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Energy Comfort 2000 - A THERMIE demonstration project of eight passive and low energy non-domestic buildings.

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Abstract

Energy Comfort 2000 is a THERMIE supported Target project in which seven non-domestic buildings have been designed, built and are being monitored. An eighth building was designed but unfortunately has not finally been built. All are Passive and Low Energy buildings, designed to avoid or minimise the use of air-conditioning, by using the architectural design and construction of the building to produce adequate internal comfort conditions. Overall energy consumption is calculated to be less than 50% compared with traditional buildings and early monitoring has confirmed these predictions. Internal comfort is being checked by measurements and occupant surveys and overall environmental performance by the Environmental Preference Method and BREEAM. Dissemination of the conclusions of the project form an important part of the project and brochures, posters and Information Dossiers are available focusing of how replication can be achieved at all levels. EC2000 has produced exemplar buildings, facts and figures on performance, and a pool of knowledge and experience which can all be used in future developments and initiatives such as the City of Tomorrow.

INTRODUCTION

Energy Comfort 2000 is an archetypal demonstration project on Passive and Low Energy Architecture. It was designed to demonstrate non-domestic buildings which avoided the use of air-conditioning but which provided good standards of internal comfort. The only solution is the "Passive" building. And an excellent solution it can be. Why did EC2000 want to avoid air-conditioning? For the dual reasons that air-conditioning in practice is usually responsible for a vast waste of energy and that well designed passive buildings are healthier and better liked by occupants.

The project took shape as a complex mixture of building types, designs and systems. Some buildings were offices, some education buildings of mixed use, others multifunctional public buildings, and whilst all used passive and low energy features in their design, air-conditioning and mechanical ventilation were not excluded completely. Some uses and some climates were thought to make the use of active ventilation and cooling almost essential to give adequate comfort conditions. So there is a mixture of fully naturally ventilated offices, through mechanically ventilated offices and buildings with air conditioning in some specific parts, to full air-conditioning (which is only used under peak weather conditions). Other passive features such as insulation, daylighting, night cooling, solar shading, etc. are included in all buildings to greater or lesser extents. Another dimension of the EC2000 building matrix was building promoters and users. Some buildings were built for the direct use of the owner, others for use by the general public and others for renting out to others. In terms of promoting Passive and Low Energy Architecture and getting more of this type of building actually built, this last issues is of major importance and often does not get enough attention.

Eight building projects were eventually started and seven buildings have been built and are in use. This paper describes the eight buildings, the techniques and technologies used in the buildings and results of monitoring of internal conditions and energy consumption.

THE BACKGROUND TO ENERGY COMFORT 2000.

Energy Comfort 2000 was the first European Commission non-domestic building Targeted Project, set up in 1992 by a consortium of Esbensen Consulting Engineers (Denmark), ECD Energy and Environment (UK), W/E Consultants (The Netherlands) and EMMA(Spain). The project was approved under the THERMIE programme in July 1993 and will be completed at the end of 1998. The total EC grant was 3.49 million ECU.

The promoters of the eight buildings are project partners and the project comprises design, construction, commissioning, monitoring and reporting of the buildings as usual under THERMIE but also includes a number of "Horizontal Activities" including design workshops, environmental assessment, cross project evaluation, production of "Information Dossiers" and dissemination activities. Meetings of all partners and participants have taken place every six months in the various countries involved, to discuss, assess and visit the buildings.

THE EIGHT BUILDINGS IN OUTLINE.

EXPO 98, Multi-purpose Pavilion. Lisbon, PORTUGAL.

The pavilion and exhibition centre housing a maximum of 16,000 spectators is designed for use during EXPO 98 and afterwards as a major venue in Lisbon. It is adjacent to the new Tagus bridge and gives the appearance of an upturned boat in keeping with the "Oceans" theme of EXPO 98. The laminated wood dome is covered in aluminium on top of insulation. Displacement ventilation, with heating or cooling supplied from a new district system and river water (for pre-cooling), is used during events. Passive ventilation and daylighting are used when there are no events. Completed early 1998.

Maison Mediterranee des Sciences Humaines, and UFR, Aix en Provence, FRANCE.

These two buildings provide various facilities for the University of Aix en Provence and combine a number of energy saving features appropriate to the local climate. Most important of these are the use of internal thermal mass, solar shading, natural ventilation via the courtyards and active solar heating for the floor of the library. The buildings were occupied from the autumn semester 1997.

AVAX SA Construction Company Headquarters Offices, Athens, GREECE.

This narrow, east facing office building uses moveable external vertical shading devices to reduce solar gain in the morning, allowing the building to operate without active cooling for most of the year. Night cooling using the exposed thermal mass of the building, natural cross ventilation and ceiling fans support the "mixed mode" strategy in which the air-conditioning only needs to be turned on in peak months. AVAX SA move into their building early in 1998.

Tax Office Extension. Enschede, THE NETHERLANDS.

This new office is an example of the importance given to environmentally friendly buildings by the Netherlands Building Agency, the Rijksgebouwendienst. Careful integrated design of daylighting, artificial lighting, solar shading, natural ventilation, thermal mass and the heating system, make this a very low energy office. Other "environmental" features include rainwater collection and use, selection of environmental materials, nesting boxes and a roof mounted photovoltaic array. Completed November 1996, the monitoring report is due in spring 1998.

Public Multi-functional Building, Het Stadserf, Schiedam, THE NETHERLANDS.

This major development by the municipality follows a trend in high profile, low energy, naturally ventilated buildings in the Netherlands. A total of 19,000 square metres of facilities are provided, including a library, offices, archives, a theatre and conference facilities. Self regulating ventilation openings, combined with daylighting and high insulation levels, make this a low energy building with high comfort levels for both workers and visitors. The building is in use from early in 1998

University Learning Resources Centre. Chelmsford, U.K.

Officially opened by the Queen of England in 1995, and now called the Queen's Building, this combination of offices, library and other facilities is fully naturally ventilated with the help of two central atria. Daylighting and shading systems were carefully designed to reduce unwanted heat gains and thermal mass was added on the top floor to reduce maximum temperatures, activated by an automatic night cooling system. A year of monitoring showed very low energy consumption of just over 100kWhr per square metre per year, 74% less than an equivalent air-conditioned building, with acceptable internal comfort conditions. This was the first buildings to prove the correctness of the EC2000 strategy.

City Office Park development, Leeds, UK.

This visually attractive, highly gazed office is built round a central atrium which supports the mechanical ventilation system in maintaining high indoor air quality. Although designed to operate under a range of conditions without active cooling, chilled ceiling panels are being fitted by the tenant to allow the building to be occupied 24 hours a day if necessary, thus making the night cooling system inoperable. Occupation is planned to start towards the middle of 1998.

Office Development, Edificios Intecos, Valladolid, SPAIN.

This large speculative office was designed to avoid the use of air-conditioning by using a mixture of active and passive, solar heating and cooling. Set in the very variable climate of Valladolid, central Spain, every part of the building was to play a part in the energy saving strategy of the whole. Unfortunately the building will not now be constructed under EC2000 due to planning and financing problems, but it is intended to start construction shortly.

WHO OWNS EC2000 BUILDINGS AND WHAT DO THEY THINK.

THERMIE is a technology demonstration programme and EC2000 contains many innovative technologies for passive and low energy buildings. But THERMIE is also about dissemination and replication, getting the demonstrated technologies and techniques into the mainstream, in this case, of building construction. Thus getting to the right people and influencing them must be one of the aims. There are a number of target audiences:

- professionals, the architects and engineers
- the clients, the owners
- the client's advisors, financial and technical
- the users.

Professionals have all been involved in EC2000 meetings and although all professions have their dinosaurs and ostriches, generally progress on technical issues is possible and the technical journals can be used to good effect. The users are such a diverse group that it is difficult for them to be brought into dissemination activities.

The clients

The client group is often the most important and most difficult to influence. If the client wants a passive low energy building, he or she is very likely to be able to get it ("He who pays the piper, calls the tune", as we say in England). If the client just wants a normal comfortable, reliable and cheap building it is less likely to be innovative. The client's traditional advisors tend to be highly conserva-

tive and to recommend the same traditional buildings, dull and air-conditioned. The clients and owners of EC2000 buildings were obviously supportive of the low energy, passive buildings, as they signed up for EC2000. They are a good mix of: public bodies, the Netherlands Government Building Agency (the Rijksgebouwendienst), Schiedam Municipality; semi-public bodies, Atlantico the EXPO 98 client, and the two universities; and private companies, AVAX SA in Greece, British Gas Properties in UK and INTECO in Spain. But they all have different reasons.

The public bodies had energy and environmental policies and felt it their duty to show the right way forward, maybe the commercial pressures were not too great and the occupants co-operative. This gave them the scope to try out something innovative that had some small comfort risks attached. Public bodies often do lead the way. The Rijksgebouwendienst is very positive in this and has done a lot of publicity about the Enschede building.

Semi-public bodies are in a similar position. The EXPO 98 building is a show case of architectural and innovative design and demonstrates the essential forward-looking nature of a world event. The publicity value of innovation is important in promoting the building and the event. Anglia Polytechnic University in the UK had three reasons, the educational value of an innovative building, the publicity value to attract students (and maybe to attract the Queen's stamp of approval!) and the opportunity to reduce running costs (which has proved subsequently to be very significant). The University of Aix en Provence again values the educational and publicity aspects.

The private sector companies seem to see the innovative buildings as promoting whatever they are selling, AVAX SA wanted a showpiece building for its Headquarters, to show that it was an innovative company. British Gas thought that a low energy, environmentally friendly building would attract renters, which they subsequently believe to have been true, despite the delay in renting the building (this is now thought to be due to the recession in the UK economy at the time of completing the building). The INTECO building was a little different, as it was meant to be a working example of an active and passive solar building. The design seemed quite successful in attracting attention and potential occupants, but not so successful in attracting the financial organisations needed to provide the initial capital.

The client's advisors

Unfortunately the EC2000 project has not had much direct contact with those people advising the client. EC2000 clients have either made the decision on their own or have relied on the architect and/or engineers. This may be unusual in the world of non-domestic property development and more attention is surely required in this area.

EC2000 is not a research project, the buildings are mainstream, highly functional buildings in use by commercial and professional organisations. This is one of the important messages to be put over and some of the Information Dossiers pursue this theme.

THE INFLUENCE OF EC2000 AND HOW THE MESSAGES ARE BEING PROMOTED

Many organisations and individuals and involved in EC2000 and the six monthly meetings attract between 20 and 30 people. Information has been disseminated internally within the organisations via the EC2000 newsletters and this is one way in which the ideas developed in EC2000 are taken up in other projects and can become integrated into the policies of organisations.

Local replication

EC2000 has influenced the organisations involved and various developments are under way. In the UK, British Gas Properties has an environmental policy for all its developments and sees the Leeds building as one in a series developing the ideas, believing that environmental issues are one important factor in current speculative office developments. Anglia Polytechnic University is currently designing a new block adjacent to the Queen's Building which adopts a low energy passive design and incorporates many of the features of the Queen's Building together with currently innovative technologies including ground water cooling and photovoltaic shading devices (another THERMIE application has been made). In the Netherlands, the Rijksgebouwendienst are now moving their environmental buildings strategy on to refurbishment and are currently designing a passive and low energy refurbishment of an existing office block outside Utrecht. The Rectorat of the University of Aix en Provence is promoting the new buildings as examples for future developments of University buildings in France. Avax SA are to use the headquarters building in their company brochure to promote themselves as builders of this type of development.

Wider replication

The major purpose of EC2000 is to stimulate replication far outside the involved parties. This is being done in a number of ways, the web site, conference papers, articles in technical journals, educational packs, posters, individual and joint brochures and a series of "Information Dossiers". Currently available are the general EC2000 brochure and individual brochures on each building and the first eight Information Dossiers. These are entitled:

- Fire safety in Atria
- natural ventilation and cooling strategies in new office designs
- Energy efficient buildings -the client' experiences
- Control strategies for passive buildings
- Windows - the key to passive design
- Design standards for energy efficient buildings
- Environmental assessment of seven new buildings
- Energy saving building technologies explained.

Later dossiers will summarise the results of monitoring of the buildings, discussing the energy consumption, costs and comfort conditions achieved in the buildings.

These Information Dossiers distil out the specific experience of the EC2000 buildings on a number of subjects, so that the reader can see and compare different strategies and effects. They are not intended to be design manuals but rather to show different examples of systems and components of passive and low energy buildings , to show that it is possible and how they work in practice.

Whilst most of the Dossiers address technical issues, two focus on the concerns of the client with the goal of education and to dispel fears that may exist about commissioning a "low energy building".

More plans have been made for further dissemination, including a professional video, a source of electronic photographs for journalists, posters and further conference promotion, mailouts and articles in technical journals. All to take place when the final results of the projects are available.

INTEGRATED DESIGN – METHODOLOGY FOR DESIGNING SUSTAINABLE BUILDING DESIGNS

The integrated design process

The achievement of high energy savings in new non-domestic buildings are typically not just a result of using smart components or high-tech solutions. The prime factor in sustainable energy design is the close collaboration between all partners in the building design team with a common goal for the building. Building orientation, choice of materials, glazing, window size, control strategy for heating and ventilation etc. all have do be drafted, reviewed and redesigned in an iterative process in order to fulfil the goal of a building with high robustness towards changes in use, low energy consumption and high visual and thermal comfort.

One of the prime lessons learned from this design process is the importance of defining the right indoor climate parameters and required level of comfort. Too often building clients of non-domestic buildings by standard demand specific equipment like fully mechanical ventilation and active cooling to express a wish in having a well controlled indoor climate. If the design team of such a building are not allowed to investigate the possibilities for achieving the same indoor climate quality by other means than the specific technical solution, the options for having a sustainable building with low energy consumption are very limited.

The design teams of EC2000 projects have had the possibility to have a dialogue with the clients of the building and discussing the goals of the building in terms of energy consumption and indoor climate, more than discussing different types of components specified in the brief.

The energy concepts of EC2000 buildings

The EC2000 design philosophy started with the most general aspects of the building: orientation, indoor climate demands, internal heat gains, window design, solar protection and daylight control, making the most of the building itself as an energy system and then using different specific components and installations as additions to cope with extreme conditions. This way of designing in and reviewing the building energy concept has been an important task in the EC2000 project, where different building types have been designed with very different specifications for use, flexibility, interior design and in different climates. The design teams have used different thermal simulation tools: tsbi3, DOE2 and TAS and daylighting simulation tools Adeline/Radiance, at a very early stage in the design process, to analyse the consequences of different design options for each building.

The components in the building designs include light shelves for improving the use of daylight, natural ventilation, thermal mass through exposed concrete ceilings and walls, efficient solar shading (not compromising the utilisation of daylight), insulation and the use of environmentally friendly materials.

The analysis of cost effectiveness of the different measures is quite complex due to the strong interaction between different components of the buildings. This means that the individual installations cannot be fully evaluated without taking into consideration the costs (or savings) in other elements such as building orientation, materials etc. For some of the buildings however, the analysis is relative simple since the investment in installations per square metre of floor area are lower than for ordinary buildings. This is the case for the Anglia Polytechnic Learning Resource Centre and the extension of the Tax Office in Enschede in the Netherlands. Here the energy savings of the buildings are achieved with only zero or marginal extra investments costs compared to ordinary buildings. Full analyses of the building capital costs and fuel savings will be provided when the monitoring is completed.

The energy target set for EC2000 buildings was a minimum of 50% savings overall compared with a comparable traditional building. This was exceeded in all the design calculations and both buildings for which monitoring results are available at present show even higher savings. Monitoring has in both cases shown up defects in the construction and operation of the buildings and when these problems are solved, even greater savings are expected, demonstrating that both good design and good management and control are needed for full efficiency.

COMFORT CONDITIONS AND THE ENVIRONMENT

EC2000 recognised from the start that occupant comfort could not be sacrificed at the altar of energy efficiency. Whilst the achievement of energy efficiency is essential for the future of the world, for the conservation of fossil fuel sources and for the economic competitiveness of Europe, building occupants expect, and rightly so, high quality internal conditions. EC2000 set out to create internal comfort conditions which would provide a pleasant and productive workplace but avoiding as far as possible the use of active systems such as air-conditioning. The reasons for this are twofold. First, energy audits of existing buildings show that air-conditioning systems in practice are high energy users. This may be due to poor design but is frequently due to poor controls and appalling use of controls. Or a mixture of all three. Second, air-conditioning does not necessarily provide good internal comfort conditions. The concept of sick building syndrome is now well known, if not well understood, and poor air-conditioning systems (or maintenance of them) is closely linked to many examples.

The EC2000 challenge was by careful design to eliminate all unnecessary mechanical plant, to hand back the control of comfort to the occupant and in other ways to provide a healthy and comfortable workplace. Thus the inclusion of general environmental assessment also aimed to improve both the local and global conditions.

Passive buildings require active occupants and active control

Each EC2000 project developed a strategy to achieve an energy efficient and comfortable building. A definition of an energy conscious and comfortable control strategy might be: a control strategy to make automatic controls and the users co-operate to achieve optimal climate at minimum energy use. Control strategies can be developed for heating, lighting, ventilation, solar shading, cooling etc. A simple control strategy for space heating would involve a weather dependant temperature of the hot supply water and thermostatic valves at the radiators. Optimal comfort is achieved as the users is able to adjust the temperature locally. Automatic controls may also switch off the heating outside office hours to save energy and costs. A sophisticated control system involves a Building Management System. Users have the possibility to adjust the local climate to their needs, for example by changing the temperature, operating solar

shading or opening a window. The control strategy allows for this influence of users. Cost savings are reached on energy and maintenance, for example because lighting is automatically switched off when rooms are left unoccupied, fans only run when necessary etc.. A important issue in the design of control strategies is the interaction of automatic controls with the behaviour and needs of users. For example, users working after office hours should have the possibility to overrule the heating setback. A well designed strategy will also avoid negative interactions between the user and the automatic system: systems in which the blinds automatically close in summer and the users have to switch on the light.

User survey results

The seven completed projects are being assessed using a similar user survey, based on the European Audit project, thereby creating insight in how the users appreciate the comfort in these innovative buildings. The most significant results have been the high appreciation of good daylight conditions and individual control over the climate in office buildings.

Also the EC2000 buildings can be compared to the experiences in 56 office buildings throughout Europe, which show the EC2000 projects to have better comfort levels. Within projects, the surveys have also helped to demonstrate how the control strategies over the buildings can be improved.

Environmental assessment

The environmental quality of the EC2000 projects has also been assessed. The aim of the environmental assessment programme carried out by W/E Consultants (NL) and ECD Energy and Environment was:-

- to widen the scope of the design of the project from energy to energy related environmental impacts of buildings.
- to enhance the ecological quality of the projects.

Within EC2000 the best elements of existing national systems were used, i.e. a combination of the Dutch Environmental Preference method (Handbook of Sustainable Building) and the British BREEAM method. Experiences with the two methods showed that they can complement each other. Also, they appear to be generally applicable throughout Europe. On detailed level however, adaptations to regional and climatic differences are necessary. For instance wood preservatives depend on climatic conditions. Another example is the common South European solution to use ceramic elements for roof constructions.

Both methods have been used by arranging specific meetings with the design teams. This work resulted in certain design improvements, as environmental criteria are still not well understood by many design teams.

The EC2000 environmental assessment programme later resulted in the THERMIE B initiative to develop "BE2AM", the European Building Energy and Environmental Assessment Method.

WHERE DO WE GO FROM HERE?

EC2000 and other projects show a small number of significant exemplar buildings in different countries of the EU. This is the purpose of demonstration projects, to show the way forward, what can be done and how to do it.

EC2000 is one of the several EU buildings demonstration projects, but dealing with non-domestic buildings, whilst most others relate to primarily residential developments. The same experience is shared by them all: a steady increase in interest in environmental and low energy (or highly energy efficient) buildings, an interest noted by all the practices involved in the field.

Furthermore, concern about environmental and energy efficiency issues in buildings, although being somewhat different fields, work to the same aim, that energy efficiency and high quality living (or working) standards are complementary and not in opposition.

This leads to the generation of new models for living, based on the concept of sustainability, recognised by the EU as the only possible solution for future growth of mankind.

Where are we now?

Much work is yet to be done. In relative terms, the number of realisations is minute. To increase this number, many changes have to take place. The evolution has started but it must be made to go on.

A general awareness undoubtedly exists in the industry but problems encountered include:

- Different countries have a different pace according to their particular conditions. Energy and particularly, environment are more likely to become relevant issues in a densely populated area than in a low density area.
- The decision makers are often not as informed as they could be, which becomes particularly serious in the case of public promoters. Private promoters can see the environmental design as a way of differentiating their product from that of their competitors, but they do not want to innovate abruptly for fear of loosing their place in their market sector. Besides this the need for innovation is only clear if there was sufficient market competition and players often prefer to wait patiently to be "the second".
- Even in the case where there is a will to go for a new design, the decision process is very complex and is largely influenced by the many criteria other than energy and environment, which are often considered as secondary or luxury aspects and may be dropped during the development process.
- The individual with an awareness of energy and environmental issues, does not find easy channels to energy efficient and environmentally sound buildings. To start with, what to ask for and to whom? Many people would probably buy these types of buildings if they were generally available, even at a higher price, but how do they find them?
- Energy efficient construction frequently means a different approach, the introduction of which causes difficulties in a traditional field such as the construction industry. There are intellectual difficulties for the designers and technicians involved which are sometimes difficult to overcome. Perceived extra cost is a problem mostly due to the difficulty in estimating costs of new aspects, plus the intellectual barriers that have to be overcome, rather than with the product itself.
- Financing problems are also present. Constructing highly energy efficient buildings represents an additional risk on top of the regular risk associated with every building promotion. As the risk is difficult to evaluate, this in itself may stop such a project.
- Regulations have been shown to promote change to a certain extent, but only work well if co-ordinated with other actions.

- However, EC2000 and other demonstration projects are producing results, in three areas particularly:
- exemplar buildings to see and visit
- facts and numbers on energy, environment and comfort, to demonstrate success
- experience and knowledge to be used.

The City of Tomorrow- framework to move forward

There is clearly tremendous room for improvement, and there are some signs that a very important and accelerating change in the market is taking place. Many people believe that we face a situation where there is an clear and urgent need to build in an energy efficient and environmentally friendly way, there is a will to do it, most people would buy even at a higher cost, and promoters and builders would build when there was a demand.

The City of Tomorrow presents the view of what we all want for the future of urban living, safe, friendly, clean, sustainable, equitable for all, generally pleasant, etc. Passive and Low Energy Architecture, as developed in EC2000, clearly plays a very important role in both the vision and the realisation. Within the City of Tomorrow framework we can build on all our current experiences.

The experience of EC2000 indicates that the following are some of the areas where particular effort is needed:

- Improve communication channels generally, use new ones, create networks that actually work;
- More high quality demonstration projects with targeted dissemination;
- Continue dialogue with the users and occupants to satisfy needs and develop proper understanding in both directions;
- Allow for continuous technological development, and integrating the new with the old ideas;
- Develop improved management and use of buildings and their energy systems;
- Continue the education of building professionals in the latest energy saving techniques;
- Demonstrate refurbishment techniques that make existing buildings function in energy and comfort terms like the best new buildings.

The pieces of the jigsaw are all on the planning table, they need determination, skill and effort to fit them together to make the reality of the tomorrow we all want.