Sustainable Tall Buildings – Fact or Fiction?

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Summary

The words sustainable, green and environmentally friendly are used by many to promote their buildings. All buildings, high-rise and low-rise deep plan, could be more sustainable in terms of their design, the construction process, their operation and the impact on the community. After reviewing some of the ways to achieve this by using renewable energy sources such as wind turbines and photovoltaics, designing very low energy demand buildings and the economic and social issues associated with developments, this paper examines whether tall buildings can be truly sustainable.

1.0 Introduction

There is no doubt that sustainability considerations need to be incorporated into building design for both legislative and moral reasons. At the same time, high-rise buildings are required for sound commercial reasons such as, in the City of London:-

- A requirement for more office accommodation
- Their efficiency with respect to land use
- The ability to serve many people from existing transport and services infrastructure
- Occupier demand for prestigious locations.

This leads naturally to a demand for sustainable tall buildings to satisfy both of these requirements. The issue is then can they be built, and if so what features do they have?

1.1 What is Sustainable Development?

There are many definitions of sustainable development; the most popular is from the Brundtland Report[1] "Meeting the needs of the present without compromising the ability of future generations to meet their own needs."

The UK Government's strategy is centred on ensuring "A Better Quality of Life"[2] for everyone, now and for future generations to come. It has four key objectives:-

- Maintenance of high and stable levels of economic growth and employment;
- Effective protection of the environment;
- Prudent use of natural resources;
- Social progress, which recognises the needs of everyone.

Others may choose to define sustainable development differently:

- The Natural Step System Conditions[3]
- William McDonough's fractal triangle design diagram.[4]

The Government's key document on Sustainable Construction is "Building a Better Quality of Life"[5].

In addition to the Government, clients and designers defining the sustainability agenda, the City has a role. Socially Responsible Investment (SRI) funds are only a very small proportion of the total investment portfolio, but they are currently growing rapidly. And the analysts employed to manage these funds will have their own definitions of sustainability.

1.2 What is a Tall Building?

Tall buildings are often regarded as being greater than 20 storeys. However, a tall building is really defined with respect to the height of the surrounding buildings. If the majority of the buildings in a city are 3 or 4 storeys, then a 12 storey building would be considered tall. In locations such as New York or Hong Kong, a tall building is 40 plus storeys high. This paper examines primarily tall buildings in the UK, i.e buildings of 20 storeys or more.

The tall buildings considered here are assumed to be residential, offices, retail or hotel accommodation, with a requirement for building services, not industrial processes or multi-storey car parks.

1.3 What is a Sustainable Tall Building?

A sustainable building is one in which the design team have struck a balance between environmental, economic and social issues at all stages – design, construction, operation and change of use/end of life. This may involve greater emphasis on different aspects at different stages in the building's life, for example energy for building services and transport of building users and occupants and associated CO_2 emissions are key to sustainable operation.

A purist's definition of a sustainable tall building is one which emits no pollution to air, land and water, and can be economically occupied throughout its design life, whilst contributing positively to the local community.

So the challenge is to achieve sustainability and build high-rise buildings. There are specific aspects where tall buildings are less sustainable than low rise, e.g. in their requirement for energy for vertical transportation, but there are others where they undoubtedly have advantages e.g. utility of land in densely populated urban areas. So the advantages need to be capitalised on, and the disadvantages minimised or mitigated.

Design teams should work with their clients to develop a vision, and challenge the reasons why that vision can't be realised (there are bound to be some good commercial and practical reasons) rather than start with a conventional design and apply small tweaks. In this way, our journey towards buildings that are more sustainable will be quicker.

1.4 Measuring the Sustainability of Tall Buildings

There are a number of environmental assessment processes, design tools and key performance indicators for sustainability, although none of them are specifically intended for high-rise construction. These include the Building Research Establishment Environmental Assessment Method (BREEAM)[6], the Civil Engineering Environmental Quality and Assessment Award (CEEQUAL)[7], ARUP's Sustainable Project Appraisal Routine (SPeAR), the DTI's Movement for Innovation (M4i)[8] indicators, and DETR's (now DEFRA) "Quality of Life Counts"[9] indicators.

These schemes allocate different weightings to the significance of issues, and thus the same building will score differently depending on which system you use. For example, a design that has a very low operational energy may result in a high score in one scheme, whereas in another scheme this factor might be given less weighting, and so result in a lower overall score. The Corporation of London document "Tall Buildings and Sustainability"[10] reviews this topic in more detail.

2.0 Location, Location, Location…

We all know the expression location, location, location. This is a useful way to remind us that sustainable development has at least three components:

- The impact of location on economic issues (availability of land, alternative accommodation and labour; costs of land, building costs; cost of energy supplies; quality of neighbouring developments and desirability; future flexibility)
- The impact of location on environmental issues (quality of land; biodiversity; transport links for construction workers, materials, building occupants and visitors, congestion, air quality, energy requirements, opportunities for energy sourcing) and
- The impact of location on social issues (health & safety; quality of indoor environment; degree of control over the indoor environment; impact on neighbours; impact on the community).

3.0 Economic Growth and Employment

Economic considerations are vital with any form of development. The UK Government sees sustainable development as a key to sustained economic growth and therefore will view any new building against the backdrop of economic success. Buildings or the opportunity to develop can attract employers and develop economies. One of the main drivers for local authorities in the UK to construct new buildings is to generate a sustainable community.

So the first issue is the economic viability of the building. A building that cannot be let may be demolished, irrespective of the design life, undermining considerations to reduce its energy in use etc. Certain building types are more lettable than others, and for a given building site only certain forms of building are viable. On the other hand, developing in an "undesirable" area, and contributing to its regeneration, can be a major contribution to sustainability in its own right.

Another consideration is "Is the market really ready for sustainable/green buildings?" or would such a building limit your potential market as it would be considered too wacky/risky by many? Building designers may be constrained by market forces more than by technological issues.

City centre developments in general are taller than those in a rural environment mainly due to the cost of the land. A brownfield site is likely to be more costly to develop, but there may be substantial cost savings in terms of the existing provision of public transport, and no need to provide parking for occupants and visitors. On the other hand, there may be constraints on the construction process itself in terms of hours of access and working, congestion, and the ability to operate Just in Time materials delivery.

The location of a building will also determine the cost of materials, both in terms of elemental costs and total building costs.

Where the building is situated can also be a significant factor in the ability to attract and retain a workforce, both in terms of ease of access and the desirability of the area, e.g. some areas of London are very desirable with great public transport links.

Some types of development may be regarded as more sustainable than others. The benefits of converting existing buildings rather than demolishing and rebuilding them in terms of reduced materials use and waste will need to be balanced against the opportunities for designing a new building with low energy requirements, and which can utilise renewable energy. Densities often have to be reduced with new developments, increasing the land take and impacting on the economics.

The sustainability can also be improved through maximising the utilisation of the building. This can be through long hours of operation, or the provision of services, which can be shared with others –, in the same building, in the same company or in the local community (e.g. sports, conference and canteen facilities).

Issues that are specific to high-rise include:

- The cost of land (likely to favour tall buildings)
- The limit on the availability of land (favouring high rise development)
- The ratio of nett to gross floor area (likely to favour low-rise, due to space requirements for vertical risers, lifts etc)
- The cost of construction (likely to favour low rise developments, due to the costs of cranes, days lost on site through windy weather etc)
- The cost of maintenance – ease of window cleaning, redecorations and repairs will favour low-rise developments.

4.0 Land-use, Ecology and Pollution

A city centre site is often a brownfield site and therefore regarded as more sustainable than using a greenfield site. One of the main drivers for tall buildings is to minimise the use of land. If a city centre developer wants to minimise the impact on land use, the only way to expand is upwards. Therefore, high-rise buildings are likely to be the preferred option in dense urban areas.

There is a generally held view that if a site is a brownfield site, developing it will improve it, whereas developing a greenfield site will be detrimental however sympathetic the development is to the surrounding landscape. Nevertheless, if there are good commercial reasons for developing on greenfield sites, the important issue is to capitalise on the advantages provided. These include the opportunity to build mixed-use developments of housing and business parks e.g. the Cambourne scheme in Cambridgeshire, better prospects for use of renewable energy and daylighting, opportunities for rainwater collection and on-site reed beds for water filtration, and planting to encourage indigenous species.

Tall buildings in an urban context can suffer from more problems with over shading and rights to light, can cause or be the cause of glare, and can create wind tunnels. However it should be possible to overcome all of these issues through good design.

Pollution can be thought of in terms of emissions to air, land and water. The most significant emission to air is carbon dioxide, which is addressed under energy sources and transportation. Emissions to land are mostly solid waste materials, which are discussed in section 5.4. Regarding water pollution, this is most likely to occur during the construction stage as a result of spills and water run-off. Good practice can overcome this for any building form. Action can also be taken where there are large areas of car parking say, to ensure that there surface is permeable and so reduce incidence of flooding, and at larger sites, water can be treated on-site as noted above.

5.0 Prudent use of Natural Resources

5.1 Energy Demand

Energy demand is not the major issue within a sustainable building; it is how this energy has been generated. The major Government driver is to reducing greenhouse gas emissions and in the short term any reduction in building energy demand contributes to this aim.

Hours of occupation impact on the suitability of different HVAC strategies, so that Combined Heat and Power (CHP) may be well suited for a 24-hour operation building, but such occupancy may prohibit natural ventilation with nighttime purging. Indeed, natural ventilation of offices will be harder to achieve in the taller high-rise buildings, due to increased wind speeds and noise associated with openable windows at height.

The need to install lifts in tall buildings will increase energy demands, but the daylighting potential is better than in low-rise deep plan buildings. There are always trade-offs between different environmental considerations associated with supplying the energy used within a building, but low energy use is a fundamental key to sustainable development.

5.2 Energy Sources

All buildings in the modern world use energy, and modern culture emphasises the electronic age. The architectural, engineering and construction industries are also advocating e-construction. The Movement for Innovation (M4I) have many demonstration projects looking at rethinking the construction process, and the use of electronics to aid information flows would advocate that more and more buildings require electrical energy. If a building is then to be truly sustainable that energy should be generated on site tapping into natural energy sources.

The key to having a net zero CO_2 building is the ability to create your own energy on site. This is influenced by the geographical location, as well as specific site constraints. For example, if a solar array were to be placed on a building in London this would only generate half the energy of the same collector area situated in Southern California. However, even in the UK, there is still great potential to capture the massive solar resource with vertically mounted building integrated photovoltaics.

Certain locations will be able to benefit from wave energy, and a coastal scheme in the UK could easily generate four times the energy of a similar scheme off the coast of equatorial Africa. There is believed to be over 5000 times more energy in wave and tidal energy than we currently use in the world.

In the UK, we are ideally suited to capture a huge wind resource, either for offshore wind generated grid electricity or locally generated electricity from on-site wind turbines. Wind turbines can exploit higher wind speeds around tall buildings or at the top and can be designed for low noise emissions Different types are suitable such as the ducted wind turbines used on the Lighthouse project in Glasgow and the H-Darrieus vertical turbines. The recently published report on “Wind Energy for the Built Environment”.[11] funded by the European Commission looks at the integration of wind turbines into tall buildings.

A tall building can take advantage of renewable energy sources in the same way that a low-rise structure can, but the choice of source might be different. There are likely to be more opportunities to use wind energy in high-rise buildings, and there may be unrestricted solar access depending on the proximity of neighbouring buildings, but there will be less space to install a rooftop solar array. Bill Dunster’s Flower Tower prototype Eco-functional tower block incorporates a vertical-axis wind turbine and this combined with photovoltaic panels installed on the roof and the wall elements make the building largely self-sufficient in energy.

The Mayor’s draft energy strategy for London[12] has targets to help meet the UK nationwide target of 10 per cent renewable energy obligation by 2010 and looks at achieving a 20 per cent level by 2020. Domestic hot water can easily be generated from rooftop mounted solar plate exchangers or evacuated tube solar thermal collectors.

Alternatively, with either built form, “green energy” can be purchased, leading to no or low emissions from electricity consumption. This approach may favour electrical solutions rather than gas for heating and hot water.

5.3 Operational and Embodied Energy

Many of the low energy buildings in the UK use thermal mass and natural ventilation solutions to produce low operational energy. However with very low operational; energy buildings, their embodied energy is a much more significant part of the total. It can be argued that in cooler climates mechanical ventilation systems can be more economic than naturally ventilated solutions due to the ability to recover heat from the exhaust air to preheat the fresh air. The local climate of a development really determines the type of solution that is required, and more and more people now talk about the holistic approach within the sustainable development debate.

The software package from the BRE called ENVEST has “ecopoints” to help benchmark the environmental performance of buildings. This is an excellent starting point, and provides the opportunity to evaluate different built forms. With a steel or concrete frame structure ENVEST will often favour low-rise building forms. Timber constructions will provide the lowest embodied energy and this construction form is not applicable to high-rise buildings.

The most important factor in materials selection has to be functionality. Therefore tall buildings face more constraints than low-rise developments. Both have the potential to use modular components, reducing time on site, and development costs.

Designing to avoid the need for bespoke components should be more efficient, and the use of standard sizes will reduce waste.

For low impact materials, distance travelled to site can be a key component of their overall impact.

Many man-hours have been spent researching embodied energy within materials, but is this really the best environmental indicator for selection of materials? For instance aluminium requires large amounts of energy to create it, but this energy may be from a totally renewable source i.e. hydro, and the material is inherently recyclable. We need an environmental impact indicator that looks at how the material has been created and whether the material ultimately can be easily recycled.

Another issue is the boundary taken when looking at the emissions. For example for cement, if the factory generates energy on site, are the emissions from producing the cement being compared on the same basis as those from another product, where the electricity is imported and the emissions occur elsewhere?

5.4 Waste

The Government's waste hierarchy promotes

- Reduction
- Re-use
- Recycling

The use of reclaimed and recycled materials is discussed in detail within the joint CIRIA/DETR Publication on this subject[13]. Opportunities exist in buildings for recycling of waste, but space for compactors and waste segregation at ground level may be more restricted in high-rise developments.

5.5 Transport

The debate here is more of a rural verses urban debate than a high-rise verses low-rise.

The amount of miles travelled during the construction phase – by contractors, the design team, raw materials, recycled materials and waste materials can be impossible to specify and monitor. The aim must be to run full lorries, either by combining deliveries from several suppliers, or linking deliveries and waste collection.

A more significant issue is the movement of building occupants and visitors. Is a town centre site with good public transport links, drawing staff in from a 50 mile radius, more sustainable than a Greenfield site, where individuals commute by car, but travel only 5 miles a day? And the greenfield site may provide the possibility of providing an LPG station, reducing emissions from personal as well business journeys.

Being in a town centre maximises the opportunity for combining journeys, and freeing up leisure time. Lunch hours and journeys to and from work can be utilised for errands such as shopping, banking, and going to the library or dry cleaners so minimising travel to work may result in additional journeys at other times. Clearly access to data on personal travel is very difficult to obtain without individuals keeping travel records.

Finally, there are options for both energy use and transport to purchase carbon credits to offset the emissions associated with the development.

6.0 Social and Ethical Issues

6.1 Sustainable Communities

The sustainable community is at the heart of the Government's strategy on sustainable development, and sustainability has an unavoidable ethical dimension. During any building procurement process, the social needs of the building's neighbours will be high on the agenda, even if this is just a means to an end in getting planning permission. What can the local community gain from the creation of a new building?

As noted above, any development provides an opportunity to provide facilities for the surrounding community, and it can be an opportunity to employ and, if necessary, train the local workforce, to contribute both in the construction phase, and in delivering the building's primary work function.

There are also opportunities for engagement with the local community – from school children painting hoardings, to educational trips and work placement opportunities.

What specifically can high-rise buildings contribute? For those working in and visiting them, there can be the advantages of a prime location in terms of establishing a centre of excellence, transport links, and amenity. There is also the opportunity to sustain in-house catering, banking and sporting facilities as a result of the number of people in one building.

6.2 Health and Well-being

During the construction phase, a high-rise building may take longer, increasing the disturbance to neighbours.

A number of health and safety issues can also be raised, relevant both to occupants and visitors, and to neighbours. The majority of construction accidents occur as a result of falls both from a building and onto someone. Clearly there is a bigger risk of this associated with building taller buildings.

There are also issues associated with means of escape following the threat of or actual fire, earthquake, act of terrorism or extreme weather condition. Not only is it an issue of the height of the building, but also the number of people in one place at one time. Perception of risk, even if misplaced, can be a significant factor impacting on well-being.

Following the recent terrorist incidents in New York and other attacks on tall buildings, their vulnerability to this sort of attack has been highlighted. As a result, workers and visitors may feel unsafe in high-rise buildings, which is a new issue for designers to face. Insurance premiums may also reflect this, another factor to be taken into consideration when determining the economic viability.

Positive aspects relating to a sense of well-being associated with all building types are the availability of daylight, connection with the outside world, and the view. The ability to control the immediate environment also improves overall satisfaction. In high-rise buildings, whilst there may be advantages in terms of daylighting and views out, openable windows may not be possible on safety grounds or due to wind effects.

7.0 Conclusions

We have discussed a wide range of Economic, Environmental, Resource and Social issues, illustrating ways to improve sustainability in all building types, and drawing out, where relevant, the opportunities or constraints applicable to tall buildings.
There is no definitive answer - all buildings could be more sustainable, although certain building forms are inherently more sustainable than others. Selection of the site plays an important role in making any building sustainable. Therefore in some cases, the debate is more about rural vs urban sites.

The key to achieving high quality sustainable buildings is to look at the ideal and work back, rather than our traditional approach of an incremental improvement on the last building we were involved with. Technology is changing rapidly and the blue sky thinking of 10 years ago can now be mainstream economic construction.

Tall buildings can be totally sustainable; the barriers are principally economic and social rather than technological. Economic barriers include capital costs for renewable energy sources and market acceptability, whilst social considerations include visual impact, novelty and safety.

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