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A Strategy for Future Ventilation Research and Application

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Air Infiltration and Ventilation Centre

University of Warwick Science Park
Sovereign Court
Sir William Lyons Road
Coventry CV4 7EZ
Great Britain

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Additional copies of this report may be obtained from:

The Air Infiltration and Ventilation Centre
University of Warwick Science Park
Barclays Venture Centre
Sir William Lyons Road
Coventry CV4 7EZ
Great Britain

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Martin Liddament

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Preface

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among the twenty-one IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources and energy research development and demonstration (RD&D). This is achieved in part through a programme of collaborative RD&D consisting of forty-two Implementing Agreements, containing a total of over eighty separate energy RD&D projects. This publication forms one element of this programme.

Energy Conservation in Buildings and Community Systems

The IEA sponsors research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is sponsoring various exercises to predict more accurately the energy use of buildings, including comparison of existing computer programs, building monitoring, comparison of calculation methods, as well as air quality and studies of occupancy. Seventeen countries have elected to participate in this area and have designated contracting parties to the Implementing Agreement covering collaborative research in this area. The designation by governments of a number of private organisations, as well as universities and government laboratories, as contracting parties, has 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. The importance of associating industry with government sponsored energy research and development is recognized in the IEA, and every effort is made to encourage this trend.

The Executive Committee

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 that all projects fit into a pre-determined strategy, without unnecessary overlap or duplication but with effective liaison and communication. The Executive Committee has initiated the following projects to date (completed projects are identified by *):

I Load Energy Determination of Buildings*
II Ekistics and Advanced Community Energy Systems*
III Energy Conservation in Residential Buildings*
IV Glasgow Commercial Building Monitoring*

V	Air Infiltration and Ventilation Centre
VI	Energy Systems and Design of Communities*
VII	Local Government Energy Planning*
VIII	Inhabitant Behaviour with Regard to Ventilation*
IX	Minimum Ventilation Rates*
X	Building HVAC Systems Simulation*
XI	Energy Auditing*
XII	Windows and Fenestration*
XIII	Energy Management in Hospitals*
XIV	Condensation*
XV	Energy Efficiency in Schools*
XVI	BEMS - 1: Energy Management Procedures*
XVII	BEMS - 2: Evaluation and Emulation Techniques
XVIII	Demand Controlled Ventilating Systems*
XIX	Low Slope Roof Systems
XX	Air Flow Patterns within Buildings*
XXI	Thermal Modelling
XXII	Energy Efficient Communities
XXIII	Multizone Air Flow Modelling (COMIS)
XXIV	Heat Air and Moisture Transfer in Envelopes
XXV	Real Time HEVAC Simulation
XXVI	Energy Efficient Ventilation of Large Enclosures

Annex V Air Infiltration and Ventilation Centre

The IEA Executive Committee (Building and Community Systems) has highlighted areas where the level of knowledge is unsatisfactory and there was unanimous aggreement that infiltration was the area about which least was known. An infiltration group was formed drawing experts from most progressive countries, their long term aim to encourage joint international research and increase the world pool of knowledge on infiltration and ventilation. Much valuable but sporadic and uncoordinated research was already taking place and after some initial groundwork the experts group recommended to their executive the formation of an Air Infiltration and Ventilation Centre. This recommendation was accepted and proposals for its establishment were invited internationally.

The aims of the Centre are the standardisation of techniques, the validation of models, the catalogue and transfer of information, and the encouragement of research. It is intended to be a review body for current world research, to ensure full dissemination of this research and based on a knowledge of work already done to give direction and firm basis for future research in the Participating Countries.

The Participants in this task are Belgium, Canada, Denmark, Germany, Finland, France, Italy, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom and the United States of America.

Executive Summary

The objective of this strategy is to identify the research needed to understand, develop and promote the role of ventilation in the control of energy use for optimum indoor air quality. To achieve this, the following tasks are proposed:

(i) evaluate the existing energy impact of ventilation.

The energy significance of ventilation heating and cooling loss, in both domestic and non domestic buildings, needs to be accurately identified. This is important for future energy policy planning and for use as a reference level against which future ventilation energy reductions can be compared.

(ii) establish indoor air quality needs.

Indoor air quality needs should be identified and pollutants should be categorised according to unavoidable and avoidable sources. Any extra energy and cost impact of ventilating to mitigate avoidable pollutant sources can then be found.

(iii) identify the role of ventilation in controlling IAQ.

The role of ventilation as a mechanism for controlling indoor air quality should be assessed. Where ventilation is inappropriate or expensive, other control measures should be identified.

(iv) evaluate optimum ventilation needs.

An evaluation of the optimum ventilation appropriate for the needs of occupants and for diluting and removing unavoidable pollutants should be undertaken.

(v) assess the energy impact of optimum ventilation.

The energy needed for providing optimum ventilation should be evaluated. This may then be compared with the results of task (i) to establish an energy reduction target.

(vi) achieve energy and cost effective ventilation

Factors that influence energy and cost effective ventilation must be identified. These include climate, building type and size, occupant considerations, reliability and cost.

(vii) disseminate results through a guide to ventilation

Results should be published in a guide to ventilation. This publication should be aimed at policy makers, designers and other end users who can ensure the widespread use of results.

An important aim of this strategy is to provide a foundation for future ventilation analysis within the International Energy Agency. This should address energy and air quality aspects of ventilation and be integrated within an overall strategy for building energy planning.

1. Introduction

Ventilation and the movement of air in buildings play an essential role in the indoor environment. A continuous supply of fresh air is vital for the support of metabolism and for the dilution and removal of pollutants. An inadequate supply of fresh air or poor air distribution may result in high levels of indoor contaminants and discomfort; it could also result in more serious problems related to health. Additionally, air is a fundamental transport mechanism for heating and cooling occupied spaces.

The impact of ventilation on energy use can be considerable. Total building energy use is variously estimated to account for 30% of all energy consumed in International Energy Agency Countries. Of this, as much as 50% can be associated with ventilation and air infiltration. As living standards throughout the world improve, it may be expected that building occupants will demand ever increasing standards of comfort. This will inevitably result in increased demand on building energy use and further heighten concerns over global pollution. Much can be achieved to reduce energy demand by improving energy efficiency. However, as the thermal performance of buildings improves, ventilation will become the dominant source of building energy loss. Unfortunately, reducing ventilation as a means to minimise energy demand, has become inextricably linked to problems associated with unhealthy buildings. Ventilation is thus an essential parameter in both energy and indoor air quality control.

The purpose of this report is to assess future ventilation research and development needs. An objective has been to identify the prime objectives and tasks needed to secure energy efficient ventilation without detriment to indoor air quality. It is intended that this strategy should be used to formulate a plan for future ventilation analysis within the International Energy Agency. These proposals are therefore seen as a basis for collaborative IEA research programmes. Proposed tasks are summarised in Tables 1-3 at the end of this report.

Many of these proposals build on the results of previous annexes of the IEA Implementing Agreement on Energy Conservation in Buildings and Community Systems (ECB&CS). In addition, some aspects are currently being addressed by ongoing annexes or proposed future annexes. Relevant Annexes are listed in Table 4 and are summarised in the Appendices.

Several of these proposals were also outlined by the AIVC at a European Community Workshop on Indoor Air Quality Management, held in Lausanne, Switzerland in May 1991. Some have since been incorporated in the EC Executive Summary of Research Needs and are now included as IAQ R&D topics in the European Joule II Energy Programme.

2. Objectives

A summary of objectives is outlined in Figure 1. The principal intention is to identify the research needed to understand, develop and promote the role of ventilation in indoor air quality and energy control. To achieve this, the following tasks have been identified:

- evaluate the energy impact of ventilation heating and cooling losses in the present building stock.
- Assess indoor air quality needs.
- identify the influence of ventilation in controlling IAQ and comfort.
- evaluate optimum ventilation needs.
- assess the energy impact of optimum ventilation.
- identify the conditions needed to achieve energy efficient and cost effective ventilation.
- disseminate results.

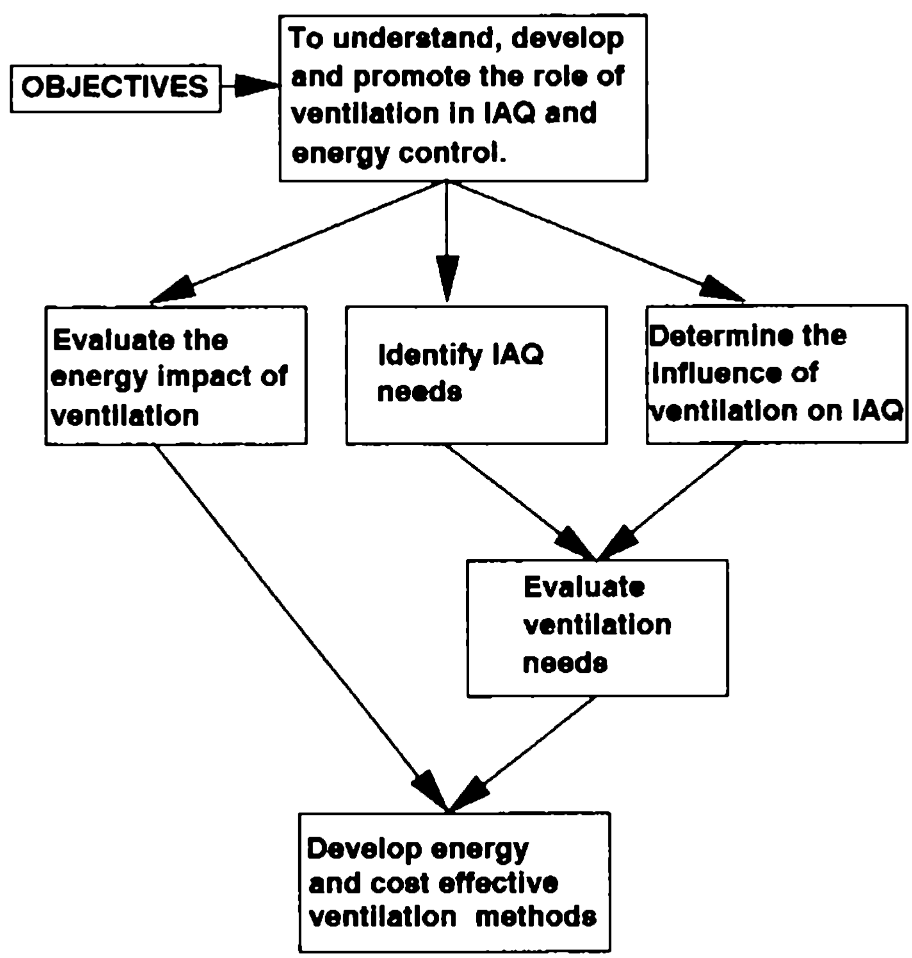


Figure 1: A strategy for IEA ventilation analysis

These activities are subdivided into a series of subtasks and related activities in the following sections.
In formulating this strategy, care has been taken to ensure that ventilation has not been dissociated from other aspects of building energy use. This is because ventilation is only one aspect of the building energy equation and, ultimately, any research programme must be integrated within an overall building energy strategy. Above all, an attempt has been made to ensure that this programme is motivated by a clear need to achieve an energy efficient high quality indoor environment.
This strategy is aimed at both heating and cooling needs and at all types of buildings. It is also aimed at the existing building stock and at the needs of future buildings.

3. Proposed Tasks

3.1 Evaluate The Energy Impact Of Ventilation Heating And Cooling Losses In The Present Building Stock

A comprehensive review of ventilation rates and associated energy use in existing buildings is needed to evaluate total ventilation energy loss. This is important for future energy policy planning and for use as a reference level against which future ventilation energy reductions can be compared. Several methods are proposed as summarised in Figure 2. A further objective is to highlight deficiencies in existing information and to identify areas of additional research that may be needed to improve the accuracy of estimates.

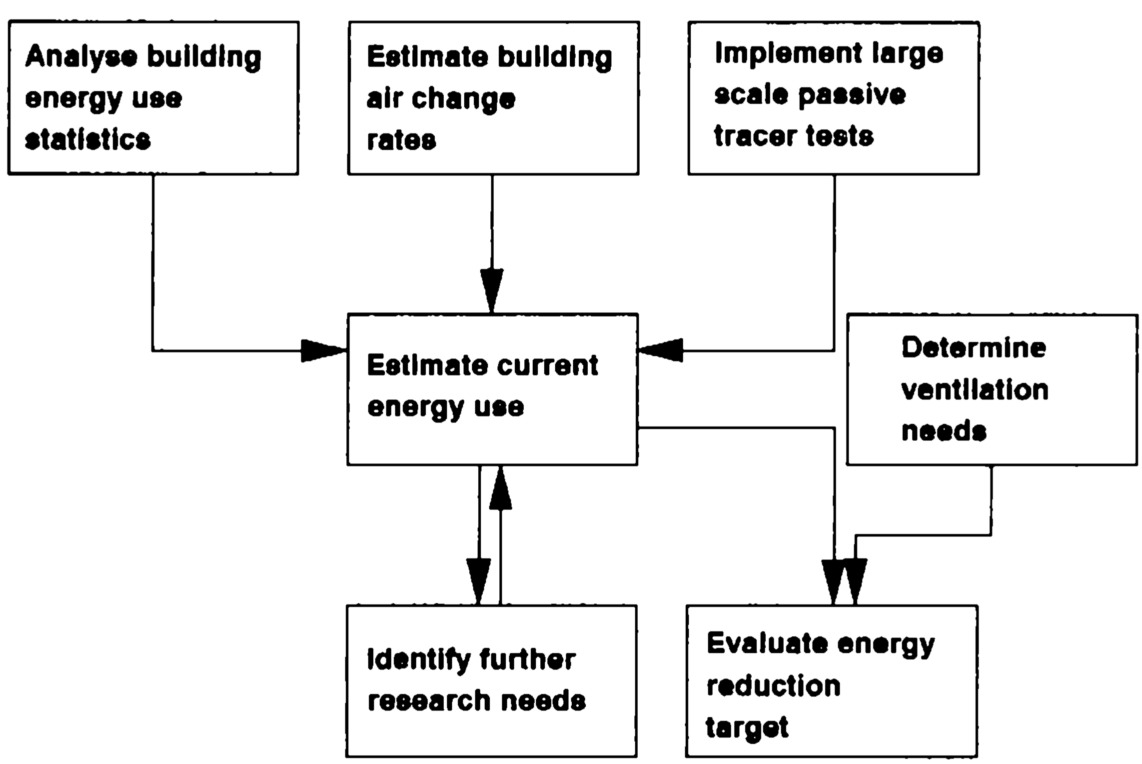


Figure 2: Energy impact of ventilation

Proposed subtasks include:

3.1.1 Analyse Existing Building Energy Use Statistics

The purpose of this task is to obtain an approximate value of ventilation energy loss from published energy use statistics. Published data are available in many countries and can be used to estimate building energy use for space heating and cooling. A ventilation estimate can be based on a proportion of the total value (eg 50%).

3.1.2 Analyse Building Air Change Data

A complementary method is to categorise the building stock of each country in terms of building type, number within each type and approximate volumes. Estimates of air change rate, according to building type, combined with climatic data may then be used to determine ventilation energy use within each building category. This approach is discussed in further detail in section 3.5. These results should be compared with those obtained in 3.1.1.

3.1.3 Analyse Population Needs

A third approach is to make an estimate of ventilation energy demand based on occupant needs. This may be derived by assuming a basic occupant ventilation requirement (Section 3.4) from which a total ventilation rate may be estimated.

3.1.4 Implement Large Scale Passive Tracer Techniques

The above methods can only provide an approximate range of ventilation energy estimates. Much more precise knowledge about buildings and the influence of occupants is needed for a reliable energy study. This needs to be based on ventilation measurement techniques. In the past, air change measurements have relied on the use of complex tracer gas instrumentation which is unsuitable for large scale studies. As a consequence, the number of buildings tested has been minimal. Also, measurement periods have tended to be short and, frequently, test buildings have been unoccupied. Many existing results are therefore not representative of the general building stock. More recently, passive tracer gas methods have become available. These enable inexpensive measurements to be made in occupied buildings over extended periods. Most significantly, this method measures total air change rate, including that resulting from window opening and other occupancy actions.

Large scale testing is currently taking place in several countries. It is proposed, therefore, that a review of existing passive tracer measurement programmes and results is made and the value of existing data is assessed. A programme should then be developed for a future international study. This should involve organising passive measurements in a statistically significant number of buildings in each country, com-

bined with supporting detailed measurements in a small subset of buildings. Supporting measurements should include constant concentration tracer gas testing and airtightness testing. The constant tracer gas results will provide a means to check and, if necessary, calibrate the passive tracer tests. They will also provide guidance on seasonal and climate variations in ventilation rates. Additionally airtightness results may be combined with tracer gas data to evaluate the significance of airtightness on ventilation rates in occupied buildings. A correlation between airtightness and air change rates in occupied buildings may then be determined.
This activity provides an opportunity for a task shared study to understand ventilation energy use in the existing building stock. Tasks 3.1.1 to 3.1.3 involve a compilation and review of existing knowledge which is included within the AIVC programme (Appendix 1).

3.2 Identify Indoor Air Quality Needs

Ventilation is needed to maintain good indoor air quality by diluting and removing pollutants emitted within the ventilated space. It is important, therefore, to have knowledge of the characteristics of indoor pollutants and to assess indoor air quality needs. While much of the work within this topic area falls outside the domain of the IEA, the results are vital for the evaluation of ventilation needs. Potential tasks for assessing these needs are outlined in Figure 3.

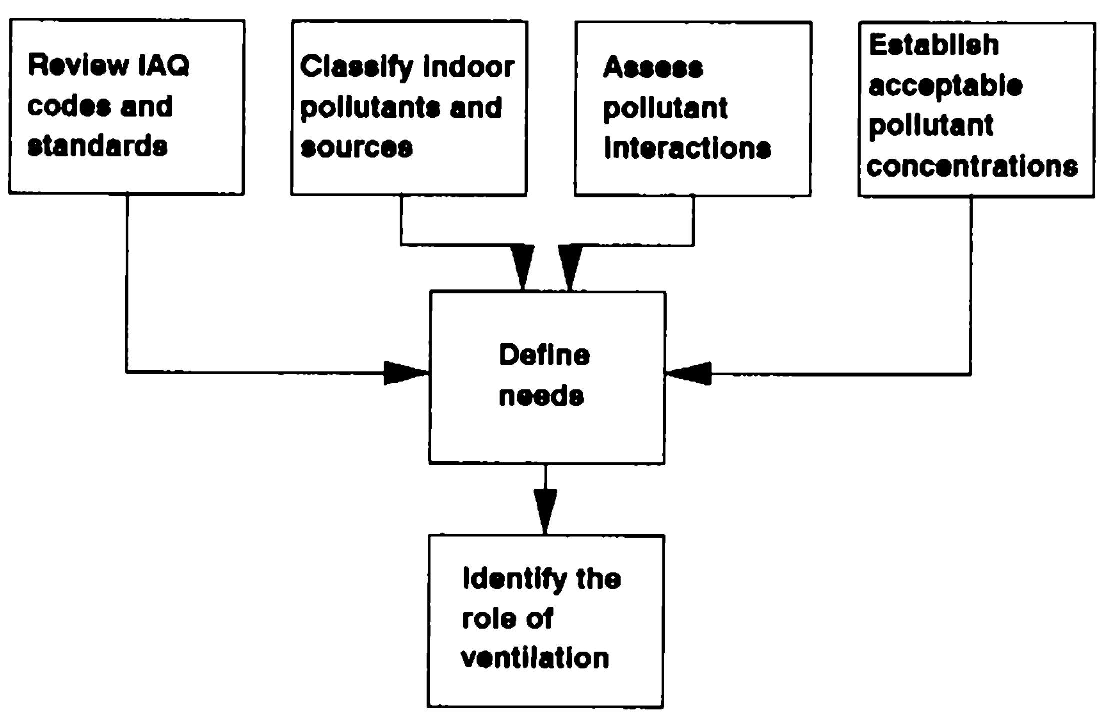


Figure 3: Indoor air quality needs

Complementary measurement work is proposed by ECB&CS Annex 26 (Appendix 3) and by a proposed Annex on evaluating domestic ventilation systems (Appendix 4). Previous IEA investigations on aspects of this problem have been undertaken by ECB&CS Annex 9 (Indoor Pollutants) and by Annex 14 (Moisture) (Appendix 2).

Proposed activities include:

3.2.1Reviewing Existing Indoor Air Quality Codes, Standards, Requirements And Knowledge

Many recommendations and requirements covering maximum concentrations of pollutants exist in all countries. These requirements are under frequent review as concerns over the toxicity of various pollutants grow. Often maximum values are based on short term threshold limit values instead of comfort values. Therefore, different needs may be expected to apply to the office or home than may be acceptable within industrial environments. A review of existing requirements is proposed, so that a consensus may be established on acceptable pollutant concentrations. Results from this task should be included in the AIVC database. Since this is essentially a review activity, this task forms part of the AIVC work programme (Appendix 1).

3.2.2 Classifying Indoor Pollutants, Sources And Sinks

Knowledge is needed of the many pollutants to be found in buildings. While this is not necessarily an IEA activity, a review is nevertheless needed. This should contain information on emission characteristics of common materials, toxicity and any restrictions imposed by countries on materials. Current research should be reviewed in the context of materials to be found in different types of building. Institutions undertaking analysis in this area should be included in the AIVC's survey of research and results incorporated within the Centre's database.

3.2.3 Assessing The Interaction Of Pollutants

Concern is sometimes expressed over the chemical interaction between pollutants. Problems include the interaction of ozone with electronic components and the adsorption of volatile organic compounds on to surfaces. Again, this is not an IEA topic but a review of research is essential. This should take the form of a literature review, the identification of research groups and a brief summary of existing knowledge.

3.2.4 Establishing Acceptable Pollutant Concentrations

This is also a specialist task which relies on medical judgment and on the experience of air quality specialists. The IEA role should be to remain aware of progress and to ensure that available knowledge is disseminated to health groups and standards committees. Therefore, IEA activity should be restricted to identifying information sources and to collating information. This activity should also build on the results of ECB&CS Annex 9 on minimum ventilation (Appendix 2).

3.3 To Identify the Role of Ventilation in Controlling Indoor Air Quality and Comfort Conditions

Arguably, airborne pollutants should be controlled by restriction or by elimination of the contaminant source, however, it often falls upon ventilation to dilute and remove pollutants. The limit to which ventilation provides a suitable method of control should be determined and the cost compared with that of other control measures.

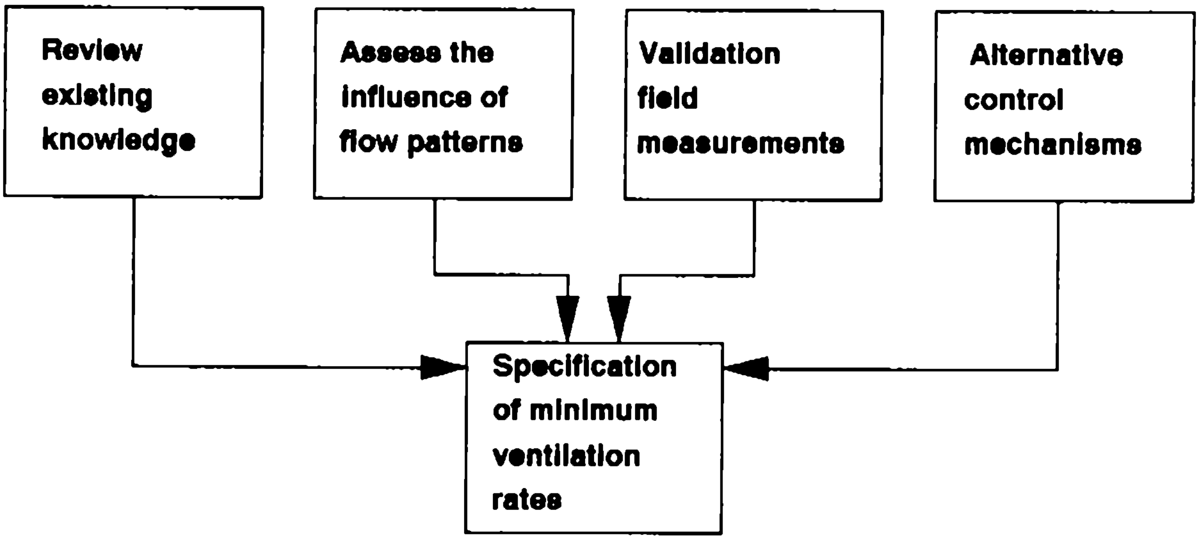


Figure 4: Influence of ventilation on indoor air quality

Proposed tasks are outlined in Figure 4 and include:

3.3.1 Reviewing Existing Knowledge

Much conflicting evidence exists concerning the role of ventilation in controlling indoor air quality. A review is needed to assess current knowledge and to highlight specific case studies identifying relationships between indoor air quality and ventilation in occupied buildings. This should focus on research that has looked for links between IAQ problems and ventilation rates. This review must identify the conditions for which ventilation is or is not an appropriate control strategy and provide guidelines accordingly.

3.3.2 Identifying The Influence Of Flow Rates, Flow Patterns And Ventilation Efficiency On The Control Of Pollutants

The efficiency of a ventilation system in minimising pollutant levels is dependent on the air flow pattern and the mixing characteristics of supply air with pollutants. Much further knowledge is needed in understanding and predicting the processes of air flow and mixing. Currently, measurement techniques are used to determine ventilation efficiency. However, flow and mixing patterns are a function of momentum and buoyancy forces, location and strength of pollutant source, room layout and the configuration of the ventilation system. Thus ventilation efficiency is often unique to the enclosure in which measurements are made. It is therefore difficult to use measurement data, other than by scale modelling, to predict ventilation efficiency at the design stage. To overcome this problem, improved simulation models, for predicting air flow patterns and ventilation efficiency, are needed. Much development has already taken place in ECB&CS Annex 20 (Appendix 2), which has undertaken the preliminary validation of computational fluid dynamic codes. This work is currently being extended by Annex 26 which is investigating air flow in large enclosures (Appendix 3).

It is also essential to understand the pattern of air movement and pollutant transport between zones. Factors such as ventilation strategy, flow paths and pollutant source locations, combine to influence pollutant distribution and air quality from one zone to another. Prediction methods are currently being developed and assessed by Annex 23 (multizone modelling - see Appendix 3).

3.3.3 Undertaking Field Measurements To Assess The Role Of Ventilation

Complementary to a numerical understanding of air flow and pollutant mixing is the need for supporting validation measurements. Documented field measurements from as wide a range of sources as possible are needed. This is necessary for validation and for comparing the performance of alternative ventilation strategies in controlling indoor air quality. Measurement data are also needed to compare the performances of alternative ventilation strategies. Many of these needs are being addressed by ECB&CS Annex 23 on multizone modelling and by Annex 26 on air flow in large enclosures (Appendix 3). Test chamber measurement data are also available from Annex 20 (Appendix 2). Data from these annexes and other available sources will be incorporated into the AIVC's numerical database. In the past, many measurements of ventilation efficiency have been made in buildings and test enclosures. These data should be collated and used to assess the performance of air flow models as design tools for predicting indices of ventilation efficiency.

3.3.4 Specifying Minimum Ventilation Rates And Identifying Alternative Control Mechanisms

Based on knowledge of pollutant emission and on air flow and pollutant mixing, control mechanisms to minimise indoor pollutant concentrations should be categorised. Appropriate minimum ventilation rates and strategies should be defined. Previous IEA work includes Annex 9 on the specification of minimum ventilation rates and alternative control measures (Appendix 2). Other control mechanisms ,such as the elimination of pollutants, should be reviewed.

3.4 To Evaluate Optimum Ventilation Needs

Once the role of ventilation has been identified, optimum ventilation rates must be established. Of principal importance is the need to separate the absolute requirements of occupants, from the needs to dilute and remove other, possibly unnecessary, sources of indoor pollutants. By so doing, it will be possible to establish the true cost of controlling pollutant emissions in buildings by ventilation. Such costs may then be compared with the cost of alternative control measures. It is proposed that an evaluation should be made of ventilation needs and that occupant needs are separated from those of other indoor air quality considerations. Future work should also address problems of external and apparently unidentifiable air quality problems. Ventilation needs must be clearly defined and, where possible, alternative control measures researched. These proposals build on the work of ECB&CS Annex 9 on minimum ventilation rates and measures for controlling indoor air quality (Appendix 2).

When considering ventilation needs, several aspects of air quality must be considered. These are summarised in Figure 5 and include:

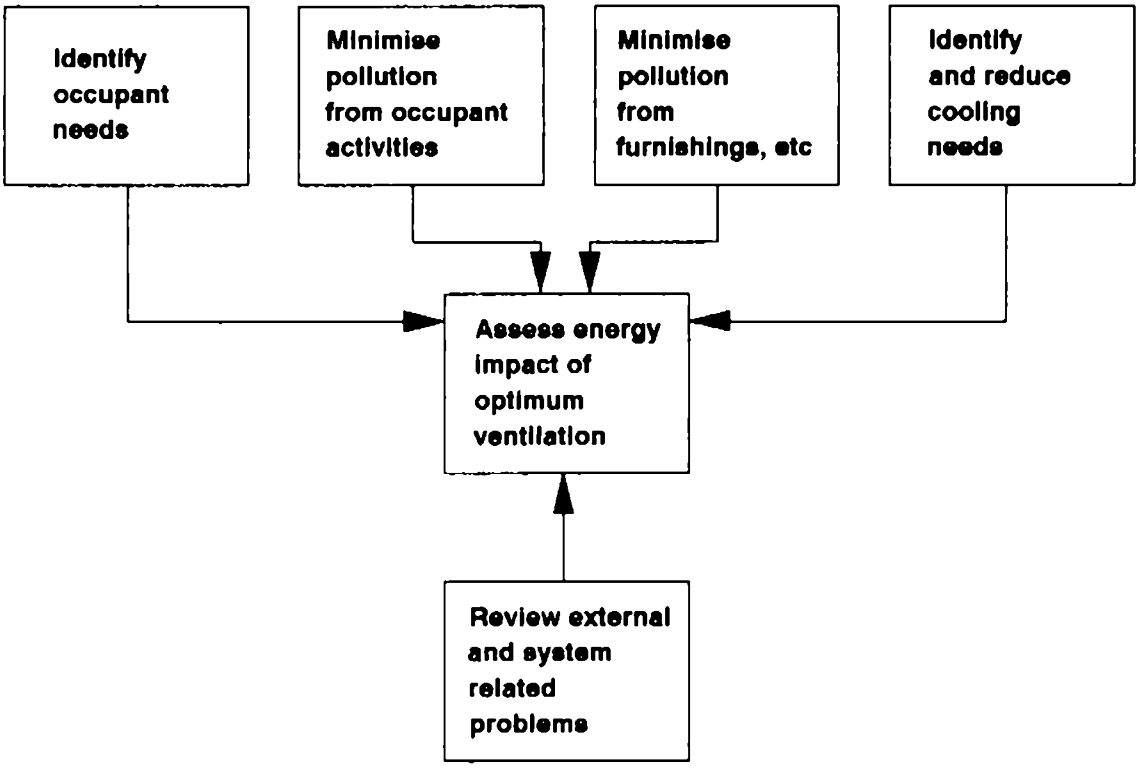


Figure 5: Optimum ventilation needs

3.4.1 Metabolic Pollution (CO_2 And Odour)

The need to ventilate to limit metabolically produced carbon dioxide and odour to acceptable levels represents a minimum ventilation requirement and hence the minimum ventilation energy condition. A building, or a zone within a building, in which high concentrations of metabolically produced pollutants are measured, indicates insufficient ventilation. Furthermore, for a given occupancy pattern, the problem of excessive concentrations of metabolic pollution can only be solved by increasing the rate of ventilation. Thus occupant ventilation need, for optimum air quality, represents a minimum ventilation requirement. This requirement should be clearly identified.

3.4.2 Pollutants Produced By The Activities Of Occupants

Pollution is produced through normal day to day activities of occupants. Typical pollutants include tobacco smoke, moisture from cooking and washing, and pollution generated by using office equipment (eg laser printers and photocopiers). If the rate of ventilation needed to control the concentration of such pollutants is greater than that needed to satisfy metabolic pollution, then a cost penalty may be incurred. Additional ventilation capacity may also need to be installed. The additional ventilation requirement to satisfy pollution generated by occupant activities should therefore be identified and methods found to reduce such needs.

3.4.3 Pollutants Produced By Emissions From Building Fixtures And Furnishings

This is, again, a very important issue. Ventilation capacity may be designed according to planned occupant loading and not anticipate emissions from fabrics and furnishings. Typical pollutants include volatile organic compounds (VOC's), and formaldehyde. As with item 3.4.2, control by ventilation may incur increased energy costs and the need for extra ventilation capacity. The ventilation needs of polluting materials must therefore be specified and alternative emission control measures considered.

3.4.4 Cooling Needs

Sometimes the dominant need for ventilation may be to meet cooling needs due to excess heat gains within the space. These needs should therefore be assessed and design trends and research to minimise excess gains reviewed. New low energy technology in both lighting and electrical appliances may reduce heat loads in the future. Similarly, improved building design should minimise excess external heat gains. Both will reduce the need to provide ventilation for cooling purposes. These aspects need to be addressed by future ECB&CS Annexes and by the Future Buildings Forum (Appendix 5)

3.4.5 External Pollution

Poor indoor air quality may occur through the ingress of external pollution such as traffic exhaust emissions or other outdoor hazards. Generally, increased ventilation of the internal space will not solve these problems. An evaluation of methods to minimise the ingress of external pollutants is needed. This should review airtightness requirements, filtration needs and the positioning of supply air intakes.

3.4.6 Ventilation System Problems

Once identifiable sources of pollution have been eliminated, further air related problems can materialise. This may be especially a problem with air conditioned spaces. Some evidence points to toxic microbiological or fungal infection of the duct work or poor maintenance. Poor system design resulting in cross contamination between exhaust and supply openings may also cause a problem. Again, it is unlikely that increasing the ventilation rate will improve air quality. Tasks need to be devoted to improved design and maintenance. Design guidance on the positioning of exhaust vents, to avoid re-entry into adjacent supply openings, is also needed.

3.5 Assess the Energy Benefit of Optimum Ventilation

Results from the preceding sections will enable the energy benefit of optimum ventilation to be evaluated. The basic steps are illustrated in Figure 6 and include:

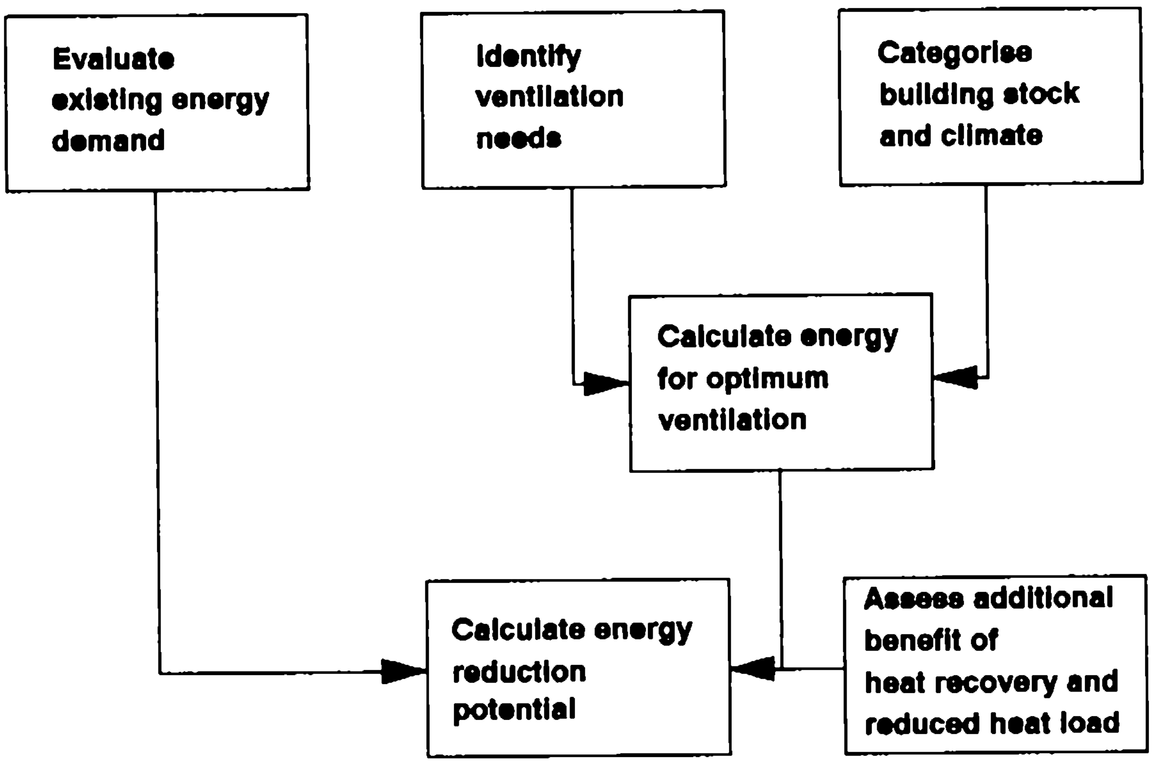


Figure 6: Achieve energy and cost effective ventilation - system design needs

3.5.1 Evaluate Existing Ventilation Energy Demand

Methods to evaluate existing ventilation energy demand are described in Section 3.1. Evaluation of the current position is essential in finding the energy benefit of optimum ventilation.

3.5.2 Identify Needs And Minimum Ventilation Rates

The identification of needs is covered in Sections 3.2 - 3.4. Minimum requirements should, where possible, be set by metabolic needs. Other needs should be avoided by restricting pollutant emissions.

3.5.3 Categorise Building Stock

Information on the building stock including building types, location, enclosed volumes and occupancy patterns is necessary to assess the magnitude of ventilation need according to building type. Early studies by the AIVC have shown that, while information on dwellings is well known, data for other types of buildings are less well documented. Data on the building stock are essential for all building energy studies and effort is therefore needed to obtain such information.

3.5.4 Climatic Data

Regional average climatic data, especially covering temperature, are needed to convert ventilation rate into an energy demand for heating or cooling. Requirements cover average daily temperature, average daytime temperature and degree day data.

3.5.5 Calculate Energy Impact Of Optimum Ventilation

By using the preceding information, the energy impact of optimum ventilation for each type of building may be derived. The total ventilation rate should be calculated for each building category within each climatic zone. From this, the energy impact may be evaluated.

3.5.6 Evaluate Energy Benefit

The basic energy benefit of optimum ventilation may be evaluated directly from the results of 3.5.1 and 3.5.5. This may be compared with current ventilation energy use to set goals for reduced energy demand.

3.5.7 Assess The Potential For Ventilation Heat Recovery

Once the basic energy benefit of optimum ventilation has been established, the role of heat recovery devices for further reducing ventilation energy use may be evaluated. Considerable potential for saving energy by heat recovery exists but performance depends on reliability, cost and building airtightness. System aspects are covered in further detail in Section 3.6.

3.6 Achieve Energy and Cost Effective Ventilation

Further tasks are needed to develop energy and cost effective ventilation strategies. Activities to achieve this goal include system specification, design considerations and the development and application of design tools. These aspects are considered in the following sections.

3.6.1 System Specification

System specification parameters are outlined in Figure 7. Important needs include:

(i) identifying ventilation need.

Tasks aimed at establishing this need have been identified in the preceding sections.

(ii) identifying the energy performance of alternative ventilation strategies.

The goal of future design should be to meet the identified ventilation need with minimum use of energy. An analysis of system performance is therefore required. This analysis should consider all main strategies and quantify the energy advantages and disadvantages of each. With mechanical systems, the supply cost should be identified, whereas with natural systems, the heating or cooling losses associated with poor control and over supply should be included.

(iii) comparison of cost performance.

System costs ultimately fall on the building occupier. Therefore, to be widely accepted, the cost performance of the system must be competitive. Consequently, a study of the cost performance of alternative strategies is needed. This should cover capital and installation costs, maintenance/replacement costs and the cost of providing the necessary installation space. The benefits of heat recovery, heat pumps and demand controlled systems should also be assessed in relation to field results and operational costs.

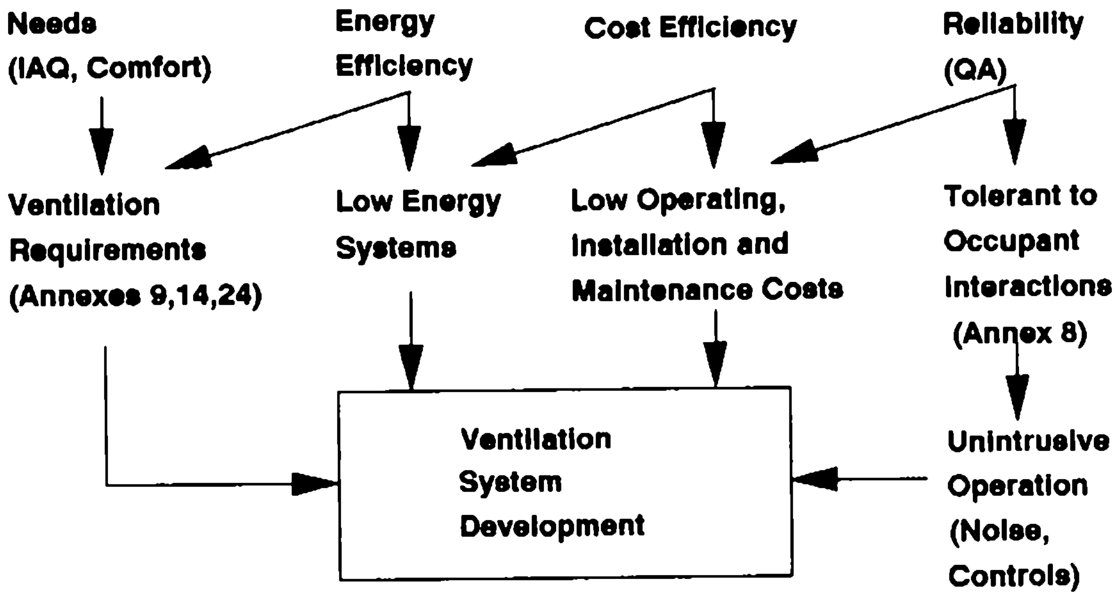


Figure 7: Achieve energy and cost effective ventilation - selection of strategies

(iv) system development

Further system development is needed to improve the air change efficiency and the pollutant removal effectiveness of ventilation systems. This must essentially be industry based.

(v) reliability

The long term reliability of systems needs to be evaluated. Over recent years many new systems have been installed in a wide range of different types of buildings. The experience gained from these installations in terms of reliability and performance targets should be reviewed.

(vi) acceptability to occupants

Occupant tolerance to the system is essential. Tasks are needed to focus on the interaction of occupants with ventilation systems. This is to ensure that ventilation design goals are achieved in practice. The use of controls, the influence of window and door opening and the intrusion of noise needs to be assessed. This analysis should build on the previous work of ECB&CS Annex 8 on occupant interaction (Appendix 2).

3.6.2 Design Considerations

The final choice of ventilation system will depend on many design considerations; these are summarised in Figure 8.

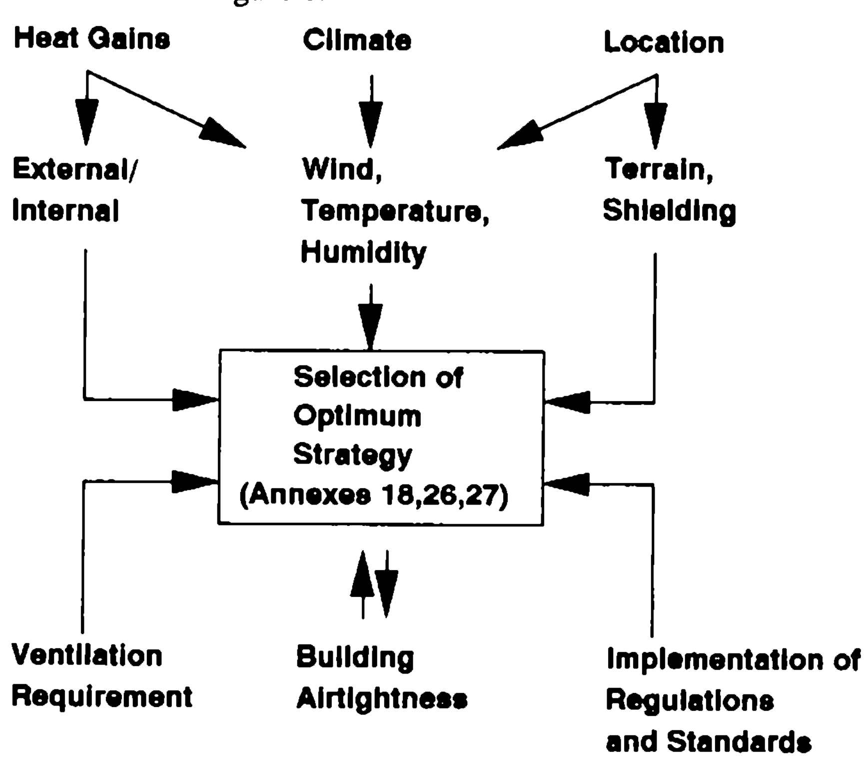


Figure 8: Achieve energy and cost effective ventilation - design tools

Future research needs include:

(i) optimising building envelope tightness

Ventilation performance is especially influenced by the porosity of the building shell. An evaluation of optimum airtightness and an assessment of how these requirements can be achieved in normal construction practice is needed. Maximum acceptable airtightness values should also be established to ensure an adequate air supply in the event of a ventilation system failure. The significance of airtightness on the performance of heat recovery systems is also needed.

(ii) assess influence of building size and use on internal heat gains

Building size and purpose has a major influence on heat loads and gains. High rates of ventilation may be needed to satisfy cooling needs or, alternatively, artificial cooling combined with minimum fresh air ventilation may prove to be more cost efficient. A review of existing knowledge in this field is needed. Additionally, long-term trends in building energy use must be undertaken to identify future potential in minimising internal energy loads. This review should evaluate, for example, the impact of lower power needs for office equipment and lighting. Much of this area of activity falls upon the ECB&CS Future Buildings Forum (Appendix 5).

(iii) the role of climate

The significance of ventilation as a source of energy loss depends on climatic severity. Thus, an energy efficient option in one climatic zone may be inappropriate in another. A set of criteria, based on existing knowledge and experience, is needed to guide designers and policy makers in system selection appropriate to climate. The proposed future Annex on methods to evaluate domestic ventilation systems (Appendix 4) will begin this task by reviewing the various needs for dwellings.

(vi) terrain and shielding

The influence of local topography and shielding, on infiltration and ventilation, needs to be quantified and the benefits of sheltered belts should be determined.

(v) standards

All ventilation designs must conform to relevant Codes and Standards. As new knowledge becomes available, these are being continuously reviewed and updated. Appropriate knowledge must therefore be made available to regulatory authorities and the latest developments must be disseminated. A database of Standards is proposed as part of the AIVC's future programme (Appendix 1).

3.6.3 Design Tools

Tools need to be developed to improve ventilation design. Many new tools will be derived from current mathematical developments aimed at analysing fluid flow. Also developments in measurement techniques are needed to aid the design process and to validate numerical models. Needs are identified in Figure 9 and include:

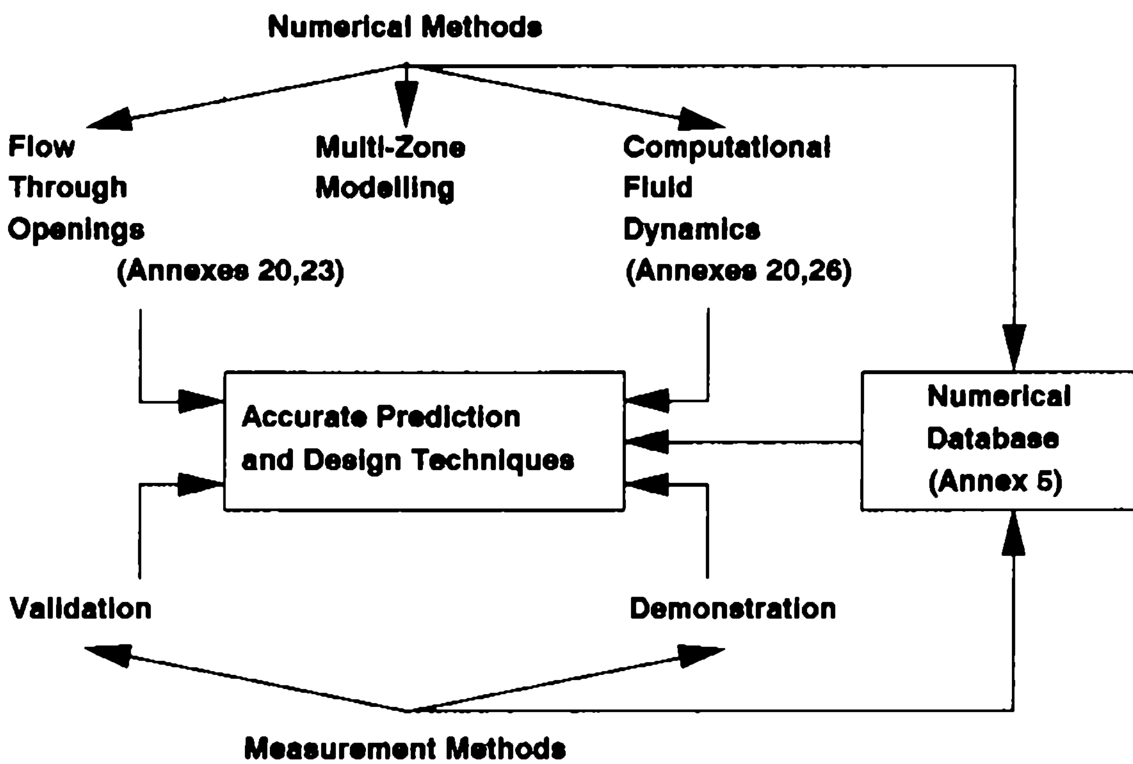


Figure 9:

(i) Numerical Tools

The prediction of ventilation rate and ventilation efficiency continues to be difficult. This primarily arises from uncertainty over boundary conditions and from uncertainties over the methods of physical modelling. Current modelling techniques focus on multizone methods and computational fluid mechanics (CFD).

Multizone methods are used to predict air flow between zones, while computational fluid dynamics is used to predict air flow patterns within individual zones. Techniques for multizone analysis have improved considerably following the work of Annex 20 (Appendix 2). Further tasks, to improve this technique and to improve the representation of flow through openings, are currently being addressed by Annex 23 (Appendix 3).

Computational fluid dynamics has recently become more widely used in building air flow analysis. While gaining increasing acceptance as a design tool, field validation is weak. Uncertainties also exist over the validity of turbulence representation, treatment of boundaries and coarseness of grid systems. Further development, combined with validation, is therefore needed. Many of these aspects are being incorporated within ECB&CS Annex 26 (Appendix 3).

(ii) measurement techniques

Measurement techniques are essential for the development and validation of design tools. They also have importance in displaying the potential of design techniques. These needs include:

- demonstrate new ventilation technology.

Many developments in ventilation technology have recently taken place and much of this work has been supported by case studies and demonstration projects. A review of case studies is needed to provide an evaluation of successes and problems associated with new techniques. Such a review would also provide an indication of climatic influences and occupant reactions in addition to energy saving potential and air quality performance.

- verify flow characteristics of openings.

Simplifying assumptions are necessarily used to represent the characteristics of flow through openings such as doors, building penetrations and cracks. Measurement data are needed to support assumptions concerning flow through openings and to support the development of numerical tools. These needs are being addressed by ECB&CS Annex 23 (Appendix 3).

- validate flow models.

Existing and new data are needed for the validation of air flow and ventilation models. A review of existing data is proposed. In addition new data will be derived from Annexes 23 and 26.

3.7 Dissemination

To ensure the widest possible application of results, a major task is to coordinate, review and disseminate the results of programmes developed from this strategy proposal. Main tasks include preparing a Guide to Ventilation which is included in the AIVC future programme (Appendix 1). The intended target audience should include the designer, policy maker, environmentalist and other 'end users' who can ensure the widespread use of this information. The proposed subject coverage includes sections on:

- the need for ventilation
- air quality implications
- energy implications

- climatic factors
- strategies
- building requirements (airtightness, internal structure)
- standards
- examples
- building type (commercial, dwellings)
- goals - what is achievable.

Further details of the AIVC programme are summarised in Appendix 1.

4 . Conclusions And Summary Of Tasks

The purpose of this strategy has been to identify the research needed to understand, develop and promote the role of ventilation in the control of energy use for optimum indoor air quality. This is essential, since ventilation can have a considerable impact on total building energy use and on indoor climate. As the thermal performance of buildings improve and as building services and design become more energy efficient, ventilation will become the dominant source of building energy use in buildings. Thus, future approaches to ventilation will have an important impact on global energy needs. Design strategies, ventilation needs and the control of indoor pollutants need to be assessed. Furthermore, the energy impact of future ventilation needs must be evaluated, and target values for alternative approaches investigated. To achieve these goals, the following tasks have been proposed:

- evaluate the existing energy impact of ventilation.
- establish indoor air quality needs.
- identify the role of ventilation in controlling indoor air quality.
- evaluate optimum ventilation needs.
- assess the energy impact of optimum ventilation.
- achieve energy and cost effective ventilation.
- disseminate results through a guide to ventilation.

Many proposed tasks are concerned with reviewing and assessing current knowledge. It is expected that these reviews will provide substantial data for inclusion within the AIVC database.

The main activities proposed in this plan are summarised in Tables 1-3. These Tables include interest areas (policy makers, industry, etc), possible research groups and reference to existing or past IEA Annexes. Many research programmes of the International Energy Agency are conducted as task shared activities between institutions in member countries. Related air flow annexes and proposals of the IEA Future Buildings Forum are listed in Table 4 and are summarised in the Appendices.

The target audiences for this analysis are policy makers, designers and other end users who can ensure the widespread use of results. Above all, a fundamental aim of this strategy is to provide a foundation for future ventilation analysis within the International Energy Agency. This should address energy and air quality aspects of ventilation and be integrated within an overall building energy planning strategy.

Table 1 Summary of Energy Impact Research Needs

Topics	User Groups:			Project Needed	Potential Project Group	Previous/ Existing Annex
	Policy Makers	Designers	Building Operators			
Energy impact of ventilation						
Evaluate ventilation energy loss in the existing building stock	*		*	Analysis of building energy use statistics	Task shared /AIVC	
	*		*	Estimate ventilation rates	Task shared /AIVC	
	*		*	Large scale passive measurements	Task shared and other groups	
Evaluate optimum ventilation needs	*	*	*	Assess ventilation needs	Task shared and IAQ groups	Annex 9 Annex 14 Annex 26
Evaluate energy reduction target	*			Review of data and results	Task shared /AIVC	
Alternative energy reduction measures	*	*		Evaluate in-situ heat recovery performance	Task shared	
Identify further research	*			Strategic Planning	AIVC and ExCo	

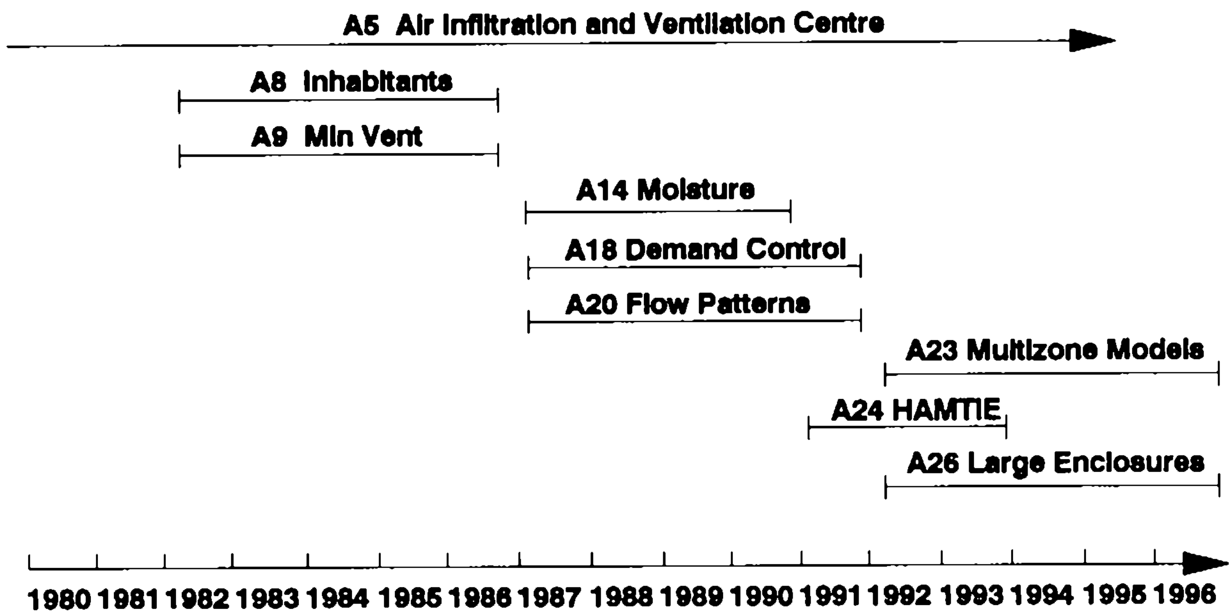
Table 2 Summary Indoor Air Quality Needs

Topics	User Groups:			Project Needed	Potential Project Group	Previous/ Existing Annex
	Policy Makers	Designers	Building Operators			
Indoor Air Quality needs						
Assess IAQ requirements	*			Review IAQ standards and regulations	AIVC	Annex 5 (AIVC)
	*			Classify indoor pollutants and sources	IAQ specialists	Annex 9
	*			Assess pollutant interactions	Chemists	
	*			establish acceptable pollutant levels	Medical experts	Annex 9 Annex 14 Annex 18
Identify the role of ventilation in controlling IAQ	*			Review existing knowledge	AIVC	
	*			Evalaute other IAQ control measures	Task shared	

Table 3 Achieve Energy and Cost Effective Ventilation

Topics	User Groups:			Project Needed	Potential Project Group	Previous/ Existing Annex
	Policy Makers	Designers	Building Operators			
Optimise Design						
Evaluate/develop strategies	*	*	*	Produce a Guide to Ventilation	AIVC	
		*		Develop cost-effective systems	Industry/ research	New Annex (Appendix 4)
		*		Develop controls	Industry/ research	Annex 18
		*	*	Ergonomic design	Industry/ research	Annex 8
	*	*	*	Evaluate systems	Task shared	Annex 18 Annex 26
Design tools		*		Numerical models and measurements	Industry/ research	Annex 20 Annex 23 Annex 26
Climate, heat loads and cooling	*	*	*	Minimise heat loads and cooling needs	Task shared	Future Buildings Forum

Table 4 Summary of Air Flow Annexes



Country Participation

Country	Annex								
	5	8	9	14	18	20	23	24	26
Belgium	*	*		*	*	*	*	*	#
Canada	*		*		*	*	*	*	#
Denmark	*		*		*	*	#	*	#
Finland	*		*		*	*	#	*	#
France	*					*	*	*	#
Germany	*	*	*	*	*	*	#	*	#
Greece							#		#
Italy	*		*	*	*	*	*	*	#
Japan							*		#
Netherlands	*	*	*	*	*	*	*	*	#
New Zealand	*						#		#
Norway	*		*		*	*	#		#
Sweden	*		*		*	*	#		#
Switzerland	*	*	*		*	*	#	*	#
Turkey							#		#
United Kingdom	*	*	*	*		*	#	*	#
United States	*		*			*	*		#
CEC (Europe)			*				#		#

participation to be confirmed

Appendix 1
International Energy Agency Implementing Agreement on Energy Conservation in Buildings and Community Systems (ECB&CS).

Annex 5 Air Infiltration And Ventilation Centre

Programme Plan 1992 - 1995

Over the present operating period, the Air Infiltration and Ventilation Centre has undergone substantial development. At the start of this period it moved to Warwick University Science Park in the West Midlands of the United Kingdom. Since this time, the Centre's independent and international stature has grown considerably, with the AIVC now being represented on many international committees and groups. These include ASHRAE, the European Commission and the organising committees for Indoor Air 93 (Finland) and Ventilation Effectiveness (Japan).

Further internationalisation has been achieved by the introduction of visiting overseas specialists to the AIVC. During the previous operating period, specialists, on three month visits, came from Canada, Germany, the Netherlands, New Zealand and the United States.

On the technical front, the AIVC's numerical database has been developed. The Centre's interaction with related annexes is also well established. Much useful data from these annexes and from other activities have been published in a series of related Technical Notes. Technical Reviews covering air flow simulation, air change efficiency, advanced ventilation systems, measurement techniques and combined ventilation and thermal heat loss modelling, have been published.

On the information front, considerable growth has taken place with increased demand being placed on the Centre's services. The operation of an international information and library service has proved to be very successful. AIRBASE, the AIVC's bibliographic database is now available on floppy disk and may readily be inserted into 'PC' based computers. "Recent Addition", the AIVC's quarterly update on information in AIRBASE has more than doubled in size over the last three years. This reflects the extensive growth in publications and literature concerned with the impact of air change on both energy use and indoor air quality. In addition, the Centre's worldwide Survey of Ventilation and Related Air Quality Research is now stored as a separate chapter within AIRBASE.

"Air Infiltration Review", the AIVC's quarterly journal and newsletter, has also expanded in both content and distribution. "AIR" continues to include short technical articles which are intended to reflect current ideas and progress. Many researchers in all participating countries contribute regularly to this journal. "AIR" is sent to organisations in over 40 countries.

The Centre's conferences and workshops continue to provide a forum for the world's experts to meet and exchange ideas. Selected papers from these meetings have recently been published in "Indoor Air". The results of these conferences and of other AIVC activities are beginning to influence the direction of ventilation developments in many countries.

The Future

Air change and air movement may be expected to become the dominant heat (and cooling) loss mechanism in buildings of the next century. Furthermore, its impact on global energy use will increase substantially. Improving living standards throughout the world will mean that occupants of buildings will demand an ever increasing standard of comfort. The proposed technical goals for the next operating period are to evaluate the energy impact of ventilation, to quantify the precise role that ventilation has in meeting air quality requirements and to set the conditions needed for cost effective ventilation. Thus, full focus will be given to the energy implications of ventilation. This technical programme will be supported by a continued information and dissemination service. Above all, the future programme will be motivated by a clear need to achieve an energy efficient, high quality indoor environment.

Proposed Work Programme

To fulfill these objectives, the following work programme is proposed:

Bibliographic Information

(i) AIRBASE

It is proposed that the Centre's information service should continue in the same format as presently structured. In addition, increased emphasis should be given to the wider availability and use of AIRBASE. On current projection, it is estimated that AIRBASE will more than double in size to between 8000 and 10000 articles by the end of the 1995 operating period.

(ii) Survey of Current Research

This Survey has recently been incorporated into an AIRBASE file which may be interrogated using IDEALIST software. The results of this survey have been widely used and it is updated as new projects are identified. The scope of the survey will continue to be directed at ventilation issues as they influence energy and air quality.

(iii) Ventilation Related Standards Database

A new database is proposed following the AIRBASE format. This will focus on Standards, Codes and Regulations related to ventilation and associated topics. It will therefore form an extension to existing Standards compilation activities of the AIVC but will be much easier to distribute, interrogate and update.

(iv) International Library Service

The above databases will be used in support of the AIVC's existing international library service. This service continues to be very popular and forms the backbone of the AIVC's information service.

(v) Recent Additions to AIRBASE

Recent Additions is published quarterly and contains a complete record of all information added to AIRBASE. It is proposed that this publication should continue and include additions to the new current research and standards databases.

Technical Analysis and Information

It is proposed that the thrust of the AIVC's technical work programme should be directed at a full assessment of the energy implications of ventilation. This should include identifying the role of ventilation as a control of indoor air quality, and identifying minimum energy ventilation strategies. In addition, the performance assessment of numerical models, the development of the AIVC Numerical Database and the Centre's interaction with related air flow annexes should continue. Thus, the following activities are proposed:

(i) Analysis of the Energy Implications of Ventilation

A technical review to determine the energy implications of current air change rates in existing buildings is planned. This should also evaluate the potential reduction in ventilation energy consumption that may be achieved by more efficient ventilation.

(ii) Reviewing the Role of Ventilation in Controlling IAQ

There are currently many uncertainties and much misunderstanding concerning the role of ventilation in relation to the control or maintenance of good indoor air quality. Since the rate of ventilation in buildings has a substantial energy effect, it is essential that the role of ventilation in relation to indoor air quality is properly understood. A review on the role of ventilation for air quality control is therefore proposed. This will assess existing information and measurement data and identify future research needs that could be undertaken as task shared IEA research.

(iii) Producing a Guide to Ventilation

It is proposed that the outcome of tasks (i) and (ii) above should be used in the preparation of a Guide to Ventilation. The target audience should be designers, policy makers, environmentalists and other 'end users who can implement the widespread use of this information. The intention of the guide is to encapsulate the knowledge obtained by the AIVC and by related IEA air flow annexes for the benefit of the target groups.

This publication will include sections on:

- the need for ventilation
- air quality implications
- energy implications
- climatic factors
- strategies
- building requirements (airtightness, internal structure)
- standards
- examples
- building type (commercial, dwellings)
- goals - what is achievable.

(iv) Model Evaluation and Numerical Database Development.

In support of the above programmes, it is proposed that the Centre's ongoing activities in relation to model evaluation and numerical database development should continue. This should take place together with related task shared activities. The AIVC's numerical database will also ensure efficient development and evaluation of future design tools.

Dissemination

Dissemination is a vital role of the Centre which ensures that its knowledge base is utilised. Therefore, its conference and workshop programme, its interaction with other annexes, its publicity programmes and its technical newsletter and publication activities will continue.

Strategic Programming

An important part of the current workplan has been to develop a strategy for identifying future areas of energy related ventilation research. This has resulted in the preparation of a strategy plan which outlines future needs and shows how current IEA and other activities mesh to provide a coherent approach. An objective of the forthcoming period is to continue this strategic analysis and to ensure that ventilation is incorporated within an overall strategy for building energy use.

Appendix 2
International Energy Agency Implementing Agreement on Energy Conservation in Buildings and Community Systems (ECB&CS)

Completed Air Flow Related ECB&CS Annexes

A2.1 Annex 8 - Inhabitants Behaviour with Regard to Ventilation

Start Date: 1982
End Date: 1986

This Annex measured inhabitants' behaviour with regard to ventilation and assessed whether this behaviour could be modified to reduce ventilation energy demand yet maintain optimum indoor air quality. Studies were based on naturally ventilated buildings and were principally concerned with monitoring window and door opening.

The main objectives were to:

- determine the actual behaviour of the inhabitants and to correlate it to the outdoor and indoor climate.
- estimate the amount of energy losses due to this behaviour.
- study the motivation for inhabitants' actions.
- study whether occupants behaviour could be modified and to estimate the amount of energy savings which might result therefrom.

Three experimental methods were used to describe the actual behaviour of the inhabitants; these were:

- survey techniques (interviews, postal questionnaire)
- self observation (diary forms)
- observation techniques (observer, photograph, microswitches)

Measurements included an analysis of window use throughout the year, including variation due to type of room and according to external conditions. The diurnal use of windows was also investigated.

Results

The study found that perceived comfort was the most important factor governing window opening. Other factors included both temporal (season of the year, etc), spatial (room characteristics etc), environmental (perceived indoor air quality etc), human (socio-cultural factors etc) and external (outdoor climate). The analysis of these results has led to a simple nomogram to estimate ventilation rates due to occupancy combined with that due to the infiltration and ventilation rates.

The overall conclusions of the study were:

- ventilation behaviour (its frequency and duration and its underlying motives) is related to the type of room in which it occurs.
- differences between households, in patterns of ventilation behaviour, were expressed by differences in strategy used to control the indoor environment (eg its temperature, air quality, and the presence of external noise) in relation to the outdoors.
- ventilation behaviour is highly weather dependent but this dependency varies by type of room. Also, considerable differences exist between households in their sensitivity to temperature variation.
- ventilation behaviour is influenced by the design characteristics of the dwellings and its heating system. This can be improved by making ventilation easier to control.
- the basic air change of a dwelling, without window opening, may be inferred from the air leakage at 50Pa.
- there is no significant association between window use and dwelling volume.
- analysis of data provided support for the simple categorisation of additional average seasonal ventilation rate due to window use.
- it is important to give information to inhabitants of dwellings so that they can optimize their ventilation behaviour by balancing between low energy use and adequate indoor air quality. Since ventilation facilities must be available for inhabitants to use in an appropriate way, information campaigns need to be directed at builders and developers of dwellings and devices, as well as to government administrators.
- the adoption of energy conserving behaviour demands that the individual must perceive, favourably evaluate, understand and remember information given to him.

Annex Publication: Dubrul, C. Inhabitants behaviour with regard to ventilation. AIVC Technical Note 23 1988.

Participating Countries: Belgium, Germany, Netherlands, Switzerland and the United Kingdom.

A2.2 Annex 9 - Minimum Ventilation Rates and Measures for Controlling Indoor Air Quality.

Start Date: 1982
End Date: 1986

The aim of this project was to optimize the conflicting requirements between energy conservation and the maintenance of a healthy indoor air climate. The optimization of these requirements has resulted in guidelines for minimum ventilation rates which are sufficient to meet fresh air demand but small enough to avoid energy waste. This Annex focused on important work towards establishing the criteria necessary to determine minimum ventilation rates.

The objectives of this Annex were to:

- collect background information needed for setting minimum ventilation standards. This included ventilation needs based on degree of activity, air quality, comfort and moisture. Special problems such as requirements for combustion appliances inside living areas were also included.
- propose criteria for assessing and evaluating ventilation standards.
- prepare a research and development programme to resolve problems inhibiting the establishment of ventilation standards.

Results and conclusions included:

- the identification of the main indoor pollutants in residential and other buildings. Measures to reduce the concentrations of these pollutants were proposed. Proposed measures were dependent upon the chemical nature of the pollutant, its sources, and emission characteristics.
- the most effective method of controlling many indoor air pollutants, including formaldehyde and radon, was control at source. Other measures included dilution and local extraction ventilation, removal from air by filtration or source control by sealing and restriction.
- for energy conservation, it was concluded that if an airborne pollutant could be controlled or avoided economically by means other than ventilation, then such an approach should be taken.

A shortened Annex report describing the results has been compiled into AIVC Technical Note 26. This covers:

- source characteristics - origin and special features of pollutants.
- effects of pollutants.
- health risks, annoyance and irritation, damage to building fabric.

- control measures; limiting concentrations, source control and related measures, and ventilation rates.
- ventilation strategy - conclusions and recommendations for pollutant control and its effect on ventilation.

The report summarises the preferred measures for controlling pollutants and, where appropriate, suggests minimum ventilation rates applicable to a typical household.

Publication:

Haberda, F. and Trepte, L. Minimum ventilation rates and measures for controlling indoor air quality. AIVC Technical Note 26. 1989

Participating Countries: Canada, Denmark, Germany, European Community (Ispra Establishment), Finland, Italy, The Netherlands, Norway, Sweden, Switzerland, United Kingdom, United States of America.

A2.3 Annex 14 - Condensation and Energy

Start Date: 1987
End Date: 1990

The unbalanced introduction of energy conservation measures has generated many condensation problems both in new and existing buildings. These problems are not only a barrier to the successful introduction of energy conservation but they also result in severe social problems and can affect building quality.

The phenomena observed are related to building construction practices and human behaviour changes with regard to energy use (lower inside temperatures, less ventilation). Statistical studies in different countries have shown that problems due to condensation are widespread. Therefore, a well coordinated international effort was necessary, not only to study their origin and implications, but also to find solutions to them.

The objectives of this Annex were to:

- provide architects, building owners, practitioners and researchers with improved knowledge of mould and surface condensation. This included evaluating the critical conditions for mould growth and assessing the influence of material properties.
- introduce improved calculation models, incorporating air, heat and moisture transfer to predict properly the phenomena of mould and surface condensation and to validate possible solutions.
- develop energy conserving and cost effective strategies and complementary design methods, techniques and data for avoiding mould and surface condensation in new buildings or for preventing further degradation in problem buildings.

Publications:

The results have been compiled into a four-volume annex report covering:

Volume 1 - Source Book. This manual is divided into six chapters, covering material properties, mould, thermal modelling, hygric modelling, combined heat, moisture and air transport modelling and boundary conditions.

Volume 2 - Guidelines and Practice. This is divided into four chapters covering: performance description, links with rational use of energy, mould performance checks for new design, and solving existing mould and surface condensation problems.

Volume 3 - Catalogue of Material Properties. This is divided into two chapters covering standards and a database. The database chapter contains information collected on building, insulation and finishing materials and on vapour retarders.

Volume 4 - Case Studies. Six case studies are examined; these are: Zolder (Belgium), Ruhrgebeit (Germany), IACP - Torino (Italy), Pijnacker (Netherlands), Alexanderpolder (Netherlands) and Edinburgh (United Kingdom).

Participating Countries: Belgium, Germany, Italy, The Netherlands and the United Kingdom.

A2.4 Annex 18 - Demand Controlled Ventilation Systems.

Start Date: 1987
End Date : 1991

The objectives of this Annex were to develop means, methods and strategies for demand controlled ventilating systems and to contribute to implementing knowledge accumulated during the work of the Annex. The work was directed at ventilation systems in different types of buildings exemplified by single family houses, apartment buildings, schools, commercial buildings and administration buildings.

Results from IEA Annex 9 (minimum Ventilation Rates) were used to assess basic ventilation requirements.

A main objective of this task was to develop an efficient ventilating system by demand control. This was based on analysis of the ventilation effectiveness and proposed ventilation rates for different users in domestic, office and school buildings.

The work of the Annex was divided into three subtasks; these were:

Subtask A - a review of existing technology.

Subtask B - case studies.

Subtask C - design and operation of demand controlled ventilating systems.

Publications:

(i) Raatschen, W. Demand controlled ventilating systems: state of the art review. Swedish Council for Building Research 1990.

(ii) Raatschen, W. Demand controlled ventilating systems: sensor market survey. Swedish Council for Building Research, 1992.

(iii) Demand Controlled Ventilating Systems: Annex 18 source book. (to be published).

Participating Countries: Belgium, Canada, Denmark, Germany, Finland, Italy, The Netherlands, Norway, Sweden and Switzerland.

A2.5 Annex 20 - Air Flow Patterns within Buildings

Start Date: 1987
End Date: 1991

The objectives of this Annex were to improve and evaluate the performance of flow simulation techniques for single and multi room applications and to establish their viability as design tools.

Accurate prediction of air, contaminant, and energy transport is essential for the optimization (by the designer) of energy consumption, indoor air quality and thermal comfort.

The Annex was organized into two parallel subtasks; these were:

Subtask 1 - Room air and contaminant flow. The basic approach of this subtask was to solve identical problems in different participating countries by different methods and in different facilities. The results were then collected, analysed and compared. This approach enabled each country to assess the performance of employed methods. It also provided a methodology and experimental data sets to evaluate future simulation models.

Subtask 2 - Multi zone air and contaminant flow and related measurement techniques. This task focused on identifying areas where accurate design knowledge was lacking and could be improved by international cooperation. For each topic, a task group was formed and a coordinator nominated.

Task groups included:

new algorithms:

- air flow through large openings.
- inhabitant behaviour, eg simulated use of doors and windows.
- air flow-driven contaminants.
- multi room ventilation efficiency.

measurement methods:

- multi zone airflow measurement methods.

databases and data sets:

- databases for planning and validation.

Summary of Results.

The results of subtask 1 included a detailed description of the benchmark exercises and quantitative comparisons of measurements and simulations. Results also included a critical evaluation to assess the performance of room air flow simulation techniques and their applicability as design tools.

This evaluation concludes that CFD codes can predict room air movement with sufficient realism to be of use to design practice. Three areas of further work have been identified; these are: modelling of supply jets, modelling of turbulence and representation of thermal wall functions.

The results of Subtask 2 suggest that algorithms, measurement techniques, validation data and experimental methods have been developed and tested and are ready for integration into multi zone air flow models.

Publications:

(i) Lemaire, A.D.
Room Air and Contaminant Flow, Evaluation of Computational Methods
Subtask-1 Summary Report, 1992.

(ii) Roulet, C.-A., and Vandaele, L.
Air Flow Patterns in Buildings: Measurement Techniques
Technical Note AIVC 34 (1991).

(iii) Roulet, C.-A., Cretton, P., Fritsch, R. and Scartezzini, J.-L.
Stochastic model of inhabitant behaviour in regard to ventilation. Annex 20
Subtask-2 Technical Report (1992).

Participating Countries: Belgium, Canada, Denmark, Finland, France, Germany, , Italy, The Netherlands, Norway, Sweden, and Switzerland, United Kingdom and United States of America.

Appendix 3 - International Energy Agency Implementing Agreement on Energy Conservation in Buildings and Community Systems (ECB&CS).

Ongoing Annexes

A3.1 Annex 23 - Multizone Airflow Modelling.

Start Date: 1992
End Date: 1996

Several computer models have been developed to calculate infiltration related energy losses and the resulting air flow distribution in buildings. The objective of this Annex is to study physical phenomena causing air flow and pollutant transport (eg moisture) in multizone buildings. It is also intended to develop modules to be integrated in a multizone air flow modelling system. The system itself shall be user friendly and structured to be incorporated in thermal building simulation models. Furthermore, special emphasis shall be given to provide data necessary to use the system. The comparison between results from the model and from in situ tests is an important part of this Annex.

The Annex has been divided into three subtasks:

Subtask 1 - System Development.

This task is aimed at developing an air flow modelling system incorporating new knowledge. It is also proposed to develop user friendly interfaces, and to demonstrate the coupling with a thermal model. Results will include a hardware independent multizone air flow modelling system and user guide.

Subtask 2 - Data Acquisition.

This subtask is designed to obtain data sets for evaluation, obtain default input values and to perform a sensitivity analysis. Results will form databases of default values for evaluation purposes. A sensitivity analysis will be published as a report.

Subtask 3 - System Evaluation.

The aim of this subtask is to evaluate the air flow modelling system. The evaluation exercise will be documented, by a step by step process. Starting with benchmark cases, the goal is to evaluate the modelling system with measured data sets from real buildings.

Publications: Allard F.V., Dorer V.B., Feustel H.E., et al Fundamentals of the multizone air flow model - COMIS.
Technical Note AIVC 29, 1990.

Participating Countries: Belgium, Canada, France, Italy, The Netherlands, Japan and the United States of America.

A3.2 Annex 24 - Heat, Air and Moisture Transport in Insulated Envelope Parts. "HAMTIE"

Start Date: 1991
End Date: 1993

The objectives of this Annex are to model and study the fundamental physical phenomena behind and the consequences of heat, air and moisture transfer through new and retrofitted insulated envelope parts. A special emphasis will be put on the energy quality, depending in air tightness, hygric behaviour and durability aspects of the construction. The knowledge gained by this analysis will be applied to performance formulation and to checking the design and production of new retrofitted parts.

This Annex is seen as a follow up to Annex 14. Condensation and energy.

This Annex has been divided into 5 subtasks; these are:

Subtask 1 - Model and Algorithm Development

This task includes improving modelling techniques and testing simplified models for predicting the combined effects of HAM- transport on insulation quality, hygric behaviour and durability.

Subtask 2 - Inside and External Environmental Conditions.

This task includes selecting environmental parameters and a methodology of handling them and the development of exemplary sets of environmental conditions.

Subtask 3 - Material and Layer Properties.

This task includes data collecting on thermal hygric and air properties of materials and layers and substantial fresh measuring work, especially on the moisture and air properties.

Subtask 4 - Experimental Verification.

Experimental verification includes hot box and field tests on HAM- transport in envelope parts and comparing measurement results with model prediction.

Subtask 5 - Performances and Practice.

This task includes the translation of HAM- knowledge in correct design and execution of highly insulated new and retrofitted envelope parts.

Participating Countries: Belgium, Canada, Finland, Italy, The Netherlands and United Kingdom. Observers: Denmark, France, Germany and Switzerland

A3.3 Annex 26 Energy-Efficient Ventilation in Large Enclosures

Start Date: 1992
End Date: 1996

The objectives of this Annex are to develop methods to minimise ventilation energy consumption for optimum air quality and comfort, provide for the safe removal of contaminants and distribute fresh air efficiently within large enclosures. Building types include offices, factories, shopping centres, atria, passenger terminals and entertainment facilities.

Methods to define and solve problems include bibliographic review, the development of techniques for field measurements, field measurements, laboratory measurements and combined thermal and air flow modelling.

Products will comprise reports describing methods for designing, providing and checking satisfactory ventilation in large enclosures. Other products will include:

- measurement methods for checking the performance of new installations.
- recommendations for energy efficient methods of localised contaminant.
- guidelines for the application of mathematical models to the design process for the simulation of thermal dynamics of building components, surface radiation, temperature distribution, air motion, and their interactions.
- datasets of field measurements for inclusion within the AIVC database.

Participating Countries: to be confirmed.

Appendix 4 - International Energy Agency Implementing Agreement on Energy Conservation in Buildings and Community Systems (ECB&CS).

Proposed New Air Flow Annexes

A4.1 Methods for Evaluating Domestic Ventilation Systems

The objectives of this Annex are to:

- develop methods for evaluating domestic ventilation systems.
- validate the method with data obtained by measurement.
- demonstrate the use of methods.

Three subtasks are proposed; these are:

Subtask 1 - State of the Art Assessment

This will focus on giving an overview of system solutions. It will include an evaluation of the most frequently used domestic ventilation systems and review existing evaluation methods. A report presenting an overview of systems, trends and the development of new systems will be prepared.

Subtask 2 - Development and Validation of Evaluation Methods

The objective of this task is to define parameters for the evaluation of ventilation systems and to select methods for use within the Annex. Where appropriate, new methods will be developed and validated. A report on methods and results will be written.

Subtask 3 - Demonstration and Application of Evaluation Methods

Evaluation methods will be applied to evaluating the performance of ventilation systems. These results will be published as an Annex report.

Operating Period:

Preparation Time: 12 Months

Working Time: 36 Months

APPENDIX 5

IEA - Energy Conservation in Buildings and Community Systems

Future Buildings Forum

Work Plan for Future Buildings Forum (FBF)

"An IEA Think-Tank Exploring Buildings of the 21st Century"

Abstract

The Future Buildings Forum was established to contribute to a sustainable society by the year 2025 and beyond. Inherent in this objective is the responsibility of each generation to ensure that the next one inherits an adequate natural and economic endowment. Unfortunately, the present approach depends too heavily on non-sustainable resources. Developed nations have fossil fuel-driven economies, which will lead to the depletion of energy reserves and environmental degradation.

The International Energy Agency Programme on Energy Conservation in Buildings and Community Systems will help mitigate this dilemma by establishing a programme that will integrate buildings of the future into a sustainable world society. The International Energy Agency's (IEA) Future Buildings Forum will address energy, environmental, economic and technological issues affecting building research needs, and will consider the possible impact of social and demographic, natural resource, urban planning, and transportation trends.

Purpose

The purpose of the Future Buildings Forum is to identify and encourage research, based on long-term issues, to ensure that buildings will contribute to a sustainable society by the year 2025 and beyond.

Scope

The scope of the Forum includes energy, environmental, economic, and technological research affecting buildings, and considers the effect of social and demographic, natural resource, urban planning, and transportation trends.

Goal

The Forum will identify and promote future research of participating countries while broadening the scope of IEA Programmes.

Objectives

The objectives of the Forum are:

- to identify and study energy, environmental, economic, and technological issues that will affect the building industry by the year 2025, and beyond.

- to define research priorities to resolve these issues in and outside the building industry; and to monitor and disseminate technological advances affecting the state-of-the future in building technology.

- to influence the efficient conception, design, construction, renovation, and operation of buildings.

Approach

The Future Buildings Forum will be conducted by the Buildings and Community Systems Executive Committee, in close cooperation with other related IEA implementing agreements and the Commission of the European Communities (DG-12).

The Forum is open to any individual or group that wishes to participate but participation at some workshops and experts' meetings may be restricted by invitation.

Executive Committee members of the Buildings and Community Systems implementing agreements are expected to be country representatives and will be responsible for contacts within their countries.

An Organizing Committee is responsible for Forum policy and management. It will be chaired by a member of the Buildings and Community Systems Executive Committee and will be supported by a secretariat. The members of the Organizing Committee are the Group Leaders of planned and ongoing FBF actions.

Through its Sub-Groups, the Forum will:

- evaluate the issues, selected by the Forum, to determine their potential effects on important topics such as energy supply, environmental quality, and the status of the built environment.

- employ methodologies for analyzing technological advances and determining how those advances might be used by the building industry to meet the challenges of the coming century.

- consolidate the information collected and analyzed to allow Forum participants, their IEA counterparts, and researchers in participating countries to examine different impact scenarios based on the issues studied.

- synthesize the output of the initiative as input to IEA Programme long-term research and development plans.

The Forum will meet at the discretion of the Chairman, but at least every three years. These meetings will:

- establish an international, multi-disciplinary network of "futurist" experts.

- identify and collectively agree on the relevant long-term issues to be studied.

The Organizing Committee will meet at least twice a year.

Sub-Groups will be suggested by Forum participants to work on specific issues and will be confirmed by the Organizing Committee.

Each Sub-Group will normally organize a workshop with the aim of characterizing the international trends that affect the issue, exploring needed research, and determining whether current research and development projects address the needs sufficiently. If not, they will develop appropriate research programmes and propose them to the most relevant IEA implementing Agreement for adoption and execution.

Sub-Group leaders are responsible for the organization of the workshops and reporting its results. They are members of the Forum Organizing Committee.

Organisation:

Funding:

Forum expenses will be shared by all participants. Participants bear their own costs resulting from information gathering, expert analysis work, attendance at, and organization of workshops and Forum meetings.

Technical and database support will be by the Air Infiltration and Ventilation Centre. The United States will provide the Forum Secretariat.

Results:

The Forum will conduct a series of workshops or seminars on specific topics. As analyses are completed, results will be published in publications such as Executive Committee newsletters, workshop proceedings, and futurist journals.

The Forum will maintain an information base, providing member countries substantive information, such as on the trends that will affect buildings globally and regionally and on new technologies that are developed for buildings, or should be, and technologies from other industries that could be adapted to buildings.

Detailed analysis of long-term trends and future technologies will be presented and used for the definition of future research agendas. The evolution of a conceptual framework will give participants a tool to help them plan research and make energy efficient policies.

Initial Work Plan - Sub-Groups

This initial work plan is the product of a Future Buildings Forum Workshop held October 3-5, 1990 in Den Haag, the Netherlands. The purpose of the workshop was to review several pertinent issues and decide which should be pursued by the Forum. Six tasks were proposed at the Den Haag Workshop. Sub Group leaders for each issue were selected at the summer 1991 Meeting of the FBF Organizing Committee. Leaders will be responsible for working with Executive Committee members to identify workshop participants and setting the work scope for the Sub-Group. The first workshops are expected to be held in 1992. The end result will be recommendations to the various Executive Committees on future annexes and tasks.

Proposed workshops are:

A. Innovative Cooling Techniques

Issue: The diminution of mechanical cooling in buildings of the 21st century by developing new cooling strategies will reduce energy consumption and CO2 production and minimize the need for halogenated refrigerants.

Aims: - to understand the likely changes in cooling needs for future buildings arising from both climate change and the developments in technologies that impose internal heat gains on the building, e.g., computers and lighting. The scope will be restricted to buildings cooled primarily for the purpose of human comfort.

- to develop strategies and technologies that can meet the perceived needs for cooling, preferably by load management, load removal and passive/hybrid means.

B. Low Energy Buildings

Issue: Low energy buildings, which will only depend on renewable energies, will require the optimization of advanced structural and installation components and their interaction in the building as a whole. This applies equally to new and existing residential and non-residential buildings.

Aims: - to identify and stimulate future developments in advanced components and technical systems such as full industrialized techniques and integrated technical systems.

- to create interactive design aids, supported by a database of appropriate solutions.

- to develop demonstration projects for future building technologies and concepts.

- to disseminate the results through education, demonstration, guidance, etc.

C. Building Futures Analytical Framework

Issue: There is a great deal of knowledge about the trends and likelihood of events that will influence the future of the built environment. Notwithstanding the fact that discontinuities in trends and unexpected events will upset any forecast, the potential impacts of changes in the building sector, in energy supplies, restrictions on energy and material use, environmental protection needs, climate change, demographics, material science is undeniable. Understanding the interrelations of these and their influence on the building industry is more important than understanding many of the details.

Aim: - to explore the relevance of alternative approaches to interpreting the future, an approach has to be taken, which takes into account the impacts of rapid technological, social and economic changes in a threatened environment. The impact of these alternatives on building design, materials, components, operations and usage has to be included. If there are methods that could be made pertinent, then the object would be to define an IEA Annex that will improve information available to designers of new and renovated buildings and that will facilitate construction that is sustainable with minimal adverse environmental impact. It will also provide an analytical tool that will help interpretation of the inter-relationships of future possibilities. This could be valuable for policy makers, regulatory authorities, as well as industry researchers and planners, for identifying long term research priorities.

D. Interfacing Advanced Mechanical Systems (AMS)

Issue: Building mechanical systems should be flexibly designed for energy retrofitting and adoption of new technologies. Without interfacing guidelines, opportunities to save energy through energy retrofitting are minimal.

Aim: - to enhance the adoption of advanced technologies, such as micro-cogeneration, catalytic heating equipment, high efficiency heat recovery, and building integrated thermal storage, through initiatives to develop interface specifications, design concepts and guidelines.

E. Building Envelopes as Energy Management Systems

Issue: The building envelope already serves many different functions. In the future, this number will increase and also include integration of heating and cooling systems as well as changeable properties, energy related or not. The building envelope must be treated as a total system rather than separate components. For buildings to be most efficient, envelope designs and systems must minimise non-renewable energy used for heating, cooling, and lighting through optimal system integration.

Aims: - to identify existing building envelope functions, assess immediate improvement possibilities, define additional future functions, and study their system integration and to determine their impact on buildings.

- to study the impact of advanced envelope technologies on the energy consumption of a building and to determine the need for further research and development.

F. Efficient Use of Electricity

Issue: The use of electricity has a major impact on both fossil fuel use and environmental degradation. The challenge for the Future Buildings Forum is to identify ways to improve appliances, components and systems to use less electricity. This is an especially important issue as it affects existing buildings and community energy use.

Aim: -to coalesce understanding of base demand and peak loading issues. Peak load issues include load management, hydrogen generation and fuel switching for peak avoidance; base demand reduction issues include conservation measures and more efficient appliances and systems, photovoltaics and cogeneration. Fuel cells and superconductivity are important "breakthrough areas" to be considered in all issues.

THE AIR INFILTRATION AND VENTILATION CENTRE was inaugurated through the International Energy Agency and is funded by the following thirteen countries:

Belgium, Canada, Denmark, Germany, Finland, France, Italy, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom and United States of America.

The Air Infiltration and Ventilation Centre provides technical support to those engaged in the study and prediction of air leakage and the consequential losses of energy in buildings. The aim is to promote the understanding of the complex air infiltration processes and to advance the effective application of energy saving measures in both the design of new buildings and the improvement of existing building stock.

Air Infiltration and Ventilation Centre

University of Warwick Science Park,
Sovereign Court,
Sir William Lyons Road,
Coventry CV4 7EZ,
Great Britain.

Telephone: +44 (0) 203 692050
Fax: +44 (0) 203 416306

Operating Agent for International Energy Agency, The Oscar Faber Partnership, Upper Marlborough Road, St. Albans, UK