



# Are Naturally Ventilated LEED Buildings Healthier?

Stefan Storey<sup>a</sup>, Karen Bartlett<sup>b</sup>

## Summary

- Green building rating systems such as Leadership in Energy and Environmental Design (LEED) employ a variety of design solutions to reduce energy and minimize environmental damage. These solutions, such as the use of passive ventilation, do not necessarily lead to improvements in occupant health
  - Passive ventilation strategies employed to reduce energy can lead to uneven airflow distribution and low air exchange rates. This can potentially lead to localized increases in building related emissions such as the off-gassing of volatile organic compounds.
  - Methods to reduce volatile organic compounds (VOC) and airborne particulate entrainment, such as the elimination of carpets and furnishings, can result in increased acoustical noise and reverberation time. Passive ventilation apertures that allow the free movement of air between rooms and corridors can lead to uncontrolled noise transmission.

- Prescriptive measures embedded in the LEED rating system and the structure of the rating method (selective point scoring) do not always ensure high Indoor Air Quality (IAQ).
  - LEED recognizes the need to encourage low emission materials and provides support for alternative material selection. However, periodic measures of performance provide meaningful information for building managers and occupants.
  - LEED buildings may qualify for a high level of certification with multiple points for energy efficiency but the minimum number of points for IAQ. This means that a high certification level such as Platinum or Gold is not necessarily synonymous with high quality indoor environments.
- There exists a research gap between how buildings are designed and how buildings perform in terms of human health. The knowledge gap can be remediated by:
  - Incorporating lessons learned from Sick Building Syndrome (SBS) studies which can be used to inform both future exposure studies and mitigation strategies for green buildings with ventilation problems.
  - Acknowledging the need to move away from prescriptive design processes employed by LEED and towards performance-based measurements enforced by regionally determined benchmark standards.

evidence  
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<sup>a</sup> Institute of Resources, Environment & Sustainability, University of British Columbia

<sup>b</sup> School of Environmental Health, University of British Columbia

## Introduction

This report, highlighting pertinent indoor health issues for naturally ventilated LEED buildings, is relevant for building health inspectors, building code regulators, building science researchers, and regional policy-makers. The report summarizes the potential health impacts to building occupants, the effectiveness of LEED New Construction (NC) indoor air quality strategies and the research gap between building design and measured performance.

### What is a LEED building?

LEED NC 3.0 is a voluntary, market-based building assessment method. LEED uses a point scoring system to rate the “greenness” of a building on an escalating scale from LEED Certified (40-49 points) to the highest level LEED Platinum (>80 points). Points are distributed in categories spanning many building metrics, including water efficiency, low-impact building site location, energy and atmosphere impact minimization, material and resources consumption, and indoor environmental quality (IEQ).

### LEED 2009 strategies on IEQ

For LEED NC, there are 15 points available for IEQ, of which 2 points are mandatory and 13 are optional. The two mandatory points require indoor ventilation rates to minimally perform to ASHRAE 62.1-2007 guidelines and to minimize the entrainment of tobacco smoke in occupied zones. The non-mandatory points include monitoring of CO<sub>2</sub> levels, increased ventilation, an indoor air quality management plan for the construction and pre-occupancy phases, the use of low emission materials, and the management of indoor chemical/pollutant source control. The remainder of the points are available for supporting indoor comfort and verification. LEED does not significantly differentiate between the common indoor pollutants which include volatile organic compounds, aldehydes including formaldehyde, biologic agents including allergens, mould and endotoxins, ultrafine particulate matter including combustion products, and gases including carbon monoxide or H<sub>2</sub>S from sanitary vents. LEED does not specify occupancy limits for each of these IAQ metrics. Instead LEED outlines mitigating strategies such as the use of materials that emit low levels of Volatile Organic Compounds (VOC)<sup>1</sup>, increased ventilation (30% over ASHRAE 60.1-2007 for mechanically ventilated buildings and (CIBSE)

Applications Manual 10: 2005 guidelines for naturally ventilated buildings), air flush-out protocols for construction and pre-occupancy phases, basic guidelines to control indoor chemical dispersion, thermal comfort guidelines (ASHRAE 55-2004) and a Post-Occupancy Evaluation (POE) survey.

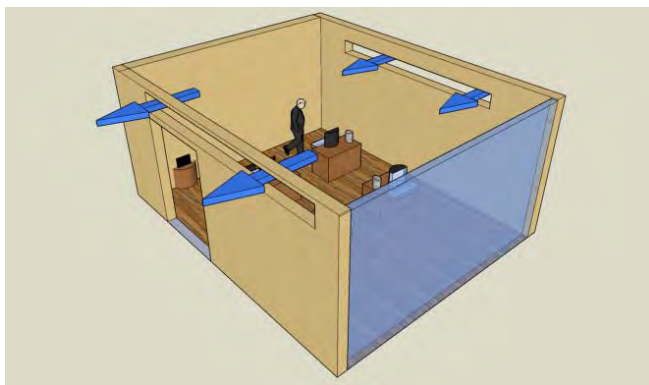
## Ventilation strategies and Indoor Environmental Quality

The overall intent of the LEED approach is to combine energy efficiency, environmental impact reduction, and high indoor air quality. One of the most pervasive building design strategies used to achieve these design goals is the use of natural ventilation. Broadly classified, there are three modes of ventilation: fully mechanical, naturally ventilated, and hybrid systems. Natural ventilation (NV) relies on the stack effect (vertical buoyancy), or crosswinds (horizontal wind pressure), to introduce outside air to occupied spaces. NV buildings save energy by avoiding the use of motor driven air handling units.<sup>2</sup> Eliminating forced air also has the advantage of lowering fibre counts by reducing the entrainment of small particulate matter residing in air ducting systems. Studies have shown that mechanical systems can have up to four times the number of suspended airborne dust particles when compared to NV buildings.<sup>3</sup> However, while NV buildings have lower dust counts, and a reduction in acoustical noise generated by mechanical blowers and air vents, they expose indoor occupants to other potential health risks. Natural ventilation relies on small differential pressure differences between the outside air and interior spaces. These small pressure differences are relatively sensitive to local wind and temperature fluctuations and can lead to non-uniform flow rates, both spatially and temporally.<sup>4</sup>

- Outdoor pollution sources: Air intakes for stack-effect ventilated buildings are often located at low levels of the building structure. Direct outdoor air supply at street level can allow traffic pollution (combustion gases and ultrafine particulate matter) to enter the building unchecked and cause degraded indoor air quality.<sup>5, 6</sup>
- Indoor pollution sources: Without adequate venting of all interior spaces, local concentrations of indoor pollutants can build up in local regions within the building. Of particular concern is the potential of VOCs, such as formaldehyde, which can accumulate in rooms containing stagnant air. This is a critical issue for the off-gassing of new

furnishings and finishings after a renovation or rebuild.<sup>7</sup>

- Additionally, natural ventilation may allow the transmission of internally generated noise. Ventilation apertures are installed in NV buildings to allow airflow between rooms and offices. These apertures also allow the transfer of unattenuated noise (see Figure 1). In office environments, noise levels in LEED buildings have been shown by POE studies to be unsatisfactory. Recent studies suggest that chronic exposure to low and medium intensity (50-75 dBA) noise is also an important environmental stressor.
- Studies in school and office environments have shown elevated blood pressure and urinary stress hormone levels associated with increased exposure to low-level noise.<sup>8,9</sup>
- Workers in noisy office environments often self-report increased levels of stress<sup>10,11</sup> and noise has been linked to stress related symptoms (headaches, nausea, musculoskeletal problems) in people suffering from "Sick Building Syndrome" (SBS).<sup>12-14</sup> Additionally, low frequency noise has been found to sensitize occupants to the symptoms of SBS.<sup>15</sup>



**Figure 1.** Ventilation aperture configuration in NV buildings: Typical natural ventilation pathways are located above doorways, with the arrows in the figure representing airflow. In practice, the width of the apertures varies, with the slots frequently designed to span an entire wall of an office.

The issues outlined indicate a unique set of challenges to ensuring high indoor environmental conditions in NV buildings. However, experimental studies have shown that natural ventilation strategies can work effectively if occupant behaviour is well-informed and occupants have easily accessible controls.<sup>16</sup> High-quality comfort can be attained in NV buildings, but considerable attention must be directed to the design of intuitive

controls that enhance the ability of occupants to adapt to adverse conditions.<sup>17-19</sup> Well-managed and properly operated NV buildings have been found to reduce the reported frequency of SBS type symptoms.<sup>20-23</sup>

## How is LEED performing?

Broadly, performance evaluation is divided into three groups: pre-build design (target) performance, post-occupancy evaluation by users, and measured analytical performance. The current understanding of LEED indoor environmental performance is underdeveloped; although numerous post-occupancy studies involving building occupants have been completed, studies focused on the efficacy of design approaches and measured performance research are sparse.

- The design, or anticipated, performance of LEED has been reviewed by the National Center of Healthy Housing (NCHH).<sup>24,25</sup> Guidelines for LEED homes were compared against a comprehensive basket of NCHH best practices for IEQ strategies. LEED homes were found to be trailing behind the American Lung Association (ALA) Health House, EPA Indoor Air Package, and Enterprise Community Partners Green Communities guidelines, but superior to the National Association of Home Builders Green Building Program. Of the problems cited, protection from contaminants such as lead, radon, and pesticides are not uniformly covered by LEED.
- Post-occupancy evaluations of LEED buildings show that the acoustic performance of LEED consistently lags behind conventional buildings.<sup>26,27</sup> For LEED buildings, considerations such as office layout are critically important for IEQ.<sup>28</sup> Open plan offices, often adopted in NV design, exacerbate problems such as noise transmission, speech privacy, thermal comfort, and lighting distribution.
- Measured performance studies of NV LEED buildings are relatively rare; however, preliminary studies show that measured CO<sub>2</sub> levels in non-LEED NV classrooms can exceed ASHRAE 62 limits.<sup>29</sup> Similarly, acoustics studies have shown excessive noise transmission in NV "Green Buildings."<sup>30,31</sup>
- Although LEED encourages the installation of CO<sub>2</sub> sensors (non-mandatory point IEQ Credit 1), CO<sub>2</sub> readings do not necessarily act as a proxy variable to indicate IAQ.<sup>32</sup> Because occupants are usually

the source of CO<sub>2</sub>, clearly organic compounds can build up even when occupancy is low. Furthermore, LEED does not set any numerical limits on the presence of any of the main analytes of IEQ during occupancy. Paradoxically, LEED lists hard limits for IAQ pollutants during construction and pre-occupancy phases, but no limits for the occupancy phase.

Understanding the IEQ performance of buildings is best determined through either continuous or at least periodic interval monitoring. Leadership in this regard has been taken by the Living Building Challenge which requires air quality testing pre-occupancy and after nine months of occupancy to measure levels of Respirable Suspended Particulates (RSP) and Total Volatile Organic Compounds (TVOC).<sup>33</sup> Developing a protocol on periodical performance measurement, in addition to rigorous benchmarks, will be key to ensuring high performance from LEED buildings.

## Conclusion

Naturally ventilated LEED NC buildings are a major step forward in terms of supporting high IEQ. However, a weakness of the LEED IEQ points system is a reliance on a prescriptive approach. Without mandatory measured performance strategies, along with benchmark limits for VOC and other pollutants, high IEQ cannot be ensured. Additionally, high levels of LEED Certification do not necessarily result in high IEQ. Since most LEED points are voluntary, many points can be scored in other areas, such as energy efficiency, meaning that points acquired for advanced IEQ can be relatively few.

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## Evidence Gaps

Currently, little is known about the performance of NV LEED. This is partly due to the relatively recent arrival of large numbers of LEED Buildings and also due to the difficulty in obtaining permission to test buildings. With the impending exponential increase in LEED buildings, further research is required to identify appropriate IEQ performance indices, types of exposure for occupants, collective impacts of exposure, types of interventions, and the relative costs and benefits of resulting health outcomes. Exposure information needs to be applicable to a broad spectrum of building types, to various populations, and tailored to individual cultural and geographical needs.<sup>34-36</sup> Additionally, building designers need to involve multiple stakeholders to ensure that policies and methods employed to support high IEQ involve building owners, managers and occupants during the design phase.<sup>37</sup> For example, 'Green leasing' provides an opportunity to develop binding agreements between owners and leaseholders so that both parties can benefit from performance-based IAQ strategies.

Finally, measures must be taken to fill the research gap between building design and building performance. Novel research is required to investigate indoor chemistry, the mode of dispersion of indoor aerosols over short-time frames, and the interactions between various volatile indoor air pollutants.<sup>38, 39</sup>

## Further Information Sources:

Future studies in IEQ can refer to surveys of jurisdictional guidelines on IAQ.<sup>34, 40, 41</sup>

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400 East Tower  
555 W 12<sup>th</sup> Avenue  
Vancouver, BC V5Z 3X7

Tel.: 604-707-2445  
Fax: 604-707-2444  
[contact@ncceh.ca](mailto:contact@ncceh.ca)



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