

# Health Implications of Energy-Efficient Housing Designs: Critical Factors and Solutions

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## Abstract

Energy-efficient buildings designed to meet contemporary standards may introduce new health risks. Indoor air quality is determined by building design, construction quality, and occupant behaviour. The objective of this study was to identify potential health-related risk factors that can be detected at the design stage of residential buildings.

We analysed floor plans and visual documentation of 150 detached houses from the Hungarian National Model Plan Catalogue, which provides cost- and energy-efficient designs that are compatible with local urban character and offer high living standards for middle-class households. Eighteen architectural factors were identified that may adversely affect indoor air quality through room sizing, spatial configuration, ventilation potential, and thermal performance.

The average planned floor area of the house designs was 134.1 m<sup>2</sup> (range: 60–295 m<sup>2</sup>), with a mean of 4.4 rooms (range: 2–7). Six percent of the designs featured flat roofs, while 64% had unconverted pitched roofs. Thirteen and a half percent were permitted for sloping sites, where deficient waterproofing increases moisture-related risks. Based on design documentation, natural cross-ventilation could not be ensured in 59.3% of dwellings (14.7% in living rooms and 58% in bedrooms), indicating limited natural ventilation potential.

The installation of mechanical ventilation systems is constrained where dedicated technical spaces are lacking (28.7%). In 18.7% of cases, neither natural nor mechanical ventilation was planned. Basements or semi-basements opening directly into living spaces appeared in 4% of the designs, while attic access was always located within living areas. Attached garages were present in 14.7% of the plans, representing potential sources of indoor pollutants.

Additional indoor air contamination may occur in dwellings with fireplaces (19.3%) and open-plan kitchens (88%), due to combustion by-products and fungal spores associated with firewood storage and food preparation. Condensation and mould growth may develop at geometric thermal bridges (78%), corner windows (22.7%), and junctions between windows and partition walls

(10.7%). Increased humidity loads and dust mite proliferation were observed in combined bedroom–bathroom layouts (9.3%).

Hidden mould growth in bedrooms is frequently associated with water infiltration in gypsum board walls, particularly where non-load-bearing partitions separate bedrooms from wet rooms (68%). A compounded risk occurs when inadequate cross-ventilation and thermal bridges are present in the same space (54.7%).

The findings indicate a clear need for enhanced professional training of designers and engineers regarding the health impacts of modern energy-efficient buildings. Certain risk factors become critical primarily in cases of poor construction quality or inappropriate building use, highlighting the importance of technical supervision during construction. Furthermore, occupants must be informed about proper building operation and maintenance practices.

Through these measures, it is possible to improve not only the energy performance of buildings but also the health and quality of life of their occupants.