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ENERGY EFFICIENCY and home automation

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Abstract

This working paper examines the potential linkages between home automation systems and the promotion of energy efficiency in the home. There has been relatively little interest in the relationship between information technologies and environmental policy. It is often assumed that IT is environmental benign and can easily be applied to promote improvements in environmental conditions. This paper briefly reviews the development of home automation technologies and competing systems available in the US, Europe and more specifically the UK. It argues that there are serious difficulties assuming that home automation technologies have a significant role in the development of domestic energy efficiency. There are three central problem areas: simple energy conservation and efficiency measures such as insulation and appliances are likely to generate more cost effective energy savings that expensive automation systems; the systems are likely to be targeted at premium customers sold on the basis of improved control and convenience rather than energy savings; and finally, the systems raise serious questions about access and control of information in the home. Regulation will be needed to ensure the potential environmental benefits of home automation systems can be realised.

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CONTENTS

1. INTRODUCTION

There is relatively little research that has critically examined the relationship between Information Technologies (IT) - communications, computing and software systems - and the environmental debate (Marvin 1993). Much of the literature on IT and the environment is characterised by highly utopian and technological deterministic perspectives. It is assumed that IT is an inherently environmentally benign set of technologies which can easily be manipulated to optimise the environmental performance of buildings, infrastructure networks and cities. IT certainly has none of the direct environmental emissions associated with older infrastructure networks such as energy, water, waste and transportation systems. But there is already mounting evidence that the indirect effects of IT technologies are not necessarily environmentally benign. For instance they can stimulate new demands for movement and mobility, enhance the efficiency and attractiveness of travel and increase the effective capacity of older infrastructure systems with little critical debate about the environmental implications (Marvin 1994).

This paper attempts place the development of home automation and domestic energy efficiency within a more critical framework. It examines the potential tensions, conflicts and contradictions between attempts to improve domestic energy efficiency and the potential role of home automation systems. This issue was selected for further analysis for six reasons:

· In the UK buildings are responsible for about 50% of energy consumption and are responsible for a similar proportion of Co2 emissions. The total estimated Co2 emissions from the household sector amounted to 174 million tons in 1987 equivalent to 29% of total UK energy-related emissions (BRE 1990).

· Nearly 50% of emissions are associated with space heating, 22% with hot water and electrical appliances are responsible for 25%. Although electricity is responsible for only 17% of delivered energy it produces 45% of total Co2 emissions in the domestic sector. In comparison with equivalent units of gas, oil, and solid fuel, electricity is the greatest polluter and most costly day-time energy source.

· Government policy has tended to focus policies for tackling energy efficiency at the larger industrial and commercial users. Policies for improving the energy efficiency of some 20 million households is based on the action of residents supported by increases in energy prices, advice from gas and electricity utilities and a scheme to help low income households (Owen 1994).

· Although the domestic sector is responsible for a high proportion of emissions at least 6.6 million households suffer some form of 'fuel poverty'. These households cannot afford to heat their poorly insulated homes to achieve an adequate level of thermal comfort and already spend a much higher proportion of their income on fuel than better off households (Boardman 1991). Increasing the energy consumption of these households without improvements in energy efficiency would further raise levels of Co2 emissions.

· Appliance manufacturers, builders and energy utilities have shown interest in the application of home automation systems to improve the energy efficiency of the home. Although previously focused on intelligent buildings in the commercial and industrial sector the falling price of technology has led to the development of systems which could manage space and water heating systems and control the use of individual appliances.

There has been relatively little assessment of the potential role of these systems in improvements of energy efficiency in the domestic sector. Most attempts to improve energy efficiency have focused on three sets of practices.

Firstly, potential improvements to the insulation levels of existing and soon-to-built housing stock. The Building Research Establishment (BRE) has estimated that a total reduction of 30 million tonnes of Co2 per year could be achieved through improved insulation. This is equivalent to about a fifth of the present level of emissions from housing and about 5% of the total UK emissions. The leading contributors in this reduction are cavity wall insulation and double glazing.
Secondly, the more efficient use of electricity. For instance low energy light bulbs, minimum standards of efficiency for new appliances and the energy efficiency labelling. The BRE estimated that these measures could contribute to a reduction of up to 15 million tonnes of Co2 per year. This reduction is made more significant by the fact that the energy savings are all in electricity and, for each unit of electricity consumed, this releases about four times as much Co2 as an equivalent unit of natural gas.
Finally, the development of fuel switching. This involves the substitution of an alternative for electricity in the competitive uses of cooking, space and water heating, where an alternative is available, safe and acceptable. Off-peak electricity (used as Economy 7 or with White Meter night storage heaters) is a cheaper fuel and may be marginally less polluting because of the greater proportion supplied by nuclear power. Any additional demand for off-peak electricity, however, would have to be supplied by fossil fuel plant. There is the potential for switching to other types of fuel such as gas and renewable sources. The types of renewable energy which may be used practically by the individual household are very limited, but those which are feasible have been well technologically developed. Passive solar energy design for domestic buildings is currently one of the most economically attractive renewable energy technologies, and, to a much lesser extent, so is active solar heating.
It is essential to bring together and control energy production and consumption. These processes may be combined under the heading of energy management. Energy management may be divided into two parts:
· the provision of new and more efficient methods of delivering and conserving energy and,
· services to ensure that total energy use is spread through the day in such a way as to take maximum advantage of lower tariffs and other forms of energy, including those from renewable sources.
Energy management is itself only part of another management system in the home - termed home automation. This may be defined as "the linking together of both existing and new domestic appliances and communications, in order to give easier and far more finely tuned control over what goes on in the home, as well as to improve connections between the home and the outside world" (RMDP 1987). According to Miles (1988) home automation is expected to provide one of the largest new markets ever for suppliers of both goods and services and in particular the introduction of information technology (IT) in the home. IT provides a method of integrating systems within the home electronically and means that the systems can become responsive and flexible to change.
In energy management, IT can be used to provide a system that is both integrated and interactive. It allows a house to be reactive to the time of day, the seasons of the year, diurnal changes in temperature, sunlight strength and direction, changes in the time of peak energy demand and lower energy tariffs. The use of IT in energy management represents just one of its applications in the home. Other potential uses, some of which are already used in the home, of IT are shown in Figure 1.
The aim of this paper is to examine the potential role of home automation and energy management systems in the reduction of home energy consumption. Section 2 outlines the scope of home automation technologies. Section 3 reviews the status of home automation in the US, Europe and the UK. Section 4 examines specific examples of energy management

systems. Section 5 reviews levels of interest in energy efficiency and IT and the scope for introducing systems. Section 6 critical examines the role of home automation in domestic energy policy.

Figure 1: Potential applications of IT in household activities

Household Activities	Potential Applications
Energy Management	
	Programmable appliances sensitive to environmental changes & load management
Health	
Health maintenance	Lifestyle planning & monitoring
Curative medicine	Diagnostic programmes & remote counselling
Emergency care	Emergency alarms
Household Management	
Cooking	Menu assistance, automated ovens
Gardening	Garden planning aids, automatic watering
Household maintenance	Monitoring heat loss, damp, etc.
Appliance maintenance	Fault-finding with sophisticated goods
Shopping	Teleshopping & consumer information
Communications	
Transport	Travel booking and route planning
Telecommunications	Electronic mail, interactive services
Household Security	Fire and intruder alarms
Financial Services	
Banking and tax	Telebanking, budget planning
Stock brokerage	Buying and selling of stocks and shares
Working from Home	
	Tele-education, teleworking.
Entertainment	
Spectator sport	Booking seats, delivering video recordings
Cultural facilities	Electronic libraries and newspapers
Games	Video games, computer-assisted games

After: NEDO (1987)

2. HOME AUTOMATION technology

Home automation requires domestic appliances to be fitted with the capability to respond to changes in the home environment, initiate messages, and receive and act on information from other appliances, including messages from the outside the home perhaps relayed by the telephone system. Information technology gives the capacity for fine-tuning the home environment through the installation and utilisation of three types of IT devices, communications media, control devices and storage media.

2.1 Communications Media

There are currently three types of internal domestic communication - specialised cable and wiring, mains wiring and infra-red and radio. Figure 2 shows some of the advantages and disadvantages of each method. They are all commonly used in the home today, for instance, infra-red is used for remote controls of televisions, radio in some security devices and in portable telephones, mains signalling for baby alarms, and specialised wiring in alarm and security systems.

Figure 2: COMPARISONS OF DOMESTIC COMMUNICATIONS MEDIA

METHOD	ADVANTAGES	DISADVANTAGES
Specialised wiring	Huge quantities of data, especially if optical fibres	Requires new installation
Mains signalling	Existing infrastructure	Limited data - eg. on/off & status reports; 'leakage' of signals to other homes' apparatus.
Infra-red & radio	No re-wiring needed; permits physical mobility of users; high levels of data can be transmitted.	Interference - but standards available to overcome this problem.

After: Miles (1988)

The electricity companies have funded much of the research on the use of mains signalling for home automation in the UK. Because mains signalling utilises the existing wiring in a house, it may be used for communication both in the newbuild and the retrofit house market. Mains signalling is the communications media used in the UK Credanet home automation system which provides the most up-to-date working example of mains signalling. The control console of Credanet is connected to a small power unit which is itself connected directly to the mains supply. Mains-interface units or "MITES" receive instructions passed from the central controller and transmitted along the mains wiring. These MITES are power outlet sockets, lighting roses (to which sensors are connected), and appliances with special plugs, connected to the mains supply in other parts of the house. During the installation of Credanet, each device is identified by a code which is then used when controlling the appliances in the home. Installation of the Credanet is simplified and cheapened by the use of mains signalling because of the minimum amount of specialised wiring required.

The US Smart House project requires specialised wiring and is thus more appropriate for the newbuild market. This is designed so that power and communications are combined in a single cable carrying three wires: one for electricity, one to transmit control signals and data, and the third carry audio and video signals. This integration of media may eventually be used in intelligent buildings in the UK with plug and socket systems carrying power together with digital communications lines, perhaps using coaxial or optical fibres as media.

The use of infra-red and radio, already common place in many homes, may become an important communications media in the future, facilitating the remote programming of the house. But the telephone most significant in communication with the home. Home automation is likely to provide a greater market for cordless devices which allow access to telephony and related services from wherever the user is. These devices are known as 'Personal Communications Terminals' (PCTs) and, in the automated home, will be used as cordless alpha-numeric pads ('Telepads') for integrating the functions of cordless telephony, and the control of appliances and devices within the home.

2.2 Control Devices

Home automation is used to manage the internal home environment according to the users programmed criteria. This is achieved through the use of meters, sensors and controls which can respond to changes in the external environment. These are of particular relevance in energy management systems.

Domestic meters in common use provide little information for the householder but there are currently several 'smart' meters undergoing trials in the UK. These go part of the way to integrating the control of energy (and water) consumption into a home management system and increasing energy efficiency in the home. Remote metering by the electricity companies would allow meters to be read without the need for meter readers to physically visit homes. In the automated home, meters could provide more information and flexibility for the householder. For instance, meters should indicate the running total of energy consumed since the last bill, and how much it has cost. In order to reduce fuel bills, the meter should be programmable to alter the amount of energy supplied to various appliances, in response to changes in both the energy tariff and the source and size of the demand from appliances. This would permit energy companies to introduce more complicated tariff structures so as to manage loads more effectively. For example, one particular form of energy user, such as the hot water system, may have to be given a reduced energy supply if the overall demand is above a certain level when a higher tariff period starts. This type of meter is not yet on the domestic market , although trials and pilot schemes to test various new kinds of meters are being carried out.

Horstmann Timers and Controls Limited have developed both Economy 7 controls and metering systems. Their most sophisticated system, The Electronic 7, is compatible with GMT or GMT/BST tariffs and its boost timers may be programmed so that immersion heaters are switched directly by the electricity companies' tariff control equipment. Unfortunately, this control does not extend to the switching on of other appliances - this is the role of the home controller or the individually programmed appliances. Horstmann's 'Multi-rate Metering System Series 2' can be used to convert single-rate domestic meters to ones which can meter total electricity consumption at up to five rates. A hand held unit is then used to programme the System and also for meter reading and storage of meter data. Both these 'smart' developments from Horstmann go part way to controlling electricity consumption in the home, but neither provide an integrated energy management system in terms of altering the amount of energy supplied to various appliances depending upon demand in the rest of the house and the time of day, nor take into account the switching to other forms of energy. This illustrates the need for joint co-operation between the different energy suppliers if integrated energy system are to be established in the home.

Home automation creates the need for equipment to be able to respond to messages, to detect the identity of individuals seeking to operate appliances, and to be aware of changes in the environment. Such sensors and recognition equipment are already available, for instance smoke detectors, and in the US prototype cookers which respond to instructions only when they are given by someone of adult height are currently undergoing trials. Home control systems such as the Horstmann Home Controller incorporate low hot water and frost sensors. Controls on an increasing number of domestic goods already incorporate a microprocessor, designed primarily to direct a sequence of actions. In the automated home, controls must be more sophisticated and have the ability to be programmed, to respond to instructions, to initiate complex sequences of events, to recognise and accept messages for the appliance to which they are attached and respond to messages from outside the home.

2.3 Storage Media

Information which changes frequently and loses value if it ceases to be current must enter the house via a communications or IT network. This information may either be 'on-line' and continually updated from outside the house, or held on a portable storage medium with which the householder can programme the automated system himself. The choice of storage media obviously depends upon the type of external communications network that is available.

3. HOME AUTOMATION INITIATIVES

3.1 Current Developments: US and Europe

The remote control or 'programmability' of domestic appliances has been achievable for some time provided enough electronics and computer power were utilised. Until the 1980's, however, the commercial sale of such products was prohibited by their high price. Nevertheless, improvements in the functionality and reductions in the costs of information technology has spawned a range of demonstration houses over the years, from firms, exhibitions and enthusiastic individuals.

US Home Automation Initiatives

Although there are a range of home automation initiatives in the US summarised in Figure 3 current attention has focused on two rival programmes which started in the early 1980s - CEbus and Smart House.

In 1982 The Electronic Industries Association first examined the potential of home automation and commenced efforts to develop non-propriety standards. Their 'CEbus' (Consumer Electronic Bus) design is a detailed set of instructions on how to encode and transmit information within the home (Brody 1988). The system has now been renamed 'Home Product Link' and permits interactive communication among a wide variety of household products. The bus could carry information from a personal computer to a printer, for example, or from a central VCR to televisions throughout the house. The dishwasher could then alert the water heater to prepare a batch of hot water before starting its cycle. At other times, water could be kept cooler, saving energy. Brody points out that some of the main benefits of the CEbus would not go to the homeowners, but to the companies that service them as smart appliances plugged into the Bus detect impending failure and automatically alert a repair centre, even if the fault was so minor that it could be repaired by the homeowner. CEbus also has the potential for energy management applications. Energy utilities could send signals to household appliances - perhaps even shutting down non-essential appliances during times of maximum power demand. This could help delay demand for further power plants and increase energy efficiency in the home.

Figure 3: Home automation: the early lineup

Company	Product Name	Description
Archinetics	Max	Controls and monitors security, lighting, and energy systems. Can be programmed via telephone; has a synthetic voice.
CyberLynx	SmartHome	Programmed with an Apple or IBM PCW computer; links security to control of lights and appliances.
Enerlogic Systems	ES-1400	Adds logical decision-making to the automation system mode made by X-10.
Hypertek	HomeBrain	Programmed with an IBM PC or compatible computer, which can then be disconnected or used for other tasks. Uses a touchscreen interface.
Mitsubishi	Home Automation	Controls energy, security, communication, and entertainment systems; works via the telephone. Video intercom monitors a child's room or sees who's at the door.
Unity Systems	Home Manager	Emphasises energy management automatic dampers in ductworks adjust the temperature of individual rooms. Uses a touchscreen interface.
X-10 USA	Powerhouse	Plug-in modules that transmit on/off commands to lights and appliances through existing wiring.

After: Brody (1988)

Smart House is a limited partnership in the US, established under the National Association of Home Builders (NAHB) in 1985. It has developed a set of standards for home automation control, communication, cabling and installation for use in homes. The Smart House concept is aimed primarily at the new homes market although components for retrofit into existing homes are not expected until 1995 (Garrett 1990). The Smart House system was commercially launched in April 1991 at a cost including the wiring needed of $5000 (Garrett 1990) even before the first 'Smart' appliance is attached. The NAHB has set up a wholly owned subsidiary, the Smart House Development Venture, to promote the automation concept. The venture has developed a radical new method of wiring that not only eases automation but also greatly lessens the chance of electrically caused fires or injuries. The project cleared a significant hurdle in 1987 when the National Electric Code was revised to permit the new type of wiring. In 1988, 41 companies had signed contracts to make components of the Smart House. These were followed by the appliance makers, in particular manufacturers of heating, ventilation and air-conditioning equipment. This type of partnership makes for a comprehensive automation system whereby all appliances in the home are integrated.

The Smart House proposed by NAHB differs radically from an ordinary dwelling. Its design centres round the installation of a single cable which contains three wires. The first carries electricity, the second transmits control signals and data, and the third handles audio and video signals. Because each wire connects to each outlet in the house, these multipurpose receptacles would accommodate a variety of appliances, from toasters and hair driers to telephones, stereo speakers and smoke alarms. In addition, flexible gas piping is installed throughout the house and electronically controlled valves then automate gas appliances. Perhaps most futuristic are the ideas associated with the interaction between appliances. Brody (1988) gives the following examples - the ringing of the doorbell could relay a signal to the controller telling it to cut off power to any vacuum cleaner that might be plugged in at the time, and when a washing machine has finished its cycle, it could pass the word along to the television set which would flash the message on the screen.

European Home Automation Initiatives

European firms started automated home development slightly later than in the US and Japan. It is only within the last few years that large companies such as Electrolux and Creda have launched subsystems of home automation. The most activity to date appears to have been in France. Here the term 'Domotique' refers to the new technologies of the home of the future and encompasses more than simple home automation, according to the president of the French association for the home of the future APMF (Association Pour les Maisons du Futur): "It refers to the wider concept of the intelligent home, covering the integration and interactivity of all the various aspects and services " (Betts 1988). Domotique is still somewhat in its infancy in France, although forecasters expect the intelligent home market to quickly grow during the 1990's. The APMF commissioned a showpiece home of the future - the Maison Du Futur which is situated in Paris and it demonstrates just how Europe have trailed behind Japan and the US in home automation development. The house contains many electronic products, such as smart meters, intercoms, faxes, computers etc. But, unlike the US equivalents, there is little integration between these and other domestic appliances, with each having its own separate remote control handset (Haddon 1990).

One key to the future development of home automation in Europe is the definition of a common European standard, as used in the US and the Smart House project. This is now being undertaken by a group of seven European electronics companies including Thorn EMI, GEC and Mullard of the UK, Electrolux of Sweden, Phillips of the Netherlands, Siemens of Germany and Thomson of France (Betts 1988). These companies joined forces in 1987 in a two-year project called Integrated Home Systems to produce a common standard for home networks in Europe. This project achieved its main goal of producing outline specifications for a provisory standard.

3.2 UK Home Automation Initiatives

In the UK the National Economic Development Office (NEDO) had a major role in developing awareness of the automated or intelligent home market. In 1984 the NEDO Task Force on 'Interactive Home Systems' (IHS) was launched focusing on two central issues. First, the requirements for setting standards on interactive home systems, these could permit the creation of open systems, allowing consumers to build up home automation services using products and services from a number of different companies. Second, the identification of key products and services that would establish consumer acceptance and demand. According to NEDO, an Integrated Home System comprises of a series of networks of domestic appliances, the integration of which is facilitated by information technology. These networks are known as sub-systems and they provide integrated services within a particular area of domestic activity. NEDO predict that this integration has, and is likely to continue to do so, developed first in three areas:

· Entertainment systems, with common controls and output devices, and convergence between audio, video and computer communications in laser disc systems.
· Security systems, with fire and smoke alarms, emergency callers and intruder detectors linked to central alarm facilities.
· Energy management systems, based on remote metering by the public utilities.
NEDO proposes that these three areas could then be integrated into an interactive total home system, as shown in Figure 4.

FIGURE 4: THE NETWORKING OF HOUSEHOLD FUNCTIONS

3.3 Credanet Home Control System

An example of a UK home automated system is 'Credanet'.Credanet is an 'integrated house system to control and monitor, from both within and away from home, household energy management and security' (Creda 1990). The system was launched in 1991 and with planned future developments it is hoped to also embrace other functions such as shopping orders, health monitoring and working from home. Credanet uses existing mains wiring to carry signals between each unit. It may, therefore, be available to both the new dwelling and the retrofit market. The system has been designed to be fully compatible with the new European standards for IHS (Integrated Home Systems) and as an expandable system, to take advantage of any new developments. The Credanet central control is a central wall-mounted processor with a LCD display and built-in transceiver unit and software for basic command and control functions. A remote access unit, which connects into a telephone socket, enables the control of many of the functions to be exercised from a remote location and works also as an answering machine. Credanet offers four main automation systems:

Heating Management

Temperature sensors linked to Credanet enable flexibility of temperature control and this can be done for all electric controlled heaters either singly in individual rooms or for the whole house. Sixteen different daily programmes are available for controlling each room and these may be overridden from the central control point. Credanet can also control two immersion heaters for "demand" and "off-peak" so that water temperature can be set and programmed and it will also indicate the amount of hot water remaining.

Lighting control

Light programming can be automatic on a daily or weekly cycle and special programmes can be stored to operate when the house is unoccupied to give the impression of internal activity.

Security Management

Security and safety sensors can be connected to Credanet. These include door and window switches, pressure mats, passive infra-red detectors, smoke detectors, gas detectors and water detectors. The sensors may be armed and disarmed separately or collectively, and may be programmed to sound alarm signals inside or outside the premises. In addition, the presence of an intruder in a particular room may be displayed on the control screen.

Appliance control.

Appliances may be controlled by Credanet. For example, table-lamps may be programmed or brightness controlled in the same way as fixed lights, or the speed of a fan may be adjusted. If portable appliances are moved to new locations, Credanet will still identify the correct device to control.

Under the 'Smart House' project in the US, appliance manufacturers co-operated with housebuilders in order to develop and promote the automated home. This is also the case for Credanet where the appliance makers Creda and the housebuilders Potton Homes have shared in the prestige and publicity of the joint project. In the future, several important developments to the Credanet are foreseen. These include the management and control of energy consumption using tariff information derived from the meter teleswitch; a development which will reduce household energy bills. A telephone access device will also shortly be available, which will enable control of many of the functions to be exercised from a remote location, with responses in natural speech.

4. ENERGY MANAGEMENT SYSTEMS

4.1 The Focus on Electricity

The systems described so far are only applicable to one form of energy and its metering and control - electricity. The use of IT in the home does rely on electricity as the energy supply for the transmitting of information, messages and responses, and for the control and running of electrical appliances. Increased energy efficiency and control through electronic home systems are not only of relevance to electricity supplies, however. As shown in the introduction of this paper, electricity is the most costly form of domestic energy, both in terms of price to the consumer and its environmental costs. The other principal source of energy in homes is gas which has more limited use in the home but is cheaper and its use is less environmentally damaging.

4.2 Gas

In France, Gaz de France have provided flexible control and billing of gas usage for individual occupants in blocks of flats. In the UK, research has tended to focus on the development of efficient gas appliances, such as the domestic condensing gas boilers, and the development of 'smart' meters which indicate how much gas has been used and its cost. But there has been little or no research into the integration of gas appliances into home automation systems. One move in this direction has, however, been made in the UK by 'Ofgas', the Office of Gas Supply. Their report entitled "Least-cost Planning in the Gas Industry" argues that 'least cost planning' can, on the basis of US experience, be applied to gas as well as to electricity (Ofgas 1990). The least-cost strategy provides for meeting the need for energy services with the least costly mix of energy supplies and energy efficiency improvements (Ofgas 1990). This strategy, if accepted by British Gas, will offer further scope for energy management in the UK.

The starting point of least-cost planning is that customers are interested in what fuel can do for them (provide heat, light, etc) rather than in gas and electricity per se, and that they are concerned about the size of their bills rather than the tariffs per unit of consumption. Thus, a method which used conservation measures or employed energy-efficient systems to supply consumers with the same services at a higher tariff, but for a lower overall bill, would be welcomed. Least cost planning is widely used in the US by the electricity and gas companies and there a model for financial evaluation of any proposed change in either the supply or conservation of fuel has been developed. In the model, companies take into account not only their own immediate financial interests and those of their customers, but also the interests of the wider population in avoiding pollution. In the electricity industry two factors make this approach attractive: the very high capacity needed to meet peak demand, and the huge cost of new generating stations when demand exceeds existing capacity. It can be much cheaper all round to pay customers to reduce consumption than to increase supply. Least cost planning in the US gas industry is still in its infancy, but planning in several states has already begun. Ofgas believes that British Gas has avoidable costs, such as supply contracts, distribution and storage, and costs associated with the provision of gas at peak periods which can be included in the least cost modelling process. With the privatisation of the gas industry and the fact that British Gas' main aim has been to sell as much gas as it can, the proposal to provide as many services as cheaply as possible may not be received favourably by British Gas and its shareholders. It is probable that large financial or regulatory incentives may be needed to change their way of thinking.

At present, the possible financial incentives are unclear, because least cost modelling has not been undertaken in the UK, and there are no legal requirements to use gas more efficiently or to take wider interests into account. In the future, however, wider societal interest in pollution control and energy efficiency will receive legal recognition before very long. At the same time, according to the report, the question of avoidable costs will become more pressing as current supply arrangements run out. There are clear implications here for the home automation industries as it may be cost effective for British Gas to offer their customers incentives not only to improve home insulation, but also to install systems aimed at reducing peak demand and increasing energy efficiency. These moves will increase the market for sophisticated gas meters, switches and fully integrated energy management systems which can manage more than one energy type.

4.3 Renewable energy

Amongst the range of renewable energy sources there are only two which may be practically utilised by the individual householder: active and passive solar heating. The use of passive solar heating by appropriate building design is regarded as a more economically attractive option by the UK government than direct or active solar heating, for which the British climate is not ideal.

The former Department of Energy estimated that by combining passive solar design with current energy efficiency measures, household energy costs can be reduced by up to 40% (Department of Energy 1988). The Department funded a passive solar R&D programme which include a major field trial in Milton Keynes. The monitored results showed the impressive contribution that solar energy can make: on average, nearly a quarter of the house heat demand (24%) was supplied by passive solar energy. The best savings are to made by deploying passive solar design principles in both siting and construction: the houses are south-facing and unshaded with concentrations of glazing and conservatories on their south sides where the living areas of the houses are also situated. North-facing windows are smaller and serve rooms less frequently in use such as utility rooms and bathrooms.

There appears to have been very little research into the use of integrated energy systems which incorporate energy derived from renewable sources. One exception to this is a project run by Hancock & Littler (1987) which involved the monitoring of six dwellings with roof constructions modified to admit solar gains. In this, solar roofspace systems were studied as contributors to the heating and venting of dwellings where wall insulation is uneconomic and other problems such as condensation occur and where direct solar gain through windows is limited by overshading from closely spaced buildings. These systems may be used as part of an urban regeneration package whereby the solar roofspace system is substituted for the conventional replacement roof, and thus the real cost of the solar roof can be reduced.

The roofspace solar system has a winter heating mode in which the heat is circulated and recirculated throughout the house by fans. The whole system is controlled from a central point which allows the solar system to be given preference over the house central heating by automatically lowering the central heating set-point for the period of activity of the solar system. To continue to gain solar heat at higher temperatures each householder may select a higher house set-point to 'overheat' the house and temperatures are raised during peak periods of solar gains. The system also has a summer self-venting/cooling mode whereby air is automatically drawn in to limit the roof temperature. This project demonstrates the use of controls to integrate a renewable energy source with fossil fuel-produced energy to provide domestic space heating.

5. ENERGY EFFICIENCY AND IT

5.1 Meeting Customers' Needs?

Market research seem to suggest that home automation offers an enormous potential market, calculated by NEDO to exceed œ8 billion a year world-wide this decade. This market is very broad with opportunities for many different industries which offer electronically controlled domestic products, systems and services.

A consumer survey by NEDO/RMDP offered the participant descriptions of 38 products and services. Energy management and household security produced most initial interest among consumers. The concept of easier, more comprehensive and sensitive control of the domestic environment proved popular, as did an emphasis on reliability. When questioned further on energy management, it became apparent that consumers disliked systems which threatened to transfer responsibility from humans to machines, but liked having increased control over their energy usage. Telecommunications links which allow householders to over-ride pre-programmed sequences from outside the home were also popular. Making better use of different tariffs for energy through the 24 hours of the day was seen as having an important role in reducing costs.

There was, however, some scepticism about the practicality of this, if savings depend on adoption of rigid routines or major re-scheduling of domestic activities. A number of other organisations have carried out consumer research into home automation in recent years and their findings reflect those of the NEDO research. For example, a survey of American home-owners showed the three features of home automation rated most highly were energy conservation 62.2%, convenience 62.0% and safety 60.4% (Professional Builder December 1987). In France, a study reported at the 'Domotique 88' conference showed that 69% of those questioned marked energy conservation as their main reason for having home automation and 63% automated security systems.

These surveys show that among the variety of home automation services offered, energy management and domestic security are of outstanding importance to consumers. One of the main justifications for home automation and energy management was perceived to be the more efficient use of energy, and energy usage was seen as an area where saving money ranked as an objective alongside increased comfort. In addition, consumers were asked to rank the various home automation systems in terms of perceived popularity across the population as a whole. Again, security and energy management were judged likely to be successful because almost everyone occupies property and uses energy, and therefore has something quite specific to gain from the automation systems - increased security, and the more efficient use of fuel. The development of automated home systems requires not just the buying of the technology - to be of relevance to people it has to be used. Little research has been done on the actual usage of novel IT-related devices in the home.

5.2 Retrofit or Newbuild?

When considering the growth of home automation in the UK a central issue is whether the systems should be introduced by including the necessary infrastructure in newbuilt houses, or whether retrofitting of older houses is more appropriate. The eventual shape of home systems may well vary according to whether developments are led by builders or by manufacturers of home appliances. For example, newbuilds can be cabled to provide for almost every eventuality in home systems, while retrofitting will need to take account of existing communications within the home and the establishment of common standards for the appliances.

In order to take this discussion further, it is first necessary to consider the nature of the UK's current housing stock. In the US and Japan, houses tend to have a shorter life, and projects like the builder-led Smart House in America work because there is a large enough newbuild market to justify the development costs. The UK, like other European countries, contains a far higher proportion of older housing, and so requires home automation systems geared to the retrofit market, which means designing for ease of installation. Consequently in Europe most home automation initiatives come from appliance manufacturers and are heavily influenced by the needs of the older housing stock, which alone can produce the necessary volume of demand.

Most home automation companies aim their systems at the new build house market. The most convenient time to equip a home for automation is before it is completed - stringing wire is much easier and cheaper before walls and ceilings are erected. In addition the cost of an automation system may be paid off more easily when incorporated into a 20 or 30 year mortgage.

One view among housebuilders is that home automation provides a potential marketing advantage and the installation of home systems in newbuilds is cheaper than retrofitting as system costs can be incorporated into a new mortgage. According to a survey carried out by The Intelligent Home (1990) most builders see demand for energy efficiency as the "probable first boost for home systems". It is important to note here, however, that the biggest contribution to low energy costs comes from the design of buildings and the materials used. The purchase price of automated energy efficiency homes remains crucial. Potential buyers may prefer the lower purchase price on rival developments to the chance of a lifetime of low outgoings after a payback period of not much longer than a year (Intelligent Home 1990). In the US, the 'Smart House' programme demonstrates that co-operation between appliance manufacturers and housebuilders one way forward for the growth of home automation in the UK.

6. CONCLUSIONS

6.1 The Relevance of Home Automation?

Although the developers of home automation systems have tended to claim that the systems can make a valuable contribution to improvements in energy efficiency there is relatively little evidence to support this contention. There are three central areas of concern here:

Firstly, it tends to be assumed that more effective and sophisticated control over domestic energy systems can unproblematically promote improvements in energy efficiency. But given the high cost of home automation systems it is likely that much simpler measures such as insulation and high efficiency appliances will have more cost effective impact on reducing levels of domestic energy consumption. Although market research seems to indicate that customers are interested in the energy management function of home automation systems there is little evidence to assess their potential contribution to improvements in energy management. It is assumed that householders will respond to the higher level of control they can exert over energy systems by generating savings but alternatively it may result in patterns of use which increase levels of energy consumption.

Secondly, the high cost of retrofitting home automation system into existing homes and the innovative nature of the systems in new homes means they are likely to be targeted at premium customers. It is unlikely that the systems will have much relevance to meeting the energy efficiency needs of most households. The appliance manufacturers, builders and energy utilities are interested in using home automation systems as a way of 'adding value' to the basic services they provide. Home automation services represent major new markets for products and premium services. There is major competition to define proprietary systems and capture the communications link into the home as companies attempt to shape and capture this potential growth market. This means that there is a danger that different systems will not be able to communicate as manufacturers attempt to lock customers into particular systems. Competition in the energy sector is likely to mean that systems will be fuel specific - electricity or gas and possibly exclude the use of renewable systems.

Finally, home automation raises serious questions about surveillance and control of the home. These systems can monitor use of the home and individual appliances and can also be used to identify which appliances a households owns. This form of information on energy use, appliance use and ownership becomes a powerful commodity as utilities, builders and appliance manufacturers and suppliers compete for market share. There is also the potential for the fuel utilities to control the time of use of particular appliances such as washing machines and spin dryers as they shape energy demand to minimise energy use or reduce the costs of supply. Consequently home automation systems could open up control of appliances in the home to external agencies.

Although home automation systems could have a role in domestic energy efficiency it is not likely to be particularly significant. It is likely that home automation products and services will be targeted at premium customers - an energy elite - while the bulk of householders will have little to do with these systems. While there may be the potential for the development of home energy management systems in the UK there is a need, however, to ensure that regulation attempts to promote their potential energy efficiency benefits. This would require controls to ensure that:

· Standards are set for integrated home energy systems which allow open systems and enable consumers to build up the systems using products and services from a number of companies.

· The systems are comprehensive, yet flexible, to allow for future developments and innovations in the home automation field.

· The system should consist of a central controller which is connected to 'smart' meters of electricity, gas (and solid fuel when used) and which can integrate the use of these forms of energy.

· The systems can integrate renewable energy sources such as the use of passive solar designs for new houses.

· The control system should be as 'user-friendly' as possible, with an extensive range of programmable options.

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Utilities could play a key role in the development of home automation and energy efficiency appliances. They already have information on energy use, have to read meters and are actively looking to diversify from their core activities into new markets. However, utilities do not necessary have an interest in promoting energy savings. Instead home automation could be used to capture customers and prevent them from shifting to alternative fuel suppliers. But home automation is of relatively little interest to marginal and low income customers in fuel poverty. Instead IT have been used to develop new forms of pre-payment metering technology based on the use of chargeable smart cards or keys. These shift the problems of non-payment and re-payment of debt away from the utility and on to the customer. The widespread introduction of pre-payment technology largely explains the apparent reduction in gas and electricity 'disconnections'.

Table 1: Carbon dioxide emissions from and the cost of main domestic fuels in the UK 1989 (delivered energy)

FUEL	kg CO2/kWh	p/kWh
Electricity		
- general tariff	0.83	6.12
- off peak	0.83	2.22
Gas (@ 39.8p/therm)	0.20	1.36
Coal	0.33	1.18
Oil	0.30	1.26

Source: Boardman (1990)

Table 2: UK domestic sector carbon dioxide emissions (1987) by use and fuel (in million tonnes CO2)

	Gas	Electricity	Solid Fuel	Oil	Total
Space heating	42	15	17	7	81
Water heating	15	13	8	2	38
Cooking	4	7	0	0	11
Appliances	0	42	0	0	42
Total	61	77	25	9	172
% of emissions	35	45	15	5	100
% of delivered energy	59	17	17	7	100

Source: FOE (1990b)

FIGURE 5: THE NETWORKING OF HOUSEHOLD FUNCTIONS

Fire alarms

Burglar alarms

Medical alarms

Intelligent
security
systems
External messaging
Household monitors
responsive to
external enquiries
'Central'
controllers
Energy metering
Water metering
ADVANCED
IHS
Home energy
management
systems
Heating systems
Laundry appliances
Cooking appliances
Audio entertainment
Home entertainment
systems
Advanced data
communications
Video entertainment
High-quality
interactive
telecommunications
After: NEDO (1987)

SUMARY

The problems of global warming and increasing carbon dioxide levels in the earth's atmosphere are currently at the forefront of many politicians' and scientists' minds. The burning of fossil fuels, primarily to generate electricity, contributes to about half of all carbon dioxide produced and, in the present climate of privatisation of the energy industries, it would seem unlikely that significant reductions in carbon dioxide emissions will be made in the near future. This paper examines the contribution to reducing the carbon dioxide emissions that may be made by one energy consumer, the domestic sector. Households account for approximately one third of UK energy-related carbon dioxide emissions and through the introduction of energy efficiency measures and management systems, energy consumption may be reduced.

Energy management is examined as part of the whole concept of 'home automation' and information technology. The development of home automation, predominantly in the US and Japan, is traced and this reveals the lack of integrated energy management systems that are available abroad on the current domestic market. Research into current home automation and energy management systems in the UK shows that such 'smart' devices are being developed but on a very ad hoc approach. This has resulted in there being little or no interaction or cooperation between the different energy suppliers and appliance makers. The applicability of renewable energy in the home is studied and it is suggested that this 'clean' form of energy may be integrated into home management systems.

Thus, it would appear that the potential energy savings and reductions in carbon dioxide emissions that could be achieved by the integration of different energy sources in the home is not being exploited in the UK and abroad. The concept of the complete home energy management system is suggested, with a reliance upon electricity and information technology for the running and control of the system, but with significant contributions to the total energy demand of the house from 'cleaner' sources, such as from gas and renewable energy.

TABLES

Current IT and home automation research and investment by the UK's electricity companies and electrical components industry is being directed towards developing the total home controller system. The Electricity Council Research Establishment is currently monitoring the trials of the 'Central Control System' developed by Photrax. This system uses mains wiring as the communications media and consists of a wall-mounted controller and several receivers which are fitted near to the appliances to be controlled. The controller monitors energy consumption and temperatures and allows the pre-programmed switching of heating, lighting, hot water, security lighting and domestic appliances. The Control System is available with 16, 32 or 64 channels, with each channel having 16 independent time periods available on any days of the week. These time periods can also be linked to the Economy 7 tariff so as to make use of cheaper electricity. The System, as well as providing programmed control, also allows for manual control and local override control of direct heaters, appliances and lights and it is possible to conduct status checks of the house and remotely control appliances via the telephone.

5. ENERGY EFFICIENCY IN LOW INCOME HOUSEHOLDS

7.1 The National Home Energy Rating Scheme

When discussing energy efficiency, it is useful to have a measure of just how efficient given homes are and a mass energy audit of the total housing stock can offer the potential of nationwide comparisons. The National Energy Foundation, a recently formed charity promoting energy awareness and its efficient use, has developed a nationwide standard for measuring the energy efficiency of homes. A house or flat can be awarded a rating on a scale from 0 (very energy inefficient) to 10 (very energy efficient), although decimal points are used so the scale is actually between 0 to 100. A home built to the 1990 Building Regulations would score only about 6, but a very recent change to the scale has increased this to 7 or 8, so that new housebuilders have some incentive to build more efficient houses (Mandeville 1990).

The National Energy Foundation has calculated that some two thirds of the dwellings in the UK would have a rating below 4 and raising all the houses in the country by just one point on the scale would save œ1.8 billion a year on energy expenditure. This translates into a 4% reduction of UK CO_2 emissions, thereby making a significant contribution to combatting the greenhouse effect. The Rating is calculated using several computer programmess and takes into account many factors including house age, number of storeys, floor plan, insulation, glazing, heating system and controls, ventilation, and building materials. The Rating can also take into account the use of active and passive solar heating in the home and so may be used to assess the efficiency of the integrated energy home.

7.2 Towards a partial solution?

Having shown that the majority of homes in the UK have a low Rating value, there is obviously large scope for improvement in energy efficiency, especially through the more wide spread use of cavity wall insulation and better heating controls. There are, however, a number of barriers which prevent these measures being taken, including:

Finance - Householders rarely have the money to carry out major projects.

Short Term Horizons - People tend to spend the money they have on items where they see an immediate benefit (eg. videoo recorders, washing machines). Energy efficiency improvements are therefore given a low priority.

Low Income Households - People on low incomes or supplementary benefit are only able to afford the cheapest measures such as draughtproofing. The total annual energy bill for the UK housing sector is in the order of œ11 billion and of this, it is estimated that low-income households consume energy worth about œ2 billion (Hughes 1990). Preliminary studies have shown that there are potential annual energy efficiency improvements worth œ300 million if measures recommended by the Department of Energy were adopted in those new-build and refurbishment projects into which energy measures can be most cost-effectively introduced.

In any single end-use sector such as low-income households there can be a wide range of building types, eg pre-1919 low-rise inner-city housing, high-rise flats, new housing etc. It is known that those considering energy efficiency improvements to their housing stock, such as Housing Associations and Local Authorities, are more likely to be convinced to do so by tangible examples rather than a set of theories or principles. The Energy Efficiency Office (EEO) run by The Department of Energy have, with this in mind, set up one demonstration example of every category of low-income home type under their Best Practice programme.

7.3 Local solutions to the national energy problem

Investments in energy efficiency improvements in low-income homes must be cost-effective for the owners. This necessitates both the provision of grants to the owners to carry out the improvements and the organising of the distribution of these grants. In the north-east there has been particular interest in energy issues by Newcastle City Council which established an Energy Advice Unit in 1979 and a local home insulation project for low-income households, Keeping Newcastle Warm. Since then Newcastle has become the base for a network of insulation projects nationwide. Branching out from this base, a national organisation, Neighbourhood Energy Action (NEA) was established to facilitate the formation of similar insulation projects across the country. NEA has been responsible for the initiation of 300 insulation projects, supporting 5,000 jobs predominantly through Manpower Services Commission funding. They mainly install draughtproofing in low-income homes and, in some cases, also loft insulation partly paid for by the Government's Homes Insulation Scheme.

Whilst addressing urgent social needs, both for employment and improvement in heating conditions amongst the elderly and disadvantaged, these projects are nevertheless limited in their scope relative to the broader possibilities for energy efficiency improvement in the UK building stock as a whole. Although it is true that they have demonstrated in many areas the possibilities for tackling energy efficiency problems, so that other local authorities have taken up funding for similar initiatives to those in Newcastle (for example, the Cardiff Energy Action City initiative and the activities of the Urban Centre for Appropriate Technology in Bristol (Atkinson 1987)), it cannot be said that any coherent or comprehensive approach to the local energy efficiency question is in sight.

Atkinson (1987) points out that, in the US and Europe, a vital contribution to combatting energy problems is made by increased local intervention in the energy economy. Energy efficiency is contrary to the interests of the fuel industries, particularly with the privatisation of the gas and electricity industries, and the great power they wield in the UK has severely inhibited any movement towards real improvements in energy efficiency organised at the most effective - namely the local - level. There has been increasing interest at the local level to implement effective energy efficiency measures, including the development of municipal heat distribution systems (district heating - DH) that could make use of waste heat from electricity generation (combined heat and power - CHP) so as to reduce heating costs, the national energy bill and CO_2 emissions. This interest in DH and CHP is somewhat dampened by the fact that local authorities are expected to find private finance for such projects. This, according to Atkinson, requires at least a 10% real rate of return, and then compete in terms of energy sales with the electricity supply industry which makes investments on the basis of a 5% Government-stipulated test discount rate. Thus if CHP/DH schemes do go ahead, much of the advantage will accrue to financiers rather than local customers.

The answer to these problems would appear for the UK to have a structure of energy institutions which involves a division of responsibilities between local and regional energy agencies. These would undertake integrated planning and the construction and operation of energy infrastructure on a departmental basis. This would have the effect of decentralising the UK's energy institutions and facilitate in local initiatives to increase energy efficiency, including the use of DH and CHP to reduce local heating costs.

introduction

It has become more widely accepted that human activity is on a large enough scale to affect global climate patterns through the 'greenhouse effect'. Several different gases associated with human activity are contributing to the greenhouse effect including carbon dioxide (CO_2), methane, chlorofluorocarbons and nitrous oxide. CO_2 is estimated to account for about half of the man-made components of the greenhouse effect, most of it originating from the burning of fossil fuels to produce energy.

The main domestic fuels vary in the amount they cost and in the CO_2 released when they are used. The amount of variation, averaged over the whole year, is given in Table 1, per unit of delivered energy. Electricity is both the greatest polluter and the most expensive form of energy (during the day) at four times the level and price of gas. Off-peak electricity is cheaper and may be marginally less polluting because of the greater proportion supplied by nuclear power. This matter has been the subject of much debate due to the environmental effects of nuclear pollution, but, in terms of CO2 emissions and the greenhouse effect, the production of electricity by nuclear fission does result in less greenhouse gases being emitted. For any additional demand of off-peak electricity, however, this would have to be supplied by a coal-fired plant, hence the same level of CO2 emissions is used for all time periods. The maybe exacerbated by electricity privatisation which pushes the Regional Electricity Companies (RECs) into a reliance on ever-increasing sales of electricity to maintain profits. Under privatisation investments to improve end-use energy efficiency will cost the Companies money and will appear to reduce sales of electricity (ref).

In the UK, buildings are responsible for about half of all energy consumption and a similar proportion of energy-related CO2 emissions. This may be broken down further to show that the total estimated CO2 emissions from UK household energy use amounted to 174 million tonnes in 1987 which is equivalent to 29% of the total UK energy-related emissions (BRE 1990). Table 2 shows that almost half of this CO2 is emitted indirectly through space heating but it should be noted that using electrical appliances also causes significant levels of emissions.

There is as yet no clearly defined Government policy to deal with global warming, though a wide variety of measures has been suggested (for example the House of Commons Energy Committee: Energy Policy Implications of the Greenhouse Effect - Report and Evideonce, HMSO July 1989). Common to many proposals is increasing the price of fossil fuels in order to discourage use and encourage energy efficiency measures. In addition, the central push tends to be for large and fast cuts in fossil fuel use. This means targeting industry and commerce where energy use is high and often wasteful, and the number and range of target consumers are relatively small and narrow compared with the domestic sector. This approach appears to ignore the 174 million tonnes of CO2 emitted by the use of energy in UK homes in 1987 and it would appear equally important to concentrate future action to reduce global warming within homes as well as within industry and commerce.

The first approach to the problem of global warming does, however, cause further repercussions and conflicts by increasing the incidence of 'fuel poverty'. It is estimated that some 6.6 million households in the UK are cold every winter because they cannot afford fuel to keep their homes warm - they have cold, damp and mouldy homes and suffer 'fuel poverty' (FOE 1990b). These households receive at least 75 per cent of their income from the various state benefits and spend a larger percentage of their income on fuel than better-off families. This is due to the fact that few poor households have wall and loft insulation or double glazing and only about half have central heating - the cheapest way to warm a home. Increasing the income of the fuel poor by raising benefit levels is a commonly proposed policy response to the problem of fuel poverty but this results in greater pollution. The Friends of the Earth estimate that by spending an extra #3 per week on fuel in each household would increase CO2 emissions by some 15 million tonnes per year (FOE 1990b).

Thus it it follows from this discussion that there are several approaches that can be followed in order to reduce CO2 emissions resulting from energy use in the domestic sector. These are discussed below.

It is perhaps more useful to consider switching to other types of energy in order to reduce CO2 emissions and reduce fuel bills. As Table 1 shows, the use of gas, coal and oil all result in approximately two thirds less CO2 being emitted and are cheaper even than off-peak electricity per unit of heat energy. The least polluting form of energy, however, is that produced from renewable sources. This type of energy may be produced at two scales: at a national level whereby the energy produced is fed into the National Grid for distribution, and at a very local scale where individual households may produce and consume their own energy. According to the Department of Energy, renewable energy sources (which include geothermal energy, wave energy, wind energy, tidal energy, solar energy and biofuels) "could be making a modest but useful contribution to UK energy supplies from about the year 2000 onwards" (DOE 1987). At present, only approximately 3% of electricity produced in the UK comes from renewable sources; the majority of this from hydro-electric schemes in upland areas. There are many inherent problems with renewable energy, including a reluctance by the Department of Energy to increase its spending on renewable research and development programmes. The modern world demands energy that is spatially concentrated and available 24 hours a day: unfortunately renewable types of energy are diffuse - the waves off the Hebrides have an average power density of about 45 megawatts a kilometre but it would require a 300 kilometre stretch of wave energy devices just to satisfy a fifth of the UK's present electricity needs. They are also variable - the wind does not blow consistently over the land and their supply does not always coincide with demand - solar radiation, for example, is at its most intense in the summer months when the need for heating is at its least.

The use of wind energy and small-scale hydro power have much more limited applications for the individual and are not viable economically without subsidies. They are used, however, in remote areas where the individual has additional energy demands, for example on farmsteads.

From the above discussion it would appear that, in order to reduce the amount of CO2 emitted as a result of energy use in the domestic sector,

Integrated energy management goes beyond the kind of service currently offered under such services as 'Budget Warmth', a scheme which undertakes to provideo the elderly with one room which is maintained at a given temperature every day of the year, at a fixed weekly cost. This type of scheme, operated in the north-east by Northern Electric and the local authorities, takes into account both the forecast temperature and the size and insulation factor of the chosen room in calculating the amount of heat to be delivered. It does, however, not integrate the provision of warmth into a complete energy management package which includes suitable new insulation.

TABLE 6: RANKING OF DOMESTIC SYSTEMS - INSTITUT LOUIS HARRIS

	% OF RESPONDENTS REGARDING FAVOURABLY:
Systems for preventing domestic accidents	88
Heating systems reacting to presence of people	83
Control of functioning of domestic appliances	78
Monitoring of energy usage	75
Automatic surveillance systems against crime etc	75
Temperature control	69
Remote banking	62
Air conditioning	62
Lighting systems reacting to the presence of people	61
Home working, using a computer	54
Remote control of heating	49
Mobile furniture	42
Robots to do the housework	34
Remote garden watering	29
Shopping by minitel	26
Control screen in every room	23
Television screen in every room	10

Source: Proceedings of the Domotique 88 Conference

Information technologies provide the principal means of achieving this level of functional integration:

· the addition of control mechanisms to domestic equipment, so that appliances can be automatically switched on or off, or switched to another mode, in response to prompts from outside or to programmed instructions.

· the development of links between domestic appliances, including heating appliances, enabling them to send each other prompts and messages.

· provision of a user-friendly method allowing people to program their appliances, or send messages to them, or be informed of malfunctions or other changes of state.

· methods which allow communication between linked appliances in the home, and sources of messages, instructions and other information outside the home.

· methods of disseminating information through the home, using communication networks.

The Smart House system has come under a lot of criticism in the US, most of it based on the secrecy surrounding the development of the system, and the high cost of the system which means it will have a limited and exclusive market. Despite this, European companies are following with interest the Smart House Venture and it is realised that, if the system fails in the US, then it is unlikely to succeed in Europe where the rate of building new homes is much lower.

This research reveals that, despite the potential reductions in CO_2 emissions that may be achieved through both energy efficiency measures and integrated energy management in the home, little has, and is, being done to carry these initiatives through. The importance of increasing the energy efficiency of houses through their physical design and insulation measures must be continued to be stressed by the Government. This applies to both existing housing stock and new build, as they have the potential for making a more significant contribution to the reduction of CO_2 emissions than the introduction of energy management systems into homes.

In order to improve energy efficiency within the newbuild housing market, there should be an increased role for the Building Regulations, so that they stipulate improved insulation standards and incorporate design features concerned with passive solar heating. Energy consumption may also be reduced by using alternative and more energy efficient household appliances. In September of this year, a Government report stated that a law should be introduced to make it illegal to produce or sell energy inefficient appliances (Energy Efficiency Office, Department of Energy, 1990). This idea has, so far, been mostly talk, as has the proposal to energy label electrical appliances. Both proposals need to implemented as soon as