Communities and Local Government

UK GREEN BUILDING COUNCIL

Report on carbon reductions in new non-domestic buildings

Report from UK Green Building Council

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The following report is a collaboration written by the UK Green Building Council members, in particular:

Report on carbon reductions in new non-domestic buildings

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UK Green Building Council
December 2007
Department for Communities and Local Government

The findings and recommendations in this report are those of the authors and do not necessarily represent the views of the Department for Communities and Local Government

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Contents

Executive summary

The Climate Change Bill of 2007 sets challenging targets for carbon reductions across the UK. Clearly, buildings would need to deliver significant reductions as part of this overall target.

The publication of the Code for Sustainable Homes set out targets to achieve radical emissions reductions from new homes. This project was commissioned to add to the understanding of whether similar targets in the non-domestic sector can be set and achieved and on what timescale.

The complexity and scale of this task required an industry-wide analysis. The UK-GBC is an industry-led, independent, not for profit, membership-based organisation made up of world class engineering practices, architects, project and cost management consultants, developers, NGOs and many others including leading academia, and was considered the best organisation to undertake the research.

In tackling the task the UK-GBC endeavoured to answer the following questions:

1. What is total energy use in non-domestic buildings?
2. Is it feasible to reduce the carbon emissions resulting from this energy use down to zero?
3. What would be the estimated cost of these carbon emissions reductions?
4. Over what timescale could zero carbon new non-domestic buildings be achieved?

In order to answer these questions the project was broken down into a number of sections as detailed below in Section 1: Approach and Structure.

Question 1: What is total energy use in buildings?

After collecting considerable amounts of existing energy-use data in non-domestic buildings from across the membership of the UK-GBC, and modelling a number of building types, estimates of total energy use could be calculated. However, energy-use data for non-domestic buildings was found to be inconsistent, ad hoc and by no means complete. A greater understanding of energy use in buildings is essential not only to understanding the feasibility and cost of zero carbon new non-domestic buildings, but also to the successful implementation of policy measures to achieve it.

Therefore the **first recommendation of this report is the implementation of Energy Performance in Buildings Directive** (EPBD) as soon as possible, which must include Display Energy Certificates (DEC) for all new and existing non-domestic buildings in sufficient detail to better the understanding of the non-domestic building stock. If implemented in conjunction with a consistent data gathering and reporting mechanism, this will allow accurate data to be gathered around the actual use of energy. With this data it will be possible to design and model future buildings with confidence that energy consumption estimates are accurate. Therefore the **second recommendation is the construction of a national database** to collate and store this data and make it available to the whole industry.

In addition, although not necessarily related to new-buildings, accurate building energy displays could contribute to the development of zero carbon energy solutions which encompass both new and existing buildings.

Question 2: Is it feasible to reduce this energy use and the consequent carbon emissions resulting down to zero?

It is difficult to generalise across all non-domestic building forms and uses, but in general, energy use, and in particular the electricity to heat ratio, is significantly higher for non-domestic buildings than it is for domestic property. This means that for most building forms and uses, the implementation of on-site renewable energy solutions is much more challenging. Indeed, the report shows that on-site renewable energy solutions that are capable of meeting all building energy demand are unlikely in most instances, without significant heat dumping or connection to a local heat network.

This leads to **recommendation three: the implementation of an effective hierarchy for carbon emissions reductions including energy efficiency in design and the use of on-site, near-site and off-site renewable energy generation solutions.** It is relatively well understood, but always worth stating, that there should be a clear hierarchy for achieving emissions reductions, starting with demand reduction, through passive design measures and high-performance specification. As discussed throughout this document, even sources of "renewable energy" can have a finite capacity, and therefore as much, if not more, effort should be put in to designing out energy demand as is put in to designing in energy generation and supply.

Once high levels of passive performance have been achieved the issue of energy supply can be addressed. Ideally the generation capacity should be located as close to the development as possible in order to avoid unnecessary distribution losses, increase local awareness of energy supply issues, and ensure that all available renewable energy capacity is exploited. Potential mechanisms for implementing this are discussed in more detail in Section 8.3, but all solutions would need to ensure additional renewable energy generation to avoid double counting of carbon reductions, eg retirement of Renewable Obligation Certificates (ROCs).

It is also recognised that the considerable renewable resources of the UK, although very large (one of the largest in Europe) are nonetheless limited (see Section 8.1.1.7) and therefore the use of local resources should be prioritised before the use of national off-site sources. Testing of when this should be prioritised should form part of the work on a resource estimation tool.

Therefore the **fourth recommendation is the construction of a UK-wide renewable resource estimation tool**, tied to local planning requirements. This tool would be used at the planning stage of developments to assess their renewable energy potential. This would need to take into account the potential both for renewable energy generation on the site and for decentralised energy networks which should be tested and set by the planning authority.

The **fifth recommendation is that certain minimum energy efficiency measures also be incorporated** within higher levels of any rating system, much the same as the Code for Sustainable Homes has a minimum heat loss parameter (see Section 8.3.5). This should include minimum cooling load parameters for building uses in order to ensure efficient use of resources before drawing upon UK-wide resources.

Question 3: What is the estimated cost of these carbon emissions reductions?

The estimated cost of delivering all new non-domestic buildings to zero carbon standards varies widely with both the form and the use of the building.

Very few true zero carbon non-domestic buildings have been constructed in the UK; as a result there is little empirical evidence as to what a cost premium might be. Furthermore, due to performance and quality drivers, there is a wide range of costs associated with functionally similar non-residential buildings. Due to the absence of an established knowledge resource and the high variability in baseline costs, the reporting of the extra cost of zero carbon on the basis of a percentage addition runs the risk of significant error, and misrepresenting the factors that drive the cost premium in the first place.

Information was taken from completed projects, which are likely to have relatively low occupation-related loads. The associated modelling, which is based on scenarios that more closely reflect the current commercial marketplace, suggests that the premium could range from over 30 per cent down to as low as 5 or 10 per cent of current baseline costs given sufficient time for the market to develop, and detailed specifications to be costed. In some extreme cases, the premium could well be higher than this (see Section 6.6.3).

It is important to note that considerable work in building a knowledge base which matches cost premiums with building type and building performance will be required to enable a confident and contextually accurate assessment to be made.

It is recognised that significant carbon reductions are required to mitigate the onset of climate change, but that the economic drivers for this are not yet in place to respond to the recommendations of the Stern Review. Therefore **recommendation six is that policy intervention is required and should cut across many policy areas:** planning, Building Regulations and energy as a minimum.

This report highlights the fact that energy-demand reductions for building occupiers are not financially incentivised at current energy prices. Therefore, occupiers must be engaged in demand reduction.

To do this, and to ensure additionality for the whole lifetime of the building, the **seventh recommendation** is that consideration should be given to **requiring the occupier to pay for the actual amount of carbon emitted (as shown on the DEC) over and above that predicted to be used by the building by the Energy Performance Certificate (EPC).**

Question 4: Over what timescale could zero carbon new non-domestic buildings be achieved?

With commercial property valuations at very high levels, there is little prospect for further upward growth. As a result, an increase in cost related to low-carbon construction is likely to affect either levels of rent, developer profitability or the price paid for land in the first instance.

That said, the market is already gearing up to achieve the challenging targets of the Code for Sustainable Homes and this has been achieved by setting a clear road map for the whole industry to work towards.

A challenging yet achievable timeframe for achieving zero carbon new non-domestic buildings along the lines set for housing is needed to allow the market to innovate, adapt and deliver in a way which ensures both the achievement of carbon reduction goals and the stability of the property sector.

A similar regulatory escalator to that in place for housing is required for non-domestic buildings. Therefore **recommendation eight is that the timeline should begin with the next revision of the Building Regulations** with step changes at each revision of the Building Regulations, concluding with a zero carbon standard but adding in an extra level of zero 'regulated' energy use.

The above cost estimates suggest a very wide range of timelines to achieving zero carbon as set out in Section 8.2. However, if a zero carbon new non-domestic buildings target is to be set, this research suggests that with a trajectory in place similar to that adopted for the Code for Sustainable Homes, and the above "zero 'regulated energy'" step added, a deadline of 2020 could be adopted.

This trajectory needs to be clear and fixed to give the industry firm direction to plan and achieve this target. Further work is needed to understand the cost of such a trajectory and to set these costs in the context of the Stern Review, see Section 7.2.1.

This work has suggested that collaboration between UK-GBC, as the co-ordinating voice of the industry, and Government, can define the most direct road map by bringing together all sectors of the building industry and related organisations in search of common goals. The project would need to be continuous and ongoing. The different organisations participating in the UK-GBC provide effective checks and balances through debate and industry consultation at the very highest level.

The release of the Callcutt Review and the subsequent announcement of an investigation into the feasibility of a delivery body to coordinate the delivery of zero carbon homes by 2016 is very relevant. Given the findings and recommendations in this report, attention should be given to how the delivery of all zero carbon buildings can be co-ordinated and delivered.

Broader Considerations

This report investigates the opportunities for achieving zero carbon new non-domestic buildings. Although this is an important element in reducing the carbon emissions associated with non-domestic buildings, it does not present the whole picture. Given the rate of replacement of the non-domestic building stock attention must be given to the refurbishment of existing stock in order to achieve the carbon emissions savings required to meet national carbon reduction targets going forward.

In addition, this report concentrates only on the energy consumed directly by new non-domestic buildings and does not consider the overall building carbon footprint. This carbon footprint, which could include the links between the building and transport networks, logistics, water use, embodied energy and construction energy use for example, would present a more holistic picture of the carbon emissions associated with non-domestic buildings.

Section 1:

Approach and Structure

The scope

The requirements contained in the initial invitation to tender were complex and far reaching, and the timescale challenging. The proposals set out below are the broad stages that were undertaken in order to deliver the key requirements of the brief. However, it is important to stress that much more detailed work needs to be carried out in order to produce detailed findings to tackle this challenge in depth.

In order to complete this project, eight stages were undertaken, as outlined below.

Eight project stages

Glossary of terms

Provides a glossary of terms.

Section 1: Introduction

Introduces the project, highlights the ground-breaking approach in undertaking the project, sets out the structure of the report and details the methodology used. In addition, section 2.3.2 details those issues which, although very relevant to the future delivery of zero carbon non-domestic buildings, are not included within the scope of this project.

Section 2: Definition of zero carbon

Details the definition of zero carbon employed.

Government have recently undergone a period of trying to unify the current definitions of zero carbon across various policy areas. However, for the purposes of this project it was felt that some additions to that definition might be required and this is discussed in Section 3.

Section 3: Building modelling

Is concerned with the modelling of building fabric energy consumption of non-domestic buildings.

It has been assumed throughout this project that the method for the implementation of zero carbon non-domestic buildings would be through the use of the Simplified Building Energy Model (SBEM). That is not to say it has been assumed that the methodology within the SBEM cannot be changed, but simply that it will be used in some form to evaluate the level of carbon dioxide emissions from a development for future version of Part L2A of the Building Regulations. How this would work is discussed in Section 4.1 and Appendix A.

Three built forms (shallow plan, low rise; deep plan, high rise; and sheds) were agreed to cover the majority of building construction types, within which a wide variety of non-domestic uses are undertaken (see Section 4).

The UK Green Building Council therefore put out a call to its members for SBEM models of projects matching the three generic built forms; these projects were then modelled down to zero carbon, ie zero regulated energy through a series of energy efficiency and renewable technology enhancements (see Section 4.1).

In order to validate these results, more detailed, dynamic modelling of the three generic built forms was also undertaken (see Section 4.2). This was both to assess whether SBEM contained any unintended inbuilt barriers to achieving zero carbon within its calculation methodology and to understand any differences between SBEM and dynamic modelling software. The deep plan model was also assumed to contain technology, lighting and small power, which is likely to be on the market in 2030 in order to understand how building energy use patterns may change over time (see Section 4.2.3).

Section 4: Existing building data gathering

Sets out the data gathered from existing buildings around the building occupant energy consumption.

The way in which buildings are used in practice is often very different from what is modelled and therefore in order to understand total building energy use, in particular the 'occupant energy' use, data collection from existing buildings needed to be undertaken. The dynamic modelling software used by Heriot-Watt makes a calculation of occupant use, and SBEM uses the National Calculations Methodology (NCM) in order to estimate small power use and thus heat gains in order to determine cooling requirements. The data-gathering element of this project should enable us to understand the accuracy of these simulations.

The members of the UK-GBC were therefore asked to provide real building energy use data. The Energy Consumption Guides were also used to estimate occupant energy for building types for which sufficient data could not be collected within the limited time frame of the project.

Section 5: Costing zero carbon

Provides analysis of the costs involved in achieving zero carbon for new non-domestic buildings

Combining the modelling results and monitored data it was possible to estimate a total building carbon emissions rate for each building type. The modelled carbon reductions and any additional carbon emissions that needed to be generated from renewable energy could then be costed.

Section 6: *Achieving zero carbon*
details the mechanisms available to achieve zero carbon for new non-domestic buildings.

It was anticipated that achieving zero carbon for both 'regulated energy' and 'occupant energy' may not be possible using purely energy efficiency measure and on-site renewable energy technologies, therefore methodologies for achieving zero carbon were considered as the final stage of the assessment.

This then also informed the proposed levels of carbon reduction that could be used as rating levels in a non-domestic sustainable building rating system and that could be incrementally introduced into Building Regulations.

Section 7: *Recommendations*
sets out the recommendations for achieving zero carbon non-domestic buildings and the possible methods for implementation.

Appendices
Comprehensive appendices are also included, containing the more detailed analysis by specialists in their field that form the basis of this report.

Issues considered out of scope

As discussed earlier, this project investigates the feasibility of achieving zero carbon new non-domestic buildings. As explained in Section 4, UCL advised that dynamically modelling three generic building forms was likely to yield more accurate results due to the difficulty in defining non-domestic buildings any other way. This would also provide additional benefits when deciding the best approach for refurbishment, re-use and demolition in the future. These generic building forms present an adequate picture of the situation from which to move forward. However, there are a number of other issues which, in further developing the approach to the delivery of new non-domestic buildings will need to be considered, and these are discussed below.

Variations in non-domestic building types and forms
The diversity of the non-domestic building stock poses considerable challenges for energy performance analysis, evaluation, monitoring and policy development (by comparison the domestic stock constitutes little more than a single uniform building use). The diversity is expressed in a very wide range of built forms, sizes and activities. Built forms include single floor sheds, very large multi-floor deep plan buildings (internal load dominated) and shallow plan buildings (fabric load dominated). Each of these forms exists in sizes ranging from small 'kiosks' and markets, to large retailing sheds, office tower blocks, large department stores, hospitals, giant distribution warehouses, industrial sheds and factories. The range of activities accommodated in them is equally diverse, from shops to car repair and showrooms, from office work to bingo, from crèches to scientific research, from

occasional use community centres to intensively conditioned full-time care homes.

The complexity of the stock is further exacerbated by the web of relationships between premises and buildings, and by mixed activities within buildings. Buildings may contain a single occupant or a single occupant may be spread through numerous buildings as in a hospital or university. Many buildings contain numerous occupants. Each of the combinations may be metered in various idiosyncratic ways, so that landlord and tenant use may be indistinguishable or unidentified. A single building may contain multiple sources of heating and cooling, some under control of a landlord, others under control of tenants. Business parks may provide central heating and cooling to multiple buildings of different characteristics, tenancies and uses. Common examples of mixed activities are banks and shops with their own offices above, or warehouses with shops. Offices above shops are a common office type. Petrol stations are commonly found combined with small grocery shops, or attached to supermarkets. Any mix of groceries, car repair workshops, garages, car sales and petrol sales may exist on a single site.

These complexities, although not considered as part of this project, could significantly affect the costs and feasibility of zero carbon non-domestic buildings and therefore need to be considered further. The generic built forms that were studied are outlined in Section 4.

Developments and location

Developments are difficult to define, particularly in relation to the detail of the differences in renewable options they imply. Many non-domestic developments are single buildings or demolition-rebuilds on small plots. Others may be one or two buildings on equally restricted sites.

Options for renewables are limited on many such sites, due to a lack of solar access, lack of sufficient roof and wall surfaces on which to place PV and solar thermal, and unreliable and turbulent wind resources. The options for incorporation of renewable energy generation vary in relation to urban and rural sites and the geographical availability of natural resources such as wind and sunshine.

The analysis of multi-purpose and multi-use developments would have added a very substantial layer of complexity to the project, requiring multiple building specifications, along with fabrics, shared systems, allowing for local sky horizons and so forth. . As a result, the project team has considered only single, stand-alone buildings.

Some of the solutions that are explored later in the project suggest that consideration of the building in the wider context of its location and the mix of buildings and building uses need to be taken into account, as it may result in some 'big wins', and this is an area for further work.

Level of cost benefit analysis

One can view low and zero carbon policy implementation at the levels of buildings, localities or nationally. . Analyses can examine only the building's energy use in operation, or include the energy use in materials used to construct the building, its services, and any renewables options. One can cost on the basis of additions to already proposed new buildings, or the full cost of replacement of an existing building.

The project has analysed pathways to zero carbon non-domestic buildings on a single building basis (but with carefully controlled allowance of off-site renewables). It is an important question however whether the challenge of zero carbon non-domestic buildings is best approached from the point of view of buildings, or on a regional or national basis.

It is assumed that all areas of society need to reduce their carbon emissions significantly, and thus this project concentrates on the costs associated with the efficient reduction of carbon emissions from new non-domestic building stock, it being assumed that other associated areas (existing non-domestic building stock, transport etc) are to be dealt with separately.

Existing buildings and building replacement

Important to the issue of a national approach including the existing non-domestic stock, is the rate of replacement of the stock. The stock is replaced only slowly. Rates of replacement vary widely from place to place and are driven by local economic conditions and regeneration policies long before they are driven by energy performance. Much of the current stock is old, built in the 1960s, between the wars, or before the first world war. It is difficult to estimate how much of the existing stock would be replaced by 2050, but at current demolition and new-build rates (themselves uncertain) it is likely to be around 30 per cent at best.

This project therefore only considers one aspect of building energy use, the new non-domestic building stock which currently produces no carbon emissions as nothing has been built following the recommendations of this report (true at the time of writing). 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.

Carbon Footprinting

In its broadest context the 'carbon footprint' of a building will include not just the carbon produced as a result of the energy used directly by the building. There are broader issues related to how building users produce carbon as a result of their interactions with the building. This is particularly important with regard to how employees and logistics interface with the local transport network. The links between the building and its users and public transport, walking, cycling and private car use all drive the overall carbon footprint of the building. This is particularly related to the location of the building and the corresponding array of transport options available. The higher the use of sustainable transport modes in commuting patterns the lower the associated transport 'carbon footprint'.

In addition, there are carbon implications associated with water usage and treatment, waste production and treatment mechanisms, the embodied energy of the materials used, construction strategies, the recyclability of the materials used at the end of the life of the building and the carbon implications of the logistics of servicing the building.

Therefore, this project is concerned with direct building energy consumption and not the holistic 'carbon footprint' of the building. Further research would be required to understand this full carbon footprint and the links between manufacturing, transport systems, water systems, etc.

Glossary

Regulated energy All energy use that is regulated by Building RegulationsRegulations Part L 2006 and predicted by the Simplified Building Energy Model (SBEM) (actual use of the building systems may vary from this and the difference is covered in "occupant energy' use).

Occupant energy All energy use on a development that is not regulated, and predicted, by Building Regulations, which includes:

- Occupant fit-out systems post building sign off
- Operation and maintenance of regulated energy systems not predicted by Building Regulations Part L 2006
- Small power use

Regulated variant by building use Regulated energy that varies from the regulated energy for the building type due to building use.

'Industrial processes' Further work to determine what should be excluded from this work in terms of loads needs to be undertaken, but the for the purposes of this report 'industrial process' has been taken from the definition of plant and equipment held by the Inland Revenue.

On-site renewable Renewable energy produced on-site

Near-site renewable Renewable energy generated near to the site that is provided for all or part of the community, eg decentralised energy generation linked to a community heat network or renewable connected via private wire. A more detailed definition drawing the boundaries between off-site and near-site needs to be developed as part of the work moving forward from this report.

Off-site renewable Renewable energy produced remote from the site, but within the UK, that are additional to renewable energy generation capacity installed under the Renewables Obligation scheme. Further work is needed to determine how this additionality could be regulated.

Section 2

Introduction

The Communities and Local Government 'Green Commercial Buildings Task Group' commissioned the UK Green Building Council (UK-GBC) to investigate the costs and benefits of raising the energy performance standards in new non-domestic buildings above those currently set out in the Building Regulations en route to zero carbon.

The project is concerned with new-build non-domestic properties; refurbishment projects associated with the existing building stock will not be included in the research. Given the low rate of non-domestic building turnover, the resource efficiency implications of refurbishment is an important element in the overall picture of resource efficiency in the non-domestic sector. Therefore, although this project is not concerned with refurbishment, the work carried out has, as far as possible, taken into account the effects on and possible future inclusions of, existing building stock regulation.

The UK Green Building Council (UK-GBC) is an industry-led, independent, not for profit, membership-based organisation committed to dramatically improving the sustainability of the built environment by radically transforming the way it is planned, designed, constructed, maintained and operated. More information on the UK-GBC can be found at www.ukgbc.org.

The UK-GBC is made up of world class engineering practices, architects, project and cost management consultants, developers, NGOs and many others including leading academia, all of whom have been engaged in gathering, collating, processing and interpreting the data required to fully understand the implications of zero carbon development.

The Carbon Reductions in New Non-Domestic Buildings project implemented a ground-breaking approach for establishing an evidence base for future policy.

The UK-GBC drew together a team from its membership including engineers from several of the world's top engineering consultancies, along with developers, architects and cost consultants to deliver a more balanced and thorough project. Despite the fact that many of the companies involved were competitors, and the research represented a potential market advantage, they worked co-operatively to deliver an industry-wide response to the brief. The task in hand was a formidable one, but the differing resources and expertise of the UK Green Building Council members meant the project had access to a greater knowledge base than any one organisation could possess alone. Problems were solved in multiple iterations as experts from different fields commented on the work throughout.

University College London (UCL) and Heriot-Watt University brought leading edge research to the project, and the Buildings Research Establishment (BRE) used their experience of policy making and policy implementation to review the work and ensure the suggestions coming from the group were realistic and practicable.

This project represents a highly innovative initiative by government to work with the industry as a whole to address the issue of climate change. While a group approach can require more pro-active management, the members of the UK-GBC understood the importance of the undertaking and worked collaboratively to deliver on time.

The open approach established by Communities and Local Government has led to a uniquely productive environment, resulting in frank discussion of the issues. The outcome of the work therefore focuses as much on the questions that must be answered in order to provide the solutions. A few primary issues have emerged as fundamental if true progress is to be made.

The sense of urgency that many of us feel relating to climate change, and therefore the keen political pace, must be tempered by the fact that solutions must be measured and feedback collated over time. The desire for fast answers could lead to substantial investment in false directions, leading to slower overall progress against the true objective. Adjustment must be continuous and accelerating, but not rushed.

Over-prescriptive guidance should be avoided. Such guidance often arises from a particular engineering viewpoint in response to a particular brief, but non-domestic buildings vary extremely widely in terms of location, use, size, and design. Commercial drivers also vary widely. Targets and regulations should be set out in terms of objectives rather than methods.

Furthermore, carbon dioxide emissions in use must be better understood if real progress is to be made, rather than simply design and construction standards, albeit that these are fundamental to achieving the required performance. Current building environmental assessment tools do not address this.

There is a lack of co-ordinated feedback data for non-domestic buildings. A national framework is required together with a requirement for building owners and/or operators to monitor, display and contribute to a national building energy performance database.

Carbon dioxide emissions resulting from the activities within buildings are much greater than many current models suggest (the so-called regulated energy elements, Section 5). This is primarily electrical consumption. Different levers are required to address this element, including working with industries such as ICT at an international level to incentivise R+D into reduced electrical consumption. Carbon intensity of activities within public buildings should also be analysed to inform the discussion.

Section 3

Definition of a zero carbon building

The definition of 'zero carbon' within government has been the subject of much debate recently and there are sure to be further modifications in the future. In order to maintain a level of consistency, the UK-GBC requested that the client define what, for the purposes of this project, should be considered zero carbon, and the following is a précis of the resulting document.

3.1 Communities and Local Government Definition of zero carbon

3.1.1 Definition

In the consultation paper *Building a Greener Future and the Code for Sustainable Homes* (CSH), Communities and Local Government stated that zero carbon means that a home should be zero carbon (net over the year) for all energy use in the home. This would include energy use from cooking, washing and electronic entertainment appliances as well as space heating, cooling, ventilation, lighting and hot water.

This means that any energy (and hence carbon emissions) drawn from the grid (electricity or gas) would have to be 'replaced' by energy generated from low and zero carbon technologies, and exported to the grid to offset those carbon emissions.

To have a comparable definition for non-domestic buildings would mean that the following equipment would be included:

- Use of electronic equipment in offices (such as computers, servers, telephones etc)
- Use of refrigeration in supermarkets (which accounts for about 40 per cent to 50 per cent of their electricity demand)

The following would be excluded:

- Energy used for 'industrial processes'. (though credit would still be given for district heating schemes)
- Lifetime carbon impact of technologies (ie any carbon emissions associated with manufacture as well as use),
- Transport emissions
- Actual behaviour of people occupying the buildings

- A full consideration of embodied carbon
- Actual appliance use in new buildings (assumed averages are considered)
- Green tariffs
- Offsetting, that is improving the energy efficiency of an existing building in lieu

Note: the project should try and take a pragmatic view concerning what uses are included – and where uses become an 'industrial process' and so should be excluded, and recommend where the line should be drawn.

What is important is to ensure that, on average, the actual carbon emissions from a new building are zero in net terms over the year, taking account of typical behaviour.

Communities and Local Government recognise that including energy use from office equipment, refrigeration etc in the definition of zero carbon means that builders / owners / tenants will need to look into zero and low carbon sources of electricity supply, an area currently outside Building Regulations.

3.1.2 Allowable solutions

Should zero carbon have to be achieved at the level of the individual building, at the development level, or off-site?

For homes, solutions to zero carbon for the 2016 target are acceptable at the development level. This should be the same for new non-domestic buildings. So for example, if a development was served by a wind turbine that provided renewable energy to the whole development, then that should be an acceptable way to achieve zero carbon. These types of solutions are acceptable for any type of technology that has a physical connection to the development, even if the technology is partly or wholly located away from the development site itself.

However, a more difficult issue is whether solutions that deliver zero or low carbon energy away from the development should also be allowed to meet the zero carbon target.

Communities and Local Government accept that there may be certain circumstances or particular sites where it may be difficult for developers to achieve zero carbon. However, evidence is already showing that the range of appropriate technologies is growing over time, and the costs falling. Communities and Local Government expect much better evidence to emerge over the next few years about what can be achieved, and at what cost.

So for the purposes of this work, Communities and Local Government would like to analyse buildings, and the technological solutions (including their associated costs and benefits) that could be used to achieve zero carbon. In the first instance we should look at technologies such as:

- more efficient systems
- fabric improvements
- passive cooling
- better control systems
- better building management
- building-level Low and Zero Carbon (LZC) technologies
- development-level LZC technologies

This project 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.

When considering this piece of work Communities and Local Government would like it to be consistent with the CSH that:

- The CSH estimates the average energy used by appliances in a typical home (and hence their carbon emissions) using a formula based on the floor area of the building
- Level 5 of the CSH is zero carbon as far as Part L 2006 is concerned (i.e. heating, lighting, hot water, fans and pumps etc.)
- Level 6 of the CSH is 'Level 5 plus appliances' ie all energy use in the home.

3.2 Further discussion of zero carbon

3.2.1 Forms of zero carbon

There are a number of generally accepted forms of 'zero carbon' and it is the careful discussion of each of these forms, and policy instruments to regulate these that is further discussed below.

UCL have defined five forms of zero carbon in order of stringency:

1. Self sustaining site (ie 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.

From the allowable solutions given by Communities and Local Government in Section 3.1.2, zero carbon forms 1 to 3 would be allowed currently under the CSH. Zero carbon form 4 has been discussed extensively in the task group meetings with the client and it has been recognised that it would have to be carefully regulated (this is discussed further in later sections). Zero carbon form 5 has been specifically excluded in the definition provided by Communities and Local Government in Section 2.1.1, which was broadly agreed by the task group undertaking this work.

3.2.2 Zero carbon hierarchy

The Communities and Local Government definition of zero carbon paper proposes a number of technical options. The Communities and Local Government paper also stated that 'this project 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.'

More efficient systems and passive cooling are important options not originally listed above but ones that could deliver significant reduction in energy consumption of buildings. Future Building Regulations should therefore consider a way of prioritising the reduction of energy demands through the elimination of active cooling systems where possible to a greater extent.

Section 4

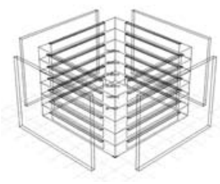
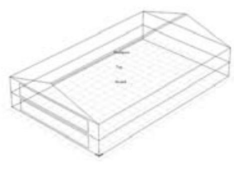
Building modelling

The original UK-GBC tender for this project proposed:

The first stage of the project will involve gathering data on current buildings and new building design projects, including the TER, BER, and usage class. As this data is coming from pre-existing projects, it saves a significant amount of modelling time, and should mean that a much larger data set can be analysed, efficiently and cost effectively. The data will be fed into a bespoke database where it can be interrogated.

Predicted difficulties in obtaining sufficient remodelled data from industry, and limitations in commonly-used models prompted the Bartlett to suggest an alternative approach, to examine just three physical building types (Bruhns 2007). This approach was based on work already carried out by Heriot-Watt university in the Carbon Visions Building (CVB) programme (see references) and a large non-domestic buildings research programme funded by DEFRA between 1992 and 2002 (NDBS project). The Bartlett suggested the use of three simplified built forms that between them cover much of the non-domestic stock, described in the following table.

Table 1: Generic Building Types

Group	Description	Uses	Typical construction	
1	Shallow plan sidelit	Offices, hospitals, education and numerous uses	Various fabrics and glazing, rarely full curtain wall glazing. Commonly low-rise 3-6 floors, but can be high rise.	
2	Deep plan high rise	Mainly offices, almost always air-conditioned	Commonly high-rise, often full glazing.	
3	Sheds	Warehouses, factories, supermarkets, various large and out of town retail	Single floor, large floor-to-ceiling height, little glazing.	

Dynamic modelling software estimates the energy demands of buildings by modelling how the building responds to the ambient conditions as they vary, responding to internal conditions eg changes in lighting levels throughout the day as they vary. Steady state modelling packages such as iSBEM estimate average space heating and cooling requirements of the building using single parameters to describe climate and internal conditions on a monthly basis. This means that although both can estimate annual energy demands, and thus both can be used for the purposes of achieving compliance with Building Regulations, steady state models cannot, and should not, be used as design tools. Therefore only dynamic models can be used for internal comfort calculations such as overheating estimates.

Dynamic calculations are not required when calculating total annual energy demand; however, given precision in the initial assumptions made by the building, dynamic modelling is likely to present a more realistic description of building energy requirements. Validation of this assumption was one aim of the project and therefore both the modelling techniques of existing SBEM models and The Bartlett/Herriot-Watt approach of dynamically modelling a limited number of generic forms have been used for this project.

4.1 SBEM models

4.1.1 SBEM methodology

The National Calculation Method (NCM) for the EPBD (Energy Performance of Buildings Directive) is defined by the Department for Communities and Local Government. The procedure for demonstrating compliance with the Building Regulations for buildings other than dwellings is to calculate the annual energy use for a proposed building and compare it with the energy use of a comparable 'notional' building. Both calculations make use of standard sets of data for different activity areas and call on common databases of construction and service elements. A similar process is used to produce an 'asset rating' in accordance with the EPBD. The NCM therefore comprises the underlying method plus the standard data sets.

The NCM allows the actual calculation to be carried out either by approved simulation software, or by a new simplified tool based on a set of CEN standards. That tool has recently been developed for Communities and Local Government by BRE in 2006 and is calledSimplified Building Energy Model or SBEM. Appendix A sets out the basis for the SBEM calculation.

SBEM is capable of covering the emissions arising from the building services themselves. Greater use of the method will enable a refinement of the data used as the basis for assumptions, thus enabling these to be improved over time.

4.1.2 iSBEM modelling methodology Conclusions

A number of UK-GBC members provided SBEM models for existing projects and attempted to model them down to zero carbon (zero regulated energy); an example calculation can be found in appendix B.

The methodology for undertaking this process was to calculate the target emission rate for the building as for a normal Part L compliance calculation. Energy efficiency improvement measures were then cumulatively added in order of easiest and most cost effective to achieve, and building emissions rates given following each improvement as figure1 and table 2 illustrate below.

Once all feasible energy efficiency measures had been applied, renewable energy solutions were then added to the building in order to try to reduce the 'regulated' carbon emissions down to zero. A number of modellers took this one step further and attempted to reduce the carbon emissions down to the level the NCM calculated for small power use. (One element of the 'occupant energy use'.) An example of this is shown in figure 1 and table 2 below.

Figure 1: Example energy efficiency measures

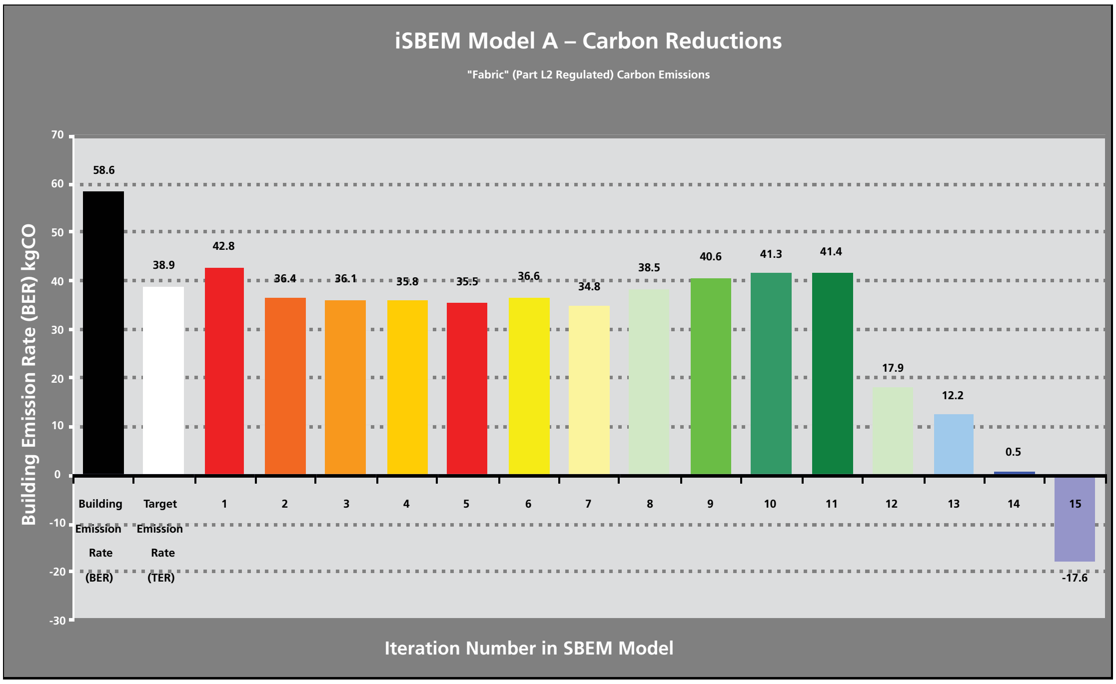


Table 2: Example energy efficiency measures	
1	Bring plant efficiencies up to modern levels. Boiler efficiency 89 per cent. Chiller COP 4.3. SFP 2.0 W/L/s. Duct & AHU airtightness. Controls and monitoring.
2	Office lighting 14 W/m^2 (passes Part L).
3	Other lighting at 3 W/m^2 per 100 lux.
4	No heating, cooling or lighting of external stairwells.
5	Tint atria glazing outer pane to transmittance of 0.06 (poor daylight factor?).
6	Improvement to façade u-values found to be counter productive at Uaverage = 0.45.
7	Gas-fired CHP to provide all hot water for heating and sanitary hot water (note: lots of part load operation due to seasonal nature of demand. Assumes efficiency of 50 per cent thermal, 20 per cent electrical.)
8	Trigeneration using 100kW absorption chiller (COP 0.68).
9	200kW absorption chillers.
10	300kW absorption chillers.
11	400kW absorption chillers (peak cooling demand = 450kW. Utilisation falls as absorption chiller size increases.)
12	Renewable fuelling of trigeneration with 400kW of the cooling from absorption chillers.
13	Rooftop PV 750m^2 of polycrystalline type, 11 per cent efficiency.
14	Ground level PV 13 per cent efficiency 1613 m^2.
15	A further 2323m^2 of 11 per cent efficient PV. Mounted elsewhere as insufficient façade space.

4.1.3 SBEM modelling results

The UK-GBC members have been providing a number of SBEM model results for the three generic building forms, with a variety of building uses. The table below outlines for the received models, both the types of buildings and the level of detail. The graph shows the total predicted carbon dioxide emissions for each received model, broken down into contributions from gas, non-cooling electricity, and cooling electricity.

Table 3: iSBEM models			
Building Type	**SBEM – demand data only**	**SBEM – modelled to Zero Carbon**	**TOTAL**
Shallow plan, low rise	3	1	4
Deep plan, high rise	5	3	8
Shed, minimal & fully glazed	2	4	6

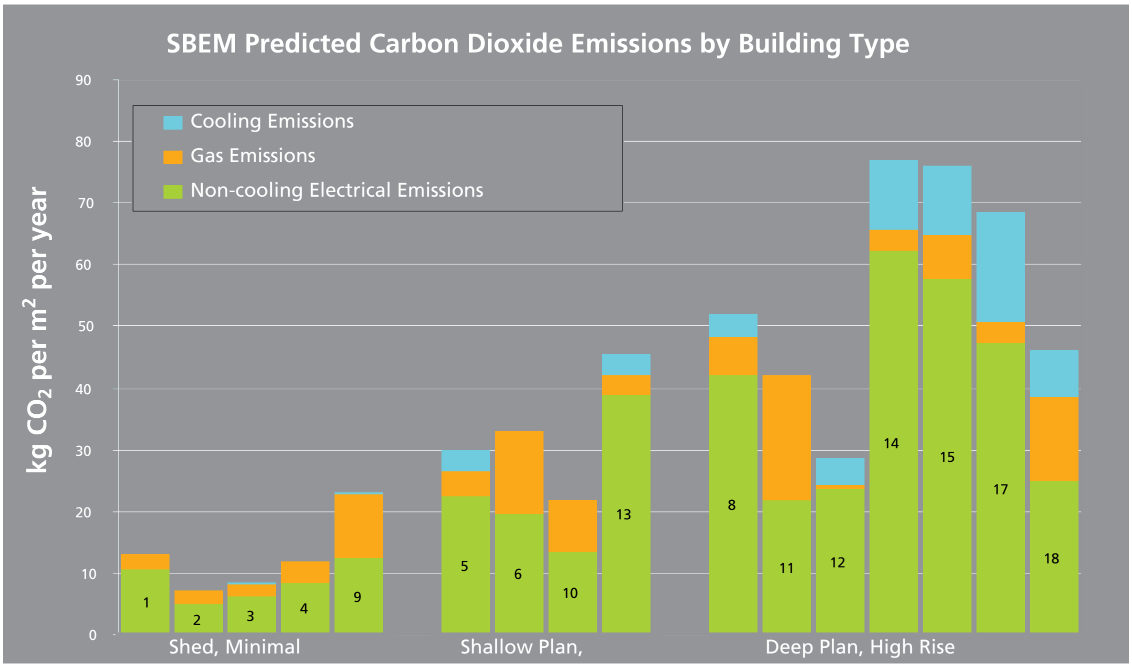
4.1.4 Conclusions of SBEM modelling

Although many of the UK-GBC members used approved modules of specialist modelling programs such as IES and TAS, others used iSBEM (interface for the Simplified Building Energy Model) and it seems that the process, at least, of modelling down to zero carbon was feasible. The barriers to this are discussed further in Section 8.1.2.

Table 4: iSBEM energy efficiency improvements towards zero carbon

		Baseline Emissions (kgC/m≤/yr)				**Emissions after Energy Efficiency (kgC/m≤/yr)**	
Building Type	**Model Number**	**Gas Emissions**	**Non-cooling Electrical Emissions**	**Cooling Emissions**	**Total Carbon Emissions**	**Total Carbon Emissions**	**Reduction in Carbon Emissions**
Shed	9	10.3	12.5	0.2	22.9	None given	0.0
	1	2.7	10.5	0.0	13.2	11.3	1.9
	4	3.6	8.3	0.0	11.9	9.6	2.4
	3	1.9	6.3	0.2	8.4	6.6	1.8
	2	2.1	5.0	0.0	7.1	5.3	1.8
Shallow	13	3.1	38.9	3.6	45.6	19.2	26.5
	5	3.9	22.6	3.3	29.7	None given	0.0
	6	13.5	19.5	0.1	33.1	None given	0.0
	10	8.5	13.3	0.0	21.8	None given	0.0
Deep	14	3.4	62.2	11.4	77.0	17.9	59.1
	15	7.0	57.7	11.2	75.9	None given	0.0
	17	3.7	47.2	17.6	68.4	None given	0.0
	8	6.3	42.0	3.6	52.0	None given	0.0
	18	13.9	24.9	7.4	48.5	46.4	2.1
	12	0.8	23.6	4.4	28.7	None given	0.0
	11	20.2	21.9	0.0	42.1	None given	0.0

Figure 2: SBEM BER rates for submitted models



The ECON 'occupant energy' use is significantly greater than the modelled occupant energy use.

The variety of approaches and perceived possibilities to carbon reduction generated by the wide variety of input from across the UK-GBC membership raises some questions about how the market in general would react to any zero carbon requirement. A more consistent approach that could have been achieved by a single consultant undertaking this work would not, however, be as representative a test of the ability of the market to achieve zero carbon using SBEM.

The differing assumptions and starting points for energy efficiency measures highlights the need to guide the industry transparently with minimum energy efficiency parameters while not being prescriptive in the solutions proposed.

4.2 Dynamic modelling

Dynamic modelling has been undertaken using ESP-r by Heriot-Watt-University. A full copy of the report can be found in Appendix B.

4.2.1 Introduction to esp-r modelling methodology

Dynamic modelling software estimates the space heating and cooling requirement of buildings by considering the transient behaviour of the building on an hourly basis. It therefore considers how the building responds to the ambient conditions as they vary and how the building responds to internal conditions eg changes in lighting levels throughout the day. Steady state modelling packages such as iSBEM estimate space heating and cooling requirements of the building using single parameters to describe climate and internal conditions.

It should be stressed that both are a representation of the building condition. The extent to which they provide a realistic estimation of the energy consumption of a building is based largely on the veracity of assumptions made when developing the model. The aim of the modeller is not per se to generate the precise energy consumption of the building but to estimate an indication of its magnitude. It is crucial that the assumptions made spring from an empirical basis to ensure that at the very least the correct vector is assigned to any technological interventions. It is in this debate that the benefits of a steady state versus a dynamic modelling approach lies i.e. are the correct pathways to carbon reduction being signposted by these approaches. This is an area that is in need of a more comprehensive empirical grounding that encompasses not just technological data-gathering but also behavioural response to deployed technology.

The dynamic modelling of the generic building types acts as a comparator to the iSBEM calculation. It is the intention that this project forms part of an ongoing process involving the wider built environment and academic community. These analyses will contribute to the assessment of whether any inherent barriers exist within the iSBEM calculation that might hinder the user in achieving zero carbon. It should also act as a useful comparator to the results of the SBEM calculations and predicted costs of achieving zero carbon new non-domestic buildings.

Heriot-Watt modelled the deep plan office assuming what they consider to be likely technological changes over the period to 2020 in terms of lighting and heat gain of small power, which was intended to bring some understanding as to how changing demands could affect a timeline to zero carbon.

4.2.2 Dynamic modelling results

The table below shows dynamically modelled data can be dramatically reduced over a Part L 2006 compliant building.

Table 5: Dynamic modelling results

Variant	Heating Demand	Cooling Demand	Small Power Demand		Lighting Demand		Fans, Pumps and Ventilation Demand
	kWh/m^2/yr	kWh/m^2/yr	kWh/m^2/yr	Watts/m^2	kWh/m^2/yr	Watts/m^2	kWh/m^2/yr
Shallow plan, low rise	5.4	18.7	47.6	7.9	20.8	9.4	5.0
Deep plan, high rise	5.8	12.2	23.5	4.4	10.9	6.2	4.1
Shed, minimal glazing (Option 1)	5.7	41.4	17.9	2.2	101.5	20	6.7
Shed, minimal glazing (Option 2)	5.7	41.4	17.9	2.2	101.5	20	4.2

Notes:
The deep plan office is modelled containing technology from 2020, thus lighting and small power create lower heat gains, consequently reducing cooling demands. For this reason the two offices are not directly comparable.
Heating demands shown here are very low due to super insulation levels modelled by Heriot-Watt which may in reality be difficult to construct.
Lighting demands in the sheds are very high due to retail sheds being modelled, which again makes direct comparisons of the models more complex.

4.2.3 Conclusions of dynamic modelling

Heriot-Watt University considered building fabric, end use equipment, HVAC and on-site technological interventions that could be made to three generic non-domestic buildings in order to ascertain the extent to which net-zero carbon non-domestic buildings of these types were achievable on-site. Esp-r building simulation software was used in addition to a range of bespoke supply side models, developed at Heriot-Watt University as part of the Carbon Vision Buildings programme, TARBASE. For the range of technological options considered, net zero-carbon was not achieved in any of the generic buildings. The principal obstacle was in defining sufficient on-site generating capacity that would meet (not match) the electrical demand of the buildings. Even if the thermal comfort and desired air quality of the building could be met by zero carbon routes, insufficient low or zero carbon electricity could be generated on-site to offset the large energy consumption of the buildings.

The closest technological route found to providing net zero carbon was through the deployment of combined cooling, heat and power (CCHP) plant based on highly electrically efficient fuel cell technology. However, a substantial proportion of the heat and power generated by the candidate CCHP system could not be used instantaneously by the building in question and had to be either exported for use by neighbouring buildings or dumped. It should be pointed out that the ability of CCHP plant to reduce carbon emissions in buildings is heavily dependant on the electrical efficiency of the prime mover, the CCHP central generating plant/engine, especially in commercial offices where the cooling demand is predominant. The research undertaken indicated that for the offices studied here prime movers with electrical efficiencies above 44 per cent were required to cause emissions to reduce. Currently this would preclude all prime mover technology other than that based on fuel cells if the plant is run on gas.

The list of technologies modelled was not by any means exhaustive although it did concentrate on the most likely solutions. A number of other technological solutions that could be considered in net zero carbon contexts are discussed in Appendix C. However, the issue of exporting or dumping excess on-site energy production is likely to be an overarching theme of any technology considered in the where these could generate the required amount of heat and electricity on-site to achieve zero carbon.

The option of an 'all-electric' building through the use of a heat pump is potentially low-energy. However, due to the carbon intensity of the grid, unless there is (again) sufficient low-carbon on-site generation then the carbon emissions of the building could be significant. It is therefore unlikely that such a scenario would achieve net-zero carbon, although it could provide a template for a low-energy building that might be satisfied by low-carbon electricity generation through a near-site or off-site solution.

Their study concludes: 'with the technologies considered here, there is little evidence to suggest that net zero carbon non-domestic buildings of the types described can be designed. Further, the findings would seem to challenge the underlying philosophy of the zero-carbon approach whereby the building is considered as a single entity. Any attempts to satisfy the requirements of the building in a net zero carbon way are likely to require the over production of energy – both electrical and thermal. It would therefore seem more appropriate to consider community options for the built environment where individual buildings could house distributed generation systems which are then linked together to deliver community energy needs.'

4.3 Comparison of SBEM and dynamic modelling

The energy demands that Heriot-Watt were able to reduce the generic forms down to through the use of energy efficiency were very high due to the high U-Values and low infiltration rates modelled. The models are not directly comparable since the lighting and small power demands have been altered for 2020 technology in the deep plan variant, however it does demonstrate that considerable reductions in energy demands can be made.

4.4 Conclusions

The results shown in tables 4 and 5 demonstrate how significant improvements on energy use can be made from the Part L compliant SBEM models. The analysis shown here represents part of a wider requirement of the built environment to identify modelling approaches that will allow technology pathways for net zero carbon to be identified. The results depicted here suggest that both modelling approaches could be used to understand the impact of interventions, although with the caveats eluded to earlier regarding empirical validation and also by alerting the reader to the point made below.

Table 4, above demonstrates the dramatic differences that can be seen with regards to energy demand within the same built form dependant on its use and the problems inherent in ensuring that the assumptions upon which the modelling approach are based are consistent with expected practice. For instance, the illustration for the sheds shows a very high lighting demand within the retail sheds.

4.4.1 The impact of future technology

The results of modelling the deep plan form containing likely changes in lighting and small power technology resulted in a net reduction in both small power use and therefore cooling demands. This outcome is extremely important when one considers the issue of ensuring that the technology deployed at the very least moves the building in the right direction. A possible effect of future end-use technology change is that it may be possible to construct highly specified future offices with internal gains low enough for passive cooling technologies to be considered. This represents a different technology direction to highly efficient mechanical cooling plant and is perhaps one area where the use of iSBEM is flawed when considering pathways to zero carbon.

Section 5

Existing building data

5.1 New existing building data

5.1.1 Data collected

The UK-GBC members have provided a variety of existing building data which is of varying detail. Below is a table of the building types and number of data points collated and incorporated within the analysis.

Table 6: Collected real building data points

Building type	**No. of data points**
Offices – standard type 1	51
Offices – standard type 2	56
Offices – standard type 3	129
Offices – prestige type 4	6
Offices – unspecified type	10
Total Offices	**252**
Schools – nursery	228
Schools – primary	11,010
Schools – secondary	2,019
Warehouse (no cooling)	10
Warehouse with cooling (eg food distribution)	2
Retail	34
Shopping Centre	6
University Buildings	7
Library	2
W/C	1
Hotel + C/H Offices	2
Court Building	1
Health Centre	2
Unspecified	9
TOTAL	**13,837**

Unfortunately, due to the tight time constraints of the project and the idiosyncratic natures of data that is currently collected within the industry, sufficient depth of detail across the spectrum of non-domestic buildings has been difficult to realise. This is not a slight on the industry but it does further highlight the need for DECs to be required on all new non-domestic buildings for the creation of a national database to collate this data so that it can be used to further this, and other, research and policy direction.

5.1.2 Difficulty in collecting data collected

In relation to the domestic sector, energy use in the non-domestic sector is not well understood. This state of affairs is a consequence of the diversity of organisations involved in provision and management of the non-domestic stock, its physical and economic heterogeneity and the relatively minor financial role of energy costs in the overall costs of non-domestic business activities (as described in Section 6). Additionally, monitoring and understanding the non-domestic stock has not had the long term political priority that has been assigned to the domestic stock.

The stock diversity means that, for surveys corresponding to the English House Condition Survey, by which the non-domestic stock might be better understood, data collection would be expensive because so many more data points would be necessary to provide adequate sampling of the whole stock. Only one such survey has been carried out (commissioned by DEFRA in the 1990s), including 650 premises and requiring several years work from a research team.

An alternative to understanding non-domestic energy use is opportunistic use of other data sources, such as national energy use statistics, Valuation Office Agency floorspace statistics, various market research data sources and directories. There are also a variety of smaller research surveys, carried out by universities, consultants and other agencies over the past 20 years, of energy use in particular sectors, and those data accumulated within some of the organisations with significant property ownership or management portfolios, as part of their own management processes.

These sources are very often either incomplete, out of date, of unknown representativeness, missing key data at least in part, incorporate inconsistent and incompatible classifications, or commonly, several of the above.

Nor should these comments be construed as a criticism of any of the organisations involved. The relative importance of various determinants of non-domestic energy use is still the subject of debate among professionals, for example the importance of fabric vs internal loads in various building types. As a consequence, each organisation collecting data that might help understand non-domestic energy use is constrained either by the requirements of their own core business processes (VOA, utilities), the lack of data standards (classifications and entity type definitions) or a still incomplete theoretical foundation from which to define key data requirements.

The issues described here are borne out by the experience of this project in the collection and use of existing building data from GBC member organisations. Several members responded to this request but the data were able to be used for no more than to confirm the general level of benchmarks in various ECONECON (Best Practice Programme) energy consumption guides.

Data requirements for monitoring and evaluating energy performance in existing buildings is discussed in more detail in Appendix D.

5.2 Energy consumption (ECON) existing building data

The collection of data from UK-GBC members and work carried out by Heriot-Watt University has shown that electricity use in non-domestic buildings has risen very closely in line with floor space, i.e. all the energy efficiency measures of Building Regulations have been negated by an increased use of energy for small power uses, which is likely to have had an impact on cooling energy use.

This indicates that guides such as ECON 19 (CIBSE Energy Consumption Guide 19 – Energy Consumption in Offices) are still likely to be reasonable guides for assessing energy consumption, and with a little filtering they can be adjusted to compare with current new-buildings.

However, the benchmark data contained in these guides is now some 15 years out of date. As such, it may underestimate the usage of IT and lighting equipment found in modern day offices, and therefore an office which is assessed using ECON 19 benchmarks may have too high a heating demand and too low a cooling demand. This is of crucial importance when considering net zero carbon pathways as the low or zero carbon electricity requirement of an office with a 2007 equipment and lighting profile may be substantially higher than for the same office using ECON 19 guidelines. This again underlines the need for a greater empirical basis upon which to make technology, policy and investment decisions.

Since the time to collect good quality building data has been limited it was therefore agreed that the appropriate ECON guides could be used to assess building occupant energy use for the categories of buildings outlined in the table below.

Table 7: Building types assessed	
Energy Consumption Guide Building Class	**Associated Building Type**
DIY Store	Shed, minimal glazing
Non-food store	Shed, minimal glazing
Dept Store	Shed, minimal glazing
Small Food Store	Shed, minimal glazing
Supermarket	Shed, minimal glazing
Cinema	Deep plan, high rise
Offices Nat Vent Cellular – Type 1	Shallow plan, low rise
Offices Nat Vent Open Plan – Type 2	Shallow plan, low rise
Offices – A/C standard – Type 3	Deep plan, high rise
Offices – Prestige A/C – Type 4	Deep plan, high rise
Business/Holiday	Deep plan, high rise
Leisure	Deep plan, high rise
Primary School	Shallow plan, low rise
Education (Secondary, no pool)	Shallow plan, low rise
Light Manufacturing	Shed, minimal glazing
Health Care – GP (cottage health care)	Shallow plan, low rise
Library – education – A/C	Deep plan, high rise
Library – education – Nat Vent	Deep plan, high rise
Libraries – public buildings	Deep plan, high rise
Restaurant with bar	Deep plan, high rise
Fast food restaurant	Deep plan, high rise
Pub restaurant	Deep plan, high rise
Public House	Deep plan, high rise

From the ECON data it has been possible to estimate the 'regulated energy' use and the "occupant energy', this calculation is described in more detail in Appendix E. From this it has been possible to estimate the costs of achieving varying levels of carbon reduction as outlined in Section 6 below.

5.3 Conversion from ECON guides to current practice

Previous policies applied to various sectors have been designed to reduce the nation's energy use and carbon emissions, but in general, energy use has continued to increase regardless. In the non-domestic stock the steady increase of electricity use is approximately proportional to floorspace. That is, the efficiency of electricity use is, overall, untouched by policy. Gas use appears over the past decade to have decreased in relation to floorspace. However, the variations in annual energy use do not follow any discernable pattern in relation to recent climate, meaning this reduction cannot be due to a change in UK temperatures.

It is notoriously difficult to collect good existing building data that is broken down into regulated and occupant energy use for gas, electricity and cooling with a good understanding of the building systems and occupancy as outlined in Section 5.1.2.

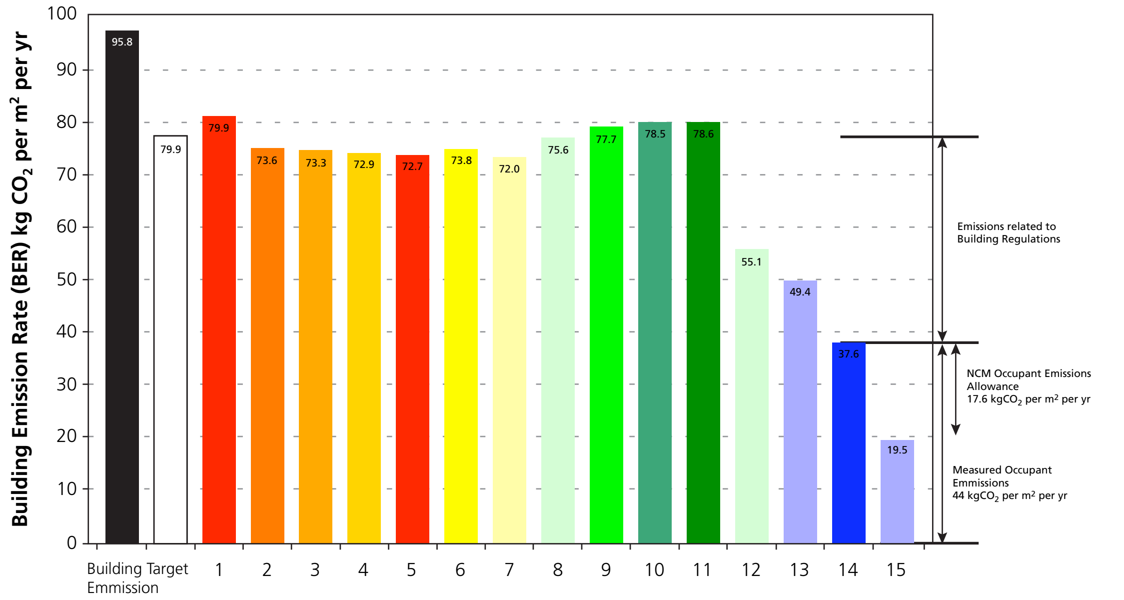
Given the limited time available for this project, collection of such good quality data in sufficient volumes has proved difficult. However, sufficient data has been collected to confirm the work undertaken by UCL suggesting that energy use in buildings has increased in-line with floor space.

5.4 Conclusions

A calculation formula to determine occupant energy use based on floor area is not possible in any generic way for new non-domestic buildings as has been done for the Code for Sustainable Homes. The refinement of the NCM outlined in Section 8.1.2, is recommended to undertake the role of occupant energy use estimation.

There are some significant differences between what the NCM calculates as occupant energy use and what ECON, and the UK-GBC-collected data, suggest is actual building occupant energy consumption. As can be seen from the graph of an example calculation below, the NCM calculated the occupant use to be 18.1kgCO_2/m^2/year.

Figure 3: Example of SBEM carbon reduction modelling methodology



This falls short by some 19.5 1kgCO_2/m²/year of actual data, in other words the actual energy use is twice that estimated by SBEM. How this can be resolved is discussed in Section 8.1.2 and Appendix A, however there are a number of reasons why this might be the case.

Firstly the hours of operation within iSBEM are fixed, assuming energy use and heat gains for a limited period, when in reality buildings are often used far more intensively than this. There are also a number of energy uses that are not included in the NCM such as external lighting and lifts.

Section 6

Costing zero carbon

6.1 Introduction: the value of zero carbon

There is little market evidence to show that occupiers of commercial buildings (and domestic buildings) or investors are prepared to pay a higher price for low or zero carbon buildings. However, there are some early signs that the market may be changing and these issues are discussed by King Sturge LLP in Appendix F with reference to four subject areas: the value of energy; corporate image and Corporate Social Responsibility (CSR); valuation and investment risk; and valuation and the law.

The conclusion is that the market may be changing, but slowly, and generally only for the larger companies that are concerned with CSR. Improvement to regulations to raise a level playing field would be the way to achieve real carbon reductions across the industry.

This has a profound implication for this work and the route to achieve the carbon reductions necessary to achieve the Government targets for 2050. It highlights the need, in fact, desire, among some developers, for regulatory change to achieve zero carbon new non-domestic buildings.

6.2 Challenges with costing zero carbon non-domestic buildings

6.2.1 Overview

The cost exercises carried out in connection with this report have been based on analysis of a strictly limited range of options as to how zero-carbon performance might be achieved.

With the limited time frame of the project it has not been possible to cost detailed building specifications for a variety of LZC scenarios for a range of buildings types. This is because, in such a cutting-edge field, it is difficult to extrapolate costs and specifications from the small number of completed examples. This means that the process of introducing energy efficiency improvements to a single building in its first design iteration has the potential to result in initially high cost estimates which are subsequently reduced once specific opportunities are identified.

Evidence from the first iteration of Code 6 homes is that significant changes in building form as well as construction are required to achieve zero carbon targets. It is likely that non-domestic buildings will also evolve in response to the zero carbon imperative as they have to other requirements related to user comfort, flexibility etc. Unfortunately, the models on which the cost assessments have been based do not enjoy the luxury of being able to predict the directions in which building design might evolve in response to low-carbon policy, and as a result, the costs reported are likely to represent premiums driven by the following factors:

- Selection of specific design and specification options
- Access to current technology solutions
- Access to on-site zero-carbon solutions only (the conclusion being that near-site and off-site renewables will be needed to achieve zero carbon at a lower cost)

As a result, it could be argued that the cost assessments represent something close to a worst case scenario, in that there are likely to be technological and market capacity developments which help to mitigate cost premiums.

There remains a risk of substantial cost escalation however, if buildings are required to become more complex to reduce carbon emissions, not to mention the inherent risk that more complex buildings can be easier to run badly and thus can emit more carbon dioxide. Use of natural ventilation and thermal mass is a good example of this, where savings in ventilation plant and distribution are typically offset and exceeded by costs associated with the overall natural ventilation solution. In particular for non-domestic buildings which typically involve substantial cooling loads, the zero carbon challenge is likely to require more intervention than might be necessary in a domestic scheme – whether achieved on-site, near-site or off-site.

6.2.2 Further actions required

The cost exercises carried out in connection with this report are highly solution-specific and do not constitute a definitive statement as to the costs of zero carbon non-residential building. In particular they cannot be compared to some of the cost assessments of the impact of Code for Sustainable Homes, which is based on a more homogenous product and predictable technology path.

In order to assess the potential for cost premium associated with non-domestic buildings, the following steps need to be taken:

- Confirmation of loads and energy consumption associated with a range of non-domestic buildings
- Identification of the appropriate mix of LZC solutions related to building fabric, building systems, on-site and off-site renewable, to deliver an economical solution to the low carbon challenge – eg an assessment of carbon reduction/pound additional expenditure

- Adoption of a whole life assessment framework, particularly with regard to the efficacy of carbon reduction
- Consideration of the impact of LZC design on building function, flexibility and economic life, particularly with reference to capital valuations
- Consideration of the wider development costs of LZC infrastructure

6.3 Costing SBEM modelled buildings

6.3.1 Methodology for costing iSBEM modelled buildings

The costing of the SBEM models was undertaken in the following manner:

1. The figures generated by the dynamic modelling were used as the base figure as a starting point so the two methods can be compared sensibly.

2. The figures used dynamic modelling on envelope and window enhancement.

6.3.2 Results: the cost of low carbon buildings modelled in iSBEM

The costs were therefore very similar to those for the dynamic modelling and are contained in the section below.

6.4 Costing dynamically modelled buildings

6.4.1 Introduction

The cost review of the outputs of Heriot-Watt's modelling has been undertaken by Davis Langdon LLP using inputs from specialist teams focusing on Building Envelope and Building Services Costs. The assessment of the Heriot-Watt proposals has been based on well developed generic cost models which provide robust baseline costs and which can be adapted to take into account the differing geometry and specification of a specific design option.

Davis Langdon have been involved in a number of published reviews of the cost impacts of low energy buildings including reviews of the impacts of Part L 2006 and the EPBD, both published in industry journals such as Building Magazine.

Whilst there are many variables in design for energy conservation, the modelling undertaken by Heriot-Watt has focused on four key variables:

- Thermal performance of the building fabric and natural ventilation
- Increased thermal mass
- Use of CHP/CCHP as a high-efficiency source of power, heating and cooling
- Optimal use of on-site renewables

Davis Langdon's modelling has focused on the cost impact of these variables, and has assumed that all other aspects of building specification, performance and cost remain at current levels of cost.

In our assessment, we have not tested the dynamic model to confirm whether it represents the most effective solution from either a technical or economic perspective.

As such, the model and the associated costs represent one approach to delivering zero carbon new non-domestic buildings, and there could be other opportunities which require further consideration.

For example, some technical options described in Communities and Local Government's definition of zero carbon paper have not been explicitly allowed for in the dynamic model, including:

- Better control systems
- Better building management
- Development level LZC

Aspects of an enhanced level of building management and control are implicit in the naturally ventilated solution described in the dynamic model. However, it should be noted that other aspects of BMS have not been factored into the model.

6.4.2 Methodology for costing dynamically modelled buildings

Cost models based on current specifications and cost levels have been adapted to the geometry and specification required by the Heriot-Watt models. The key characteristics of this approach are as follows:

Technical and specification considerations

- The assessment has been based solely on design enhancements modelled by the Heriot-Watt team. There is no relationship with the analysis in 4.1.2 with regard to progressive enhancements identified using SBEM, or current practice in delivery of low-energy commercial buildings.
- The floor plates used are generic in that they could be used for a number of building types and uses. However, for the purposes of the cost assessment it has been assumed that the buildings are designed as commercial office or retail space. As a result, certain assumptions have been made with respect to the specification of the building fabric, finishes and building services which would not necessarily apply to other uses (schools and hospitals for example). In all cases it has been assumed that the buildings have been completed to a stage where they are ready to be given their final fit-out by their end-user occupier.

- These uses imply relatively intensive occupation and equipment loads, which in turn create a high hurdle for LZC, which inevitably has an impact on mitigation measures and cost.
- The cost implications of variations in building layout affect the extent of external walls and windows and the area of roof. Variation in wall area has been modelled using the wall:floor ratio as the key variable. The initial net cost takes into account differences in the efficiency of layout, explaining why the shallow plan building is more expensive.
- Alternative specifications for walls, windows and so on have been modelled on the basis of extra over costs for the varying components required to meet the performance. These details have been provided by Heriot-Watt. The technologies adopted: high mass concrete and extensive insulation are conventional and we have used current market rates. Some of the specification requirements, particularly for glazing, are on the boundaries of what can be physically achieved.
- The adoption of a ventilation and cooling strategy based on thermal mass is reflected in savings for suspended ceilings in the office building, together with increased costs for slab insulation, soffit finish and exposed building services installations.
- The CCHP system, together with the associated chillers and thermal stores, has been costed on the basis of the loads sized by Heriot-Watt

Estimating and pricing considerations

- Costs are aggregated and presented using floor area as a devisor (£/m^2 gross internal floor area (gifa)). This means that the costs of common elements of construction can be extrapolated from one building to another. The results of the assessment are presented as a percentage extra over the current base cost of a Part L compliant building.
- The initial costs have been assessed net of the contractor's preliminaries, management costs and overheads and profit, which have been added as a final adjustment. No adjustment to the preliminaries calculation has been made for any additional on-site management requirements required to improve building quality which might be expected with a low-energy building.
- Costs are adjusted to a common datum, using indices and adjustment factors. For the purposes of this study, costs are current at 4th quarter 2007, based on an Outer London location.
- Costs of all green technologies are at current prices and no attempt has been made to extrapolate what established market prices might be once sustained demand for these products are in place. There is an expectation that costs associated with low carbon construction will fall, and as products such as insulants and PV panels become more efficient then some cost reductions can be anticipated. On the other hand, where the revised specification implies greater mass, higher levels of engineering performance or a better standard of on-site installation, then there is a significant risk of an inherent and hard to mitigate cost premium.

6.4.3 Results: the cost of dynamically modelled low carbon buildings

Results are set out in table 9 below. The overall costs of the building-wide enhancements to building fabric, building services and renewables are summarised and presented as extra over costs:

Table 8: Cost of low carbon dynamically modelled buildings

	Shallow Plan Office £/m≤ GIFA	Deep Plan Office £/m≤ GIFA	Retail Warehouse £/m≤ GIFA
Net base building cost	1640	1520	480
Extra over cost of enhancements to:			
1. External envelope and windows	270	230	230
2. Thermal mass (exposed soffit etc)	60	60	–
3. HVAC	70	50	110
Revised net cost without renewables	**2040**	**1860**	**820**
3. Renewables	90	90	230
Revised net cost for all measures	**2130**	**1950**	**1050**
Preliminaries and contingencies	510	460	220
Total cost	**2640**	**2410**	**1270**
Percentage extra over cost without renewables	**24%**	**22%**	**71%**
Percentage extra over cost for all measures	**30%**	**28%**	**119%**

For all three models, the costs of improvements to the external envelope are the main cost driver. In a further iteration of this research, it may be worthwhile modelling the cost effectiveness of different approaches to managing external heat loads. In the case of the retail warehouse, costs of renewables are also disproportionately high, as a similar array of PVs and wind turbines to that used for the offices are apportioned over a smaller floor area. Looking in more detail at the costs of the external envelope, over 50 per cent of expenditure is associated with improving the thermal performance of glazing and providing shading to reduce solar gain. The results of this analysis suggest that innovation in the external envelope, exploiting improvements in physical performance whilst maintaining internal comfort conditions represents a very important area for LZC progress, but also that there are risks of diminishing returns as thermal performance requirements intrude on other aspects of value.

The results for the retail warehouse illustrate the scale of challenge associated with making significant improvements to the performance of simple building types with little thermal mass and limited services content. In this instance, there is not sufficient cost in either the building envelope or building services to offset the enhanced specification – in essence, the sustainability features proposed are extras.

6.5 Conclusions

6.5.1 Limitations

Due to the limited time frame for this project, a number of limitations in the costing analysis have been highlighted by the costs consultants as requiring further work. These include:

- Consideration of alternative design strategies. The performance of the external wall has been specified to achieve very high U values at significant cost premiums. Alternative approaches to managing losses and gains at the building perimeter could, for example, be modelled on a cost:performance basis.
- Payback. No assessment of the cost effectiveness, in terms of carbon or energy cost reduction of any of the enhancements has been made.
- Costs of CCHP-based HVAC. The straight substitution of CCHP-based heating and cooling appears, in the context of the exercise, a relatively low-cost, low-impact low carbon enhancement.
- Costs of enhanced thermal mass. The use of exposed soffits to increase thermal mass introduces a number of aesthetics-related cost drivers including finishes, appearance of services, constraints on adaptability and so on.

6.5.2 Carbon reduction costs – regulated energy

In an ideal world it would have been possible to work out the range of regulated energy use for each building and cost each one individually. Unfortunately within the time frame that has not been possible and therefore an estimation of the range has been calculated.

The three generic building types have been modelled using both iSBEM and dynamic modelling software as outlined above. The results of the SBEM calculations have been costed to give a range of costs for achieving zero carbon regulated energy for that generic building type. However, it is recognised that the range of SBEM models does not cover the full range of non-domestic building uses, and there are building types with exceptional energy use that have not been covered.

These extreme uses have been accounted for by subtracting the closest SBEM model from the ECON-regulated energy use. This allows an additional energy reduction cost to be added in a similar manner to occupant energy use as outlined in Section 6.5.3 below (see Appendix E).

Although not unexpectedly high, the above figures demonstrate significant cost increases associated with energy efficiency measures.

However, as noted in Section 6.4.3, these primarily relate to fabric improvements which, as insulation technology advances, are likely to reduce in cost rapidly, particularly given the driver the Code for Sustainable Homes is having on fabric and air tightness.

6.5.3 Carbon reduction costs – occupant energy

Reducing occupant energy use to zero is an even more difficult element of the study to predict, as it varies significantly not only by building type and use, but also by the particular occupants that are using the building. The calculation for cost of reducing average occupant energy use to zero has therefore necessarily been a relatively simplistic one of assuming a cost per $kgCO_2$ offset, be that from on-site, near-site or off-site renewables and multiplying it by the occupant use for a variety of renewable energy technologies (see Appendix E for the basis of these calculations).

These costs assume that the full capital investment in the renewable energy is made by the developer, when in reality; the developer may use an Energy Services Company (ESCo) to provide some, if not all, of the funding for the infrastructure in return for the revenue of running that infrastructure over the lifetime of the asset.

Table 9: Estimated cost for varying renewables

Cost of Implementation: £ per kg CO_2 avoided each year	
Capital Cost of Small Scale Wind	£12.50
Capital Cost of Solar PV	£14.78
Capital Cost of Biomass CHP	£1.15
Capital Cost of Large Scale Wind	£1.02

Notes
The costs in the above table assume full up front capital investment are paid by the developer, whereas in reality the costs might be taken by an ESCo in return for the revenue gained from running the asset for the lifetime of that asset.

It should be noted that these figures were also used to achieve carbon neutrality with regard to regulated energy.

As can be seen from the above table, off-site renewables are often significantly cheaper, and a debate around the efficient use of the resources available to a development before tapping into the limited resource of the rest of the country is discussed in Section 8.3.4 below.

6.5.4 Cost of ROCs

The Renewables Obligation (RO) requires all electricity suppliers to hold a certain number of Renewable Obligation Certificates (ROCs) at the end of each year. ROCs are received for each MWh of renewable energy generation and the number of ROCs to be held is increased year on year by the regulator (Ofgem) with the intention of stimulating investment in renewable energy generation.

The RO is in place of feed-in tariffs that are used across much of Europe which fix energy prices for electricity from renewable resources. The price of ROCs may vary, but increases in the number required to be held by suppliers is intended to enable continued renewable energy generation investment.

Any system for non-domestic buildings that allows investment in renewable energy may not need the income for the ROCs to make the project viable because capital investment has already been obtained. However, the role of ROCs needs to be considered; if the renewable energy solution for non-domestic buildings allows investment by developers, and ROCs could be freely sold onto the market the price would plummet and electricity suppliers would no longer be incentised to continue increasing the renewable content of the grid. In other words, additionality would not be guaranteed.

There are a number of mechanisms in which this could be countered, and further work is required to assess the most appropriate solution:

1. Allow sale of ROCs and increase the number required to be held by electricity suppliers to an appropriate level. This would allow a harmonised approach between Communities and Local Government and BERR that would make the proposed 2020 target for 20 per cent renewable energy more manageable and more easily measurable, and would enable an easy mechanism for occupier contributions over the lifetime of the building. However off-site renewable developers would be receiving double investment, firstly from the developer and secondly from the ROCs. Also, this process could significantly impact the non-domestic emissions trading scheme currently being considered.

2. Ensure all renewable energy installed under the non-domestic buildings programme does not qualify for ROCs. This approach however does not guarantee additionality for the lifetime of the building or incentivise the occupier to reduce demand.

This is a significant area that needs to be considered and forms part of the work to be undertaken on the accreditation of off-site renewables.

6.5.5 Renewable energy costs

The costs outlined in the following sections are some examples of the make-up costs that would be required in addition to energy efficiency measures in order to achieve zero carbon 'regulated' emissions, level 5, and total zero carbon, zero 'regulated' carbon emissions and zero 'occupant' carbon emissions, level 6. These are based on the capital costs as outlined in Section 6.5.3, however, depending on the mechanism set up to allow developers to invest in near-site and off-site renewable energy, investment needed in ESCos could be significantly less than the figures quoted below, given that these ESCos could then generate revenues by running the assets. Furthermore, these figures quoted here are for today's prices, and significant economies of scale and changes to market may reduce these costs further, hence, the total increased costs quoted in Section 6.6.3 reflect that the capital costs could drop from an estimated 30 per cent down to as little as 5 per cent over time, given the correct market control, regulatory framework etc.

This is a significant consideration, and the savings in energy usage from other resources are assumed to be reinvested in zero carbon new non-domestic buildings (see Section 7.2.1).

6.5.5.1 On-site renewables

Some example costs of achieving carbon neutrality (regulated energy,which would be equivalent to Code for Sustainable Homes level 5) and zero carbon (including occupier loads such as small power, what would be equivalent to Code for Sustainable Homes level 6) using on-site renewables can be summarised for the studied buildings in the following tables for small scale wind and photovoltaic cells (PV).

Table 10: Example additional costs (to that of energy efficiency) of small scale wind

	Level 5 with Small Scale Wind		Level 6 with Small Scale Wind	
Building classification	Ave. Renewable Capital Cost / m≤	Average % Increase over Baseline	Ave. Renewable Capital Cost / m≤	Average % Increase over Baseline
DIY Store	£500	60.0%	£800	90.0%
Non-food store	£700	80.0%	£1,100	120.0%
Dept Store	£700	80.0%	£1,400	160.0%
Small Food Store	£200	20.0%	£2,000	240.0%
Supermarket	£800	90.0%	£4,700	560.0%
Cinema	£1,000	100.0%	£1,400	140.0%
Offices Nat Vent Cellular - Type 1	£300	20.0%	£400	40.0%
Offices Nat Vent Open Plan - Type 2	£200	10.0%	£500	30.0%
Offices - A/C standard - Type 3	£600	40.0%	£1,100	80.0%
Offices - Prestige A/C - Type 4	£400	20.0%	£1,700	90.0%
Business/Holiday	£600	30.0%	£1,400	60.0%
Leisure	£1,200	120.0%	£2,200	220.0%
Primary School	£200	20.0%	£300	30.0%
Education (Secondary, no pool)	£100	10.0%	£200	20.0%
Light Manufacturing	£300	80.0%	£1,100	270.0%
Health Care - GP (cottage health care)	£600	50.0%	£900	70.0%
Library - education - A/C	£1,100	90.0%	£2,300	190.0%
Library - education - Nat Vent	£200	20.0%	£500	40.0%
Libraries - public buildings	£200	20.0%	£400	30.0%
Restaurant with bar	£1,100	70.0%	£4,600	300.0%
Fast food restaurant	£800	90.0%	£5,100	590.0%
Pub restaurant	£800	80.0%	£2,500	250.0%

Notes
The costs in the above table assume full up-front capital investment is paid by the developer, whereas in reality the costs might be taken by an ESCo in return for the revenue gained from running the asset for the lifetime of that asset.

As can be seen from the above tables, the increase in costs can be very significant for small scale wind. However, this depends greatly on the wind resource available which means that costs could vary widely depending on location.

The table below for PV shows costs almost double that, assuming favourable orientation of the panels, highlighting the significant costs of on-site renewables and the need to allow developers to use other sources of renewable energy.

Table 11: Example additional costs (to that of energy efficiency) of PV

	Level 5 with PV		Level 6 with PV	
Building classification	Ave. Renewable Capital Cost per m≤	Ave. % Increase over Baseline	Ave. Renewable Capital Cost per m≤	Ave. % Increase over Baseline
DIY Store	£630	74.1%	£910	107.1%
Non-food store	£800	94.1%	£1,260	148.2%
Dept Store	£820	96.5%	£1,620	190.6%
Small Food Store	£250	29.4%	£2,390	281.2%
Supermarket	£920	108.2%	£5,610	660.0%
Cinema	£1,200	120.0%	£1,590	159.0%
Offices Nat Vent Cellular - Type 1	£310	25.8%	£510	42.5%
Offices Nat Vent Open Plan - Type 2	£230	16.4%	£550	39.3%
Offices - A/C standard - Type 3	£700	50.0%	£1,250	89.3%
Offices - Prestige A/C - Type 4	£520	28.9%	£1,950	108.3%
Business/Holiday	£760	34.5%	£1,590	72.3%
Leisure	£1,360	136.0%	£2,600	260.0%
Primary School	£260	21.7%	£390	32.5%
Education (Secondary, no pool)	£150	12.5%	£290	24.2%
Light Manufacturing	£380	95.0%	£1,270	317.5%
Health Care - GP (cottage health care)	£740	61.7%	£1,030	85.8%
Library - education - A/C	£1,290	107.5%	£2,760	230.0%
Library - education - Nat Vent	£270	22.5%	£570	47.5%
Libraries - public buildings	£240	20.0%	£420	35.0%
Restaurant with bar	£1,300	86.7%	£5,390	359.3%
Fast food restaurant	£890	104.7%	£5,970	702.4%
Pub restaurant	£930	93.0%	£2,990	299.0%

Notes
The costs in the above table assume full up front capital investment are paid by the developer, whereas in reality the costs might be taken by an ESCo in return for the revenue gained from running the asset for the lifetime of that asset.

6.5.5.2 Near-site renewables

There are a number of possible renewable solutions that could be classed as 'near-site', including, but not limited to, community CHP powered by a renewable resource such as wood chip biomass and community wind connected via private wire. Again work on what is classed as 'near-site' renewables should form part of the remit of the work on accreditation of off-site renewables.

An example of the cost of achieving zero carbon (including occupier loads such as small power, that would be equivalent to Code for Sustainable Homes level 6) using near-site renewables (eg contribution to community CHP) is significantly lower in cost than the on-site solutions. It should again be noted that these costs are in addition to the energy efficiency costs that have been estimated at between 5-30 per cent.

Table 12: Example additional costs (to that of energy efficiency) of biomass CHP

	Level 5 with Biomass CHP		Level 6 with Biomass CHP	
Building classification	Ave. Renewable Capital Cost per m≤	Ave. % Increase over Baseline	Ave. Renewable Capital Cost per m≤	Ave. % Increase over Baseline
DIY Store	£50	5.9%	£70	8.2%
Non-food store	£60	7.1%	£100	11.8%
Dept Store	£60	7.1%	£130	15.3%
Small Food Store	£20	2.4%	£190	22.4%
Supermarket	£70	8.2%	£440	51.8%
Cinema	£90	9.0%	£120	12.0%
Offices Nat Vent Cellular - Type 1	£20	1.7%	£40	3.3%
Offices Nat Vent Open Plan - Type 2	£20	1.4%	£40	2.9%
Offices - A/C standard - Type 3	£50	3.6%	£100	7.1%
Offices - Prestige A/C - Type 4	£40	2.2%	£150	8.3%
Business/Holiday	£60	2.7%	£120	5.5%
Leisure	£110	11.0%	£200	20.0%
Primary School	£20	1.7%	£30	2.5%
Education (Secondary, no pool)	£10	0.8%	£20	1.7%
Light Manufacturing	£30	7.5%	£100	25.0%
Health Care - GP (cottage health care)	£60	5.0%	£80	6.7%
Library - education - A/C	£100	8.3%	£210	17.5%
Library - education - Nat Vent	£20	1.7%	£40	3.3%
Libraries - public buildings	£20	1.7%	£30	2.5%
Restaurant with bar	£100	6.7%	£420	28.0%
Fast food restaurant	£70	8.2%	£460	54.1%
Pub restaurant	£70	7.0%	£230	23.0%

Notes:
The costs in the above table assume full up-front capital investment is paid by the developer, whereas in reality the costs might be taken by an ESCo in return for the revenue gained from running the asset for the lifetime of that asset.

The costs for near-site renewables can be seen to be significantly cheaper than those of on-site renewables, however, the overall cost of achieving level 6 could still be quite significant when the additional to the energy efficiency costs, estimated at between 30 per cent and 5 per cent.

6.5.5.3 Off-site renewables

There are a number of possible off-site renewable energy solutions such as wave, tidal, large scale biomass etc. however, the most obvious of these is large scale wind.

Table 13: Example additional costs (to that of energy efficiency) of large scale wind

	Level 5 with Large Scale Wind		**Level 6 with Large Scale Wind**	
Building classification	Ave. Renewable Capital Cost per m≤	Ave. % Increase over Baseline	Ave. Renewable Capital Cost per m≤	Ave. % Increase over Baseline
DIY Store	£43	5.1%	£60	7.1%
Non-food store	£56	6.5%	£90	10.6%
Dept Store	£57	6.7%	£110	12.9%
Small Food Store	£17	2.0%	£170	20.0%
Supermarket	£64	7.5%	£390	45.9%
Cinema	£83	8.3%	£110	11.0%
Offices Nat Vent Cellular - Type 1	£21	1.8%	£40	3.3%
Offices Nat Vent Open Plan - Type 2	£16	1.2%	£40	2.9%
Offices - A/C standard - Type 3	£49	3.5%	£90	6.4%
Offices - Prestige A/C - Type 4	£36	2.0%	£140	7.8%
Business/Holiday	£53	2.4%	£110	5.0%
Leisure	£94	9.4%	£180	18.0%
Primary School	£18	1.5%	£30	2.5%
Education (Secondary, no pool)	£10	0.9%	£20	1.7%
Light Manufacturing	£26	6.5%	£90	22.5%
Health Care - GP (cottage health care)	£51	4.3%	£70	5.8%
Library - education - A/C	£90	7.5%	£190	15.8%
Library - education - Nat Vent	£19	1.6%	£40	3.3%
Libraries - public buildings	£17	1.4%	£30	2.5%
Restaurant with bar	£90	6.0%	£370	24.7%
Fast food restaurant	£61	7.2%	£410	48.2%
Pub restaurant	£65	6.5%	£210	21.0%

Notes:
The costs in the above table assume full up-front capital investment is paid by the developer, whereas in reality the costs might be taken by an ESCo in return for the revenue gained from running the asset for the lifetime of that asset.

In this example the costs for off-site renewables can be seen to be the cheapest solution, however, this can vary significantly depending on location, particularly if offshore wind is used. The overall cost of achieving level 6 could still be quite significant when the additional to the energy efficiency costs, estimated at between 30-5 per cent, are added. However, further work is need to define these energy efficiency costs for each building type, particularly as the most suitable solutions for individual buildings may vary for a wide range of reasons.

6.6 Conclusions

6.6.1 Impact on value

The property market is currently characterised by a combination of high construction costs and historically high capital valuations, driven in part by low finance costs. Construction cost inflation is currently running at 1.5 to 2 per cent higher than RPI. Looking forward, there is little prospect of a significant reduction in the pressure on prices, and as a result, construction will continue a long-term trend of increasing in cost at a faster rate than the general economy. This will increase pressure on affordability and viability. With commercial property valuations at very high levels, there is little prospect for further upward growth – future rental increases and so on already having been taken into account in the calculation of the investment yield. As a result, an increase in cost related to low carbon construction is likely to affect either levels of rent, developer profitability or the price paid for land in the first instance. In the context of commercial development cycles, requirements for enhanced sustainability which result in significantly higher construction costs could delay a recovery if the balance between cost and income/value adversely affected viability.

Building efficiency is a key aspect of value, and developers have strived to maximise the floor area of buildings by minimising the thickness of external wall construction. The adoption of a heavily-insulated wall construction, potentially over 300mm thicker than conventional curtain wall/cladding solutions could also have an impact on capital values. For the deep plan office, the configuration most suited to a high value location, the increase of the thickness of the external wall zone by 300mm suggests a loss of net lettable floor area (and hence capital value) of approximately 5 per cent.

6.6.2 Impact on usability of space

Functional and utility considerations that need to be accounted for in the development of commercial space include the following. No doubt technological development will enable some of these requirements to be met within the context of low/zero carbon buildings, but in other cases, the impact on the function and value of space will need to be considered carefully:

- Efficiency of space planning: efficient space planning which optimises the use of space and the effectiveness of organisations is not necessarily compatible with ideal dimensions for cross or side ventilation
- Density of office occupation: trends in office occupation are for higher levels of occupation, both in terms of density of workstations and intensity of use through ‘flexible working’. Commentators such as OPD (Occupational Property Databank) are tracking a trend towards more efficient use of space, with future implications for heating, cooling and power loads. This can actually have a positive overall carbon dioxide emission since per person emissions may drop

- Provision for high intensity uses: space planning trends are moving towards the centralised provision of high heat gain uses such as printing and copying. This approach makes better use of floor space but results in concentrated heat sources that are difficult to manage with mixed-mode ventilation and cooling solutions; however, these may be easier to recover heat from and/or may result in lower cooling in other areas.

6.6.3 Estimating the expected cost increase of zero carbon over time

As outlined above, there are a number of limitations to the costing methodology undertaken for this project. These limitations have been imposed by the short timescale, difficulty in accurately predicting total building energy use, lack of previous cost experience of zero carbon non-domestic buildings and implications of not having detailed zero carbon specifications to work from. This, and the fact that non-domestic buildings vary so widely in use, function and location, even for the same building type, means that a range of cost increases needs to be given.

As can be seen in table 8, the costs of energy efficiency measures modelled using iSBEM can be significant. However, information taken from a few completed projects, which are likely to have relatively low occupation-related loads, and the modelling associated with this report based on scenarios which more closely reflect the current commercial marketplace, suggest that the premium could range from over 30 per cent down to as low as 5 or 10 per cent of current baseline costs given sufficient time for the market to develop, and detailed specifications to be costed. In some extreme cases, the premium could well be higher than this.

With a number of zero carbon projects which include non-domestic buildings being planned or constructed at present, further understanding of these figures could be gathered imminently. However, much of this work is still in the early stages of design and further experience is needed before these figures can be published with confidence. Indeed, such developments generally contain a favourable mix of building types and uses and therefore cannot be extrapolated across the whole non-domestic sector.

This means that the lower cost estimates within the range cannot be used as the basis for policy making or investment decisions, and considerable work in building a knowledge base which matches cost premiums with building type and building performance will be required to enable a confident and contextually confident assessment to be made.

Section 7

Achieving zero carbon on all new non-domestic buildings in the UK

7.1 Existing policy tools

In order to achieve zero carbon new non-domestic buildings in the UK there is a need, and from some developers, even a desire, for a policy change. Section 6.1 highlighted the fact that economic drivers are currently not in place to drive the building stock towards zero carbon. There are a number of existing policy tools that could be adapted in order to drive the agenda forward and these are outlined below.

7.1.1 Building Regulations Part L

The main, and most obvious policy tool currently governing energy consumption in new non-domestic construction is Part L of the Building Regulations 2006. Building Regulations sets the legal minimum standards for construction in the UK, and Part L deals specifically with energy consumption, regulating areas such as air-tightness, solar gains, and energy for heating, lighting and ventilation. In 2006 Building Regulations was updated and Part L was revised to be more demanding. However; Building Regulations only deal with a proportion of the total energy consumption in buildings, the 'regulated energy', so if the tool to evaluate this energy cannot be adapted to take account of 'occupant energy' use, additional tools may be required if the issue of energy consumption, and the associated Greenhouse Gas (GHG) emissions, is to be tackled realistically and effectively in order to achieve radical change.

There is surprisingly little driving sustainability in the non-domestic sector and the market model itself presents several intrinsic barriers to investment in better-performing buildings, as discussed in Section 6 and Appendix F. Much of the political will behind increasing performance of non-domestic construction beyond building regulations to date has come in the form of the Planning Policy Supplements 1 & 22, which enable Local Authorities (LAs) to set 'Merton Rule' -style policies in their local development documents; however, it is unclear how the upcoming Supplement PPS1 on Climate Change will affect this.

7.1.2 'Merton Rule'

The so-called 'Merton Rule' named after one of the first London Boroughs to implement a planning requirement that all major developments use on-site renewable energy generation to supply 10 per cent of their energy requirements. This followed the Greater

London Authority's Regional Development plan, the London Plan, which set targets for carbon reductions and encourages local boroughs to set their own targets through the planning system. Since Merton, about 80 local authorities have implemented similar policies, with a further 70 or so expressing an intention to do so, supported by PPS22.

Local Authority requirements for on-site renewables have been the source of much debate and have both strong support and opposition.

Supporters argue that they are a vital driver for high-performance buildings, as design teams will struggle to improve the performance of the thermal envelope in order to reduce the amount of renewable generation equipment required to meet the percentage target. Supporters also claim that these initiatives provide crucial pump-prime funding for the incipient UK micro-renewables market and encourage occupiers to think about the energy they use.

However, others argue that the focus on micro-generation is misplaced, and opportunities to make greater emissions reductions are being missed. Furthermore, while these policies have created an almost competitive spirit among local authorities keen to out-do each other; and while this competition could be a positive force, so far it has resulted in local authorities simply asking for higher percentage contributions of on-site renewable energy rather than being more imaginative and creative to ensure policies that actually work are implemented, recognised and rewarded.

As well as the more specific issues with requiring on-site renewable, there is a more generic question about local initiatives vs. national. The local approach can foster innovation and act as a testing ground for national policy; but, it can also lead to a patchwork of different policies that increase confusion in the industry.

For example, when councils first started implementing percentage on-site renewable energy targets, some councils framed their targets in terms of energy (kWh's) while others did so in terms of CO_2 (kg) which caused confusion; more recently the GLA has increased its demands from 10 per cent to 20 per cent – however, it is unclear what the baseline should be; ie 20 per cent of what? When the London Plan first came out, it referred to 'total energy' – 'regulated energy' plus 'occupant energy'. In the examination in public (EiP) the GLA stated that it was 10 per cent of SAP (regulated) energy, and therefore the 20 per cent would be taken from the same baseline. Given that in a domestic building the regulated energy is around 50 per cent of the total energy, this means that the increase from 10 per cent to 20 per cent is actually little change, as it's gone from 10 per cent of 100 per cent to 20 per cent of 50 per cent. However, for non-domestic construction the energy loads are much less uniform and so the potential for confusion is significant.

Clearly, what is desired is a way to foster local innovation within a national framework, so that policy is influenced from both the top-down and the bottom-up directions, all the while providing the market with security and reassurance about future demands.

7.1.3 'BREEAM'

While technically not a 'policy tool' BREEAM is an important part of the drive for better building performance. English Partnerships require BREEAM assessments for projects they fund and English Central Government has requirements for BREEAM assessments for its estate.

7.1.4 'Zero carbon'

Reductions in predicted emissions from developments are to be encouraged, but as long as they are only aiming for a proportion of the emissions, the development will still represent an increase in national emissions from the built environment, therefore mechanisms must be sought that can herd the UK building stock towards zero carbon as quickly as possible. These new measures should fit together in a suite of measures that complement each other, making the process of reducing national GHG emissions from the built environment as easy as possible. We should not lose sight of this as our primary goal. Furthermore, there is a more technical issue of the predicted emission vs. actual emissions, with empirical evidence suggesting that the latter could be 200-300 per cent greater than the former. The reasons for this are explained in more detail in Section 5, but it is important to bear this in mind when relying on predicted emissions figures to deliver real-life reductions.

7.2 Conclusions

7.2.1 Cost implications

The analysis in section 6 suggests that achieving zero carbon for new non-domestic buildings will increase the capital cost of construction by between 5 per cent and 30 per cent. At current prices and rates of construction of non-domestic buildings, that implies an approximate incremental capital cost of between £2 billion to £12 billion a year.

The Stern Report estimated that the annual cost of stabilising the level of greenhouse gases in the atmosphere at an acceptable level would be around 1 per cent of global GDP if action was taken promptly, but higher if action was delayed. One per cent of the UK's current GDP is £13.5 billion. However, buildings contribute about 40 per cent of total greenhouse gas emissions, of which about two-thirds come from domestic buildings and one third from non-domestic buildings.

Further analysis of what this means needs to be undertaken once more precise cost estimates for the achievement of zero carbon new non-domestic buildings have been gathered. The calculations, however, could be undertaken using the methodology outlined in the following paragraphs.

If the constraint of 1 per cent of GDP is accepted, then these calculations suggest that a graduated approach to reducing carbon emissions from new non-domestic buildings would be more appropriate than aiming now for zero carbon. For example, a 50 per cent reduction in the energy consumption of new non-domestic buildings would produce savings of about £200 million each year (£1 billion after five years, and so on). As the savings in energy consumption accumulate as a result of investment in energy efficiency measures, the target can be progressively increased without further increasing the net GDP cost.

How quickly a zero carbon standard for new non-domestic buildings can be achieved through a gradual approach obviously depends on the level of investment that is mandated. Assuming a 50 per cent reduction in energy consumption by new non-domestic buildings can be achieved by spending £6 billion a year (half the amount required to achieve zero carbon), then savings would be generated at a sufficient rate to justify raising the standard to zero carbon within 15 years. If further intermediate steps were introduced, then the zero carbon target could be reached earlier – potentially within 10 years – but the proportion of GDP devoted to the task would rise temporarily (until the extra savings were realised).

The above methodology assumes that all of the non-domestic 'share' of the 1 per cent GDP is invested in new non-domestic building's achievement of zero carbon. If in 2050 30 per cent of non-domestic buildings will have been built after 2007 then this calculations could be altered to only invest 30 per cent of that 'share'.

At the lower end of the cost increase estimates, the practicality of implanting legislation and allowing sufficient time for industry to adjust to the new requirements actually proves more important than the capital investment required. This means that even when taking account of all of the new non-domestic buildings 'share' of the 1 per cent GDP, the trajectory suggests 2016 to 2020 may be achievable; however, as outlined above, more detailed calculations are required to achieve cost certainty, it is recommended that this study be taken forward as soon as possible.

At the higher end of the cost increase estimates outlined in Section 6, the dominating investment actually comes from the energy savings to the economy from zero/low carbon new non-domestic buildings which mount considerably year on year past 2020. This means that even when taking account of all of the new non-domestic buildings 'share' of the 1 per cent GDP, the trajectory stretches into the middle of the century, however, as outlined above more detailed calculations are required to achieve cost certainty.

Section 8

Recommendations

8.1 Barriers to implementation of zero carbon in Building Regulations

There are a number of barriers and issues in the current construction climate that need to be addressed in order to achieve the target of zero carbon new non-domestic buildings along the required trajectory.

8.1.1 Energy performance in buildings

8.1.1.1 Relationship to other schemes operating in the UK

Implementation should be coordinated with Communities and Local Government development of the Energy Performance of Buildings Directive (EPBD) based asset and operational ratings schemes. This does not simply mean for example, adding a further category to the DEC (Displayed Energy Certificate), but a full commonality of benchmarking classification and calculating methods.

Full and precise accounting of on-site energy use, on-site unmetered and metered renewables, near-site generation and all delivered fuels is itself a non-trivial matter. Several reports and papers on the implementation of asset and operational ratings, written for Communities and Local Government by their contractors for EPBD development, discuss the details of energy wares accounting, eg Bordass 2006, Bordass 2007.

8.1.1.2 Energy design models

Whatever the goals, compliance with Building Regulations, control of facility operating costs, or zero carbon new non-domestic buildings, building energy use models are a central part of the design process and thus the provision of buildings. However, research has repeatedly shown the discrepancy between modelled and real building energy use.

The most significant development in building science over the last thirty years has been the development of computer models to assess the energy and environmental performance of buildings. These models are now regularly used to assess the potential impact of energy-efficient technologies in the design and refurbishment of buildings. However, when buildings are refurbished or new buildings built, they can use up to twice the theoretical energy performance. This is a serious problem which can significantly impact on the potential for the world to achieve carbon reduction targets.

8.1.1.3 Policy development

As things stand, the building industry is unlikely to achieve model-based targets in reality and this problem needs to be addressed at a national level. The causes of the discrepancy between model predictions and actual building energy use must first be understood, then incorporated into model structure, input data requirements and the ways models are used. These methodological improvements need to be based on sufficient empirical data rather than further modelling. The tools used in design consultancies need to be able to predict real building energy use, and national policy needs to enable the design process to do that and mandate that it does.

8.1.1.4 Policy implementation

Improved policing of Building Regulations is required, along with a widely and deeply embedded industry knowledge of how to achieve zero carbon non-domestic buildings.

8.1.1.5 Policy monitoring

Sophisticated and accessible meter data is mandatory to confirm that buildings really do achieve their designed and approved goals. The difficulties of reliably discerning real trends in the non-domestic stock and their causes are discussed in Sections 5.1.2.

There is a particular synergy with EPBD driven Operational Rating schemes here and the requirement of data for Display Energy Certificates (DECs). DECs might provide only a general purpose benchmarking, useful as such, but constrained by a wish to minimise the load of data collection on building owners and occupants. There is an opportunity to make them much richer in quality, if the more detailed data included in the 'technical table' can be collated in a national database and the difficulties experienced in this project could be avoided in the future.

Energy performance in general, and new policies in particular, need to incorporate fabric design in new-buildings, and possibly fabric modifications and control in existing buildings. DECs provide an important potential data source for monitoring implementation of new policy (or any other energy policy) but in relation to this project, confirming zero carbon compliance is complicated by the exclusion of actual behaviour of people in buildings and actual appliance use from the project analyses (Communities and Local Government 2007), but their inclusion in DECs. The need for commonality and compatibility of schemes can therefore only be reiterated.

8.1.1.6 The longer term

It is necessary to keep a watching brief and even now take into account future policies likely to enhance that which can be achieved with technical low and zero carbon design, for instance, cap and trading schemes and carbon rationing.

The implementation of these schemes could dramatically change the utility of a policy mandating new non-domestic buildings, either making its specified goals more difficult to achieve, or simply redundant amongst Government initiatives, fiscal measures and economic forces that will be of necessity applied to the whole of the non-domestic stock, new and existing.

8.1.1.7 Limited renewable resources

'Renewable energy' means that the energy produced by a particular resource can be produced for an infinite amount of time; it does not however mean that the resource is infinite. In other words, a renewable resource can produce an infinite amount of energy only if given an infinite amount of time.

Fossil fuels on the other hand are limited in terms of resource available at any one time as well as being finite in that they will run out. Therefore, given infinite time fossil fuels would still only produce a finite amount of energy.

An example of a finite renewable resource is biomass. Biomass is a renewable resource and can be grown year on year for an infinite amount of time. However, there is limited space on the planet for the growth of biomass and once that space has been assigned for biomass growth to supply a specific energy need, that resource is no longer available until that energy use no longer exists. In other words, that energy need can be supplied for infinite time but no other need can be supplied by that particular space.

It is key to appreciate this in the context of new non-domestic buildings in the UK becoming zero carbon, because it is the finite renewable resources of the UK that they will be tapping in to achieve zero carbon. Section 8.3.4 below outlines how this barrier could be managed.

8.1.2 Does SBEM need to change?

There are two key questions to ask of SBEM's capabilities when looking at achieving zero carbon in new non-domestic buildings:

1. Can the tool adequately model zero carbon?

2. Can the tool be used to calculate actual building energy use rather than an estimate that allows comparison between buildings but may not reflect that actual use? If not, can it be adapted to do so?

To be consistent with the definition of a zero carbon dwelling, a zero carbon non-domestic building would be defined as one where the net carbon emissions resulting from both the operation of the building services and the activities that it houses (normalised) are zero.

SBEM has some deficiencies when considering zero carbon. These are as follows:

1. SBEM is currently a monthly average calculation method. Design of very low and zero carbon buildings is likely to require a more refined calculation (ie on an hourly basis) in

order to properly model the impact of passive features and building form on energy use during the diurnal cycle.

2. The calculation engine cannot properly model more complex building solutions (mostly fabric-related) such as night-time ventilation and fabric coupled cooling strategies for example. These present significant opportunities for achieving the higher performance targets envisaged and as such this limitation in SBEM would need to be resolved.

3. SBEM calculates the loads resulting from small power and operational equipment within the building and space functions using standardised W/m^2 levels. These are used to determine heating and cooling loads but are not currently included within reports or the final rating. This would be a simple matter to change within the tool.

4. Specialist lighting, both task- and process-related are similarly included in the heat and cooling load calculation but are not included within the rating reports. This is also simple to amend.

5. Contributions from off-site grid-connected renewable and other LZC technologies.

For these reasons SBEM would need to be revisited if it was to be able to form the basis for a zero carbon evaluation tool. Many simulation models would suffer from similar difficulties and further work is needed to understand the potential changes that are required.

8.1.3 Accreditation of off-site renewables

The UK-GBC will establish a group made up of a cross section of stakeholders from the sector, who will gather expert evidence and report by spring 2008 on the best way to accredit off-site renewables. The work of the group is part of the UK-GBC's contribution to the 2016 Taskforce, established by Housing Minister Yvette Cooper and the HBF. It is recommended that the findings of that report be applied to this work on carbon reductions in new non-domestic buildings.

8.1.4 Carbon intensity of grid

The current carbon intensity of the UK electricity grid is in the region of 0.50-0.52kgCO_2/kWh (calculated on an annual basis from DUKES). The most optimistic future plant deployment situation in the period 2010-2020 would see this carbon intensity fall to a level between 0.422-0.275 kgCO_2/kWh (G Killip, 2005). However, the future fuel mix of network electricity generation is subject to the Electricity Supply Industry economic paradigm, which at present is only marginally affected by carbon emissions. Its principal drivers are low price volatility and security of supply, a situation that currently favours coal plant over gas. There may therefore be in the short term (in lieu of successful implementation of carbon capture and storage) an increase in network carbon intensity, a trend that indeed has been evident since 2002.

This is an important consideration for technology deployment, particularly when net zero carbon solutions are sought. For instance, heat pump technology which could efficiently provide heating and cooling for many non-domestic buildings would be disadvantaged from a carbon emission reduction perspective by rising network emissions. Network carbon intensity may therefore play a role in determining the level of electricity consumption in a building and the consequent amount of renewable, low or zero carbon generation that would have to be deployed to achieve a net zero carbon solution.

8.2 Proposed Levels for carbon reductions

It is proposed that, like the Code for Sustainable Homes, 6 levels of carbon reduction are used in order to ensure consistency across the industry (see table below). The trajectory to arrive at the various levels of carbon reduction differs dependent upon the level of additional build costs in order to deliver zero carbon.

However, due to the high occupant energy use in relation to regulated energy use in non-domestic buildings, there are difficult practical issues to be overcome in moving from level 5 to level 6. Therefore, any timeline moving to level 6 must be cognisant of these difficulties and be able to respond with appropriate policies.

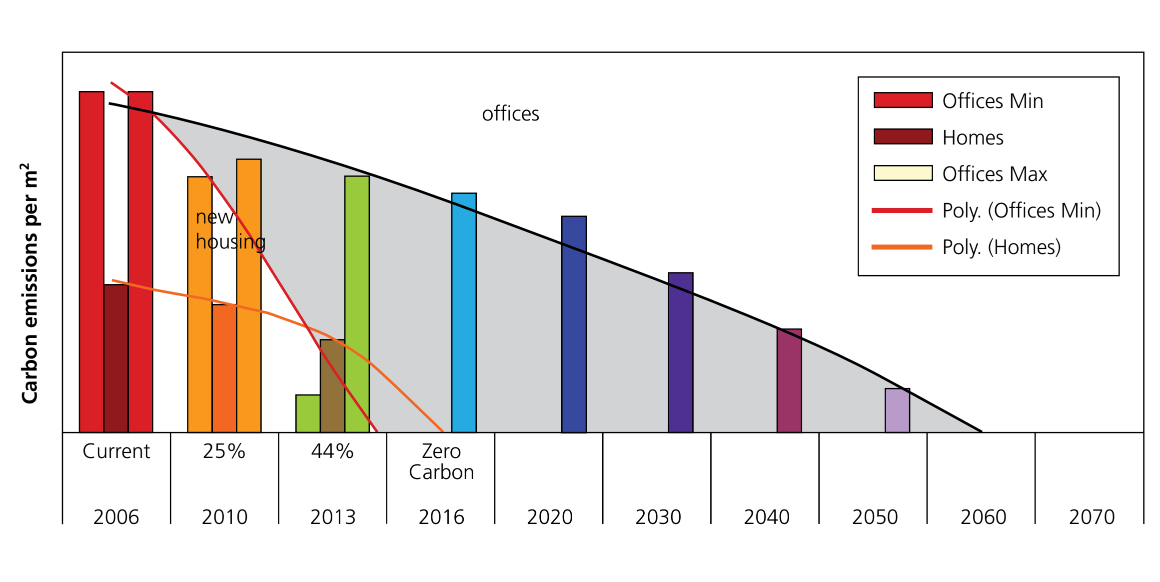
Further work to establish the costs for zero carbon new non-domestic buildings is required to confirm the proposed trajectories to zero carbon detailed in the table below. The 5 per cent cost increase suggested in the above cost range of 30 per cent reducing to 5 per cent in some cases, is likely to only apply to a limited number of non-domestic building types but could be accommodated relatively quickly within the 1 per cent GDP set out in Section 7.2.1. A figure that might be more applicable across the sector of 10 per cent has therefore been chosen to illustrate likely timescales in table 14.

Table 14: Possible trajectories to zero carbon new non-domestic buildings

Code level	Carbon reduction (% of regulated energy)	Timescale for delivery at 10% additional build cost	Timescale for delivery at 30% additional build cost
1	10		
2	18		
3	25	2010	2013
4	44	2013	2025
5	100		
6	Zero Carbon regulated energy and occupant energy	2016	2050

As can be seen from table 14, the cost estimates lead to a wide timescale across which a trajectory to zero carbon could be realised. Figure 4 indicates the relative carbon emissions from a non-domestic building (in this case an office has been used) and the carbon emissions from homes. The trajectory set out in the CSH is shown as are the two trajectories set out above.

Figure 4



As noted above, the change from level 4 to level 6 set out in the CSH may be too great a step for non-domestic buildings. This can be seen in the sharp fall of the curve in figure 4 for the lower cost estimate. It is therefore suggested that an additional stage in the regulatory escalator be added for non-domestic buildings at the equivalent of CSH level 5, ie zero 'regulated' energy.

This would mean if a zero carbon new non-domestic buildings target is to be set, this research suggests that with a trajectory in place similar to that adopted for the Code for Sustainable Homes, and the above "zero 'regulated'" step is added, a deadline of 2020 could be adopted.

8.3 Methods for implementation

The success of the zero carbon new non-domestic buildings policy will be at least as dependent on its implementation as it is on the cost and use of available technologies.

8.3.1 Establishment of a national database

The first recommendation of this report is that a national building performance database should be established in order to properly understand energy use in the non-domestic stock and assess compliance with regulation (see Section 5.1.2).

8.3.2 Cost of ROCs

Communities and Local Government made it very clear in their definition of zero carbon for this project (see Section 1) that any near-site or off-site carbon-reduction solutions would have to be additional. That is to say, green tariffs could not be used and renewable energy certificates (ROCs) would have to be retired. An intervention is needed to ensure that carbon reductions are not double counted and the retirement of ROCs could be one way of achieving this; however, a separate instrument could be constructed if necessary.

The steady trend of increasing energy use in the UK indicates that while Building Regulations have attempted to reduce 'regulated' energy, occupiers of buildings have done little to address energy consumption. This can be explained by the fact that the drivers to reduce energy are limited (see Section 6).

In order to redress this, and to spread the burden of carbon reductions into the lifetime of the building and thus incentivise further carbon reductions, it is recommended that the occupier pay for the price of ROCs associated with near-site and off-site renewables.

The mechanism for doing this will need to be further developed, but near-site and off-site ESCos are likely to still require the price of ROCs in order to maintain sound business cases.

Whatever the mechanism, it is recommended that DECs could determine what amount of ROCs are required to be paid for year on year, giving further weight to the argument that they should be implemented in all new non-domestic stock without delay.

8.3.3 Planning requirements

There are two points to consider with regard to planning and zero carbon new non-domestic buildings.

Firstly, the value of a development is locked in once planning is gained, and understanding the costs of realising that planning permission are therefore key to the process. It is therefore essential that any solution for zero carbon new non-domestic buildings that might have a significant cost implication, as this report shows these solutions almost invariably do, needs to be fully understood.

Secondly, planning in the UK is designed to ensure that the local community is developed in a sustainable manner ensuring that the available resources and space are used to its best advantage. The planning system therefore necessarily sets parameters for development to ensure this is the case.

Why should this not apply to energy? Renewable energy resource is limited in capacity as outlined above in Section 8.1.1.7. It is therefore key that local resources are used. This may often only be a small percentage (below 10 per cent in some cases) but nonetheless the resources should be used as a priority (see Section 8.1.1.7). For example, a local heat network run on gas CHP may save carbon in a dense location but will not do so in a rural situation where long pipe runs would drop efficiency below that of centralised electricity generation and local condensing boilers.

Space planning by local planning authorities therefore needs to incorporate energy planning, undertaking heat mapping and community renewable potential in order to assign the best near-site solutions in terms of carbon reduction and maximising the use of resources. This can then be fed into planning requirements as has been done for other elements of development in section 106 agreements.

This space planning would then take forward the process started by 'the Merton Rule', as outlined in Section 7.1.2, and require connection to or funding for a local distributed energy system to be administered by a local authority or on its behalf.

At a national level, regional planning could undertake similar assessments in order to determine suitable locations for appropriate off-site renewables. These could be administered by an independent body similar to Ofgem on behalf of the regional planning authorities. Developments could then invest in this if on-site and near-site solutions are not feasible in order to meet their carbon-reduction requirements.

8.3.4 Development renewable resource estimation

Once developed, it is more difficult to extract the renewable resource of a given piece of land as a retro-fit measure. Therefore, in order to ensure that all renewable resources that can be efficiently captured are captured, a measure of the renewable resource needs to be undertaken prior to development.

This does not mean that every square foot of surface the sun strikes should be covered with PV, but rather that a measure is made of the resource and the potential for its capture is assessed both in technical and economic feasibility.

An early version of this would be the London Renewables publication 'Integrating renewable energy into new developments: Toolkit for planners, developers and consults' – 'The Toolkit' as it is known. The tool set out to enable 'the Merton Rule' to be implemented quickly and easily.

It is therefore suggested that such a tool be developed for Part L and be integrated with the planning system to understand the renewable resource of a site and determine if it can be feasibly utilised. This tool would assess the on-site renewable resource of a development, but it could also assess the near-site potential for renewable energy.

A near-site, or community, estimate of the feasibility of heat networks for example could be undertaken by the local council or borough following energy (heat) mapping and identification of suitable energy supplies to reduce carbon. This could all be part of setting planning requirements as outlined in the section above (Section 8.3.3).

8.3.5 Minimum standards of energy efficiency

In order to ensure that the renewable resources outlined in Section 8.1.1.7 are not needlessly exploited and thus the finite resources depleted unnecessarily, it is recommended that minimum standards for energy efficiency be increased within the Building Regulations. This has been done in the Code for Sustainable Homes with the heat loss parameter for example. For non-domestic buildings this is also likely to include a cooling parameter, setting cooling loads due to solar gain per m^2 of wall area for varying building uses and types.

Listing these requirements is a matter for further development, but it seems clear for the cost calculations of this report that these requirements may need to be different for different building forms, even building uses.

Sheds are used in the construction industry because of their inherently cheap construction costs and therefore increasing the Heat Loss Parameter (HLP) to the same level of requirement as other built forms represents a much higher percentage of the overall construction costs. That is not to say that sheds should not be required to reach zero carbon on the same trajectory as the other built forms, but that the level of minimum energy efficiency requirements needs to be set appropriately for each building type, and additional carbon reductions would then be achieved through assessment of the renewable resources either on-site, near-site or off-site as outlined in Section 8.3.4 above.

8.3.6 Energy efficiency investment in other buildings

Given the potential difficulty of achieving zero carbon in new non-domestic buildings through the provision of on-site renewable solutions, there exists the option of allowing the investment in carbon-saving measures in existing buildings. In effect, this would offset the carbon emissions from a new-build non-domestic building against a reduction in carbon emissions from an existing building. This would result in a net 'zero carbon' new non-domestic building.

This could, if undertaken correctly, afford the opportunity to reduce carbon emissions of the non-domestic stock overall. However, care would have to be taken in designing any such scheme. Setting aside any considerations around the requirements and incentives for increasing energy efficiency in existing non-domestic buildings going forward, the introduction of any 'offsetting' scheme would need to ensure that any offset carbon was not lost when the existing building concerned was rebuilt. In addition, any such scheme must also consider the possible negative implications on the overall level of renewable energy generation capacity. If any such scheme were to be considered, it is crucial that checks and balances are in place to ensure that the scheme does not detract from the achievement of zero carbon non-domestic buildings and that offsetting is undertaken only as a last resort.

Section 9

References

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Appendix A

The Simplified Building Energy Model (SBEM)

Methods for implementation

A.1.1. National Calculation Method

A.1.1.1. Introduction to NCM

The National Calculation Method for the EPBD (Energy Performance of Buildings Directive) is defined by the Department for Communities and Local Government. The procedure for demonstrating compliance with the Building Regulations for buildings other than dwellings is by calculating the annual energy use for a proposed building and comparing it with the energy use of a comparable 'notional' building. Both calculations make use of standard sets of data for different activity areas and call on common databases of construction and service elements. A similar process is used to produce a 'asset rating' in accordance with the EPBD. The NCM therefore comprises the underlying method plus the standard data sets.

The NCM allows the actual calculation to be carried out either by an approved simulation software (click here for details), or by a new simplified tool based on a set of CEN standards. That tool has been developed for Communities and Local Government by BRE and is called SBEM – Simplified Building Energy Model. It is accompanied by a basic user interface – iSBEM.

A.1.1.2. Introduction to SBEM

The Simplified Building Energy Model (SBEM) calculates the energy used by non-domestic buildings. It has been developed in response to the requirements of the European Union's Energy Performance in Buildings Directive (EPBD). It was developed by BRE for Communities and Local Government as the default calculation tool for checking compliance with Approved Document L2A of the Building Regulations for England and Wales. It also plays a similar role in connection with regulations in Scotland and Northern Ireland and will form the basis of the calculation for the Energy Performance Certificate also required by the EPBD.

SBEM is a computer program that provides an analysis of a building's energy consumption. SBEM calculates monthly energy use and carbon dioxide emissions of a building given a description of the building geometry, construction, use, HVAC and lighting equipment. It was originally based on the Dutch methodology NEN 2916:1998 (Energy Performance of Non-Residential Buildings) and has since been modified to comply with the emerging CEN Standards.

SBEM makes use of standard data contained on associated databases and available with other software.

The purpose of SBEM and its interface iSBEM is to produce consistent and reliable evaluations of energy use in non-domestic buildings for Building Regulations Compliance (and eventually for Building Performance Certification purposes.) Although it may assist the design process, it is not primarily a design tool. It does not calculate internal temperatures, for example.

As iSBEM is a compliance procedure and not a design tool, if the performance of a particular feature is critical to the design, even if it can be represented in SBEM, it is prudent to use the most appropriate modelling tool for design purposes. In any case, SBEM should not be used for system sizing.

This paper sets out the basic principles of the calculation tool and the database structure that underpins the methodology. Further Information can be obtained from the SBEM Website at http://www.sbem-online.co.uk/

A.1.1.3. The calculation process

A.1.1.3.1. Calculation overview

SBEM takes inputs from the software user and various databases, and, by calculation, produces a result in terms of the annual CO_2 emissions resulting from the energy used by the building and its occupants. Some of the inputs are standardised to allow consistent comparisons for building regulation and energy rating purposes in new and existing buildings.

SBEM calculates the energy demands of each space in the building according to the activity within it. Different activities may have different temperatures, operating periods, lighting levels, etc. SBEM calculates the heating and cooling energy demands by carrying out an energy balance based on monthly average weather conditions. This is combined with information about system efficiencies in order to determine the energy consumption. The energy used for lighting and domestic hot water is also calculated.

Once the data has been input using iSBEM, the SBEM calculation engine:

1. calculates lighting energy requirements on a standardised basis, which takes into account the glazing area, shading, light source, and lighting control systems
2. establishes the standardised heat and moisture gains in each activity area, from the database
3. calculates the heat energy flows between each activity area and the outside environment, where they are adjacent to each other, using CEN standard algorithms

4. applies appropriate HVAC system efficiencies to determine the delivered energy requirements to maintain thermal conditions
5. aggregates the delivered energy by source, and converts it into equivalent CO_2 emissions. This comprises the Building Energy Rating (BER).
6. determines, on the same basis, the CO_2 emissions of a notional building with the same geometry, usage, heat gains, temperature, lighting and ventilation conditions, and weather but with building component construction, HVAC and lighting systems which just meet the listed 2002 Building Regulation or deemed to satisfy requirements
7. applies an improvement factor to each zone within the notional building, which varies dependent on the HVAC system strategy employed in that zone. The resulting CO_2 emissions comprise the Target Energy Rating (TER).

The BER and TER calculations are then handed over to the compliance checking module, BRUKL, to complete the assessment. BRUKL:

1. compares the BER with the TER, and determines a pass or fail based on the relative performance of the proposed building
2. undertakes a compliance check on certain parameters drawn from information input using iSBEM.

Finally reports are prepared to the standard format to provide

1. comparison of BER & TER,
2. confirmation of the elemental compliance check

Intermediate results produced by SBEM are available in electronic format, to assist any diagnostic checks on the proposed building:

1. data reflection (to confirm entry associated with results)
2. monthly profiles of energy use by each end use and fuel type
3. total electricity and fossil fuel use, and resulting carbon emissions

A.1.1.3.2. Inputs and information sources

The inputs to the energy calculation include:

- Physical configuration of the different areas of the building ('geometry')
- Internal conditions to be maintained in each activity zone (area in which identifiable, standardised activities take place)
- External conditions

- Factors affecting fabric and ventilation heat losses, including insulation levels, airtightness, deliberate natural ventilation, and the geometry of the building
- Expected heat gains which are determined by the occupancy pattern, installed equipment (including lighting and IT), and solar heat gains which will depend on glazing areas, thermal mass, geometry, and orientation
- Information about the heating, cooling, lighting and other building services systems

The input module iSBEM acts as the interface between the user and the SBEM calculation. As far as possible, the user is guided towards appropriate databases, and then the input is formatted so that data is presented correctly to the calculation and compliance checking module.

The steps involved in the input are as follows:

1. User defines the activities taking place and inputs the areas they occupy in the proposed building
2. Conditions in each of those areas are determined from a standard database
3. Durations of those conditions in each activity area are established from the database
4. User inputs the areas and constructions of the building components surrounding each activity area
5. User selects, from the standard database, a set of weather data relevant to the building location
6. User selects HVAC and lighting systems and their control systems, and indicates which activity areas they serve
7. Provided that supporting evidence is available, the user is enabled to over-write default assumptions for construction and building services parameters
8. Finally, the interface enables the user to see reports on the CO_2 emissions comparison and compliance check undertaken by the BRUKL module (or similar modules for Scotland and Northern Ireland)

Hence, the user interacts with user interface module, iSBEM, and sets up a model of the building by describing its size, how it is used, how it is constructed, and how it is serviced. After the calculations are performed, the results and out reports become accessible through the interface.

When the calculation is used for building regulations compliance checking or energy performance certificate purposes, the software should draw information from the sources described below.

A.1.1.3.3. User input

The user identifies the zones suitable for the analysis, according to the zoning rules (see Section A.1.1.5) by examining the building and/or its drawings. The user describes the geometry of the building, ie, areas, orientation, etc. of the building envelopes and zones, using location plans, architectural drawings, and, if necessary, measurements on site.

A.1.1.4. Databases

A.1.1.4.1. Accessible databases

By interacting with the software interface, the user can access databases for standardised construction details and for accepted performance data for heating, ventilation, and air conditioning systems. These databases are 'accessible' in that the user can override some default parameters by supplying their own data.

Hence, the user provides the software with the U-value and thermal mass for the building elements, the HVAC systems efficiencies, and lighting data and controls by either selecting from the internal databases, using the 'inference' procedures, or inputting parameters directly (see Sections A.1.1.13 and A.1.1.14).

A.1.1.5.2. Locked databases

SBEM also draws information from some 'locked' databases on activity parameters and weather data. These databases are 'locked' because the user cannot alter their parameters as they need to be the same for similar buildings to allow fair and consistent comparison.

Hence, the selection of occupancy conditions and profiles for spaces with different activities come from a database inside the software determined by the user-selected building type and zonal activity (see Section A.1.1.5). The external conditions come from the internal weather database determined by the user-selected location (see Section A.1.1.5).

A.1.1.5. Overview of the Activity Database – purpose and contents

The NCM requires the activity definitions for a building to be defined by selecting from a set of standardised activities. For this purpose, an activity database has been prepared, and is available from the NCM website. The database contains a comprehensive list of building types (29 in total, see Table 1, for the full list), and the space types that might exist in each one (64 in total, see Table 2). Each building type has a selection of the 64 activity types to choose from.

The NCM divides each building up into a series of zones, each of which may have different internal conditions or durations of operation. This enables the calculation to be more analytical about the energy consumption of a mix of uses in a particular building, rather than relying on a generic type such as "office" or "school". The approach of setting up multiple activity areas allows such buildings to be defined more correctly.

Table 1: List of building types

1	AIRPORT TERMINALS
2	BUS STATION/TRAIN STATION/SEAPORT TERMINAL
3	COMMUNITY/DAY CENTRE
4	CROWN AND COUNTY COURTS
5	DWELLING
6	EMERGENCY SERVICES
7	FURTHER EDUCATION UNIVERSITIES
8	HOSPITAL
9	HOTEL
10	INDUSTRIAL PROCESS BUILDING
11	LAUNDRETTE
12	LIBRARIES/MUSEUMS/GALLERIES
13	MISCELLANEOUS 24HR ACTIVITIES
14	NURSING RESIDENTIAL HOMES AND HOSTELS
15	OFFICE
16	PRIMARY HEALTH CARE BUILDINGS
17	PRIMARY SCHOOL
18	PRISONS
19	RESTAURANT/PUBLIC HOUSE
20	RETAIL
21	RETAIL WAREHOUSES
22	SECONDARY SCHOOL
23	SOCIAL CLUBS
24	SPORTS CENTRE/LEISURE CENTRE
25	SPORTS GROUND ARENA
26	TELEPHONE EXCHANGES
27	THEATRES/CINEMAS/MUSIC HALLS AND AUDITORIA
28	WAREHOUSE AND STORAGE
29	WORKSHOPS/MAINTENANCE DEPOT

Table 2: List of Activity areas (in some cases the definition of activity areas will change slightly depending on building type)			
1	A&E consulting/treatment/work areas	32	Meeting room
2	Baggage Reclaim area	33	Open plan office
3	Bathroom	34	Operating theatre
4	Bedroom	35	Patient accommodation (Day)
5	Cell (police/prison)	36	Patient accommodation (wards)
6	Cellular office	37	Performance area (stage)
7	Changing facilities	38	Physiotherapy Studio
8	Check in area	39	Plant room
9	Circulation area	40	Post Mortem Facility
10	Circulation area- non public	41	Public circulation areas
11	Classroom	42	Reception
12	Common circulation areas	43	Sales area – chilled
13	Common room/staff room/lounge	44	Sales area – electrical
14	Consulting/treatment areas	45	Sales area – general
15	Data Centre	46	Security check area
16	Diagnostic Imaging	47	Speculative industrial space
17	Display area	48	Speculative office space
18	Dry sports hall	49	Speculative retail space
19	Eating/drinking area	50	Storage area
20	Fitness Studio	51	Storage area – chilled
21	Fitness suite/gym	52	Storage area – cold room (<0degC)
22	Food preparation area	53	Swimming pool
23	Hall/lecture theatre/assembly area	54	Tea making
24	High density IT work space	55	Toilet
25	Hydrotherapy pool hall	56	Waiting room
26	Ice rink	57	Ward common room/staff room/ lounge
27	Industrial process area	58	Ward offices
28	Intensive care/high dependency	59	Warehouse sales area – chilled
29	IT equipment	60	Warehouse sales area – electrical
30	Laboratory	61	Warehouse sales area – general
31	Laundry	62	Warehouse storage

In order to achieve consistency in comparisons between similar buildings, which may be used in different actual operating patterns, a number of parameters for the activity areas are fixed for each activity and building type rather than left to the discretion of users. These are:

- Heating and cooling temperature and humidity set points
- Lighting standards
- Ventilation standards
- Occupation densities and associated internal gains
- Gains from equipment
- Internal moisture gains in the case of swimming pools and kitchens
- Duration when these set points, standards, occupation densities and gains are to be maintained
- Set back conditions for when they are not maintained.
- Hot water demand

The data are drawn from respected sources such as CIBSE recommendations, supplemented and modified where necessary to cover activity areas not listed in such sources. The need is to ensure that comparisons are made on a standardised, consistent basis. For this reason the energy and CO_2 emission calculations should not be regarded as predictions for the building in actual use. Actual data will need to be normalised before any comparison can be made with SBEM outputs.

Details of the parameters and schedules included in the database along with details on how they are used to calculate the values needed for SBEM or any other energy simulation software are described below.

A.1.1.6. Occupation densities and associated internal gains

An occupancy density, metabolic rate, and schedule of occupancy is used to calculate the internal heat gains from people. The percentage of the metabolic gains which are sensible rather than latent (released as moisture) is also taken into account.

A.1.1.7. Heating and cooling set points and set back temperatures

The heating and cooling set points define the conditions which the selected HVAC system will be assumed to maintain for the period defined by the heating and cooling schedules. For the unoccupied period, the system will be assumed to maintain the space at the set back temperature defined in the database.

A.1.1.8. Lighting standards

The database contains the lux levels which need to be maintained in each activity area for the period defined by the lighting schedules. This level of illumination is then provided by the lighting system selected by the user. In addition to general lighting, some activities are assumed to have display lighting. The lux levels, along with the user selected lighting system are used to calculate the heat gains from lighting. Details of the expected switching system is also included for the definition of the notional building.

A.1.1.9. Ventilation requirements

The database contains the required fresh air rate for each activity for the occupied period. This value is used along with the occupancy (as described below) to calculate the quantity of ambient air which then need to be heated or cooled to the required heating or cooling set point. Whether or not the activity will include high pressure filtration is also defined in the database (such as commercial kitchens and hospital operating theatres).

A.1.1.10. Heat gains from equipment

Following a similar procedure as for calculating heat gains from people and lighting, the database calculates the expected heat gains from equipment for each activity based on the Watts per square meter and schedules of activity.

A.1.1.11. Humidity requirements

The database contains the maximum and minimum humidity requirements for each activity. This information is for dynamic simulation models.

A.1.1.12. Domestic Hot Water requirements

A hot water demand is defined for all occupied spaces. The hot water demand is associated with the occupied spaces rather than the spaces where the hot water is accessed, ie, there is a demand for hot water associated with an office rather than a toilet or tea room.

A.1.1.13. Constructions

The SBEM user can specify the U-value and thermal mass information for a particular wall, window, roof or floor for which the construction is accurately known.

Where the construction is less precisely known the SBEM user can make use of SBEM's construction and glazing databases. These databases each contain a library of constructions covering different regulation periods and different generic types of construction. Once the user has selected the construction, the database provides a U-value and thermal mass and, in the case of glazing, solar factors, and these values are then fed directly into the SBEM calculation.

For cases where the SBEM user has only minimal information, SBEM has an inference procedure. When using the inference procedure, the user supplies basic data such as the sector (building use), the building regulations that were in use at the time of construction, and a description of the generic type of construction. SBEM will then select the type of construction which most closely matches the description selected in the inference and will use this construction as the basis for the U-value and thermal mass value that is to be used in the calculation.

A.1.1.14. HVAC system efficiencies

SBEM needs to take account of the efficiencies of HVAC systems which serve each zone or group of zones in order to determine the relationship between energy demands for heating, cooling, ventilation, lighting and humidity control in each zone and the delivered energy required by the systems to meet these demands.

SBEM follows the practice of the draft standard prEN 15243, of using three systems performance parameters instead of the more familiar two (seasonal heating and cooling system efficiency). Specifically, auxiliary energy used by pumps, fans etc is accounted for separately. This avoids the complications of trying to attribute auxiliary energy across different services provided by the same system. And of including different energy sources within the same definition. Therefore the three systems parameters are:

- System Energy efficiency ration (SEER)
- System Coefficient of Performance (SCoP)
- Auxiliary Energy value (AEV)

The values of SEER, SCoP and Auxiliary energy for 20-plus HVAC systems in the database have been determined by calculation, but have been validated against experience with real systems from a number of UK and European monitoring and other projects. As with the construction details, the database values can be overridden by the user if verifiable alternative information is available.

A.1.1.15. Weather database

In order to calculate the reaction of the building and systems to the variable loads imposed by the external environment, SBEM needs an input of the following average monthly data for the location.

- Global solar irradiation on:
- Horizontal surface
- Vertical walls for different orientations
- External temperature

For the purposes of the SBEM database these have been converted to monthly values.

Appendix B

SBEM Modelling methodology

B.1. Building Description

The building is a deep plan office with central atria. Including external stairways, the building comprises of 6930 m^2 gross floor area over four levels. Fan coils are used to provide heating and cooling. The building is located in the London area, so the CIBSE test reference year for London is used for the computer calculation.

Full height glazing is used on the façade but good solar control is provided (shading coefficient 0.37). The building is divided into offices, meeting/conference rooms kitchen and staff room. Toilets are located at the central core area, between the atria and entrance area.

A curtain wall U value of 1.7 W/m^2K is provided on the southern aspect and 1.5 W/m^2K on other sides. A U value of 0.2 W/m^2K and 0.25 W/m^2K is provided on the roof and floor slab respectively.

The design small power loads and ventilation rates are all irrelevant since the National Calculation Method (NCM) imposes standardised values for these.

B.2. Calculation results

The calculations were performed using the Apache software version 5.6.2. The initial outcome predicted a Building Emission Rate (BER) of 58.62 $Kg\text{-}CO_2/m^2$. A Target Emission Rate (TER) of 38.88 $Kg\text{-}CO_2/m^2$ for 2006 building regulations was calculated. Although this result suggests the building fails 2002 building regulations, this is not necessarily the case, since the initial calculation uses software default plant efficiency, which isn't necessarily true for the real building.

The first measure taken to lower carbon emissions was to increase plant efficiency. This involved setting chiller seasonal COP to 4.3, boiler efficiency to 89 per cent and specific fan power to 2.0 W/L/s. Furthermore duct and AHU airtightness standards were imposed and controls and monitoring were set. The effect of these measures was to bring the BER to 42.78 $Kg\text{-}CO_2/m^2$.

Lighting power levels were lowered to 14 W/m^2 from the default values in office spaces. This lowers the BER to 36.42 $Kg\text{-}CO_2/m^2$. This brings the building up to 2006 standards of carbon emissions. If other lighting is improved to 3 W/m^2 per 100 lux the BER is further reduced to 36.42 $Kg\text{-}CO_2/m^2$.

If the atria glazing is tinted so that the outer pane has a transmittance of 0.06 then the BER is further lowered to 35.53 Kg-CO_2/m^2. It could be argued however that this would lower daylight levels in the atria and partly defeat the purpose of having it. An alternative energy saving strategy would be to have individual control of luminaries, which were daylight linked. An improvement to the solar protection on the curtain walling was not considered since shading was already included in the design.

Improvements to the curtain wall U values were found to be counter-productive. Lowering the U values to 0.45 W/m^2K resulted in the BER increasing to 36.63 Kg-CO_2/m^2, so this strategy was not pursued further. This outcome is not unusual in simulations performed by HalcrowYolles. It arises since heat loads in the office result in cooling occurring more commonly than heating. The improvement to insulation levels keeps the heat in, and creates more cooling requirements for the plant.

A further improvement in carbon emissions is obtained by using gas fired CHP to provide hot water for heating and sanitary hot water. Note this strategy results in lots of part load operation due to the seasonal and fluctuating nature of demand. Furthermore the plant size is small since the need for hot water is limited. Assuming an electrical efficiency of 20 per cent and a thermal efficiency of 50 per cent, the BER is lowered to 34.83 Kg-CO_2/m^2.

If trigeneration is employed using absorption chillers for cooling, then greater use of generators is possible (due to increased demand for hot water). The following results are obtained as absorption chiller capacity is increased:

100 kW absorption chiller	BER=38.48 Kg-CO_2/m^2
200 kW absorption chiller	BER=40.59 Kg-CO_2/m^2
300 kW absorption chiller	BER=41.32 Kg-CO_2/m^2
400 kW absorption chiller	BER=41.43 Kg-CO_2/m^2

Note that the use of the absorption chiller is counter productive with the emission rates increasing, as more of the cooling requirements are met with trigeneration. The relative influence of absorption chilling decreases as capacity increases, because utilisation falls as peak cooling (450 kW) is approached.

The above result suggests that trigeneration is not helpful but this outcome is purely a result of the assumed performance data. A different outcome would arise if different efficiencies (in particular electrical efficiency) were assumed.

- HalcrowYolles used a conservative 20 per cent electrical generation efficiency because the plant needs to operate frequently at part load and the small CHP size may limit us to engine driven options. This low efficiency means less useful electricity from the gas consumption.

- HalcrowYolles used a COP of 0.68 for the absorption chillers since it is likely that heating is available at a maximum of about 90C (because only engine driven options are available at small scale). A better COP would be feasible if steam or high temperature water were provided by the CHP system.
- As mentioned above the electrical chillers displaced by the absorption chilling had a COP of 4.3. The relatively high performance of these chillers means that carbon savings from their redundancy, are lessened.

Although the above use of trigeneration appears counterproductive a carbon emission reduction can be achieved if CHP is fuelled renewably. If options are limited to engine driven types this would entail use of biodiesel (which isn't entirely carbon neutral). If a district, renewable-fuelled CHP system were employed then steam and gasification options may be feasible and better efficiencies may be possible. Use of the above efficiencies would act to lower the BER to 17.92 Kg-CO_2/m^2.

Approximately 750 m^2 of PV could be located on the rooftop. If this were a monocrystalline type of 13 per cent efficiency the BER could be lowered to 12.23 Kg-CO_2/m^2. Some green space is available between the site and road. If a further 1620 m^2 of similar PV were located here the BER could be lowered to zero.

The BER defined by the national calculation method excludes the carbon emissions arising from small power loads within the building. However the NCM does define values for these, in order that the building can be simulated. The values for these small power loads suggest that complete carbon neutrality is reached at a BER of minus 17.6Kg-CO_2/m^2. A further 2320 m^2 of similar PV would be needed to reach this. This brings the total area of panels to 4690 m^2, in addition to the renewable fuelled trigeneration. Locating this much PV on site would prove challenging. It would be necessary to use some of the existing car park space. The panels could be mounted on a structure so that cars could park beneath them.

B.3. Mixed Developments

On another example HalcrowYolles obtained carbon neutrality by exploiting the fact that apartments have a much greater need for hot water than offices. With a development of offices and apartments a renewable-fuelled CHP plant can be used to supply electricity for office and export, and the apartments consume the waste heat. In the example studied trigeneration was not used.

The seasonal nature of the hot water need poses some practical difficulties. It is important for the development to have sufficient apartments to create sufficient hot water demand. Otherwise not enough renewable electricity is generated to compensate for the offices consumption. It should be noted that future apartments will have a reducing need for hot water. In the example studied considerable use of PV was also necessary.

B.4. Conclusion

Given the extreme need for PV (or other renewable electricity) any reduction in the buildings electrical demands would be highly beneficial. The NCM does not permit a reduction in small power use and this is traditionally outside the scope of building regulations. Incentivizing occupiers to lower consumption and energy rating of office equipment are important future steps.

Appendix C

GBC non-domestic net-zero carbon buildings

25th September 2007 – Final Report

A.D. Peacock, D. Jenkins and D. Kane

C.1. Introduction

The UK Government has recently published a policy statement indicating a desire that by 2016 all new build housing will be net zero carbon[1]. The extent to which this approach will be efficient (using either resource or economic metrics) in decarbonising the housing sector is still to be determined[2]. This project aims to consider the merit of extending this net zero carbon concept to non-domestic buildings.

It is important at the outset to outline the scope of the project. For three building variants a series of technologies and design options will be considered that could feasibly be incorporated into non-domestic buildings over the period to 2020. The extent to which these technologies move the building towards carbon neutrality will be ascertained and some of the issues associated with the approaches taken will be discussed. It is important to state from the outset that the project does not aim to identify optimal technology or design pathways to achieving low or zero carbon buildings. Alternative solutions to those proposed here are undoubtedly possible.

The three defined building variants, described below, are a shallow plan office with internal gains based on 2005 lighting and IT technology and CIBSE Test Reference Year (TRY) climate file for London[3]; a deep plan office with internal gains based on 2020 technology and a modified CIBSE TRY climate file indicative of possible 2020 London climate; and a large retail shed with internal gains based on 2005 technology and climate.

For each variant, gains and energy usage are calculated via a "bottom-up" approach, with equipment individually defined with daily electrical profiles (based on hourly estimations of use). Likewise, lighting and occupant gains are based on 24-hour profiles. This approach builds on that taken in the TARBASE project[4,5].

The following sections provide a general discussion of low-carbon HVAC systems (Section 2) and onsite generation (Section 3), followed by the implementation of these systems with the defined building variants (Section 4).

C.2. Options for low-carbon HVAC systems

Suitable systems for providing heating, cooling and ventilation to non-domestic buildings will be looked at by estimating the likely HVAC load of the described variants. With respect to this, it is vital to understand internal gains (and their direct link to occupant usage of small power and internal gains) and how a change in this internal profile can dramatically affect the choice, and operation, of the HVAC systems.

C.2.1. Ventilation approach

The described buildings will require a ventilation rate of 10l/s/person during occupancy hours[6], usually satisfied by mechanical ventilation. It is possible to modify the simple architectural shapes considered here to enhance the performance of natural ventilation and this is a well researched pathway with a profusion of options available to the practitioner[7,8]. For the purposes of this study, the assessment of possible approaches to satisfying the ventilation requirements passively was not possible.

Rules of thumb have been used to determine the role that natural ventilation may play in each of the building variants. For instance, due to the shallow-plan aspect of variant 1 (see Section 4), there exists the possibility of satisfying the ventilation requirements through natural cross-ventilation (through horizontal vents in the walls). This would reduce (or potentially eliminate) the need for mechanical ventilation.

In the case of variants 2 and 3, the deep-plan build of the office will make it more difficult to provide ventilation through natural means alone although mixed mode ventilation systems are feasible.

C.2.2. Night-time cooling with thermal mass

With regards to cooling, thermal mass used with night-time ventilation can be applied to non-domestic buildings[9]. The aim is to investigate the degree to which the cooling load of a typical office/non-domestic building can be reduced. A simple approach is taken here, with exposed thermal mass on the ceiling of the building and each zone thermally isolated from each other. Air is supplied during the evening if the temperature of the office exceeds 21°C. Clearly, greater effects can be achieved if the air is entrained through the thermal mass (via cavities in the ceiling) rather than across the surface. However, the scale of change possible using this technique can be estimated using the approach described.

This project uses CIBSE TRY climate files which provide an indication of the cooling requirement of a building. They do not however give an indication of the risk of overheating as they do not attempt to characterise extreme events. The TRY (for London) provides average climate information for the period 1983-2005. A reference Design Summer Year (DSY), defining a very warm year, would need to be interrogated to understand the extent of this risk more thoroughly.

Another aspect of this cooling approach is in assuming that the test or design reference years adequately describe the night time climate in London. Kolokotroni's work[10] has suggested that the Heathrow weather data should be increased by on average 1.7°C during the period 11pm to 6pm for offices located within a 3km radius of City of London to account for the urban heat island effect. The effect of future climate change is likely to exacerbate the urban heat island effect and make cooling strategies based on night time cooling less applicable.

The methodology for applying night-time cooling is based on previous studies in non-domestic buildings[11,12].

C.2.3. Heat pumps

The inclusion of air-to-air heat pumps, or Air Source Heat Pumps (ASHP), will be considered for one building variant. The estimated coefficient of performance (COP) of heat pumps, in both heating and cooling mode, make them viable alternatives, in terms of carbon abatement potential, to gas-fired boilers and traditional air-conditioning plant[13]. The heat pump, due to its versatility in supplying heat or coolth, may offer capital expenditure advantages over the installation of discrete heating and cooling systems. Also, although it will not have the advantage of electrical export (which would be produced from a CCHP system, see Section 2.5), the actual energy consumption would be relatively small.

C.2.4. CHP

For buildings with substantial heating and electrical requirements for a substantial part of the year, Combined Heat and Power (CHP) can be a relatively low-carbon option.

As an example of CHP operation, the performance of a candidate CHP plant was computed using hourly demand data for Variant 2 that accounted for attendant start up conditions and parasitic loads. The applicability of CHP to this building is extremely questionable as the run time of the unit would be approximately 1000 hours if sized to meet peak thermal load. Smaller systems could be investigated in conjunction with thermal storage options to boost run times but the annual electricity generation is unlikely to be much different from that quoted here. However, it is useful to include CHP in the zero carbon section here so that the full scope of "ZC generation" options available to the building in question could be investigated.

The thermal demand of Variant 2, the deep plan office was, initially, estimated to be 3.8kWh/m^2. If this thermal demand were met by a 100kW CHP plant of 35 per cent electrical efficiency the electrical output would be approximately 12.5MWh pa. If the input fuel were zero carbon ie biomass (with appropriate assumptions and caveats) then this electricity production in turn could be deemed to be zero-carbon. However, with large cooling loads being present in non-domestic buildings, CHP combined with a cooling mechanism was deemed to be more effective (see Section 2.5).

C.2.5. CCHP

Combined Cooling, Heating and Power (CCHP) essentially involves a high-efficiency CHP system that produces coolth by passing otherwise waste heat through an absorption chiller[14,15,16]. This technology will be considered for each building variant as a method of meeting or exceeding on-site electrical demands with a derived carbon intensity of generated electricity which is significantly lower than any quoted for the national grid. This derived carbon intensity accounts for the displaced generation, by means of gas and/or electricity, of heat and coolth, by recovered thermal output from the CCHP prime mover. The coupling of high- temperature solid oxide fuel cells with absorption chillers (with associated heat and coolth buffers) will be investigated, with due attention paid to the compatibility of building demand profile and technology modulation constraints.

The use of this technology is effectively, in addition to other onsite generation, making the building a small power plant. When considered on a large-scale, there are certain arguments against this being a desirable model – particularly when looking at the magnitude of export and cost of the systems being installed. However, as discussed later, the level of electrical generation required to meet just the small power and lighting energy consumptions of the building require that, if the ideal is a net-zero carbon non-domestic building, the inevitable outcome is onsite generation at a high magnitude. With CCHP, the advantage is that the system is required throughout the year (for heating and cooling), thus providing year-round electrical output.

Due to the large amount of electrical generation required (see Sections 3 and 4), the CCHP unit will be producing considerable thermal generation, and so there will be a need for cooling towers to reject surplus heat (ie heat that is not used or stored onsite). This surplus heat is increased due to problems of modulation when using fuel-cell CHP (where the system cannot be modulated below 30 per cent of the rated power).

C.3. Onsite generation

The chosen onsite generation technologies are photovoltaic (PV), micro-wind and CHP. PV and wind have been sized based on the largest systems likely to be situated on the respective buildings. So, for example, while larger turbines might be installed in a car-park area, a rooftop turbine is unlikely to be larger than 1.5kW due to structural and building planning issues. Similarly, while large PV systems currently exist for non-domestic buildings (eg PV Pergola Shell Building in Rijswijk, Netherlands), it is unlikely that an installation of greater than 50 per cent of the roof area would be carried out (due to the physical area actually available on most non-domestic buildings as well as the economic constraints).

Existing PV, CHP and micro-wind models (from the Tarbase programme) are used to assess the potential of micro-generation for medium-sized non-domestic buildings. Table 1 provides estimates for suitable PV and wind installations in the described variants (though these will clearly vary depending on location and micro-climate – other options will be specified relating to these variables).

CHP systems are sized based on CIBSE calculations, where the system must satisfy a worst-case heating day scenario. As this is, with the absorption chiller, a CCHP system, is also has to satisfy a worst-case cooling day (after accounting for absorption chiller efficiency).

Table 1: Initial estimates for PV and Wind energy yields for building variants using Tarbase generation models

	Available roofspace	Suggested PV installation	Suggested wind installation	Suggested CHP installation	Annual wind turbine output (MWh/yr)*	Annual PV output (MWh/yr)†	Annual CHP output (MWh/yr)
Variant 1	900 m^2	450 m^2 of PV on flat surface	10 no. 1.5kW turbines	Fuel-cell, 47% electrical efficiency, 302kWe peak	5.4–36	51	356
Variant 2	900 m^2	450 m^2 of PV on flat surface	10 no. 1.5kW turbines	Fuel-cell, 47% electrical efficiency, 233kWe peak	5.4–36	51	277
Variant 3	approx 1000m^2	400 m^2 of PV on south-facing surface	12 no. 1.5kW turbines	Fuel-cell, 47% electrical efficiency, 120kWe peak	6.5–43	49	179

* Based on low wind speed and high wind speed suburban datasets (10-minutely data over entire year)
† Based on current Mono-crystalline manufacturers' data and London CIBSE Test Reference Year including model for inverter losses

Table 1 is indicative of large-scale use of current technologies (with the fuel-CHP being very much at the high end of current prototypes). However, there is the potential to increase PV output using more efficient technologies[17]. To estimate the effectiveness of near-future PV technologies is non-trivial as merely quantifying an improved efficiency is not sufficient in specifying the total energy yield and technology penetration – the response of the material to temperature changes as well as likely degradation, maintenance and, perhaps most importantly, costs would all need to be investigated. Regardless of the chosen technology, the total power output specified in Table 1 is extremely large for any PV installation – a more efficient technology might produce an improved power per unit area but it is likely that, as a result, such an expensive technology would be used for a smaller surface area.

C.4. Building variants

This project is being conducted in conjunction with Harry Bruhns and Phil Steadman at UCL. They are currently involved in a research project whose aim is to construct a stock model of the UK non-domestic sector. The buildings that were used to here to investigate the zero-carbon concept were selected because of their relevance to this stock model ie they hold a degree of statistical representation. The lessons learned from these buildings have some relevance to certain aspects of the stock but caution should be taken in assuming any form of universality.

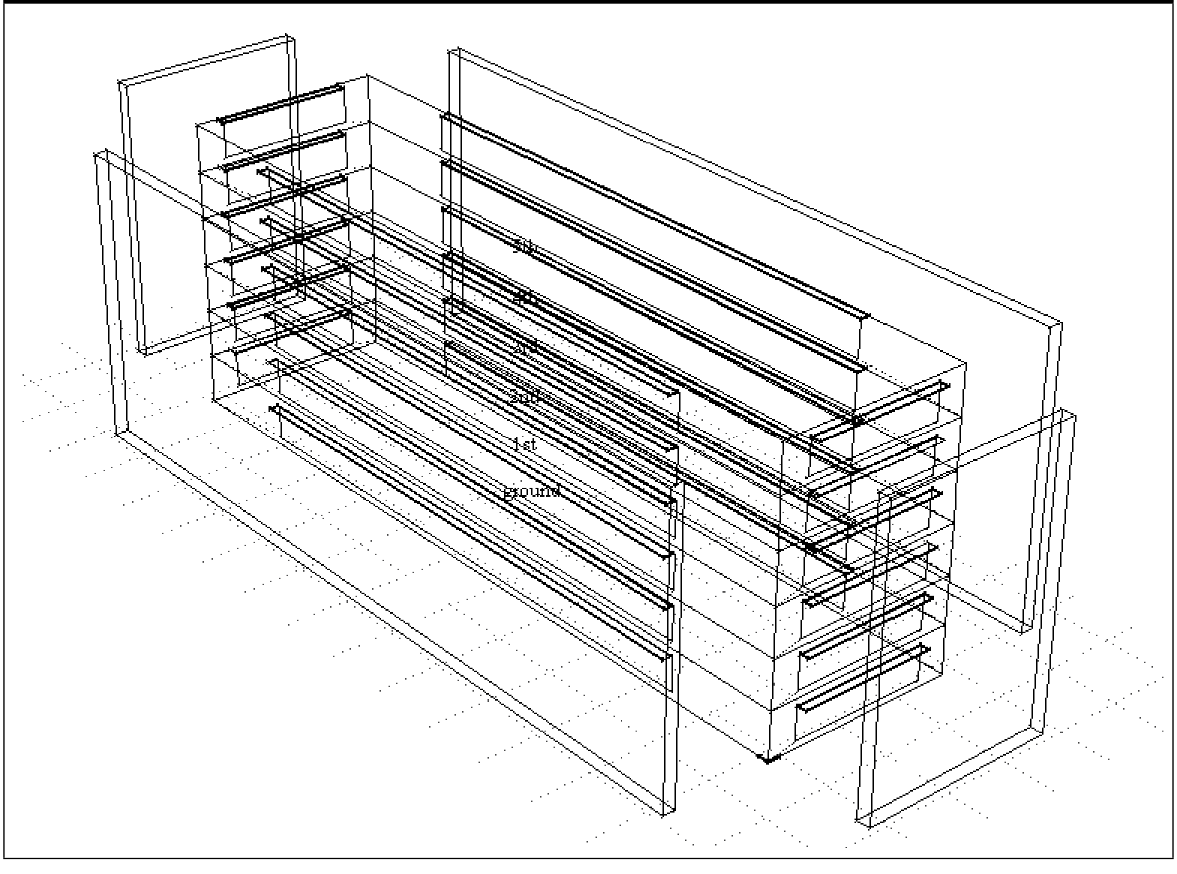
The shapes chosen are architecturally simple and no additional features such as atria are considered. Clearly, additional features could be incorporated into the design of these buildings that would for instance enhance the performance of natural ventilation. A comparative analysis of potential design initiatives was deemed, however to be outside the remit of this project.

The glazing ratio's used here for the offices are 60 per cent which is in excess of the guidance in Part L 2006 states that states that 40 per cent should be used as a baseline. Whilst this is the case, little evidence exists to suggest that this is guidance is being strictly adhered to. The variants as described were constructed with the input of project partners in the practitioner community who were content that the glazing levels could not be considered as architecturally abnormal.

Heating and cooling requirements are predicted through simulation in ESP-r building software, with the results passed through HVAC models for the specified technologies. To achieve maximum net carbon reduction, CCHP systems are used in all variants, with a combination of passive ventilation and night-time cooling. For the retail shed (variant 3), an alternative option is provided in the form of an ASHP. This is suggested as a lower-cost and, from the point of view of managing electrical export, less disruptive technology.

C.4.1. Shallow-plan office

Figure 1: Variant 1, 6-storey shallow-plan office



Location: London urban environment, surrounded by similarly sized offices

Height: 6 storeys x 3.7m

Width: 15m

Length: 60m

Total Floor area: 5400m^2

Construction: Highly-insulated concrete panels (U-value of 0.08W/m^{2}K) and glazing 60 per cent of total wall area (triple-glazed argon, U-value of 0.7W/m^{2}K). External shading on all glazing for reduced solar gain.

Infiltration rate: 0.05 ach

Ventilation rate: 10l/s/person

Chosen HVAC systems: CCHP system with absorption chiller and thermal store (302kW, 272kW, 380kW respective peak thermal, electrical and coolth output; Heat store capacity 581kWh; Coolth store capacity 81kWh). Requires cooling tower for thermal dump

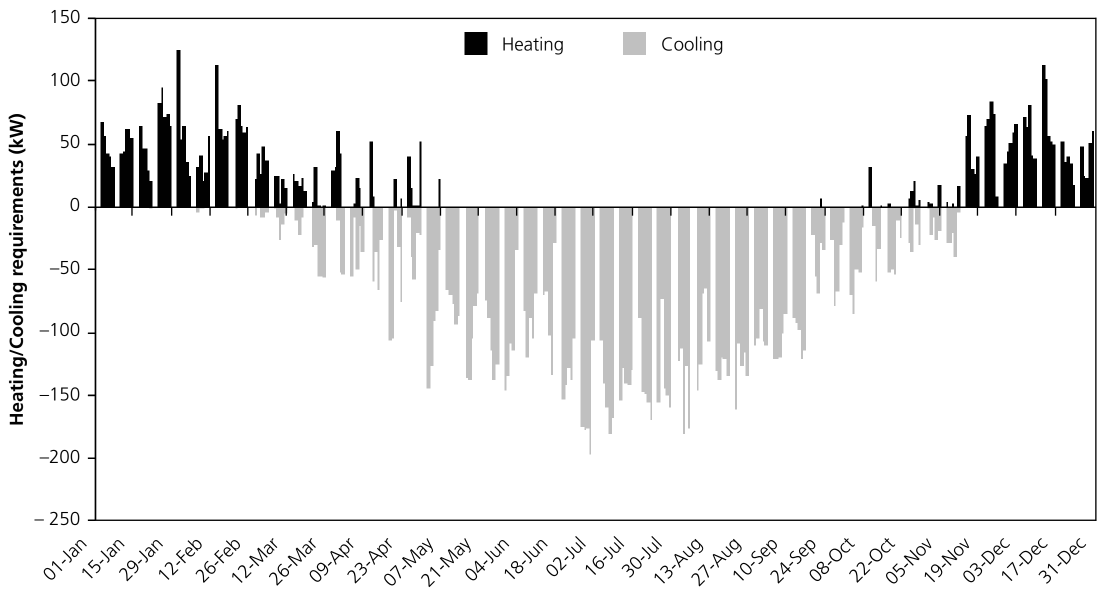
Peak Small Power gain: 7.9W/m^2 (based on 14m^2 per person occupancy and current IT technology)

Peak Lighting gain: 9.4W/m^2 (using T5 fluorescent lighting)

C.4.1.1. Heating and cooling

The heat and coolth requirements of the entire building are given in Figure 2 using the above data.

Figure 2: Heating and cooling requirements of Variant 1



These loads are requirements (ie required output of any system) and so, to calculate actual energy usage, the results of Figure 2 have to be passed through suitable heating and cooling systems, with prescribed energy efficiencies and COPs (see Table 2).

C.4.1.2. Ventilation

The design rule of passive cross-ventilation (ie ventilating a space by allowing air to, passively, travel from one side of the building to the opposite side) is that, for a building to achieve this, the ratio of floor-ceiling height to building width must be less than 5[7]. Alternatively, single sided ventilation will provide ventilation to a distance of 2.5 x floor-ceiling height. The remainder of the building would have to be satisfied through mechanical ventilation. This rule-of-thumb is applied to all three building variants.

In the case of variant 1, this would result in a completely passively ventilated building during the day. However, to reduce the sizeable cooling load, heat will be ejected through the use of mechanical fans during the night (ie night-time ventilation). This technique is made more effective through the use of thermal mass (see Section 2.2). For the purposes of this investigation, fans (10l/s/person) are applied outside working hours (ie 7pm to 9am) when the internal temperature is greater than 21°C. For the system as described, flow rates in excess of 10l/s/person were investigated but the effect on annual cooling load was found to be marginal. This results in night-time fans operating for 2141 hours per year, with a resulting annual energy consumption of 10MWh (this figure is included in Table 2 as part of the Fans/Pumps/Ventilation consumption).

C.4.1.3. Final energy consumption

The predicted energy consumption of variant 1 is given in Table 2 using the previously specified details for small power, lighting and HVAC.

Table 2: Energy consumption of Variant 1 with electrical gains

	Energy Usage		Peak gain
	MWh	**kWh/m²**	**W/m²**
Small power	257	47.6	7.9
Lighting	112	20.8	9.4
CCHP system (gas)	757	140.2	n/a
Fans/Pumps/Ventilation	27	5.0	n/a
TOTAL ELECTRIC	397	73.5	17.3
TOTAL GAS	757	140.2	n/a

The use of such a large CCHP system has resulted in a high gas energy consumption. This is partly by design, with the carbon intensity of gas being significantly lower than that of grid electricity. While this results in a gas consumption being even higher than the electrical consumption, there is considerable electrical export (and therefore carbon credit) from this gas usage (see Section 4.4).

The fuel-cell CCHP system produces electrical export at such an efficiency that, even if a large amount of heat is dumped, it is still beneficial to keep the system running as the electrical energy produce will have a lower carbon content than grid electricity (this is assuming that all the exported electrical energy is used elsewhere). However, this argument is only true for systems with an electrical efficiency of 46 per cent or more. For efficiencies below this (and, currently, the chosen efficiency of 47 per cent is optimistic, though achievable[18]), it is not always preferable to produce excessive electrical export (based on a grid CO_2 intensity of 0.43kgCO_2/kWh).

C.4.1.4. Supply-demand matching of consumption and generation

When assessing the merits of electrical onsite generation, it is important to ascertain the level of export being produced by the various systems. This is achieved by comparing the electrical requirements with the electrical generation on a suitable timescale (in this case hourly, though for smaller buildings minutely would usually be used). Selected weeks, in June and December, are shown in Figures 3 and 4 respectively.

Figure 3: Supply and demand of electrical energy for Variant 1 in a June week

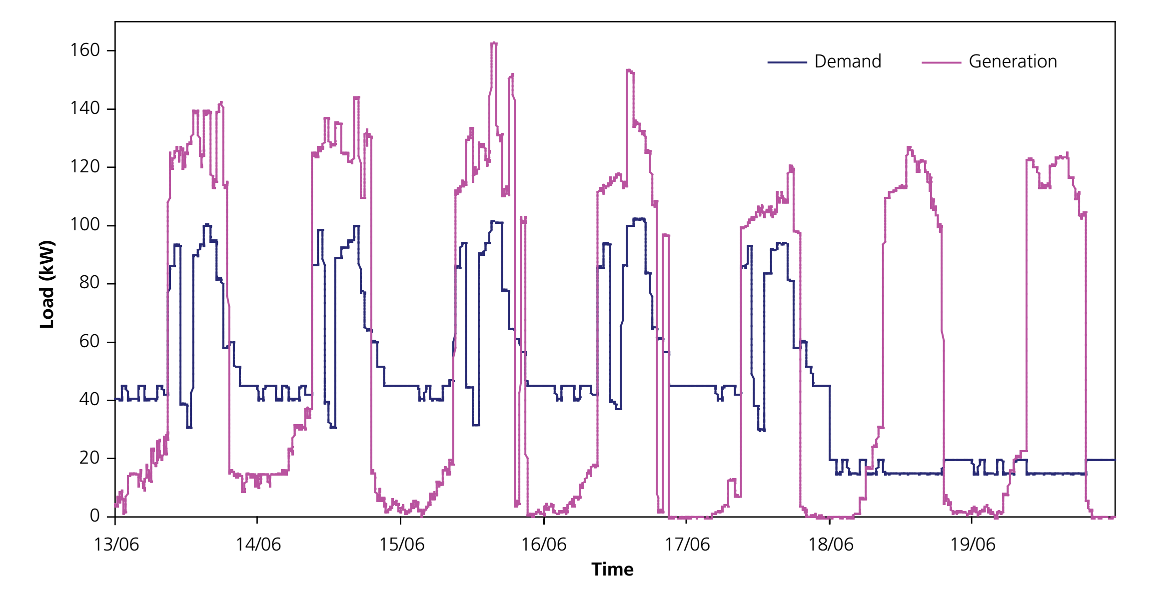
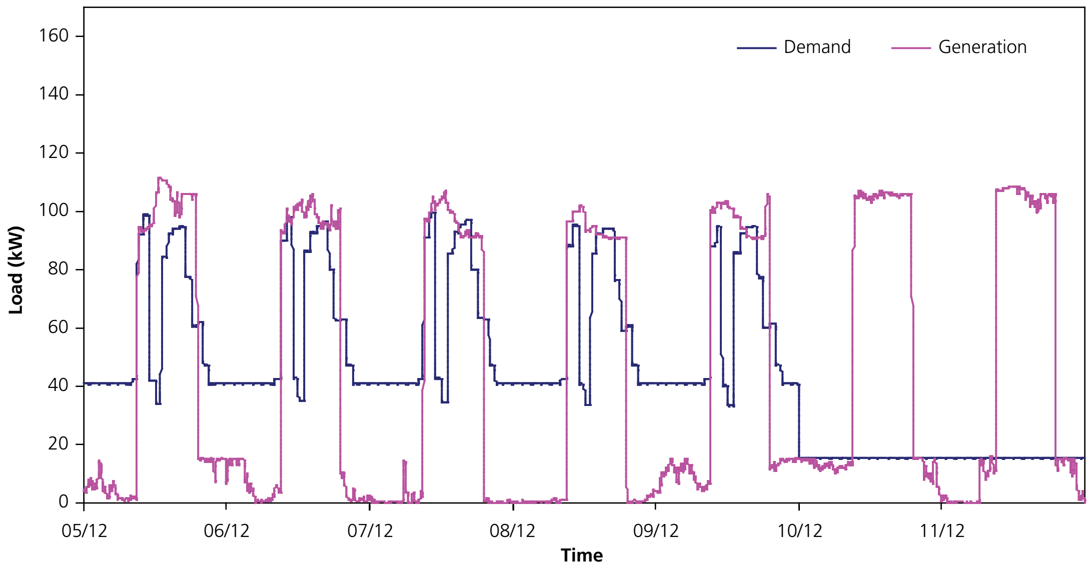


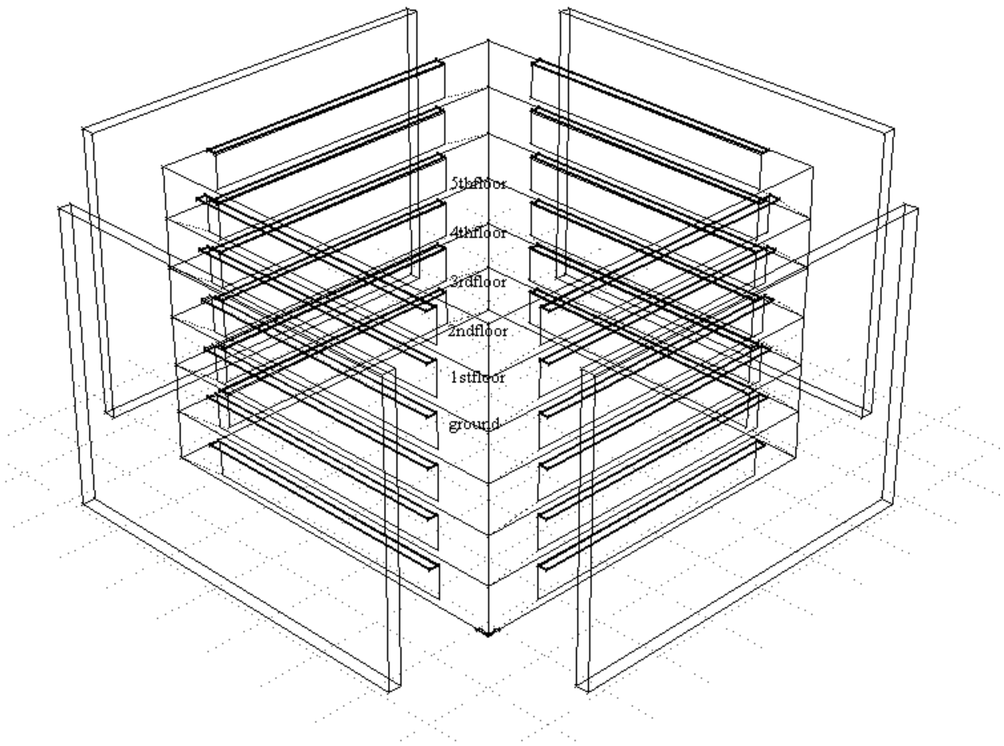
Figure 4: Supply and demand of electrical energy for Variant 1 in a December week



Looking at these figures across the year shows that 44 per cent of the onsite generation is exported (or could be stored for use onsite) and 38 per cent of the electrical demand is satisfied by grid import.

C.4.2. Deep-plan office (with predicted future internal gains)

Figure 5: Varient 2, 6-storey deep-plan office



Location: London urban environment, surrounded by similarly sized offices

Height: 6 storeys x 3.7m

Width: 30m

Length: 30m

Total Floor area: 5400m^2

Construction: Highly-insulated concrete panels (U-value of 0.08W/m^{2}K) and glazing 60 per cent of total wall area (triple-glazed argon, U-value of 0.7W/m^{2}K). External shading on all glazing for reduced solar gain.

Infiltration rate: 0.05 ach

Ventilation rate: 10l/s/person

Chosen HVAC systems: CCHP system with absorption chiller and thermal store (233kW, 210kW, 266kW respective peak thermal, electrical and coolth output; Heat store capacity 581kWh; Coolth store capacity 76kWh). Requires cooling tower for thermal dump

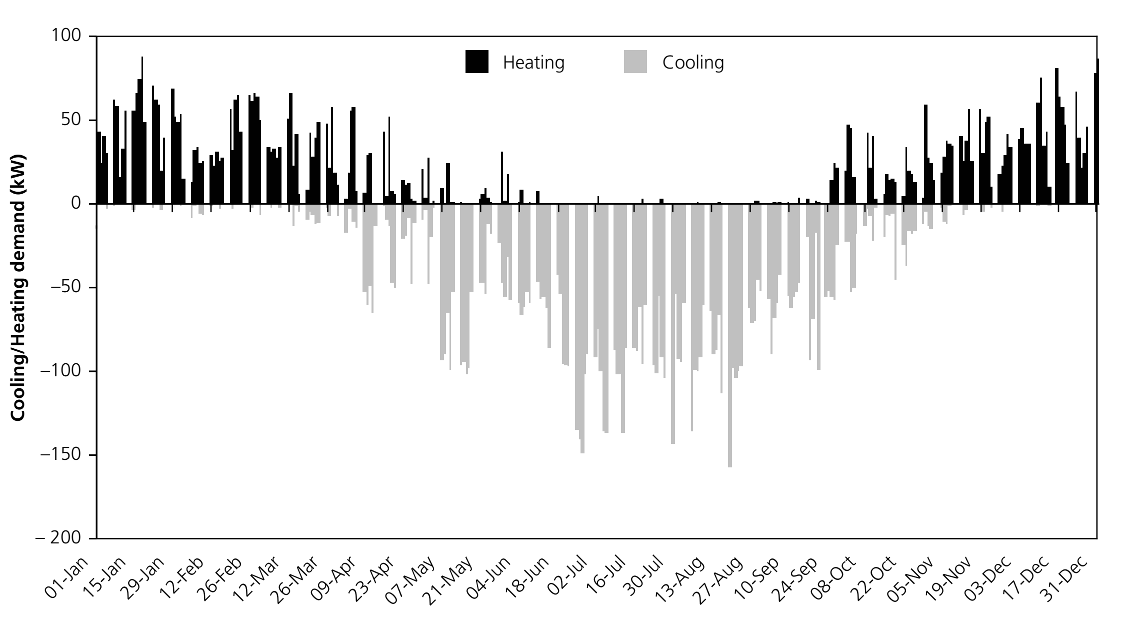
Peak Small Power gain: 4.4W/m^2 (based on 14m^2 per person occupancy and future IT technology and energy management)

Peak Lighting gain: 6.2W/m^2 (using future LED lighting)

C.4.2.1. Heating and Cooling

The heat and coolth requirements of the entire building are given in Figure 6 using the above data.

Figure 6: Heating and cooling requirements of Variant 1



The energy consumptions associated with providing this heat and coolth are shown in Table 3.

C.4.2.2. Ventilation

As with Variant 1, the possibility of passive daytime ventilation is investigated. However, due to the deep-plan aspect ratio of the building, it is not possible to satisfy the entire building through passive ventilation alone. Using the same design rule of Section 4.1.2 it is found that 84 per cent of the floor area is suitable for passive ventilation, with the remaining 16 per cent requiring ventilation fans (operating at 10l/s/person) during occupancy hours (the energy consumption for which is included in Table 3). The energy consumption of these daytime fans is 2MWh per year.

Night-time ventilation is again used, with the same control logic as Variant 1. Although the internal gains are much reduced in Variant 2, the layout of the building results in night-time fans operating for slightly longer than Variant 1. This is mainly due to Variant 1 having a high glazing to volume ratio (due to its elongated shape), and so, even without night-time fans, would be losing considerable heat during the night anyway. The consequence of these factors is a building requiring night-time fans to be operated for 2377 hours per year with a resulting annual energy consumption of 11MWh.

C.4.2.3. Final energy consumption

The predicted energy consumption of variant 2 is given in Table 3 using the previously specified details for small power, lighting and HVAC.

Table 3: Energy consumption of Variant 2 with electrical gains

	Energy Usage		Peak gain
	MWh	kWh/m²	W/m²
Small power	127	23.5	4.4
Lighting	59	10.9	6.2
CCHP system (gas)	589	109.1	n/a
Fans/Pumps/Ventilation	22	4.1	n/a
TOTAL ELECTRIC	208	38.5	10.6
TOTAL GAS	589	109.1	n/a

As with Variant 1, there is a large gas consumption associated with the CCHP system. However, despite having the same total floor area as Variant 1, the CCHP system is used less throughout the year. This is mainly due to the reduced coolth requirement, as a result of the reduced internal gains (due to improved equipment and lighting). Therefore, the absorption chiller is not having to output as much coolth, and so does not require as much heat from the CHP system. Also due to equipment/lighting improvements, the total electrical consumption is significantly reduced.

C.4.2.4. Supply-demand matching of consumption and generation

As with Variant 1, a supply-demand matching exercise is performed for Variant 2 for June and December.

Figure 7: Supply and demand of electrical energy for Variant 2 in a June week

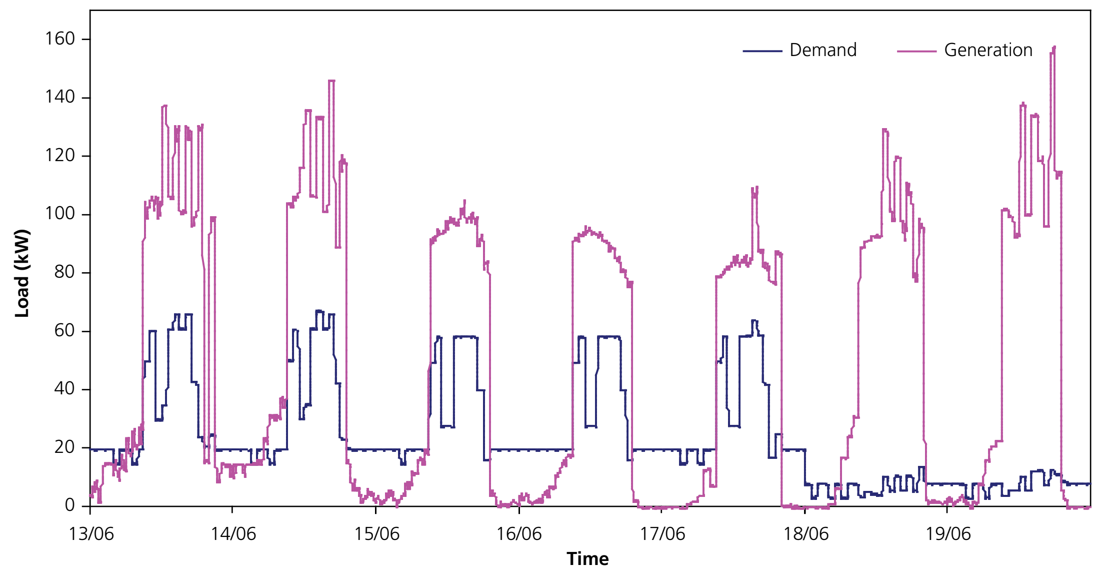
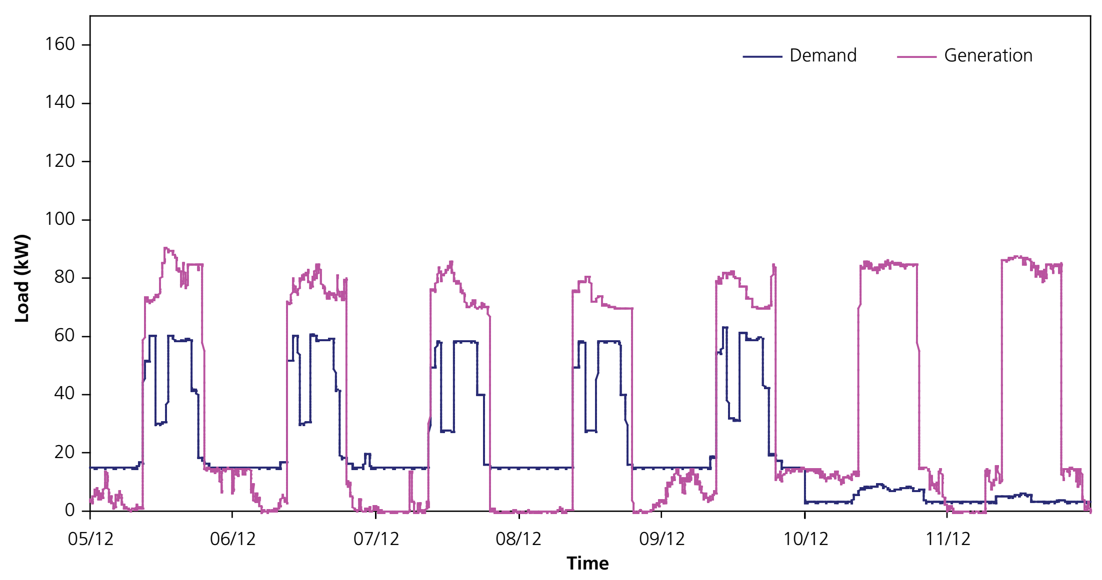


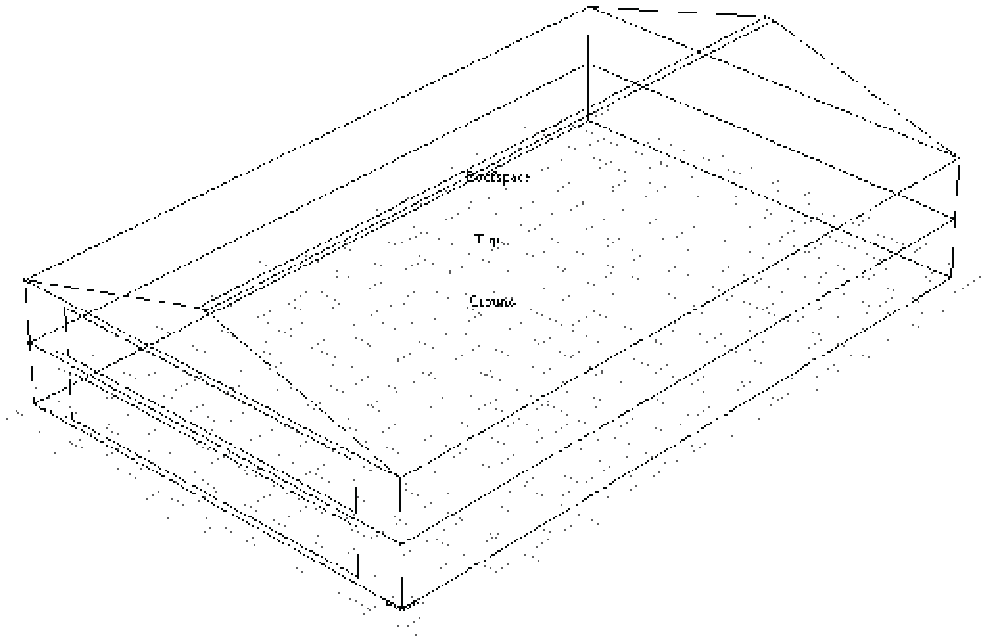
Figure 8: Supply and demand of electrical energy for Variant 2 in a December week



The annual picture shows that, due to the reduced electrical demand when compared to Variant 1, the percentage of demand satisfied by import is lower, at 24 per cent, and the percentage of onsite generation exported is higher, at 58 per cent. When such a large amount of energy is being exported, and a relatively large amount of electrical demand is being satisfied onsite, this raises the possibility of electrical storage being used (eg batteries, capacitors etc). However, this has been ignored for this study mainly due to the additional costs (when expenditure for onsite generation is already likely to be very high).

C.4.3. Retail Shed

Figure 9: Varient 3, 2-storey retail shed



Location: London out-of-town shopping centre, adjoined (by long walls) to similar buildings

Height: 2 storeys x 4m (with pitched-roof space, height at apex of 3.5m)

Width: 25m

Length: 40m

Total Floor area: 2000m^2

Construction: Highly-insulated blockwork (U-value of 0.08W/m^{2}K) and glazing 60 per cent of front wall area (triple-glazed argon, U-value of 0.7W/m^{2}K).

Infiltration rate: 0.05 ach

Ventilation rate: 10l/s/person

Chosen HVAC systems OPTION 1: CCHP system with absorption chiller and thermal store (120kW, 108kW, 152kW respective peak thermal, electrical and coolth output; Heat store capacity 581kWh; Coolth store capacity 70kWh). Requires cooling tower for thermal dump

Chosen HVAC systems OPTION 2: ASHP system with peak thermal and coolth output of 152kW and 138kW respectively. Average heating COP 2.8; average cooling COP 4.5 (based on model accounting for part-loading and ambient temperatures)

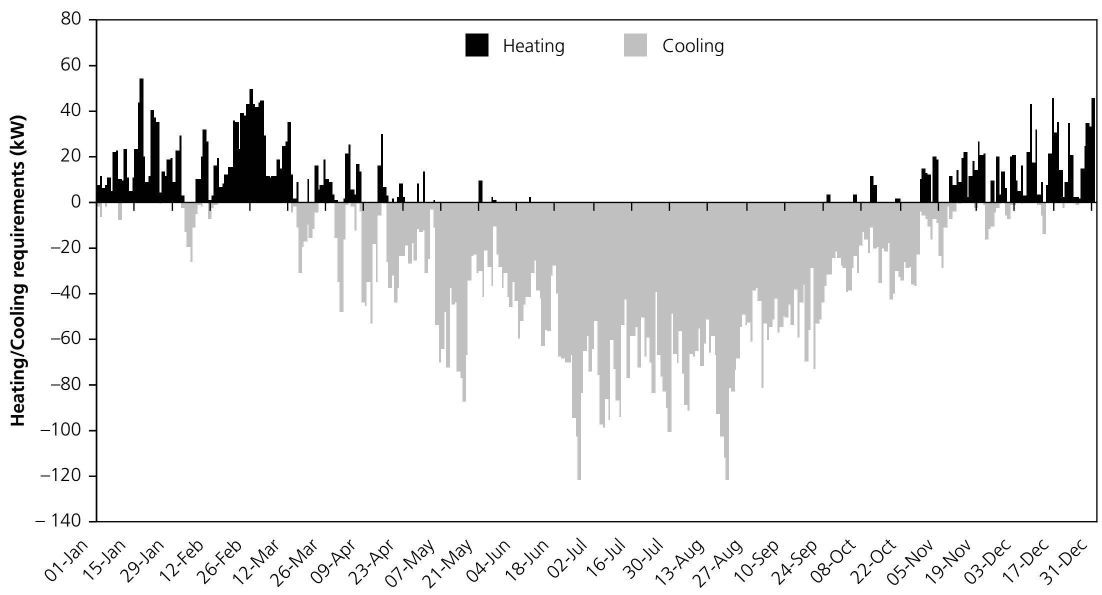
Peak Small Power gain: 2.2W/m^2 (based on typical occupancy and current technology)

Peak Lighting gain: 20W/m^2 (using combination of fluorescent and halogen lighting)

C.4.3.1. Heating and Cooling

The heat and coolth requirements of the entire building are given in Figure 10 using the above data.

Figure 10: Heating and cooling requirements of Variant 3



The relatively large cooling requirements of this building are mainly due to the very high internal gains from the lighting (much of which is halogen lighting, with a relatively poor efficacy). The above requirements will now be satisfied using the previously described CCHP scenario and also with an ASHP scenario.

C.4.3.2. Ventilation

As with Variant 2, the building is too wide to accommodate 100 per cent passive ventilation. However, a large part of the building, estimated at 85 per cent, could be passively ventilated with the remaining mechanical ventilation accounting for 1.3MWh per year in electrical energy.

Night-time ventilation is again utilised, being operated for 2838 hours per year (again due to the high internal gains). This results in a night-time ventilation energy consumption of 7MWh per year.

C.4.3.3. Final energy consumption

The first scenario uses the aforementioned CCHP system for satisfying the heating and cooling requirements, with all energy consumption shown in Table 4.

Table 4: Energy consumption of Variant 3 with electrical gains for CCHP scenario			
	Energy Usage		**Peak gain**
	MWh	**kWh/m²**	**W/m²**
Small power	36	17.9	2.2
Lighting	203	101.5	19.6
CCHP system (gas)	381	190.3	n/a
Fans/Pumps/Ventilation	13	6.7	n/a
TOTAL ELECTRIC	252	126.0	21.8
TOTAL GAS	381	190.3	n/a

For retail variants, small power energy consumption is often relatively small, but lighting consumption is a highly significant factor, both in terms of direct energy usage and the effect that this will have on cooling loads (see Figure 10). While there is considerable promise in the area of LED lighting[19] (as with Variant 2), the current trend is for retail premises to use halogen lighting with fluorescent lighting used for larger spaces. Electrical loads are therefore high and, to produce a large amount of onsite generation, a large CCHP system is used, with a subsequently large gas consumption.

If we apply a heat pump to the same variant, Table 5 is produced.

Table 5: Energy consumption of Variant 3 with electrical gains for ASHP scenario			
	Energy Usage		**Peak gain**
	MWh	**kWh/m²**	**W/m²**
Small power	36	17.9	2.2
Lighting	203	101.5	19.6
Heating	4	2.0	n/a
Cooling	18	9.1	n/a
Fans/Pumps/Ventilation	8	4.2	n/a
Hot water	19	9.6	n/a
TOTAL ELECTRIC	289	144.3	21.8
TOTAL GAS	0	0.0	n/a

For this scenario, it is likely that electrically-heated hot water would be used for the toilets and staff areas. While this is often energy-efficient (with point-of-use heaters having very small losses), it can significantly increase the CO_2 emissions of a building when using grid electricity. The same general problem can be applied to the use of a heat pump – while the energy use of the building is reduced (compared to the CCHP scenario), as the building is now all-electric, the CO_2 intensity of the grid will result in potentially large carbon emissions. There is also the fact that there will be no electrical generation other than that produced from PV and wind (see Section 4.4).

Heating and cooling consumption figures are based on the electrical consumption of the heat pump itself, with other parasitic electrical loads include in the Fans/Pumps/Ventilation category (which also includes day and night-time ventilation).

C.4.3.4. Supply-demand matching of consumption and generation

The June and December weeks for the CCHP scenario, are shown in Figures 11 and 12.

Figure 11: Supply and demand of electrical energy for Variant 3 in a June week for CCHP scenario

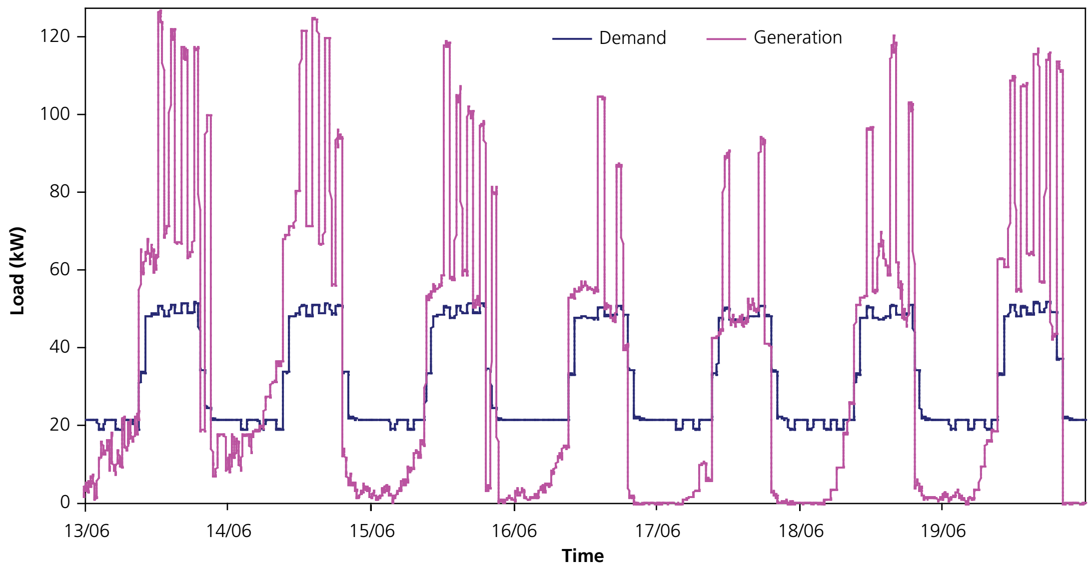
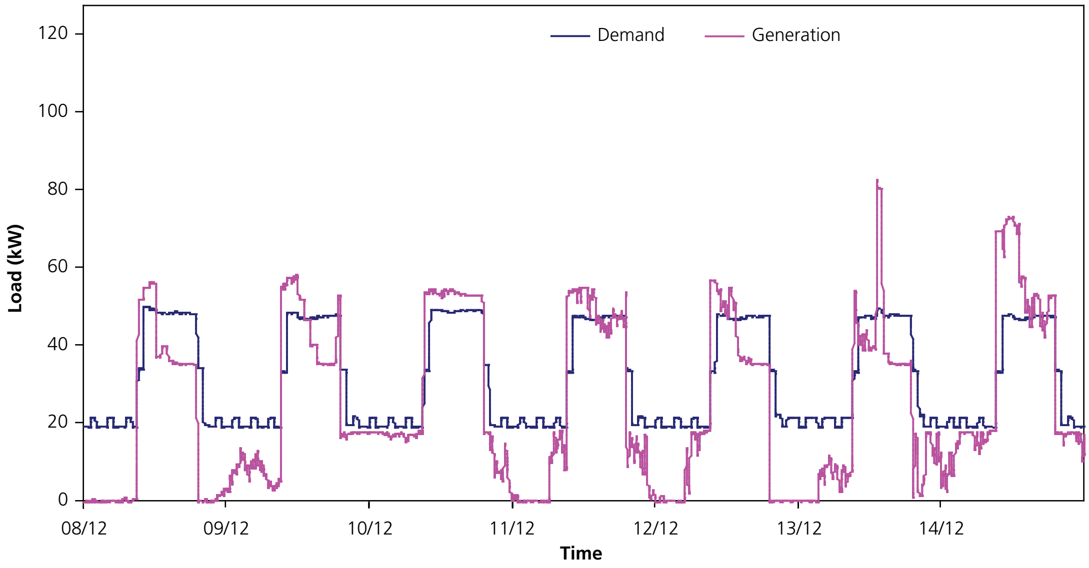


Figure 12: Supply and demand of electrical energy for Variant 3 in a December week for CCHP scenario



With the majority of the CCHP usage being related to coolth provision (due to the duration and magnitude of the cooling period, see Figure 10), there is significantly more onsite generation during the summer than the winter. Over the course of the year, 32 per cent of the demand is satisfied by grid import and 28 per cent of the electricity generated onsite is exported.

Figures 13 and 14 show the corresponding graphs for the ASHP scenario.

Figure 13: Supply and demand of electrical energy for Variant 3 in a June week for ASHP scenario

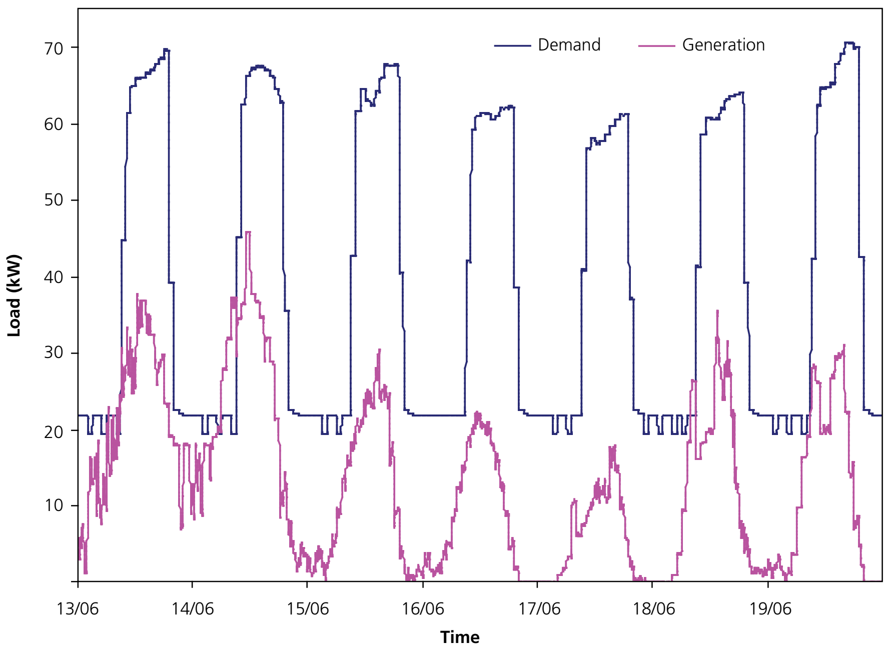
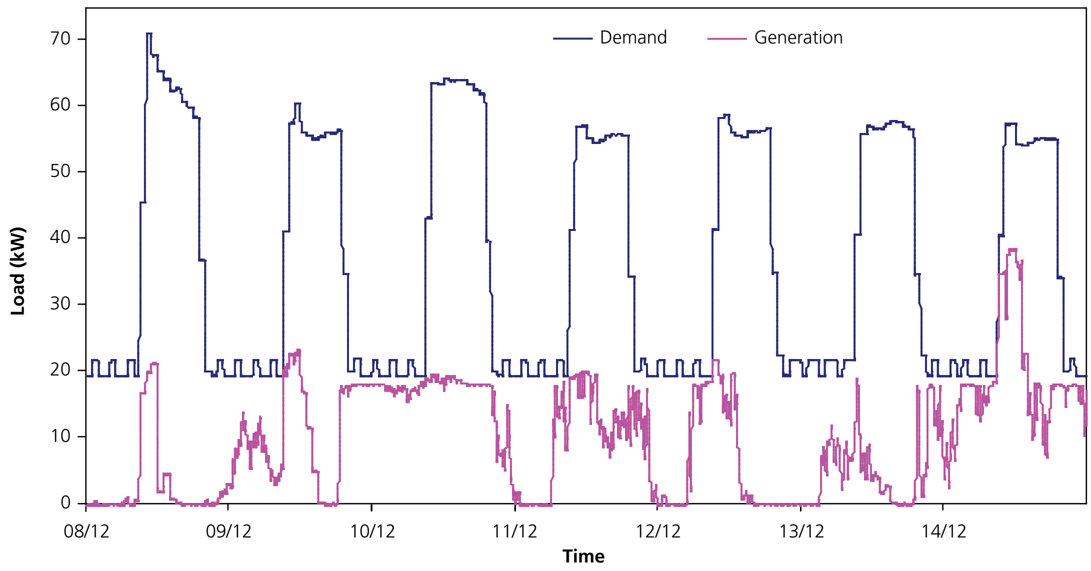


Figure 14: Supply and demand of electrical energy for Variant 3 in a December week for ASHP scenario



With the CHP system no longer present, the effect on onsite generation is obvious. However, this provides an energy efficient scenario where the building, is not been "run to produce energy" (as the CCHP system would have to be to produce a large amount of onsite generation). It demonstrates the subtle difference between what might be called energy-efficient and net low-carbon. As Tables 4 and 5 show, the ASHP scenario requires less energy to be used onsite. The CCHP uses more energy but, as it generates significant export, this is offset so that, as seen in Section 4.4, it has lower net-carbon emissions.

As a result of the lower electrical onsite generation, the ASHP scenario, throughout the year, exports just over 1 per cent of its generated electricity. However, 74 per cent of the demand has to be satisfied by the grid.

C.4.4. Total net carbon emissions of buildings

Table 6 gives the final net CO_2 emissions of each variant.

Table 6: Summary of energy and CO_2 figures associated with the building variants

	Total electrical energy use (MWh/yr)	Total gas energy use (MWh/yr)	Total Zero Carbon generation (MWh/yr)	CO_2 produced by building (tCO_2/yr)	CO_2 offset by building (tCO_2/yr)	Net CO_2 of building (tCO_2/yr)	% of demand offset by net-zero carbon generation
V1 – Shallow Plan 2005	397	757	412	314	177	137	56.4
V2 – Deep Plan 2030	208	589	333	201	143	58	71.2
V3 – Retail Shed (HP)	289	0	56	124	24	100	19.2
V3 – Retail Shed (CCHP)	252	381	234	181	101	80	55.8

All CCHP variants achieve an offset of 56-71 per cent, ie this percentage of the building carbon emissions are offset by onsite generation. Variant 1 has net CO_2 emissions of 137 tonnes per year, largely due to the small power and lighting energy consumption.

Variant 2 has a significantly lower net CO_2 figure of 58 tonnes per year, emphasising the effect of the equipment in a building on the total energy consumption of that building.

Variant 3 has net CO_2 emissions of 80 tonnes per year, largely due to lighting energy consumption. These figures are all despite the fact that the level of onsite generation is vast, effectively resulting in each building being a micro-power station.

The ASHP scenario of Variant 3 shows lower CO_2 emissions produced (when compared to the CCHP scenario) but the net figure of 100 tonnes per year is higher due to lower onsite generation. However, as a realistic low-carbon option, this building might be more desired, particularly from an economics perspective. It is clear that, when relying on CHP or CCHP as a means for achieving very low net zero carbon buildings, the operation of that system might directly be affected by the level of export you require. This will reach the level where, for large outputs, the building can just be thought of as having its own power station that is exporting large amounts of low-carbon electricity. This situation would only be desirable if this generated export was actually being used, for example, in a district scheme or even stored onsite.

C.5. Notes on Zero-Carbon Electricity Production

Regardless of the chosen options for cooling, heating and ventilating a building (which in themselves could be passive or low-carbon), there will be a substantial electrical load from small power and lighting in the described variants (and, indeed, most non-domestic buildings in the UK). This electrical load, if attempting to reach a net-zero carbon goal, would have to be satisfied by renewable sources. Even when looking at "future" technologies (which, as in variant 2, could be smaller than those currently experienced), this electrical requirement might be beyond the boundaries of current on-site generation technologies.

Taking the on-site estimates from Table 1, for Variant 2, the total zero-carbon generation, ZC_t, is:

$$ZC_t = O_{pv} + O_w + O_{chp}$$

$$= 364 \text{ MWh maximum (assuming high wind yield site)}$$

where O_{pv}, O_w and O_{chp} are the estimated annual outputs of the three identified micro-/small-scale generation technologies, PV, wind and CHP respectively.

This compares to approximately 186MWh for the small power and lighting consumption estimates for variant 2 (estimated using future lighting and IT technology). However, this has come at an energy detriment (from gas usage) of 589MWh, hence the building not achieving a net-zero carbon figure. Without CHP, the small power and lighting energy consumption is always likely to be significantly more than electricity generated onsite for non-domestic buildings.

The options highlighted here suggest a choice between reducing energy consumption while simultaneously reducing energy generation (ie no CHP system), or treating the building as a base for producing low-carbon power though the use of a CHP or (when a significant cooling load is present) CCHP. In the latter scenario the energy demand is relatively large, but this is accompanied by a large amount of onsite generation. However, even in this latter scenario, net-zero carbon has not been reached and, for the majority of current and near-future non-domestic building, this target is unlikely to be reached without prohibitive costs.

C.6. Conclusions

This analysis would suggest that even if the thermal comfort and desired air quality of the building could be met by zero carbon routes, insufficient low or zero carbon electricity could be generated on-site to offset the large energy consumption of the building.

While the generation technologies listed in this report are by no means exhaustive, the outcome of any analysis is highly likely to be that no current onsite generation technology can produce the levels of electricity generation required for non-domestic buildings.

Also, this report, while looking at on site generation, passive and night-time ventilation and low U-value building fabric, has not looked at other low-carbon technologies such as, for example, using phase-change materials in the building fabric; internal shading; passive daytime cooling and solar thermal technologies (which may be a useful option for smaller non-domestic buildings with significant hot water requirements). However, all these innovations would not solve one of the main problems of energy use in non-domestic buildings, ie the use of IT equipment and fluorescent lighting. Variant 2 provides an example of what might be achieved if standards for IT and lighting are pushed towards energy efficient technologies, and reducing this demand is arguably more effective than overloading a building with expensive onsite generation technologies.

The option of an "all-electric" building through the use of a heat pump is potentially low-energy. However, due to the carbon intensity of the grid, unless there is (again) sufficient low-carbon onsite generation then the carbon emissions of the building will be significant. It is therefore highly unlikely that such a scenario would achieve net-zero carbon, although it could provide a template for a low-energy building that might be satisfied by low-carbon generation (either through a future decarbonised network or, perhaps more likely, a low-carbon local distributed generation scheme, as discussed below).

The other scenario considered is to displace as much grid electricity as possible through a large gas-powered onsite generation system (ie CCHP). To generate the large levels of low-carbon electrical output, a considerable quantity of excess thermal output is produced. Although not specifically within the remit of this study, the logical step would then be to use this to satisfy thermal requirements of other buildings. This, combined with the sheer size of the unit, raises the question of why this form of energy generation should be considered building-integrated, ie is it, when dealing with non-domestic buildings, more prudent to think of low-carbon communities rather than low-carbon buildings? A system of the type specified would arguably be better served as part of a district heating/micro-gird/distributed generation scheme. Such a system might ultimately ensure that exported electrical generation from the CCHP system would be used locally (and therefore genuinely have a carbon credit), as well as providing a use for the excess thermal output (that would otherwise be dumped).

This study would therefore conclude that, with the technologies considered here, there is little evidence to suggest that net zero carbon non-domestic buildings of the types described can be designed. Further, the findings would seem to challenge the underlying philosophy of the zero-carbon approach whereby the building is considered as a single entity. Any attempts to satisfy the requirements of the building in a net zero carbon way are likely to require the over production of energy – both electrical and thermal. It would therefore seem more appropriate to consider community options for the built environment where individual buildings could house distributed generation systems which are then linked together to deliver community energy needs.

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Appendix D

Data collection for existing buildings

D.1. General comments re existing energy usage data collection

Collecting useful data on existing energy consumption in non-domestic buildings is often a more complex task than anticipated. The complexity arises in part from the extreme diversity of the nondomestic buildings and the activities they accommodate; a diversity of size ranging from kiosks to Canada Wharf and large hospitals, of activities from newsagents to large malls, from internet cafes to regional computer centres, It extends to topology (the ways in which the different entities are related to each other) involving buildings containing a single occupant, a single occupant in numerous buildings (hospital or university), and buildings contain many occupants. Each of these may be metered in numerous ways, so that landlord and tenant use may be indistinguishable, combined together or unidentified, business parks may provide central heating and cooling to multiple buildings and tenants, large institutions may have numerous meter points crossing over each other. The crucial point is that actual energy consumption is only discernable where it is metered, and the relationship of metering to tenants and buildings may be difficult to unravel in a data source.

D.2. Distinction between modelled data and actual energy consumption

Energy use data will generally be available in quite different forms from that which comes out of design models in general, SBEM in particular. Models will provide a calculation for heating and cooling demand, but actual consumption data for a building or premises is generally only known by fuel. End-uses (heating, cooling, appliances etc) will not be known unless they are specifically submetered.

D.3. Distinction between data on the building, and on the activity accommodated within the building

For many buildings the activity (office, shop etc) is likely to a stronger driver of energy use than the physical form of the building. And frequently only the activity is collected in energy data. However the analyses of this project were centered on built forms. Three generic types of building (shallow, deep, shed) were devised for the purposes of doing the zero carbon analyses. The many of the analysed measures are targetted at fabric, as is much of government policy.

Information on both activities and buildings is required to monitor energy performance.

D.4. Multiple purposes of energy data

The vast majority of actual energy data comes from meters, but these are in the first instance provided for billing energy use. Metered data is increasingly called upon to evaluate energy use but unless it is known where the energy channelled through a particular meter goes, and what end-uses, the data are difficult to interpret. In addition to billing, meter data may be called upon for such as the following purposes.

- Identify problems and opportunities for energy savings and cost reductions in a particular building.
- Identify high consumers among a set of buildings (eg a company portfolio) and thus which buildings provide opportunities for energy and cost savings.
- Monitoring overall efficiency of a set of buildings in relation to the stock, for benchmarking, monitoring the impact of organisational strategies, provision of information to corporate social responsibility aspirations, or confirming that government policy directives have been met.
- Completion of mandated energy labelling requirements.

Each of these imposes slightly different requirements on the data. Always it is necessary to have complete energy consumption data for a known floorspace and activity. Evaluating the effectiveness or performance of that energy use in turn requires additional data on the physical characteristics of buildings, operating schedules and conditions, plant and appliances within the buildings, control systems, zoning and so forth. Increasing amounts of data are generally required for more reliable performance evaluation and targetting savings investments.

Always the balance is between the cost of collecting information and the value of that information to building owners and occupiers, or the degree to which the data are mandated by government policies. The fairly detailed information needed to understand actual energy consumption is not generally collected in company databases. Indeed there does not yet exist a generally agreed set of information that is required to evaluate a building's energy performance in any depth, that can be used consistently across the wide range of types, sizes and activities in the nondomestic stock.

However the data requirements for Display Energy Certificates (DECs) required for operational rating are believed to be a useful step towards such a general purpose energy performance data definition, although the OR data requirements have been kept to an absolute minimum to avoid imposing an undue load on commercial building owners and occupants. The DEC data include activity, floorspace (GIA) and energy use broken down by some fuel and end-use categories, with allowance for a small number of special energy uses which can be allowed for only if separately metered.

The following lists information that may useful in various ways, and may be reasonably available, in order of priority.

1. Minimum useful information

1.1 For each fuel used in a facility, total delivered energy use for one full year, in kWh other fuel or energy measurements units

1.2 Floorspace

1.3 Activity

Notes

If the energy use is not available for each fuel, the total energy use is nevertheless of interest, though it can only be used for crude benchmarking.

Fuel costs are not required specifically required, but analysis of cost data in conjunction with consumption data may be of interest to evaluating low carbon options.

2. Useful refinements

2.1 Whether or not the facility is air conditioned

2.2 Whether or not the data describe a whole building, or premises within a building, or in some cases several buildings together.

2.3 Number of floors (the detail of this item data depends on 2.2)

2.4 Whether or not the area data and the energy consumption data correspond precisely and fully. For example a part building premises may have metered electricity but obtain heating and cooling from a central system with the cost of that included pro-rata in rent.

2.5 Major additional uses. Other major building services and/or energy uses (escalators, server room, catering facility, gym etc) that will have a significant impact on the total energy use of the facility and that are included in the energy data.

2.6 Measurement convention. Whether the floorspace data is gross or net, or other measurement convention (NIA, GIA, GEA, HCA). The latter, HCA, refers to heated or conditioned area, is the most useful for analysing energy performance. It is frequently approximated by GIA.

2.7 Major changes in functions, uses or sizes within the period for which energy data is provided.

With items 1 and at least some of 2, analysis can produce useful information beyond a mere statement of energy use, possibly to be compared to a benchmark.

3. Further information

Beyond items 1 and 2 the judgement about useful information depends on what is available in a source database and its completeness and definitional consistency. All of the following items of information can be used to generate more precise statistics on energy consumption and refine the evaluation of energy performance evaluation of individual facilities.

About the building

Clarity about what is included and excluded in the floorspace, and how well that corresponds to the area served by the meters.

Fabric (eg brick, block, full glazing, metal etc).

Glazing (eg full, strip, traditional, low glazing, none etc).

Load bearing or framed structure

Built form type (eg, shallow plan, deep plan, single floor shed)

Internal layout (eg open plan, cellular)

Age of building, years since major refurbishment

Sub-category (eg Twenty-three 19 office types)

About the building services

Type of heating

Type(s) of HVAC plant and areas serviced by each type

Counts and installed loads of various plant and appliances. Even incomplete information can be useful here.

Process energy uses, if present.

About the activities in the building

Number of employees (can be complicated with hot desking, part-timers, client space etc)

Other proxy size and use measures (nos. covers, beds, classrooms, hotel rooms etc)

Occupancy schedule (hours per week)

Non-standard occupancy pattern in relation to the specified activity

Floorspace assigned to different activities, eg in large complex buildings such as hospitals, likely to include ward space, offices, laboratories, workshops and garages.

Whether or not the facility has an energy manager (full time, part time, part of FM contract etc).

About the energy data

Year phase (start and end months of periods other than Jan-Dec calendar year)

Data for several full years. This gives more reliable statistics, and year to year variations are also informative.

Seasonal fuel consumption (eg billing intervals) or smaller time intervals as available. This can give base loads

Sub-metering data along with some information about what is sub-metered. This can give energy end-uses.

What constitutes a reasonably good activity classification

Likely to indicate the kinds of services in building or premises, in general

Will discriminate between major occupancy patterns (eg office, hospital, restaurant …)

The CaRB project has a comprehensive activity classification that can be used at variable levels of generality and detail.

Frequently the safest way to classify is to describe the activities in a few words and leave assigning specific categories to someone familiar with activity classification.

Appendix E

Calculation methodology used in determining regulated and occupant energy use, and costs of reaching levels 5 and 6

E.1. Calculating Predicted Energy Consumption Data by Building Type

It was necessary to carry out quite broad brush calculations on minimally adequate data sources to infer the impact of building regulations on Econ data, so that it could be used to estimate occupant energy as defined below. Some of these methods are based on previous work by Arup, while others are newly developed for this project.

Trends suggests that building regulations may have had an impact on heating energy use, but this must remain a supposition in the absence of more detailed analysis involving regulations changes, construction and demolition rates and longer time series. Climate factors might also have overridden building regulations effects

Thus, it must be emphasized that further development of an LZC policy needs, among other things, robust data on the impact of previous building regulations on performance of newer buildings under the 1995, 2002, and 2006 building regulations.

The methodology we used follows:

The data contained in the Energy Consumption guides is broken down into varying levels of detail depending on the particular guide and type of building. The energy consumption is broken down into regulated (such as gas for heating or electricity for lighting) and non-regulated (such as gas for cooking or electricity for IT equipment) uses. For every building type, data is given for both typical building consumption and "best practice" consumption.

For the purposes of this exercise, there is an incentive for developers to improve performance of regulated energy. For occupant consumption, there is less of a drive to improve. As a result, the base case energy indicator of the building was taken to be made up of the best practice indicator for "regulated energy" and the typical practice indicator for "occupant energy" uses.

The example below demonstrates this method for the fossil fuel use of a prestige air conditioned office.

Type 4 – Air conditioned prestige	kWh/m² treated floor area/year		Affected by Building Regulations?
	Good Practice	**Typical Practice**	
Heating and hot water gas/oil	107	201	
Hot water gas/oil	12	20	Yes
Heating gas/oil	95	181	Yes
Catering gas	7	9	No
Fossil fuel benchmark	**114**	**210**	

The next stage of the process was to identify the age of the data contained in the consumption guides so that the number of Buildings Regulations revisions to which the base case data should be subjected could be ascertained. In most cases the data was uplifted three times representing changes made in 1995, 2002 and 2006.

The Building Regulations improvement from 1981-1995 and 1995-2002 only governed improvements to fabric u-values not to systems and plant. A direct comparison to the Building Regulations that followed which give a prescribed level of carbon dioxide emissions reduction and also consider heating and electrical systems is not possible (a building with improved u-values but inefficient plant could be a net higher producer of carbon per m^2). However, by considering a reduction in energy consumption that is proportional to the reduction in u-values, less an allowance for cold bridging, it has been estimated that there was a 5 per cent carbon reduction between regulations '81-'95 and '95-'02 across all property types. 2006 Building Regulations required a reduction in carbon emissions of 28 per cent for air conditioned non-domestic buildings and 23.5 per cent for non air conditioned buildings.

The energy indicators obtained in the first stage were converted to CO_2 emissions using the carbon dioxide emissions factors from Part L; 0.422 kg CO_2 per kWh for electricity and 0.194 kg CO_2 per kWh for gas. All fossil fuel use was assumed to be natural gas. The 5 per cent reductions in CO_2 emissions for the 1995 and 2002 revisions and the 23.5 per cent/ 28 per cent improvement for the 2006 revision were applied sequentially to the portion of energy subject to Building Regulations. So, in the previous example, the reduction would be applied to the CO_2 emissions associated with the 107kWh/m^2/yr of gas used for space and water heating but not to the catering gas use. Electricity use was treated in exactly the same way and the same level of improvement was applied.

Having reduced the gas carbon dioxide emissions, the figure obtained was then converted back into energy use. The portion of energy use which was not regulated by building regulations was then added back on, giving the final energy consumption indicator for a building built to 2006 Regulations. The whole process is illustrated in the example below using the figures above for a prestige, air conditioned office.

Total fossil fuel indicator = 114 kWh/m²/yr
Fossil fuel use subject to Bld Regs = 107kWh/m²/yr

CO_2 emissions subject to Bld Regs = 107 x 0.194 = 20.8 $kgCO_2$

Reduction for 1995 regulations = (100% – 5%) x 20.8 = 19.8 $kgCO_2$
Reduction for 2002 regulations = (100% – 5%) x 19.8 = 18.8 $kgCO_2$
Reduction for 2006 regulations = (1-(0.28 x 0.67)) x 18.8 = 15.3 $kgCO_2$

2006 level Bld Regs energy use = 15.3/0.194 = 79 kWh/m²/yr
Other energy use = 114-107 = 7 kWh/m²/yr

2006 building fossil fuel indicator = 79 + 7 = 86 kWh/m²/yr

E.2. Calculating Expected Building Emissions

Building type refers to the three categories identified by Heriot-Watt University.

Building class refers to the twenty-three categories of buildings broken down by end use.

Using SBEM, contributors computed the expected gas, non-cooling electrical, and cooling electrical loads for the buildings. Contributors trialled different measures (varying U-values, air infiltration, COPs, etc) to reduce the regulated carbon emissions to zero, and the cost of implementing these measures was calculated by the Quantity Surveyors.

Next, twenty-three relevant classes of buildings were identified from the ECON guides. The predicted consumption data (calculated as described in previous section) was used for typical total gas, non-cooling electric, and cooling electric use per m² by building classification. Each of these three areas of energy use was broken down into occupant and regulated energy use. These figures, given in kWh/m²/year, were converted into carbon emissions, using the scale factors of 0.194 kg CO_2/kWh for natural gas and 0.422 kg CO_2/kWh for electricity.

The building type for each of these building classes was then established. Based on CO_2 emissions, the closest SBEM model (of the same building type) was matched up with each building class. This gives an appropriate SBEM model for each of the twenty-three building classes. For each building class, the expected cost of implementing the efficiency measures to reduce building carbon emissions will simply be the cost calculated by the quantity surveyors for that building type.

In order to achieve level 5 rating, beyond the first efficiency measures, all regulated building energy must have net zero carbon emissions. If the SBEM model matched with a particular building class consumes less energy than the predicted ECON specified energy use, this gap (termed here the "Regulated Variant" energy use) must be zero. The additional emissions associated with the Regulated Variant energy will be reduced through the use of renewable energy.

The amount of carbon emissions associated with the "regulated variant" is known (the difference between Twenty-three carbon emissions for the building type and the SBEM carbon emissions for the building class). Using the scale factors, these carbon figures are converted back into kWh, giving the amount of energy which must be generated each year through zero-carbon technologies. For each of four technologies modelled (large scale wind, small scale wind, biomass CHP, and PV), using maximum and minimum costs (£) per kW installed and capacity factors, the range of possible costs for supplying the given amount of energy was calculated. Similarly, a maximum and minimum cost for the ROCs per kWh is used to determine the annual cost of ROCs associated with this power generation.

The cost of achieving level 6 buildings is calculated in a similar manner, the difference being the renewable energy supply must meet the demand for all regulated and occupant energy use in the building.

Appendix F

Value of zero carbon

There is almost no market evidence which shows that occupiers of commercial buildings (and domestic buildings) or investors are prepared to higher price for a low or zero carbon building. However, there are some early signs that the market may be changing – but it is very early days and it may be many years before there are significant price shifts.

There are four ways to understand this subject. They are:

1. The Value of Energy
2. Corporate Image and Corporate Social Responsibility
3. Valuation and Investment Risk
4. Valuation and the Law

F.1. The Value of Energy

It is now fully understood that energy has been and will continue to rise in real terms. The days when, in the mid 1980s, a barrel of oil cost only $9 on the global oil market are gone for ever. Events following the horrors of 9/11 emphasized the vulnerable nature of oil coming from the Middle East. Arguably, Hurricane Katrina in 2005 and the damage to New Orleans did more to alert the world to this dilemma than any other single event.

Then in the Winter of 2005/2006 Russia turned off the natural gas supply into Western Europe. This was the biggest wake up call yet to the fact that oil energy prices are extremely vulnerable to change, and that the less stable parts of the global economy may have a significant impact on the mature economies.

However, energy is a percentage of an occupiers costs, is relatively low. In **"Building Sustainability in the Balance"** published by Estates Gazette in 2003 (authors S.Sayce, A.Walker and A.McIntosh) page 45, included the following table:

Cost Item	**Relative cost**
Salaries	130
Gross Office Rent	21
Total Energy	1.81
Repair & Maintenance	1.37

Original Source: Hawken et al (1999)

In recent years office rents have increased significantly, especially in places like Central London. As offices in the West End of London have headed to an all-time high of £100 per ft² (and sometimes even higher). The cost of energy to an occupier has become even less significant.

Whilst this general statement cannot be applied to all office markets, it does emphasize how **unimportant** the price of energy is, when focusing occupier's minds on reducing their carbon footprint.

A major project undertaken by King Sturge and the Urban Land Institute in 2006/07 involved a number of focus group discussions around Europe (Poland, Sweden, UK, France and Italy), as well as a questionnaire survey amongst members and case study analysis. What emerged from this was that some shopping centre owners (such as Hammerson Plc) are increasingly aware of the cost of energy in running a shopping centre. But there is confusing amongst tenants: whilst shop tenants say they are interested in a low energy shop unit. When it comes to identifying a suitable building from which to trade, this is deemed to be very low in terms of their importance.

In recent years, King Sturge has also tried to persuade retail tenants to refit their buildings using sustainable materials, and reducing the energy consumption (such as introducing low energy lighting). This has met with a very disinterested response so far.

In the "Bid Sheds" Logistics Property Market, major developers such as ProLogis and Gazeley have however taken this more seriously and have developed a number of low energy buildings, both in their construction methods and in use. However, this is more to do with market image and the need to obtain planning permission in market areas across Europe where there may be political sensitivities unless it can be shown they are addressing the issue of the carbon footprint.

F.2. Market Imagine and Corporate Social Responsibility

Major retailers such as have increasingly focused their public relations image on social and carbon issues. However, much of this is still perceived to be window dressing. A number of surveys recently have suggested that, so far, they have not made a radical shift in reducing their carbon footprints. Nor have they reduced the level of waste, especially in terms of carrier bags and packaging generally.

That said, Marks & Spencer announced their Plan A Campaign in 2007 outlining a comprehensive 100 point plan to tackle **carbon neutrality, waste to landfill, sustainable sourcing,new standards in ethical trading** M&S CEO Stuart Rose said that 'the company will change beyond recognition the way it operates over the next five years. M&S will become carbon neutral, only using offsetting as a last resort'.

Their first three trial stores to open since the launch of the campaign have delivered between 25–55 per cent energy savings, up to 95 per cent reduction in CO_2 and delivered 80 per cent of construction waste being recycle or reused. The company states whilst there is an expectation for M&S to deliver, it also makes good business sense.

Also it was the CEO of Wal*mart, Lee Scott who said after Hurricane Katrina that he aimed to make Wal*Mart 100 per cent supplied by renewable energy, create zero waste & only sell product that sustain the environment. A number of other major property companies and occupiers have also become increasingly aware of their corporate social responsibility. The ULI project (referred to above) found that this is far more prevalent with Anglo-Saxon stock market companies but less apparent across mainland Europe. In this latter market, there is a feeling that they will "wait until the law changes" before they change their market behaviour.

Corporate Social Responsibility has also become an issue for number of the major banks. This has been led by HSBC who have stated in 2006 that they aimed to become "carbon neutral".

The above examples demonstrate that there is a growing awareness but there is a very long way to go before major occupiers, or major property investors, take the issue seriously.

F.3. Valuation and Investment Risk

A few years ago Kingston University led a project entitled **"The Sustainable Property Appraisal Project"**. This was sponsored by the DTI, Prudential, Investment Property Forum, Boots, Drivers Jonas, Universities Superannuation Scheme Ltd, Investment Property Databank and Forum for the Future.

The aim of the project was to provide property investors and occupiers with a scheme for reflecting sustainability within the appraisal of commercial property assets. From this, tools were developed that enabled an assessment to be made reflecting investment worth.
If focused on the concept of future-proofing property is by using a sustainable property appraisal tool.

It was the most comprehensive analysis yet undertaken and provided an analysis of how to internalise into an investment appraisal the potential "sustainable" costs might have an impact on investment values in the future. By necessity, the appraisal tool generate was relatively comprehensive, and therefore raised a level of complexity which did not appeal to investors in the property market.

The common valuation concept in the property investment market is the concept of the "all risk investment yield", which is arrived at by analysing comparable market data, and making certain assumptions about the type of property involved in terms of its location, design and tenancy structure. In other words, the age of a building within a given town or city in relation to the demand for that property (and the rental value), is going to have a far bigger impact on the investors understanding of the investment work, rather than issues of energy use, adaptability, pollutants, waste control, water use-age, etc.

The sustainable property appraisal project provides a useful starting point in a very complicated topic area for the property market.

In parallel, a property consultancy "Upstream" has began the process of suggesting that there is a "third dimension" to all property investments. Whilst property investors try to balance out potential returns against potential risks, and will pay a lower price yet higher investment yield for a more risky building (and vice versa), the third dimension is to understand the sustainability of that income.

Upstream has developed a generic investment model to advice property investment portfolios on how to regard the asset management of each property. Whilst it is in its early days, it does at least provide long-term investors, such as pension funds, life insurance companies and major property companies, with an understanding and a sustainable risk assessment tool to assist with better asset management and portfolio analysis.

More recently Angus McIntosh wrote an article in the Estates Gazette under the title of **"Depreciation Delusion"**. It undertook a generic analysis of property investment appraisals but suggested that "social cost benefit analysis" or the concept of "natural capitalism" are unhelpful in terms of the private investment market.

A general property investment "discounted cash-flow model" was created to demonstrate the impact that rising costs; social sustainability factors (such as taxation, insurance and security) rising economic factors (such as internal repairs and the replacement of fixtures and fittings and heating systems) and environment factors (such as cleaning costs, waste disposal, water and sewage cost and energy), might have on the net rental income to investors.

In other words, it is suggested that occupiers have a number of costs to meet and it is only the **net income** (after other fix costs have been met), which returns to the investor. If this net income is reduced (due to other costs rising faster than inflation) that makes the investment income vulnerable, and may undermine the investment value.

The article suggested how a portfolio might be reassessed, in terms of an asset management strategy according to this type of analysis.

F.4. Valuation and the Law

The three ways of looking at market valuation as discussed above (the cost of energy, CSR and asset depreciation), might each be accelerated by legal changes. Whilst there are an on-going number of legal changes at any one moment in time, the two which stand out for having the most impact in the current market are:

Building Regulations – especially the changes to Part L Building Regulations relating to the design of buildings (but this does not have any impact on old buildings, unless they are substantially rebuilt, or demolished).

Energy Performance Certificates – on all buildings across Europe will focus attention of those buildings which are energy efficient than others. Whilst most countries across Europe (apart from Greece, Poland and Estonia) have now adopted this European Directive, and whilst in theory it should come into practise in 2009, not only might its implication be delayed, the impact on property investment values is likely also to be slow.

A large amount of analysis so far has been on construction methods, and to some extent Building Regulations and Energy Performance Certificates focus on this aspect of property. However, property is used (both internally and in terms of its location within a town and city) can be far more influential in terms of a building's life-cycle energy consumption than its construction.

It is well known from a number of market projects (King Sturge with Ipsos MORI produced some data) that over 70 per cent of the working population drive to and from work. It is also known from a number of projects that most buildings in Great Britain (both commercial and domestic) are more than 20 years old – 70 per cent of the built stock was constructed before 1985.

Workspace inefficiency arguably contributes to a far higher carbon footprint than a modern well designed building. For instance, a well designed telephone call centre, per operative, may be far more energy efficient than a 19th century town converted to office use.

Currently, most of the assessment tools, such as BREEAM and LEED, are focused on new build projects. A major challenge will be a method by which the use of buildings can be changed by adjusting the price point in the building to encourage their more efficient use.

Adapting buildings to a low carbon economy is a major challenge; it is estimated for instance that there is more than 200 million ft^2 of office space in Central London alone. But as yet, there is no market evidence that the higher cost of energy (or low carbon buildings) are having an impact on the office rents occupiers are prepared to pay to carry out their business.

Typically, over 80 per cent of a service sector company's turnover is paid out in salary, and less than 10 per cent is paid out in terms of a building's occupation cost. Of that 10 per cent, less than 1 per cent may be expended upon energy consumption. Typically, office occupiers are far more concerned about the costs of staff and their productivity, than on saving energy.

Appendix G

Trends in non-domestic stock energy use

There are no adequate surveys from which widespread changes in the patterns of energy use in non-domestic buildings may be discerned and quantified. There are a number of reasons for this, the complexity of the stock (as discussed in Section 3.1.2) including the consequent difficulty and expense of data collection, the range of organisations involved.

Hence to in the search for information which described the overall nondomestic stock and from which general trends might be discerned, the CaRB project turned to DUKES (Digest of UK Energy Statistics) and various sources of floorspace data, predominantly the Valuation Office Agency.

The results of this work were somewhat unexpected. Electricity use in the UK non-domestic stock as a whole is known to have been increasing steadily for the past decade or more. It is generally thought that the overall increase is due to a steadily increasing intensity of stock electricity use (energy use normalised by floor area, typically expressed as kWh/m^2). The increased is typically assumed to arise from the increased use of air conditioning, IT equipment and lighting.

However an analysis of DUKES data shows that the increased electricity use simply follows floor space, and gas use has remained broadly constant, suggesting a decreased use in relation to floor space intensity.

G.1. Trends in overall stock energy use

The following charts show gas and electricity use from 1996 to 2004.

Chart 1: Annual electricity consumption by Public Administration and Commercial Sectors of the UK nondomestic building stock

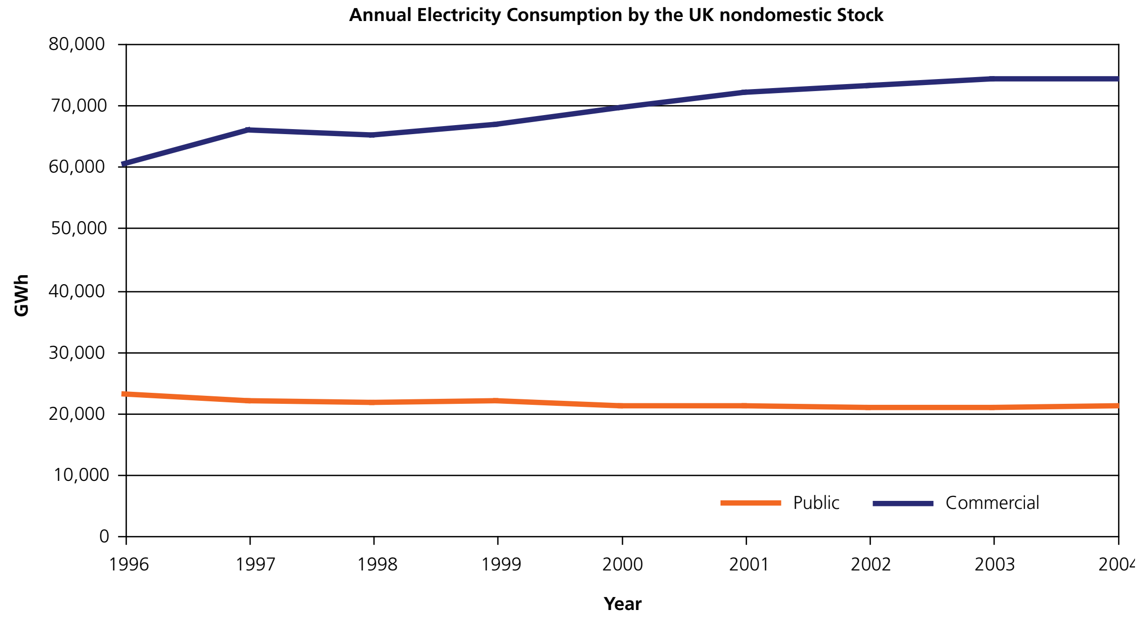
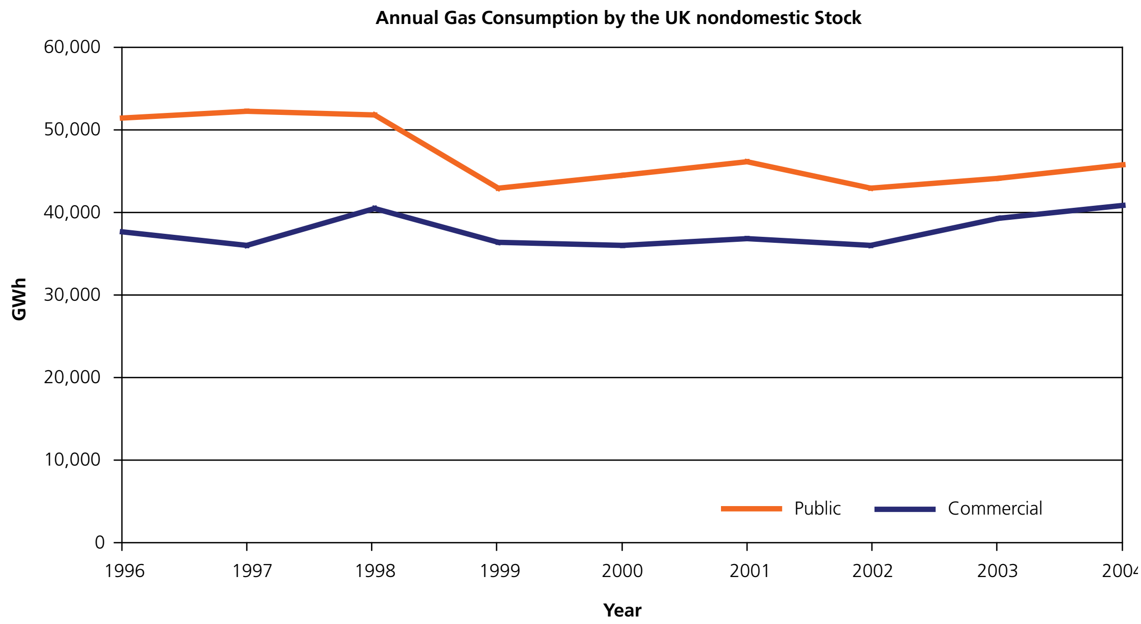


Chart 2: Annual gas consumption by Public Administration and Commercial Sectors of the UK nondomestic building stock



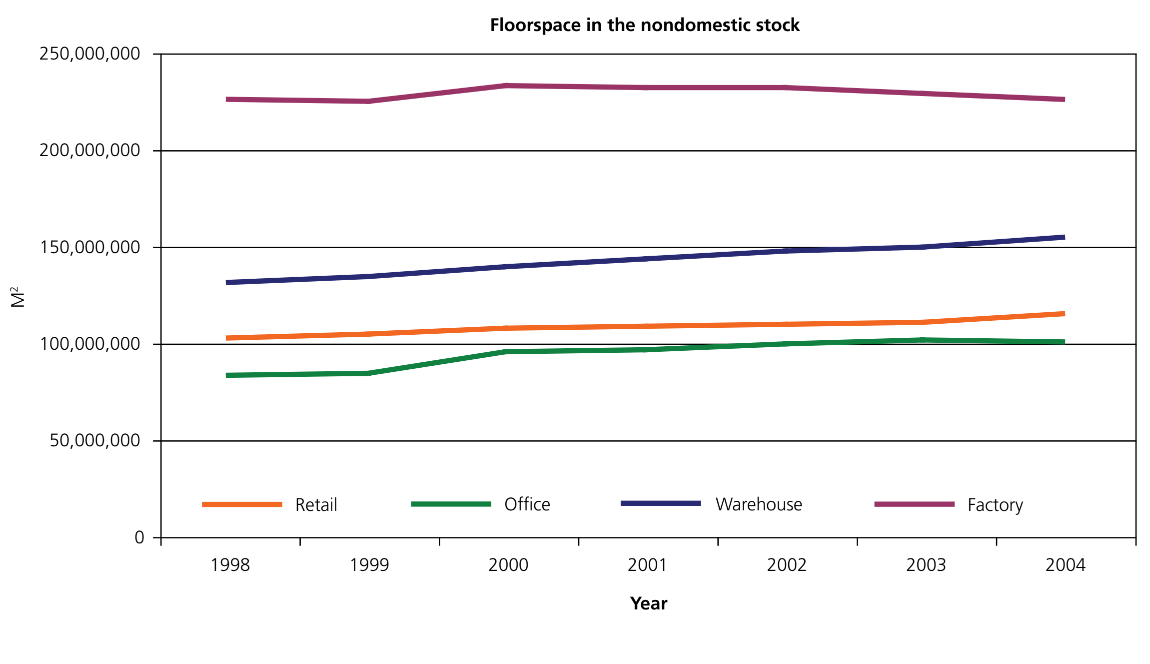
Over the period 1996 to 2004 electricity use for the commercial sector has increased by 23 per cent while for Public Administration it has decreased by 9 per cent. Gas use for the commercial sector has increased by 9 per cent while for the public sector it has decreased by 10 per cent and varies noticeably from year to year. Changes in gas use might be expected from any of several factors. For example one might expect gas use to be decreased by warmer winters or to rise with the overall increase in floorspace. An additional increase might be expected from restaurant premises, which have grown faster than the rest of the nondomestic stock.

In summary, electricity us is indeed increasing, and gas goes up and down a little from year to year, a variation which one might suppose to be due to warmer and colder years.

However, floorspace has also increased steadily over the same period.

Trends in overall stock floorspace

Chart 3: Floorspace by Valuation Office Agency bulk class



Trends in nondomestic electricity use

Inspection of the data underlying Chart 3 shows

Table 1: Changes in bulk class floorspace from 1998 to 2004	
1 retail	+11%
2 office	+21%
3 warehouse	+18%
4 factory	0%
Total	**+10%**

From DUKES data in Charts 1 and 2 above, we get the following changes in energy use over the same period.

Table 2: Change in energy use for the PACS (public administration + commercial sector) from 1998 to 2004	
Electricity	+10%
Gas	–6%
Total	**+2%**

It appears that electricity consumption closely follows overall floorspace. That is, to a first approximation, the increase in nondomestic electricity use is accounted for simply by the increase in total nondomestic floorspace.

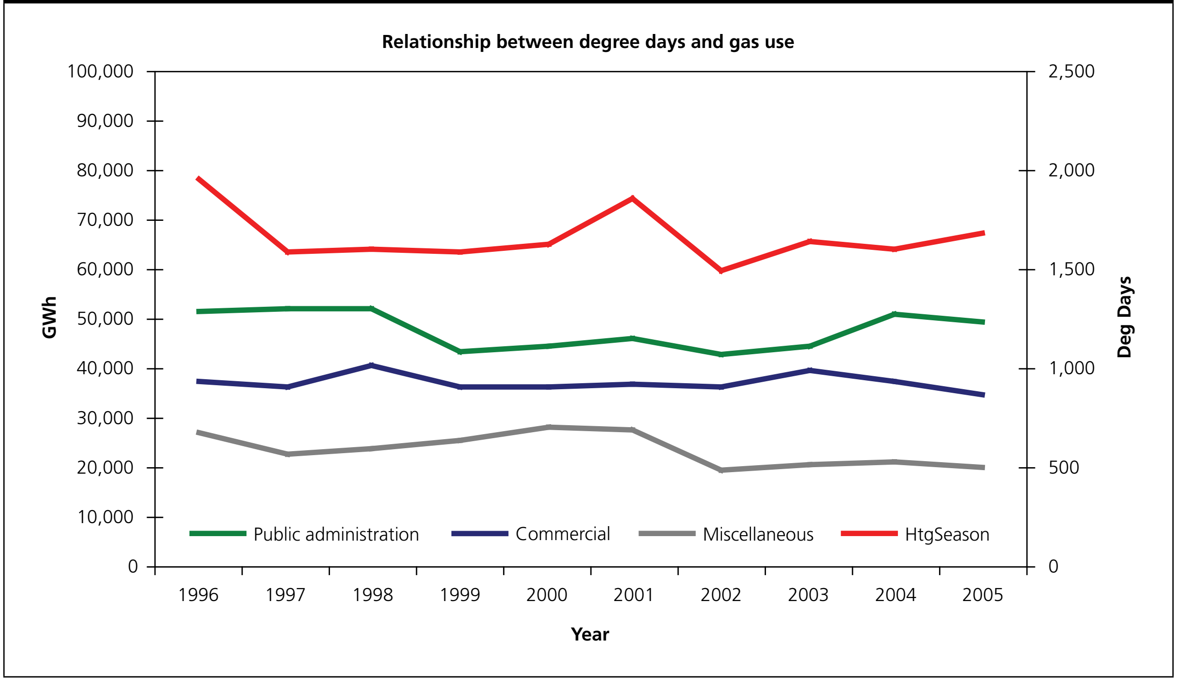
That gas consumption appears to have decreased slightly, despite the overall increase in floorspace, suggests a reduction in heating energy use (kWh/m^2).

Limitations in the quality, compatibility and completeness of data allow only a moderately greater depth of analysis of these gas and electricity trends, including in particular a crude estimate of public sector floorspace. However this work has made no substantive changes to the above conclusions.

G.2. Trends in non-domestic gas use

It was speculated above that the variation from year to year in gas energy use would be due to warmer and colder years. However such a hypothesis is not born out by climate data, as shown in the following chart.

Chart 4: Annual nondomestic gas use and heating season degree days



Gas use for public and commercial buildings sometimes appears to follow a similar pattern, but then diverges. Neither follows annual degree days except for a very slight increase associated with the very high degree days of 2001.

Analyses subsequent to the above have confirmed that gas use does follow strong seasonal patterns. This is unsurprising, the differences in temperature between seasons are much larger than the differences from year to year.

G.3. Conclusions

G.3.1. Electricity intensity is largely unchanged.

To a first approximation the intensity of electricity (electricity use per square meter) is unchanged over the past decade or so. However it may be, indeed it is quite likely, that the overall results mask diverging changes within the nondomestic building stock. That is, some groups of buildings may have become more efficient (as defined by intensity), others may have become less so. There are insufficient data available on buildings and activity types within the stock to … this

There are numerous factors that would be expected to drive energy up or down, for example:

- increased use of air conditioning.
- increased use of refrigeration in shops.
- increased use of lighting.

- increased use of 24/7 servers and server rooms
- increased use of efficient luminaires.
- increased efficiency of IT and other appliances.
- the impact of building regulations.

While there are small studies that quantify some of these factors in a few buildings, it is not possible to make robust statements about their impact on the energy use of the stock as a whole.

G.3.2. Gas intensity appears to be decreasing

Given that floorspace is steadily increasing, and gas use is broadly constant, it follows that the average gas kwH/m^2 is decreasing. As with electricity it is not known if this is a general decrease throughout the stock, or a phenomenon occurring in parts of the stock only. Changes in Building Regulations occurred in 1982, 1990,1995 and 2002.

These changes be a factor in the overall decrease in gas intensity but this not shown by Chart 4.

The lack of correlation between gas use and warmer or colder winters suggests one can speculate that building control systems throughout the UK are inadequately responsive to eternal conditions. However this remains for now a speculation.

Further work is ongoing to attempt to unravel the determinants of overall gas energy use in the nondomestic stock.

G.3.3. Floorspace data are inadequate for energy policy

There is insufficient detailed data on floorspace in the stock to discern the impacts of either business and usual drivers or of government policy. What data are available are incompatible at a basic level, a problem also commented on by the House of Lords in …

For the trends work described in the appendix is was necessary, because of differences in the definitions used by DUKES, and by the VOA to bundle most of the nondomestic stock into a single general floorspace category. A particular issue is that central government offices are counted as commercial offices by the VOA, but as Public Administration in DUKES. Secondly, while the floorspace statistics, derived from VOA data, provide good data for the bulk classes (shop, office, warehouse and factory), important parts of the nondomestic stock are accounted for by other major public sector categories, education and health. CaRB has not as yet obtained a reliable floorspace time series for these sectors.

G.3.4. Relevance to LZC nondomestic strategy

This appendix has been about understanding historical energy use in nondomestic buildings that have already been built. However the difficulties encountered in this are directly pertinent to LZC nondomestic strategies in two ways

One is the use of existing data in the methodology used to obtain LZC options and costs. These needed to take account of and design to patterns of energy use in the existing stock. These patterns are not well understood and it was necessary to incorporate such data sources as could be obtained and analysed within the time frame and resources available to this project. Further and more in-depth analysis of the patterns of energy use in different kinds of nondomestic buildings and the way these are changing over time is essential to developing a robust LZC strategy.

Further, the methodology has analysed and developed LZC pathways for a handful of common built forms and activities. The nondomestic stock as a whole is extremely diverse. A comprehensive LZC strategy needs to be effectively applicable to the whole of the stock and thus requires a great deal more data.

Two is the need for monitoring the impact of an LZC strategy after it has been implemented. Discerning whether or not an LZC strategy has been effective will, without a considerable improvement in data sources, be just as problematic as has been interpreting recent historical trends. Improved data is required on floorspace and energy for all types of buildings and activities in the nondomestic stock.