

# D1 - A literature list for energy efficient IAQ management

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**December 2025**

**Editors**

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Published by INIVE, Sint-Pietersnieuwstraat 41, B-9000 Ghent, Belgium.

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ISBN 978-2-930471-76-1

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# Preface

## The 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 international cooperation among the 30 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

## The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes (TCPs). The mission of the IEA Energy in Buildings and Communities (IEA EBC) TCP is to support the acceleration of the transformation of the built environment towards more energy efficient and sustainable buildings and communities, by the development and dissemination of knowledge, technologies and processes and other solutions through international collaborative research and open innovation. (Until 2013, the IEA EBC Programme was known as the IEA Energy Conservation in Buildings and Community Systems Programme, ECBCS.).

The high priority research themes in the EBC Strategic Plan 2019-2024 are based on research drivers, national programmes within the EBC participating countries, the Future Buildings Forum (FBF) Think Tank Workshop held in Singapore in October 2017 and a Strategy Planning Workshop held at the EBC Executive Committee Meeting in November 2017. The research themes represent a collective input of the Executive Committee members and Operating Agents to exploit technological and other opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy technologies, systems and processes. Future EBC collaborative research and innovation work should have its focus on these themes.

At the Strategy Planning Workshop in 2017, some 40 research themes were developed. From those 40 themes, 10 themes of special high priority have been extracted, taking into consideration a score that was given to each theme at the workshop. The 10 high priority themes can be separated in two types namely 'Objectives' and 'Means'. These two groups are distinguished for a better understanding of the different themes.

Objectives: The strategic objectives of the EBC TCP are as follows:

- reinforcing the technical and economic basis for refurbishment of existing buildings, including financing, engagement of stakeholders and promotion of co-benefits;
- improvement of planning, construction and management processes to reduce the performance gap between design stage assessments and real-world operation;
- the creation of 'low tech', robust and affordable technologies;
- the further development of energy efficient cooling in hot and humid, or dry climates, avoiding mechanical cooling if possible; the creation of holistic solution sets for district level systems taking into account energy grids, overall performance, business models, engagement of stakeholders, and transport energy system implications.

Means: The strategic objectives of the EBC TCP will be achieved by the means listed below:

- the creation of tools for supporting design and construction through to operations and maintenance, including building energy standards and life cycle analysis (LCA);
- benefitting from 'living labs' to provide experience of and overcome barriers to adoption of energy efficiency measures;
- improving smart control of building services technical installations, including occupant and operator interfaces;
- addressing data issues in buildings, including non-intrusive and secure data collection;
- the development of building information modelling (BIM) as a game changer, from design and construction through to operations and maintenance.

The themes in both groups can be the subject for new Annexes, but what distinguishes them is that the 'objectives' themes are final goals or solutions (or part of) for an energy efficient built environment, while the 'means' themes are instruments or enablers to reach such a goal. These themes are explained in more detail in the EBC Strategic Plan 2019-2024.

## The Executive Committee

Overall control of the IEA EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA EBC Implementing Agreement. At the present time, the

following projects have been initiated by the IEA EBC Executive Committee, with completed projects identified by (\*) and joint projects with the IEA Solar Heating and Cooling Technology Collaboration Programme by (☼):

- Annex 1: Load Energy Determination of Buildings (\*)
- Annex 2: Ekistics and Advanced Community Energy Systems (\*)
- Annex 3: Energy Conservation in Residential Buildings (\*)
- Annex 4: Glasgow Commercial Building Monitoring (\*)
- Annex 5: Air Infiltration and Ventilation Centre
- Annex 6: Energy Systems and Design of Communities (\*)
- Annex 7: Local Government Energy Planning (\*)
- Annex 8: Inhabitants Behaviour with Regard to Ventilation (\*)
- Annex 9: Minimum Ventilation Rates (\*)
- Annex 10: Building HVAC System Simulation (\*)
- Annex 11: Energy Auditing (\*)
- Annex 12: Windows and Fenestration (\*)
- Annex 13: Energy Management in Hospitals (\*)
- Annex 14: Condensation and Energy (\*)
- Annex 15: Energy Efficiency in Schools (\*)
- Annex 16: BEMS 1- User Interfaces and System Integration (\*)
- Annex 17: BEMS 2- Evaluation and Emulation Techniques (\*)
- Annex 18: Demand Controlled Ventilation Systems (\*)
- Annex 19: Low Slope Roof Systems (\*)
- Annex 20: Air Flow Patterns within Buildings (\*)
- Annex 21: Thermal Modelling (\*)
- Annex 22: Energy Efficient Communities (\*)
- Annex 23: Multi Zone Air Flow Modelling (COMIS) (\*)
- Annex 24: Heat, Air and Moisture Transfer in Envelopes (\*)
- Annex 25: Real time HVAC Simulation (\*)
- Annex 26: Energy Efficient Ventilation of Large Enclosures (\*)
- Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (\*)
- Annex 28: Low Energy Cooling Systems (\*)
- Annex 29: ☼ Daylight in Buildings (\*)
- Annex 30: Bringing Simulation to Application (\*)
- Annex 31: Energy-Related Environmental Impact of Buildings (\*)
- Annex 32: Integral Building Envelope Performance Assessment (\*)
- Annex 33: Advanced Local Energy Planning (\*)
- Annex 34: Computer-Aided Evaluation of HVAC System Performance (\*)
- Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (\*)
- Annex 36: Retrofitting of Educational Buildings (\*)
- Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (\*)
- Annex 38: ☼ Solar Sustainable Housing (\*)
- Annex 39: High Performance Insulation Systems (\*)
- Annex 40: Building Commissioning to Improve Energy Performance (\*)
- Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG) (\*)
- Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (\*)
- Annex 43: ☼ Testing and Validation of Building Energy Simulation Tools (\*)
- Annex 44: Integrating Environmentally Responsive Elements in Buildings (\*)
- Annex 45: Energy Efficient Electric Lighting for Buildings (\*)
- Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (\*)
- Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings (\*)
- Annex 48: Heat Pumping and Reversible Air Conditioning (\*)
- Annex 49: Low Exergy Systems for High Performance Buildings and Communities (\*)
- Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings (\*)
- Annex 51: Energy Efficient Communities (\*)
- Annex 52: ☼ Towards Net Zero Energy Solar Buildings (\*)

Annex 53: Total Energy Use in Buildings: Analysis and Evaluation Methods (\*)

Annex 54: Integration of Micro-Generation and Related Energy Technologies in Buildings (\*)

Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost (RAP-RETRO) (\*)

Annex 56: Cost Effective Energy and CO<sub>2</sub> Emissions Optimization in Building Renovation (\*)

Annex 57: Evaluation of Embodied Energy and CO<sub>2</sub> Equivalent Emissions for Building Construction (\*)

Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements (\*)

Annex 59: High Temperature Cooling and Low Temperature Heating in Buildings (\*)

Annex 60: New Generation Computational Tools for Building and Community Energy Systems (\*)

Annex 61: Business and Technical Concepts for Deep Energy Retrofit of Public Buildings (\*)

Annex 62: Ventilative Cooling (\*)

Annex 63: Implementation of Energy Strategies in Communities (\*)

Annex 64: LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles (\*)

Annex 65: Long-Term Performance of Super-Insulating Materials in Building Components and Systems (\*)

Annex 66: Definition and Simulation of Occupant Behavior in Buildings (\*)

Annex 67: Energy Flexible Buildings (\*)

Annex 68: Indoor Air Quality Design and Control in Low Energy Residential Buildings (\*)

Annex 69: Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings (\*)

Annex 70: Energy Epidemiology: Analysis of Real Building Energy Use at Scale (\*)

Annex 71: Building Energy Performance Assessment Based on In-situ Measurements (\*)

Annex 72: Assessing Life Cycle Related Environmental Impacts Caused by Buildings (\*)

Annex 73: Towards Net Zero Energy Resilient Public Communities (\*)

Annex 74: Competition and Living Lab Platform (\*)

Annex 75: Cost-effective Building Renovation at District Level Combining Energy Efficiency and Renewables (\*)

Annex 76: ☼ Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO<sub>2</sub> Emissions (\*)

Annex 77: ☼ Integrated Solutions for Daylight and Electric Lighting (\*)

Annex 78: Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications (\*)

Annex 79: Occupant-Centric Building Design and Operation (\*)

Annex 80: Resilient Cooling (\*)

Annex 81: Data-Driven Smart Buildings (\*)

Annex 82: Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems (\*)

Annex 83: Positive Energy Districts

Annex 84: Demand Management of Buildings in Thermal Networks (\*)

Annex 85: Indirect Evaporative Cooling

Annex 86: Energy Efficient Indoor Air Quality Management in Residential Buildings (\*)

Annex 87: Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems

Annex 88: Evaluation and Demonstration of Actual Energy Efficiency of Heat Pump Systems in Buildings

Annex 89: Ways to Implement Net-zero Whole Life Carbon Buildings

Annex 90: EBC Annex 90 / SHC Task 70 Low Carbon, High Comfort Integrated Lighting

Annex 91: Open BIM for Energy Efficient Buildings

Annex 92: Smart Materials for Energy-Efficient Heating, Cooling and IAQ Control in Residential Buildings

Annex 93: Energy Resilience of the Buildings in Remote Cold Regions

Annex 94: Validation and Verification of In-situ Building Energy Performance Measurement Techniques

Annex 95: Human-centric Building Design and Operation for a Changing Climate

Annex 96: Grid Integrated Control of Buildings

Annex 97: Sustainable Cooling in Cities

Annex 98: Flexibilization and Optimization of Heat Pump Systems in Existing Buildings through Secondary-Side Digitalization

Annex 99: Air Cleaning for Sustainable and Resilient Buildings

  

Working Group – Energy Efficiency in Educational Buildings (\*)

Working Group – Indicators of Energy Efficiency in Cold Climate Buildings (\*)

Working Group – Annex 36 Extension: The Energy Concept Adviser (\*)

Working Group – HVAC Energy Calculation Methodologies for Non-residential Buildings (\*)

Working Group – Cities and Communities (\*)

Working Group – Building Energy Codes

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# 1. Introduction

This deliverable provides the reader with a literature list that includes selected papers and reports related to the topic of energy efficient IAQ management. It can serve as a reference to identify useful further reading on the topics of metrics, sources and exposures, smart materials as an IAQ management strategy and ensuring performance for smart ventilation. It is organized in 4 chapters around these themes. In addition to a set of core references, chapters 3, 4 and 5 also include an extended corpus of literature related to the topic.

In addition to the print version of the document, the list is also available in a range of common reference management software formats, providing added functionality such as sorting, searching and archiving, supporting the use of its content in research and reporting.

## 2. ST1: Metrics and development of an IAQ management strategy rating method Completed Projects

- (1) Al Assaad, D.; Sengupta, A.; Breesch, H. A Novel Quantitative Assessment Framework of the IAQ Resilience Performance of Buildings: The Resilience Score Metric. *Build. Environ.* **2023**, *243*, 110669. <https://doi.org/doi.org/10.1016/j.buildenv.2023.110669>.
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## 4. ST3 : Smart materials as an IAQ management strategy

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## 5. ST4 : Ensuring performance for smart ventilation

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