Why natural ventilation?

Documented benefits of natural ventilation in the scientific literature

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1 Energy efficiency

It is difficult to quantify in a general way the potential energy savings related to natural ventilation since they depend on the intended use of the building and the climate in which it lies. However, natural ventilation relies on natural forces and does not require fan to drive airflows. Electrical energy of fans can constitute 25% of the overall electrical energy consumption of a mechanical ventilated building. To some extent, a balanced mechanical system can compensate for this by making use of heat recovery, but to be successful a very tight envelope is required (1).
The sources of energy savings related to natural ventilation strategies are as follows:

- Reduction in the fan power used for mechanical ventilation to drive flow into and out of the building;
- Reduction of cooling loads due to the increased ventilation rates (2,3);
- Reduction of cooling loads due to more relaxed comfort ranges (see par. 7).

The potential building energy demand reduction also depend on the set of energy savings measures, such as reducing the internal loads, improving building envelope air tightness and installing external shading systems. In mild climates, a reduction of internal and solar loads implies less cooling demand and also smaller energy savings due to natural ventilation. In cold climates, highly insulated and airtight buildings have to face with high overheating risk (4) which can be significantly reduced by means of natural ventilation (5). In warm climates, a reduction of internal and solar loads implies energy savings due to the less use of air conditioning.

2 Potential for lower capital cost

HVAC equipment for mechanical ventilation and air conditioning can account for up to 20% of the capital cost of the new building or retrofit intervention.
If natural ventilation systems can replace mechanical ventilation and air conditioning system entirely, then natural ventilation is less costly. The Chartered Institution of Building Services Engineers (CIBSE) (6) outlined benchmark comparison for capital cost savings of the order of 15% for naturally ventilated buildings compared to the air conditioned ones.
However, design costs can be higher. As natural ventilation design affects building shape, architectural and urban decisions, both for the building and the surroundings, it is during early-design-stages when the definition of ventilation strategies is more effective (7). Most experts agree that the skills of a multidisciplinary design team and an Integrated Design Process (IDP) become indispensable to the implementation of an effective natural

ventilation strategy. This implies 5 - 10% higher design effort and costs during the early design phases because more expertise and know-how are required. However, costs of the later design phases could be 5 - 10% lower, operational costs could be 70 - 90% lower and costs due to building faults could be 10 – 30 % less because of better planning and better follow up during construction.

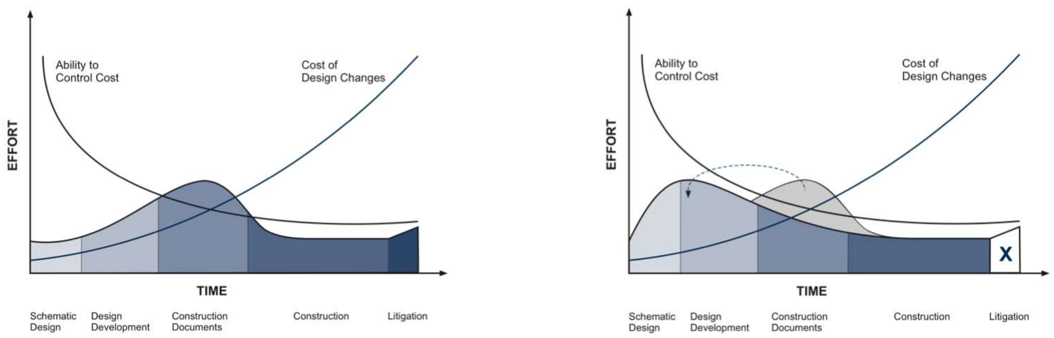


Figure 1. Traditional design process (left) and integrated design process (right). Source: MatrID project (8)

Depending on to the indoor environment expectations of the building owner, natural ventilation systems might not be enough to keep an acceptable thermal comfort and indoor air quality level and mechanical system shall supply to this deficiency. Mixed mode ventilation system are more expensive since capital costs include both mechanical system and natural ventilation system costs. The higher capital costs can be however justified by a life cycle assessment analysis considering the potential lower operating costs as well as by other qualitative, psychological effects of natural ventilation on building occupants (see point 9).

3 Reduced space for plants

Natural ventilation uses typically between 2-5% less plant space versus 5-8% used by HVAC, which can be utilized and improve net to gross ratios (6).

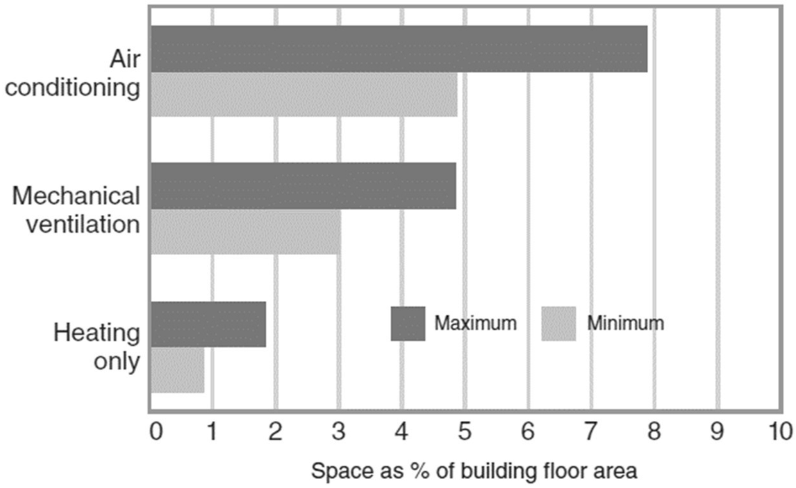


Figure 2. Space requirements for HVAC systems (plant-room and service shafts as a percentage of gross floor area). Source: CIBSE Applications Manual AM10 (6)

Natural ventilation does not require space for duct network leaving free use of floor-to-ceiling height. Additional space is often required for atria and chimneys, but this can be exploited also for daylighting purposes.

Therefore, the adoption of a natural ventilation system instead of mechanical ventilation can improve building aesthetics.

Thanks to the lower impact on building aesthetical appearance, natural ventilation is a preferred solution in case of historic buildings, often implemented by reactivating natural ventilation strategies used originally (9).

4 Plug and play refurbishment opportunity

The trend towards plug and play refurbishment systems aims at accelerating the building energy retrofit process. Unlike traditional building refurbishment processes, plug and play building envelope renovation can happen very fast and take place while users keep occupying the building with minimal disruption. Since plug and play system often includes window replacement, natural ventilation strategies can be easily implemented by adding window actuators.

TNO, an independent Dutch research center, estimates that currently 86% of Europe's windows are equipped with inefficient glazing (10). Considering the fact that on average windows remain in buildings for 30 years and currently more than 70% of the existing building stock was constructed before 1990 (11), the replacement of old windows became one of the most common energy retrofit measure.

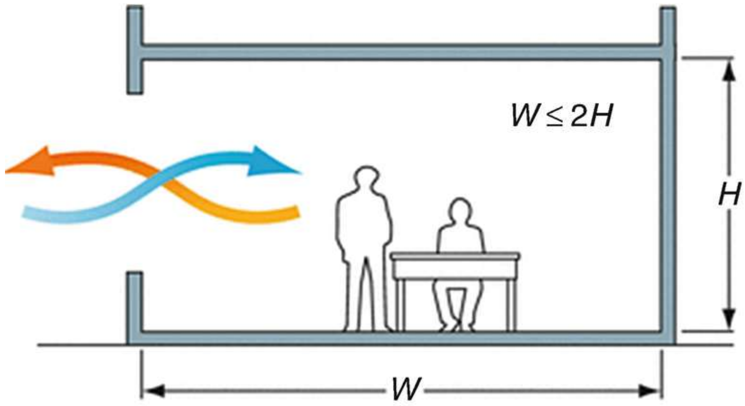
Furthermore, new windows and efficient HVAC systems are known to increase the value of a property.

5 Reduced operation costs, maintenance and replacement

Natural ventilation systems are almost maintenance free. There is no filters replacement need and no ducts to be cleaned.

6 Compatibility with daylighting

Measure to enhance daylight also favour the use of natural ventilation (12). Both daylighting and natural ventilation benefit from limited penetration depth (typically W<2H for single-sided ventilation, W<5H for cross ventilation) and increased floor-to-ceiling height (6). Glazed skylights promote stack effect allowing stack ventilation and maximum daylight.



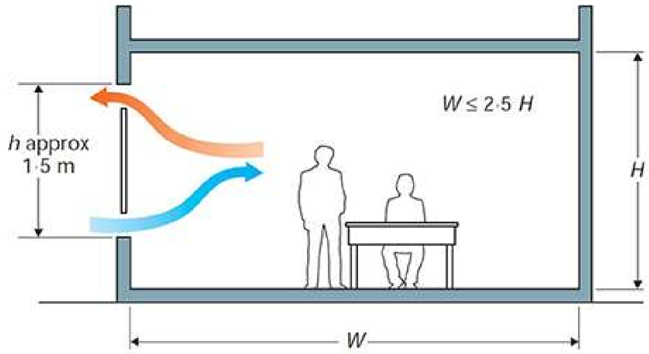


Figure 3. Recommended penetration depth for single sided-ventilation with single opening (top), with double opening (middle), cross ventilation (bottom). Source: CIBSE Applications Manual AM10 (6)

7 Increased range of thermal comfort

In naturally ventilated buildings people tend to feel comfortable in much warmer temperatures than in mechanically cooled buildings due to shifting expectations and preferences as a result of occupants having an active role on indoor environment control.

This was demonstrated by a research study conducted in the '90s under the supervision of the American Society of Heating, Refrigerating and Air Conditioning Engineers (13). Researchers from US and Australia analysed a large database (14) of research results in building comfort studies from all over the world. The results reported a clear dependence of indoor comfort temperatures on outdoor air temperature specially in natural ventilated buildings.

Based on this evidence, ASHRAE (ANSI/ASHRAE 55-2013) and EU standards (EN 15251:2007) were recently updated recommending more relaxed comfort ranges for naturally ventilated buildings (Figure 4).

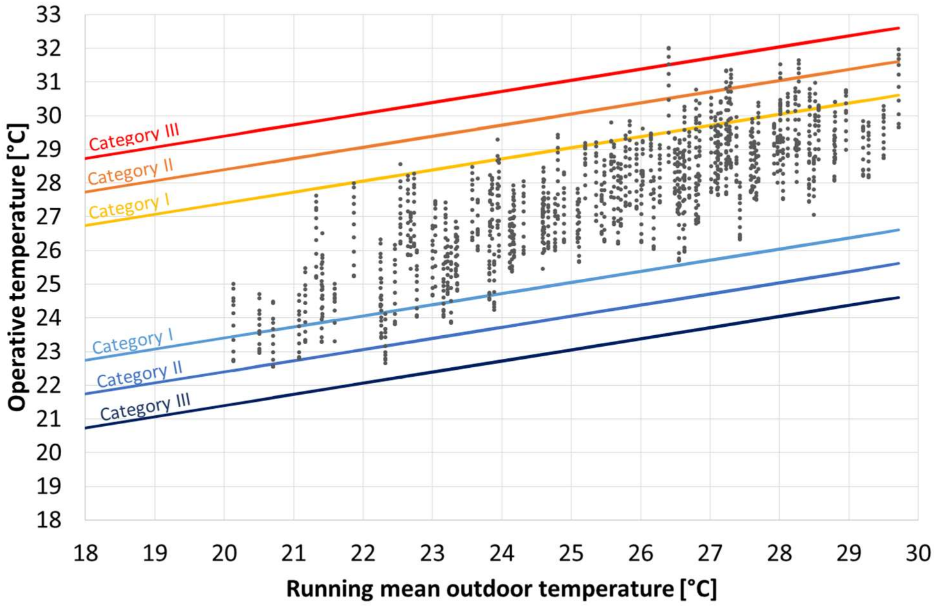
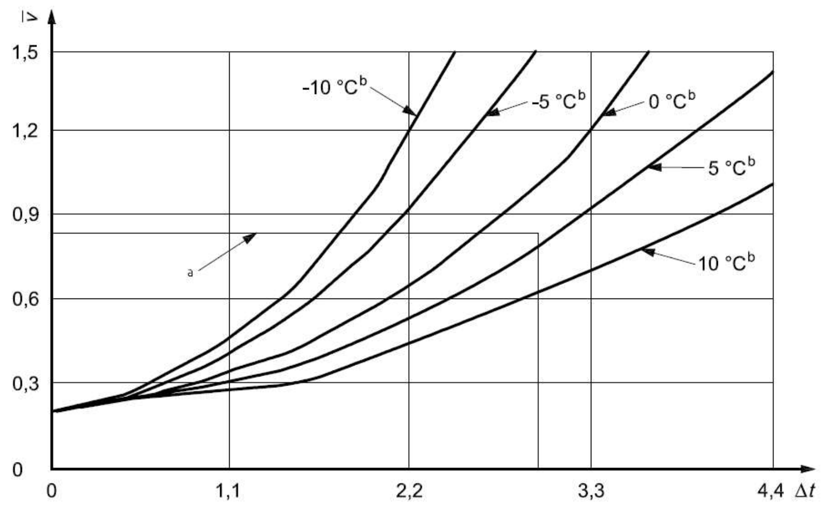


Figure 4. Upper and lower operative temperature limits depending on running mean outdoor temperature, according to standard EN 15251:2007

Furthermore, under summer conditions increased air velocity may be used to compensate for increased air temperatures. For example, as effect of an air movement with 0.5 m/s air velocity, the perceived temperature can be 1.6 K less than the room air temperature.



For light primarily sedentary activity, Δt should be < 3 °C and $\bar{v}$ < 0,82 m/s.

Key

Δt temperature rise above 26 °C

$\bar{v}$ mean air velocity, m/s

a Limits for light, primarily sedentary, activity.

b $(\bar{t}_r - t_a)$, °C (t_a, air temperature, °C; $\bar{t}_r$, mean radiant temperature, °C).

Figure 5. Air velocity required to offset increased temperature. Source: UNI EN ISO 7730:2005

8 User satisfaction and productivity

Occupants are more satisfied with their indoor environment in naturally ventilated and mixed mode buildings than in mechanically ventilated and air-conditioned buildings.

A study conducted by the Centre for Built Environment1 of UC Berkeley benchmarked mixed mode buildings over a survey database of over 47'000 interviews of buildings occupants as performing exceptionally well compared to the building stock (15).

Another research study was conducted on 5'000 occupants of 14 German office buildings (6 of them naturally ventilated and 8 of them air-conditioned) built between 1990 and 1995 (16). Interviews of building occupants showed that occupants of naturally ventilated buildings are significantly more satisfied with their thermal environment than occupants of air-conditioned buildings.

The occupant preference of natural ventilation over air-conditioning and mechanical ventilation is mainly because occupants can easily access and understand their indoor environment control and are not completely isolated from the external environment. Occupants have generally higher control on indoor environment in naturally ventilated buildings since openable windows can be easily designed into a natural ventilation strategy. Research studies based on available epidemiological data show that in general, higher ventilation rates will reduce health outcomes (17). The minimum ventilation rates above which some health outcomes can be avoided are currently under discussion. Occupants of naturally ventilated buildings experience from 25% to 67% less sick building syndrome symptoms compared to those in air-conditioned buildings (18). This benefits could be however outweighed by higher exposure to ozone and PM related health effects depending on outdoor air pollution levels (19).

Although the amount of research on the relationship between user satisfaction with their IEQ and productivity is limited at this time, the results increasingly link a higher IEQ to higher productivity both in schools and office buildings (12,20,21).

The Center for Building Performance and Diagnostics[2] at Carnegie Mellon University developed a case-based cost-benefit analysis tool (Building Investment Decision Support) (22) that calculates the economic value added of investing in high performance building systems based on the findings of building owners and researchers around the world. They demonstrated that replace or supplement mechanical ventilation with natural ventilation

[1] http://www.cbe.berkeley.edu/
[2] http://soa.cmu.edu/cbpd/

or mixed-mode conditioning achieves 0.8-1.3% health cost savings, and 3-18% productivity gain, for an average ROI of at least 120%.

9 Sustainable design

The current trend towards sustainable design is promoting the use of natural ventilation for new buildings and in building renovation. Natural ventilation relies on pressure differences inside and around the building due to temperature stratification or wind. Therefore, it is regarded as a passive solution and part of many sustainable and high performance building guidelines such as:

- ASHRAE Advanced Energy Design Guides https://www.ashrae.org/standards-research--technology/advanced-energy-design-guides
- National Institute of Building Sciences: Whole Building Design Guide https://www.wbdg.org/resources/naturalventilation.php#
- LEEDv4 for Building Design and Construction http://www.usgbc.org/guide/bdc
- Living Building Challenge https://living-future.org/sites/default/files/16-0504%20LBC%203_1_v03-web.pdf
- Environment Design Guide http://www.environmentdesignguide.com.au/
- Energy Design Resources: Design guidelines https://energydesignresources.com/resources/publications/design-guidelines.aspx
- A guide to Integrated Energy Design http://www.integrateddesign.eu/downloads/Some_principles_revised_NormalQuality.pdf
- CIBSE Guide A: Environmental Design http://www.cibse.org/knowledge/knowledge-items/detail?id=a0q20000008I79JAAS
- Sustainable tropical building design – Guidelines for commercial buildings http://www.cairns.qld.gov.au/__data/assets/pdf_file/0003/45642/BuildingDesign.pdf

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