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Buildings and the Environment

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This article is based on a keynote presentation made at the Royal Society of Medicine, London, 17th December 1990, on the occasion of the "First Invited Lecture" of Oscar Faber Applied Research, and describes the impact of research in IEA countries on Buildings and the environment.

Research is developing and pushing forward the frontiers of knowledge in how to develop, design, construct and operate buildings of the future; buildings which will be compatible with increasingly severe environmental constraints, and adapted to the needs of comfort and convenience of an increasingly demanding body of users.

"Buildings and the Envronment" is a very general title for a paper, and it is the intention of the author to interpret the word "environment" in a variety of ways. But in an attempt to introduce some order into such a potentially vast field of enquiry, it is suggested that we focus on just a few specific topics, the examination of which may help in presenting an international overview of the way Governments have been thinking, and should be thinking about the building sector in relation to their energy policies.

Firstly, the following points will be considered, which seem to be of particular relevance:

1) The evolution of government policies to save energy in buildings.

2) The forces influencing future policies.

3) The possible implications for the building industry.

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1. The Evolution of Government Energy-Related Policies on Buildings

Few people need reminding that out of the total OECD consumption of energy, nearly one fifth is dissipated in buildings of all varieties, essentially on space conditioning and lighting. In addition, the building industry absorbs the use of substantial energy in the manufacture of materials and products destined for construction. In 1973, 40% of energy consumption in the built environment was satisfied from oil-based products; by 1988 the proportion had shrunk to 25%. This of course, did not happen by accident. Market forces, or in plain language, higher oil prices played their part in inducing consumers to switch to other fuels, and to improve their energy "housekeeping" where this was feasible. But Government policies also played their part in a whole series of measures designed to raise public awareness of the need to save energy, and to provide the incentives and know-how to do so. The ultimate success of this effort can only be judged by the results, but here lies the dilemma; first, because relatively few mechanisms existed for follow up and verification of the *effectiveness* of Government measures at the level of the individual users (i.e. gathering information on how much energy they had actually saved through the tax rebates, grants and loans etc. from which they had benefited); and second, because the contribution of private initiatives for energy saving - partly through better housekeeping, partly through new investment - in the building sector largely remains unidentified. The theme of lack of information will be of further consideration later.

The member countries of the OECD can point with some pride to the substantial reductions they have achieved in reducing oil consumption, and in the amount of energy required to produce a unit of Gross National Product - the so-called "energy intensiveness".(See Figures 1 and 2.)

Given the significance of the residential/commercial energy consuming sector, some proportion of these reductions must be attributed to higher efficiency of buildings and to the effects of State intervention.

As an example of the situation in the UK, many people must be aware of Government energy-related policy developments on buildings over the years, but it might be worthwhile to attempt a short recapitulation. The Home Insulation Scheme to provide grants to owners and tenants for loft insulation and draught-proofing was of course, one of the first Government initiatives, and enjoyed a substantial measure of success while it was in force for all income groups.

We had Insulation Projects by local authorities for lower income groups, but by June 1989, over 600,000 homes had participated in this scheme.

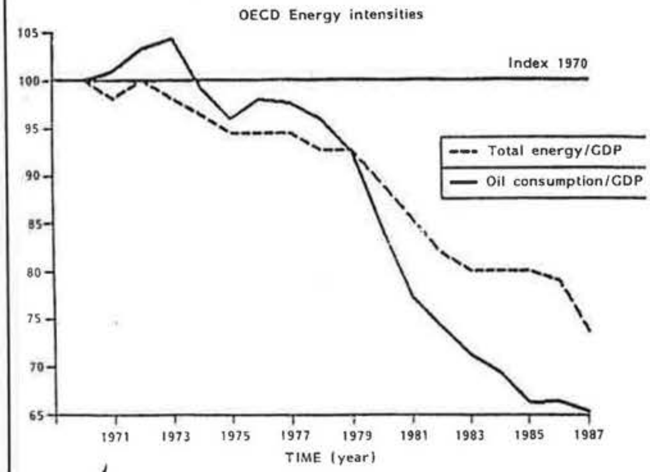

Figure 1:

We have a separate Government Agency and Development Corporation promoting an ambitious scheme for energy saving in housing at Milton Keynes Energy Park, northwest of London, where more than 1000 housing units are planned, fifty of which are already completed with excellent results.

In 1987, the UK government issued guidelines to departments on the use of contract energy management; and a new initiative to promote energy efficiency in the public sector was announced in 1989. With target savings of 15% of current use over the next five years in public buildings, the Government hoped to set the example to the private sector.

But from April 1990, the UK is now subject to new building regulations designed to save about 20% of space heating requirements relative to current levels. As for documentation, a "Code of Practice for Energy Efficiency in Buildings" (BS 8207), and a "Code of Practice for Energy Efficiency in Housing

Air Infiltration Review

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Refurbishment" (BS 8211) - both with an associated Design Guide - were published in 1985 and 1988 respectively. More recently, a series of thirteen booklets has been published, aimed at building occupiers, and includes energy performance yardsticks for all major types of non-domestic buildings.

Looking at the more general picture, we can do no better than to quote from the most recent (1989) review by the International Energy Agency of the Energy Policies and Programmes of its 21 member countries.

Country	Energy Intensity
Canada	0.64
Sweden	0.52
USA	0.44
Germany	0.41
UK	0.41
France	0.35
Italy	0.32
Japan	0.27

Figure 2

In fact, there have been few major changes in Government policies and programmes in the residential/commercial building sector of energy consumption over the recent years. Virtually all IEA Governments have continued some information programmes designed to encourage or assist consumers in saving energy in residences. A number of countries also subsidise or require the provision of energy audits for residences, although some of these audit programmes, such as the Residential Conservation Service in the United States have been recently phased out. Outside the residential sector, there are comparatively few information or technical assistance programmes. With respect to new building, almost all IEA countries continue to maintain efficiency standards in both the residential and commercial sectors, and some countries took steps to update or strengthen the enforcement of these standards during 1988 and 1989.

According to the European Commission, the diversity of building codes in Europe is beginning to narrow, but the Commission is still striving to strengthen building standards with a model reference code, given that 20% of the buildings estimated to be still standing in ten year's time have not yet been built; and that insulation is two to four times less expensive during construction than during retrofit.

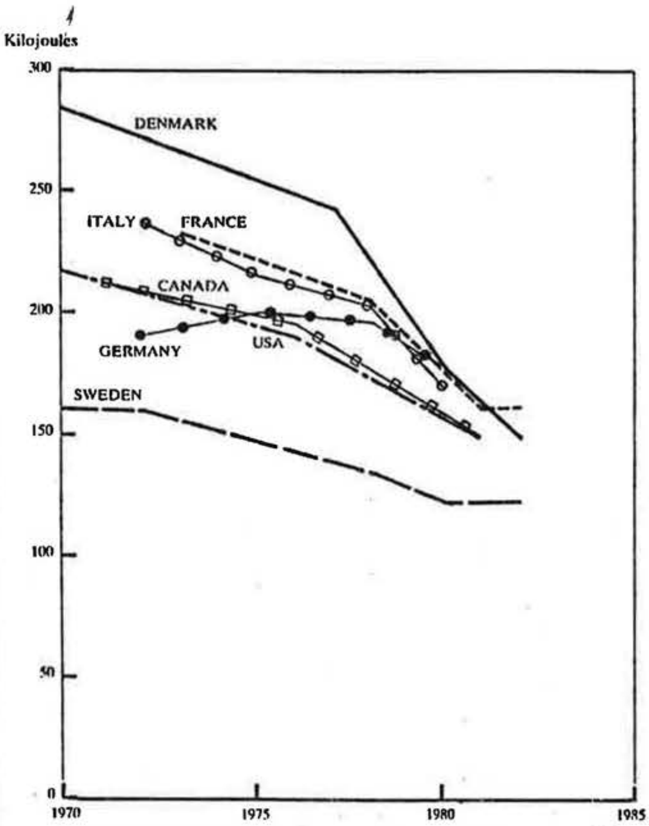
Efficiency standards for new residential equipment and appliances began to be implemented in the United States during the past two years, and the establishment of similar standards was being considered in some other countries, including Australia and members of the European Community. Energy efficiency labels for new appliances have been available in many IEA countries for some years, either under mandatory or voluntary programmes.

While comparatively few countries still have substantial financial incentive programmes for energy conserving investments in building, during 1988 and 1989 action was taken by a few governments or large utilities to initiate or significantly expand such incentives.

Finally, most countries maintained programmes to conserve energy in public, especially government owned buildings.

The limited data available on energy efficiency trends in the residential/commercial buildings energy consuming sector suggests that, as in the transport sector, the rate of efficiency improvement in appliances and whole building is now slowing down.

This is disappointing, considering the important gains in the efficiency of space heating which were achieved in the residential sector in response to the initial oil shocks. (See Figure 3)



Useful energy is energy consumption for space heating multiplied by an average furnace efficiency for oil/gas burners of 66%, for solids of 55%.

Source: Schipper, Ketoff and Kahane, "Explaining Residential Energy Use by International Bottom-Up Comparisons", *Annual Review of Energy* 1985, 10:341-405.

Figure 3: Space heat. Useful energy per degree-day per square metre (1970-1982)

This achievement has to be seen in the context of significant structural change in the residential sub-sector over the period 1972-1982 in the most prosperous OECD countries. Larger living areas were being enjoyed by a smaller number of people per household; people became more addicted to space heating and cooling and additional household appliances; and their energy use per dwelling could have been expected to rise between 10% and 20% had it not been for the higher efficiency of boilers, air conditioners, domestic appliances, insulation etc.

The commercial sub-sector, which also encompasses agriculture and public services, is one which has eluded accurate analysis of energy efficiency trends due to its complexity. However, one study which adopted energy use per employee as an indicator, came up with the following table:

Percentage Change 1970-82	
Denmark (1)	-19
Germany	-12
Norway	-13
Sweden	-15
United Kingdom	-12
United States	-24

(1) For Denmark 1972-82 was used.

It has been concluded that since overall economic activity continued to increase over this period, these gains can only have been achieved through a wide range of energy conservation actions in both new and existing buildings.

Thus has the Residential and Commercial Buildings sector of energy consumption made its contribution to the decline in energy intensiveness to which we referred earlier.

However, it must be borne in mind that energy savings should be compatible with the need to preserve a good indoor environment. Energy reductions of the '70's and '80's took place at a time when many new chemical entities were introduced into building materials, furnishings and furniture. With this became associated the problems of the "sick building syndrome" (which will be discussed in more detail later). Efficient ventilation, for example, is therefore essential if the working environment is to optimise the comfort and health of the building occupants.

No brief review of the topic of Government influence in the sphere of energy and building would be complete without mention of one crucial factor in Government energy policy which attracts less publicity, but which is still vital in maintaining an incentive to economise in the use of energy; that is Government energy pricing policy.

The governing principles adopted by OECD Member Governments in the conduct of their economic policies, imply that where a world market exists for a commodity, the price to the consumer should reflect the world market price; and indeed considerable progress has been achieved since 1973 in relating coal and oil consumer prices to the world market. Gas and electricity pricing involve complex issues which will not be discussed now. Sufficient to say in general terms that in some countries there are still fuel subsidies, price controls and other market distortions which tend to result in a lower consumer price than the world price, thus effectively sabotaging the incentive to save energy.

The moment is perhaps now opportune to turn to a review of the major forces which are likely to be influencing the formulation and conduct of national energy policies in the future.

2. The Factors Influencing Future Energy Policies

It is at this point that we may take up the issue of the "Environment", but as was indicated earlier, to explore the implications of that word in the broadest sense, and to avoid limiting discussion to air quality, land and water pollution and possible global climate change. The building industry must also surely be interested in the political, social and economic environment, in which it has to operate; not forgetting the technology environment, for whether we like it or not, many of today's problems, imagined or real, will require solutions which only technology applications can provide.

As far as the political aspects are concerned, one of the main preoccupations will be continuity of energy supply, principally oil, although electricity could also pose some problems. Nevertheless, experience of the last fifteen years has shown that whereas the Residential/Commercial and Industrial energy consuming sectors have the flexibility to switch fuels, the Transport sector remains hostage to oil. This has its implications for the building industry as will be shown later.

Politico-social trends are also emerging which will strongly influence future energy policies for the Residential sector. The decline in population growth in the OECD countries as a group, and the ageing of the population, can be expected to affect residential energy consumption. In order to encourage larger families for the young, more spacious accommodation at affordable prices needs to be available. On the other hand, many older people may resist being moved into special (and more energy efficient) accommodation for the aged, and prefer to remain in their life-long environment, where their energy consumption may be higher than is strictly necessary.

A further potential complicating factor for the housing market could be the urgent need for the renewal of sub-standard housing stock in some ex-Communist countries (100,000 new homes needed immediately in what used to be Eastern Germany); and the possibly massive immigration of people seeking an improved life-style in the West. Such events - largely imponderable - would place an extra burden upon an energy supply system already under constraint from a *further* political issue which also has strong social overtones.

This is the general concern to arrest the progressive degradation of the physical environment, i.e. through acid rain, ozone depletion and to avert a perceived threat of global climate change. Undeniably, this is a strong driving force in the current climate of opinion, and is likely to result in stricter measures for heat and electricity production, and the accelerated development of new materials for building insulation and new working fluids for refrigeration and heat pumps.

All these factors are extremely difficult to quantify in terms of their repercussions on the economic environment. But it seems clear that the result will be higher costs for energy and capital installations, and will give fresh impetus to improved energy efficiency and energy-related technology development.

But like all forces, this impetus requires a means by which its effect can be communicated. This then brings us to the all-important issue of information.

It is almost axiomatic that suppliers of energy-using and energy-saving equipment and energy consumers need to have access to adequate sources of information about what should be done to improve energy efficiency; and above all, how to do it!

At the outbreak of the first oil shock, such organised networks on energy saving information were lacking, but at the same time there was a flood of new conservation products and services, trying to break into a potentially lucrative market. Some of these innovations yielded disappointing results in terms of costs, reliability, and energy savings. For example, the heat pump was regarded as a promising energy-saving device, but did not live up to initial expectations. The use of urea formaldehyde insulation in housing and its subsequent banning in many countries because of health and performance problems is another typical case of the lack of credibility which undermined a number of campaigns to improve building energy efficiency.

The collapse of oil prices in 1986 spelt ruin for a number of energy performance service companies. Potential profits from energy savings in the projects in which they had invested in partnership with industrialists and building owners, disappeared almost overnight.

Whatever public funds were available for energy R&D prior to the first oil shock had been almost entirely devoted to civilian nuclear power applications, but from 1975 onwards we see an increasing Government investment in projects to achieve energy savings in the relatively short-term. (See Figure 4)

The scale of this effort was modest however, never exceeding 7% of the total IEA energy R&D budgets. Even so, much useful work was accomplished in the areas of improved building insulation, heating and ventilating, and in improved techniques for district heating, where oil could be replaced by combustion of waste material and the use of heat pumps.

However, in some countries, this valuable new knowledge and experience was not able to filter through to consumers, due to the lack of an effective national infrastructure for the dissemination of information on energy saving.

But even where information campaigns did work reasonably well, such as in the UK and in Canada, the know-how remained within national frontiers.

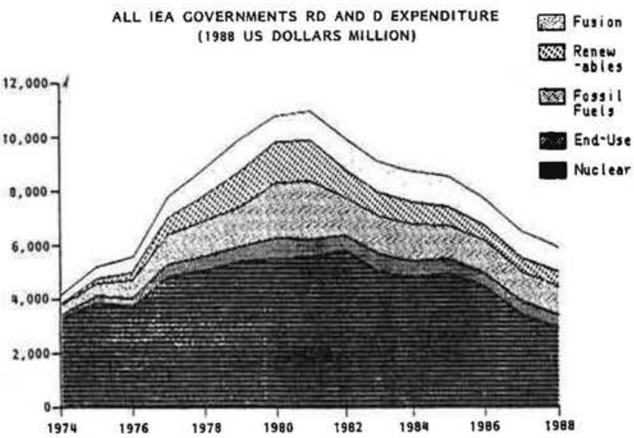


Figure 4

It was with the objective of enlarging the field of awareness of achievements in energy saving and of the economic benefits; and of re-kindling consumer interest in the whole ethic of energy efficiency, that the International Energy Agency pursued a policy of establishing Information Centres, concerned not only with the promotion of energy saving techniques, but also with the dissemination of actual achievements in demonstration of energy saving technology in a wide variety of applications. Some readers will already be familiar with these Centres - the AIVC itself; and two at Sittard, Netherlands, dealing with Heat Pumps and the most recent - CADDET, the Centre for the Analysis and Dissemination of Demonstrated Energy Technologies.

These activities are mentioned as they have a key complementary role to play in shaping the thinking of energy policy planners, architects, engineers, building construction companies and a wide variety of end-users. Reliable information, properly disseminated can thus be regarded as another important force influencing future energy policies.

Energy efficiency regulation as a force has clearly already made its mark upon the building industry. The more energy efficient designs already adopted by the housing construction industry and equipment manufacturers are likely to be retained, regardless of short-term changes in market signals. The procedure for developing and reviewing building codes has been laborious and is likely to continue to be so, given the multitude of special interest groups involved. Moreover, even with the most sophisticated design techniques, energy saving can only be estimated, since consumption depends so much on consumer behaviour, such as opening outside doors and windows and setting thermostats. This is non-technology, an area of research which is still in its infancy.

As far as really large buildings are concerned, relatively few construction companies possess the necessary technical skills and access to finance to embark on the higher investment cost involved in an energy efficient building, which might also render their bid uncompetitive. Moreover, the building owner has less motivation to specify energy saving measures if he does not have to bear building running costs, i.e. where these are incumbent on the tenant.

Finally, when it comes to deciding whether to construct a new building or to retrofit an existing one to comply with new energy efficiency standards, cost will always tend to be the overriding factor in the trade-off (unless energy costs triple or quadruple over the next three or four decades). Only continued regulation can resolve these conflicting interests in determining the building environment of the 21st century.

3. The Possible Implications for the Building Industry

The heavy dependence of transport on oil and oil products was mentioned earlier. In 1973 oil use in the OECD transport sector was 38% of total OECD oil consumption. In spite of two major oil shocks and steep price increases, this proportion is now well over 50% and still rising. In fact, the world's present 500 million road vehicles (which are responsible for 85% of oil consumption in the transportation sector) are expected to triple or even quadruple during the next two or three decades. The implications for acid precipitation and carbon dioxide production are horrific, not to speak of the waste of energy and productive time in traffic congestion.

One possible solution may be a revival of the self-contained community. In bygone days, access to water supplies and the influence of the Church were unifying factors in achieving social agglomerations. The 21st century may see the rational use of energy as the driving force in establishing townships where energy supply and demand are fully integrated into the working and leisure routines of energy self-sufficient communities. These communities would enjoy such amenities as low (or zero) energy housing, electric cars, district heating, and widespread use of energy storage in conjunction with heat pumps; all of which are technology related developments.

If technology and environmental concerns are to mould the future, what must be done in the design, construction, and operation of new buildings to respond?

Environmental factors (in the broadest sense) will be the most difficult to quantify, given the complexity of their interaction and the unpredictability of their scale of influence.

Technology is something we can feel more at home with, since our knowledge and experience is based upon more solid ground for charting a course for the future.

It seems clear that building design may have to change radically if oil and electricity become decreasing options for heating and cooling; and CFC-based foam or advanced plastic (petroleum based) insulation materials are proscribed. Renewable energy can play some part in the range of technology options open to us, but the systems approach in building design together with high quality workmanship, thorough inspection and testing, and skilful operation and maintenance holds substantial potential savings from non-renewable energy sources - in some cases up to 80% of current average consumption.

How well equipped therefore, are the energy technologists to satisfy these needs? It is useful to report here on a list of R&D areas that a group of IEA experts identified as being crucial for energy efficiency buildings of the 21st century:

- more standardisation of design codes/ components/performance specifications;
- system integration;
- cost effective solar energy (photovoltaic and/or thermal panels;
- electrochromic windows and walls;
- transparent/translucent insulation;
- energy storage;
- CFC replacements in insulation and equipment;
- improved distribution and insulation technology for low density DH;
- accurate and fool-proof heat metering for single family homes;
- non-electric heat pumps with environmentally acceptable refrigerants.

As a concept, the heat pump has been around for a long time, as we can see from the following chronological table. (See Figure 5)

But it is only the last fifteen years which have witnessed a growing body of development work and application, all of which has yielded important gains in knowledge.

Coefficients of Performance, i.e. energy out to energy in, have improved significantly; costs have come down, although nowhere near enough; and performance-wise they have had a marked success in the dual operating mode of heating and cooling, particularly in Japan and the Southern United States.

However, with some exceptions, their technical and economic performance in heating applications has only been disappointing. This is particularly unfortunate for most of Europe, which hitherto has had little requirement for cooling applications. One of the biggest problems has been that many of these heat pumps have been oversized for their applications; and in many of the smaller installations, have contained an unnecessary number of system components. These factors have driven up the installation costs, which are already substantially higher than a conventional boiler. Thus the utilisation time has to be maximised, which of course doesn't happen when the heat pump is too big for the job.

HEAT PUMP – a new technology ?

1824	Carnot	Dissertations
1834	Peltier	Thermoelectric cooling/heating
1834	Pelletan	Mechanical vapour recompression
1834	Perkins	Refrigeration – ether compression
1844	Gorrie	Refrigeration – air compression
1852	Kelvin	Heat pump – air compression
1855/57	Harrison	Refrigeration – ether compression
1855/57	von Rittinger	Mechanical vapour recompression
1859	Carré	Refrigeration – absorption

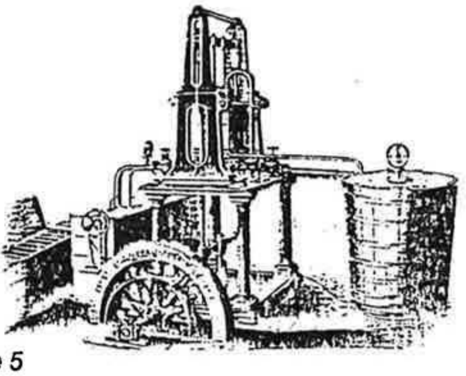


Figure 5

As for the future, the elimination of CFC-based working fluids in compression driven heat pumps no longer seems to be a problem according to an article in the Financial Times of 28th November, 1990.

However, the fact that most compression type units have need for an electric drive could be a further dissuading factor in a more electricity-saving conscious community, but this potential disadvantage could be overcome by substituting with gas engine driven heat pumps, which have already shown much promise in Japan. Nevertheless, the heat pump of the future is most likely to be that which operates on the absorption principle, but here again the working fluid currently involved - ammonia - is again the centre of a polemic, this time for toxicity reasons.

To come back to the listing of research priorities we looked at a few moments ago; of the above aspirations, perhaps the most challenging is that of system integration, which in a way transcends R&D on the efficient performance of specific building materials, components and equipment. The systems integration approach offers further increases in energy efficiency, based upon the premise that a building functions most efficiently when it is designed, constructed, operated and maintained to take maximum advantage of the energy performance *interaction* of its parts. Hence the concept of the "intelligent" building, which reacts not only to its outside environment (temperature, humidity, radiant energy), but also possesses an internal metabolism of its own, much the same as a living organism.

Building research, oriented towards energy saving was something of an orphan until fifteen years ago. Even if the Iranian fiasco of 1951, the 1956 Suez crisis, and the subsequent setting up of OPEC may have created some doubts about the long-term security of oil supplies, expectations from nuclear power in the late 1950's and during the 1960's was so high as to invoke scorn on any attempts to justify the development of energy efficient buildings.

Even when the nuclear dream began to fade, and the "clean use of coal" became the battle cry for electricity generation after the first oil shock, both politicians and the public alike remained convinced until only recently, that there would always be some substitute for oil to generate and to satisfy the burgeoning demand for energy that we witness today.

To quote an example, in Sweden although oil consumption in the built environment has halved since 1974, the use of electrical energy for space heating, operation of building services systems, domestic appliances and office equipment has trebled! This is one of the reasons why the Swedes are having second thoughts about the phasing out of nuclear power.

Now that the spectre of global climate change begins to loom, and Governments are giving sober consideration to penalising emissions of carbon dioxide, there is a growing realisation that electricity does not grow on trees.

This shrinking of the energy supply perspective can only add further force to the argument for higher energy efficiency, in which the building industry can play its part through technology applications. But the history of technology development shows that it can take up to a quarter of a century to span the gap from laboratory to market penetration, so there is no time to be lost in reviving the flagging fortunes of research, development and demonstration programmes to achieve the super energy efficient and environmentally "friendly" buildings of the next generation.