International Collaboration within the IEA Energy Conservation in Buildings and Community Systems Programme

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Abstract

Collaboration on energy technology research and development through the International Energy Agency (IEA) contributes to the economic development, energy security and environmental protection objectives of Member countries.

The IEA Energy Technology Collaboration Programme provides a framework for experts to work co-operatively and share results. The benefits typically include sharing costs, pooling resources, and avoiding unproductive research paths. Further, participants are able to spread the risks associated with the choice of research priorities. The outcomes of collaboration enable the research and development objectives of national energy technology programmes to be better achieved at a lower cost.

This paper introduces one of the IEA collaborative programme on Energy Conservation in Buildings and Community Systems programme (ECBCS) and highlights the achievements of a number of its collaborative projects.

1. THE INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organization for Economic Cooperation and Development (OECD). Its purpose is to implement an International Energy Programme. It carries out a comprehensive programme of energy cooperation among 23 of OECD's 24 member countries, and allows for the participation of non-member countries.

The challenges the IEA member countries face in the energy sector have evolved over the past two decades. Energy security remains a primary goal. But in recent years there has been increasing awareness of the significance, for energy policy and energy security, of two further factors: concern over the environmental impact of energy-related activities and the growing globalization of energy issues, as countries' economies and energy markets become increasingly interdependent but nevertheless different in terms of energy sources, price etc.

The objectives of the IEA are:

- to improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use
- to encourage collaboration among member countries in energy research, and technology development and demonstration

- to ensure that environmental considerations are taken into account in the formulation of energy policy
- to maintain and improve a system for coping with oil disruptions
- to operate a permanent information system on the oil market and other sources of energy
- to maintain cooperative relations with non-member countries and international organizations

1.1 Organization of the Collaboration Programme

IEA energy technology activities are set up under simple contractual arrangements called Implementing Agreements. The Implementing Agreement provides the legal mechanism for establishing the commitments of the participants, the management structure to guide the activity, and the distribution of the benefits derived from the co-operative work.

There are currently 41 active IEA Implementing Agreements covering fossil fuels technologies, renewable energy technologies, efficient energy end-use technologies, fusion technology and energy technology information centres. Research expenditures of more than $100M (US) per annum are coordinated, providing substantial cost savings.

A provision for non IEA-Member countries to participate in Agreements as Associate Participants was introduced in 1992. The Republic of Korea, the Russian Federation, Poland, Israel, Brazil, Venezuela and China have become Associate Participants in a number of Implementing Agreements.

The Implementing Agreements are managed by Executive Committees made up of experts nominated by the participating countries. The various activities of each Implementing Agreement are set out in separate Annexes and are managed on a day to day basis by an Operating Agent. The Implementing Agreements are monitored by technical and policy experts who represent Member countries on the IEA Governing Board, Committee on Energy Research and Technology (CERT), and three Working Parties on specific technology areas. All resources for projects are supplied by the Participants rather than by the IEA. The resources are provided by Participants contributing financial resources (cost-sharing) or by Participants devoting specified resources to the agreed work programme (task-sharing).

2. ENERGY CONSERVATION IN BUILDING AND COMMUNITY SYSTEMS

Approximately one third of primary energy is consumed in non industrial buildings, such as dwellings, offices, hospitals and schools where it is needed for thermal conditioning, lighting and the operation of appliances. The percentage of the total energy used in non industrial buildings varies from 30 to 50% depending on the country. Exceptions are countries without heavy industries; such as Denmark and The Netherlands where the energy used in the built environment is estimated to vary from 50 to 70%.

Hence this sector represents a major contributor to fossil fuel use and carbon dioxide production. Following uncertainties in energy supply and recent concern over the risk of global warming, many countries have now introduced target values for energy savings in buildings. Overall, these are aimed at reducing energy consumption by between 15-30%.

To achieve such aims, international co-operation in which research activities and knowledge can be shared is seen as an essential.

In recognition of the significance of energy use in buildings, the International Energy Agency (IEA) has established an Implementing Agreement on Energy Conservation in Buildings and Community Systems (ECBCS). This is aimed at initiating research and providing an international focus for building energy efficiency. Tasks are directed at generic energy saving technologies and activities that support their application in practice. Results are also used both nationally and internationally to develop relevant standards and guidelines.

Member organizations of the ECBCS are drawn from a total of 21 Countries and the European Commission. The designation by governments of a number of private organizations, as well as universities and government laboratories, as contracting parties have provided a broader range of expertise to tackle the projects in the different technology areas than would have been the case if participation was restricted to governments. Participation in any particular programme of research is optional and most commonly takes the form of a 'task shared' Annex in which each participant commits an agreed level of effort. Typically an Annex will operate for a four year period. Occasionally, an Annex may be jointly funded, in which case a single institution receives funding from participants to undertake a given task.

Overall control of the programme is maintained by an Executive Committee, which not only monitors existing projects but identifies new areas where collaborative effort may be beneficial. The Executive Committee ensures all projects fit into a predetermined strategy without unnecessary overlap or duplication but with effective liaison and communication.

2.1 Programme Objectives:

General objective of the BCS Implementing Agreement is to facilitate and to accelerate introduction of new and improved energy conservation and environmentally sustainable technologies into buildings and community systems. In order to achieve that both technical and non-technical goals are defined. Specific objectives of the BCS R&D programme are:

- to support the development of generic energy conservation technologies within international collaboration
- to support technology transfer to industry and to other end-users by dissemination of information, through demonstration projects and case studies and through attracting direct industry participation
- to contribute to the development of international standards, test methods, measuring techniques and evaluation/assessment methods
- to remove technical and to some extend also non-technical obstacles to the penetration of new advancements in energy conservation technologies
- to encourage non-Member countries to participate in BCS activities by inviting their industries which are recognized in the specific area of the Annex, to accelerate the introduction of energy efficient technologies in these countries.

The work of the BCS programme covers a large number of areas, including: design tools (early-stage, LCC-analysis, etc.), community planning tools, system engineering, building automation and energy management systems, advanced technical systems (lighting, envelope, HVAC systems, heat recovery), operational technologies, advanced

building materials and components, indoor air quality and ventilation; energy retrofitting, and integration of energy conservation and renewable energy technologies.

The R&D activities cover both new and existing buildings, residential and office/commercial buildings, even though main emphasis is on improving the energy-efficiency of the existing building stock because of the declining trend in new construction.

2.2 Activities of the Buildings and Community Systems Program:

Since the start of the Agreement in 1977, the Executive Committee has initiated 34 collaborative projects (Annexes) with 25 of them completed and reported. The work addressed the main R&D areas reaffirmed as part of the Strategy Plan. These projects resulted in a large number of reports with results ranging from international state-of-the-art review to design guidelines, to validated simulation models and energy analysis tools.

To enhance the dissemination of the program results, the ExCo encourages participation of industry in collaborative projects, it publishes a semi-annual Newsletter, publicizes the work on an Internet World Wide Web page (www.ecbcs.org), and encourages presentation of the results at relevant national and international conferences.

Description of all annexes and a list of resulting publications are available on the Web page. Some of the main R&D areas and annexes addressing these areas are summarized below. More details are sometimes given on some annexes to illustrate particular achievements.

2.2.1 Energy Management and Control Systems

The implementation of building energy management and control systems can result in a considerable reduction in energy use. Efforts have concentrated on providing guidelines for selecting suitable systems (Annex 16), the development and assessment of building HVAC emulation tools (Annexes 10, 17 and 30) and of diagnostic and fault detection techniques (Annexes 25 and 34).

Annex 16 examined the functions of a number of existing monitoring and control systems, how these worked in various countries and climates and the cost reductions that resulted from system implementation. Sensor types and installations were assessed, a number of buildings fitted with computerized energy management systems were inspected to gain experience with different applications and experiences were also collected through interviews with manufacturers, consultants and property managers. Examples indicated that investment in computerized energy management and control systems can result in 15-30% energy saving, depending on operating strategy.

While Annex 16 primary task was to examine existing systems, the purpose of Annex 17 was to develop the algorithms used in the control systems. The options for better control were demonstrated by means of simulations using different operating strategies. Two simulation software packages were used: TRNSYS and HVACSIM, and emulators were developed and implemented at six different sites. Comparisons have also been made between various emulators (e.g. for the operation of the boiler, cooling system, cooling tower, supply and return air fans) and results were in most cases within 5%. The work indicated that emulators can be used to inspect or examine the hardware and software of the control system, assess the structure, control strategies and algorithms, fine-tune the default or pre-set values and train operating personnel.

2.2.2 Development and Evaluation of Design Tools

Several annexes have been devoted to the development and application of design tools including thermal simulation (Annexes 10 and 21). Several models have been developed and/or assessed, many of which are in the public domain. The work of Annex 21 (in collaboration with Task 12 of the Solar Heating and Cooling program) has resulted in a comprehensive method to test and help correct computer-based energy analysis models. This work has been accepted by national accreditation bodies and is leading to better design and assessment of energy efficient buildings.

Effective energy reduction is dependent on improving the energy efficiency of the building stock without compromising occupant comfort or building integrity and durability especially in relation to moisture accumulation. Efforts have been dedicated to developing computer prediction models and design guidelines for building envelope systems (Annexes 14, 19 and 24). Annex 14 objective was to provide architects, building owners and practitioners with better knowledge and understanding of the physical background of the phenomena of condensation, including material characteristics and critical conditions for mold growth. Also to provide better computational models, taking heat, air and moisture in account in predicting surface condensation and potential solutions to avoid it. Design and practice guidelines were produced and presented in one of the final reports.

Motivated by the work of Annex 14 and the fact that national building codes and standards continued to treat the subject of combined heat, air and moisture performance in a very elementary way, 14 countries have joined in Annex 24 to improve the understanding of heat, air and moisture transport in new and retrofitted envelope parts and to analyze the consequences of thermal and hygric performance on durability. The annex resulted in the most comprehensive compilation of computer models and material property data. It also defined the concept of Indoor Climate Class with the governing parameter as the indoor-outdoor vapour pressure excess, to classify the hygrothermal stress on the envelope. Finally, the consequences for energy consumption of enthalpy flow, latent heat release and moisture content were quantified in exemplary practical cases. Parasitic airflow was highlighted as a major cause of unwanted extra losses and moisture accumulation. Examples of effects on durability were also given for cases of biological and chemical attacks and mechanical degradation.

2.2.3 Ventilation and Indoor Air Quality

It is estimated that 30% or more of space conditioning load (heating and cooling) of a building is in the departing air stream. Therefore, in addition to impacting the indoor air quality, ventilation has an important energy implication. ECBCS program has concentrated on understanding the role of ventilation and evaluating ventilation systems. Studies have focused on energy efficient ventilation strategies and methods for predicting air flow patterns (annexes 20, 23 and 26). Other aspects include evaluating the impact of air infiltration on ventilation and energy performance and the use of ventilation heat recovery systems (Annexes 8, 9, 18 and 27). Information on air related aspects is disseminated through the Air Infiltration and Ventilation Centre (AIVC or Annex 5).

Annex 20 was formed to evaluate the performance of single- and multi-zone air and contaminant flow simulation techniques and to establish their viability as design tools. The evaluation was done through a number of simulation exercises covering free, forced and mixed convection cases as well as a displacement ventilation case. This also provided a

methodology and data sets for future work. Computational fluid dynamics (CFD) codes were found to predict room air movement with sufficient realism to be of use to design practice, however significant skill and experience are still required to use such codes. The work also identified three areas needing of further development, modeling of supply air jets, turbulence and thermal wall functions. In the area of multi-zone modelling, experts of Annex 20 developed a number of algorithms including flow through large openings and single sided ventilation, inhabitant behaviour (use of doors and windows), air flow-driven contaminants and multi-room ventilation efficiency. These development were now incorporated into simulation code COMIS developed in Annex 23.

Experiences of Annex 20 were also extended to Annex 26, to provide design guidance on the application of air flow simulation tools for understanding ventilation in large enclosures such as shopping malls, atria, airport terminals and covered theaters and stadiums. Each of these presents enormous design challenges in relation to heating and cooling loads, the provision of good indoor air quality and protection against fire and smoke movement. The annex developed new methods that have provided new guidance on the operation and applicability of CFD models. "Simple" analysis tools were developed for basic engineering application. These included the "flow element" technique in which the flow field is predicted by individually analyzing each flow element, i.e. jets, plumes, boundary layer flow, etc. In addition, a simplified measurement procedure to evaluate building air leakage has been devised, and existing infra-red photography methods have been adapted to map surface temperatures inside spaces that can only be viewed from oblique angles. CFD predictions have been compared with measured results and demonstrated to predict the flow and thermal patterns to a reasonable degree of accuracy including coping with the complexities of radiative exchange. Various developments of Annex 26 were incorporated into a "tool kit" aimed at assisting the practitioner to achieve proper flow pattern control for energy efficient ventilation.

2.2.4 Advanced Building Materials and Systems

Developments in window technologies, to improve the thermal insulation value as well as the use of natural daylight and passive heating and cooling techniques, have a considerable impact on energy efficiency of buildings. These technologies are developed and assessed in various annexes on windows (Annex 12), daylighting (Annex 29) and Low energy cooling (Annex 28). Combined with these are prediction methods and a variety of new materials and energy efficient systems for use in buildings.

2.2.5 Community Systems Energy Planning

Widespread implementation of energy conserving technologies and measures depends on the scale of penetration. Various projects are aimed at developing community wide strategies or local area planning. Activities are concentrating on the development of planning tools and implementation strategies that optimizes the energy use within a whole community (Annexes 22 and 33). This involves the co-operation of local authorities willing to participate in the use of proper planning tools as part of an international case study approach.

2.2.6 The Future Building Forum

An important part of the ECBCS program is the Future Building Forum - 2025. This is aimed at identifying long-term energy, environmental, economic and technical issues and assessing their impact on future buildings. The Forum also monitors technological

advances appropriate to building science and defines research priorities based on emerging technologies that will ensure that buildings contribute to a sustainable society by the year 2025 and beyond. The direction of the FBF is maintained through regular workshops and expert meetings; six workshops on various subjects were held to-date (proceeding available through the AIVC). The FBF Organizing Committee includes representatives from all building-related IEA Implementing Agreements including: District Heating and Cooling, Heat Pumps, Energy Storage and Solar Heating and Cooling.

2.2.7 New Activities:

Several new Annexes have recently been established each aimed at improving the application of knowledge to practice. These activities include:

Energy Related Environmental Impact of Building - Annex 31

The main intention of this project is to document and develop techniques that can be used to analyze how energy use in buildings impacts on the interior, local, regional and global environments. The planed work covers: documentation of methods and data; analysis; demonstration; and information transfer.

The project will be centered around life cycle analysis combined with the impact of the infrastructure associated with building and the energy chains involved in delivering energy to buildings.

Integral Building Envelope Performance Analysis - Annex 32

This activity is aimed at the optimization of the building envelope to achieve energy efficiency combined with a good indoor environment. Two main tasks are proposed to develop appropriate methodology for performance analysis and to establish case studies to assist in improving and demonstrating optimization methods. These studies will incorporate new construction, renovation, laboratory tests and full scale demonstration.

Advanced Local Area Planning - Annex 33

Major effect has recently been undertaken in several countries to develop local energy planning concepts (LEP) into a tool for the integrated planning of entire communities. This combines knowledge at the "microscopic" or individual building design level with system analysis at the "macroscopic" or community level. Not only is modern day LEP concerned with minimizing the cost of energy supply but also in integrating demand and supply side measures with environmental requirements and the planning and decision process.

There is now an enormous diversity of planning tools which are available to the planner, however a wide gap still exists between available techniques and there application in current practice. The objective of annex 33 is to close this gap by producing tools to support practical application.

Computer Aided Fault Detection and Diagnosis - Annex 34

A recent study has indicated that 20-30% energy savings in commercial buildings is achievable by re-commissioning of the HVAC systems to rectify faulty operation. Current strategies do not explicitly optimize performance and cannot respond to the occurrence of faults which cause performance to deteriorate. The objective of this Annex is to work with control manufacturers, industrial partners and/or building owners and operators to demonstrate the benefit of computer aided fault detection and diagnostic systems. Methods will be incorporated either in stand alone "PC" based systems or incorporated within a future generation of "smart" building control systems.

3. Summary

Since 1977, the IEA Buildings and Community Systems program of collaborative research has significantly contributed to the knowledge and expertise on efficient energy use in buildings. The outcomes of the collaboration have enabled the research and development objectives of national energy technology programmes in participating countries to be better achieved at a lower cost and a very high quality.

4. Bibliography

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