DISCUSSION PAPER ON IEA ANNEX XXI CALCULATION OF ENERGY AND ENVIRONMENTAL PERFORMANCE OF BUILDINGS

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1. Objectives

The objectives of this discussion paper are:

* to define the new Annex on "Calculation of Energy and Environmental Performance of Buildings";

* to determine feasibility of the Annex i.e. whether the full Annex should go head or could the objectives of the Task be accomplished through other means such as conference, workshops, international associations; and

* to describe various sub-tasks of the Annex (assuming it is needed).

2. Terms of Reference

At a meeting of the IEA Executive Committee held in Ottawa, Canada, in June 1988, it was decided to conduct a definition/ feasibility study into the formation of a new Annex entitled "Calculation of Energy and Environmental Performance of Buildings" - with participation from international experts. The need for such a study was identified to avoid any start-up uncertainty about the Annex. This study is being carried out by a Task Group with participation from twelve countries led by the U.K. The study phase is expected to be completed by May/June 1989.

Following a workshop on Thermal Modelling held at Horgen, Zurich, Switzerland, 24-26 May 1988, U.K. prepared a draft proposal (copy attached) on the objectives and sub-tasks of the proposed Annex.

The first meeting of the Task Group was held in Abingdon, U.K., 7-9 December 1988. At this meeting representatives of twelve countries discussed and exchanged R&D related activities already completed and/or underway in their own country. At the conclusion of the three day meeting, a number of tasks were assigned to member countries for further revision and development. It was also decided to prepare a discussion paper on the topic because IEA representatives expressed a common desire to further assess the appropriateness of sub-tasks A, B and C to the proposed Annex. Canada volunteered to prepare the discussion paper.

2.2 Annex Approval Criteria

The approval of Annexes is based on the following criteria:

3. Background

The Building Energy and Environmental Performance Programs

The science of providing appropriate environmental conditions in buildings has undergone significant advancement in recent years. Computer simulation of thermodynamic behaviour of external and internal loads in the conditioned space has also undergone significant advance since computers were first introduced to design and analysis communities in 1965. The first use of computers in building design was for duct and equipment sizing based on heating and cooling load calculations, artificial lighting systems, and structural design. This was followed by energy simulation for engineering analysis and architectural considerations in an effort to conserve energy in buildings. This action was precipitated in large measure by the energy crisis throughout the western world in 1973.

Initially, energy simulation program was seen as a powerful computational aid to the building energy analyst and designer. However, as analysis techniques became more sophisticated (for example, by the addition of sub-routines to calculate solar load effects, thermal mass considerations, interzone heat transfer, dynamic thermal characteristics, and others) the programs became more complex. It became increasingly difficult to keep track of the intentions of the internal assumptions in the computer codes and to interpret the results.

The ASHRAE bibliography of energy simulation of buildings lists more than 200 programs many of which

produce different results using the same algorithms. There are approximately another 100 programs in Europe and elsewhere not included in the ASHRAE bibliography. In addition, Computer Aided Design (CAD) programs are rapidly gaining popularity with the architecture and engineering communities and over 50 known CAD programs are now available in North America and Europe.

There may well be another 50 simulation programs dealing with other environmental issues such as lighting (both artificial and daylighting schemes), indoor air movement and moisture migration with which the Annex is also concerned.

The Building Industry

By and large these programs serve the architectural and engineering community in the efficient and economical design of all types of building facilities. It is therefore appropriate to first understand the size and diversity of the building and construction industry which these programs were designed and developed to serve. In North America the construction industry is worth some $500 billion and worth about $700 billion in the rest of the industrialized world with free market economies.

With the possible exception of Japan, the construction industry, unlike the automobile industry, throughout the Western world is highly fragmented. While the automobile industry is vertically integrated, the buildings industry is horizontally dispersed. The designer, owner, developer, builder, operator, and occupant are not necessarily the same party and unless the owner/ developer decides to build quality building, there is not much the other parties can do to improve the environmental performance of the building. Only governments who own, occupy and operate buildings have the resources to enforce strict guidelines for the construction of quality building from conception to occupation. Such buildings account for only one-half on one percent of all buildings.

The Nature of Simulation Programs

At the Leesburg workshop, sponsored by the U.S. Department of Energy in April 1983, thirty-seven experts representing all segments of the building industry examined building simulation from the perspective of researchers, designers and manufacturers. It was concluded that:

* the researcher's ideal program is a test bed for investigating new ideas and algorithms for developing a better understanding of how buildings use energy. The researcher must have complete access to the algorithm's complex variables and the ability to manipulate them at will.

* the designer is primarily interested in a program that can be used in a conversational mode quickly and easily for all phases of design. This helps him make economical energy efficiency decisions.

* a manufacturer's ideal program is a tool which he would offer to designers to help them select equipment. Such a program would provide the designer with information in which he would have confidence at an acceptable cost.

Two points stood out clearly in the discussion of the ideal programs and current public and private sector programs: 1. those programs available today are far from ideal, and 2. a significant amount of research on basic energy processes in buildings, the development of algorithms and validation procedures is needed to move the programs toward the ideal. Also, in their review of the ideal research program, participants recommended that government researchers and agencies avoid competing with private sector programs by trying to make their programs user-friendly, by seeking to develop user documentation for those outside their community, or by forcing the exclusive use of these programs through regulations. Dissemination of research results from government efforts to improve their test programs was considered essential.

4. Significant Events

Prior to the formation of Annex 21, other work related to building simulation and modelling was carried out under the auspices of IEA Tasks I, 4 and I0. Although considerable effort was expended in determining the best technique for evaluating building simulation programs and comparing them either to a bench mark reference program or to actual data, results of these efforts have mostly been inconclusive.

In 1979, the National Research Council of Canada conducted a study in which they compared energy analyses carried out by 23 different Analysts. The Analysts used the Meriwether ESA series programs to do energy analyses on an IEA test building. The study revealed that, depending on the assumptions made by the analyst vis-a-vis the design and operation of the building systems, any result was possible. In fact, the test results showed very little agreement among the analysts on the design load, energy consumption, solar loads and ventilation rates even though they all had the same specifications to work with.

In 1984 Public Works Canada (PWC) conducted a national survey of potential users of building simulation programs. The survey, which included builders, architects, building owners, operators and others, showed that users were looking for programs that were readily available, user friendly, that run on micro computers and are fully supported. Based on the results of the survey, a series of BESA programs were commissioned from which four new packages were made available for worldwide distribution.

In August 1985, the US Department of Energy sponsored a Building Energy Simulation Conference in Seattle, Washington. The purpose of this conference was similar to that of Canada's in 1984. However, they chose to bring together various experts in the industry for the purpose of reviewing worldwide simulation research and development, effective simulation applications from users' point of view, micro- computer techniques dealing with programs for the use of microcomputers, user-interface techniques, new program developments, validation and other research development. Over 70 papers were presented by various well-known authors in the field of building simulation. A panel discussion ensued and although no clear consensus emerged, it was discovered there was a need for an international session to deal with the simulation aspect. What emerged from this meeting was the International Building Performance Simulation Association (IBPSA).

IBPSA was organized in January 1986 at the ASHRAE meeting in San Francisco, and following intensive meetings, the objectives of the session were established (Appendix A). ASHRAE, for various reasons, has shied away from dealing with standards on energy simulation techniques and has been reluctant to give building simulation a higher priority because they feel this is an area they should stay away from. However, there should be a consensus in the building industry on how we should the users in both universities and in industry.

The Building Environmental Performance Analysis Club (BEPAC) was initiated in the summer of 1987 in the U.K. The aim of BEPAC is "to improve the quality of building performance by encouraging the use and development of environmental prediction methods for buildings". The importance of the end product is namely the building. Elegant and sophisticated computer programs are of no value in themselves; they only have value if they make a positive contribution to the quality of the built environment. BEPAC is about environmental modelling and not just energy programs. It is concerned with other environmental issues such as lighting, air movement, and acoustics as well as thermal and energy simulation. BEPAC is concerned about a wide range of prediction techniques and not just detailed simulation methods, they will seek to encourage the use of appropriate methods.

In 1987, Public Works Canada (PWC) conducted a market survey of computer programs capable of energy analysis in North America. The findings of this survey were published and distributed at the Abington meeting in December 1988. Findings pointed out that the North American market for these programs is extremely small and that even though there are over 200 programs available, only 5% of them are being marketed and supported and actually used by the consulting community. It also pointed out that the market is small is because only engineers are using these programs; architects are not yet sold on the idea of doing building simulation.

The January 1988 issue of Energy and Buildings published in Lausanne, Switzerland, devoted its entire issue to the topic of building energy simulation. It dealt with the worldwide state-of-the-art simulation review, validation techniques and future thrusts.

The Automated Procedures for Energy Consultants (APEC), comprised of private businesses, has been in existence since 1968. This is the oldest private sector organization and has produced many programs in energy simulation. They have long recognized the need for design-type programs and they have made efforts to integrate their programs with CADD systems.

APEC has a limited membership of approximately 200 members and they recognize that there is a limited market growth.

5. ISSUES

In view of the significant milestones and after nearly 25 years of developments, there is still no consensus on what type of programs are needed and why. It is also apparent that significant duplication of R & D effort exists among those countries who have already spent millions of dollars in the development of sophisticated programs and techniques to perform a variety of simulations on buildings. In addition, there are a number of issues that need to be addressed before a common purpose can be agreed upon. The following discussion delineates some of the issues to be resolved:

a) **Research bias in the development of programs.** Researchers have always looked for the perfect tool to calculate the exact number of BTUs consumed by a building system or the precise amount of air flow required to provide the ventilation needs of the occupants. What researchers frequently fail to recognize is that a building is supposed

to be a comfortable shelter for its inhabitants. These same inhabitants, however, perversely insist on opening and closing windows to experience the great outdoors thereby diluting the effectiveness of perfect calculations. Thus while the perfect tool is certainly desirable, it should not preclude the development a less-than-perfect tool that yields practical, and useful, results.

Research is no doubt essential in the development and growth of simulation programs but the research must be focused to meet user needs. For example, research is needed to understand why computer simulations are still unable to solve certain flow mechanisms. One should note that these issues involve are air infiltration and thermal mass problems.

b) **Emphasis on "absolute" accuracy vs trends in energy use.** As discussed above, it is less important to achieve absolute accuracy in the calculation procedure than to establish trends in energy use. Even though the mathematical model of the thermodynamic behaviour of a space has matured considerably, it is still far from being perfect. The perfect model will remain an elusive goal without proper monitoring and feedback to the original model.

c) **Program development with strong bias for energy calculations.** What is needed are practical design tools and not more energy calculations.

d) **Fragmentation of building industry.** Because the building industry is fragmented, owner/developers, with the exception of governments, do not normally place much emphasis on the life-cycle cost of owning and operating a building. Encouraging such emphasis with tax incentives are ineffective because they generally result in a quick profit at the expense of a quality building.

e) **Lack of standards and guidelines for evaluating and validating programs**. Considerable effort has been expended in Europe and North America to develop a benchmark program against which to compare other programs. However, there is still little or no consensus among experts as to which approaches best address this critical missing element.

f) Proper application of simulation programs. In fact users frequently apply programs incorrectly or inappropriately because the programs are typically too complex to learn and understand or too costly to operate. Neither are there any criteria to help users select programs wisely.

6. EMERGING TRENDS

Automated control of buildings

Over the past twenty years we have seen significant improvements in the automated control of buildings. The application of microprocessor technology to centralized systems for automated building control has ushered in the introduction of energy conservation strategies in commercial and industrial buildings.

Growth of CAD

As 1990 approaches, it is hard to find an engineering or architectural office in North America that does not have a computer of one sort or another. In 1984, nearly three-quarters of building design professionals were using microcomputers in their offices. A 1987 survey showed that word processing, specification writing, CAD and financial management were the most widely used software packages. The same survey projected a short-term rise in the use of CAD, energy analysis and facility management software of almost 50 per cent.

With more than 300,000 CAD systems now installed in North America, the worldwide CAD market is projected at over one million units by 1990.

Whole Building Simulation

Young engineers and architects now graduating from Canadian universities are fully conversant with sophisticated CAD and energy analysis systems. We are now seeing the integration of specific domain software into CAD systems that can accommodate complex interaction among building components and achieve whole building simulation hitherto not possible. Not only is the quality of the simulation enhanced by optimization techniques, but the systems are easier to use and hence more accessible.
A further trend is the development of "object-oriented" programming methods that facilitate the integration of building simulation with automatic control strategies.

Control Strategies

Knowledge-based expert systems enable the experience of professionals to be built into the control strategy. Continued development of this approach will involve the expert system in modifying predetermined control strategies in response to a problem with

minimal intervention by the operator.

Central control systems can now provide comfortable building environmental conditions with minimum energy consumption. A further advance would be to integrate the building energy analysis and design programs with the automatic control system.

There has also been progress toward 'adaptive' or 'predictive' control strategies. Such systems have some capability for calculating future indoor conditions based on weather forecasts. As well as being able to control the building functions with preprogrammed instructions, such systems can also modify the instructions through the input of variable parameters derived from monitored data.

7. STRATEGY

Although a considerable amount of time and effort has been expended over the years, little real progress has been achieved toward the development of a benchmark program against which the performance of other programs can be compared has yet to be identified let alone validated.

There are several hundred programs available in both Europe and North America but very few of them are of much practical use because of a chronic history of inconsistent results.

The divergent requirements of different users make it difficult to design programs that meet such disparate demands. Researchers want a vehicle to investigate new ideas; designers are interested in programs useful in all phases of design while manufacturers want a tool to ???

It is clear that existing programs are not only far from ideal, they are equally far from being useful to the larger segment of users. Programs, no matter how sophisticated, are of little value if they do not make a positive contribution to the built environment.

It is also clear that much more research is necessary to characterize many of the basic energy processes in buildings, to facilitate the development of algorithms and to lead the way to the development of validation procedure

Insufficient emphasis has been placed on transferring building simulation technology to the nascent standards in the university milieu. Although various countries are addressing the problem, a great deal more effort is needed to introduce the technology into the formal educational process.

The programs in use before the l980s were developed for mainframe computers and were, for the most part, User Hostile. However, since the early l980's considerably more emphasis has been placed on user friendliness in microcomputers.

There are no standards in either area and the pro forma is inadequate for a benchmark.

As an organization, what can the IEA do that is not already being done?
In light of all that has gone before and all that is going on now, what should our mission be?

What should we be doing to enhance the transfer of knowledge to the user community.

In what way should we be co-operating with the various government research and development agencies?

What short- and intermediate-term plans must we have to undertake research and development in building simulation programs?

What must we do to coordinate research and development among government, industry and universities? It is apparent that the universities are beginning to introduce these programs into their curricula.

What can IEA do to sharpen the state-of-the-art just a bit more?

Vast information resources such as the National Technical Informatics Services of the US Department of Commerce, SCS Organization based in Europe are accessible and have published information on software programs.

What can the IEA forum do to enhance the existing system?

To answer the questions, we first must review the kind and degree of influence the IEA can exert on member countries. IEA would like member countries to undertake various research activities for the common good of all countries. This means setting, discussing and debating policy issues, technical issues and implementation.

The IEA should set direction for furthering the development of the relevant technologies, should provide a vision, should apply strategic direction for the program technologies in the area of energy building simulation and environmental performance.

8. RECOMMENDATIONS

1. Establish a benchmark program against which other programs may be compared.

2. Broaden the scope of the objective. The existing definition, dealing only with credibility and useability, is limited in scope for the IEA audience. Certainly, credibility and useability are important factors and should be part of the Annex but they should not constitute its limits. The new Annex must, as well, address several other, more critical issues if it is to be an effective tool.

3. Determine where the gaps are in our efforts to make effective use of existing programs.

4. Determine what Governments' strategic long-term goals are so IEA can establish effective liaison for the purpose of co-operation and technology transfer and to avoid duplication of valuable time and effort.

5. The Annex must address policy and strategic direction. The IEA must develop policies on such areas as the transfer of knowledge to the user community, the development of a benchmark program, the establishment of design tool calculations, and the establishment of liaison with emerging organizations to exchange technologies and discuss methods of achieving common goals

6. The IEA must pursue its goals with intelligence and common sense so as to be seen as an organization capable of leadership and vision.

7. Develop standard methods of documenting results.

8. Establish documentation standards and formats.

9. Develop standard techniques for testing system algorithms.

10 The IEA should look to the immediate future as young, highly-motivated engineers and architects graduate into the field with new ideas and technologies, with unbridled enthusiasms and spirit, and with deeper insights and raised expectations. If the IEA is unable to produce the required programs and simulations, it may well be overtaken by those more capable sharpening the leading edge of technology.