PASSIVE VENTILATION COOLING IN URBAN BUILDINGS: AN ESTIMATION OF POTENTIAL ENVIRONMENTAL IMPACT BENEFITS

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ABSTRACT

This paper describes work currently being carried out to evaluate the environmental impact and energy savings potential from the application of passive ventilation cooling in urban buildings. The work is carried out as part of an ALTENER project focussing on solar and passive ventilation for urban buildings. The study involves the collection of information for current building stock in four European countries; UK, France, Spain and Greece. It includes data on the percentage of buildings by type (residential and non-domestic such as offices and educational) in each country and the percentage of urban building in relation to the total building stock. Such information is difficult to obtain in the same form for each country and the collected data are presented in as meaningful a form as possible. In particular, an attempt was made to define the 'urbanness' of buildings in relation to data available from national surveys. An estimate of possible environmental impact benefits for a case-study office building based on the UK ecopoints method is presented.

KEYWORDS

Passive ventilation, cooling, urban buildings, environmental impact, perceived barriers.

INTRODUCTION

Naturally ventilated and cooled buildings consume less energy than mechanically ventilated and cooled buildings. Published measured data suggest that UK naturally ventilated office buildings consume 50% less delivered primary energy for heating, ventilation and cooling than air-conditioned office buildings (ECON19, 1998). There is thus a significant potential to reduce energy consumption in the building stock in the European Union by encouraging the uptake of natural ventilation while minimising the use of air conditioning.

Most buildings are concentrated in urban areas. Various barriers, including those of external noise and air pollution, have traditionally prohibited the use of solar assisted and natural ventilation in urban buildings. However, recently there has been a considerable amount of research in Europe and internationally on advancing the use of solar assisted and natural ventilation, either for improving indoor air quality or for cooling purposes. A website (SolVent, 2001) has been created as a result of a project funded by the EC ALTENER Programme which contains information on how to apply solar and passive ventilation in urban buildings by presenting existing scientific and technological information including case studies and design solutions.

This paper reports on on-going continuation work to quantify the reduced environmental impact by the application of passive ventilation in urban buildings by gathering information from four countries on the existing building stock and its location in urban or rural areas. These data are presented first and then an estimate of the reduced environmental impact of an office building in the UK based on the Ecopoints method.

DIVERSITY OF BUILDING TYPES AND THE URBAN: RURAL SPLIT

It was necessary to broadly categorise the building stock in categories according to use. This will also affect cooling requirements. Traditionally, building stock is divided into domestic and non-domestic buildings and this broad classification has been followed in this study. It became apparent that the climate in some of the countries included in this project (e.g. UK) can help in the avoidance of mechanical cooling in housing. The situation might be different in warmer climates (e.g. Greece and Spain). However, an assessment of the domestic building stock is included for all four countries.

The non-domestic stock covers a wide range of uses from manufacturing to educational, from hospitals to offices, etc. The stock is broken down where possible into different relevant groups. Not all the information that is desirable is actually available and statistics for some of the four countries are lacking in detail. Estimates have been made where necessary to provide figures to fill these gaps and help provide a complete picture.

To focus on urban buildings alone it is necessary to exclude rural ones. There are many definitions of rural (and urban) areas, e.g. they may be based on population density, on settlement size, on distance (or journey time) to a larger centre. Moreover, perception of rurality may vary with country density.

For this project, however, the important criterion is whether a location is likely to be seen (by developers, tenants, etc.) as being unsuitable for non-mechanical ventilation. Such an area should be included in this study. There is no uncertainty about including obviously urban areas, but the threshold or cut-off density, at which an area should be excluded is less clear. The settlement size approach to determining urbanness was adopted as data were available in this form for all partner countries. Depending on data availability, there are some differences in the cut-off density used for the suburban category. Some countries include small towns (approximately 3-10,000 population) within the stock assessed as suburban. Although the background air pollution is likely to be low, and therefore not perceived as a barrier, local air and noise pollution may still be of concern. Overshadowing may also be seen as a problem (where solar assistance is potentially viable). The following definitions were used for each partner country:

TABLE 1
Settlement population forming the basis for building stock urban:suburban:rural split

Area type	Population of Settlement			
	UK	Greece	Spain	France
Urban	> 50,000	> 10,000	> 50,000	> 50,000
Suburban	3-50,000	2000-10,000	10,000-50,000	5,000-50,000
Rural	< 3,000	<2,000	<10,000	<5,000

EXISTING BUILDING STOCK DATA IN UK, GREECE, SPAIN AND FRANCE.

Building stock split by urbanness

Table 2 presents data from the four countries split by urbanness as defined in Table 1. These data cover domestic and non-domestic buildings. Some additional information and sources for the percentages included in the Table 2 are noted below.

TABLE 2
Building stock split into urban, suburban and rural percentage

Area type	Percentage of Buildings			
	UK	Greece	Spain	France
Urban	67	30	20	20
Suburban	22	18	27	28
Rural	11	52	53	52

- Few data were found on the urbanness of the UK building stock. Data presented are based on domestic household data and were analysed by DTLR (Survey of English Housing, 1998) to produce settlement size statistics for England. Data for Scotland has only an urban: rural split. The data were divided as follows. Scottish rural data were assumed to be 'really' rural. The urban part was then divided into urban and suburban according to the distribution of these parts in the data for England. Wales and Northern Ireland were assumed to have the same distributions as Scotland. Little information on the urbanness of non-domestic stock was found. Distribution by region in England and Wales was known but the subsequent urban split has been based on the domestic split. It should also be mentioned that the population in England is approximately 80% of the UK population. England is a highly populated country – eight times the population density of the US and over twice that of France.
- Greek data are based on the 1990 building inventory (National Inventory, 1990). It should be noted that no difference was observed by comparing 1990 data with 1980 data in the urban percentage of buildings although suburban buildings increased by 3%. Almost half of urban buildings are located in Athens with 25% in the northern Greece, 18% in central Greece and 10% in the islands. Most of the rural buildings are located in Northern and Central Greece (80%), 17% in islands.
- Spanish data are also based on the 1990 building inventory (I.N.E, 1990).
- French data are not based on the existing building stock, but on a snap shot of buildings approved in 1999 divided by region and population of cities (Le compte du logement en France, 2000).

Building stock split by use

Table 3 presents data from the four countries divided into domestic and non-domestic. Non-domestic buildings are further subdivided to categories according to their main use. The data presented include rural, suburban and urban buildings. Some explanatory notes are included.

TABLE 3
Building stock split by use.

Building Use	Percentage of Buildings			
	UK	Greece	Spain	France
Domestic	94	75	92	83
Non-domestic	6	25	8	17
	Percentage of non-domestic buildings			
Office	14	14	13	9
Educational	1.5	1.7	3	3.3
Retail	30		43	9.5
Hotels		1.3		
Restaurants			14	
Factory	15	5	13	11.5
Warehouse	10			27

- In the case of Greece, the percentage of domestic urban buildings is higher that the percentage of total buildings presented in Table 3. 86% of urban buildings are domestic.
- In the case of Greece, the percentage of office buildings includes shops.
- In the case of France the percentage of building is based on new buildings approved over 20 years (1980-1999).

From data presented above, it is seen that a high percentage of buildings are domestic and therefore a high reduction in environmental impact could be achieved by avoiding mechanical cooling. At present, a very low percentage of domestic buildings is mechanically cooled in the UK, France and Spain. However, the use of air-conditioning especially in southern European countries has been increasing in the domestic sector over the last few years. In Greece, between the years 1990 and 1996 the sales of domestic air-conditioning units has increased with more than 100000 units per year being sold, representing an increase of power demand of 100MW per year. The peak electricity demand has also increased from slightly over 4 GW to approximately 7GW (APASCUE, 2002).

In the UK, mechanical cooling is increasing in the non-domestic sector. In England and Wales only 2% of the non-domestic floor area of pre 1900 buildings include air-conditioning while the percentage reached 5% for buildings between 1965-1970, 14% for buildings between 1981-1990 and 20% for buildings from 1991. More than 50% of the office floor area and more than 30% of the retail floor area of buildings built after 1991 is air-conditioned.

In Spain, mechanical ventilation systems are not common in domestic buildings and central air-conditioning is negligible. On the other hand, most commercial and institutional buildings have mechanical ventilation systems installed (80% of commercial buildings and 82% of institutional buildings). It can therefore be assumed that a high percentage of office and retail buildings might already include mechanical cooling.

In France, the total energy consumption of offices has increased, on average 3% per year with a total energy consumption of 39.3TWh in 1990. It is estimated that HVAC services are responsible for 60% of the energy consumption in offices with electricity representing approximately 40% of the energy used. The average energy consumption for office buildings is 240kWh/m^2/year while buildings in the educational and research sector consume 190kWh/m^2/year (CEREN 1993).

It has been estimated that the energy demand for cooling is 30kWh/m^2/year in the residential sector in Southern European countries. In office and commercial buildings, the cooling demand is higher due to internal and solar heat gains. (APASCUE, 2002).

ENVIRONMENTAL IMPACT REDUCTION: UK OFFICE BUILDING CASE STUDY

This section attempts to quantify the reduction of the environmental impact by urban buildings by avoiding the use of mechanical cooling by using passive ventilation strategies. This is demonstrated by carrying out a comparison of an air-conditioned and passively ventilated office building in the UK. Both embodied and operational energy is taken into account and the environmental impact index used is the UK ecopoint. This specific index of assessing the environmental impact of buildings has been developed by BRE (BRE, 2000) and an environmental impact analysis tool has become available which includes the impact of building services (ENVEST, 2000). Therefore, the impact of ventilation and cooling on the embodied and operational costs of a building could be estimated.

A UK Ecopoint score is a measure of the overall environmental impact of a particular product or process covering a number of environmental impacts: Climate change, Fossil fuel depletion, Ozone depletion, Freight transport, Human toxicity to air, Waste disposal, Water extraction, Acid deposition, Ecotoxicity, Eutrophication, Summer Smog, Minerals Extraction.

The impact of a process or building is computed relative to the annual impact of the average UK citizen, i.e. to the per capita energy consumption, or water use, mineral use, etc. These normalized impacts are then weighted (more practical importance is given to certain environmental impacts than others) so that the average UK citizen has an impact of 100 ecopoints/year. In terms of energy consumption 100 ecopoints represent 32,000 kWh – the energy used by or on behalf of each person.
Using ENVEST a comparative analysis was carried out of the environmental impact of a typical urban air-conditioned office building and a purpose designed urban passively ventilated office building. The operational life of both buildings is assumed to be 60 years. Apart from the ventilation and cooling systems, the form and construction of the buildings differ as follows:

- FORM: The air conditioned (AC)-office has a square foot print while the passively ventilated (PV) office is L-shaped to be suitable for cross ventilation. This affects the environmental impact estimates because of the increased external surfaces for the PV-office.
- CONSTRUCTION: Sealed windows and relatively lightweight steel construction is assumed for the AC-office while exposed concrete and brick is assumed for the PV-office to increase the heat capacity of the building (essential for natural ventilation cooling systems).

Figure 1 shows a comparison between the two types of buildings. It can be seen that in this case the embodied energy ecopoints are similar but the operational energy impact is reduced by approximately 10 ecopoints per square metre of floor area over 60 years for the passively ventilated building.

Ten ecopoints per square metre of floor area over sixty years is a significant environmental impact reduction. In energy terms, this would be equivalent to 53kWh of electricity per year per square meter of floor area or 150kWh/day for an urban office of 1000m^2.

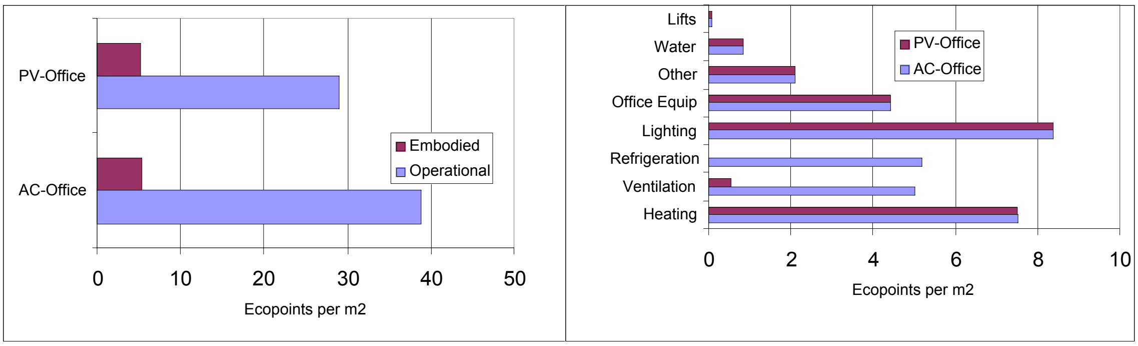

Figure 1: Embodied and Operational Ecopoints comparison between an air-conditioned and passively ventilated office building in the UK

CONCLUDING REMARKS

Information from four countries (UK, France, Spain and Greece) on the existing building stock and its location in urban or rural areas has been presented. Categorisation of the building stock as urban, suburban or rural was based on settlement size. (They are differences in this definition in each country as indicated in Table 1). According to data analysed, approximately 90% of the UK building stock can be categorised as urban or suburban while the same figure is less than 50% in the other three countries. Domestic buildings are the highest percentage of building stock in all countries. Significant environmental impact reduction can be achieved by using passive ventilation for cooling in southern European countries where the demand for cooling is high because of external climatic conditions. The potential is less clear for countries with moderate climate. In all four countries, office, educational, retail and warehouse buildings comprise an identifiable percentage of the non-domestic building stock. Internal heat gains are significant in such buildings and the potential of reduced environmental impact is less dependent on climate. An estimate of the reduced environmental impact of an office building in the UK based on the Ecopoints method has been presented which indicates substantial environmental impact reduction due to the operation of the building over its life cycle of 60 years by adopting passive ventilation.

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