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Towards More Sustainable Tall Buildings

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Faber Maunsell is recognized by the Sunday Times as one of the 100 Best Companies to Work For and Financial Timest Best Workplaces in 2007. The company is a Foundation Member of Tomorrow's Co., which promotes relationships with all stakeholders and is proactive in implementing the European Quality Foundation Business Excellence Model to deliver continuous improvement. Faber Maunsell was established in 2002 following the merger of Oscar Faber in 2001 by AECOM and the merger with Maunsell U.K. and Metcalf & Eddy U.K. In 2005, Bullen Consultants were merged into Faber Maunsell.

Dalton, who has more than 36 years of professional consulting experience, began his career in London and Glasgow with Oscar Faber. In the late 1970s, he joined Wright Air Conditioning, a design contracting and maintenance firm, becoming a Board Member in 1980. He launched Wright Design & Management, a consultancy arm of the company in 1984. Dalton re-joined Oscar Faber in 1990 serving as a main board director. He became managing director in 1995 and chief executive in 1998 before joining AECOM in 2001.

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Abstract
In February 2002 Faber Maunsell undertook a landmark assessment of sustainability issues associated with tall buildings for the Corporation of London entitled "Tall Buildings and Sustainability". Since publication there have been significant developments both in the regulatory regimes associated with sustainable development in London specifically, and in the UK generally. There is also a much greater level of knowledge of sustainability issues and solutions associated with tall buildings. This paper provides an update to the work published in 2002, and covers:

- Key recent sustainability drivers and requirements for developments in London from a planning and regulatory perspective, with a particular focus on lower carbon footprints.
- Growing recognition that a key sustainability requirement revolves around the need for a common agenda between investors, developers, landlords, tenants, and their respective supply chains.
- A brief review of some of the experiences of "sustainable" buildings from a carbon footprint perspective.

The paper concludes with the view that sustainability outcomes will only be fully successful if sustainability priorities are shared by the planners, investors, developers, landlords, occupants, and their respective supply chains.

Keywords: Sustainability; development; carbon, supply chain

Introduction

Given rapid urbanization and limited land available for development, and the need to look at sustainability issues associated with developments as a whole, for example transportation and overall life cycle resource efficiencies, it has been argued (Pank, 2002) that tall buildings offer a more sustainable solution for many of today's cities.

However commonly accepted definitions (eg Bruntland) identify more of an approach to sustainability than providing specific goals or targets. As sustainability issues are context dependant, eg sustainability priorities in the developing world are often different to the developed world, and evolve as a reflection of public, political, and commercial sentiment, this is an area where we need to constantly review and update progress and priorities.

Implicit in most definitions of sustainability is that of "resource efficiency" – using economic, social, and environmental assets as efficiently as possible. In this context a key element of any sustainable building must be that it is "fit for purpose", both on construction, and being adaptable moving into the future. Although this is to many a statement of the obvious, there are instances of "sustainability exemplars" where the attempt at innovation that presses back the boundaries of innovation can result in a building which lacks the potential for future adaptability.

In the UK there is general acceptance that sustainability issues need to be addressed at the development level as a whole, in addition to consideration of individual buildings(eg GLA, 2006). As such sustainability issues associated with tall buildings need to be considered in the context of the wider development picture – for example how the building's energy supply systems can be integrated with the existing and future "low or zero carbon" energy supply infrastructure.

In February 2002 Faber Maunsell undertook a landmark assessment of sustainability issues associated with tall buildings for the Corporation of London (Pank, 2002) entitled "Tall Buildings and Sustainability".

This paper builds on the assessments and concepts in that paper. In particular it: evaluates the drivers of sustainability priorities for tall buildings in London and the UK that set the agenda for what is constructed; evaluates the importance of having a consistent set of sustainability objectives from investors through to occupiers; and briefly assesses some of the successes in realizing sustainability issues in tall buildings with a particular focus on reducing the building's "carbon footprint" – one of today's key sustainability priorities.

Sustainability Drivers

Figure 1: Example of material supporting a particular organizations' focus on carbon emissions (source: Carbon Trust poster). CSR has become an important sustainability driver.

There are a number of drivers that identify the sustainability priorities of a tall building:

- National priorities enshrined in for example national regulations or fiscal incentives.
- Local priorities associated with planning – in the UK sustainable development is at the heart of the planning system, and this translates into conditions associated with individual developments.
- Company sustainability priorities (Figure 1), as enshrined in Corporate Social Responsibility (CSR) reports. Those involved in the tall building often have their own policies regarding sustainability that impact on investment decisions.
- Business & industry sentiment as to what "sustainability" means in a particular location, or for particular buildings.
- Professional "best practice" (Figure 2) such as that from the Chartered Institution of Building Services Engineers (CIBSE, 2007) that highlights key sustainability issues that, in their case, building services engineers are encouraged to consider in their professional activities.

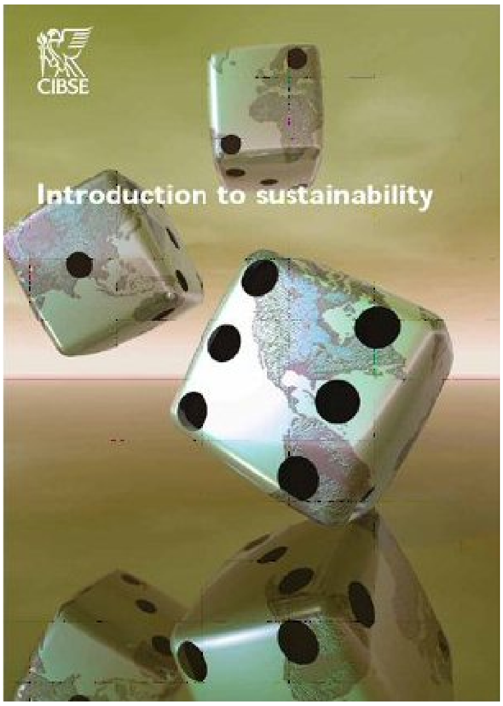

Figure 2: Chartered Institution of Building Services Engineers professional guidance - "Introduction to sustainability"

Sustainability is seen by many as being about achieving a mutually beneficial balance between environmental, economic, and social issues – the so-called "triple bottom line" approach. An example of this would be the reduction of waste through good management practices at site. Such a move has economic (less waste, hence less cost), social (fewer deliveries to site), and environmental (less material used, less energy consumed in transport) benefits.

Others recognize that although such win—win situations are achievable on specific issues, in practice many sustainability issues require a trade-off between various sustainability priorities. For example if a particular tall building includes a requirement for affordable (ie low cost) key worker accommodation, as a sustainability priority, the outcome in terms of design and operational solutions will be different than if the sustainability priority is to develop a zero-carbon building. Hence for a building to be "sustainable" it is necessary that all involved in the development of a tall building agree sustainability priorities and objectives.

In practice sustainability priorities, and particularly the outcomes associated with sustainability features, with a particular tall building are affected by:

- Affordability – and given that developers pay for capital, and tenants running costs, arguments are increasingly focused on the overall impact of a more sustainable approach in terms of perceived value (and eg this could include the benefits of a shorter planning approvals process, or higher rental income), than narrow simple paybacks based on the cost effectiveness of individual sustainability features.

- The investor – developer – landlord – tenant relationship. Unless there is a degree of commonality between these key players there will be a discontinuity somewhere in the process where there is a risk that sustainability objectives will be lost as a result of "value engineering" or some other process by just one of the parties. This has been recognized by the British Property Federation and others (eg BPF, 2007).
- The ability of their supply chain (eg designer – constructor – commissioner – operator) to actually deliver sustainable solutions. Key issues here are: the ability of the supply chain to operate in an integrated and informed manner, something that has not always been the norm, (eg see Latham, 1994, Egan, 1998); and the importance of ensuring that for example occupier or landlord sustainability requirements are passed to the supply chain in practice (MOBS - Faber Maunsell, 2005).

Specific sustainability drivers at the Government, corporate, and industry level are covered in the following sections.

National and Local Government Sustainability Objectives and their Implementation

The sustainability agenda and associated priorities are to an extent a political issue that reflects society's wider objectives. In the UK there is a remarkable degree of consensus as to the overall goal of promoting more sustainable buildings in the UK across all political parties in the UK, although with some significant differences in the proposed detail of how sustainability is to be driven forward.

In the UK, and indeed generally in Europe, there is significant political consensus that climate change needs to be tackled. It is seen by many (eg Stern, 2006) as the most important issue facing the world. The level of commitment and consensus on the need to tackle climate change issues means that presently it is the most important single sustainability issue affecting development.

Government commitments and associated legislation is targeted at reducing UK CO_2 emissions by 60% by 2050, and as building related emissions account for 44% of all UK carbon emissions, the sector is seen as particularly important. There are two main regulatory regimes that tackle this:

- Building Regulations (CLG, 2006) which stipulate minimum performance standards for carbon emissions (no longer simple energy use) associated with HVAC and lighting systems, including standards for fabric and minimum efficiencies of individual HVAC and lighting components;
- Planning, where within London (eg see GLA, 2006), the target is for new developments to be able to produce 20% of their energy needs through on-site production from renewable energy sources.

Targets for carbon emissions reduction associated with both Building Regulations (in 2006 emissions reductions were tightened by at least 20% for all building types) and Planning requirements (the target used to be for 10% renewables in London) have recently been tightened, and the Government has signaled its commitment to further tighten standards associated with regulations, and has gone out to consultation with its proposed "Planning Policy Statement: Planning and Climate Change – Supplement to Planning Policy Statement 1" – which will set the planning guidelines for all planning bodies including the GLA.

Because of the geometry of tall buildings – small footprint, and large surface area - both these requirements, and the underlying policy objective to reduce climate change, have major ramifications for tall buildings in the UK.

In addition to statutory standards associated with building related carbon emissions, the European Commission (EC), through individual Member States, is introducing a series of mandatory building energy labels (EC, 2002) and requirements for regular inspection of air conditioning plant. The provision of mandatory energy labels (Figure 3 is an illustration of a possible label) should aid the transformation of the property market by adding value to those buildings with a lower "carbon footprint" because of many occupiers stated CSR priorities.

However the impact that the energy label will have on the property market, particularly with tall buildings, is still an unknown quantity. Although energy labels have contributed to a very significant improvements in energy efficiency associated with white goods, such as fridges and freezers, the exact impact of such labels on the energy performance of buildings in practice is less certain given the more complex nature of the market. However Government commitments to occupy buildings in the "upper quartile" of energy performance may be an indicator of the impact of such labels.

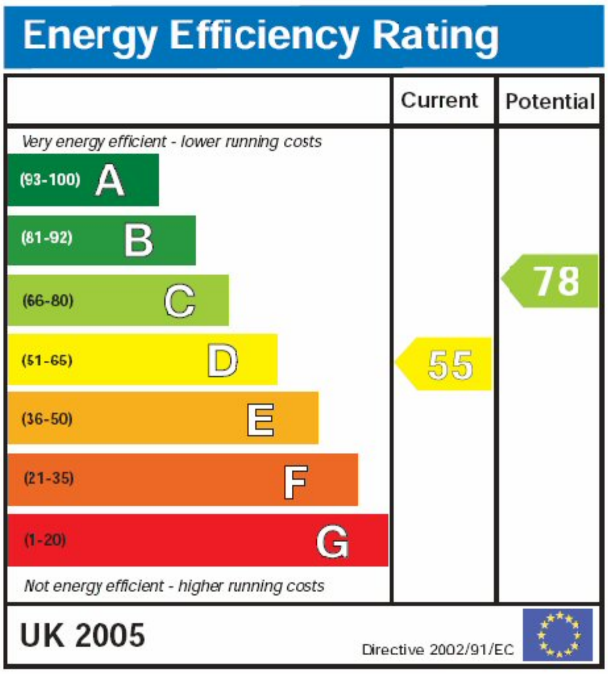

Figure 3. Building energy labels will become compulsory shortly for all building types.

It could be argued that Local and National Government sustainability requirements relating to, for example, energy, water, and waste, are minimum standards, and hence future tall buildings need to exceed current buildings if they are to be deemed to be "sustainable". Government proposals for future requirements have a major part to play in establishing such a market trend, as one of the key market drivers for investors, beyond the ethical investment market, is the perceived risk associated with future legislation.

Market Drivers & Requirements

In addition to issues associated with perceived risks from future legislation there are a number of both clear and emerging market factors that have changed market sentiment in London, and the rest of the UK to placing sustainability issues at the top of the agenda regarding tall buildings. It could be argued that market sentiment now recognizes that sustainability is a key issue both in terms of planning consent, and the value of that building in terms of future rental income. Factors that are driving this sentiment, and dictating the sustainability agenda in terms of sustainable solutions include:

- The BREEAM environmental label (BREEAM, 2007)
- Corporate Social Responsibility (CSR)
- Investor awareness of sustainability as a risk issue

BREEAM, the model for LEED in the USA, has been implemented in the UK for around 20 years. As such it is well established and over time has become the accepted market benchmark relating to sustainability in non-domestic building sectors in the UK. It has reached a degree of acceptance such that very few major developments in London will not have a BREEAM (Building Research Establishment's Environmental Assessment Method) certificate, and the current trend from many developers in London is to require BREEAM "Very Good" (broadly comparable with LEED "Platinum"), or BREEAM "Excellent".

Jointly developed by BRE and Faber Maunsell, most practitioners would agree that BREEAM has been instrumental in developing the sustainability agenda in buildings in the UK, and in raising the bar on an on-going basis to ensure that today's "new practice" becomes tomorrow's "best practice". At the same time, as BREEAM is seen as a measure of a building's sustainability it essentially dictates the sustainability features that are included in a building (Figure 4).

BREEAM has been a hugely positive driver of ensuring a broad range of sustainability issues are considered. It, like other similar schemes, works by providing points under a variety of sustainability issues where specific criteria are met. These points are then added up and the level of certificate depends on the total score.

Figure 4. Canary Wharf development, London

Set a BREEAM "Excellent" rating as part of the design brief.

The list of main headings covered by the BREEAM scheme are:

- Energy
- Transport
- Pollution
- Materials
- Water
- Land Use and Ecology

- Health & Wellbeing
- Management

There are two inherent shortcomings associated with the approach adopted by BREEAM, LEED and other similar environmental labels in terms of delivering sustainability outcomes in practice:

- Because the focus in obtaining a certificate at a particular level is to score a certain number of points, in many instances measures are undertaken that allow the score to be met in such a way as to limit overall costs. Because of this key sustainability issues that are important for a particular building may not always be fully addressed. This is recognized by the operation of the scheme in that it looks to change the number of points associated with specific issues over the time so as to reflect "best practice". As an example of the potential pitfalls of such a scheme, in an early version of BREEAM it was possible to achieve a BREEAM "Very Good" score whilst failing to meet statutory minimum requirements for energy performance.
- Whilst BREEAM awards points for ensuring that features are in place that will allow the building to be managed more sustainably, by their very nature schemes such as BREEAM are focused on design / construction rather than operation in practice. For a building to be truly sustainable it needs to be both constructed and operated with sustainability issues in mind, and not just with sustainability measures being put in place. The potential introduction of mandatory public display energy certificates (the Energy Performance of Buildings Directive does not necessarily require the public display of energy performance in non-Government buildings) based on actual energy use may offer a way of tackling this issue at least in part.

In England & Wales the Government has recently adopted very aggressive future targets for homes assessed through its Code for Sustainable Homes (CLG, 2007), which is similar in nature to BREEAM. The approach used for the Code for Sustainable Homes is likely to be mirrored by the proposal that industry leads the development of a non-residential version of the code (GBC, 2007).

Corporate Social Responsibility (CSR) is seen as an increasingly important driver, particularly for major corporates. CSR is increasingly linked to overall perception of "brand" and with that customer loyalty, and employee recruitment & retention. As such tenants are increasingly looking to occupy more environmentally sensitive buildings. The major constraint at present is the limited availability of such buildings.

Issues associated with implementing sustainability measures in tall buildings

Although there are a number of clear drivers as to why sustainability will need to be considered in future tall buildings there are a number of issues associated with the implementation of such measures that need to be recognized so that sustainability can be properly tackled.

This paper takes the view that many of these barriers are "institutional" rather than technology focused. Key issues are the:

- Regulatory and planning environment framework.
- Investor – Developer – Landlord – Tennant relationships, which is particularly important for tall buildings because they entail significant investment, and are usually multi-tenanted.
- The nature, and interaction, of the supply chain providing design – construction – commissioning - operational services.
- Ability of the construction industry to rapidly identify and implement "best practice", whilst there are relatively few exemplar sustainable tall buildings in the UK.

Regulations and planning are separate systems in the UK. Regulations look to ensure minimum carbon emission standards associated with HVAC and lighting requirements and efficiencies of individual buildings, whilst the planning regime is aimed at taking a broader view of sustainable development, and plays a particular role in promoting the uptake of renewables (hence the 20% renewables target for new developments in London). The two regimes do not interface well at present. In both planning and building regulations there are issues associated with actual compliance with requirements (CLG, 2007).

The two regimes have different remits. The Building Regulations are developed so as to ensure that minimum carbon performance standards, once the social cost of carbon emissions is included, are set to be "cost effective" in terms of energy savings payback against capital cost from a national perspective for individual buildings (CLG, 2005). Current planning requirements (eg see GLA, 2006) require (see figure 5) that the investment in renewable energy is based on affordability for the development as a whole (ie not the cost effectiveness of the individual renewable energy technology), and the technical availability of renewable energy supplies.

It could be argued that the planning regime in practice is focused not just on reducing carbon emission, but from a wider sustainability perspective on creating a market for renewable energy technologies, and so to develop the skills base in the industry and to reduce future costs. However the net effect is that Regulations and Planning, although both promoting a reduction in carbon emissions, are doing so from a different cost base and perspective, and hence encouraging different solutions.

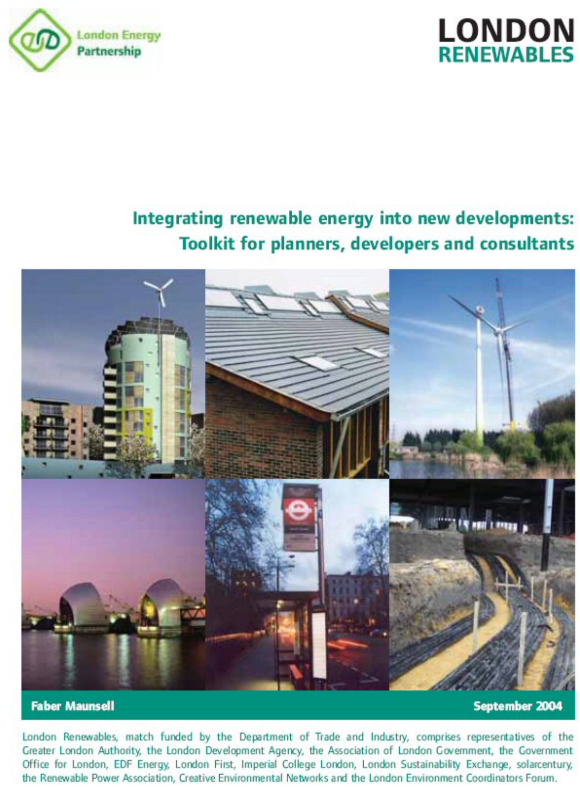

Figure 5: The London renewables toolkit developed for GLA to allow planners and developers assess site-based renewables.

Some have argued that the most cost effective manner of reducing UK CO_2 emissions should always be encouraged so as to reduce the impact on the economy as a whole. From experience of integrating renewables in many buildings in London, from a purely short term economic perspective this would usually mean that if the definition of "site based" (ie the zone where renewable energy would need to be supplied from) were to be extended to the UK as a whole, then the outcome would often be to support the development of renewable energy schemes such as wind farms elsewhere. However it is recognized that there are numerous costs and benefits of such an approach, and that at present the planning system does not allow for what might be seen by some as a form of offsetting.

Operating tall buildings in a more sustainable manner

Although there are a number of clear drivers as to why sustainability is required for tall buildings as part of design and construction, it is recognized that an issue will always be how to operate existing tall buildings in a more sustainable manner, and how to ensure that future tall buildings will be operated in a more sustainable manner.

In existing tall buildings, purchasing and service procurement can have a major impact on sustainability. There are two sides to sustainable procurement for most businesses:

- As providers of goods and services, and
- As clients for goods and services.

Sustainable procurement should consider environmental, social and economic issues and can be applied as a three-stage process:

- Negative screening – avoid products and services that are known to have negative impacts on the environment, human health and wellbeing.
- Sustainable preference – prefer products and services that can show they are addressing their negative environmental, social and economic impacts effectively and demonstrate net positive impacts in some areas.
- Active engagement – accepting that products and services cannot always be procured on the basis of sustainability preference alone, work with suppliers and service providers to improve their sustainability performance.

A series of guidance notes and tools are available arising from a series of industry led projects looking at how best to manage and operate existing buildings in a more sustainable fashion (MOBS, 2005). A brief summary of this work is that it highlights the need for sustainability priorities associated with the building's landlord, and in particular the building tenants, being passed through their supply chain, and for there being a process of transparent reporting on outcomes associated with these sustainability priorities. The landlord tenant relationship is clearly instrumental here, but the issues for tall buildings are simply a more complicated mix of the issues for multi-tenanted buildings as a whole.

Specific win-win sustainability opportunities for tall buildings

There are a number of generic opportunities to make tall buildings more sustainable, with many of the issues identified in the Corporation of London report (Pank, 2002) remaining applicable.

A generic approach is to require a high BREEAM rating, such as "Excellent" and at least meeting, and preferably exceeding carbon performance and on-site renewable targets. As a brief summary, some issues that apply particularly to tall buildings up to "shell and core" stage are:

- Early development of common sustainability agenda across Local Government, investors, developer, and likely landlord and tenants.
- Design structure to use a mix of steel and concrete that provides structural strength and flexibility, but using various "green guides"

(eg Anderson, 2005)) to help select materials with the lowest environmental impact. Smart design and construction practices that minimize material use and waste are clearly a "quick win".

- Consideration of structure to be adaptive to anticipated climate change. Some buildings (UKCIP, 2005) are already being developed so that they will be able to cope with future climate change. The European Commission (EC, 2007) has also identified the future market opportunity for climate adaptive buildings (figure 6).
- Ensure excellent control of solar gain, and potential use of natural ventilation strategies
- Consider the opportunities to tie in with local energy service provision so as to look beyond the renewables opportunities available on-site.

The sustainability agenda in London, and much of the UK, is increasingly dominated by planning and regulatory requirements and those of the environmental labeling scheme BREEAM.

Experience – Reducing carbon footprints of future tall buildings

Energy efficiency HVAC, lighting, transportation systems, and small power use equipment within buildings (computers etc) and fabric measures that protect against excessive solar gain or high thermal transfer through the fabric are inherently the best way of reducing a building's carbon footprint. On-site generation of power – for example associated with the use of combined heat and power (CHP), or tri-generation (power, heating, and cooling), can also provide significant carbon reduction benefits.

The GLA requirements for buildings (GLA, 2006) stipulate consideration of CHP and of site-based renewable energy. Given the costs of including on-site renewables this requirement has the benefit of further tightening the requirements for the building to be energy efficient in its operation.

A number of renewable energy technologies can be included as part of site development, but in the case of tall buildings many have relatively limited potential. A brief summary of some of these technologies in terms of their potential application in tall buildings, based in part on actual experience, is summarized in the following paragraphs:

Photo-voltaics (PV), the conversion of solar energy to electricity, is a potential opportunity for tall buildings given their skin-to-volume ratio. In the UK the potential for PV is somewhat limited by the climate, and generating costs / kWh are relatively high and uneconomic if simple paybacks are used. PV systems have evolved rapidly in recent years and some very high efficiency systems have now been demonstrated in laboratories. Practically there is a direct link between the efficiencies of the various commercially available systems and their costs. Although in the UK electricity produced from PV systems is non cost effective on a simple energy generation payback basis. Other factors such as subsidies, displaced cost of fabric elements, and the value of PV as demonstrating commitment of a company to a greener future can tilt matters in favor of PV. In tall building structures PV arrays would be expected to be building integrated, and so largely vertical whereas for optimal electricity generation they should be tilted. This reduces their effectiveness a little, but less so at high geographic latitudes than elsewhere. However various PV system options are available, and the generation of electricity from PV at least coincides with periods of potential overheating from solar gain. PV technology continues to evolve rapidly, and costs fall, and although electricity produced from such systems in commercial low rise applications tends to generate only a small proportion of a building's energy use, the skin-to-volume ratio associated with tall buildings might improve on the levels of energy produced as a percentage of total energy consumption.

Wind energy, where a number of innovative approaches have been proposed to overcome the restrictions inherent with the use of wind energy because of the low footprint of the building (eg ZedFactory, 2007, Pank, 2002). There are two main options here. First to include a wind turbine as an integral part of the building fabric - although no such systems are yet operational to the authors knowledge. Second is for the turbine to be mounted between buildings (the nearing construction Bahrain World Trade Centre), or even on the top of buildings. Turbines benefits from the relatively high wind speeds at altitude, although the building design or wind energy resource needs to be such that the turbines can be operated efficiently. In both instances the basic economics of either losing space and / or having to reinforce structure need to be considered as well as the other costs and benefits of using a wind turbine. Although the same issues as with PV apply in terms of the different factors affecting cost effectiveness, and the energy generated from wind turbines in theory can be significant (Bahrain World Trade Centre wind turbines are estimated as producing 11-15% of total energy needs in press (World architectural press, 2007)). Anecdotal evidence in the UK press indicates that the energy performance of small building integrated wind turbines in the UK has been less impressive than some manufacturers / designers imply because of issues associated with the actual level of wind resource and the impact of turbulence on efficiency. Of note is the observation that it is not just necessary to incorporate a wind turbine (or other renewable energy technology), but that these technologies need to be installed, commissioned, and maintained in an appropriate fashion. Arguably such processes can be expected to be carried out more effectively where the wind generator is large.

Heat pumps, which use the ground, or some local supply of water, as a source of heating, cooling, or to maximize the efficiency of conventional cooling systems has potential depending on the nature of the available resource, but the resource is again limited by the available footprint compared to the volume of a tall building. Where water is extracted from the ground, in the UK an abstraction license is required and experience suggests that such licenses are only being provided for typically a 20 year period, so implying a degree of risk to the building owner that the license will not be renewed.

Solar water heating has some very limited potential, but the requirement of most tall buildings is for electricity for equipment, and for cooling.

Fuel cells – which typically convert hydrogen to electricity. Here the issue is the source of the hydrogen. In some proposed developments in London the source of the hydrogen is natural gas which is broken down on site to give hydrogen and carbon dioxide. Although such a source of hydrogen is therefore not free of carbon dioxide emissions, because of the high generating efficiencies of fuel cells (60%) the overall result is theoretically electricity produced at a lower carbon dioxide burden than the current UK national grid. Fuel cells become a true renewable only if hydrogen is first produced from a renewable resource, eg through electrolysis. Most analysts agree that because of costs, the so-called hydrogen economy is decades away. Fuel cells are also currently very expensive, and can usually only be justified if a wide range of other value benefits (eg shorter route to planning consent) are considered. Because of their economics, there are only a handful of significantly sized fuel cell systems currently in use globally.

Biomass, including the use of biomass to power tri-generation systems is seen as the solution to many developments where low or zero carbon solutions are favored. Although some European countries (eg Austria) make considerable use of biofuels, experience within the UK, especially when combined to the use of tri-generation (combined heating, cooling and power production) is proposed, is very limited and for certain ranges of generation capacities, unknown. Biomass is also not zero carbon because of energy used in its production and transport, and its use in city centers has an implication on air quality – which is another sustainability issue that can be expected to limit its use in tall buildings. One issue common to all bio-mass schemes is the need for a dependable supply chain.

Integration of tall buildings with 3rd party energy centers based on renewable energy sources has been proposed, and it could be argued that the GLA requirement of requiring communal heating schemes in apartments is about encouraging a city wide network of combined heating, cooling, and power production facilities. Some have also postulated that the rejected heat from tall buildings be harnessed for use elsewhere in the city – although there are clearly technical and cost issues associated with this. At present there are a number of institutional barriers and a perceived lack of market willingness, for such an approach. However given the geometry of tall buildings, national targets for carbon emission reduction, and the current planning targets for on-site renewable energy, this may be one of the best options for tall buildings moving forward.

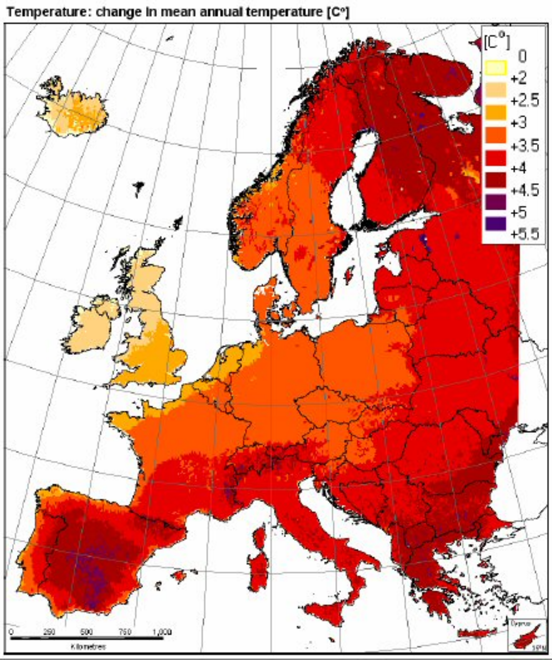

Figure 6. Climate change predictions (source EC, 2007) indicate that buildings built today will need to operate in a different climate in future years, and so need to be "climate adaptable". Risks associated with climate change are becoming increasingly important to investors.

Conclusion

Sustainability is a concept that involves taking a long term view of environmental, economic and social issues. It should be recognized that the sustainability agenda varies across the world, and that it continues to evolve to reflect political, economic, and business priorities. In the UK as a whole, and in London in particular, sustainability is a major requirement for tall buildings. Given:

- Very aggressive national carbon emission reduction targets, which are shared by all political parties;
- London's sustainability policies relating to the use of on-site renewable energy sources;
- The geometry of tall buildings;

The greatest single sustainability challenge for tall buildings it could be argued is the reduction of their carbon footprint.

Major sustainability drivers in the UK are: current and proposed legislation aimed at making buildings more sustainable; long term risk management from major investors; CSR; and market sentiment amongst developers that, particularly for high profile buildings, now requires tall buildings to be ever more sustainable using the BREEAM assessment methodology.

For tall buildings to be more sustainable, in practice it is necessary:

- To align sustainability priorities across local government, investors, developers, landlords, and tenants;
- For the design, construction, and operational supply chain associated with the building to be required to meet those sustainability objectives.

In the past these priorities and capabilities have not always been aligned.

Tall buildings offer significant challenges regarding the implementation of some sustainability priorities because of their size, and relatively small footprint, however a case can be made that they offer a more sustainable approach to development if a broader picture of urban development is considered.

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