ANNEX **86**

EBC

Energy in Building and Communities Programme

D3 – Appendix 2: ST2 – Summary of analyzed studies

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Participating countries in the EBC: Australia, Austria, Belgium, Brazil, Canada, P.R. China, Czech Republic, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Republic of Korea, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, Turkey, United Kingdom and the United States of America.

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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 (*)
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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 (*)
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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_2 Emissions Optimization in Building Renovation (*)
Annex 57: Evaluation of Embodied Energy and CO_2 Equivalent Emissions for Building Construction (*)
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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_2 Emissions (*)
Annex 77: ☼ Integrated Solutions for Daylight and Electric Lighting (*)
Annex 78: Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications (*)
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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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ST2 – Summary of analyzed studies

Austria: Lüftung 3.0, Lodenareal

The “Lüftung 3.0” study investigated the difference in IAQ of new residential homes in Austria equipped with and without mechanical balanced ventilation. IAQ measurements were performed twice (approx. 3 months and 12 months after move-in) of 123 homes built in the years 2010 to 2012 located in different locations in Austria. Thereof, 62 homes were highly energy efficient homes equipped with mechanical ventilation system with heat recovery MVHR and 61 were “conventional” homes built to the Austrian building standard (OIB RL6), relying on occupant-driven window airing for ventilation. During both appointments, measurements were taken of indoor air pollutants (volatile organic compounds, aldehydes, mould spores, dust mite allergens, radon) in living rooms and bedrooms, and climatological parameters (CO2 as ventilation parameter, temperature, humidity) were recorded over the course of a week in bedrooms. Additionally, air volume flows and noise levels were measured in buildings with ventilation systems. Measurements were only made during fall, winter and spring season.

In the “Lodenareal” measurement study, energy use and indoor environmental data was collected during long-term monitoring of a social housing project built and certified to the Passive House (PH) standard in Innsbruck, Austria. Indoor temperature (C°), CO2 concentration and relative humidity (%) levels were continuously logged in 18 of the 354 apartments over the course of three years (2010-2012). The volatile organic compound concentrations were also measured before the tenants moved in. For direct comparison with a low-energy building without mechanical ventilation, measurements were extended to six of 18 apartments of a residential building constructed in the same years (2008-2009) by the same social housing company in the nearby city of “Kufstein”. These homes relied on occupant-driven window airing for ventilation.

Within the EU-funded project “Sinfonia” refurbishment measures to reduce the energy demand in the cities of Innsbruck, Austria and Bolzano, Italy were investigated. Within the performance monitoring activities, indoor environmental quality parameters (CO2, T, RH) were measured in 185 dwellings with and without mechanical ventilation retrofit over a period of at least one year each. For minimal intrusiveness the CO2 measurement location was within the extract duct (dwelling central) representing the dwelling average concentration in mechanically ventilated homes and in the central corridor for window aired homes.

Belgium: Renson

The central MEV system measures the local IAQ level in the rooms by measuring CO2, RH or VOC, depending on the room type. Based on the amount of contamination, the desired local exhaust rate is set. The standard version of this system includes the wet rooms, while the extended version includes dry rooms. Of all installed MEV systems of this type, those connected to the Internet send their data to the Cloud. To date, more than 8500 systems send data regularly. The IAQ and flow rate data studied ran from May 1, 2022 to June 30, 2023, with a sampling interval of 5 minutes. This MEV system is usually installed in new homes or homes undergoing major renovations in Belgium. According to Belgian EPB regulations, these buildings must achieve an A label with respect to energy efficiency. There is no information on whether the building is rural or urban.

Switzerland: Buren

The apartments compared in this study belong to a house built in 2017 in Büren, Switzerland. There are two apartments on the first floor and two apartments on the second floor. Each level has one apartment with a surface area of 80 m2 and one with a surface area of 113 m2. The top apartments have only windows to ventilate the rooms. The bottom two apartments each have a Zehnder balanced ventilation unit with an enthalpy exchanger. The comparison during an entire year focuses on the type of ventilation used (windows only, or mechanical balanced ventilation), the resulting indoor air quality and the necessary energy consumption to heat and cool the apartments. As an indicator of indoor air quality, the CO2 values were measured in ppm.

Denmark: IECH

The Indoor Environment and Children’s Health study focused on the impact of the indoor environment on asthma and allergy among children in Odense, Denmark. A subset of 500 children between 3 and 5 years of age was selected for the second phase of the study, which was a case-base investigation including 200 symptomatic children (cases) and 300 randomly selected children (bases). The homes were located in a 20-kilometer vicinity from the center of Odense, the third largest city in Denmark. The homes included apartments (11.4%), single- family houses (69.2%) and row houses (18.3%). 58.8% of the homes had natural ventilation. The rest of the homes had mechanical ventilation. This was, however, mostly mechanical exhaust. Only 4 homes had mechanical exhaust and supply ventilation. Temperature, relative humidity, and the concentration of carbon dioxide were continuously measured over a minimum of 2 days and 2 nights in the bedrooms of the children. The families were asked to maintain their regular routine regarding opening the doors and windows. The measurements were performed between 10 March and 18 May 2008.

France: ALLO

The ALLO project (2018-2021) wanted to be innovative in the way of approaching information and its dissemination to residents of a recently refurbished social building. The ten voluntary homes were representative of the tenants of the selected building and balanced from the point of view of the male/female distribution with a more or less continuous presence throughout the day and for some with prerequisites on hygienic or sanitary aspects by their professional activity. Four parameters have been measured in the living room: temperature, relative humidity, carbon dioxide and PM (1, 2.5 and 10). The values of these variables were collected and processed every 5 minutes to inform occupants via simplified indicators about the quality of their indoor environment, so that they could act in case of bad quality alert. Data available are from December 2020 to April 2022 for all except for PM whose instrumentation has been deployed later (September 2021 to April 2022) for six apartments.

Great Britain: AMR, BSD standard 3.14 (VentStdStudy)

The aim of the AMR study was to examine the impact of building ventilation of the type and nature of microorganisms in homes. This involved environmental monitoring in 21 homes over a 6-9 month period (Oct 2018 – June 2019). Temperature, RH and CO2 were logged at 10-min intervals in the living room, main bedroom and kitchen in each home over this period (using Gemini Tiny Tags). To provide further context for ventilation, we installed low-cost Foobot sensors to indicate levels of air quality and to record the presence of Volatile Organic Compounds (VOCs) and fine particulates (PM2.5), and as a means of trialling the efficacy of such sensors for future large-scale studies. These sensors were positioned beside the Tinytag sensors (where possible), for comparative purposes. One external tinytag temp/RH sensor was installed at each development to record ambient temperature and relative humidity levels at 10-min intervals (concurrent with indoor monitoring).

The overall purpose of the BSD Standard 3.14 study was to investigate the effect the changes to Scottish Building Standards in 2015 - requiring the installation of carbon dioxide monitors in all new homes – has had on ventilation and indoor air quality. Living room and bedroom temperature, RH and CO2 levels were monitored at 15-min intervals in 16 homes (Dec 2021 – Aug 2022) with HomeLINK Environmental Sensors Ei1025. A building survey and ventilation audit was performed, which included measurement of airflow rates of mechanical systems (using SwemaFlow 126 air capture hood). Nine homes were selected for detailed monitoring over a two-week period (Mar-Apr 2022), which included the measurement of temperature, RH, CO2, pressure, tVOCs, PM1, PM2.5, PM10 at 5-min intervals in the main living space (using Duomo Ltd. LoRaWAN Wireless IAQ sensor). An occupant diary was used to capture details on occupancy levels and behaviours during the measurement period.

Ireland: VALIDate, ALIVE, ARDEN

The VALIDate project (2019–2021) conducted a longitudinal study to monitor indoor environmental quality (IEQ) in energy-efficient Irish homes, addressing gaps in long-term air pollutant data. Unlike short-term monitoring studies, this research focused on whole-house ventilation performance, continuously collecting IEQ data over 18 months during heating and cooling seasons. Participating dwellings had a designed primary energy use below 75 $kWh/m^2 \cdot yr$ and included 87 homes, evenly split between urban and rural areas: 60 mechanically ventilated, 23 naturally ventilated, and 4 with demand-control ventilation. Consumer-grade sensors logged temperature, humidity, CO2, VOCs (every five minutes), and radon (hourly) in living rooms, bedrooms, kitchens, and bathrooms. Continuous monitoring enabled the study of pollutant dispersion, ventilation variability, and air pollution exposure while minimising uncertainties from occupant behaviour and short-term changes.

The ALIVE project evaluated the performance of natural ventilation in maintaining acceptable indoor environmental quality in energy-efficient Irish dwellings. Enhanced building energy performance often requires improved thermal insulation, which increases the risk of overheating. Natural ventilation offers the advantage of reducing cooling energy consumption during warmer seasons. In this context, natural ventilation refers to purpose-provided ventilation achieved through passive background ventilators in habitable rooms and intermittently operating mechanical fans in wet rooms. PM2.5, CO2, TVOCs, NO2, CO, temperature, and relative humidity were monitored in bedrooms, living rooms, and kitchens of nine semi-detached dwellings during summer and winter from 2021 to 2023. These dwellings had a maximum primary energy consumption of 75 kWh/m^2 per year and an air permeability of up to 7.0 $m^3/(h \cdot m^2)$. Both rural and urban homes were selected, with a paired comparison made within each housing estate. Time activity diaries and thermal comfort surveys gather detailed insights into occupant comfort during the measurement period.

All of the homes who participated in the ARDEN research project were participants of the Sustainable Energy Authority of Ireland Deep Energy Pilot programme. Twenty six homes were recruited and measurements of up to ten indoor air pollutants (CO, CO_2, $PM_{2.5}$, NO_2, Radon, Formaldehyde and BTEX) and thermal parameters (indoor temperature and relative humidity) were made pre- and post (in 12 homes only) or only post (in 15 homes) energy retrofit in the main living area and bedroom of the dwellings. The objective was to collect 48 hours of data (Temperature, RH, CO, CO_2,$PM_{2.5}$) during the surveys, but for various reasons in some cases shorter sampling times were obtained. A description of the methodologies used to collect pollutant and thermal data are presented in Coggins et al., 2021 and Hassan et al., 2024. Homes were located in both urban and rural locations around Ireland. Surveys were completed between 2019 and 2020 and across different seasons. All dwellings were cavity wall construction type. Prior to the retrofit all of the homes were naturally ventilated, 14 - 60 years old, with floor areas of between 87.3 and 300 m^2. Prior to the retrofit the dwellings had energy use intensity values of between 218.54 and 547.29 Kw h/(m^2.year), and building airtightness levels of > 3.68 m3/h.m^2 @50 Pa. The deep energy retrofit involved the substitution of fossil fuel-based heating systems with an air to water heat pump, and insulation upgrades necessary to achieve to a high performance fabric, reduced thermal bridging and increased building air tightness (≤ 5 m3/h.m^2 @50 Pa). Specific details regarding the retrofit measures completed are published in Coggins et al., 2021 and Hassan et al., 2024. All homes were mechanically ventilated post retrofit including demand control (DCV humidity controlled) or mechanical ventilation with health recovery (MVHR). Post retrofit the homes had energy use intensity values of between - 3.06 and 74.38 Kw h/(m^2.year).

Norway: HomeOffice-COVID

This study monitored indoor air quality in 21 homes by measuring formaldehyde, TVOC, CO2, PM1, PM2.5, relative humidity, and temperature during winter (December 8, 2020 - February 28, 2021) and summer (May 21, 2021 - June 21, 2021) in rooms used for home offices. When not used as offices, these rooms were kitchens, bedrooms and/or living rooms. The research involved homes built between 1900 and 2019, including semi-detached houses, single-family houses, and apartments. Participants, recruited from an academic environment and required to work from home at least four days a week, were instructed to maintain normal behaviors, including their usual window-opening practices. Data collection involved a low-cost sensor system placed in the breathing zone near the computer keyboard, gathering data every 5 minutes. The study, forming part of a PhD thesis at the Research Centre on ZERO Emission Neighbourhoods, also involved collecting information on participants' activities and working habits. At least three houses were measured simultaneously in the same city area to control bias regarding outdoor air.

Netherlands: Kroeven (NL_ML)

Ten terraced houses were monitored in detail over a period of two years (Jan 2013 - Dec, 2014) as part of a large renovation project in the Kroeven district of Roosendaal and in the context of the European project 7th FW project E2ReBuild (Loomans and Boxem, 2015). The single-family houses were renovated to passive house standard, focusing on extensive external thermal insulation, the addition of a solar collector and hot water storage tank, and a mechanical ventilation system with heat recovery. The main objective was to assess whether the passive house energy requirements were met while achieving acceptable indoor climate conditions. In addition to detailed monitoring of the energy flows of each house, the indoor environment (temperature, RH, CO_2 concentration) was monitored in three rooms (living room and two bedrooms). More detailed information on flow rates was also available. According to the measurement campaign, the energy targets of the Passive House concept were met for most of the houses. A clear effect of user behavior is visible. The same is true for the monitored indoor climate parameters, with overheating being a potential problem. Occupancy and occupant behavior are important parameters for the results obtained. Loomans, M.G.L.C. and Boxem, G. 2015. Rapportage Monitoring Kroeven 2013-2014. Report BWK2015-1580648. p.88. Department of the Built Environment, Eindhoven University of Technology, Eindhoven, The Netherlands (in Dutch: Report Monitoring Kroeven 2013-2014)

Spain: ClimaReady, CISC

The main aim of CLIMAREADY Project (2020-2023) was the assessment of adaptability in residential buildings to Climate Change, identifying main key parameters to minimize overheating risk in indoor environments during warmer conditions and heatwaves events. Within the tasks of the project, 23 dwellings were monitored in two different Spanish locations: i) Pamplona, Cfb and 4A climate zone, all dwellings being naturally conditioned in summer; and ii) Seville, Csa and 3A climate zone, being dwellings with AC, but being used according to particular users' preferences. Although the main aim of the study was to analyze indoor overheating, CO_2 and $PM_{2.5}$ was also monitored for 15 months and covering two summers (2021, 2022), the first one with typical conditions and the second one with the highest number of days with heatwaves so far (2022). Dwellings were selected to cover different Spanish energy codes and located in intermediate and upper floors. Monitoring includes air temperature, RH, and CO2 concentration of the living room and one bedroom of each dwelling. The dwellings were mainly naturally ventilated except three of them in Pamplona, equipped with HRV.

The data collected in CISC forms part of the campaign carried out by the IETcc of the CSIC with the support of the Ministry of Housing to increase knowledge of IAQ in existing dwellings with natural ventilation systems. A total of 12 well-maintained dwellings were monitored, with measurements taken at different times of the year for periods of 16 days on average. The monitoring was conducted between 6 December 2017 and 9 March 2020. The levels of CO_2, RH and temperature were monitored inside different living rooms. All dwellings had natural ventilation systems, and vertical natural ventilation ducts (shunts) were observed in 83% of the cases. The dwellings exhibited a variety of construction typologies common in Spain, highlighting the reinforced concrete structures and the brick façades with cavity walls. The dwellings were situated in Madrid, a city with a continental climate, which serves to exemplify the climatic conditions in a significant portion of Spain. Further information is available at Garcia-Ortega & Linares- Alemparte (2023) and Garcia-Ortega (2024).

USA: HENGH, LIA

The HENGH study evaluates the impact of California's Title 24 mechanical ventilation requirements on IAQ in 70 homes built between 2011 and 2017, focusing on energy efficiency and pollutant exposure. Mechanical ventilation, mandated to address IAQ issues arising from improved airtightness, was assessed through pollutant monitoring, activity tracking, and system performance tests. Most homes met or exceeded ventilation requirements, with median formaldehyde levels 38% lower than those reported in a 2007–08 study, and pollutant concentrations largely below health guidelines. However, operational challenges were noted, with ventilation fans functioning in only 25% of homes at first inspection, and inadequate labeling of controls. The findings highlight the need for improved labeling and control mechanisms to ensure consistent ventilation system use and compliance.

The LIA study highlights the inadequacy of kitchen ventilation systems in meeting California's Residential Building Code standards for controlling indoor air pollutants, particularly in low-income apartments. It involved field studies in 23 apartments, analysis of ventilation use in 71 homes, performance tests of over-the-range microwaves with exhaust fans, and pollutant exposure simulations. Results showed frequent operational deficiencies in mechanical ventilation systems, leading to elevated NO2 levels during gas cooking. Range hood usage was low, particularly in apartments, and was influenced by cooking frequency and pollutant generation. Over-the-range microwaves performed comparably to similarly priced range hoods. Findings emphasize the need for updated performance standards to ensure effective ventilation, particularly for substantial cooking activities in smaller, low-income homes.

Various countries: Passivhaus (SF1, SC1, MX1)

This study explores the suitability of the Passivhaus to provide and maintain high levels of IAQ in three contrasting environments: Mexico City (warm-humid climate), San Francisco (temperate climate) and Dunfermline (cold climate). One of the challenges in this area is the feasibility of collecting enough IAQ data from homes. PM2.5, tVOC, CO2, temperature and relative humidity were measured in Passivhaus and non-Passivhaus (control) dwellings at five-minute intervals. The data were collected simultaneously in the living room, kitchen, and bedroom for twelve, nine, and six months in Mexico City, San Francisco, and Dunfermline. Data from Passivhaus and control dwellings were compared to ambient levels, which allowed to evaluate the homes' level of protection against or exposure to the ambient and internal sources of pollution. The analysis of the environmental factors suggests that Passivhaus dwellings have the potential to offer a higher degree of protection against air pollution compared to the control homes. The relative levels of protection, however, depend on outdoor pollution and occupant behaviours. No significant differences between the prevalence of overheating between Passivhaus and control homes were observed. However, warmer temperatures that could lead to a higher risk of overheating and dryer environments could be perceived as unintended consequences of this approach. While the results of this study cannot be generalised, they nevertheless provide much-needed evidence on the IAQ performance of Passivhaus dwellings, enhance our knowledge of IAQ in Passivhaus homes and promote their future development in different locations.

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