THE APPLICABILITY OF PASSIVE SOLAR TECHNIQUES TO THE REFURBISHMENT OF NON-DOMESTIC BUILDINGS IN THE UK

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Expenditure on refurbishment of non-domestic buildings is expected to increase at a faster rate than that on new building. It is, therefore, important that the applicability and potential of daylighting, complete/partial natural ventilation and other passive solar techniques are assessed for use in refurbishment projects. This study assessed the technical and economic feasibility, and market acceptability of incorporating passive solar measures into non-domestic buildings at the time of refurbishment. It quantified the likely future take-up of passive solar refurbishment in non-domestic buildings and identified the individual building types likely to provide the greatest opportunities for this type of strategy. The likely national energy savings to be achieved from passive solar refurbishment of non-domestic buildings up to the year 2015 were estimated.

INTRODUCTION

For the next few years, at least, expenditure on refurbishment of non-domestic buildings is expected to increase at a faster rate than that on new building. It is, therefore, important that the applicability and potential of daylighting, complete/partial natural ventilation and other passive solar techniques are assessed for use in refurbishment projects.

However, to date there has been no review of the applicability of passive solar techniques to refurbishment. One or two design studies and field trials of individual passive solar refurbishments have been carried out and some of the considerable amount of work targeted to new build is undoubtedly relevant to the refurbishment situation. However, nothing has been done to gather all the relevant information together and view it in a commercial context. The project described here addresses this subject, using as its starting point technical and performance information derived from studies carried out through the Department of Trade and Industry's Passive Solar Programme [1], the International Energy Agency programmes [2], and work published by the Building Research Establishment [3], the Energy Efficiency Office [4], the European Union and other institutions. A key issue for the project is the market acceptability of the measures.

The cornerstones of the project are an understanding of the UK non-domestic building stock (and the associated energy use) combined with a thorough working knowledge of practical passive solar solutions.

The project objectives are:

- assessing the technical feasibility of incorporating passive solar measures into non-domestic buildings at the time of refurbishment.
- assessing the economic feasibility of adopting passive solar refurbishment of non-domestic buildings as opposed to conventional refurbishment.
- assessing the market acceptability of passive solar refurbishment of non-domestic buildings.

- quantifying the likely future take-up of passive solar refurbishment in non-domestic buildings and identify the individual building types likely to provide the greatest opportunities for this type of strategy.
- estimating the likely national energy savings to be achieved from passive solar refurbishment of non-domestic buildings up to the year 2015.

The project forms part of the Passive Solar Programme administered by ETSU on behalf of the DTI and full report is available from ETSU [5].

NON-DOMESTIC BUILDING SECTOR ANALYSIS

An extensive information search was conducted at the outset of the project. Davis, Langdon Consultancy, quantity surveyors, supplied data for non-domestic gross floor areas and refurbishment rates. Their data is shown in Table 1. The new-build rate is also included for comparison.

Table 1 Estimated non-domestic building gross floor areas, major refurbishment and new-build rates

Non-domestic sector	Stock gross floor area, km^2	Refurbishment rate, as a % of stock	New-build rate, as a % of stock
Offices	85	7.92	2.43
Health	40	4.40	1.23
Factories	205	3.54	0.98
Shops	100	3.01	1.12
Education	105	2.63	0.59
Entertainment	70	2.56	0.75
Other public buildings	80	2.08	0.57
Warehouses	140	1.67	0.41
Other comm.	80	1.50	0.42
Total	905	3.15	0.91

Since it would have been impossible to study all sectors within the time and resource available to the project 'major candidate' sectors were identified using the following criteria:

1. Significant portion of non-domestic building stock?
2. Active refurbishment activity?
3. Applicability of passive solar measures?
4. Availability of detailed stock data for candidate?
5. Availability of energy data for candidate?

The application of these criteria led to the following conclusions:

- Offices and Health buildings were self selecting as they meet all the above criteria
- Although shops and entertainment buildings have a high refurbishment rate they are much less susceptible to passive solar measures and were therefore rejected.
- Other public buildings were rejected as they are made up of a wide variety of building types that are difficult to categorise
- Educational buildings were pursued further to clarify the refurbishment rate and applicability of passive solar measures.

POSSIBLE REFURBISHMENT STRATEGIES

A catalogue of passive solar refurbishment measures was compiled to facilitate discussion with key contacts in the different non-domestic sectors considered to have the greatest passive solar potential. Schematic illustrations were used to explain simply what the effect of the different measures would be when applied to a building being refurbished. A description of each measure supports the schematic illustration and highlights the main technical points. Benefits and cost issues are indicated in the catalogue. An example illustration is shown in Figure 1.

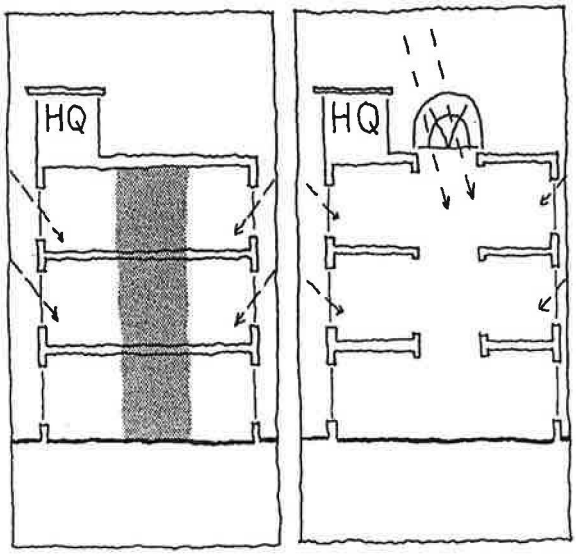

Figure 1: Example illustration showing a building before and after the addition of a central atrium.

These catalogues were sent out to key contacts prior to meeting with them. The meetings were a way of gauging the suitability of the different passive solar measures in particular sectors.

Seventeen specific measures were identified:

1. Layout improvement (arrangement of internal space, to improve access to services, daylight)
2. Redecoration with light surfaces
3. Lighting controls, efficient lamps, task lighting
4. Adjustable window blinds
5. Optimised window area
6. New "good" windows (e.g. multi-pane, low-e, gas fill, cool daylighting), operable.
7. Internal light shelves
8. Removal of suspended ceilings
9. Reduced internal gains with high efficiency lamps/low energy equipment
10. Demolition or extension to reduce plan depth, add atria/sunspaces
11. Night ventilation in conjunction with accessible thermal mass
12. Rooflights to top storey
13. Increased window head height
14. Solar control by overhangs, external shading/lightshelves
15. Transparent insulation material overcladding
16. Ventilation chimneys or equivalent
17. Chilled ceilings, comfort cooling, mechanical ventilation etc (passive features relative to air conditioning).

Case studies were presented at the interviews representing different levels of refurbishment:

1. Refitting interior and making minor alterations
2. Major fabric & interior refurbishment without radical strategic change
3. Major refurbishment with more radical change to increase buildings passive potential
4. Increasing use of passive measures in air conditioned buildings
5. Full or partial removal of air conditioning with minor change
6. Full or partial removal of air conditioning with radical change

ACCEPTABILITY OF STRATEGIES

Interviews were held with 12 key contacts covering the range of sectors and including, clients, developers, designers and agents. The general response was supportive of the principle of reducing energy consumption through the introduction of passive measures with reservations about many practical and financial issues. The response from the office sector key contacts is reported here and the measures are broadly grouped into strategies for reducing energy consumption by: lighting; heating; mechanical ventilation and air conditioning.

Strategies to Reduce Lighting Energy Consumption

Layout improvement: Opinions varied on the extent to which office re-organisation was possible in different types of offices; open plan and cellular. It was considered unlikely that partitions would be rearranged to improve access to daylight but that moving desks and filing cabinets would be possible. The new EC VDT directive (and the consequential HSE guidance) is causing considerable re-organisation and guidance on how to achieve beneficial arrangements was considered desirable.

Redecoration with light surfaces: It was generally agreed that light surfaces are preferred by developer, tenant and owner occupiers. Light coloured carpets were also considered acceptable by some, since stain resistant coatings can make them easy to clean.

Lighting controls, efficient lamps, task lighting: Developers generally believed that lighting controls were a good idea but preferred to leave these to tenant fit-out. It was felt that simple systems were appropriate to cellular offices but that more automatic systems were applicable to open plan spaces. One local authority had already refurbished most of their buildings with pull cord luminaires which are automatically switched off 4 times during the day.

High efficiency lighting, including compact fluorescent lamps and high frequency linear lamps, are increasingly being used in many office refurbishments. Two major developers use these as standard fittings in all refurbishments. Task lighting was considered an issue for the tenant, owner or occupier and as such it is difficult to control what is used.

Internal light shelves: Most were unsure of the benefits of lightshelves and could foresee problems with dust collection and hence additional cleaning. Some benefits were recognised in areas of extensive VDT use.

Rooflights to top storey: Where potential exists to add rooflights in a simple manner this was considered an attractive option. The driving force would be to provide natural light to deep plan spaces.

Increased window head height: This measure was recognised as having significant benefits, but several problems were foreseen; windows already reach under side of floor slab, window head already in line with suspended ceiling and down-stand perimeter beams which restrict window head height. This measure would only be taken as part of a major refurbishment, over-cladding or re-cladding exercise.

Strategies to Reduce Heating Energy Consumption

Optimised window area: Some potential exists for eliminating glazing below dado level and there are often health and safety reasons for doing so. Otherwise this measure was considered difficult to achieve and planning constraints were often cited as a problem.

New "good" windows, operable for natural ventilation: Window replacement is a common refurbishment action when maintenance requirements become excessive. Several developers and designers claimed to replace with low emissivity double glazed units as a standard. Most would wish to improve natural ventilation when replacing windows and advice on how to do so is needed.

Transparent Insulation Material overcladding: This measure was not considered appropriate for offices. Although Transparent Insulation Material was considered appropriate for some daylighting applications.

Strategies to Reduce Mechanical Ventilation and Air Conditioning Energy Consumption

Adjustable window blinds: Responses to this measure varied from "very useful" to "of little use and requiring regular maintenance". Venetian blinds were preferred to roller blinds as providing a greater degree of adjustment. One developer and several designers said they would include internal blinds as a standard item in most major refurbishment projects.

Removal of suspended ceilings: Interestingly suspended ceilings were disliked by several interviewees as they often become unsightly due to damage sustained during maintenance of services. Most of the developers and designers appreciated the benefits of thermal mass, but they felt that clients and tenants did not. Its was generally felt that removal of suspended ceilings may be possible when a new tenant or owner is taking over a refurbished building but not when a building is refurbished for the existing occupants.

Reduced internal gains with high efficiency lamps/low energy equipment: As stated earlier the use of high efficiency lighting is becoming standard in many refurbishment projects. Few of those interviewed felt they had much control over the selection of equipment and appliances but it was suspected that little thought was given to energy efficiency in their selection.

Demolition or extension to reduce plan depth, add atria/sunspaces: A common response was "we are moving away from deep plan towards shallower plan buildings". Both developers could see the introduction of an atria into deep plan buildings as a possible mechanism to make them more attractive to potential tenants. Even although this would reduce the net floor area it could increase the value of space per unit area.

Night purging in conjunction with accessible thermal mass: Little confidence was expressed in the idea that this could be achieved by simply leaving windows open. One developer felt that running mechanical ventilation at night would be possible if appropriate controls were incorporated. Most designers could see ways of achieving night ventilation without compromising security. One designer had actual experience of this approach working in practice.

Solar control by overhangs, external shading/lightshelves: Typically these devices were thought to be difficult to introduce in most major refurbishments for reasons of planning constraints and cost. Simple fixed devices were generally preferred and many problems were cited with mid pane blind systems.

Ventilation chimneys or equivalent: Only one interviewee expressed confidence in the operation of these devices based on the experience of a new build application.

Chilled ceilings, comfort cooling and mechanical ventilation: Opinion was divided on these measures. Some claimed to be using them increasingly whilst others felt they were "too risky".

Nature of Refurbishment in Sector

All those interviewed confirmed that there was a high level of refurbishment activity in the sector and this is likely to persist for some time. Minor refurbishments such as redecoration, lighting overhaul and blind installation or replacement can happen as frequently as every five years. Some offices receive a medium level of refurbishment on a floor by floor basis as each floor becomes vacant. This level may include replacement of lighting and suspended ceiling and possibly the addition of a raised floor.

Major refurbishments are now commonly being carried out on 60s to 70s buildings with expiring long term leases. For at least one developer this typically involved; new windows, new toilets, new lifts, new HVAC services, new lighting, new ceiling, new raised floor and some two thirds of such offices are re-clad.

A major barrier to the incorporation of passive solar measures in refurbishment of offices is the "full repairing" lease arrangement in which many tenants find themselves. This acts as a disincentive for tenants to do anything other than minimal repairs as the benefits of any improvement accrue to the landlord. In some cases landlords may be prepared to assist if a new lease is negotiated, usually with a increased rental value.

Financial Criteria and Other Influential Factors

Payback periods ranging from 1 to 5 years were quoted by different interviewees as appropriate to the office sector. Many felt that that first cost was the primary issue and if a measure could not be justified on a very short payback period (less than two years) then it would have to have significant non-energy benefits for it to be incorporated. Life cycle analysis does not appear to be commonly used in assessing the benefits of different options and little more that lip service is paid to "green issues". The crucial factor, for developers at least, is the ease of letting and there appears to be some evidence that shallower plan, daylit, and possibly naturally ventilated buildings, are becoming more popular.

ENERGY SAVINGS

The analyses of responses to individual measures, the nature of refurbishment, the financial criteria and other influential factors were used to produce a number of scenarios for the uptake of the passive solar measures. The resulting reduction in annual energy consumption for each is shown in Table 1.

Table 2 Office, Health and Education sectors primary predicted energy savings for the UK.

Scenario> Sector	Maximum possible PJ/y	Technical potential PJ/y	Realistic Scenario PJ/y	Total Primary Energy PJ/y
Offices	29.210	3.131	0.790	138.7
Health	11.870	0.665	0.190	118.1
Education	22.430	0.602	0.270	85.9

Savings for three scenarios are presented:

Maximum possible savings: savings if *all* buildings were immediately refurbished with *all* appropriate passive solar measures.

Technical potential savings: assumes *all* refurbishments each year include *all* appropriate passive strategies.

Realistic scenario savings: assumes a *realistic* uptake of passive solar measures during refurbishment each year.

MAIN CONCLUSIONS

The main conclusions to be drawn for the UK from this study are:

- The Offices, Health and Education sectors of the non-domestic building stock present the greatest potential for the application of passive solar measures.
- The technical potential for energy savings due to passive solar measures in refurbishment is very significant.
- The realistic potential saving has been estimated based on market assessment. At present refurbishment rates only 20% of the maximum possible saving will be realised for the three sectors by 2015.
- All sector contacts recognised some benefits from passive solar measures and responses were generally positive. This response was encouraging as the contacts were not passive solar enthusiasts or experts and several had a strictly commercial view of refurbishment.
- Unfortunately data on the non domestic building stock is not yet developed to a stage where it is easy to desegregate building types within each sector and this necessarily limited the analyses undertaken in this study.

BARRIERS TO UPTAKE OF PASSIVE SOLAR MEASURES

As a result of discussions with the sector contacts a number of barriers to the uptake of passive solar measures were identified. These include:

- The absence of legislation requiring such measures to be incorporated in refurbishment projects.
- Many organisations are looking for short term returns and are not prepared to invest in energy saving measures which have longer payback periods
- Where a building is owned by a developer there is little incentive to employ energy saving measures as the benefits generally accrue to the tenant in a reduction of their energy bills.
- Equally tenants are not prepared to invest any more than necessary in the repair and maintenance of their buildings as the long term benefits accrue to the landlord.

- Whilst many positive views were expressed regarding the benefits of passive solar design in refurbishment, a number of concerns were raised regarding risks of increased maintenance, operational failure, discomfort and reduction of amenity.
- A key disincentive is the current low cost of energy and the fact that greater energy cost savings can often be made through tariff negotiations.
- There appear to be major constraints on the introduction of passive measures in inner cities. These constraints are both real, relating to air and noise pollution, and perceived, as in the institutional view that air conditioning is essential for all inner city offices irrespective of the actual environment.
- A common complaint was the lack of specific guidance on the application of passive solar measures to refurbishment projects.
- There was a perceived difficulty in assessing the benefits of passive solar measures in refurbishment projects.

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