Annual cost increase per m^2	£0.68	£1.55	£2.57
Equivalent Capital Expenditure per m^2	£164	£265	£350

Table 8: Annual increments in energy costs and equivalent capital expenditure

The equivalent capital expenditure has been calculated by assuming that any LZC equipment which was funded using the capital expenditure would have a replacement interval of 25 years. The total amount of zero carbon electricity that would need to be purchased over this timeframe was calculated and converted into an equivalent single payment expressed in 2008 prices (although without taking into account factors such as interest and general inflation). It should be noted that the high levels of fuel price inflation seen for a number of recent years could, if included, significantly affect the figures for annual expenditure. Fuel price inflation has not, however, been included as there is no definitive prediction available.

These figures lead to a financial efficiency varying from £19 per $kgCO_2/m^2$ for Level 4 to £11 per $kgCO_2/m^2$ for Level 6 when the increments for the demand minimisation measures have been included.

If the annual expenditure route is taken, then the figures that would be used to calculate the annual costs could then be based not on the calculated predicted emissions but on the actual emissions from the previous financial year, achieving zero carbon in-use colleges.

7.4 Comparison of Emissions Reduction Techniques

7.4.1 Comparison of Demand Minimisation and On-site Supply Decarbonisation

The costs of achieving the different levels of emissions reduction have been calculated separately for the mandatory demand minimisation measures and the supply decarbonisation models.

Emissions Reduction Technique	Cost (£/m^2) and Percentage of Total		
	Level 4	Level 5	Level 6
Demand Minimisation	£147 (5.1%)	£226 (7.8%)	£286 (9.9%)
Supply Decarbonisation (average of on-site solutions)	£57 (2.0%)	£171 (5.9%)	£302 (10.4%)
Total	**£204 (7.1%)**	**£397 (13.7%)**	**£588 (20.3%)**

Table 9: Comparison of the cost of demand minimisation and supply decarbonisation by on-site technology

The total costs given in Table 9 are those most comparable to the figures in the UK-GBC report and are generally in agreement as the cost increment for zero carbon buildings was given as 10 – 30% [24].

At LSC Level 4, the demand minimisation costs make up the majority of the final costs but the costs become much more balanced towards Level 6. This is not unexpected, given that the reductions in BER on the supply side are much more cost efficient for level 4 where heat generation technologies can be implemented instead of the relatively more expensive electricity generation technologies.

Emissions Reduction Technique	Financial Efficiency (£ per $kgCO_2/m^2$)		
	Level 4	Level 5	Level 6
Demand Minimisation	£84	£79	£76
Supply Decarbonisation (on-site)	£7	£8	£9
Overall	**£20**	**£18**	**£16**

Table 10: Comparison of the financial efficiency of demand minimisation and supply decarbonisation by on-site technology

Even though for higher levels the costs on the demand and supply side are similar, the cost efficiency of the techniques are very different. An equivalent amount of money is used to

[24] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, Sections 6.6.3 & 8.2

achieve a smaller emissions reduction on the demand reduction side. This may lead to the conclusion that it would be better to spend any available funding increments on supply decarbonisation (once again it should be noted that the costs and therefore the financial efficiency of the demand minimisation measures probably represent a worst-case scenario).

However, this approach would lead to less efficient buildings with minimal fabric improvements being powered by larger arrays of LZC electricity generation technologies. As more buildings approach carbon neutrality, increased demand will be placed on the country's renewable energy sources. Renewable energy is not unlimited and it is reasonable to assume there is not enough renewable energy resource available to allow buildings to continue to be built with inefficient fabric and systems.

It is therefore our recommendation that despite this apparent financial inefficiency that the demand minimisation measures be made mandatory and they are implemented in preference to the decarbonisation of the energy supply.

7.5 Conclusions

7.5.1 Comparison of Supply Decarbonisation Options (On-site, Off-site and Annual Expenditure)

A comparison of the costs associated with different locations of LZC generation equipment can be seen in Table 11.

Emissions Reduction Technique	Cost Increment (£/m^2) and Percentage of Total		
	Level 4	Level 5	Level 6
Total using on-site generation only	£204 (7%)	£397 (14%)	£588 (20%)
Total incorporating off-site generation	£153 (5%)	£241 (8%)	£311 (11%)
Equivalent Capital Expenditure using Annual Funding Model	£164 (6%)	£265 (9%)	£350 (12%)

Table 11: Comparison of the cost increments of various options for supply decarbonisation

As might be expected, the costs of off-site LZC energy is significantly less when compared to on-site generation and this is reflected in the overall costs. The development and adoption of a model allowing the inclusion of off-site energy sources would increase the effectiveness of the funds available to the LSC. As long as additionality is ensured, no renewable energy will be diverted from the grid and hence the carbon content of grid electricity would not be affected.

When the capital expenditure equivalent of the annual funding model is calculated, the figures are very close to the off-site generation costs. This is not unexpected as the electricity supplied within the annual funding model would also be generated off-site at similar costs.

7.5.2 Total Cost Increment Within the LSC Budget

The LSC has a current annual budget of £800m per annum which is guaranteed until 2011. By 2014 the aim is to have renewed or modernised 90% of the total FE estate (from a 1993 benchmark). If this sum was to finance only new buildings at the predicted average costs from the standard cost models (£2,894/m^2) it would lead to the creation of approximately 276,000m^2 Gross Internal Area (GIA) of new buildings. Incorporating the additional cost of carbon reduction calculated earlier gives a reduced figure for the amount of new build that could be funded which depends on whether LSC levels four, five or six were made mandatory.

It should be noted that these figures are indicative only and are not meant to accurately reflect the actual impact in GIA funding of any incentives to promote carbon neutral colleges. They do not account for refurbishments and extensions due to the wide variation of work that these encompass.

However, it could be assumed that the percentage increase in costs for increasing levels of carbon reduction that have been calculated for new build projects could equally be applied to extensions and refurbishments. This is due to the fact that similar changes in demand minimisation and supply decarbonisation would be required to achieve LSC levels 4, 5 or 6 irrespective of the extent of the building works.

This assumption allows us to draw some conclusions as to whether a larger reduction in emissions from the Further Education estate as a whole would be realised by concentrating on a larger number of level 4 colleges or fewer level 6 developments. Indicative trends can be seen in the figures below and Table 12.

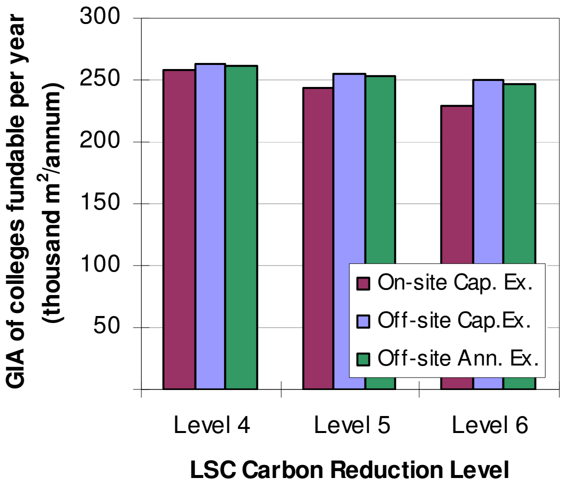


Figure 12: Impact of level of carbon reduction on funding ability of LSC

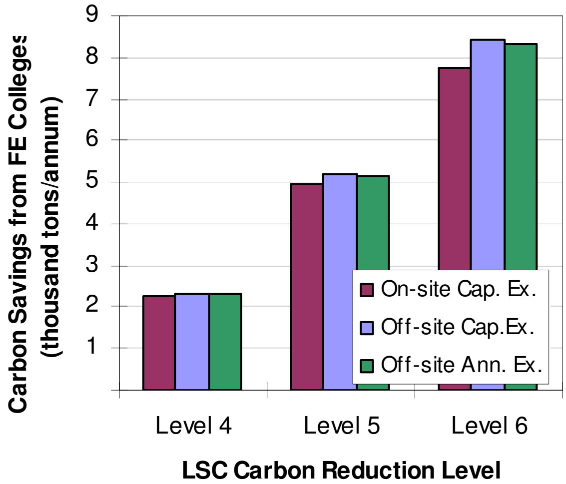


Figure 13: Impact of level of carbon reduction on reduction in emissions from FE college estate

		Level 4	Level 5	Level 6
On-site Capital Expenditure	GIA funding (m^2)	258,224	243,110	229,753
	Emission reduction (tons)	2282	4938	7735
Off-site Capital Expenditure	GIA funding (m^2)	262,542	255,221	249,667
	Emission reduction (tons)	2320	5183	8406
Off-site Annual Expenditure	GIA funding (m^2)	261,646	253,283	246,611
	Emission reduction (tons)	2312	5144	8303

Table 12: Impact of level of building emissions reduction on funding ability of LSC and reduction in emissions from FE college estate

It can be seen from the figures that the most effective way to reduce the carbon emissions from the Further Education estate is to encourage the building of as many level 6 colleges as possible. It therefore follows that to maximise the carbon reductions, the trajectory to zero carbon should be as steep as is feasible. This trajectory is further expanded upon in Section 9.

There is little discussion in this report regarding the financial pay-back period for the demand minimisation and supply decarbonisation measures used in the models. At the current prices for the measures and energy, the payback period is often longer than the projected life of the equipment. However, given the expected continued increase in energy prices, this situation may soon be changed.

8 Existing Requirements

There are a number of existing regulations and assessment methods relating to the carbon emissions of new buildings and refurbishments. Some are national, some local and some voluntary leading to a mix of requirements that might be relevant to a project. These are briefly described in this section to demonstrate how the LSC policy might interact with them.

8.1 Design Stage

There are a number of existing regulations relating to reductions in energy consumption and associated emissions in buildings at design stage. Those applicable to further education colleges are generally common to the non-domestic buildings sector and are summarised below.

8.1.1 Building Regulations

The 2006 revision to Part L of the building regulations introduced a step change in the manner in which energy savings in buildings were regulated, putting the emphasis on annual carbon emissions rather than energy use. However, the regulations are only concerned with the carbon emissions associated with predicted lighting, heating, cooling and auxiliary energy and do not include small power or actual energy in use. As such they fail to take into account a large proportion of the energy use in a building.

The building regulations also specify minimum standards of energy efficiency. The UK-GBC report recommends that the building regulations are used as the mechanism for increasing these minimum standards[25]. However in non-domestic buildings they highlight that these requirements may need to be different for different building forms, even building use.

A number of minimum standards which might be appropriate to colleges have been suggested in the section 9. However the LSC may wish to use the building regulations to enforce these requirements for consistency.

Refurbishments and extensions over a certain size are also covered by building regulations and it is proposed that any college refurbishment which qualifies for compliance with building regulations should also be required to achieve the proposed LSC level of carbon reduction.

8.1.2 'Merton Rule'

Local authority planning requirements for a certain percentage of energy used within new buildings to be provided from on-site LZC technologies are commonplace. Often referred to as the 'Merton Rule' after the London Borough that was one of the first to implement such a condition, they have a range of requirements in terms of the percentage of energy that is required to be produced and the base condition that the percentage is calculated from.

There are well understood arguments both in favour of and against the enforcement of on-site production. Solutions that may provide reductions in emissions cost-effectively and with a simple regulatory model may work for the majority of sites where the percentage of LZCs is relatively small. However, as the proportion of LZC technologies increase, the on-site solution becomes unviable for an increasing proportion of sites.

Conversely, there are valid arguments against a solution that solely relies on off-site generation.

The supplement on climate change to Planning Policy Statement 1 (PPS1) published in December 2007[26] provides further guidance for Local Authorities in developing Merton type rules and now recommends a less prescriptive approach that allows for LZC solutions appropriate to the site, including near site generation and community heating networks.

[25] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, Section 8.3.5
[26] *Planning Policy Statement: Planning and Climate Change Supplement to Planning Policy Statement 1*, DCLG

This study recommends a similar approach be adopted by the LSC with a hierarchy of solutions as detailed in section 6. However Local Authority planning requirements will still be required to be adhered to and should be considered by design teams when proposing appropriate solutions to the LSC.

Local authority planning requirements do not usually include refurbishments and extensions in their PPS1 requirements.

8.1.3 BREEAM

The BRE Environmental Assessment Method (BREEAM) can be used to assess the environmental performance of any type of building (new and existing). Credits are awarded to the building in 8 different areas which include management, health and wellbeing, energy, transport, water, materials, waste, land use, ecology and pollution. A set of environmental weightings then enables the credits to be added together to produce a single overall score. The building is then rated on a scale of: pass, good, very good or excellent and a certificate awarded to the development. Currently, Further Education colleges are covered by the bespoke version of the BREEAM system however, in the near future, a version specific to further education is to be launched.

Whilst in the non-domestic sector as a whole BREEAM can be considered to be voluntary, the LSC require that developments should normally be designed so as to achieve an ‘Excellent’ standard on the BREEAM 2008 scheme. The Government estate as a whole currently requires an “excellent” rating for all new buildings.

It is important in the consideration of a policy for zero carbon colleges to take BREEAM into account however the energy category in BREEAM is just one category in eight. The BREEAM energy category only takes into account the regulated energy and a limited number of specific aspects such as metering and lighting. This is less comprehensive than the approach required to take the further education sector towards zero carbon.

The credits available for carbon savings in the proposed BREEAM for colleges amount to 75% of the credits for the energy section and 14% of the overall final score. If the proposed levels of carbon reduction are adopted by the LSC on all new builds then this will contribute 14% to the BREEAM score (although this will be affected by amendments to the Building Regulations as these set the relative benchmark for the awarding of credits). Additional points within the pollution section may also, in effect, become mandatory. In anticipation of this it is recommended that the LSC adopt a mandatory requirement of “excellent” to ensure that standards do not slip in the other areas.

8.1.4 ‘Zero Carbon’ non domestic buildings

The UK-GBC report outlines many of the key issues relating to attaining zero carbon in the non domestic sector as a whole. In the budget statement of 12th March, the Chancellor announced that, in response to the work carried out by UK-GBC, it is the Government’s intention to require that by 2019 all new non-domestic buildings will be zero carbon. Progress following this announcement will need to be monitored to ensure that the policy adopted by the LSC is at least in line with, and possibly ahead of, targets for the sector as a whole.

8.1.5 Energy Performance Certificates (EPCs)

EPCs are a requirement of the Energy Performance in Buildings Directive. The provision of an Energy Performance Certificates will be compulsory on the construction, sale or rent of all new buildings by October 2008. As these certificates are based on the Part L BER calculation they will only be useful in comparing building designs against each other. They will not be useful in terms of monitoring real life carbon reductions or providing useful real benchmark data.

8.2 In Operation

It is becoming increasingly acknowledged that designing a low energy building is not the only consideration when addressing the carbon emissions associated with buildings in use.

Recording energy usage accurately and by end use is fundamental in addressing energy use in operation.

There are currently no regulations covering carbon emissions in the operation of buildings. There are also only a limited number of tools available to assess “in use” energy, the most well known are described below.

8.2.1 CIBSE Guide to Energy Assessment (TM22)

The CIBSE Guide to Energy Assessment (TM22)[27] provides a method for assessing the energy performance of an occupied building based on metered energy use and comparing this against published benchmarks (such as those detailed in section 4). The method uses spreadsheets to perform the calculations. Three levels of detail are described ranging from recording meter readings to recording every electrical appliance in the building and applying a usage and power rating profile.

The limitations of this method are generally poor metering records, and out of date bench marks (as discussed in section 4). Where meter readings are unavailable a methodology for estimating energy use from individual appliances is suggested, however this would be very time consuming to calculate on large buildings and actual power demand for equipment is often difficult to estimate.

8.2.2 Display Energy Certificates

Display Energy Certificates (DECs) are a requirement of the Energy Performance in Buildings Directive and will show the actual energy usage of a building, with the aim of helping the public see the energy efficiency of a building. They are based on the energy consumption of the building as recorded by gas, electricity and other meters. The information from DEC’s will be held on a central Government database to help create a more accurate energy benchmark data.

By October 2008 DEC’s will be mandatory for all public buildings greater than 1000m².

A public building is defined as a building either occupied by a public body or a building which large numbers of the public visit regularly. It is unclear whether colleges will be included in this. However eventually it is anticipated that all buildings will be required to have DECs.

DECs might provide general benchmarking but are constrained in detail by a wish to minimise the data collection requirements of building owners and occupants.

8.2.3 LSC E- mandate data

The UK-GBC report comments on the need for the establishment of a national database of building performance in order to properly understand building energy use[28].

The LSC are ahead in this respect with their eMandate program analysed in section 4 which records annual gas and electricity consumption from all colleges in the sector.

A not insignificant proportion of the college buildings in England have been constructed since the Building Regulations were altered to include mandatory extensive sub-metering. Since 2002, there has been a requirement for at least 90% of the annual energy consumption to be metered by end use. It is recommended that the eMandate process be widened to take account of this extra information where available.

[27] CIBSE Guide TM22 *Energy assessment and reporting method* (2006)
[28] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, Section 8.3.1

An area of the college that is often sub-metered irrespective of the age of the college is the catering facilities. This is due to the fact that the catering of the college is often outsourced to a third party company who bear the cost of the energy used.

The LSC eMandate process is leading the sector in energy data collection. Further details of refinements to the process which could assist colleges in achieving carbon emission reductions are discussed in the section 9 of this report.

9 Recommendations

This section sets out recommendations for the LSC consider incorporating when developing a Policy aiming towards Zero Carbon new buildings.

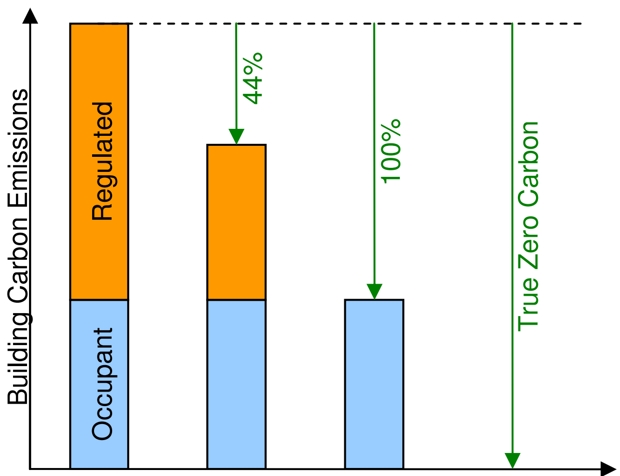
9.1 Trajectory towards Zero Carbon

The LSC has already stated its ambition for all new college buildings to be zero carbon by 2016 [29]. This target is ambitious and stretching whilst also being achievable and there is no reason to suggest altering this target.

It is recommended that instead of this target standing alone it is made part of a trajectory to Zero Carbon. This will have the following benefits:

- Reduce emissions prior to 2016. By having mandatory levels of carbon emissions reductions prior to 2016, the emissions of the developments constructed in this period will be less than if no mandatory standards were imposed.
- Provide clear and foreseeable targets for college design teams and funding bodies.
- Gradually increase the requirements on the FE design and construction sector as opposed to having a large step change in requirements. This will lead to more technically robust solutions that will be more cost effective as industry builds up experience and expertise in designing low carbon colleges.

Depending on which of the recommendations within this report are taken up, a different trajectory may emerge. More specifically, different models of the delivery of zero carbon energy will place different requirements on proposed colleges' design teams. Assuming that off-site LZC generation is to be included in some form, the proposed trajectory is as seen in Figure 14 below.



Year	2008	2010	2013	2016
Mandatory Level		LSC Level 4	LSC Level 5	LSC Level 6

Figure 14: Proposed trajectory to zero carbon FE colleges

This trajectory results in mandatory zero carbon developments sooner than the published targets for the general non-domestic sectors (set for 2019 [8]). This is possible due to the fact that the funding structure within the FE sector means that less reliance needs to be placed on how the market for the buildings would react to the increase in build costs. The practicality of zero carbon by 2016 is further increased by the wider proposed allowable solutions for LZC energy supply. A comparison of targets towards zero carbon can be found in Table 13.

[29] *Building Colleges for the Future: The LSC's National Capital Strategy for 2008–09 to 2010–11* (March 2008)

	2010	2013	2016	2019
Private Domestic	CSH Level 3	CSH Level 4	CSH Level 6	
Public Domestic	CSH Level 4	CSH Level 6		
Non-domestic				Zero Carbon
Schools			Zero Carbon	
FE Colleges	LSC Level 4	LSC Level 5	LSC Level 6	

Table 13: Comparison of proposed trajectory those previously published for other sectors

In addition, a target has been set for the Government office estate to be carbon neutral by 2012 [30]. However, this definition of carbon neutral includes off-setting which is not included in the definition used in this report.

9.2 Incentivise Low Carbon Design

It was shown in section 7 that, despite the reduced funding ability (in terms of Floor Area of College) that would result from the creation of zero carbon colleges, this is still the level to aim for to realise the largest carbon emissions reductions. It is therefore recommended that, in advance of a level being mandatory under the trajectory, the higher LSC levels are incentivised through the mechanism of enhanced funding. This will have the additional benefit of further increasing the learning within the FE college design and construction industry by encouraging the building of exemplar projects.

The proposed mechanism is that of increasing the proportion of capital funding available as the LSC level increases as shown in Figure 15. This would result in the LSC funding a larger proportion of the costs of reaching a higher level thereby reducing the burden on the college of funding the increased costs. The level of the funding increase can be adjusted to alter the increment a college must fund for an increased LSC level.

For example, if the LSC funding is increased 1.75% between the levels, then a college would see an increase of only 5% in its costs when building a level 6 college as opposed to a standard Building Regulations compliant one. This is compared to a construction cost increase of 20% if there were no increase in funding as the LSC level increased *.

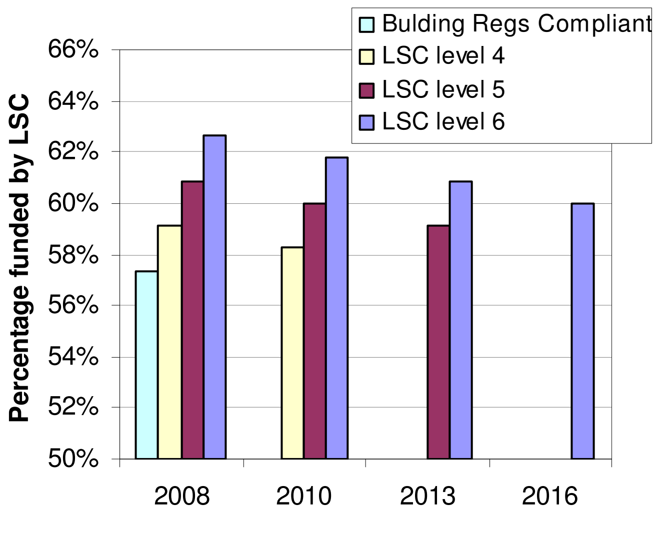


Figure 15: Example of increased capital funding as LSC level increases

[30] http://www.sustainable-development.gov.uk/government/estates/index.htm
* Note: Example figures based on LZC energy being provided entirely by on-site technology using 20% cost increment calculated in section 7.

9.3 Prioritise Demand Minimisation

As has been discussed previously, the LZC generation capability of the UK is not unlimited. If mandatory standards are not placed on the energy demand of zero carbon buildings then undue demands will be placed on this finite resource. It is also the case that the building fabric may remain largely unchanged throughout the life of the building whereas plant and services may be updated at regular, if not frequent, intervals.

To comprehensively address the demand of the building the following aspects need to be covered:

- Building fabric
- Energy efficiency of installed equipment and services
- Behaviour and awareness of the occupants with respect to energy use.

To address these aspects, a set of criteria have been developed in draft form that may form the basis of a structured approach to comprehensive demand minimisation. The criteria become more stringent and numerous as higher LSC levels of emissions reduction are aimed for. Details are also given of documentary evidence that would need to be provided to ensure that the proposed improvements are included in the building specification

The criteria would apply to all building work which is of a scale sufficient to require compliance with building regulations and is the subject of a funding application to the LSC for a proportion of the capital cost of the works. It is equally applicable to new-builds, extensions and refurbishments and where special cases are to be considered for a type of building work, these are detailed.

The detail of these criteria and, and the calculations and documentation that would need to be produced are described in detail in Appendix A.

9.3.1 The Format of the Criteria

The criteria are divided into 8 categories. These categories set out individual criteria for an assessment relating to overall CO_2 emissions and provide design limits to encourage reductions in CO_2 emissions from specific areas of end use:

1. Overall calculated building CO_2 emissions
2. Building Fabric Improvements
3. Hot Water Use Reduction
4. Internal Lighting
5. External Lighting
6. Small Power
7. Non-Standard Electrical Loads
8. Catering

The first category is concerned with the overall emissions from the development taking into account the energy demand and supply of the proposed buildings. The remaining seven categories are concerned with ensuring that a sufficient level of effort and investment has been employed in the reduction of energy demand by design prior to attention being turned to the decarbonisation of the energy supply.

In some categories the most effective way to reduce the emissions is not the alteration of the building fabric or specification but in the alteration of the behaviour of the eventual occupants. To this end, some categories have requirements on policies being in place when the building is occupied.

9.3.2 Evaluation of Level Achieved

It is not proposed that these assessment criteria be points or credits based in the style of the Code for Sustainable Homes or BREEAM. As these criteria are much less wide ranging than the Code (in that they deal only with the energy use of the buildings), it is appropriate to simply set levels at which criteria become mandatory. The overall level achieved will be that of the lowest level achieved for all sections.

9.3.3 Information sources

Where existing schemes, criteria or information are already in existence, these have been used as widely as possible. The aim in the development of the criteria is to provide the LSC with sufficient information to enable an accurate appraisal of the energy efficiency of the design whilst simultaneously adding as little workload to the design team in the need to produce extra paperwork individual to this scheme. Full references are provided within the relevant sections to allow easy access to the data required.

9.4 Allow Off-site LZC Generation

It is likely that in the case of FE colleges, and more widely among the non-domestic building sector in general, it will not be possible to generate sufficient LZC energy through on-site and near-site technology to meet the entire building's demand. This is irrespective of the extent of demand minimisation. After on- and near-site options have been exhausted, off-site LZC generation supplied via the National Grid will be required and it is recommended that a mechanism to robustly deliver this is set up.

The use of off-site generation, however, should always be secondary to practical and feasible on- and near-site options.

The UK-GBC are currently gathering evidence from a number of stakeholders and are due to report by spring 2008 on the best way to accredit off-site LZC technologies [31].

Of the procurement models that were discussed in section 6, it is those with a national or regional consolidator that will allow the most effective procurement of off-site LZC energy and it is recommended that one of these is adopted.

Under the current regulatory framework, the most robust way to ensure additionality of LZC generation capability is to directly fund the construction of new generation equipment via capital investment. This approach lends itself to the formation of a consolidator that takes a more active role in setting the national energy procurement model as opposed to simply acting as a facilitator between the colleges and any 3rd parties involved. This is described as model 4 within section 6.

It should be noted that any national standards relating to LZC generation that are brought in, for example through amendments to the Building Regulations, may differ from those proposed here and FE colleges would obviously need to comply with these standards.

9.5 Use Annual Funding to Create 'In-use' Zero Carbon Colleges

Existing methods of evaluating the carbon emissions of a building with a view to creating a zero carbon development have relied solely on the emissions levels predicted at the design stage using various tools. There is no guarantee that the actual in-use emissions will be the same as the predicted emissions and therefore no guarantee that a building is zero carbon, even if is labelled as such. The only way to create a true zero carbon development is to monitor the energy use and emissions regularly and to ensure emissions are net zero each and every year.

It is therefore recommended that the LSC consider the use of in-use energy consumption figures to ensure the predicted reductions in emissions are delivered in reality. If this approach is combined with the establishment of an energy procurement structure incorporating an active consolidator then the possibility is opened up of using a college's annual funding stream to fund the procurement of LZC energy. This would, however, need careful alignment with the preferred procurement method of direct capital funding.

[31] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, Section 8.1.3

A mechanism of incentives and penalties could be developed that would encourage colleges to reduce their emissions to a predetermined level. This is illustrated in Figure 16. In the case of new colleges the level would be set, initially, at the level predicted at the design stage.

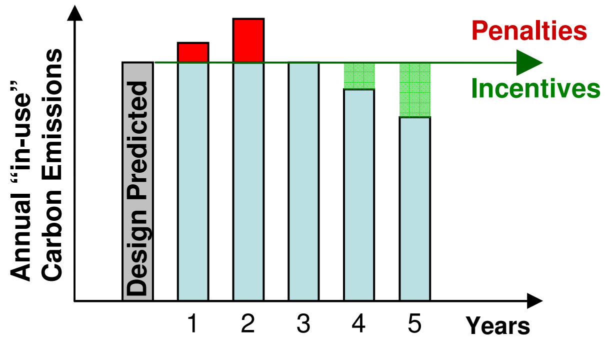


Figure 16: Possible mechanism for encouraging reductions in a college's emissions

This combination of an active consolidator purchasing LZC energy for a proportion of the college estate and a mechanism of targets and incentives linked to emissions levels would also allow the extension of the scheme to include existing colleges that have no significant capital works program planned. There would, however, need to be careful consideration into ensuring that the existing colleges had reduced their energy demand down to a suitable level prior to considering the decarbonisation of the supply.

The mechanism for the collection of the data regarding emissions is already in place in the form of the eMandate process.

9.6 Expand Scope of eMandate

The first recommendation in the UK–GBC report to CLG is to establish a national building performance database in order to properly understand energy use in the non domestic stock. Appendix D of the UK–GBC report discusses data collection in detail and identifies information that would be useful when carrying out a detailed energy audit of a building.

The FE college sector have a head start in this area as the minimum useful information (and many of the recommended useful refinements) listed in the UK-GBC report are already collected via the LSC eMandate. As of January 2008 it became compulsory for all FE colleges to submit an eMandate to the LSC. This included amongst other items, information on energy usage, floor area, age of college, key activities etc.

The information collected by the LSC to date has been invaluable. It has helped identify current trends in energy use within the sector and has been used within this report to asses the accuracy of existing published benchmarks and software predictions (sections 4 and 5).

The data currently collected by the LSC eMandate system breaks energy usage down by fuel type. This, along with other useful details of the colleges gives broad indications of energy usage in colleges but has limited use in identifying areas where energy savings could be made by individual colleges. It would be a natural progression for the eMandate process to assist individual colleges in targeting areas of high energy consumption.

Increasing amounts of data are generally required for more reliable evaluation and targeting of energy use. For the eMandate process one of the most useful refinements would be the collection of data relating to energy by end use. This will only be available from colleges with sub-metering. All colleges built since 2002 should have an element of sub-metering as required by Part L of the building regulations. Many of these sub-meters are likely to be read manually as there is no mandatory requirement for automatic metering and monitoring, nevertheless the collection of sub-metering data should be encouraged to realise energy savings.

All new colleges should have automatic metering and monitoring strategies to facilitate energy management. This is highlighted as a proposed mandatory requirement for colleges to reach the LSC carbon reduction levels as described in the workbook in appendix A. Ideally the end uses considered should relate to the categories assessed in AD Part L of the building regulations, these include space heating, water heating, cooling, lighting, and auxiliary (pumps, fans). Small power and any unusual loads (e.g. swimming pools) should also be sub-metered.

A second useful area of refinement relates to understanding energy use of individual college's year on year. This information would assist in generating energy targets for individual colleges and up to date benchmarks for the sector as a whole.

Although many of the suggestions required to facilitate the collection of the above information are already incorporated into the LSC eMandate process, a number of refinements are listed in Table 14.

	Purpose of data	
Data to be requested from eMandate	**Generation of targets & benchmarks**	**Identification of energy savings**
Sub-metering data by end use along with information about what is sub-metered.	✓	✓
For each building (or group of buildings) that is metered provide the following details: • Construction type (external walls and glazing type) • Age of building • Approximate split by floor area of activities		✓
Major changes in building use or construction in the period under consideration.	✓	
Types of HVAC plant and areas serviced by each type (e.g. naturally ventilated, mechanically ventilated, air conditioned)	✓	✓
Occupancy schedules and variations in energy consumption between weekdays, weekends and holidays.	✓	✓
Annual record of any grid displaced electricity funded by the colleges*	✓	

*Grid displaced electricity in the AD Part L2A definition comprises all electricity generated on-site. The LSC definition would be extended to include near site generation and any capital funded offsite generation.

Table 14: Refinements to LSC eMandate

In addition to the above it is recommended that the LSC use the eMandate data to record each colleges annual "in use" carbon balance. For this calculation the annual meter readings of all the fuels used by the colleges with their associated carbon factors will be required as well as the corresponding annual records of grid displaced electricity funded by the college. This information will be invaluable in understanding the discrepancies between "predicted" and "actual" carbon emissions and could help refine the LSC Zero Carbon Policy in the future. This would also be required if the LSC were to incentivise colleges to meet predefined energy targets. A central consolidator might manage this element of data collection if annual LSC funding were connected to the annual carbon balance.

Following the collection of more comprehensive data, increased analysis needs to be performed on the statistics relating to energy to ensure full use is made of the information.

Appendix A

Draft Assessment Criteria

Reduction of Carbon Emissions in F.E. Colleges

Draft Assessment Criteria

Introduction

In the following sections, a series of proposals are made for criteria that would allow the comprehensive evaluation of the carbon emissions associated with a project. These proposals would form the basis of a technical guide that would specify the detailed criteria that project teams would need to satisfy and the documentation that would need to be produced to provide evidence of compliance with the LSC carbon reduction targets. There are currently two stages to the Learning & Skills Council (LSC) capital funding application process: Application in Principle (AIP) which occurs at around the end of RIBA Stage C and Application in Detail (AID) which occurs after tendering is complete. Different levels of documentation would be appropriate for each phase and these are detailed.

The criteria would apply to all building work which is of a scale sufficient to require compliance with all relevant Building Regulations and is the subject of a funding application to the LSC for a proportion of the capital cost of the works. It is equally applicable to new-builds, extensions and refurbishments and where special cases are to be considered for a type of building work, these are detailed.

The style of these draft criteria is deliberately similar to that used in the Code for Sustainable Homes to provide a format that design teams will recognise and be familiar with.

All existing legislation, whether national or local, should be complied with in addition to any requirements laid down here.

The Format of the Criteria

The requirements are divided into 8 categories. These categories set out individual criteria for design limits to encourage reductions in CO_2 emissions from specific areas of end use and for the overall building:

	Category	Likely Responsibility
1	Overall calculated building CO_2 emissions	Building Services Engineer
2	Building Fabric Improvements	Architect
3	Hot Water Use Reduction	Building Services Engineer
4	Internal Lighting	Building Services Engineer
5	External Lighting	Building Services Engineer and Architect
6	Small Power Loads	Building Services Engineer
7	Non-Standard Electrical Loads	Building Services Engineer
8	Catering	Building Services Engineer and Specialist Catering Contractor

Only the categories that are affected by the building works would need to be complied with. For example, if the new building does not contain any catering facilities then category 8 does not apply. Category 1 applies if a Building Emission Rate needs to be calculated for Building Regulations compliance.

The first category is concerned with the overall emissions from the development taking into account the energy demand and supply of the proposed buildings. The remaining seven categories are concerned with ensuring the energy demand of the building has been reduced prior to attention being turned to the decarbonisation of the energy supply.

In some categories the most effective way to reduce the emissions is not the alteration of the building fabric or specification but in the alteration of the behaviour of the eventual occupants. To this end, some categories have requirements on policies being in place when the building is occupied.

Evaluation of Level Achieved

It is not proposed that these assessment criteria be points or credits based in the style of the Code for Sustainable Homes. As these criteria are much less wide ranging than the Code (in that they deal only with the energy use of the buildings), it is appropriate to simply set levels at which criteria become mandatory. The overall level achieved will be that of the lowest level achieved for all sections. Although this would seem to suggest that there is no benefit in exceeding the minimum specification for the level being aimed at, this is not necessarily the case. Achieving a higher level on one particular component may not benefit the overall score but it may provide a more cost effective solution to reaching the overall emissions reductions.

The lowest level defined is level 4. This is so that the levels align with the Code for Sustainable Homes levels for equivalent emissions reductions. Given the capability of the building industry at the current time and the aspiration of the LSC to reach carbon neutral in a short time-frame it was not deemed necessary to define levels 1 to 3.

		Level Achieved			Level Achieved		
		4	5	6	4	5	6
1	Overall Building CO_2 Emissions		✓			✓	
2	Building Fabric Improvements			✓			✓
3	Hot Water Use Reduction		✓			✓	
4	Internal Lighting		✓			✓	
5	External Lighting	(✓)			○ →	✓	
6	Small Electrical Loads		✓			✓	
7	Non-Standard Electrical Loads			✓			✓
8	Catering		✓			✓	

Table 15: Example of evaluating overall level achieved

Table 15 gives an example of the overall level that would be achieved for different combinations of mandatory elements for each of the sections. The overall rating for the case on the left would be Level 4 due to the level achieved in external lighting. The case on the right would achieve level 5 as the rating for external lighting has been improved.

Information sources

Where existing schemes, criteria or information is already in existence, these have been used as widely as possible. The aim in the development of the criteria was to provide the LSC with sufficient information to enable an accurate appraisal of the energy efficiency of the design whilst simultaneously adding as little workload to the design team in the need to produce extra paperwork individual to this scheme. The details can be seen in Table 16.

Criteria	Source of Existing Information
1	Requires calculations using Part L compliance software that will duplicate existing work at the design stages the applications are made.
2	Mimics the approach taken in the requirement within Building Regulations
3	Utilises existing benchmark criteria from the Water Technology Criteria List and the US Energy Star program
4	None applicable
5	Uses the same thresholds as BREEAM credit E4.
6	Uses guidance from the Carbon Trust and product lists created under the EU Energy Star Scheme for office equipment
7	References the US Energy Star program and in addition makes use of the Energy Technology Criteria List
8	References the US Energy Star program

Table 16: Sources of existing information incorporated into criteria

A1 Category 1 – Overall Building CO_2 Emissions

A1.1 Aim

To demonstrate that the proposed new building, refurbishment or extension has been designed to limit the overall emissions resulting from the operation of the building and its services.

A1.2 Assessment Criteria

Assessment is based on the percentage improvement in the Building Emission Rate (BER) from the Target Emission Rate (TER) as defined in the relevant building regulations. The BER is the calculated emissions (in $kgCO_2/m^2$/annum) from energy used for heating, hot water and lighting for the proposed building. These uses are termed the *regulated* energy. All other energy use is termed occupant energy. The TER is the maximum emission rate permitted by Building Regulations.

Additional requirements are necessary to achieve Level 6 with regard to occupant energy and these are defined within the calculation procedures.

Mandatory elements are defined in accordance with the table below.

Reduction in BER from TER	Mandatory Requirement		
	Level 4	Level 5	Level 6
44% improvement	✓		
100% (all regulated)		✓	
>100% (True Net Zero Carbon Building) as defined below			✓

Assessment of Refurbishments and Extensions

When the building work being considered is an extension, the calculations should apply only to the areas of the building required to comply with Part L2A as defined in Part L2B. Requirements for consequential improvements may apply under the Building Regulation Part L2A and are entirely separate.

This criterion does not apply to refurbishments where the BER is not required to be calculated for Building Regulations compliance.

A1.3 Information Required to Demonstrate Compliance

Application in Principle

- Notification of intention from the Design Team detailing which level of carbon reduction that will be targeted.
- Outline strategy on emissions including
    1. Techniques to be used to minimise energy demand.
    2. Intended source of low and zero carbon energy including details of any local planning conditions specifying on-site renewables.

Application in Detail

A copy of the report produced by the approved calculation tool illustrating:

- The predicted Building CO2 Emissions Rate (BER) and the Target CO2 Emission Rate (TER) from the equivalent notional building in $kgCO_2/m^2$
- The name of the approved software used to carry out the modelling.

In addition, the following is required:

- Confirmation of the expertise and experience of the individual carrying out the modelling in compliance with the requirements of the Building Regulations.
- For level 6, copies of the relevant calculations as outlined below showing calculated carbon emissions from occupant energy and how this is to be met by LZC technologies.

The BER calculations must show a negative emissions rate equal to the emissions resulting from occupant sources.

A1.4 Relevant Definitions

BER	The Building Emission Rate is the estimated CO_2 emissions per m^2 for energy used for heating, cooling, hot water and lighting. This is calculated using an approved calculation tool as defined in the relevant Building Regulations.
TER	The Target Emission Rate is the maximum allowable CO_2 emissions per m^2 for energy used for heating, cooling, hot water and lighting which would meet relevant Building Regulations. This is calculated using an approved calculation tool as defined in the relevant Building Regulations
SBEM	The Simplified Building Energy Model is a tool developed by BRE for CLG for the calculation of building emissions. Approved calculation tools are available which rely on the calculation methodology of SBEM.
Approved Calculation Tool	Approved calculation tools comprise the Simplified Building Energy Model or commercial software approved by the Department for Communities and Local Government. A list can be found on the National Calculation Method website.
Relevant Building Regulations	The Building Regulations for England and Wales Approved Document L2A: Conservation of Fuel and Power in New Buildings Other than Dwellings (2006).
True Net Zero Carbon Building	Where the net CO_2 emissions from all the energy used in the building or group of buildings are zero or lower. This includes energy consumed for heating/cooling, hot water, internal and external lighting, small power use, larger energy consuming equipment installed to provide facilities for specific curriculum activities and catering. Further clarification can be found in section 5 of the main report. Regulated energy is calculated using an approved calculation tool. Separate calculations or details apply for unregulated energy and are laid out below. Off-site LZC technologies are allowed in conjunction with the guidance laid out in section 6 of the main report.
Regulated energy	Energy included in Part L of Building Regulations i.e. heating, cooling, hot water and lighting
Occupant energy	Any energy use not included within regulated energy. Examples include small power, miscellaneous teaching equipment and catering.

A1.5 Calculation Procedures

Approved calculation tools will calculate the emissions from heating, cooling, hot water and lighting i.e. all those included in the building regulations. Separate calculation procedures are required for the remaining significant uses within a college to determine the overall emissions when level 6 is being targeted.

If offsite zero carbon electricity supplied through the National Grid is proposed, the calculation should assume, where appropriate, electricity with a Carbon Factor of zero. A report should also be submitted demonstrating that on-site & near-site LZC technologies have been considered and that they are not feasible. An LZC can be considered infeasible if it is not technically viable or if it has a financial payback period of over fifteen years.

The total emissions for level 6 compliance are the sum of the BER from the approved calculation tools results and the calculations detailed below:

A1.5.1 Calculations for Emissions Relating to Small Power

The emissions relating to small power use is calculated from the kWh/m^2 figures taken from the NCM template for Further Education buildings for the majority of spaces. These values can either be taken directly from the Part L compliance tool or calculated manually. If calculated manually, the internal area of the proposed buildings should be split down by the room activities. The annual power consumption can then be calculated for each room by multiplying the area with the figures shown in the table below.

$$Q_S = \sum A_R P_R C_F$$

Q_S Power Consumption from Small Power Use (in $kgCO_2$/annum)
A_R Total area of each Room Activity in Building (in m^2)
P_R Annual Power Consumption for each Room Activity (in kWh/m_2)
C_F Fuel carbon factor (in $kgCO_2/kWh$) for energy source as defined by Building Regulations e.g. grid supplied electricity = 0.422 $kgCO_2/kWh$

Room Activity	kWh/m^2
Bathroom	5
Bedroom	13
Cellular Office	32
Changing Facilities	20
Circulation areas	6
Classroom [Note 1]	17
Common room/staff room/lounge	18
Consulting room	18
Dry sports hall	6
Eating/drinking area	66
Fitness suite/gym	42
Food preparation area [Note 2]	125
Hall/lecture theatre/assembly area	6
High density IT work space	68
IT equipment	292
Laboratory	29
Laundry	81
Meeting room	17
Open plan office	48
Performance area (stage)	6
Plant room	351
Reception	11
Storage area	5
Swimming Pool	691
Tea Making	36
Toilet	16
Waiting room	9
Workshop / small scale	15

Note 1: Classrooms that include extra equipment over and above what can reasonably be expected to be used in the teaching of standard academic subjects should calculate the emissions relating to this equipment using the procedures in the following section.

Note 2: Catering facilities used primarily for the purpose of teaching should have their emissions calculated using the method shown in the next section. This is due to the fact that teaching kitchens tend to be more intensively used (have a higher diversity factor) and have a different mix of equipment.

The diversity factors from the NCM templates have been applied to arrive at these annual power consumption figures.

A1.5.2 Calculations for Emissions Relating to Miscellaneous Teaching Equipment

Further Education Colleges cater for a wide range of curricula such as land-based studies, health and beauty, automotive engineering and media production to name a few. With such a diverse set of teaching subjects comes an equally diverse range of specialist equipment. It is not possible to develop a standard calculation procedure to cover all eventualities so the emissions will be calculated from the predicted equipment lists for the buildings.

Any equipment that could not reasonably be expected to be present in a college teaching classroom based academic subjects should be included here. This includes ICT rooms with more computers than would be used for non-ICT teaching.

It should be noted that the power rating on the name-plate will possibly be a worst-case figure and as such could be significantly higher than the actual power consumption. For ICT equipment, guidance on the relationship between nameplate power and actual power can be taken from CIBSE Guide A (section 6.5). If the actual figure for the ICT equipment to be specified is not known then the power consumption can be assumed to be 25% of the name-plate value. For all other equipment, the nameplate power must be taken unless specific manufacturers' evidence can be provided to demonstrate the actual power consumption

The power consumption from non-standard equipment (in $kgCO_2/m^2/annum$) can be calculated using the following formula:

$$Q_N = \left[\sum \frac{nPh_d S}{1000} \right] \times C_F$$

Where:

- Q_N Power consumption from non-standard equipment (in $kgCO_2/m^2/annum$)
- n Number of each piece of equipment
- P Power consumption of equipment in Watts
- h_d Number of hours used in average school day
- S Number of school days per year = 200
- C_F Fuel carbon factor (in $kgCO_2/kWh$) for energy source as defined by Building Regulations e.g. grid supplied electricity = 0.422 $kgCO_2/kWh$

Alternatively, a table such as in this example can be completed where the total annual emissions is the sum of the right hand column.

Item	Number (a)	Power rating in kW (b)	Hours each is in use per year (c)	Fuel Carbon Factor (d)	$kgCO_2$/year a x b x c x d
Hairdryer	10	0.7	100	0.422	591
Kiln	2	6	50	0.422	253

A1.6 References and Further Information

Definition of Room Activities www.ncm.bre.co.uk

A2 Category 2 – Building Fabric Improvements

A2.1 Aim

To limit the emissions resulting from heat loss through the building fabric and to ensure that the building fabric is constructed to high standards.

A2.2 Assessment Criteria

Assessment is based on the U-values of the major thermal elements of the building work and the air-tightness of the building in accordance with the tables below.

Area weighted U value (W/m^2K)	Mandatory Requirement		
	Level 4	Level 5	Level 6
External Walls	0.25	0.20	0.15
Ground Floor	0.23	0.21	0.19
Roof	0.19	0.16	0.13
Windows and doors (whole element, not centre-pane)	2.1	1.9	1.7

As is stated in the building regulations (paragraph 38), a less demanding area weighted U-value might be an appropriate way of reducing the overall CO_2 emissions. If this case can be made then the area weighted U-value can be relaxed from the values stated above.

Air-tightness ($m^3/hr.m^2$)	Mandatory Requirement		
	Level 4	Level 5	Level 6
<7	✓		
<5		✓	✓

Assessment of Refurbishments and Extensions

Where the building work being considered is an extension, the U-value calculations must be performed for the new building fabric being constructed. The air-tightness requirement can only apply if the extension is connected to the existing building by a link-corridor or some other easily sealed area that will allow testing of the new section to be carried out. In all other cases there is no practical way to assess the air-tightness of an extension independently of the original building.

For refurbishments, the U-values apply to all thermal elements in the region of the building works. If thermal elements are not to be replaced then the U-values apply to the original materials. If poorly performing elements are not to be replaced then the refurbishment cannot be considered to be satisfying the criteria. The air tightness criteria apply irrespective of the extent of the refurbishment.

A2.3 Information Required to Demonstrate Compliance

Application in Principle

- Notification of intention from the Design Team detailing which levels of improvement for U-value and air-tightness will be targeted during the development process.
- Outline strategy on for each including:
    1. Initial materials ideas for the building elements affecting the U-vales including concept ideas on how the insulation will be improved over minimum standards.
    2. How design detail will be controlled to ensure that air-tightness is considered throughout design process.

Application in Detail

- Details of material specifications for relevant building elements with evidence that the thermal performance can be met.
- Evidence that the air-tightness of the building has been considered during the design process including drawings detailing the air-tight surface in the fabric.

- Confirmation from an airtightness consultant that the design details will lead to the required end result.

A2.4 Relevant Definitions

Air-tightness	The air tightness of the building fabric with doors and windows closed expressed in terms of number of cubic meters of air passing through the skin of the building every hour when the interior of the building is pressurised to 50Pa. Normalisation is carried out with regard to total internal floor area.

A2.5 Calculation Procedures

None required

A2.6 References and Further Information

ATTMA	Air Tightness Testing & Measurement Association (www.attma.org)
BSRIA	Building Services Research and Information Association (www.bsria.co.uk)

A3 Category 3 – Hot Water Use Reduction

A3.1 Aim

To limit the emissions resulting from the heating of hot water by reducing the amount of hot water consumed.

A3.2 Assessment Criteria

Elements are based on the inclusion in the design of fitments to reduce the consumption of hot water. The fitments required and the level at which they become mandatory are detailed in the table below.

Reduction in Emissions Arising from Hot Water Use	Mandatory Requirement		
	Level 4	Level 5	Level 6
All taps to have maximum flow of 6 litres/minute	✓	✓	✓
All showers to have maximum flow of 9 litres/minute		✓	✓
All taps to be auto sensing / touch responsive		✓	✓
Catering Dishwasher to adhere to Energy Star Criteria		✓	✓

To satisfy the first three criteria, the taps or showers must meet the conditions for inclusion onto the Water Technology List (items included on the list will automatically comply).

To satisfy the fourth criteria, the dishwashers must comply with the standards set out in the US Energy Star Program for the relevant type of dishwasher.

Assessment of Refurbishments and Extensions

Any taps or showers supplying heated water within a new extension must comply with the requirements of the level being sought.

Any new taps or showers supplying heated water within the building area being refurbished must comply with the requirements of the level being sought. Any existing units need not be replaced.

If no relevant taps or showers exist then the criteria is not applicable.

A3.3 Information Required to Demonstrate Compliance

Application in Principle

Notification of intention from the Design Team detailing which level will be targeted during the development process.

Application in Detail

A copy of the relevant sections of the Building Services Tender Documentation or Detailed Design Specification should be provided. Details should be included in the documentation to specify equipment that satisfies the criteria under consideration.

A3.4 Relevant Definitions

Water Reduction Equipment	Fittings such as flow restrictors may be fitted in taps and showers.
Flow Restrictors	Flow restrictors contain precision-made holes or filters to restrict and reduce the outlet flow and pressure.
Water Technology List	A list of water using technologies that have been assessed for their water saving performance. Inclusion on the list is subject to meeting criteria designed to reflect best practice in water consumption.

Energy star	Developed by the US Environmental Protection Agency to provide a standard for energy efficiency in many categories of electrical equipment, both domestic and commercial.

A3.5 Calculation Methods

None applicable.

A3.6 References and Further Information

Energy Star Dishwasher Criteria	http://www.energystar.gov/index.cfm?c=comm_dishwashers.pr_crit_comm_dishwashers
Water Technology List	www.eca-water.gov.uk

A4 Category 4 – Internal Lighting

A4.1 Aim

To limit the emissions resulting from the lighting of the internal space of the college.

A4.2 Assessment Criteria

Reduction in Emissions Arising From Internal Lighting	Mandatory Requirement		
	Level 4	Level 5	Level 6
100% fitment of low-energy lamps	✓	✓	✓
Installation of auto daylight dimming		✓	✓
Installation absence detection in circulation spaces		✓	✓

Where daylight dimming and absence detection are mandatory, they must be accompanied by a suitable commissioning process. The guidance contained with CIBSE Commissioning Code L should be followed. They must also incorporate manual over-rides that allow the users to switch the lights off should they choose to do so.

Assessment of Refurbishments and Extensions

Any internal lighting within a new extension must comply with the requirements of the level being sought.

Any internal lighting within a building area being refurbished must comply with the requirements of the level being sought irrespective of whether they were initially intended for replacement.

A4.3 Information Required to Demonstrate Compliance

Application in Principle

Notification of intention from the Design Team detailing which level will be targeted during the development process.

Application in Detail

A copy of the relevant sections of the Building Services Tender Documentation or Detailed Design Specification should be provided. Details should be included in the documentation to specify equipment that satisfies the criteria under consideration.

Where low energy lamps are not to be used, a valid reason must be provided as to why they are not suitable. The reason must relate to the technical capability of the lamps (e.g. response to dimming or spectrum of light output) as opposed to other reasons (e.g. cost or style). Examples of allowable exclusions can be found under *Special Process Lighting* in Part L2A of Building Regulations but this list is not necessarily exhaustive.

A4.4 Relevant Definitions

Auto daylight-dimming	The fitment of a control circuit that automatically dims the artificial light in response to the level of natural daylight reaching the relevant room or part of room. Systems where the lights are switched off with no dimming capability are not sufficient to qualify.
Absence detection	The fitment of a control circuit that can automatically detect the absence of people within the room or zone under control and reduce lighting levels accordingly. Low level ambient light is permissible for safety when system detects absence.

A4.5 Calculation Methods

None applicable.

A4.6 References and Further Information

CIBSE Commissioning Code L www.cibse.co.uk

A5 Category 5 – External Lighting

A5.1 Aim

To limit the emissions resulting from the lighting of the external space of the college.

A5.2 Assessment Criteria

Reduction in Emissions Arising From External Lighting	Mandatory Requirement Level 4	Level 5	Level 6
100% installation of low-energy lighting	Compulsory for all levels		
Installation of timed switching			

The lighting controlled by times switching should also be linked to a PIR or photocell to further optimise the system to reduce energy consumption.

Assessment of Refurbishments and Extensions

Where the building work being considered is an extension or refurbishment, only lighting being installed at the time of the building work should be considered.

A5.3 Information Required to Demonstrate Compliance

Application in Principle

Notification of intention from the Design Team detailing which level will be targeted during the development process.

Application in Detail

A copy of the relevant sections of the Building Services Tender Documentation or Detailed Design Specification should be provided. Details should be included in the documentation to specify equipment that satisfies the criteria under consideration.

Where low energy lamps are not to be used, a valid reason must be provided as to why they are not suitable. The reason must relate to the technical capability of the lamps (e.g. response to dimming or spectrum of light output) as opposed to other reasons (e.g. cost or style).

A5.4 Relevant Definitions

Timed switching	The fitment of a control circuit with an inbuilt clock that automatically switches the external lights on and off at certain predetermined times. Centralised systems which take signals from a Lighting or Building Management Systems are allowed.
Low energy lighting	Lighting with a minimum efficacy of 50 lamp lumens / circuit watt for general lighting and 70 lamp lumens / circuit watt for car parks, roads and sign lighting. Lighting employing LED light sources are also classed as low-energy. These definitions align with those in BREEAM credit E4.

A5.5 Calculation Methods

None applicable.

A5.6 References and Further Information

BREEAM	www.breeam.org

A6 Category 6 – Small Power Loads

A6.1 Aim

To minimise the emissions resulting from small power and standard office equipment within a college.

A6.2 Assessment Criteria

Reduction in Emissions from Small Power Use	Mandatory Requirement Level 4	Level 5	Level 6
Installation of Automatic Monitoring and Targeting system with prominent display of energy consumption data	Compulsory at all levels		
Energy Policy			
New equipment to be Energy Star qualified			

The Automatic Monitoring and Targeting (AM&T) System must follow the guidance contained with CIBSE TM22

Assessment of Refurbishments and Extensions

Energy Policy is required for all extensions and for refurbishments where thermal elements are changed or where there will be an increase in electronic equipment being used.

All new equipment must comply if installed at the same time as the building works and is included in the funding application.

A6.3 Information Required to Demonstrate Compliance

Application in Principle

Notification of intention from the Design Team detailing which level will be targeted during the development process.

Application in Detail

A copy of the relevant sections of the Building Services Tender Documentation or Detailed Design Specification should be provided. Details should be included in the documentation to specify equipment that satisfies the criteria under consideration.

A copy of Energy Policy and evidence that it has both top level endorsement and availability to all levels of staff in the organisation.

The specification of all new small power equipment and evidence that they are included in the Energy Star database.

A6.4 Relevant Definitions

AM&T	Automatic Monitoring and Targeting – a technique for identifying the largest areas of energy use. Can be linked to a graphical interface to be displayed in a prominent place within the college to raise awareness of the issue of energy consumption and energy saving.
Energy Policy	Policy aimed at monitoring, controlling and reducing the energy used in the new building. An existing policy in place is sufficient if it is applicable to the area of the building works under consideration. The Policy must have formal endorsement from the highest levels of the college management and teaching teams. It should be in written in accordance with Good Practice Guide 376 (GPG376) and be freely available to staff at all levels.

Energy star	Originally developed by the US Environmental Protection Agency to provide a standard for energy efficiency in many categories of electrical equipment, both domestic and commercial, Energy Star has recently been launched in Europe with a region specific database for office equipment such as PCs, monitors and printers.

A6.5 Calculation Methods

Quantification of emissions from office equipment occurs within the first criteria.

A6.6 References and Further Information

Energy Star Product Database	www.eu-energystar.org/en/en_database.htm
Good Practice Guide 376	*A strategic approach to energy and environmental management;* Carbon Trust www.carbontrust.co.uk
CIBSE TM22	*Energy assessment and reporting method*; www.cibse.org

A7 Category 7 – Miscellaneous Electrical Loads

A7.1 Aim

To reduce the emissions from:

- The operation of non-standard electrical equipment related to specialist areas of the curriculum.
- Electrical equipment installed as part of the building services.

A7.2 Assessment Criteria

Reduction in Emissions from Small Power Use	Mandatory Requirement		
	Level 4	Level 5	Level 6
Consideration of energy efficiency of non-standard teaching equipment and comparison with alternative products.	✓	✓	✓
Meeting, if appropriate, of Energy Saving Criteria as specified by Enhanced Capital Allowance Scheme.		✓	✓

Due to the specialist nature of the equipment to be included in this section it is not feasible to accurately collate information on each possible item. Therefore the design team must provide adequate information to show that the energy efficiency of the equipment has been considered for the included items.

Where a product category and associated efficiency criteria exist within the US Energy Star these must be taken into account and used as a benchmark even though the product lists may not apply to products available in the UK.

Each of the items included in the calculation for the unregulated energy (detailed within Criteria One) must have information provided.

Any equipment that is to be installed into the building for which a category exists on the Energy Technology Product List (ETPL) must be compared against the criteria within the Energy Technology Criteria List (ETCL). Products included on the ETPL automatically comply. Where the criteria are not met, valid reasons must be given for the choice of equipment.

Assessment of Refurbishments and Extensions

All new equipment must comply if installed at the same time as the building works and is included in the funding application.

A7.3 Information Required to Demonstrate Compliance

Application in Principle

Lists of types of equipment likely to be included in this category and a commitment from the Design Team that their energy efficiency will be taken into consideration

Application in Detail

For each type of equipment to be included, accurate power consumption figures must be provided (they will also be required for the calculations in Criteria 1 – Reduction in BER). In addition, a comparison of the energy consumption must be made with at least two other examples of equipment that could be used for the same function and, where applicable, comparison must be made against the US Energy Star criteria. Where the chosen item is not the most energy efficient, a reason must be provided as to why the less efficient item has been chosen.

Comparison with ETCL for all applicable equipment.

A7.4 Relevant Definitions

Energy star	Developed by the US Environmental Protection Agency to provide a standard for energy efficiency in many categories of electrical equipment, both domestic and commercial.
Energy Product Criteria List	A list of criteria relating largely to building services equipment that identifies best practice levels for energy efficiency in a number of categories.

A7.5 Calculation Methods

Quantification of emissions from relevant equipment occurs within the first criteria.

A7.6 References and Further Information

US Energy Star Database	www.energystar.gov/
Energy Product Criteria List	www.eca.gov.uk/etl/criteria/

A8 Category 8 – Catering

A8.1 Aim

To reduce the emissions from any catering facilities included in the design of the college by:

- Reducing the energy consumption of the equipment installed
- Ensuring that good operational practices are followed
- Measuring and thereby promoting the reduction in hot water consumption

A8.2 Assessment Criteria

Reduction in Emissions from Catering	Mandatory Requirement		
	Level 4	Level 5	Level 6
Energy monitoring and targeting and following best practice housekeeping standards	✓	✓	✓
New equipment Energy Star qualified where appropriate		✓	✓
Sub-metering of Hot Water use		✓	✓

To satisfy the first criteria, an energy monitoring and targeting scheme must be set up specifically to monitor the energy consumption within the catering facilities. If the company operating the catering contract is separate to the college, then a clause must be included in the contract of engagement for the catering company ensuring that they adhere to the criteria. The scheme and associated best practice housekeeping standards should be written in consultation with and following the guidance of *Introduction to Energy Efficiency Booklet 2: Catering Establishments* (now withdrawn) or equivalent.

To satisfy the second criteria, the equipment must comply with the standards set out in the US Energy Star Program if a relevant category exists.

Sub-metering of hot water use within the catering facilities should be provided either as part of the larger sub-metering scheme or separately.

Assessment of Refurbishments and Extensions

If the catering facilities are included in the building works then the criteria for the relevant level must be met.

All new equipment to be installed at the time of the building works and that is the subject of the funding application being considered is to be evaluated irrespective of the extent of the works.

A8.3 Information Required to Demonstrate Compliance

Application in Principle

Notification of intention from the Design Team detailing which level will be targeted during the development process.

Application in Detail

A copy of the energy strategy or a copy of the contract that a catering supplier is to be engaged under including the relevant clause(s) on energy targeting and monitoring. Details of how the strategy follows the guidance specified.

A copy of the relevant sections of the Building Services Tender Documentation or Detailed Design Specification should be provided. Details should be included in the documentation to specify equipment (if a relevant US Energy Star category exists) that satisfies the criteria under consideration.

A8.4 Relevant Definitions

Energy star	Developed by the US Environmental Protection Agency to provide a standard for energy efficiency in many categories of electrical equipment, both domestic and commercial.

A8.5 Calculation Methods

None applicable.

A8.6 References and Further Information

Energy Star Commercial Kitchens	http://www.energystar.gov/index.cfm?c=commercial_food_service.commercial_food_service
IEEB 2: Catering Establishments	Carbon Trust (0800 085 2005) (not available of website)

Appendix B

Modelling Methodologies and Results

B1 Modelling Methodologies

B1.1 Overall

Five Colleges have been selected for this element of the study. Each college is a real project currently at design stage within Arup.

The selection criteria were as follows:

- The proposed college building was funded or part funded by the LSC
- The college was being designed to comply with Part L2A of the Building Regulations for England and Wales using the NCM approved software simulation tool IES VE compliance (for consistency of results)
- An outline model had already been created in IES (this saved a significant amount of modelling time)

A brief summary of the remit for each of the college buildings under consideration is given below.

College 1 College Hub

This building is part of a larger college campus but is intended as the main "Hub" of the college. It is intended to provide "…a new building at the centre of the College campus to provide a focus for the site and to link the existing buildings. It is to include a new refectory, reception and Student Services, LRC and teaching and staff accommodation." It also has a few meeting rooms and offices for the heads of the college and their assistants as well as a board room.

College 2 Construction Project Manager Training College

This building is designed to simulate a construction site. There are 11 site cabins incorporated into the college building and a large simulation hall which simulates, via virtual reality, various site situations.

College 3 A-Level College

The building includes a high proportion of classroom areas.

College 4 Vocational College

The building includes specialised facilities for teaching subjects such as hair and beauty, catering etc.

College 5 A-Level College

The building includes a high proportion of classroom areas.

The following table summarise for each college the percentage split of a selection of room activities.

Percentage of Gross Floor Area (m^2)	College				
	1	2	3	4	5
Office	20	13	3	6	-
Classroom	30	4	37	35	50
Kitchen	2	0.4	0.1	5	0.6
Refectory	16	-	-	5	1.4
Circulation/WCs	15	46	40	30	36
Meeting rooms	7	17	0.5	3	-
Halls (Sports, Performance etc)	-	7	7	-	-
Stores & Plant rooms	10	5	2	9	1.0
IT Classrooms and server rooms	0.6	7	6	-	10
Staff areas	-	-	4	6	-
Laundry	-	-	-	0.4	-
Gym	-	-	-	0.8	0.7

Table 17: Percentage split of College gross floor area by room use

B1.2 Study 1

For this study the IES ApacheSim dynamic simulation module was used to calculate annual carbon emissions.

Four simulations were undertaken for each of the 5 college buildings with improvements made in step changes to the insulation and air tightness from the LSC base case defined in the LSC typical college cost models. The improvements made to the insulation and air tightness were based on what was deemed reasonable to construct with current building techniques.

These improvements are summarised below.

		Simulation			
		Current Building Regs	LSC level 4	LSC level 5	LSC level 6
Area weighted U-values W/m^2K	Roof	0.25	0.18	0.15	0.13
	External wall	0.35	0.21	0.16	0.13
	Ground floor	0.25	0.23	0.21	0.19
	External Glazing	2.13	2.1	1.9	1.4
Air tightness $m^3/hr/m^2$ @ 50pa		10	7	5	5

Table 18: Simulated fabric improvements

For the purpose of this study the following elements were standardised across each of the IES models;

- **Location** – The colleges have all been located in London and use London test reference year weather data from 2005
- **Heating Ventilation & Air conditioning (HVAC) & Domestic Hot Water (DHW) Systems** – The efficiencies and operation profiles of the HVAC and DHW systems have been taken directly from NCM templates for a notional building for the appropriate ventilation strategy. All the case studies therefore assume the same efficiencies for their HVAC equipment equivalent to a notional building designed to 2002 building regulation

standards. This was a quick method of ensuring all the models assumed the same efficiencies and profiles, but means they do not necessarily comply with Part L 2006.

- **Internal gains** – The internal gain profiles and magnitudes for lighting, occupants and equipment have been taken from the appropriate NCM template for the room activity. The NCM building assumed was University/FE College.
- **Lighting** – In accordance with a notional building as defined in Part L2A, no lighting controls have been applied to the model i.e. lights are on when the building is occupied.

The geometry, orientation and the assignment of room HVAC strategies were not changed from the original models created by the design teams.

The following table summarises, for each College, the percentage split of floor area treated by three ventilation options; natural ventilation, mechanical ventilation and air conditioning.

Ventilation Strategies (Percentage of GIA)	College				
	1	2	3	4	5
Natural Ventilation	16	24	84	36	47
Mechanical Ventilation	83	76	7	29	41
Air-Conditioning	1	0	9	35	12

Table 19: Percentage split of College gross floor area by ventilation strategy

B1.3 Study 2

For this study the IES VE compliance module[32] was used to calculate the Building Emission Rate (BER) for each of the colleges.

The BER was calculated for each college with the 3 Levels of fabric improvement described in study 1.

Fabric improvements alone were generally not enough to meet the Target Emission Rate (TER) and so the following enhancements were made to the HVAC and lighting systems;

- **Lighting assumed to be PIR (presence detection) controlled:**

  This was modelled by applying a dimming profile to all rooms reducing electrical lighting output to 80%. This is based upon the recommendations in table 7 of Part L2 2002[33] (now superseded) which it is assumed is the basis for the SBEM lighting control factors.

  Daylight linking was not modelled as this would have required significant remodelling or additional calculations to be carried out which unfortunately were not possible within the time frame of this project.

- **HVAC and DHWS systems changes:**

  The system type for natural ventilation and mechanical ventilation were assumed not to change from the notional building model. The air conditioning system was changed to active chilled beams. Boiler efficiencies were improved to represent an efficient condensing boiler. The chiller efficiency remained the same as the notional building. Heat recovery was assumed on mechanical and air conditioning systems.

  It should be noted that these models did not account for any improvement to the delivery efficiency of the domestic hot water system, only to the boiler efficiency. In reality the design team may be able to reduce domestic hot water loads further with careful design of delivery strategy.

These are purely indicative models designed to represent one possible solution and should not be used as design guidance or best practice values.

32 IES VE compliance Part L approved tool – complies with National Calculation Methodology
33 Table 7 in Approved Document Part L2 2002 edition (superseded)

Name	LSC nat. vent. system	NCM notional heating + mech. Vent. system	LSC A/C	DHWS
System Type	not set	not set	active chilled beams	
Boiler efficiency	0.98	0.98	0.98	0.98
Delivery efficiency	0.81*	0.81*	0.90*	0.5*
Heating system SCOP	0.8	0.8	0.89*	
Heat recovery		0.6	0.6	
Chiller efficiency			3.13*	
Percentage Heat rejection			10	
Delivery efficiency			1.13*	
Cooling system SSEER			2.52*	
Auxiliary Energy W/m2	0.61*	3.38*	4.98*	
Hot Water Storage				None assumed*
Secondary Circulation				None assumed*

* Default values or values generated by IES software

Table 20: HVAC system improvements modelled to meet Part L2A 2006 carbon emission requirements

B2 Modelling Results

B2.1 Study 1

The following table show the full results for study 1. The BER for each college is shown with the with the percentage improvement on the base case fabric model.

	Annual kg/CO_2/m²				
	College 1	College 2	College 3	College 4	College 5
Base case BER	27	27	25	33	23
LSC Level 4 BER	25	25	24	32	22
LSC Level 5 BER	24	23	22	32	21
LSC Level 6 BER	23	22	21	32	20
% improvement on base case	15	19	16	3	13

Table 21: Building Emission Rates for the 5 colleges with just fabric improvements

B2.2 Study 2

The following tables show the full results for study 2. The BER for each college is shown with the with the percentage improvement on the TER. The emissions for the notional building (NOT) are also listed.

	U-values W/m²K	Infiltration m³/h.m² @50pa	Annual $kgCO_2$/m²			
			BER	NOT	TER	Pass %
College 1	level 4	7	21	29	22	4
	level 5	5	20	29	22	9
	level 6	5	19	29	22	12
College 2	level 4	7	22	30	22	4
	level 5	5	20	30	22	10
	level 6	5	19	30	22	16
College 3	level 4	7	20	27	21	5
	level 5	5	18	27	21	11
	level 6	5	17	27	21	16
College 4	level 4	7	24	35	26	5
	level 5	5	24	35	26	7
	level 6	5	23	35	26	9
College 5	level 4	7	17	24	18	2
	level 5	5	16	24	18	7
	level 6	5	15	24	18	12

Table 22: Building Emission Rates for the 5 colleges with fabric, systems and lighting improvements

Appendix C

Methodology behind Cost Calculations

C1 Cost Calculation Methodology

C1.1 Demand Minimisation

The aspects of design minimisation that were likely to have the greatest impact on cost were determined and a cost increment was calculated for each of the levels and normalised to the Gross Internal Area. The increments were calculated in the following way:

- U-values and air-tightness: The standard specifications were examined in the LSC's standard cost models and the alterations that would be needed to raise the performance to suitable levels were determined (see Study 1 in Section 5).
- Thermal mass: For consistency, this cost was taken from the UK-GBC report[34] as this factor was applicable to further education colleges as members of the non-domestic buildings sector.
- Internal lighting and controls: Cost to provide presence detection and daylight dimming technology in suitable areas of the building.

There are a number of other areas of demand minimisation which should be considered but which do not have significant cost implications if considered early enough in the design process such as:

- Orientation
- Building form
- Good system design (variable pumps etc.)

It was not possible within the timeframe of this study to measure the reduction in emissions associated with these elements.

C1.2 Supply Decarbonisation Using Capital Investment

There are obviously many approaches to the minimisation of emissions by using low and zero carbon supply technologies. Each technology has its advantages and disadvantage and these are often specific to the site, project or building. To provide a broad insight into the effect technology choice would have on costs, three LZC strategies were applied to each of the five college models analysed in section 5. Where on-site electricity generation has been considered, it was assumed that a mix of small wind turbines and photovoltaics would be used.

Each of the LZC strategies were applied to each of the LSC levels of carbon reduction. The annual carbon emissions from the calculations in Study 2 of Section 5 were used to determine the quantity of LZC technologies required to meet each level.

Reduction in BER from TER	
44% improvement	LSC Level 4
100% (all Regulated Energy)	LSC Level 5
>100% (True Net Zero Carbon Building) as previously defined	LSC Level 6

Table 23: Overall emissions reduction for LSC levels of carbon reduction

For level 6, the annual carbon emissions from small power are also required to be zero. The values for small power generated by IES were used which are based on the National Calculation Methodology (NCM) template.

Combined Heat and Power (CHP) was considered for inclusion into the LSC strategies. However, whilst it may be a valid option for some colleges, it was not suitable for the college scenarios that the costs were to be based on. A number of the smaller college scenarios are based on single buildings that would make up a larger college complex. In these instances,

[34] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, Section 6.4.3

a district CHP network may have been a suitable option for a CHP system and it was not possible to build robust enough assumptions to allow it's incorporation into the strategies.

Strategy 1 Biomass + PV / Small Wind

The biomass boiler was sized to provide 50% of the peak load of the heating and hot water. This was seen as a realistic compromise between maximising the emissions reductions and increasing the cost effectiveness of the system. The hourly boiler demand profiles of the colleges were then used to determine the proportion of heat and hot water that would be provided by the boiler in each of the months of the year leading to the calculation of the emissions saved over one year.

The remaining carbon reduction for each level was attained by including a suitable amount of on-site LZC technologies.

Strategy 2 Ground Source Heat Pump + Solar Thermal + PV / Small Wind

The Ground Source Heat Pump was sized to provide 50% of the annual heat load of the colleges and the costs were calculated on this assumption. The emissions reduction from this system replacing half of the heat provided by the standard natural gas boiler was calculated as a reduction in the annual carbon emissions.

A solar thermal hot water system was then included, sized to provide 60% of the annual hot water demand. 60% is a realistic annual average contribution (given the variations is available solar energy) of a system that is sized to meet hot water demand in summer.

The remaining carbon reduction for each level was attained by including a suitable amount of on-site LZC technologies.

Strategy 3 Off-site Large Scale Wind Power

The carbon reductions for each LSC level was attained by including investment in off-site large scale wind power sufficient offset the colleges' predicted annual emissions.

C1.2.1 Cost Information used in the Calculations

The costs used in the calculations can be seen in Table 24 along with their sources. Where comparable figures are available in both the London Renewables Toolkit and the UK-GBC report, the costs from the latter have been used as they are considered to be more up to date.

Technology	Price	Units	Source
PV	£14.78	per kgCO_2 avoided	UK-GBC[35]
Small Scale Wind	£12.50	per kgCO_2 avoided	UK-GBC
Biomass boiler	£350	per kW boiler size	London Renewables Toolkit[36]
GSHP	£0.19	per kWh/annum	London Renewables Toolkit
Off-site Large Scale Wind	£1.02	per kgCO_2 avoided	UK-GBC

Table 24: LZC technology costs used in calculations with sources

C1.2.2 Emissions factors used

The carbon fuel factors for natural gas and grid electricity (both supplied and displaced) used in the supply decarbonisation calculations are those endorsed by CLG and used in Part L of the Building Regulations. They are based on forward predictions of the proportion

[35] *Report of carbon reductions in new non-domestic buildings*, UK-GBC, Section 6.5.3
[36] *Integrating renewable energy into new developments: Toolkit for planners, developers and consultants*, London Energy Partnership (www.london.gov.uk/mayor/environment/energy/docs/renewables_toolkit.pdf)

of energy being provided by different sources. There are other figures available from other organisations including those based on actual historic data.

The figures are not intended to give an exact actual carbon content of the fuel but rather an indication of the emissions that could be saved.

C1.3 Annual Expenditure

The previous section concentrates on the capital investment required to build or install enough LZC generation capability to meet the demands of the building as predicted. It was noted in section 6 that, due to the funding structure in the Further Education sector, there is scope for the annual funding of the colleges to be used to finance a proportion of the expense for carbon reductions in colleges.

The increased cost of electricity supplied by off-site LZC technologies in this instance would be the cost of the electricity at the standard market rate plus the cost of the retiring the Renewables Obligation Certificates (ROCs) for each unit of energy. The additional cost to the college is therefore the cost of the ROC, currently approximately 4.5 p/kWh.