EBC

Energy in Buildings and
Communities Programme

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EXCO Energy in Buildings and Communities

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Annex text

Indoor Air Quality Design and Control in Low Energy Residential Buildings

The project will gather the existing scientific knowledge and data on pollution sources in buildings, models on indoor hygrothermal and air quality as well as thermal systems, and will look to ways to optimize the provision of ventilation and air-conditioning. Gaps of knowledge will be identified and filled, not least by establishing links between knowledge that exists in the field of indoor air chemistry, modelling, and HVAC technology and controls.
The overall objective is to provide a generic guideline for the design and operational strategy of residential buildings which have minimal energy consumption, and at the same time maintain a very high standard regarding Indoor Air Quality based on the control of sources, sinks and flows of heat, air, moisture, and pollutants under in-use conditions.

1. Background

Highly energy efficient residential buildings need to be rather airtight, and they will include systems to ensure that the need for ventilation is met in an optimal way. Achieving such energy optimized performance can encompass a risk of high levels of pollutants indoors: Humidity, particles and various chemical compounds, where the first and the latter can both be absorbed by and emitted from materials in the building fabric and furnishings. Users influence the operation of the buildings and the generation of some of these pollutants. Building services systems, particularly the ventilation system, control and moderate indoor air pollutants, but require energy to do so. The physical condition of the pollutants, e.g. their properties affecting transport and retention in materials are often strongly influenced by the temperature, moisture and airflow conditions.

With a tighter building envelope, some atmospheric influences in indoor climates may come closer to the limits for acceptability. Indoor Air Quality may be influenced by the chemical and hygrothermal states and properties of materials, which influence the need for ventilation. Also the distribution of fine particles will be altered with new surface temperatures and airflow patterns.

IEA ECBCS Annex 41 has provided a toolset to predict the hygrothermal condition of whole buildings using HAM (Heat, Air and Moisture) analysis approaches. Some laboratory data exist regarding absorption and emission of chemical compounds from materials, but there has been insufficient consideration of the combined effects of chemical atmosphere, temperature, humidity, and ventilation requirement. The problem has relevance both where new and recycled building products are used. The whole building HAM tools, together with further data should be combined such that optimal HVAC control strategies can be investigated with the purpose to conserve energy, while not compromising the quality of the indoor environment for human occupancy.

IEA EBC Annex 18 (1987-1992) on Demand Controlled Ventilation Systems dealt with the various pollutant parameters that determine the reasons to adjust the need for ventilation optimally. However, new conditions exist in buildings today where the demand for energy efficiency has developed further, the general level of airtightness is higher than hitherto, new pollution sources exist in buildings, and also new technologies are available to monitor the indoor environment and control the ventilation rates, and to clean the air.

Overall, the research task of this project is to develop and use data, tools and technologies, which are in many cases already existing, and which in combination give an integrated picture of the airflow, hygrothermal and air quality conditions in whole buildings. The purpose is to optimize building use and operation in a way that combines energy efficiency with healthy and comfortable indoor environments.

The rationale of carrying out the proposed Annex is that buildings in the future will have to be optimized just to the limit in order to become as close as possible to being zero energy buildings. This means that the ventilation will also be reduced to just the absolutely necessary, while the quality of the indoor air must not be sacrificed. There is a need to adopt and demonstrate an integral view in the optimization that consider the sources, sink and transport of relevant pollutants that occur in buildings, including the emission of volatile organic compounds from building products, against the effect of ventilation to dilute the pollutions.

2. Objectives

Outline of purpose and reasons for the work

The overall objective is to provide a guideline for the design and control strategy of energy efficient residential buildings, which have a very high standard regarding indoor environmental quality while considering the emission and possible absorption of pollutants from building products and other sources under in-use conditions.

Key objectives

The Annex has the following specific key objectives:

- To develop a guideline regarding design and control strategies for energy efficient buildings that will not compromise the quality of the indoor environment. Operational parameters that will be dealt with will comprise, but not be limited to the means for ventilation and its control, thermal and moisture control and air purification strategies - and their optimal combination.
- To set up the metrics for required performances which combine the aspiration for very high energy performance with good indoor environmental quality.
- To identify or further develop the tools that will be needed to assist designers and managers of buildings in achieving the first key objective.
- To benefit from recent advances in sensor technology and controls, e.g. model based control principles, to identify methods to enhance indoor air quality while ensuring minimal energy consumption for operation.
- To gather existing or provide new data about indoor pollutants and properties pertaining to heat, air and moisture transfer that will be needed for the above analysis.
- To identify and investigate relevant case studies where the above mentioned performances can be examined and optimized.
- To disseminate about each of the above findings.

Scope and demarcation

The Annex will focus on design options and operational strategies, which can be used to enhance energy performance of buildings, for instance demand controlled ventilation and improvement of the building envelope by tightening and selecting better building products. These methods will be studied with a view to possible effects on Indoor Air Quality and analysed in order to find optimal solutions for good energy performance and high IAQ.

A central hypothesis of the Annex is that high IAQ buildings can only be achieved by carrying out a multi-facetted optimization. Therefore, the Annex will deal with and combine elements of knowledge which are themes of work from separate working groups, e.g. the AIVC on ventilation, university and industry groups working on chemical emissions from building products, building physicists and practitioners regarding hygrothermal conditions in buildings and their materials, and building simulation communities (e.g. IBPSA) on modelling of buildings. It will *not* be a target for the project to develop new revelations in the mentioned research areas *per se*, but only to gather and process such experiences that will serve the main purpose of the Annex.

While bringing these diversified competences into action, it will be emphasized that the scope of the project is residential buildings - both new and existing.

3. Means

The Participants shall share the coordinated work necessary to carry out this Annex. The objectives shall be achieved by the Participants' work within the theme outlined in Section 2's clause on Scope and demarcation (in the following referred to as *The theme*):

(a) Collecting in their countries, analyzing and disseminating in their countries information and data on research, innovation and demonstration within *The theme*.
(b) Facilitating the widespread dissemination and adoption of technologies within *The theme*.
(c) Monitoring developments in their national market that may have an impact on the potential for the commercialization of solutions within *The theme*.
(d) Exchanges of scientists, engineers and other specialists;
(e) Organizing meetings of experts, as appropriate, to exchange information and experience in the areas of work covered by *The theme* of this Annex.

Research within *The theme* is accomplished by work according to the below Research Strategy and division of work in the outlined Subtask.

Research Strategy;

This Annex shall provide data and tools that can be used to guide the operation of buildings in ways that are both energy efficient and ensure very good indoor environmental conditions for human occupancy.

Subtasks and division of work.

Subtask 1 Defining the metrics

A major obstacle to integrating energy and IAQ strategies in building design and optimization is the lack of a single index (marker) which would quantitatively describe the IAQ and allow comparison with the indices describing energy use. Such an index would also allow quantifying the benefits of different methods for achieving high IAQ and compared in parallel with consequences for energy and greenhouse gas emission.

A complication to develop a single marker is that hundreds of chemical or biological compounds can be found in indoor air, even in residential environments, and there is no clear consensus on which should be used to form such a marker. Our approach is to identify the pollutants that are known today that will affect IAQ and use them to construct the marker, which can be updated progressively the more data on new pollutants are available.

Our list of target pollutants needs to be set up in the first step. It will be done by first identifying pollutants that are listed by cognizant authorities as harmful, and then identifying whether they are present in residential environments and at concentrations, which can exceed the recommendations of the authorities. The latter will be used to define an indoor air quality index. The scientific literature will be reviewed and the pollutants suspected to have negative effect on IAQ, but not listed by health authorities, will be identified too. Criteria for inclusion of these pollutants such as the existence of limits of exposure for the considered pollutants will be also defined. Finally, the existing indoor air quality metrics will also be reviewed to use the best science-based indices for the evaluation of indoor air pollution.

In this subtask, existing correlations between IAQ and health care related costs will be reviewed since the index will be considered useful if it enables proper consideration of both energy and IAQ benefit in building design and operation. In particular, the index will have to include additional energy consumption needed to improve IAQ in comparison with standard practices, such as increased fan operational consumption induced by higher air change rates or additional particle/gas filters, or use of portable air cleaners.

Activity:
- The subtask will be executed by literature surveys, and by gathering inputs from previous international projects.

Deliverables:
- A literature review of pollutant studies of indoor air quality, and
- A set of performance metrics will be collected and reported from this study.

Subtask 2 Pollutant loads in residential buildings

Another obstacle to integrating energy and IAQ strategies is the lack of reliable methods and data for estimating pollutant loads in residential buildings in the way heating/cooling loads are routinely estimated. This subtask is to collect existing data and to a limited extent provide new data about properties for transport, retention and emission of chemical substances in new and recycled materials, and particle transport in residential buildings under the influence of heat, airflow and moisture conditions. Collection of results from lab tests on material and room level will be part of this study. Specifically, results will be collected and analysed from tests of emission of harmful compounds under various temperature, humidity and airflow conditions, since such data under combined exposures generally are not available for use today.

Activities:
2.1 Literature survey and researcher contacts to gather relevant data and existing knowledge on pollutant loads in residential buildings, including models
2.2 Laboratory testing and model setup to provide examples of new types of data which shall be beneficial to improve knowledge on combined effects that must be taken into consideration in order to achieve new paradigms for energy optimal operation of buildings.

Stakeholders involved:
- It is anticipated that manufacturers of building materials and inventory products shall be involved regarding testing and possible co-development of products that have minimal emission of harmful substances, or which may have function to absorb indoor pollutants.
- Public health authorities, health organizations and technological institutes who make testing for industry and run their labelling systems are also among potential stakeholders

Deliverables:
- Mechanistic emission source and sink models for estimating the net loads of pollutions over time under realistic environmental conditions. This will be published in scientific journal articles and in a project report
- A database of emission and transport properties of materials for use in models,

- A database of pollution loads in new and existing residential buildings.

Subtask 3 Modelling - review, gap analysis and categorization

Many models have been developed in the past in the field of building performance simulation (e.g. building design, life cycle analysis and energy retrofit). However, existing knowledge is still inadequate for predicting the combined effects of hygrothermal conditions and chemical reactions on various types and concentrations of indoor pollution. In light of most recent revelation of the importance of secondary emissions such as Ozone-initiated indoor air and surface chemistry, a modelling approach of the effects of combined heat, air, moisture and pollutant (CHAMPS) transport and their impact on energy and IAQ is needed.

The target of Subtask 3 is a review, gap analysis and categorization of existing models and standards. The task is to collect and develop validated reference cases by use of contemporary whole building analysis tools and methods to predict the hygrothermal conditions, absorption and transport of humidity and chemical substances, and energy consumption within buildings. The whole building perspective is realized by integral consideration of indoor air and building envelope, building users and the building services systems. The feasibility of implementing reduced order models for prediction of IAQ within existing BES tools is investigated.

The gap analysis will motivate new developments. Focus, and what can be seen as a new development, will be on methods to predict the emission and absorption of chemical compounds from materials under realistic in-use conditions regarding the CHAMPS-exposure in buildings. Notwithstanding the perspectives in new paradigms for modelling the chemical and atmospheric conditions, it will be a top priority that the methods also facilitate prediction of the energy consumption associated with the operation of buildings, such that the tools can be used to optimize operation for minimal energy consumption that satisfies the needs with respect to Indoor Air Quality.

Activities:
3.1 Literature survey and provision of knowledge about contemporary modelling capabilities in thermal whole building energy and hygrothermal analysis in combination with air flow and emission models.
3.2 Definition of selection criteria for models in order to establish a platform of tools.
3.3 Development of a paradigm for work with these models by definition of reference cases with focus on specific physical/chemical processes/effects in the field of building energy performance under high IAQ conditions.
3.4 Identification of gaps in current modelling capabilities. The gap analysis will be translated into recommendations for further development/interfacing of tools. This activity includes incorporation of the methods for analysis in modelling paradigms from other IEA activities, e.g. IEA Annex 60.
3.5 Development of new input to standards for quality assurance of modelling tools, when and if necessary, that will be needed to model the interaction between energy efficient operation and high IAQ.
3.6 Recommendation of a modelling framework with necessary components for evaluating the energy and IAQ performance various design and operation strategies

Stakeholders involved:
- Apart from partners from academia, it is anticipated that major software vendors have a vital interest in these activities and companies/research teams involved in building design tool development may contribute to the subtask.

Deliverables:
- Classification of available tools (categories: pure research tools, research tools on transition stage, commercial planning tools: sophisticated vs. simplified) on the basis of selection criteria
- Set of reference cases (problem description, tool+input parameters, solution) with focus on building energy performance under high IAQ conditions

- List of feature requests from gap analysis of available tools for integrated and coordinated design of low energy and high IAQ buildings.
- A project report and scientific papers that document the modelling facilities and their background.
- Proposals for improvement of quality assurance standards

Subtask 4 Strategies for design and control of buildings

This subtask will apply the results of previous subtasks (Indoor Air Quality metrics, pollution/emission models and databases developed in the Subtasks 1, 2 & 3 and experiences from the field studies ST5) together with existing knowledge to devise optimal and practically applicable design and control strategies for high IAQ in residential buildings. The strategies will take into account requirements for IAQ based on current standards as well as newly developed metrics based on health effects. Moreover, the type of ventilation systems (decentralized ventilation, active overflow systems etc.) and air supply mode (e.g. intermittent vs. continuous ventilation) will be considered with respect to different building types. Optimal strategy is understood as one that takes into account building energy performance, user comfort and health conditions. A matrix of different strategies shall be created to evaluate possibilities for win-win solutions (excellent IAQ at low energy consumption) as well as other alternatives that will ensure high IAQ.

Use of models and databases developed within the Annex will enable addressing new paradigms for multi-scale and local thermal and air quality management, including demand controlled ventilation that considers the transport of chemical compounds to and from the indoor atmosphere. The subtask will take into account recent advances in sensor technology to identify ways to optimize IAQ without penalising energy efficiency.

On the energy account, the subtask should seek to establish correlation factors between on one side pollutant loads in buildings and methods to mitigate these loads, and on the other side energy consumption. The ambition is that such correlations will be possible to use in future standards and by legislators when specifying regulations for IAQ requirements in highly energy efficient buildings.

Activities:
4.1 Review of relevant international information sources/activities related to IAQ design and control in residences. Information sources will include “written knowledge” like international Standards (ASHRAE 62.2, EN 15 251), existing guidelines (ASHRAE HANDBOOK – fundamentals, European Concerted Action “Indoor Air Quality and its Impact on Man”, HealthVent, AIVC) as well as requirements included in national building codes in the EU, USA and China. Results from past IAQ monitoring projects (including user surveys) documenting the performance of certain ventilation concepts/systems will also be gathered. Additionally, particular companies/designers that are front-runners in residential ventilation design in Annex participating countries will be interviewed to gather information about their design practices, used methodology and approach. The direct communication with these stakeholders will enable gathering information about barriers, problems and needs with respect to ventilation design and operation.
4.2Investigation of possible design strategies: using tools and methods from Subtasks 1, 2 and 3 to evaluate design alternatives for several building types (including ventilation requirements according to current standards as well as health-based requirements, particular building codes in different countries will be addressed). Design strategies will include also different typologies of ventilation systems (central, decentralized, ductless etc.).
4.3 Investigation of possible operational strategies: the activity will be based on case studies included in subtask 5. Tools and methods from Subtasks 1, 2 and 3 will be also applied if necessary to evaluate operation of the systems designed in 4.2. Suitability of different control strategies and operational modes (demand control, intermittent ventilation etc.) will be addressed.
4.4 Preparation of an Annex 68 guide: This activity will comprise completion of a guide on design and operation of ventilation in residential buildings to achieve high IAQ with smallest possible energy consumption. The guidebook will summarize results of previous subtask activities. Besides design and

operation of residential ventilation, the guide will also address communication to building managers and occupants focused on increasing awareness regarding importance of IAQ for health and comfort.

Stakeholders involved:
- Cooperation is anticipated with building designers, companies that provide ventilation systems and controls as well as housing associations, producers of prefabricated houses and facility management companies.

Deliverable:
- A guide on operational strategies for optimal energy performance and high IAQ in residential buildings.

Subtask 5 Field measurements and case studies

Subtask 5 will investigate and identify relevant case studies through a literature survey and run measurement campaigns in well-known field test buildings to provide data for investigation and validation in Subtask 1-4. Several sites and climates will be studied, and the field tests will include buildings declared as energy efficient or recently refurbished to become so. The field tests will focus on testing and demonstrating in practice, which low energy operational strategies can be used that will provide amenable indoor environments. Subtask 5 will as far as possible test buildings with the ventilation strategies, both current and novel, that are recommended from Subtask 4.

The tests will include studies of new ventilation patterns in highly energy efficient residential buildings based on improved airtightness, increased insulation, use of materials, and possibly also new residential behaviour.

The test buildings will be inspected with respect to the building and interior materials, furnishing and occupants' activities. Special attention will be given to documenting the materials' emission status, i.e. checking for the use of low-emitting materials. Availability of information on ventilation system control and flows as well as the necessary energy consumption data will add to the assessment of IAQ in the buildings used in the case studies.

Building operations may be optimized with only small improvements to become more energy efficient but uphold the user comfort given as IAQ. New sensor technology and model based control will provide data for proper ventilation for the future. By investigating possible adjustments of building design, material use and ventilation system and control Annex 68 will deliver a feasibility study of potential energy savings in highly energy efficient residential buildings. The buildings might have potential hygrothermal or pollution buffers that can be considered in the HVAC strategy. Simple measurement techniques e.g. analyzing the content and distribution of particles, or logging of humidity conditions for building analyses, might prove to be valuable tools when optimizing building ventilation.

The measurement results will be used for common exercises in Subtask 3 and to verify the guidelines developed in Subtask 4.

Subtask 5 will involve stakeholders. The field tests will be carried out in cooperation with industry partners from the previous subtasks and with building owners. The subtask will involve engineers and building owners/operators from the studied buildings. Problems addressed in the buildings will be brought forward. Such problems could be overheating with its subsequent increase of energy use and/or loss of comfort.

Activities:
5.1 State of the art and measurement strategy: Summary of the literature review on necessary parameters, possibly accompanied by guideline values, which are necessary to describe the IAQ in the tested buildings. Development of a methodology to obtain the relevant values needed to study, simulate and verify IAQ in highly energy efficient residential buildings.

5.2 Controlled measurements: In labs and test houses available at the universities and institutes involved in Annex 68.
5.3 In situ measurements: Examples of residential buildings, which are either new or existing (possibly retrofitted) buildings, will be chosen for investigation from different geographical regions. It shall be possible in the chosen buildings to adjust the relevant operational parameters, e.g. for ventilation control, and to monitor the relevant performance parameters for energy consumption and indoor environment.
5.4 Analysis and dissemination: The results of ST5 will be a set of demonstrations and analyses of residential buildings that achieve optimal energy and good indoor environmental conditions under various geographical and climatic situations.

Deliverables:
- Report demonstrating and analysing residential buildings, which achieve optimal energy use.
- Valuable validation data for Subtask 1-4

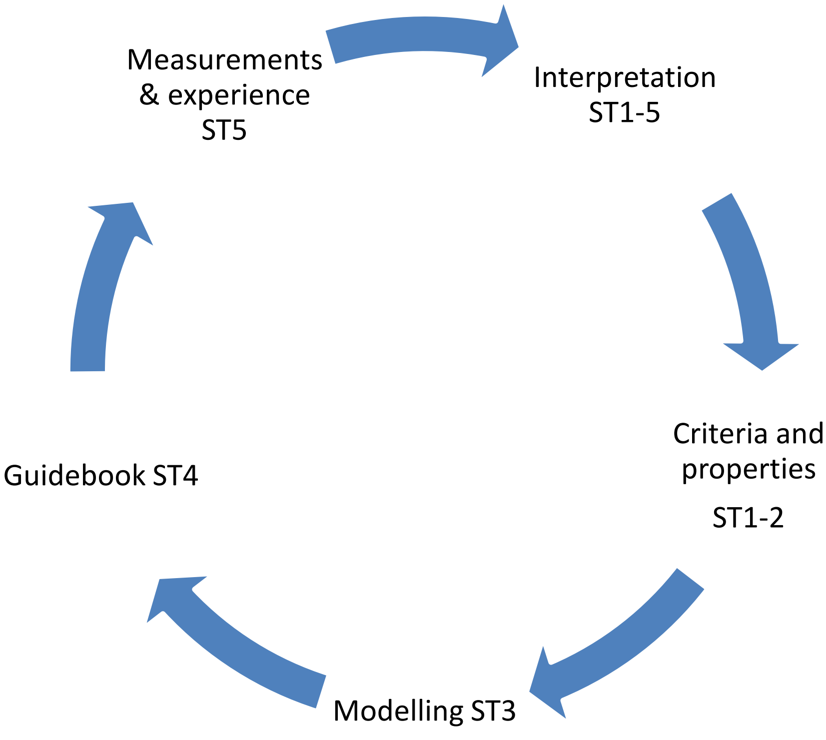


Figure 1 Work flow between subtasks

4. Results and deliverables

The project shall result in the following five reports and two databases as deliverables:

D1: Subtask 1 Report on *Metrics for high IAQ and energy efficiency in residential buildings*
D2: Subtask 2 Report on *Pollutant loads in energy efficient residential buildings under in-use conditions*
D3: Subtask 3 Report on *Modelling of IAQ and energy efficiency - review, gap analysis & categorization*
D4: Subtask 4 Report: *Guidebook on design and operation for high IAQ in energy efficient residential buildings*
D5: Subtask 5 Report on *Field tests and case studies – documentation of residential buildings, with regards to performance on achieving optimal combination of good IAQ and low energy use.*

D6: A database on *Storage and transport properties of materials for use in models*
D7: A database on *Pollution loads in existing buildings*.

Specifically, two of the reports will be distributed into the following Sections (sub-deliverables)
D 1.1: A literature review of pollutant studies of indoor air quality
D 1.2: A set of performance metrics

D 3.1: Classification of available tools on the basis of selection criteria (Section in ST3 Report)
D 3.2: Set of reference cases with focus on building energy performance under high IAQ conditions (Section in ST3 report)
D 3.3: List of feature requests from gap analysis of available tools for integrated and coordinated design of low energy and high IAQ buildings (Section in ST3 report)

Target audience

The project addresses the following primary stakeholders:
- Building designers (engineers and architects),
- Suppliers of HVAC and control systems
- Suppliers of materials used for building constructions and indoor furnishing,
- Providers of building management systems.

The project has the following secondary stakeholders:
- Buildings owners, facility managers and users,
- Authorities that stipulate the building regulations and who administrate the rules.

Outreach Activities

The project results will be disseminated through the following activities:
- Internet site and Annex newsletter targeting all groups of audiences from the above list
- Webinars targeting building designers and suppliers of relevant products. Contribution is anticipated from the research community (project participants and others).
- Sessions at relevant conferences for researchers and practitioners
- Publication in peer reviewed scientific journals
- Articles in professional magazines (national and international)
- Arrangement of public half-day events in combination with some of the expert meetings
- Common research publication in journals and at conferences
- Annex reports. The reports should be written so they target not only the research community but also building designers and managers. The reports should be written in such a way that they may be used in the curriculum in professional and higher education, as well as for classes in continued education.

5. Follow the EBC strategy plan

Overall the project will be rather crucial in fulfilling the realization of the overall vision for IEA EBC strategic plan 2014-2019 that: *By 2030, near-zero primary energy use and carbon dioxide emission solutions have been adopted in new buildings and communities, and a wide range of reliable technical solutions have been available for the existing building stock.* It will be very crucial for the successful realization of this target that such energy efficient buildings can be designed and proven to perform at least as well in terms of the indoor environment as users and owners of buildings are used to today from perhaps more energy consuming buildings. A fundamental hypothesis of the Annex is that it will be necessary to optimize for energy performance and Indoor Air Quality in a concerted and balanced way while achieving very ambitious targets in both areas.

The project relates to the following high priority Research and Innovation themes of the IEA EBC strategic plan 2014-2019:

- *Theme #1: Integrated planning and building design,* e.g. regarding establishment of knowledge about the design process for zero or low energy buildings with integrated information about the function of building envelopes (e.g. the materials) and the building energy systems (e.g. ventilation systems)
- *Theme #2: Building energy systems* concerning the optimal operation considering building/user / system interactions
- *Theme #3: Building envelope* regarding design and multiple function of the envelope.

6. Relevant associations with other ongoing IEA EBC Annexes

- IEA Annex V *Air Infiltration and Ventilation Centre*. Techniques for ventilation and its control is very crucial to the proposed Annex, and thus close links with and participation from experts who are also active in the AIVC will be needed.

- IEA EBC Annex 60 *New Generation Computational Tools for Building & Community Energy Systems*. While modelling will be needed in conjunction with the proposed Annex' Subtask 3, model development will not be topic of this Annex *per se*. We will to a maximum extent bear the development on existing tools and platforms, including such generic ones as are the topic of IEA EBC Annex 60.

- IEA EBC Annex 62 *Ventilative Cooling*. The topic of IEA EBC Annex 62 forms one of the interesting technologies to achieve good Indoor Air Quality in an energy efficient manner, and results from IEA EBC Annex 62 will be taken into consideration in the new proposed Annex.

- IEA Annex 66 *Definition and Simulation of Occupant Behaviour in Buildings*. Occupants and their behaviour are crucial when buildings shall be optimized for energy and indoor environmental performance. We will therefore establish a close link with contemporary knowledge being generated and processed in IEA EBC Annex 66.

- EBC Annex 69 *Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings*. While Annex 69 will focus on thermal comfort, many of the principles for design and control should be congruent with those that will be developed in EBC Annex 68.

The way to cooperate with these Annexes will be by arranging common expert meetings, by concerted sessions at relevant conferences, and by personal or institutional overlap in the representation of experts in the projects.

7. Time Schedule

The duration of the Annex's working phase will be three years (starting June 2015) followed by one year of reporting. Two meetings will be held every year. The Operating Agent will organize semi-annual plenary Annex meetings at varying locations, each time hosted by one of the participating countries. In connection with the plenary Annex meetings, a semi-annual subtask leaders meeting will be organized. If needed, the participants and subtask leaders of each subtask may decide to organize separate meetings. In such cases, they must inform the Operating Agent of the meeting and its results. A fourth year will be used to finish reports.

	2015		2016		2017		2018		2019	
Preparation Phase	x	x								
ST1			x	x						
ST2			x	x	x	x	x	x		
ST3			x	x	x	x	x	x		
ST4			x	x	x	x	x	x		
ST5			x	x	x	x	x	x		
Reporting									x	X

8. Funding and commitment

The work is divided into five subtasks. Each Participant shall work in at least one of the Subtasks 2-5, and optionally in Subtask 1.

Each Participant shall provide the Operating Agent with detailed reports on the results of the work carried out and to deliver information and written material to the final reports. Each Participant shall participate in the editing and review of draft reports on the Annex.

Each participant shall individually bear their own costs incurred in the Annex activities. Funding is expected to cover labour costs, consumables and investments (including eventual overhead costs) associated with the execution of activities defined in Section 3 and 4, and to cover traveling costs for participating in at least two expert meetings per year during the four-year preparation and working phases of the Annex. The working meetings shall be hosted by one of the participants. The costs of organizing and hosting the meeting shall be borne by the host participant.

All participating countries have access to the workshops and results of all subtasks. Each participating country must designate at least one individual (an active researcher, scientist or engineer, here called the expert) for each subtask in which they decide to participate. It is expected that the same expert attends all meetings and acts as technical contact regarding the national subtask contribution.

A minimum commitment of six person-months of labour for each year of the Annex term will be required for participation. For the subtask coordinators funding shall allow for six person-months and an extra two person-months per year for Annex activities. For the Operating Agent, funding shall allow for six person-months and an extra four person-months per year for Annex activities including the attendance at the two ExCo meetings per year.

9. Intellectual Property

Each Annex participant retains ownership of any knowledge brought into or developed within the Annex by that participant. Knowledge resulting from the work of more than one participant may only be published with the consent of all participants involved.

When presenting Annex related work at congresses and meetings outside the Annex, publishing in journal papers and reports the Annex shall be acknowledged as one of the vehicles that assisted in carrying out the work.

The Operating Agent will hold all intellectual property rights on the deliverables from the Annex on behalf of the participants in accordance with the EBC Implementing Agreement.

10. Management of the Annex

The Annex will be managed by the Operating Agent assisted by subtask leaders and co-leaders.

Operating Agent

The Operating Agent is responsible for the overall performance and the time schedule of the Annex, for reporting, and for information dissemination activities. The Operating Agent is Prof. Carsten Rode, Technical University of Denmark.

In addition to the obligations enumerated in Articles 4 and 7 of the IEA EBC Implementing Agreement, the Operating Agent shall:

- Prepare and distribute the results mentioned in paragraph 4 above;
- At the request of the Executive Committee, organize workshops, seminars, conferences and other meetings;
- Prepare the detailed Program of Work for the Annex in consultation with the Participants and submit the Program of Work for approval to the Executive Committee;
- Propose and maintain a methodology and a format for the submission of information on which is collected by the Participants as described in paragraph 3(a) above;
- Provide, at least semi-annually, periodic reports to the Executive Committee on the progress and the results of the work performed under the Program of Work;
- Provide to the Executive Committee, within six months after completion of all work under the Annex, a final report for its approval and transmittal to the Agency;
- In co-ordination with the Participants, use its best efforts to avoid duplication with activities of other related programs and projects implemented by or under the auspices of the Agency or by other competent bodies;
- Provide the Participants with the necessary guidelines for the work they carry out, assuring minimum duplication of effort;
- Co-ordinate the efforts of all Participants, and their National Teams, and ensure the flow of information in the Annex;
- Perform such additional services and actions as may be decided by the Executive Committee, acting by unanimity.

Subtask Leaders

The Subtask leaders shall be participants who bring a high level of expertise to the subtask they manage and who undertake substantial research and development in the field of the subtask. They are nominated by the Annex participants and approved by the IEA EBC ExCo. Duties of the subtask leaders are to:

- Co-ordinate the work performed under the subtask;
- Assist the Operating Agent in preparing the detailed work plans and editing the deliverables of the Annex;
- Direct the technical workshops of the subtask and provide the Operating Agent with the workshop results;
- Coordinate the technical reports resulting from the Subtask;

Subtask and co-subtask leaders are:

	Subtask leader	**Co-lead**
ST1 – Metrics	France (Univ. La Rochelle, Marc Abadie)	Denmark (Technical University of Denmark, Pawel Wargocki)
ST2 – Pollutant loads	Denmark (Technical University of Denmark, Menghao Qin)	USA (Syracuse Univ., Jianshun Zhang)
ST3 – Modelling	Germany (TU Dresden, John Grunewald)	USA (Syracuse Univ., Jianshun Zhang)
ST4 – Strategies	Denmark (Technical University of Denmark, Jakub Kolarik)	Norway (Norwegian University of Science and Technology, Guangyu Cao)
ST5 – Field tests and case studies	Belgium (Ghent University, Jelle Laverge)	Canada (British Columbia Institute of Technology, Fitsum Tariku)

11. Participation in the Annex

The consortium of contributors to the project comprises building physicists, experts in ventilation and controls technology, indoor air specialists, material scientists and experts in atmospheric chemistry. A list of contributors, and the subtasks in which they are active, is given in the table below.

Country/institution	ST1	ST2	ST3	ST4	ST5
Austria					
Universität Innsbruck	x		x	x	(x)
Belgium					
Ghent University	x		(x)	x	**<u>X</u>**
Canada					
British Columbia Institute of Technology			(x)	x	<u>x</u>
Health Canada		x			
China					
Nanjing University		x		x	x
Tsinghua University		x		x	x
The University of Hong Kong	X	x			x
University of Shanghai for Science and Technology		x			x
Shenzhen Institute of Building Research		x			x
Czech Republic					
CVUT Prague				x	
TU Liberec					
Denmark					
Technical University of Denmark, DTU	<u>x</u>	**<u>X</u>**	x	**<u>X</u>**	x
Danish Building Research Institute, SBi	x			x	x
Danish Technological Institute, TI	x			x	x
Estonia					
Tallinn University of Technology					
France					
Université de La Rochelle	**<u>X</u>**	x	x		x
LOCIE, Université de Savoie		(x)			x
Saint-Gobain					x
Germany					
TU Dresden		x	**<u>X</u>**		
The Netherlands					
TU Eindhoven			x		
Norway					
Norwegian University of Science and Technology, NTNU		(x)	(x)	<u>x</u>	x
Norwegian University of Life Sciences, NMBU					x
United Kingdom					
University College London, UCL					x
University of Strathclyde				x	
USA					
Syracuse University		<u>x</u>	<u>x</u>		

In the table above, **bolded** indication of an institution name indicates that a Letter of National Participation has been signed by that institution.

'x' in the table under the Subtasks indicates the institution's interest to contribute to that subtask (**<u>X</u>** as subtask leader or <u>x</u> as co-lead)

12. Summary of the Preliminary Technology Readiness Assessment

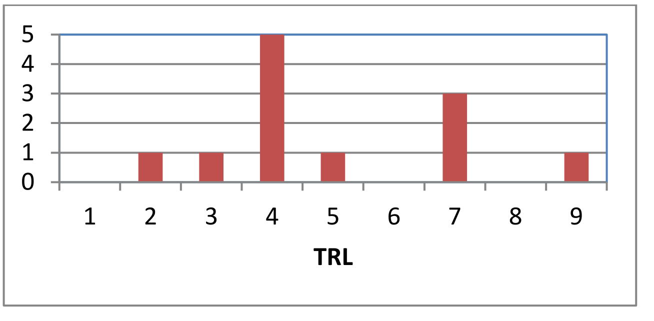
Experts from 12 countries participated in answering the Preliminary Technology Readiness Assessment. The countries represented a rather wide range of level of sophistication of the building industry, the general level of energy efficient performance of residential buildings and adaptation of measures to ensure good indoor environments. The answers in terms of TRL-assessments can be summarized in the below table.

Technology	USA	N	NL	J	F	D	S	DK	NZ	A	P	Can	Avg.	Min	Max
1. General knowledge of metrics, data and physics related to assessing the situation regarding pollutants and IEQ of buildings.	5	4	7	7	4	7	4	3	2	3.5	9	4	5.0	2	9
2. Methods to describe and model indoor pollutants and IEQ in relation to the energy-performance of residential buildings.	5	4	7	6	5	6	3.5	2	2	3.5	4	5	4.4	2	7
3. Application of the definition and models of Indoor Environmental Quality in residential buildings to improve strategies for design, operation, and retrofit of buildings.	5	3	7	6	6	3	5	4	1	1.5	6	4	4.3	1	7
Confidence in the accuracy of your assessment	5	3	4	4	5	3	5	4	4	3	4	4	4.0	3	5

A brief summary of the textual explanations can be given as:

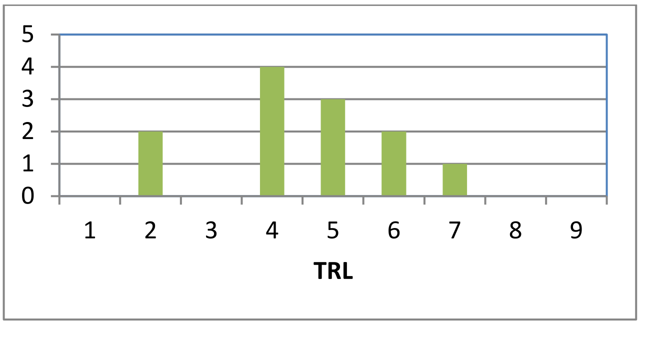
1. General knowledge of metrics, data and physics related to assessing the situation regarding pollutants and IEQ of buildings

Many countries express that basic information about emission form building products is very often known, and there are standards for some of these, and systems exist for labelling of building products used indoors and having the information in databases. However, there is a general lack of knowledge in the following sense: There are many pollutants for which we still have only little information; some of the information we have is not updated, so it does not sufficiently pertain to contemporary products and conditions; and there is only very scarce information about combined effects with temperature, humidity and ventilation levels.



2. Methods to describe and model indoor pollutants and IEQ in relation to the energy-performance of residential buildings.

Some isolated/relatively simple abilities exist to model emission of pollutants from building products. However, more global approaches are needed. Indoor pollutants are considered mainly by proxies such as CO_2 or humidity. Modelling of pollutants is also hampered by the lack of data about the pollutants, and lack of threshold values.



3. Application of the definition and models of Indoor Environmental Quality in residential buildings to improve strategies for design, operation, and retrofit of buildings.

Indoor pollutants are currently not considered in building energy simulation models. So far appropriate sensors have been missing – but are currently being developed. Application, experience and design knowledge in the combined design assessment of energy performance of IEQ optimization is expressed as being important but appears to be too scarce, or generally not consolidated