Lessons for the Application of Renewable Energy Technologies in High Density Urban Locations

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ABSTRACT: This paper examines the commercial and construction-level applicability of a range of renewable (low or zero fossil energy) technologies to a project comprising 5 No 100 unit apartment blocks of new high density urban residential development. The paper addresses the level of carbon reduction compared to capital costs of all measures compliant with current British sustainable development planning policy. The paper sets out other non-planning compliant strategies in terms of carbon reduction compared to capital cost to determine if a prescriptive target setting policy approach leads to the most effective use of capital in achieving carbon saving. The paper also examines the architectural and ongoing building management implications of successful integration of such technologies, as well as the longer-term life-cycle considerations of the different technologies and the implications on life-cycle costs. The paper also makes firm suggestions as to the appropriateness of on-site methods of renewable energy generation compared to an auditable investment approach to off-site renewable energy generation.

Keywords: renewable energy, density, planning policy

1. INTRODUCTION

This paper is set against the background of the present planning policy requirements operating in the Greater London Authority (GLA) area of Britain, which require building-related carbon dioxide (CO_2) reduction measures beyond the British Building Regulations requirements applicable with effect from April 2006 to be put in place on all new major developments. The paper also sets out the derivation of equivalent planning policies requiring the provision of renewable energy within new developments.

The paper explores whether a prescriptive Planning approach to the reduction of CO_2 emissions leads to the greatest carbon saving from a given capital expenditure. This is approached by considering a case study of a new development of 5 blocks of 100 apartments in a dense urban riverside location. The capital cost and carbon reduction achieved of all planning policy compliant options is compared against the capital cost and carbon reduction abilities of other strategies, not planning policy compliant.

The paper also tests whether prescriptive planning policy regarding the need for on-site integrated renewable technology is the most capital cost effective carbon reduction approach compared to other auditable means of providing development-linked offsite renewable energy supplies.

Whole life costing issues have not been quantified but are described against some options along with particular constraints of renewable technologies or combinations of technologies with regard to architectural form and building management relevant to the chosen case study.

2. PLANNING STRATEGY FOR SUSTAINABLE HOUSING

In the UK, the Government asked Kate Barker to review housing supply in the light of an apparent shortfall of new homes and a lack of affordable homes for young people to gain access to home ownership, seen as a measure of UK society's wellbeing. Her resulting report [1] and the Governments response to it make clear that the rate of delivery of new homes needs to increase (to some 200,000 per annum, from current figures of around 150,000). However, the UK Government also desires a large proportion of these additional homes to be on brownfield land to avoid urban sprawl and satisfy the requirements of "sustainable" communities. The 1999 Urban Taskforce report [2] demonstrated that housing density is a key factor in sustainable communities, as critical mass of numbers supports (most importantly) mixed use amenities, and new or improved public transport access. Density allows certain criteria for the "walkable" neighbourhood to apply. For example, in the UK BREEAM sustainability assessment system it is measured by living within 500m of a shop or public transport, and 1000m of a local school and other amenities. In London, the Mayor's London plan [3] clearly set out a matrix of permissible densities based on access to amenities and public transport, ranging from 30-50 units per hectare (in very suburban locations) up to 430 units per hectare in sites within 10 minutes walking distance of a town centre. As a result of these guidelines, land values and developers aspirations give rise to expectations in urban situations of very high densities.

At the same time, CO_2 reduction has become a major policy and regulatory driver. Having been a signatory to the Kyoto accord, the UK has supported EU emissions trading and seeks to extend this from 2006. UK Government has committed to a 20% CO_2 reduction by 2010 (although currently estimates it will fall short of this target) and has a number of reviews ongoing to define ways to achieve this, for example the 2006 Energy Review [4] and the Review of the Economics of Climate Change.

The EU Energy Performance of Buildings Directive (Article 7) [5] supposedly transposed into UK legislation with effect from January 2006 clearly states that necessary measures shall be taken to ensure that new buildings meet the minimum energy performance requirements and (for new buildings over 1000m²) shall ensure that the technical, environmental and economic feasibility of alternative systems is considered and taken into account before construction starts. For example, decentralised energy supply systems based on renewable energy and district or block heating or cooling supported by Combined Heat and Power (CHP) are required to be considered.

The EU Energy Performance of Buildings Directive has partly been transposed into UK law in the 2006 Energy Efficiency Building Regulations (Part L) but it is only through planning policy that the feasibility of alternative systems has been requested. Planning Policy Statement (PPS) 1 on Delivering Sustainable Development [6] and PPS 22 on Renewable Energy [7] allow for local planning authorities to put in place policies to promote the use of low carbon and renewable energy technologies. Many statutory authorities have put in place the above policies at a local level. The UK Government has recently announced the preparation and intention to consult on a new Planning Policy Statement which sets out how it expects participants in the planning process to work towards the reduction of carbon emissions in the location, siting and design of new development – this would effectively strengthen the policy from a local aspiration to a requirement.

In London, the Mayor's Energy Strategy accompanying the London Plan (2004) states that the Mayor will expect planning applications referable to him to generate sufficient energy (power and heat) from renewable sources on-site to offset 10% of the CO_2 emissions of energy used (after energy reduction measures, including fossil fuelled CHP installations wherever viable, are taken into account). This is generally termed the "10% renewables" requirement.

The London Plan is now being reviewed for a consultation draft to be published 2006-7, and further documents are expected to be adopted formally as Supplementary Planning Guidance (SPG). This is likely to include the current London Renewables Toolkit [8], which will inform a forthcoming SPG on Renewable Energy.

In practice, we find that many of the options to deliver the 10% renewable energy demand on-site present technical or supply chain difficulties. Also, where the Mayor uses his powers of referral, viable energy efficiency measures including CHP are called to be demonstrated as well as a subsequent application of 10% renewables. It is this planning policy requirement that is investigated in more detail in the following case study.

3. CASE STUDY METHODOLOGY

The chosen case study project is a high quality riverside residential development in London with an architectural form comprising main fenestration facing the river with stepped roofs at each floor level to provide views and private external terraces. See figure 1 for block elevation. The density is in the medium-high range at more than 200 dwellings per hectare. The stepped architectural form is optimised for developer value and has the effect of restricting the available area of roof which can be occupied by renewable technologies such as wind turbines and solar thermal or photovoltaic panels. On such high-density sites, it is also unrealistic to place small wind turbines at ground level, due to the low wind speeds that would be experienced.

Figure 1: Elevation of case study block

A 500-unit development consisting of 5 identical blocks of 100 apartments has been used as this size of development is large enough to be referable directly to the Mayor/GLA for planning consideration, see figure 2.

Calculations have been carried out on the basis that each block of 100 dwellings has a building heat loss characteristic equivalent to all dwellings being mid floor with a flank external wall. The energy requirements of such a dwelling has been analysed using National Home Energy Rating (2006) software incorporating the Standard Assessment Procedure to analyse the CO_2 emissions of dwellings in accordance with the April 2006 edition of Part L of the British Building Regulations. The calculated energy requirements of each block of 100 dwellings is shown in Table 1.

In order to calculate reductions in CO_2 emissions from various energy strategies, a base case has to be established. This has been taken as a Building Regulations Part L 2006 compliant development with individual gas fired condensing boilers providing all heat requirements to the apartments.

Table 1: Calculated energy demands, per block of 100 dwellings (Part L 2006 compliant) [9]

Space heating	168,740 kWh/yr
Hot water	274,230 kWh/yr
Electricity	300,860 kWh/yr

To comply with the Mayor's Energy Strategy, developments are required to have district heating networks supplied by CHP unless it can be demonstrated that this is not feasible. For a 500-unit residential scheme CHP would be appropriate, so has been included for all GLA compliant energy options. It has been calculated that the district network with CHP would reduce the Base Case CO_2 emissions by 8.9%. These resultant emissions are referred to as the CHP Case.

GLA policy requires a 10% reduction in CO_2 emissions from the CHP Case described above. Various options for meeting the 10% on-site renewables requirement have been investigated in terms of their CO_2 savings and capital cost implications, over and above the cost of a 2006 Building Regulations compliant Base Case. The GLA requirement for CHP has then been relaxed, and non-compliant methods of delivering CO_2 savings have been investigated.

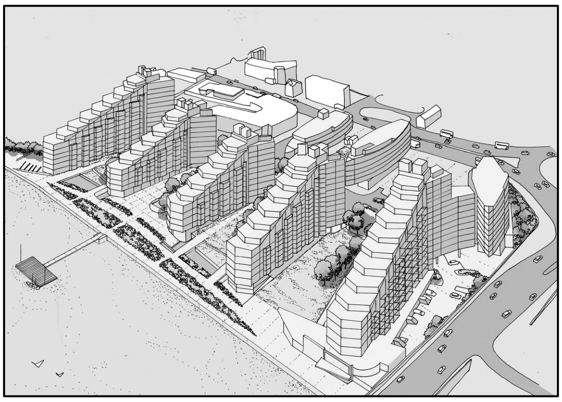

Figure 2: Applicable massing of 5 blocks

4. RESULTS AND DISCUSSION

Table 2 below summarises the capital cost and CO_2 saving for compliant planning policy engineering strategies involving policy driven provision of fossil fuel fired CHP plant plus individual renewable technologies at a scale capable of being integrated into the project.

Biomass fuelled CHP has not been proposed as at this scale the technology has not yet proved to be sufficiently robust in continued operation to be a reliable energy option. The level of micro wind turbine and medium output wind turbine provision is limited by the relatively small area of available roof which is not used as private amenity space, having regard to the need to space turbines far enough apart in order to avoid turbine-to-turbine wind interference. The available area of roof similarly limits the scale of provision of photovoltaic cells. The ground source heating system analysed is a relatively simple open loop, groundwater stable heat source system with local borehole re-injection of water after heat extraction and upgrade via block-based heat pumps. As no cooling provision is required, the energy advantages of inter-seasonal thermal storage systems such as Aquifer Thermal Energy Storage have not been analysed. Solar thermal panel provision has not been analysed in conjunction with CHP as both technologies compete to supply heat to domestic hot water installations in the summer.

Of the individual renewable technologies feasible for use on the site in conjunction with fossil fuel powered combined heat and power plant, only a biomass boiler utilised in conjunction with a gas-fired high efficiency boiler to provide space heating is capable of achieving the policy requirement of 10% CO_2 reduction after energy load reduction.

Table 3 summarises the results of all combinations of combined heat and power and renewable technologies which are capable of compliance with London planning policy.

The lowest capital cost solution is a gas-fired CHP plant sized to provide the project domestic hot water thermal load, with an element of wood chip fired boiler heat provision in conjunction with high efficiency condensing gas-fired boilers to meet the space heating thermal demand. It should be noted that there is concern with regard to whole life costing of using a substantial amount of chipped wood energy fuel in London as planning policy is likely to drive considerable numbers of biomass-fired heat generation capacity within London. This is likely to overload the chipped wood supply chain's ability to deliver wood sourced locally to London, and increased usage will impose pressure to deliver wood from farther afield. This in turn would increase the embodied energy of the wood and also potentially lead to an increase in the fuel price. In addition, there may be severe architectural integration issues with regard to achieving a flue height which is compliantly above the roof height of adjacent buildings, and access to the wood store for the delivery of fuel would also need to be allowed for.

If the above mentioned issues of biomass combustion in London outweigh the capital cost saving, or if there is sufficient concern about future price volatility leading to excessive energy operating costs, then the only compliant scenarios are CHP plant plus either micro wind turbines, medium wind turbines, or photovoltaic panels provided in conjunction with a ground source heat pump space heating installation. The choice between wind turbine provision and photovoltaic panel provision must be made on the basis of whether a proliferation of wind turbines is architecturally acceptable, or if it would be valued as a visible icon.

Table 4 gives the additional capital cost and CO_2 savings of a range of engineering, energy supply systems which are either non-compliant with current London planning policy, or which would require evere changes to the architectural form of the buildings.

Table 2: Summary table for single technology reductions in CO_2 emissions (in addition to CHP)

System*	Cost** [10]	CO_2 saved over CHP Case [11]	CO_2 saved over Base Case [12]	Capital cost per tonne CO_2 saved over Base Case
CHP + Biomass Boiler for 10% CO_2 reduction	£1,449,059	10.0%	18.0%	£7,486
CHP + Micro Wind (4 turbines per block)	£1,479,059	2.1%	10.8%	£12,322
CHP + Medium Wind (1 turbine per block)	£1,704,059	4.2%	12.7%	£12,074
CHP + PV Cells	£1,574,059	0.9%	9.7%	£14,517
CHP + Ground Source Heating (borehole water) for space heating	£1,893,706	9.2%	17.2%	£9,874

* All options include district heating
**Over and above Base case of Part L 2006 compliance (individual boilers, no renewables)

Table 3: Summary table for GLA Compliance, at least 10% reduction in CO_2 emissions from CHP case

System*	Cost** [10]	CO_2 saved over CHP Case [11]	CO_2 saved over Base Case [12]	Capital cost per tonne CO_2 saved over Base Case
CHP + Biomass Boiler for 10% CO_2 reduction	£1,449,059	10.0%	18.0%	£7,486
CHP + PV + Ground Source Heating (borehole water) for space heating	£2,088,706	10.1%	18.1%	£10,377
CHP + Micro Wind (4 turbines per block) + Ground Source Heating (Borehole water) for space heating	£1,993,706	11.2%	19.1%	£9,365
CHP + Medium Wind (1 turbine per block) + Ground Source Heating (Borehole water) for space heating	£2,218,706	13.3%	21.0%	£9,482

* All options include district heating
**Over and above Base case of Part L 2006 compliance (individual boilers, no renewables)

Table 4: Summary table for freestyle CO_2 emissions reduction

System	Cost** [10]	CO_2 saved over CHP Case [11]	CO_2 saved over Base Case [12]	Capital cost per tonne CO_2 saved over Base Case
Biomass Boiler for 95% heating & hot water (5% allowance for gas start-up & down-time)*	£1,654,059	N/A	35.2%	£4,223
CHP + Micro Wind (20 turbines per block) + Large roof area*	£1,879,059	10.4%	18.4%	£9,192
Micro Wind (20 turbines per block) + Large roof area	£500,000	N/A	9.5%	£4,739
CHP + Medium Wind (2 turbines per block) + Large roof area*	£2,029,059	8.3%	16.5%	£11,068
Medium Wind (2 turbines per block) + Large roof area	£650,000	N/A	7.6%	£7,701
CHP + PV cells + Large roof area*	£3,329,059	9.4%	17.4%	£17,171
PV cells + Large roof area	£1,950,000	N/A	8.5%	£20,537
Roof-mounted solar hot water (as individual boiler pre-heat) + Large roof area#	£1,472,500	N/A	18.6%	£7,117
Vertically-mounted solar hot water (as individual boiler pre-heat) + Large south facing vertical building area#	£1,590,000	N/A	18.6%	£7,685
CHP + Offsite Merchant Wind Power*	£1,379,059	N/A	26.2%	£5,195
Offsite Merchant Wind Power	£0	N/A	57.1%	£0

* Option includes district heating
# Option includes block based communal heating supporting individual gas-fired condensing boilers
**Over and above Base case of Part L 2006 compliance (individual boilers, no renewables)

If planning policy to require onsite, integrated renewable energy sources is retained then a biomass boiler sized to provide 95% of all heat requirements for the project has a capital cost equivalent to the planning compliant solutions but with a CO_2 saving close to twice that available from a planning compliant strategy.

Several scenarios have been investigated which would require the architectural form to be substantially changed to provide a much larger roof area for the siting of wind turbines, photovoltaic panels or solar thermal panels. In practice it is unlikely that any of these scenarios would be feasible due to the drastic effects on the architectural form, and therefore density, reduced private external space, and reduced sales values to the developer.

The option to provide vertically mounted façade integrated solar thermal panels to the south of the building will give CO_2 savings comparable to the compliant planning systems at an advantageous capital cost. However, sufficient solar penetration to a flank wall covered in approx. 470m² of solar thermal panels would be required per block (after efficiency reductions for siting the panels vertically are taken into account). If this is possible, it is likely that this installation would have a very low energy cost in use profile as there is a very large component of active solar energy provided.

In the UK it is possible to provide new capacity off-site renewable energy generation auditably linked to the energy requirements of a specific project, however this is not allowed to count towards the 10% renewables requirement under current planning policy. An example of this type of off-site development-linked renewables generation is the Merchant Wind Power (MWP) scheme offered by Ecotricity. A long-term (minimum 12 year) contract is drawn up between the development and Ecotricity, under which Ecotricity will erect a wind turbine or number of wind turbines in a suitably windy location specifically to supply the development with renewable electricity. This option has no capital cost implications to the development.

The usage of on-site gas fired CHP plant with a Merchant Wind Power contract to supply 100% renewable electricity to the site has a relatively low capital cost and a higher CO_2 saving than the planning compliant schemes.

The final system analysed involves no on-site provision of renewable energy or CHP and relies entirely on 100% of electrical requirement delivered from a MWP contract. This option has zero capital cost and the highest level of CO_2 saving of the options considered.

5. CONCLUSION

This paper is limited in the detailed scope of investigation, but it is clear that the highest level of CO_2 saving is available by the utilisation of a contract requiring specific investment in new large-scale wind turbines, positioned within a good wind environment outside the urban area. This would need a structural change in energy planning policy to become compliant.

It is also clear that the present planning policy which seems to require CHP if at all feasible precludes the much higher CO_2 saving which can be achieved utilising biomass combustion only. For the same reason it also precludes the provision of large-scale building integrated solar thermal panel provision which is likely to have the lowest whole life cost and will provide equivalent CO_2 savings to compliant planning systems whilst addressing fuel poverty to a greater level.

The conclusion of this paper is therefore that planning energy policy should be CO_2 performance related but should not offer prescribed solutions as to the most desirable technologies.

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