BUILDINGS IN THE AGE OF PARADOX

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Introduction

This paper is based on the introduction to a commissioned report prepared by Building Use Studies Ltd in early 1994 for National Power plc. National Power asked the project team (who also included David Tong, then of Building Use Studies, and Paul Ruyssevelt and Robert Cohen of Halcrow Gilbert Associates) to consider important issues likely to determine the pattern of electricity and gas consumption in buildings in fifteen years' time.

The study covered the domestic, commercial and industrial sectors and looked at the influence of:

- technological developments;
- lifestyle, behavioural and attitudinal changes among the public, building professionals and property investors; and
- commercial pressures....

on buildings, their occupancy, the environment and services within them, and hence their energy consumption.

In this extract from the study, some of the implications for buildings in the UK are explored for energy consumption, energy use, rates of change in the national building stock, key social and economic trends, influences in different building sectors and future building energy use.

Context for the study

The research undertaken suggested that we are in an Age of Paradox, an idea used by several writers on management. For example, John Harvey-Jones says

"so many things...... that we have failed to act upon in the past are going to turn into things on which we will need to have a change in perspective."[1]

Charles Handy[2] and Peter Drucker[3] discuss the change from value in material property to value in intellectual property, and John Naisbitt[4] identifies the increasing role of small players in the economy. Meanwhile habits of the past die hard, particularly in the political system and in collective expectations, with individuals, corporations and societies currently holding conflicting, paradoxical points of view.

Nowhere is this more evident than in the building environment. Investment in buildings is still, in both private and public sectors, often shortsighted and primarily driven by minimum initial cost. In the UK, the specification and quality of new buildings has tended to be dominated by their market price and investment potential rather than their value in use, and most commercial occupiers see their buildings as overheads, not assets. Nevertheless, buildings are now subject to more stringent energy-related legislation and voluntary codes of practice, and in use they are now beginning to be much more carefully evaluated for their costs and benefits.[5]

Seemingly the biggest paradox is between continued economic development and the new agenda of sustainability. In the study, *Beyond the Limits*,[6] Meadows, Meadows and Randers review worldwide trends under different scenarios and suggest that if major change does not occur over the next 25 years, the environmental consequences thereafter could seriously upset social, political and economic systems.

To our initial surprise, we concluded that, as we progress towards 2010, the agendas of business efficiency and environmental responsibility can become complementary: they are both ultimately about waste avoidance. We perceive that information technology can provide the means to meet the goals of improved economic performance and sustainability simultaneously.

The arguments in A Wood's, *North-South trade, employment and inequality*,[7] imply that time lags are a natural part of the development and maturation of socio-technical change: it is this that creates the paradoxes. It also means that, although not much change may appear to have been happening, and business may appear to be continuing as usual, this can be deceptive and the seeds of revolutionary change may already be well-and-truly sown.

Following the age of paradox in which different social and economic trends seem to be 'fighting' each other, the early 21st century is likely to become the age of transition, when more of a consensus emerges on how new social, environmental and commercial agendas will converge. The nature and timing of these changes is uncertain, but large corporations as well as governments can play a critical role in shaping outcomes. One additional catalyst which may help accelerate these changes is the millennium itself, which will provide a powerful sub-text of historical evaluation and futuristic thinking.

This general picture of paradox and uncertainty makes forecasting difficult. In some areas 'business as usual' may continue for longer than might appear to be desirable; in others, attitudes and practices may change much more rapidly than we might anticipate, as for example in the phase-out of chlorofluorocarbons (CFCs), in changing public attitudes to smoking, or indeed in the changing mix of fuels used for electricity generation. Extrapolating past trends is therefore even more unreliable than usual. While corrections are in progress, relatively slow superficial changes may also conceal the makings of radical long-term change. For example, while the aftermath of the oil crisis in the early 1970s was not as dramatic as many had predicted at the time, there was a long-term stabilisation in energy consumption in the industrialised countries, and major changes in fuel mixes in many of them.

Why the Age of Paradox?

The force behind the new perspectives is essentially globalisation, in particular the growth in world population, trade (and the associated economic disciplines) and infrastructure (especially information technology and communications). Under classical economics, this would be expected to bring much greater wealth, but Wood's analysis[8] suggests that time lags of decades are not unreasonable before the full impact is felt. Economic progress now also has to be reconciled with awareness of the constraints of a finite world, in particular, scarcity of resources and destruction and degradation of environments, either directly or via pollution. In individual countries, governments are finding that established public sector programmes, attitudes and practices consume an increasing - and increasingly unrealistic and unsustainable - proportion of total resources.

The effects of these changes are already with us in the form of international competition, world agreements on CFCs and greenhouse gases, anti-pollution legislation, and restructuring of public services (and of course utilities). These are leading to culture shifts of various kinds, forcing industries (including service industries) to increase efficiency (by reducing costs and/or adding value), shed staff, and concentrate on core activities. This in turn creates opportunities for new businesses. Competitive threats have accelerated some trends to centralisation (in spite of its relative inflexibility) although the new technologies can support more flexible arrangements and make economies of scale less obvious - yet another paradox. Indeed, the concurrent forces both to intensify and to disperse have been recurring themes in the study.

The most profound and far-reaching socio-technical change occurs when systems which were previously incompatible or in conflict suddenly become connected and start working towards the same ends. This is a large-scale social version of what Perrow[9] has called a normal accident. A major conjunction of this kind is already under way. Value management, the generic term given to the family of 'lean engineering' and 'flexible manufacturing' techniques developed by Toyota, Mitsubishi and others, seeks step-change improvements in efficiency through waste reduction, whilst also adding to the perceived value and quality of the product. Such methods have had a profound effect on efficiency in manufacturing processes, and on management thinking in the Western economies, but are yet to penetrate significantly into other sectors like construction.[10] Sustainable development is about fostering socially and environmentally responsible outcomes and behaviour. Until recently, these two systems - value engineering and sustainability - were separate, and often hostile to each other. Now they are rapidly converging. This can been seen, for example, in attitude shifts of stakeholders (shareholders, customers, governments, the public) taking an increasing interest in company activities (viz: the growth in ethical investment funds), and not just products and profits.

The sustainability argument

Energy supplies have always been vital components of political, economic and military power. Worries in the 1960s about growing scarcity were brought to life in the 1970s by the Organisation of Petroleum Exporting Countries' (OPEC) economic and political actions. More recently, concern has shifted to the dangers of pollution and global warming, and with the Bruntland Report and the Rio Summit, to the broader issue of sustainability. Sustainable development is now the policy of many governments. The UK proposals[11] are modest in relation to those of other Northern European countries, and are likely to need strengthening. For example, the UK aims to stabilise greenhouse gases at 1990 levels by the year 2000,[12] and perhaps to cut them by a further 25 per cent by 2025, while the Germans are said to be aiming for a 60 per cent cut by 2035.[13]

A study for the Dutch government[14] is considering the possibility of much larger reductions in rates of pollution and non-renewable resource consumption. In 50 years' time, it foresees world population twice (perhaps even three times) larger, at perhaps two to four times the prosperity level per individual (that is, taking third world development into account), in a world with no more (and quite probably less) capacity to furnish raw materials and absorb waste products. This implies that systems to meet the newly-emerging boundary conditions of sustainability should really be five or ten times more efficient than now.[15] Few technologies as we know them seem likely to evolve naturally to produce such large overall improvements, some radical change will be necessary and technological fixes alone are unlikely to suffice. Vergragt and Jansen[16] see the need for much change in social structure, habits and attitudes, and transitions will not necessarily be comfortable. However, they consider that the study and development of technological options will help to inform discussions about the structural and cultural changes required, and their feasibility.

Sustainability objectives will include large reductions of emissions and energy consumption, more recycling, extended life cycles including systems integration and 'cascading' (eg: re-use of waste products for other purposes), and less consumption of non-renewable raw materials.

Major changes are potentially achievable:

a) In the short term, say 5-10 years, better management, waste avoidance and minor alterations could curb unnecessary consumption and pollution by perhaps 25 per cent.

b) In the short to medium term, say 5-20 years, improved efficiency of existing technologies and end-of-pipe pollution abatement could save perhaps 25 per cent again.

c) In the medium term, say 10-30 years, better process integration could halve the remaining requirement.

d) But ultimately, totally new approaches may be necessary in many areas.

Of the four categories above, some will be mature, others newly emerging. Some may be short-term dead-ends, others will pave the way for further developments. Some will be responses to prevailing trends, opportunities and threats; others may need to be promoted by advocates. Some will happen spontaneously, others will need collective will to make them happen, for example using economic instruments (like extraction and pollution taxes) to favour more environmentally efficient technologies.[17]

Buildings, energy and carbon dioxide: the current national picture

Buildings account for half the UK's energy consumption and carbon dioxide emissions;[18] the other half is almost equally divided between transport and industrial processes. In recent years, UK annual total and building-related energy consumption and CO_2 emissions have been relatively stable, with energy-efficiency counter-balancing growth in building area, equipment and appliances. However, the proportion attributable to commercial buildings has been growing, owing to increasing stock, intensity of use, equipment levels and air-conditioning.

Industry's proportion of national energy consumption has been falling while transport's, particularly road transport's, has been rising appreciably. The government is committed[19] to stabilising CO_2 emissions at 1990 levels by 2000 and reducing them thereafter. The electricity supply industry's move from coal to gas is achieving important emission reductions. However, as the UK comes out of recession, emissions from transport are expected to increase, and industry's might too. The UK programme of reductions under the Framework Convention on Climate Change[20] therefore relies heavily on lowering building-related emissions, and in particular:

- 4 MtC (15 Mt CO_2) in the domestic sector, through measures including taxation, initiatives by the Energy Saving Trust and Building Regulations.
- 2.5 MtC (9 Mt CO_2) in business, including effects of energy advice & information.
- 1 MtC (3.5 Mt CO_2) by public sector targets.

The total of 27.5 Mt CO_2 is 10 per cent of 1990 levels. Extrapolating forward to 2010 one would anticipate target reductions in building primary energy demand of 20-25 per cent.

Energy use in buildings at present

Nearly two-thirds of the building stock is housing, and this accounts for a similar proportion of building-related fossil fuel consumption. Building-related electricity consumption is about equally spit between the domestic and non-domestic sectors. About 20 per cent of delivered energy consumption in housing, and nearly 30 per cent in non-domestic buildings, is electricity. The percentage breakdown to end uses is estimated in the table.

End use	% of total domestic energy	% electricity of domestic end uses	% of total non-domestic energy
HVAC*	57	(9)	70
Domestic hot water	25	(14)	7
Lighting	2	(100)	11
Cooking	6	(28)	5
Appliances & others	10	(100)	6

*Heating, Ventilation and Air Conditioning systems

Rates of change in the building stock

Normal replacement rates can greatly delay the impact, even of readily-available technological improvements. For example, refrigerators in the USA last 19 years on average.[21] Although refrigerators on sale in 1990 were nearly twice as efficient as in 1972, the average one operating was only as efficient as a typical 1978 model. For buildings and infrastructure, many time lags are longer. The building stock has tended to change only slowly: the underlying annual rate of new construction averages only some 0.75 per cent of total floor area. If historic rates continue, at least 85 per cent of the buildings of 2010 are already standing today. Existing housing is particularly inflexible, owing to the growth in owner-occupation: owner-occupiers do not demolish.

Nevertheless, building types on the margin can change rapidly and represent significant markets, as in the office, retail and warehousing boom in the 1980s. Within the existing stock much can also change: about 2 per cent of its floor area is subject to major refurbishment annually, and this could well be an underestimate as some activities such as shopfitting do not fall entirely within construction industry statistics. Perhaps 40 per cent of the existing stock is therefore likely to have received major attention by 2010.

Repair, maintenance, 'Do-it-yourself' (DIY) and minor alterations add to this, including specifically energy-related improvements, some of which will have been grant-aided. While services and equipment are replaced more rapidly, major items last typically 10-30 years, so unless replacement programmes are accelerated by new attitudes, governmental pressure or economic incentives it will take until about 2010 for the typical item in the field to reach the performance levels of the average item on the market today. Electrical appliances, with faster replacement rates, and disposable items (notably lamps), give opportunities for more rapid change, as do alterations to operation, control and management.

Freeman[22] argues that where changes in technology and understanding make radical system innovations possible there are five phases from innovation to maturation:

1. Initially, the main emphasis is on technical rather than organisational innovation.
2. Early adoption brings great difficulties and risks because systems (both of supply and of demand) are not yet integrated.
3. As the technology matures, the main problem becomes the diffusion from leading edge sectors to the economy as a whole. The emphasis then shifts to organisational and social innovation, and from supply to demand.
4. Advantages then become increasingly apparent and the logic self-evident.
5. Once mismatches have been overcome, the institutional factors which once contained and limited diffusion may create new 'best practice' rules and customs and encourage, stimulate and reinforce further technical innovation so that the process becomes self-fulfilling.

Until radical innovations are linked together, and give rise to new industries, services, attitudes and behaviour, their economic impact tends to be relatively small and localised. It takes a decade or more for a new paradigm to crystallise and much longer for it to diffuse throughout the system. Reviewing historic examples, such as factory automation, Freeman[23] demonstrates why the anticipated positive effects for the economy of all the recent investment in information technology have been slow to come through, as essentially we are still only entering Phase 3 (above).

Accelerating change can therefore be anticipated. Although his argument is about industrial production, because it includes a shift towards information-intensive rather than energy-intensive products, we consider that it can - and will - also pick up quickly on the environmental agenda.

Key social, political and economic trends

Two powerful drivers of change are operating at present:

- The economic system is forcing organisations to improve efficiency by minimising costs and/or increasing added value. Governments are supporting this by promoting free markets. This is helping the UK become a progressive economy with the potential to achieve higher growth and prosperity, but with a high likelihood of increasing inequalities in society,[24] which will restrict the overall impact and need tackling politically.
- Increasing awareness of environmental problems in a finite world is motivating reductions in pollution and in consumption of nonrenewable resources, and a quest for sustainability. Businesses, consumers and investors are already picking-up on these messages, while professional and industry bodies are developing new standards and codes of practice. Environmental legislation is a growth area, including energy-related building regulations. Fiscal measures are being seriously considered,[25] for example carbon taxes.

At first sight the two drivers appear to be contradictory, and indeed economic growth in the traditional sense has tended to ignore externalities and occur at the expense of the wider environment. In essence, however, both drivers are aiming at the same thing, waste avoidance, and this is likely to make them powerful allies. As National Westminster Bank's property division now says, Environmental Sense makes Business Sense, and indeed some companies that have grasped the environmental nettle have discovered important business advantages, not only in public relations (PR) but also in efficiency, profitability and morale.

The rapid growth in the power and utilisation of information technology makes the convergence of approaches and systems based on cost, value and sustainability not only feasible but virtually inevitable. It permits many things to be done more efficiently; undermines some of the past economies of scale which have tended to concentrate manufacturing, distribution, and office resources; while electronic communications can reduce long-distance movement of people and goods. As information technology matures and habits, attitudes and institutions consequently change,[26] the way we do things could alter more quickly than we might at present anticipate.

Under this scenario the value, costs and benefits of buildings will come under careful scrutiny, not just in their own right but as parts of larger systems, and with a view to avoiding waste and minimising adverse effects. There will also be a strategic re-examination of transportation: not only the technology but the means of reducing consumption of distance by people and goods.[27] Increasing objections to roadbuilding, out of-town development, and unrestrained vehicle use are foretastes of things to come, and will have major influences on the location and use of buildings. Although government has been slow to react, there are indications of changes in attitude.[28] It is not inconceivable that, within the time horizon of this study, present habits of hyperactive motorised travel might have become not only expensive, but unfashionable!

Legislation and standards

Legislative, professional and advisory standards are developing in different directions simultaneously. At present the situation is confused, and appropriate balances between health, comfort, energy and environment have not yet been reached. The UK situation is further complicated by directives from the European Union (EU), in which most countries' legislation is more prescriptive than the UK's.

Building regulations and institutional standards

Over the past 20 years, Building Regulations and Approved Documents to reduce building energy consumption have become progressively more stringent and far-reaching. The 1993 draft revisions to Part L propose extending its scope beyond thermal insulation and heating/hot water controls to requiring double glazing, considering means to limit air infiltration, and, in non-domestic buildings including lighting efficiency standards and the discouragement of air-conditioning and mechanical ventilation. Its scope is also extended to include building alterations and changes of use. Energy and CO_2 targets are also included, albeit rudimentarily. All these changes represent a radical widening of the agenda and are portents for more stringency in the future. More impetus in future can also be expected on standards for equipment efficiency, following US and Northern European models.

The Department of the Environment's present range of policy options to influence patterns of energy consumption in buildings includes building regulations, appliance efficiency standards, information dissemination and promotional campaigns, grants and energy/environmental labels. Other Government Departments may add fuel and carbon taxes, and business management and reporting standards.

The EU is proposing non-domestic energy labelling procedures, and has indicated that within five years, from a date as yet unspecified, 50 per cent of property transactions (eg: sales and leases) for commercial buildings should be so labelled.

Buildings are also affected by health, safety, and workplace-related legislation, and by standards and institutional codes. Frequently these are developed from expert consideration of single issues,[29] with little or no concern for their interaction, or their implications for design, management, energy and environment. They can therefore become strategically inappropriate, particularly if they are too prescriptive and aim too high, allowing little room for trade-off and discretion, and are now being challenged.[30]

Professional and voluntary codes

Non-mandatory standards for energy and environmental labelling include the voluntary National Housing Energy Rating (NHER) and Starpoint schemes in housing, and the Building Research Establishment Energy Assessment Method (BREEAM) in several sectors, including offices,[31] housing, retail and light industrial. These are beginning to gain authority: the Part L consultation paper suggests the BREEAM calculation for offices as an interim measure to determine whether air-conditioning is allowable, and for housing the Standardised Assessment Procedure has been developed to resolve the differences between NHER and Starpoint.

In addition to BREEAM, voluntary procedures such as the Building Services Research and Information Association's (BSRIA) Environmental Code of Practice[32] encourage the design and management of more energy and environmentally-efficient buildings. However, sometimes these documents reinforce the status quo by being obliged to reference 'single issue' standards,[33] even if they are strategically inappropriate.

The indoor environment

In recent years, there have been a succession of concerns about the indoor environment and its effects on health, with problems including asbestos; radon; formaldehyde and other volatile organics; dusts, fungi and spores; and sick building syndrome - this particularly with air-conditioning.

Many have brought ventilation performance under greater scrutiny. There are many aspects to this: outdoor pollution brought indoors; pollution generation by building materials, furnishings and equipment; introduction and circulation of pollution by ventilation systems; inadequate ventilation rates; and poor ventilation effectiveness - both actual and perceived. Recent studies[34] are exposing the importance of indoor surface pollution and the need for improving cleaning regimes and designing for cleanability. Ventilation systems themselves have also been shown to be significant sources of pollution, raising issues about the cleanliness and cleanability of plant and ductwork, the suitability of chosen air intake locations; and the practice of recirculating a proportion of outside air. Systems using 100 per cent fresh air are being advocated and designed: for economic operation, these normally require heat recovery.

Recent studies suggest that large increases in ventilation levels are seldom the right answer to these problems, and that for most purposes prevention is better than cure. Provided that materials are sensibly selected, fumes from 'dirty' areas and equipment are removed at source, gases from the ground are intercepted and prevented from entering the building, ventilation is effective and ventilation systems kept clean, there is no need for air change rates to exceed current good practice standards for building-related pollution to be reduced to satisfactory levels. Some allergic and hypersensitive people may, however, need special measures.

Chemical pollution of the outdoor air is a more insidious problem, and - other than providing coarse filtration - conventional mechanical ventilation and air conditioning systems do nothing about it. Again, prevention is better than cure, and the root cause is often vehicle emissions. However, if these are not brought under control, then in future we may see a growing need for high-purity ventilation systems.

Concerns about the indoor environment are not restricted to air quality. For example, there are serious disagreements about thermal comfort standards[35] and even about standards for museums and archives which can only be met by using full air-conditioning in spite of the fact that it is seldom affordable and often causes problems in practice.[36] The conflicts between what makes sense in traditional science and engineering terms, and what is appropriate for the individual, for manageability and for sustainability have yet to be resolved.

Property market standards

A large proportion of non-domestic buildings in the UK are rented, having been developed speculatively and held for investment purposes by developers or institutions such as pension funds. This means that the function of the property market is shaped by the attitudes of two communities, building users and developers/investors (and their advisors) with the latter being dominant. Users and investors have separate criteria of what constitutes a successful building. Users want buildings which help their businesses and organisations function effectively. Investors want secure and profitable investments for their shareholders or policy holders. Even offices which are developed by owner-occupiers cannot ignore investment criteria since an occupier may, in the future, wish to sell their building to realise its asset value and at that time the building will be valued for trading according to the investment market's criteria.

Investors' criteria are governed by the desire to procure buildings which, as far as possible, are designed to be a 'standard product' based on standard specifications such as 500 lux illumination, standard floor loadings, raised floor, and air conditioning. A standard specification is seen as desirable because it makes the valuation of a building easier and less open to dispute. Major investors cannot afford the risk of holding innovatory or unique buildings whose value is uncertain and may vary in unpredictable ways. This must not be seen as implying that institutional norms are fixed; they will change, but only if by doing so they can still achieve high return on their investment at low risk. Past examples of change to institutional norms, such as the abandonment of the 1960s narrow plan, slab-block office and the introduction of raised floors in the mid-1980s, show relatively rapid and dramatic adoption of a new standard rather than slow evolutionary change.

The property market currently works to standards which are not necessarily the most appropriate for occupiers. For example, the late-1980s office standard was substantially imported from the USA and required variable air volume (VAV) air conditioning and what is now realised to be unrealistically high structural loadings, electrical loadings, occupancy densities and air-conditioning capacity.

While the above is being questioned, and some developers have tried to achieve product differentiation during the recession, new agreed standards have not yet emerged. However, consensus seems to be moving towards shallower-plan (15 metres or less), lower-rise (three or four storeys), 'no frills' buildings, often with openable windows and a raised floor, which is often used for underfloor air supply, and supplementary cooling where necessary. Speculative development is also much less attractive (except possibly on prime sites), and joint ventures and 'pre-lets' (where the tenant, or at least the main tenant, is known before construction starts) are more common. Studies by

Building Use Studies and William Bordass Associates for the Building Research Establishment suggest that pre-let developments can produce more manageable and more energy-efficient buildings than either of the traditional speculative or owner-occupied procurement routes.

Building and organisational management
In addition to the codes already discussed which primarily affect building design and refurbishment, the importance of management is now being recognised in non-domestic buildings. The management requirements are also being addressed directly, for example by BS 5750 on quality assurance, BS 7750 on environmental management, the Energy Efficiency Office's Corporate Commitment programme, energy management initiatives, building benchmarking, and so on. These will lead to reductions in avoidable waste and pollution and accelerate investment to save energy and to improve environmental performance. They will also lead to further debate about the appropriateness of some of the technical standards laid down.

Influences on building sectors

Domestic buildings
The number of dwellings will need to grow to accommodate new and smaller households and an ageing population, though the trend to smaller households might begin to reverse within fifteen years. In addition, there will be a demand for larger houses, both through general growth if the economy improves, and through widening inequality even if it does not, and because more work and education will happen at home. The average floorspace per person will grow as households become smaller (in small units, living, circulation, kitchen and bathroom spaces are shared between fewer people), and a wider range of activities and equipment are incorporated.

Developments are likely to be on a relatively small scale and on infill sites, a result of attitude changes, planning restrictions, an increase in owner-occupation, leasehold reform and council house sales, all of which have created major obstacles to large-scale development and redevelopment. Redevelopment and major refurbishment of large estates suffering major technical or social problems will continue, with major reductions in heating energy consumption under the 'affordable warmth' agenda. Some redundant commercial buildings will be converted to domestic use.

There are no clear trends in intensity of use. For example, although more people are working at home, many more women are going out to work. The blurring of boundaries between home, work and entertainment will mean that dwellings are used for a wider range of activities than at present, and are more likely to be occupied during the day: this will also affect the demand for local shops and services. The use of the home as workplace will increase: for the self-employed, for outworkers, and for employed people in more diverse work patterns. This will often require dedicated rooms, frequently re-using space within existing dwellings, but also requiring new buildings and extensions, particularly where homeworkers collaborate or employ assistants. Re-assessment of planning regulations will be necessary.

Trends to smaller households and increases in floor area, equipment and appliances per person imply increasing overheads per person, but these overheads will be met more efficiently. In multi-person households, the tendency for people to do fewer things together and more on their own will tend to increase use of lighting and appliances, though possibly not for cooking with growth in eating-out and pre-cooked food. Average room temperatures are also likely to rise in bedrooms, etc. as more of them become occupied more like bed-sits, but increasing efficiency of boilers, controls and insulation will dominate and heating energy consumption will fall.

Non-domestic buildings
At present many organisations are re-examining themselves, making economies, and rationalising and intensifying the use of their buildings. In the process, they are not only shedding redundant space, but also finding other space inappropriate. This will stimulate demand for new buildings and refurbishment, leaving redundant buildings in its wake. Already vacancy rates are high and some redundant offices are being converted into flats.

The buildings that remain will often be smaller and well-located, for example in:

- prestigious and readily-accessible locations for head office functions requiring interactions with important people;
- readily-accessible locations for functions requiring public access, especially in buildings with large numbers of visitors, such as hospitals;
- attractive locations where highly-paid, flexible and intelligent staff need to be attracted and retained;
- low-cost locations (not necessarily in the UK[37]) for those requiring a cheap labour pool.

Locations which generate increased road traffic will cease to be favoured and towards the end of the study period motor travel distances may have begun to reduce. Poor-quality locations are likely to suffer, and towns, particularly medium-sized ones could become more attractive,[38] particularly if air quality begins to be tackled.

In offices, public, health and educational buildings, there will be general downsizing as the impact of new technology allows an increasing number of tasks to be undertaken remotely and sometimes at home. Information technology will become ubiquitous, but much of the terminal equipment will be lower-energy and more ergonomic, making fewer demands on the building environment. More attention will be given to support spaces, such as meeting rooms, storage areas and areas where specialist or vulnerable equipment is located. Equipment with more exacting requirements will tend to be put in separately-serviced spaces. The recent trend to sealed buildings with air conditioning will be partially reversed, but not necessarily reverting to traditional natural ventilation: new types of servicing will emerge (such as mixed-mode, see below).

Government buildings are likely to reduce in area with the trend to agencies and privatisation. In the past, government buildings have tended to use rather more fossil fuel and considerably less electricity than their counterparts in the private sector, so this - and the more commercial culture in government generally - may increase electricity demand.

Intensification of space use will increase demands for electrical services of all kinds: for equipment, for lighting, for ventilation, for cooling, but often with lower unit energy inputs, for example by using mixed-mode HVAC concepts. Beyond a certain point, space use intensification will require technologically more complex buildings, which are also more highly intensive in their building services and their management requirements. Some organisations may ultimately find these requirements too severe and may instead choose simpler, more self-managing buildings. Public sector organisations are already doing this.

In industrial buildings, area and building-related energy intensity will decline as buildings become better-insulated, services more efficient and process equipment and its services more self-contained. Process-related energy requirements are also falling, but electricity's market share is rising.

- Exacting processes will become increasingly specialised and automated, with dedicated building services to meet health, safety and product requirements, and the building, where required, wrapped around them all. However,
- many manufacturing and assembly processes will be increasingly undertaken by general-purpose machines in general-purpose space, and
- many tasks will become more office-like, be undertaken in office-like buildings and environments, and be subject to office-like trends.

In hotel, residential and leisure facilities, growth is anticipated. Hotels, conference centres, business centres, etc. will need to accommodate some of the functions and activities displaced by downsized business premises, and residential and nursing homes those displaced by hospitals. Recreational facilities at hotels will increase. Independent leisure and 'club' facilities will be used for some of the socialising which will no longer be accommodated to the same extent in workplace buildings, and differential pricing will improve utilisation by the general public.

In warehousing and distribution, there is likely to be continued high activity, but recent trends towards increasing space and larger units could well be reversed as more attention is given to reducing overall transportation needs. The widespread use of 'just in time' means, according to DTZ Debenham Thorpe,[39] that warehouses will perform a different set of functions than those undertaken at present. However, the effects of traffic congestion on Just-in-Time (JIT) strategies may alter this bringing about much greater emphasis on stock rotation, trans-shipment, break-bulk as well as re-packaging and more local assembly. This study concludes that a relatively small number of large distribution buildings will serve a network of smaller satellite depots.

Information technology and modularisation will permit better-managed and more efficient distribution services, supplanting some dedicated distribution systems. Companies which serve European markets are likely to develop distribution centres in the south-east, this trend will be reinforced by a proposed EU limit to heavy goods vehicle (HGV) driving speeds (50 mph in 1996) which, when coupled with existing tachometer regulations could severely restrict the extent of the market accessible in a single journey.

In shopping, growth in out-of-town centres, hypermarkets, and retail warehouses is unlikely to return to 1980s levels: there is already growing public and governmental pressure to favour local shops and town centres. While it is difficult to see how this could happen entirely by itself, such changes would support the changing work and locational practices outlined above, and the increasing realisation that road traffic growth will need to be curtailed, and when these all come together, a major shift could occur. Remote shopping is reported not to be favoured by the major UK retailers, however this will not prevent opportunities being seized by new players in the retail market.

As changes in the retail sector depend to a greater extent on changes in other areas, the future for shopping is less clearcut than in other sectors. New mixes of retail, service and location types may emerge to service foci such as airports, railway termini, hospitals and garages. New retail developments with smaller, low cost, intensively-serviced, lightweight, modular, pre-fabricated and short-lasting buildings [for example, Forte (Happy Eater), BP/Shell forecourts] will be more common. Local convenience shopping based on fresh food and fast food outlets (combined butchers/bakers/greengrocers/fishmongers, perhaps) will serve people increasingly based at home for daily requirements. Development in town and city centres may concentrate more on weekly and seasonal needs, as well as leisure shopping. There will be a revival in local and village shops serving daily needs. Some growth in mail order, teleshopping, on-line access and data delivery, electronic mail and delivery services with local franchises is anticipated.

Influences on future building energy use

Energy and electricity use by the building stock will be affected by changes in:

a) The number of buildings, with perhaps a 15 per cent nett increase in domestic floor area, but smaller nett gains (and possibly even decreases) in the non-domestic sector.

b) The occupancy and use of these buildings, and their operating characteristics. Many buildings are likely to be used more intensively than today.

c) Their thermal efficiency, which will have improved, with new construction to higher standards and many older buildings having been upgraded, both substantially reducing heating needs.

d) Their equipment levels, which will have increased, and include more electrical equipment. On the other hand, there is likely to be less single-purpose and more multipurpose systems and equipment, viz: the convergence of computers, communications, controls, information and entertainment.

e) Equipment efficiency levels, which will also have increased, sometimes radically. Their operating characteristics will also change. For example the newer, more efficient gas boilers often incorporate fans, providing new demands for electricity.

f) Internal environmental standards, which change and often improve, but not necessarily in ways which require greater energy inputs.

g) Their environmental services, which in new and refurbished buildings are likely to make more creative use of ambient energy sources and rely less upon purchased energy inputs.

h) Effectiveness of control systems, which will have improved, considerably reducing energy requirements.

j) Effectiveness of management and waste avoidance, which will also improve, particularly in non-domestic buildings.

k) Fuel substitutions, both in the traditional sense and by on-site generation, both using traditional engines [particularly Combined Heat and Power (CHP)] and renewable energy systems. Gas is likely to supplant electrical resistance heating in existing buildings, but some new and well insulated buildings will bring new opportunities for electricity, particularly where there is mechanical ventilation.

Both existing and new buildings will be affected Although many of the changes will be incremental, some will also be radical, for example the 'zero-energy' building.

Changes will have different impacts on:

1. New construction. While it is only a small proportion of total stock area, new construction will occur in the areas in which the demand is most rapidly changing (eg: by sector, building type, location). Some of these will be to the industry standards of the day (we call them New Buildings) while others, which we call Innovative Buildings, will embody more radical changes in requirements, technologies and energy consumption.

2. Refurbishment. Some major refurbishments will end up very much like new buildings, for example where buildings are stripped-out or overclad. In more constrained circumstances, and for the growing number of buildings of architectural, historic or townscape interest, opportunities for major alterations in fabric thermal performance will be more limited.

3. Fit-out and refit. Many commercial buildings now have quite rapid interior refit cycles, with major impacts on energy requirements, both increases (eg: adding air-conditioning) and reductions. Refits also provide cost-effective opportunities for incorporating energy-efficiency measures, and this is likely be reinforced by legislation, with Building Regulations applying to alterations and energy labelling of property transactions highly probable.

4. Existing buildings. Repair, maintenance can have significant effects, for example as boilers, hot water systems, chillers, controls and kitchens are replaced. DIY in housing also includes energy-related measures. Grant-aided upgrading will also occur, in particular under the proposed Energy Saving Trust programmes and through existing mechanisms such as Neighbourhood Energy Action.

Generally, we expect trends to higher energy efficiency to outweigh those to increasing standards and equipment levels.

Endnote

The indications from this study are that the building sector in the UK will undergo rapid and perhaps fundamental change in the next fifteen years. Companion papers in this publication explore some of the strategic issues involved. They point to the importance of qualities like flexibility, robustness, sustainability and adaptability, terminology which is now in widespread use amongst building professionals and their clients, but with little consensus and wide potential for misunderstanding (a symptom of paradox, perhaps?).

Greater understanding of building performance through monitoring of use and occupants' opinions is helping to shorten once-lengthy feedback loops: for instance, the Probe post-occupancy studies[40] are examining new buildings about two years after move in and publishing the main findings. Quality control of the total building system, not just its component parts, common in manufacturing and service industries, is only just beginning to gain widespread acceptance. Links between monitoring (with research studies) and briefing (with user requirement studies), are much more important, especially for clients faced with major decisions about investment in future buildings.

Trends point to more strategic thinking and aids to decision-making, greater understanding of the consequences of decisions and more information for managers about costs, performance, utilisation and productivity. This will be much more multi-disciplinary and multi-professional than in the past with far more emphasis on users' and managers' needs and less on design-dominated criteria.

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