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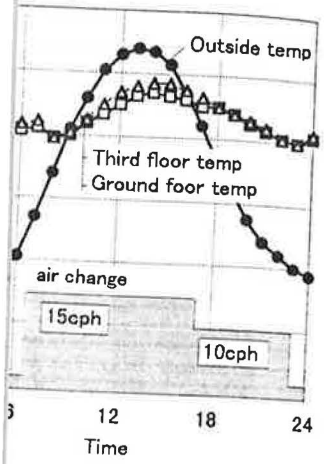

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THE STRATEGIC IMPLICATIONS FOR LARGE, DYNAMICALLY INSULATED BUILDINGS IN CITIES

Dr. Douglas CAWTHORNE*, Dr. Helen MULLIGAN**

*The University of Westminster
35 Marylebone Road, London, UK, NW1 5LS
Tel: +44(0)171 911 5000, Fax +44(0)171 911 5190

**Cambridge Architectural Research Limited
The Eden Centre, 47 City Road, Cambridge UK, CB1 1DP
Tel: +44(0)1223 460 475, Fax: +44(0)1223 464142

ABSTRACT The concept of dynamic insulation, where cold air is drawn through porous insulation in a building envelope from outside to inside, thereby returning heat energy normally lost by conduction back into the interior of the building, has been studied by several researchers, in Japan [1], Europe [2], [3], [4], [5], [6], [7], and Canada [8]. However the work to date has largely concentrated on the physical processes in individual wall, floor or roof elements and only a small number of experimental buildings (all of a small domestic scale) have been adequately monitored. While these studies have been valuable there remain wider questions concerning the suitability and realistic usefulness of dynamic insulation for use in larger buildings and city blocks. The paper describes a series of parametric studies using a new computer model called BREATHE in which a dynamically insulated house and an office building are assessed for relative gains in energy efficiency, particularly in the light of current trends towards the passive heating, cooling and ventilation of large buildings. Results indicate that dynamic insulation is most effective in climates with a large internal / external temperature difference, in buildings having a low volume to surface area ratio and / or a high air change rate.

1. INTRODUCTION

Current integrated energy efficiency and occupant comfort and health design strategies have led to the re-emergence of shallow plan, naturally ventilated and largely day-lit buildings, what Hawkes [9] has described as 'selective' environments. This is as opposed to the many deep plan, artificially lit and ventilated buildings built between the early 1950's and the late 1970's, which attempted to excluded the external environment by the use of relatively large amounts of primary energy. Fundamental to the characteristics of the selective environment is the shallow plan and consequently a greater surface area to volume ratio than is found in more compact, deep plan buildings. In a cold climate the rate of heat loss from the fabric of a building is directly proportional to its volume to surface area ratio, therefore while shallow plans favour good daylighting and ventilation, they may often increase the fabric heat loss. The concept of dynamic insulation may be useful in off-setting this fabric heat loss. In order to compare its potential with respect to deeper plan buildings (with higher volume to surface area ratios) the computer model BREATHE was used to make an assessment of potential total energy savings. A simple configuration of a contra-flux, dynamically insulated envelope allowing air to pass from a cold outside to a warm inside environment was modelled whereby energy transferred from the fabric of the building to the incoming ventilation air was recovered by a heat exchanger before the air once again left the building envelope.

1. VOLUME TO SURFACE AREA RATIOS

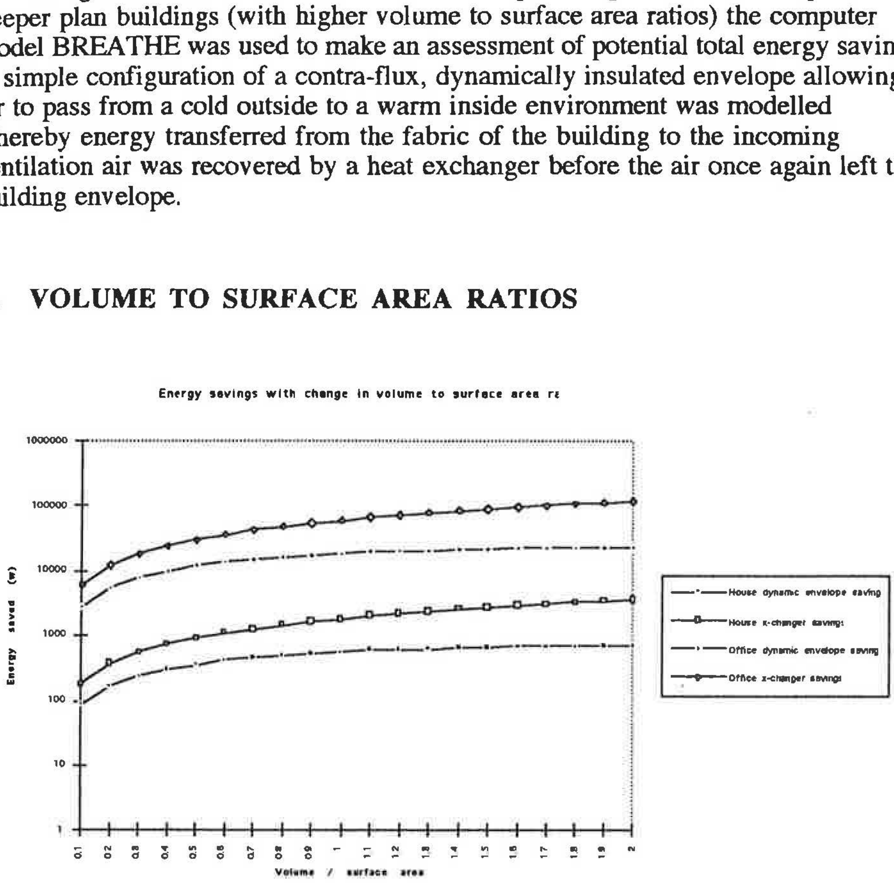

Figure 1. Energy savings with variation in the volume to surface area ratio of a house and an office building. Note that because the volumes vary, so do the savings from the use of heat exchangers to recover energy from the outgoing ventilation air.

The energy savings as a proportion of the totals for the office building and the house are identical as volume to surface are ratio increases being 31% at a ratio of 1 and 20% at a ratio 2. However the house has a ratio of 1.8 = 21% and the office has a ratio of 7.5 = 6% which indicates that the dynamic insulation in the house contributes 21% to the overall energy savings whereas the dynamic insulation in the office building only contributes 6% to the energy savings. The rest of the energy savings in both are achieved by heat reclaimed from outgoing ventilation air passing through a heat exchanger.

As a fundamental rule it can be said that **the larger a building becomes without greatly increasing its surface area the less useful dynamic insulation becomes.** This suggests that relatively greater reductions in energy

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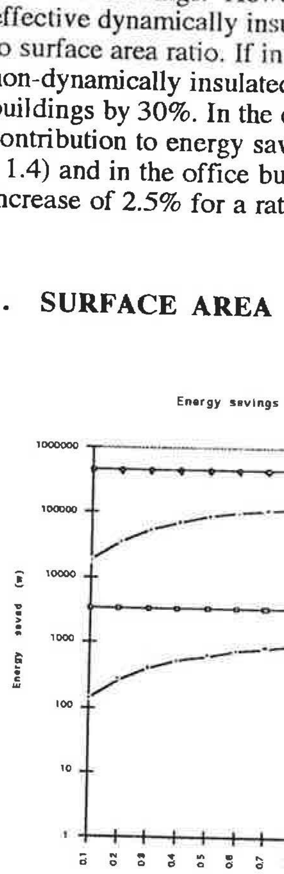

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consumption are possible for a given design modification in houses than is the case in office buildings. However the presence of conventional glazing acts to reduce the effective dynamically insulated area of buildings and decreases the effective volume to surface area ratio. If in fact the glazing in the buildings is discounted as being non-dynamically insulated then this may reduce the effective surface area of the buildings by 30%. In the case of the house this would give an increase in relative contribution to energy savings of 28% (an increase of 7% for a ratio change of 1.8 - 1.4) and in the office building an increase in relative contribution to 8.5% (an increase of 2.5% for a ratio change of 7.5 - 5.7).

2. SURFACE AREA TO VOLUME RATIOS

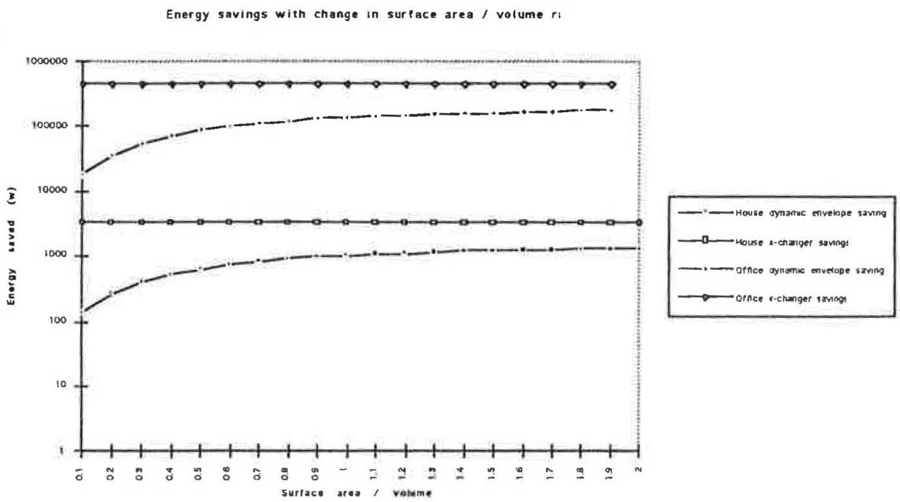

Figure 2. Energy savings with variation in surface area to volume ratio. Note that because the volumes of the buildings do not vary, the energy saved by the heat exchangers recovering energy from the outgoing ventilation air also does not change.

The dominant factors influencing the strategic implementation of dynamic insulation across a range of building types is the relationship between their surface areas and volumes. Maintaining a constant volume for the two building types and varying their surface areas yields the following insights. Firstly if volume is held constant and surface area is increased, dynamic insulation contributes increasingly to the overall energy savings. The office building has a surface area to volume ratio of 0.13. The house has a ratio of 0.55. The architectural implications of increasing surface area are obvious, courtyard and atrium buildings, shallow plan, and spine and finger layouts would be favoured. If there is an increase the dynamic surface area per constant volume this produces an increase in heat loss through the envelope such that useful heat recovery lies in the range of surface area to volume ratio of 0

- 0.7. However recovery from the heat exchanger remains constant. Similarly with a constant surface area, most useful recovery of heat occurs in the volume to surface area ratio range of 1.3 - 2. However here losses from the heat exchanger increase with volume such that at a volume to surface area ratio of approximately 0.65 they begin to exceed the decreasing losses from the dynamic envelope. These results are independent of scale and are identical for both offices and houses.

3. EXTERNAL TEMPERATURE

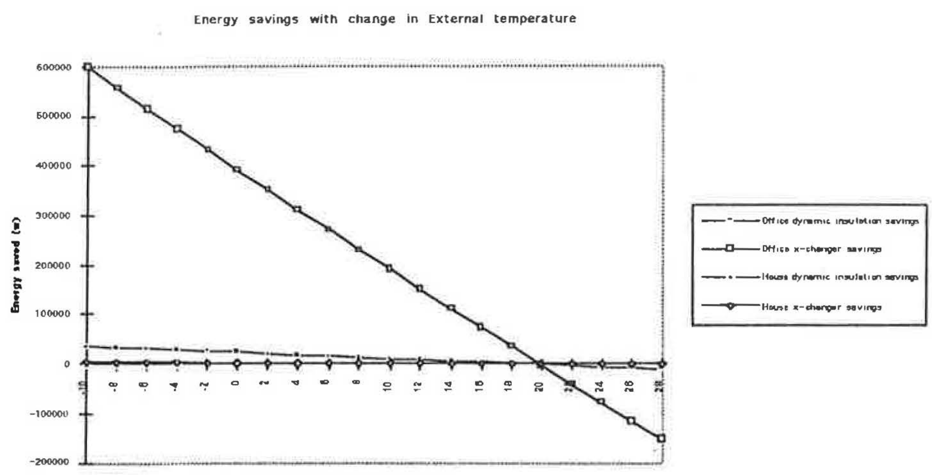

Figure 3. The relative differences in contributions of energy saved between the office building (Surface area / volume ratio 0.133) and the house (Surface area / volume ratio 0.55).

As may be expected the energy balance for a building configuration rests at the point where internal and external temperatures are the same. Dynamic insulation is of most benefit when there are significant differences between internal and external temperatures and consequently potentially greater heat flux through the envelope of the building. The greater the temperature differential the easier it is to offset the cost of implementing dynamic insulation because there is potentially greater energy savings either for heating (in cold external conditions) or cooling (in warm external conditions). It is the case that dynamic insulation can be used to maintain an internal temperature that is lower than that externally (effectively cooling a building) and this may yield heat energy from warm external air. However it is more probable that in use, windows and doors will be opened to allow natural cross ventilation for cooling. In this condition dynamic insulation is ineffective. In our opinion the benefits of dynamic insulation are most likely to be manifest in the colder months of the year. As a fraction of the energy recovered by the heat exchanger, the dynamic insulation in the house recovers more energy than that of the office building, 22% as opposed to 6%. As would be expected the increase in saved energy is linear as external temperature decreases. Clearly the presence of a heat exchanger has

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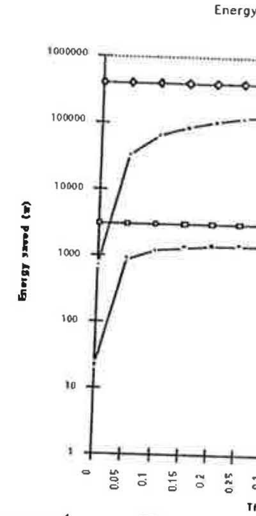

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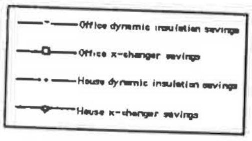

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significant effects for both building types, however because of the greater volume to surface are ratio of the office building and consequently the increased volume of air to be exhausted, relatively greater savings from heat exchangers are made in the office building.

4. THERMAL CONDUCTIVITY

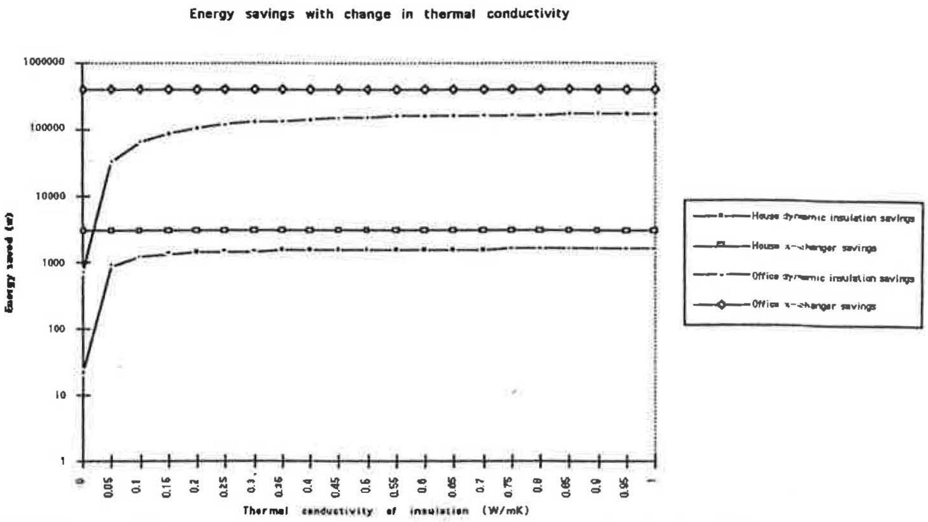

Figure 4. Energy savings with variation in the conductivity of the insulation in the building envelope. The thermal conductivity of both the office building and the house in their base case condition are 0.167 W/mK.

As the thermal conductivity of the building envelope increases and the rate of air flow through the envelope remains constant, the energy saved decreases. However, it is apparent that reductions in the thermal conductivity of the insulation material (or reductions in the insulation thickness) can be offset by increasing the air flow rate through the insulation. This offers up the possibility of using thinner insulation with higher air flow (and consequently ventilation) rates to achieve equivalent energy savings.

5. AIR CHANGE RATE

As fractions of recoverable energy from dynamic envelopes the house has an average closer to realistic ventilation rates than does the office building, 1.2 a.c.h. as opposed to 0.6 a.c.h. In other words at ventilation rates giving average heat energy savings, approximately twice the amount of energy (25% vs. 14%) is saved by the dynamic insulation in the house as opposed to that in the office. At higher rates of air change (4 a.c.h.) approximately three times the total amount of energy saved is made in the house as in the office (8% vs. 3%). Increasing the air change rate through dynamic envelopes in houses has a proportionately greater effect upon the energy loss than it does in offices. In offices for the same air change rates the heat exchanger has the greatest proportional effect upon overall heat loss.

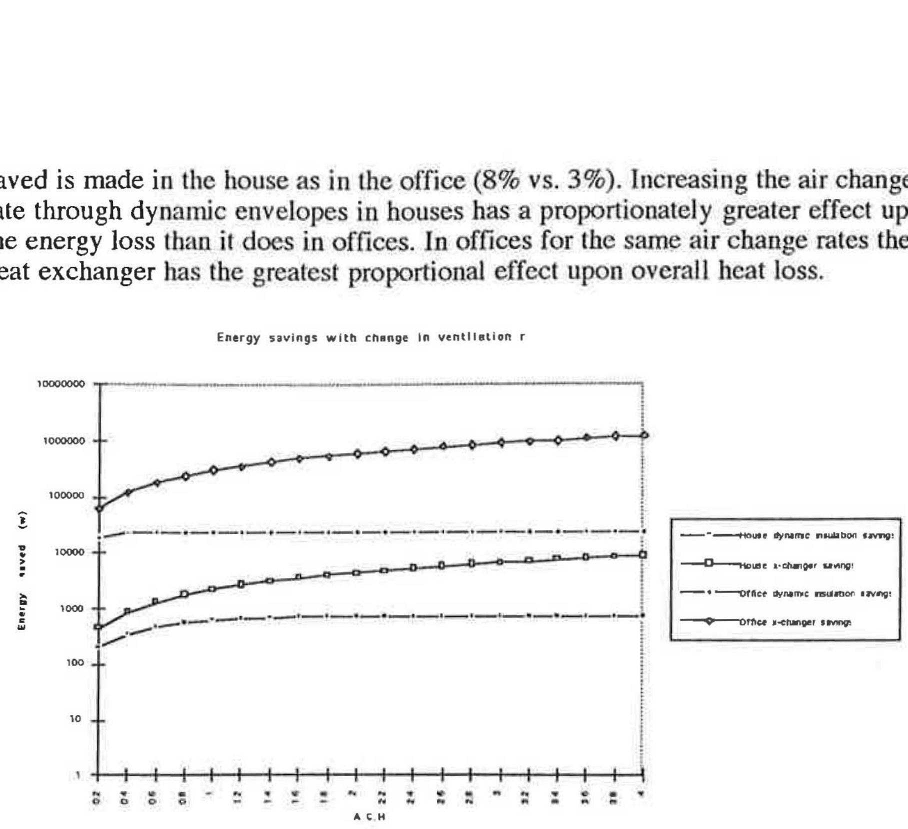

Figure 5. Energy savings for the office and house with variation in a.c. rate.

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ABSTRACT For an optir
thermal effect of lawn-plant
measurement and numerical
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performed to compare the
Result showed its distinctive
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1. INTRODUCTION

Roof-top planting preven
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