Retrofitting natural ventilation systems in UK office buildings

The BRE has examined the suitability, effectiveness and potential energy savings of retrofitting natural and low energy ventilation systems in UK offices during refurbishment projects.

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References

[1]Ruyssevelt P and Robinson P, 'The applicability of passive solar techniques to the refurbishment of non-domestic buildings', *ETSU Report No S/N7/00224/REP*, ETSU, 1995 (to order a copy telephone the ETSU Enquiries Bureau direct on 01235 436747).

[2]'Refurbishment in the office sector 1997-1998', *The Connaught Report* for the RICS, 9/97.

[3]Pout C H, Moss S A and Davidson P J, '*Non-domestic building energy fact file*', (Published by the BRE for the DETR's Global Atmosphere Division), 1/98.

[4]BRECSU, *Energy Consumption Guide 19: Energy use in offices*, DETR Energy Efficiency Best Practice Programme, 1998 (for details contact the BRECSU Enquiries Bureau on 01923 664258).

[5]Brundrett G, 'Building pressure', *Building Services Journal*, 9/97.

Further reading

Bordass W T, 'Achieving energy efficiency in office refurbishments' (Published in *21 AD Issue 2: Offices*), Oxford Brookes University School of Architecture, 2/95.

Bordass T, Bromley A K R and Leaman A J, 'Comfort, control and energy efficiency in offices', BRE Information Paper *IP 3/95*, BRE, 1995.

BRE, 'Minimising air infiltration in office buildings', BRE *Report No 265*, BRE, 1995.

Perera M D A E S, Gilham A V and Clements-Croome T D J, 'Natural ventilation in the UK: design issues for commercial and public buildings', *BSER&T*, Volume 17 No 1, 1996.

Perera M D A E S and Parkins I, 'Airtightness of UK buildings', *Environmental Policy and Practice*, Vol 2 No 2, 1992.

The use of natural and low energy ventilation systems in the UK office sector can result in significant energy and CO_2 reductions compared with the installation of air conditioning and mechanical ventilation. This holds true for refurbished buildings as well as new build.

Even so, mechanical services continue to be installed when buildings come up for refurbishment and renewal, and energy consumption for air conditioning systems is increasing rapidly as a result. Table 1 shows the UK office stock's estimated annual energy consumption and CO_2 emissions by end use.

In a Government-funded study, the Building Research Establishment (BRE) has looked at ways in which energy consumption can be improved. Specifically, the BRE has examined the suitability and effectiveness of natural and low energy ventilation strategies for incorporation in office buildings during refurbishment.

The study has focused on several strategies, including the adoption of:

- ☐ single-sided and cross ventilation;
- ☐ stack ventilation using existing shafts, risers, courtyards and stairwells;
- ☐ passive stack ventilation using atriums, double facades and solar chimneys;
- ☐ simple fan-assisted extract and/or supply systems.

Prior to the study, a national picture was formed of UK office floor area statistics (these were broken down by built form, age, construction type, air conditioning strategy and readiness for refurbishment).

An overview was also undertaken with regard to the energy and CO_2 reduction potential for retrofit with natural and low energy mechanical ventilation systems during refurbishment.

Effective control of windows and blinds helped avoid the need for air conditioning in a refurbishment of the Design Studio at the Open University, Milton Keynes.

Studies have predicted that expenditure on the refurbishment of non-domestic buildings is expected to increase at a faster rate than that on new build projects[1].

In the future, the UK office sector will probably offer the greatest national potential for the application of low energy ventilation strategies.

This view is reinforced by a recent report from the Royal Institution of Chartered Surveyors[2], which indicates that 70% of current UK office space is second-hand (built prior to 1980, or having experienced at least one lease renewal).

Of this space, more than half will not meet modern specifications and tenant requirements by the end of this year. In addition, as much as 15% of office space may be redundant at the present time.

Building owners have come to realise that they need to refurbish in order to attract new tenants, retain existing ones and improve yields.

In itself, refurbishment is recognised as being able to deliver office space more quickly and cheaply than new build, without all the problems, delays and refusals possible when planning permission for new build is required.

An awareness of the lower environmental impact with regard to the reuse of land and

TABLE 1: OFFICE ANNUAL ENERGY CONSUMPTION AND CO_2 EMISSIONS BY END USE

	Annual delivered energy (PJ)			CO_2 emissions ($MTCO_2/y$)		
End use	Fossil fuel	Electricity	Total	Fossil fuel	Electricity	Total
Heating	46	5	51	2·49	0·84	3·34
Cooling	–	11	11	–	1·82	1·82
Lighting	–	16	16	–	2·67	2·67
Other	8	23	31	0·44	3·65	4·08
Total	54	55	109	2·93	8·98	11·91

Source: Pout C H, Moss S A and Davidson P J, '*Non-domestic building energy fact file*' (Published by BRE for the DETR's Global Atmosphere Division), January 1998.

embodied energy of materials is also developing.

Office stock characteristics

In 1994, there were 277 395 office buildings in England and Wales with a total gross area of 105·4 km².

Source data from the BRE's non-domestic building energy fact file[3] has also been used to compile a more detailed picture of the office building stock.

Consider figures 1 and 2, which show data on air conditioning system design by office size, range and age (note that to scale up the data for the whole of the UK, a factor of 1:1 can be applied).

Energy and CO_2 reductions

An estimate of the energy and CO_2 reduction potential for natural and low energy ventilation as a refurbishment option in offices has been arrived at by comparing an 'optimistic' with a 'business as usual' scenario. An annual office refurbishment rate of 8% of the floor area has been used.

In the optimistic scenario, it was assumed that 75% (by floor area) of all refurbishments have incorporated natural and low energy ventilation strategies.

Data on typical and good practice office energy consumption – broken down for cooling, fans, pumps and heating[4] – has been used to estimate the possible savings from natural and low energy ventilation.

Natural and low energy ventilation retrofit can result in reduced energy use by air conditioning and mechanical ventilation (mechanical systems). This is due to the fact that there is a reduced floor area coverage by the mechanical system and/or reduced periods of the year when the mechanical systems will be required.

Natural and low energy ventilation system retrofit can also save mechanical system energy in naturally-ventilated office buildings by allowing the installation of mechanical systems to be avoided.

In recent years, the tendency has been to install mechanical systems during refurbishment for reasons of appeal in the letting market, and to cope with higher internal heat gains (due to the increasing use of IT equipment and the density of office workers).

It is assumed that 25% of refurbishments which do not incorporate low energy ventilation strategies result in no energy savings or increases.

The 'optimistic' analysis yields a saving in electrical delivered energy of 0·51 PJ/y – a 5%/y reduction in the 11 PJ/y total UK delivered electrical energy consumption for mechanical servicing for the office sector.

After 10 years, this figure will have fallen to 5·9 PJ/y due to natural and low energy ventilation retrofits.

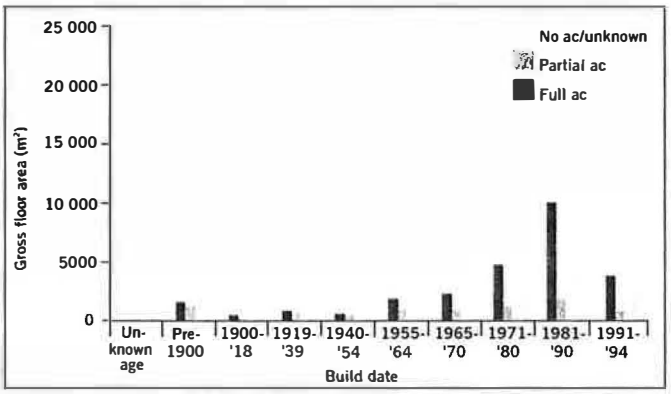

FIGURE 1: Office air conditioning in England and Wales: floor area by age of building.

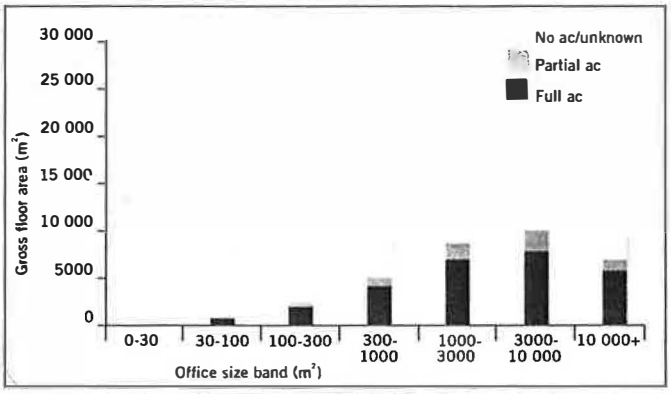

FIGURE 2: Office air conditioning in England and Wales: floor area by size band.

The 'business as usual' scenario

In the 'business as usual' scenario it is assumed that no refurbishments use natural and low energy ventilation strategies.

Replacement mechanical systems will be installed in 70% of refurbishments (by floor area) of mechanically-serviced offices.

New mechanical systems will be installed in 50% of offices which had previously been naturally ventilated.

The net effect of this strategy is that energy use will increase at 0·13 PJ/y. After ten years, the mechanical air conditioning energy use for the UK's existing office stock will have risen to 12·3 PJ/y.

The difference between the two scenarios after a decade represents a saving of approximately 6·4 PJ/y of delivered electrical energy. This is equivalent to nearly one million tonnes of avoided CO_2 emissions per year in the UK.

Improving airtightness

It is common knowledge that buildings in the UK are leaky, with uncontrolled air leakage having three major implications.

In the first instance, high energy costs will result from more air being driven through a building than was planned.

Leaky buildings also place a considerable strain on a building's heating system, particularly in windy, wintry conditions. Not only can heating systems prove to be inadequate in terms of providing full comfort, but local draughts can lead to occupant dissatisfaction.

As far as space heating requirements during the heating season are concerned, uncontrolled air infiltration represents an energy loss of over 61 000 kWh (a tightly-built structure would have an energy loss of under 20 000 kWh)[5].

Litigation by clients is another danger, with ever-increasing numbers of clients turning to the law courts to solve their building problems.

Undoubtedly, natural and low energy ventilation strategies for refurbishment would result in more airtight buildings. Such strategies would also allow controlled winter ventilation rather than ad hoc airflow from infiltration through cracks in building components and construction. This can save space heating energy.

If uncontrolled infiltration is dealt with – a common and growing problem in the UK's non-domestic building sector – and assuming an 8% rate of refurbishment per year, the BRE's energy impact tool predicts that the delivered heating energy saving for the 'optimistic' scenario would be 0·51 PJ/y.

After a decade, the UK's annual delivered space heating energy would have dropped by 10% to 45·9 PJ, while annual CO_2 emissions will be down by 0·5 mtc (million tonnes carbon) to 2·8 mtc.

Total CO_2 savings

The total savings in CO_2 emissions amount to nearly 1·5 mtc/y after a decade of the optimistic scenario.

In itself, this represents a saving of approximately 30% on the 1994 figure for total emissions for space heating and mechanical conditioning of UK office space of 5·2 mtc/y.

Although these figures can be considered somewhat optimistic, they do not include the environmental benefits to be gained from existing natural and low energy ventilation strategies in factories, education and medical health buildings.

In reality, these benefits would probably double the available floor space for which natural and low energy ventilation strategies would be appropriate.

Work that has been carried out so far has indicated the value of retrofitting natural and low energy ventilation systems during the refurbishment of office buildings.

Future research will help to develop design guidance for the construction industry by looking at the suitability of strategies for different types of offices, case studies (both real and virtual) and issues concerning cost effectiveness.