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A STRATEGY FOR INTERNATIONAL ENERGY AGENCY VENTILATION AND INDOOR AIR QUALITY RESEARCH

Martin W. Liddament
Air Infiltration and Ventilation Centre
University of Warwick Science Park
COVENTRY
United Kingdom

ABSTRACT

Ventilation provides a key defence for the protection of the indoor environment from the adverse effects of poor air quality. However, it can also contribute substantially to building energy use. Furthermore, the need to install large ventilation capacity is expensive both in terms of capital cost, maintenance needs and floor space. Hence there is considerable interest in the development of efficient ventilation systems and in minimising the emission of pollutants within buildings. The International Energy Agency's Air Infiltration and Ventilation Centre has a responsibility for providing a focal point for assessing the energy and air quality implications of Ventilation. This paper is aimed at introducing the AIVC's strategy on ventilation research and at outlining the work and results of related IEA Annexes. Conclusions stress the need for providing practitioners and policy makers with precise guidance on the energy implications and the role of ventilation in controlling indoor air quality.

1 INTRODUCTION

Ventilation is essential for the provision of fresh air to occupants and for the dilution and removal of pollutants. Generally, incoming air needs to be conditioned by either space heating or cooling, which results in the use of energy. As the design of energy efficient buildings continues to improve, ventilation is steadily becoming the dominant source of building energy use. Minimising ventilation to reduce energy consumption is therefore often seen as an attractive option. However, 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. Reducing the rate of ventilation has thus become inextricably linked to problems associated with unhealthy buildings. Arguably, indoor pollution should be controlled by the restriction or elimination of the polluting source itself but, all too often, it falls upon ventilation to mitigate this problem. This can result in unnecessary energy use and in the need to provide extra ventilation capacity. It is important, therefore, to determine exactly how much ventilation is really needed and to assess the overall energy impact of ventilation. The evaluation of these two parameters represents the cornerstone of International Energy Agency research into air flow in buildings. The purpose of this paper is to review the research which is needed and to outline the methods by which it is being accomplished within the IEA.

2 STRUCTURE OF IEA RESEARCH INTO VENTILATION

Much of the International Energy Agency's research into ventilation in buildings takes place under the auspices of an Executive Committee on Energy Conservation in Buildings and Community Systems. Additional activity takes place within an Executive Committee on Solar Heating and Cooling. Tasks or work programmes are grouped into Annexes which operate for fixed periods of, typically, three to four years. These Annexes are normally "task shared" in which research institutions in participating countries contract to commit resources to agreed programmes of work. Within the Executive Committee, there is also a jointly funded Annex called the Air Infiltration and Ventilation Centre. This is controlled by a Steering Group comprising representatives from fourteen participating countries. The fundamental task of this Centre is to provide a focus for understanding the role and energy implications of ventilation in buildings.

The Executive Committee, is represented by a total of 17 Countries and the European Community (CEC). Not all these countries participate in all of the Annexes, although Annex results are usually distributed to all ExCo members through Annex Reports. A brief structure plan is illustrated in Figure 1. This annex approach has consistently proved to be a successful method of establishing joint cooperation between countries and has contributed significantly to an understanding of the building energy and air quality process. An overview of the work of air flow related annexes is presented in this paper.

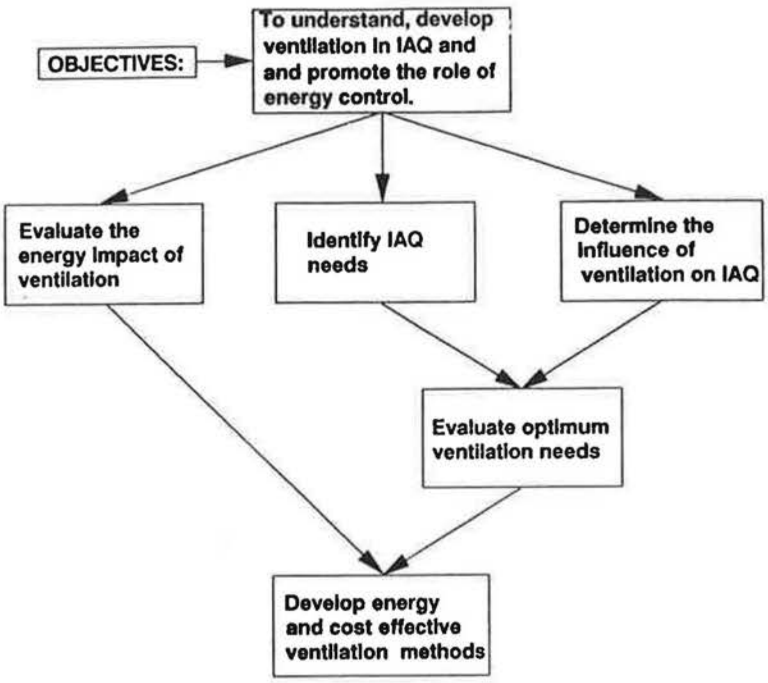
Figure 1 IEA Annex Structure

3 The Air Infiltration and Ventilation Centre - Future Research Needs

The AIVC was founded in 1979 to encourage the technical interchange of knowledge relating to infiltration and ventilation. Initially, the Centre was supported by eight countries and now has a membership of 14 countries. In fulfilling its role, it operates a full international library service, publishes technical reviews and organises regular workshops and conferences. As part of its remit, the AIVC has developed a strategy for future research (1). 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.

The principal aim 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 (Figure 2) have been identified:

Figure 2 A Strategy for IEA Ventilation Analysis



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 including:

- the analysis of existing building energy use statistics.
- the estimation of building air change data.
- an assessment of population needs.
- the large scale use of passive tracer measurements.

The first two methods are essentially based on existing information and may be used to provide a very approximate ventilation energy estimate. The third approach is based on actual needs rather than the current situation, and may be used to evaluate a reduction target for future energy use. However, much more precise knowledge about buildings and the influence of occupants is needed for a reliable energy study. Ideally, this needs to be based on ventilation measurement techniques suitable for large scale implementation in occupied buildings. An appropriate technique is the passive tracer gas method, developed by Dietz (2), which enables 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. Such testing has been used on a large scale in the United States (3) and, currently, in Sweden (4). It is proposed that a review of existing passive tracer measurement programmes and results is made. An international programme should then be developed which would involve organising passive measurements in a statistically significant number of buildings in each country. This should be combined with supporting detailed measurements in a small subset of buildings to verify the performance of the large scale testing.

3.2 Assess indoor air quality needs.

Ventilation is used to maintain good indoor air quality by diluting and removing pollutants emitted within the ventilated space. It is important 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 requirements. Research requirements include:

- reviewing existing indoor air quality codes, standards, requirements and knowledge.
- classifying indoor pollutants, sources and sinks.
- assessing the interaction of pollutants.
- establishing acceptable pollutant concentrations.

3.3 Identify the influence of ventilation in controlling IAQ and comfort.

This concentrates on the need to identify the role (and the cost) of ventilation in controlling indoor air quality and comfort. The limit to which ventilation provides a suitable method of control should be determined and the cost compared with that of other control measures. Identified tasks include:

- reviewing existing knowledge.
- identifying the influence of flow rates, flow patterns and ventilation efficiency on the control of pollutants.
- undertaking field measurements to assess the role of ventilation.
- specifying minimum ventilation rates and identifying alternative control mechanisms.

3.4 Evaluate optimum ventilation needs.

Once the role of ventilation has been identified, optimum ventilation rates must be established. It is essential 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. Future work should also address problems of external and apparently unidentifiable air quality problems. The following needs should therefore be considered:

- metabolic pollution (CO_2 and odour).
- pollutants produced by the activities of occupants (eg moisture).
- pollutants produced by emissions from building fixtures and furnishings.
- cooling needs. (High ventilation may be neede for cooling puposes.)
- external pollution.)It is unlikeley that these may be
- ventilation system problems.) controlled by ventilation.

The need to ventilate to limit metabolically produced carbon dioxide and odour to acceptable levels represents a minimum ventilation requirement. A building or zone in which high concentrations of metabolically pollutants are present, indicates inadequate ventilation. Zones in which metabolic pollutants are minimal, yet pollutants from other sources are high, indicate air quality problems which may more efficiently be controlled by elimination of the pollutant source.

3.5 Assess the energy impact of optimum ventilation.

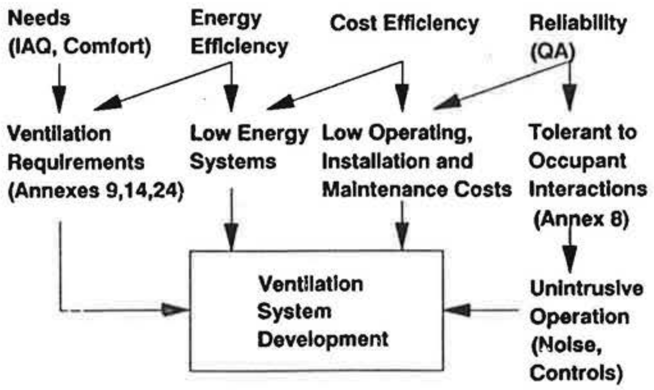
Results from the preceding tasks will enable the energy requirement of optimum ventilation to be evaluated. This is essential because it will identify the potential for ventilation energy reduction.

3.6 Identify the conditions needed to achieve energy efficient and cost effective ventilation.

This aspect covers many of the activities of future annexes. The necessary technology to implement efficient ventilation systems needs to be researched and evaluated. Tasks to achieve this goal include:

- system specification. Parameters are summarised in Figure 3 and include ventilation requirements, cost and energy effective design, minimum maintenance and acceptability to occupants.

Figure 3 Energy and Cost Effective Ventilation - System Design Needs



- design considerations. These are summarised in Figure 4 and include building airtightness, assessment of internal and external heat gains, local climate, shielding and terrain, and compliance to regulations.

- the development and application of design tools. Many design tools are being developed from mathematical models and validated using advanced measurement techniques. Future needs are summarised in Figure 5.

3.7 Disseminate results.

To ensure the widest possible application of results, a major task is to coordinate, review and disseminate the results of programmes developed from on-going research. The intention of the AIVC is to produce a Guide to Ventilation which will be aimed at the designer, policy maker, environmentalist and other 'end users' who can ensure the widespread use of this information.

Figure 4 Energy and Cost Effective Ventilation - Selection of Strategy

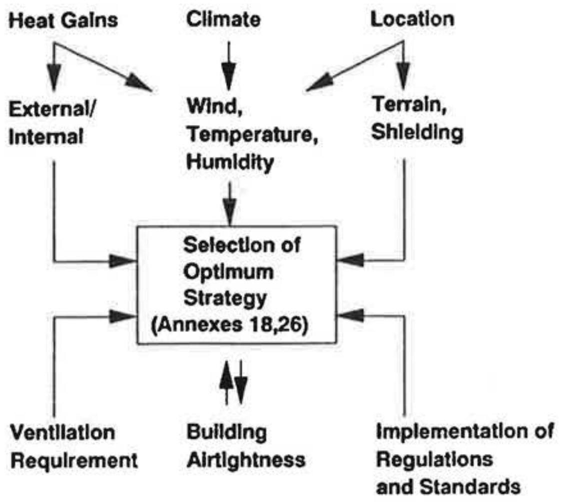
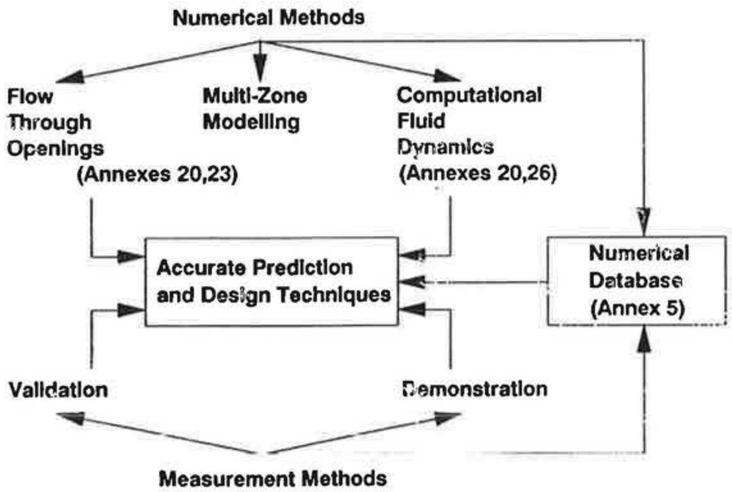


Figure 5 Energy and Cost Effective Ventilation - Design Tools



4 IEA AIR FLOW AND AIR QUALITY ANNEXES

In support of these research needs, several task shared annexes are in progress. In addition, completed annexes have provided a foundation of results on which present activities are being developed. A history and participant list of previous and current annexes is summarised in Figure 6. The principal annexes concerned with air flow and air quality are:

4.1 Annex 8 - Inhabitants Behaviour with Regard to Ventilation (1982-1986).

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 Dubrul (5). 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 can be modified and to estimate the amount of energy savings which might result therefrom.

This 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.

4.2 Annex 9 - Minimum Ventilation Rates and Measures for Controlling Indoor Air Quality (1982 - 1986).

The aim of this Annex was to optimize requirements between energy conservation and the maintenance of a healthy indoor air climate (6). 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. The objectives 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 problem inhibiting the establishment of ventilation standards.

Results included the identification of the indoor pollutants. It was also concluded that pollution should be controlled at source. Other recommended control measures included dilution and local extraction ventilation, removal from air by filtration or source control by sealing and restriction.

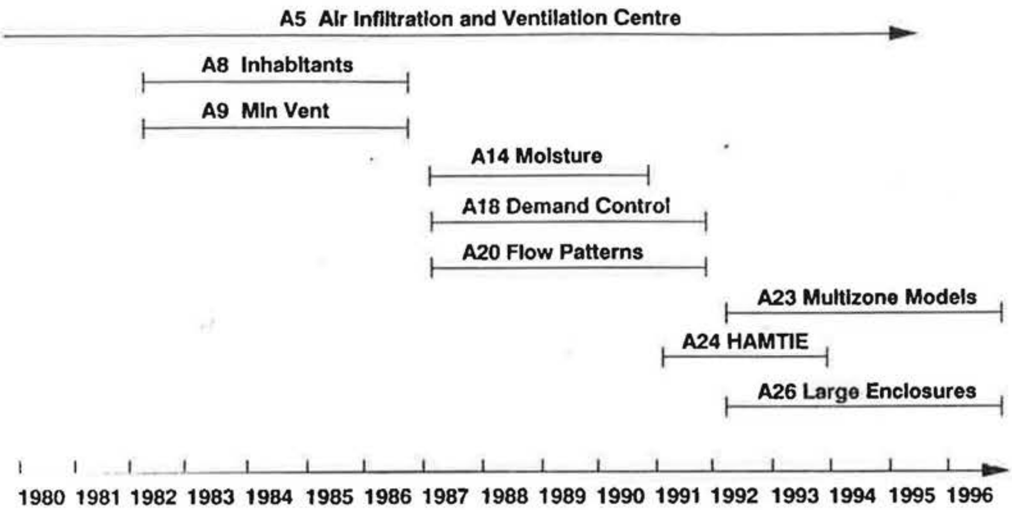
4.3 Annex 14 - Condensation and Energy (1987 - 1990).

This Annex was derived from the theory that poorly introduced 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 purpose of this Annex was to study the origin and implications of condensation and to find solutions to moisture problems. The objectives were to:

- provide architects, building owners, practitioners and researchers with improved knowledge of mould and surface condensation.
- introduce improved calculation models, incorporating air, heat and moisture transfer to predict 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.

The results have been compiled into a four-volume annex report (7). This includes a source book, guidelines, a catalogue of material properties and a compilation of case studies.

Figure 6 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

4.4 Annex 18 - Demand Controlled Ventilation Systems (1987 - 1991).

The objectives of this Annex were to develop means, methods and strategies for demand controlled ventilating systems suitable for dwellings, schools, commercial premises and other types of buildings. A main objective was to develop an efficient demand controlled system. Subtasks included:

- a review of existing technology.
- an analysis of case studies.
- the design and operation of demand controlled ventilating systems.

This study culminated in the production of comprehensive reviews of case studies, sensors and control strategies (8,9,10).

4.5 Annex 20 - Air Flow Patterns within Buildings (1987 - 1991).

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

- room air and contaminant flow (11).
- multi-zone air and contaminant flow and related measurement techniques (12,13).

The results of the first subtask included a detailed description of 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 concluded that CFD codes can predict room air movement with sufficient realism to be of use to design practice. Three areas of further work were identified; these were modelling of supply jets, modelling of turbulence and the representation of thermal wall functions.

Results from the second subtask concluded that algorithms, measurement techniques, validation data and experimental methods have been sufficiently developed and tested and are ready for integration into multi-zone air flow models.

4.5 Annex 23 - Multi-zone Air Flow Modelling (1992 - 1996).

This Annex has developed from subtask 2 of Annex 20. The objective is to study the physical phenomena causing air flow and pollutant transport (eg moisture) in multi-zone buildings. It is also intended to develop modules to be integrated in a multi-zone air flow modelling system and which may also be incorporated into thermal building simulation models (14). Particular emphasis is being given to providing the data necessary to use these modules. Comparisons between model results in situ tests will also be undertaken. Subtasks include:

- system development.
- data acquisition.
- system evaluation.

4.7 Annex 24 - Heat, Air and Moisture in Insulated Envelope Parts "HAMTIE" (1991 - 1993).

This Annex follows from Annex 14. The principal objectives 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. The knowledge gained will be applied to performance formulation and to checking the design and production of new and retrofitted parts. This Annex has been divided into 5 subtasks; these are:

- **model and algorithm development**
- **inside and external environmental conditions.**
- **material and layer properties.**
- **experimental verification.**
- **performances and practice.**

4.8 Annex 26 Energy-Efficient Ventilation in Large Enclosures (1992 - 1996).

This Annex has been developed from the results of subtask 1 of Annex 20. Intended objectives include:

- the development of methods to minimise ventilation energy consumption for optimum air quality and comfort.
- provide for the safe removal of contaminants.
- devise methods to 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.

4.9 Methods for Evaluating Domestic Ventilation Systems
(proposed Annex, title is provisional).

The objectives of this Annex are to:

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

Three subtasks are proposed; these are:

- State of the Art Assessment
- Development and Validation of Evaluation Methods
- Demonstration and Application of Evaluation Methods

The final programme for this Annex is still to be approved and an Annex number and start date has not yet been established.

4.10 Future Buildings Forum - An IEA Think-Tank Exploring Buildings of the 21st Century.

The Future Buildings Forum is not an Annex but was established by the ExCo to determine the research needed to contribute to a sustainable society by the year 2025 and beyond (15). Inherent in this objective is the responsibility of each generation to ensure that the next one inherits an adequate natural and economic endowment. 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, transportation trends. 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. 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. Its goal is to identify and promote future research of participating countries while broadening the scope of IEA Programmes. 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.

5 CONCLUSIONS

Future research must focus on identifying the energy and indoor air quality impact of ventilation. It is especially important for the designer, building occupier and the policy maker to understand the cost and energy impact of using ventilation as an indoor air quality control mechanism. This will provide an improved perspective on alternative IAQ control measures.

Clearly it is not possible for all research needs to be accomplished by a single organisation. It is only through the task sharing role of associated annexes that results are possible. This annex approach has proved to be a very successful way of establishing joint cooperation between research groups in many countries and has contributed considerably to an understanding of the building energy and air quality process.

It is important that results are presented to practitioners and policy makers in a usable form. A major objective of the AIVC is to publish a Guide to Ventilation in which the results of current developments are presented.

New research proposals are being continually developed through the IEA Future Buildings Forum, the AIVC and current annex participants. This will ensure that a coordinated approach to building environmental and energy research needs will continue to evolve.

The AIVC has an important role in ensuring that the results of air flow related research, both within the IEA and elsewhere are disseminated to organisation in participating countries.

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