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IP 2/90

April 1990

‡ 5035

Greenhouse-gas emissions and buildings in the United Kingdom

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The greenhouse effect is a natural phenomenon caused by the absorption of infra-red radiation in the lower atmosphere by certain gases, including carbon dioxide (CO_2). Man's activities are increasing the atmospheric concentrations of many of these 'greenhouse gases'. This paper explores the relationship between building energy use and the emission of CO_2 and other greenhouse gases. It also considers the scope for reducing CO_2 emissions through the application of energy efficiency measures in existing buildings.

INTRODUCTION

Global industrial development is now widely recognised to be on a scale large enough to cause changes to the composition of the atmosphere and, consequently, changes to climate. The principal man-made agents of climate change are increased concentrations of the so-called greenhouse gases which raise average temperatures in the lower atmosphere by absorbing infra-red radiation. The most important such gas is carbon dioxide (CO_2) which is produced whenever fossil fuels are burned. Other greenhouse gases include methane, nitrous oxide, ozone and the chlorofluorocarbons (CFCs). CFCs also cause damage to the stratospheric ozone layer.

Buildings are major consumers of energy for space and water heating, lighting, refrigeration, ventilation and other services. This energy together with that used for domestic appliances and office equipment, amounts to about half of total UK demand for energy and is the source of a similar proportion of all energy-related CO_2 emissions. This paper relates the major uses of energy in buildings to fuels consumed and hence to quantities of CO_2 released to the atmosphere. It shows how those quantities could be reduced through currently feasible and cost-effective improvements to energy efficiency in existing buildings. The role of buildings in the emission of other greenhouse gases is also discussed.

ENERGY USE IN BUILDINGS

Information on the use of energy by each consuming sector is available from the Digest of UK Energy Statistics[1]. Energy use in the domestic sector can be estimated fairly accurately. Much greater uncertainty exists for non-domestic buildings where, for present purposes, use has been made of a study by Hardcastle[2]. Figure 1 shows delivered energy for various sectors of the UK economy in 1987 and illustrates the importance of building consumption, particularly for electricity.

A good understanding of energy use in buildings requires a knowledge of the amounts of energy used

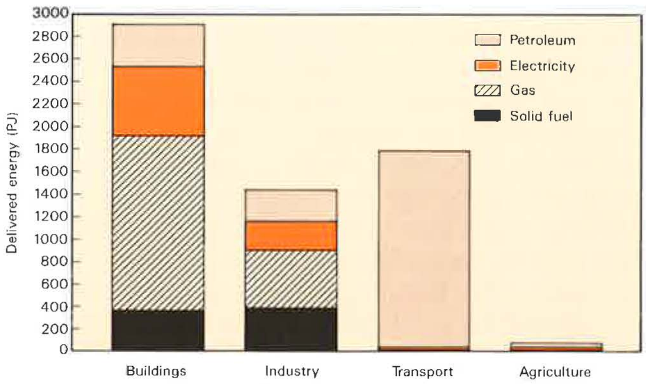

Figure 1 United Kingdom delivered energy consumption by sector and by delivered fuel type (1987)

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for various purposes and the fuels from which they are derived. A detailed study of energy use in the domestic sector has been undertaken by BRE[3]. Figure 2 shows a breakdown of domestic energy use by fuel and end use, illustrating the importance of gas as a heating fuel and the high proportion of total energy used for heating. Dwellings account for about two-thirds of building energy use overall.

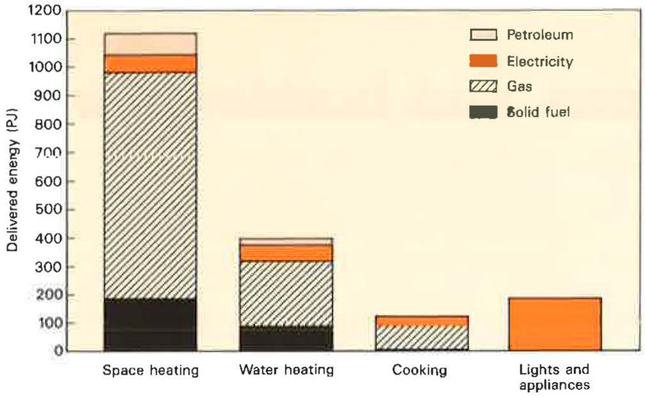

Figure 2 End uses of energy by delivered fuel type in United Kingdom dwellings (1987)

CARBON DIOXIDE EMISSIONS FROM FUEL CONSUMPTION

The various fossil fuels contain varying proportions of carbon and have different calorific values. Accordingly they emit varying amounts of CO_2 for each unit of heat they produce when burned, typical figures for the main fuels being shown in Table 1, column (a).

Table 1 Carbon dioxide emissions from various fuels used in the United Kingdom

	CO_2 emission	
Fuel	**(a) kg per gigajoule of primary energy available**	**(b) kg per gigajoule of energy delivered to consumers**
Coal	91	92
Natural gas	50	55
Petroleum	69	84
Electricity	—	231

Electricity presents a much more complicated picture since its CO_2 emissions depend entirely on how it is generated. For example, hydro-electric generation does not involve the burning of fossil fuels and produces no CO_2, while electricity generated from coal or oil clearly does. For the latter case, the efficiency of the generation process is also important since the CO_2 emissions are related to the fuel consumed rather than the electricity produced. In the UK, most of the electricity distributed by the national grid is produced from coal in power stations with an efficiency of about a third, ie about three units of energy are obtained from burning the coal for each one that is produced in the form of electricity.

It is possible to calculate the CO_2 emission associated with each unit of electricity used by consumers by taking account of the mix of fuels used in generation. Thus, although electricity produces no CO_2 at the point of consumption, an average unit of electricity consumed in the UK produces large amounts at the point of generation. Table 1, column (b), shows the amounts of CO_2 associated with each unit of fuel delivered to the consumer, including the overheads associated with generation and distribution. By this criterion, each unit of UK-produced electricity is associated with about four times as much CO_2 emission as is the equivalent amount of natural gas.

CARBON DIOXIDE EMISSIONS RESULTING FROM BUILDING ENERGY USE

Table 1, column (b), shows that very different quantities of CO_2 are associated with equivalent units of the different forms of energy used in buildings. Thus because they are based on energy units, Figures 1 and 2 do not give a fair indication of the CO_2 emissions from buildings. When the energy units are converted into CO_2 using the factors in Table 1, column (b), the relative importance of the various fuels and end uses changes considerably. A comparison between Figure 3 and Figure 1 clearly shows that electricity accounts for a larger proportion of the total CO_2 emissions than of delivered energy. Similarly, Figures 4 and 2 show that consumption by lights and appliances in dwellings becomes much more significant. Conversely, the relative importance of space heating is diminished although it is still the largest single contributor to CO_2 emissions. The reason for the changes in the relative importance of the different end uses is clear: those that rely heavily on electricity become more significant while those that rely mainly on natural gas become less so. This has important consequences when the effects of energy efficiency measures on CO_2 emissions are considered.

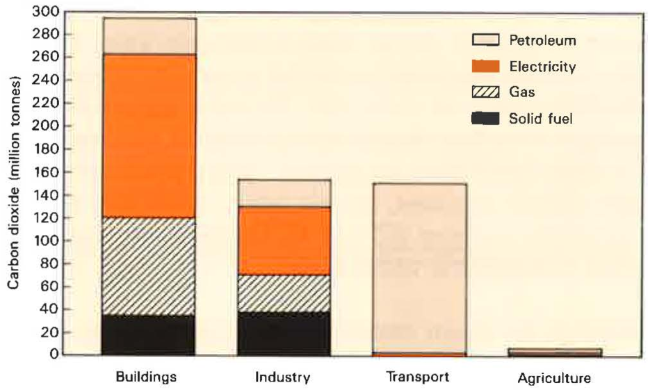

Figure 3 United Kingdom carbon dioxide emission by sector and by delivered fuel type (1987)

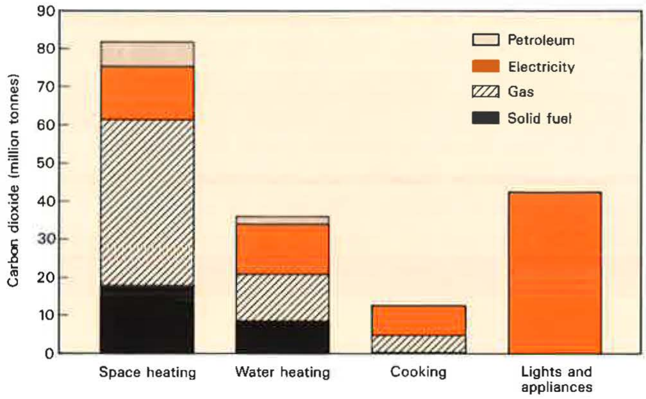

Figure 4 Carbon dioxide emission attributable to United Kingdom dwellings, by end use and by delivered fuel type (1987)

IMPROVEMENTS TO ENERGY EFFICIENCY IN EXISTING BUILDINGS

The UK has many old buildings that are in good structural condition but are poorly insulated. This is largely because they were built before thermal insulation was required by the Building Regulations or the local building by-laws which preceded the Regulations. The first national Regulations were introduced in 1965 and higher standards were established in 1976, 1982 and again in 1990. Thus many buildings erected as little as a decade ago have thermal insulation which is well below present standards, as do a large number of older buildings. Although it is generally most economical to install insulation at the time of building, there are a number of cost-effective ways in which insulation can be improved in existing dwellings. For example, most British dwellings have pitched roofs with accessible loft spaces which can be insulated very simply and cost-effectively. Other cost-effective measures include draught proofing and the insulation of external cavity walls and hot water storage tanks. Further measures are cost-effective under certain circumstances, such as double glazing when windows need to be replaced. Apart from improvements to insulation, energy efficiency can also be improved by installing more efficient heating systems and better controls.

REDUCTIONS IN CARBON DIOXIDE EMISSIONS THROUGH ENERGY EFFICIENCY IN EXISTING BUILDINGS

Particular energy efficiency measures affect specific uses of energy and hence the particular fuels that serve those uses. For example, insulation measures to the fabric of the building only affect space heating, while the replacement of a boiler might also affect water heating. When CO_2 emissions are considered, it is particularly important to attribute correctly any reductions in energy use to particular fuels because of the large differences in emissions per unit of energy (see Table 1, column (b)). This is particularly important in the case of electricity and those end uses, such as lighting and appliances, which rely mostly on electricity.

The reductions in CO_2 that could be obtained from energy-saving improvements to the housing stock have been analysed in some detail by BRE[4]. Two cases were considered. The first was confined to those measures which are considered to be cost-effective while the second also included measures that are technically quite feasible but not generally found to be cost-effective at present prices and fuel costs. The measures included in each category are summarised in Table 2. The first category includes measures which are cost-effective on their own and others, such as double glazing, which are partly justified by wider considerations than just energy efficiency. The calculated reductions amount to about 25% of present emissions for the cost-effective case. The technically possible category includes all of the first category and further measures which are capable of being carried out using well tried and readily available materials and methods. A possible reduction of 35% was estimated for the technically possible case.

Table 2 Energy-saving improvements which are cost-effective or technically possible

Cost-effective	Technically possible
Insulation improvements	
80% of all cavity walls insulated	All walls insulated
Lofts with < =25 mm insulated to 150 mm	All lofts insulated to 150 mm
Full double glazing in all homes	Full double glazing in all homes
Draught proofing in homes with <80% rooms already treated	Draught proofing in all homes
All tanks with <50 mm insulated to 80 mm	80 mm insulation to all hot water tanks
Heating efficiency improvements	
Condensing boilers in all gas centrally heated homes	Condensing boilers in all gas centrally heated homes
Improvements to cookers	
13% efficiency improvements to gas and electric cookers	25% efficiency improvements to gas and electric cookers
Improvements to lights and appliances	
10% efficiency improvements to dishwashers	20% efficiency improvements to dishwashers
38% reduction to lighting consumption	75% reduction to lighting consumption
25% efficiency improvements to refrigeration equipment	25% efficiency improvements to refrigeration equipment
20% efficiency improvements to washing machines	20% efficiency improvements to washing machines *and tumble-driers*
25% efficiency improvements to televisions	25% efficiency improvements to televisions

Figure 5 shows the estimated reductions in CO_2 which could be derived from the cost-effective case. About two-thirds of the reductions are due to insulation measures and the remainder to improvements in the efficiency of heating systems and appliances.

It is important to note that neither case is a forecast of what is likely to happen over the next 20 years but rather an estimate of the likely effect of applying

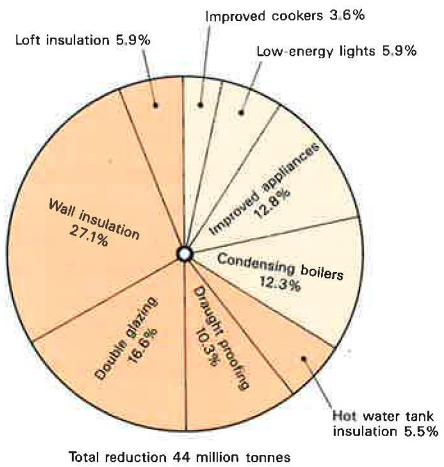

Figure 5 Domestic sector carbon dioxide reductions (million tonnes) through cost-effective energy-saving measures

those measures to present patterns of use. To estimate actual emissions at some point in the future requires account to be taken of trends in patterns of demand. Extrapolation of current trends leads to the conclusion that actual emissions are likely to remain close to present levels unless the rate of application of energy efficiency measures is accelerated.

OTHER WAYS OF REDUCING CARBON DIOXIDE EMISSIONS

The analysis just described refers strictly to measures that reduce the demand for energy. It is also possible to reduce emissions by changing the fuels used to supply that energy to ones that produce less CO_2. This could occur with the fuels consumed within buildings, for example by substituting natural gas for coal. However, the most important such change could occur in the generation of electricity for which the present CO_2 emission factor is high in the UK. An analysis of CO_2 emissions from electricity generation is beyond the scope of this paper but it is important to note that all estimates of potential reductions of CO_2 given above assume a continuation of present patterns of electricity generation. Clearly, any reductions deriving from a reduced demand for electricity would be lower if the CO_2 emission factor for electricity were itself to be reduced. A realistic forecast of future emissions would have to consider the effect of changes to the fuels used in electricity generation as well as improvements in end-use efficiency in buildings.

OTHER GREENHOUSE GASES

This paper has so far been entirely devoted to the question of CO_2 emissions connected with energy use in buildings. Table 3 shows the estimated contributions by various gases arising from all anthropogenic sources to greenhouse forcing (the warming effect associated with greenhouse-gas emissions).

Table 3 Contributions to greenhouse warming by various gases

Gas	Contribution to warming
Carbon dioxide	50%
Methane	19%
CFCs	17%
Tropospheric ozone	8%
Nitrous oxide	4%

Some of the gases in the table, other than CO_2, are also related to buildings. CFCs are widely used as working fluids in refrigeration equipment which is vital to the proper functioning of some types of building both for storage and for air conditioning. They are also used as foaming agents in some types of insulation used in buildings. Present-day buildings therefore are important sources of CFCs released to the atmosphere. CFCs are already the subject of international agreements which will greatly reduce their future use in buildings and elsewhere, so their significance as greenhouse forcing agents should decline. However, one effect of such restrictions will be to require substitutes for the CFCs used at present. It has been estimated that this will cause a small increase in the amount of energy required for refrigeration and a consequent increase in CO_2 emissions. Despite the relatively small quantities of CFCs involved, the overall contribution of CFCs to greenhouse forcing is thought to be about 17% of the present total, owing to their extreme effectiveness as greenhouse gases. Building-related usage in the UK is estimated to have accounted for about 8% of all UK CFCs in 1986[5].

Methane is another greenhouse gas which is associated with building energy use, being the main constituent of natural gas. Any leakage of methane from the gas distribution network could be seen as an 'overhead' to be added to the CO_2 that results from its combustion. This could be a very significant effect if such leakage were more than a few per cent because methane is about 30 times more effective as a greenhouse gas than CO_2.

Nitrous oxide is a greenhouse gas which is produced in low concentrations during the burning of fossil fuels. No reliable data are yet available on the quantities involved but they are thought to be small in relation to other building emissions.

CONCLUSIONS

Energy use in buildings is responsible for about half of total UK emissions of CO_2 at present. Those emissions could be reduced by a quarter of present levels through applying energy efficiency measures which are already considered to be cost-effective, if present levels of demand were maintained.

Actual future emissions will depend both on the rate at which energy efficiency is improved and on the rate of growth in demand.

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Printed in the UK for HMSO. Dd.8245168, 4/90, C95, 38938.

PERSPECTIVES

Energy efficiency to be boosted to stabilise greenhouse emissions

Energy efficiency might be about to see the legislative shot-in-the-arm which it so badly needs if Environment Minister David Trippier's statements following last month's conference on sustainable development in Bergen lead anywhere.

Trippier pledged that Britain would establish a national strategy to stabilise – and possibly reduce – emissions of greenhouse gases by November this year when the World Climate Conference takes place in Geneva.

He is quoted as stressing the importance of improvements to energy efficiency, saying that "we are going to have to move dramatically down that road". The strategy would have enormous implications for transport and energy policy, he added, and warned of the "pain and anguish" which would accompany efforts to reduce greenhouse gas emissions.

Speaking in Bergen about the declaration signed, he said "We have unanimously reinforced our commitment to both the Inter-Governmental Panel on Climate Change (IPCC) and the need for a Climate Change Convention; we have made the very important commitment to establish national strategies for limiting or reducing emissions of carbon dioxide and other greenhouse gases; and have also described examples of the sort of measures which we could take to help achieve this aim.

"These include the launch of a campaign throughout Europe and North America, "Energy Efficiency 2000", to enhance trade and cooperation on energy efficient techniques and practices, as well as policies to promote energy efficiency and renewable energy sources."

- The Watt Committee has published its suggestions for the best methods to tackle global warming, ranging in the short term from more gas-fired CHP in industry, introducing higher efficiency gas-fired power stations, promoting wind energy, increasing energy production from waste and further energy efficiency in commercial and public buildings and homes. Longer term suggestions are for the use of clean and high efficiency coal burning in power stations, carbon dioxide removal from flue gases, nuclear power and new fuels and methods of transport.
- The Building Research Establishment's Information paper 2/90 concludes that energy used in buildings could be cut by a quarter through applying energy efficiency measures which are already considered to be cost-effective.

Greenhouse gas emissions and buildings in the UK is available from BRE Publication Sales: 0923 664444.

CIBSE, RIBA advise Patten to green the White Paper

The Government's forthcoming White Paper on the environment will contain proposals for a "DoE test" for buildings to measure their energy efficiency, environmental safety and standards of maintenance; a national target for annual energy efficiency improvements of 2% per year and a new Energy Efficiency Agency; and a series of tax incentives to improve insulation standards and energy management in existing buildings. Or it will if Environment Secretary Chris Patten chooses to follow the advice offered to him by the Chartered Institution of Building Services Engineers, the Council for the Protection of Rural England and the Royal Institute of British Architects.

CIBSE also recommends the urgent tightening of the Building Regulations, discounts on the Uniform Business Rate for energy efficient buildings, and differential taxation of fuels based on their contribution to environmental pollution.

RIBA has also called for a mandatory energy efficiency rating for all new buildings, and a mandatory energy labelling scheme for all plant and appliances.

- Energy Minister Peter Morrison, talking to *Energy Today* last month, limited his predictions to anticipating a section within the White Paper relevant to the effect of energy on the environment. Asked whether he thought that legislation such as that advocated by CIBSE and the RIBA would prevail he said that he was not a legislator by nature, prefering to see voluntary codes and people taking decisions themselves. But he didn't rule out legislation.

BEMS

The BEMS users' book

The BEMS Centre has published a book on building energy management systems aimed at potential users of the technology, which, while not going into fine technical detail "should enable company managers and administrators to understand the key features, advantages and problems of real systems.

The book should enable the reader to ask the right questions when contemplating the acquisition of a system and follow through from initial thoughts to specification, installation, operation and expansion."

The BEMS Book is available from the BEMS Centre for £15 (free to members) on 0344 426511.

Transmitton becomes Andover

Transmitton Building Management Systems has changed its name to BICC Andover Controls Europe following the acquisition by its parent company BICC of Andover Controls in the US last year (see *Energy Today* December '89).

This move to tie up British BEMS suppliers with a large American manufacturer was subsequently followed by JEL (by its parent Thorn Security buying ISS Clorius UK, the importer of American Autometrix equipment) and Trend, whose parent company RTZ bought US-based Novar Electronics.

General Manager Paul Moore said that the new company contained the combined European operations of both Transmitton and Andover, and would be able to "satisfy the technological demands of the expanding European building management systems market".

The company has also moved into larger premises at its Ashby-de-la-Zouch headquarters, which includes a demonstration area for their equipment range.