Re-thinking Organizational Savings through HVAC

# Good Indoor Air Quality Leads to Good Decisions

*Insufficient ventilation causes human-produced carbon dioxide to build up indoors, decreasing employee well-being and productivity substantially. With accurate $CO_2$ measurement, both energy efficiency and employee well-being can be achieved simultaneously.*

According to the US Environmental Protection Agency heating, ventilation and air conditioning (HVAC) systems represent around 42% of the total energy costs of an average office building. This percentage depends on the climate where the building is located, but all in all, the HVAC system makes up a significant portion of the energy costs of an office building (**Figure 1**).

Green building initiatives, like the US Green Building Council's LEED v4, British BREEAM and Australian Energy Rating all encourage commercial constructors and building operators to reduce their impact on environment by increasing their energy efficiency. Especially LEED v4 stresses the importance of precise ventilation automation control using accurate sensors. Also the ASHRAE Green Standard 189.1 (USA) and the European standard EN 13779 recommend using demand controlled ventilation (DCV) primarily to reduce energy usage while promoting healthy indoor air.

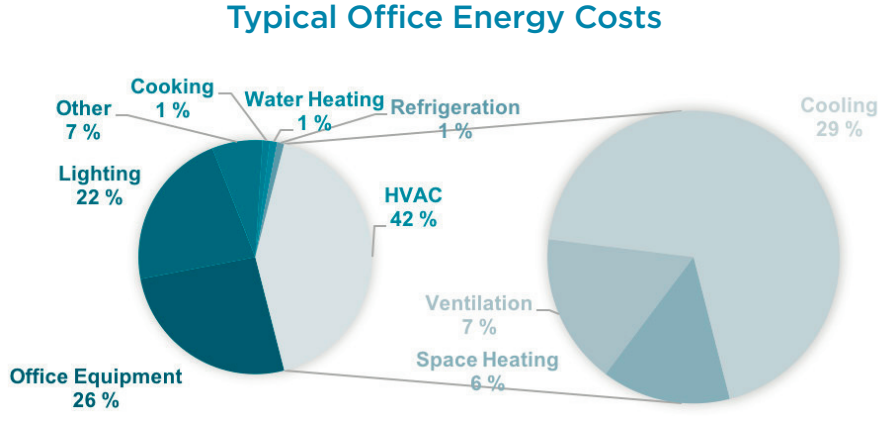


***Figure 1.*** *Typical energy costs of an office building.*

Demand controlled ventilation is proven to have a huge impact on HVAC systems' energy efficiency. The US Department of Energy conducted a research on energy savings and economics of advanced control strategies for HVAC in 2011. The research concluded that DCV contributes to the biggest energy savings in HVAC in small office buildings, strip malls, stand-alone

retails and supermarkets compared to other advanced automated ventilation strategies. Average cost savings of using DCV were calculated to be 38% for all commercial building types, which is a very significant number. The amount depends on the climate, of course; DCV is most efficient in cold climates, and coupling it with multi-speed fan control will bring more benefits also in hot climates.

## $CO_2$ Level as an Indicator of Indoor Air Quality

DVC functions by controlling ventilation according to how many people occupy a space. The aim is to provide good indoor air quality to the occupants with energy efficient ventilation.

How is good indoor air defined? The European EN standard 13779: 2007 states: "Indoor air quality can be categorized by $CO_2$ concentration." This notion sets the foundations to operate DCV by measuring $CO_2$ and controlling ventilation accordingly. The standard sets the normal expectation for indoor $CO_2$ level at 400–600 ppm, which is slightly above the normal levels in outdoor air (400 ppm). The modern ventilation systems are built around this supposition to ensure good enough indoor air quality while remaining energy efficient.

In reality, this applies mostly to modern offices with modern ventilation systems. Field studies show that regular office conditions have a 1,500 ppm concentration of $CO_2$, which may seem a very high level, but the regulatory limit considered safe for people is even higher: 5,000 ppm of carbon dioxide over an 8-hour period.

Recent studies challenge what was previously considered to be good indoor air quality. A study conducted by the National Institute of Environmental Health Sciences (NIEHS) in 2015 focused on the effects indoor air quality has on employees' cognitive abilities. The extensive study setting simulated office conditions and compared conventional offices to WWF Green and Green+[(1)] offices. Cognitive scores in crisis response, information usage and strategy, among other variables, were evaluated on the test subjects. The study showed dramatic results (**Figure 2**).

The results of the NIEHS study show how cognitive skills are decreased by the increase of carbon dioxide in indoor air. This finding shows that for example strategic skills are decreased only to 20% in indoor air with a 1,400 ppm concentration of $CO_2$ compared to the normal outdoor level of 400 ppm. Some of the more mechanical skills, like information seeking and task orientation, were not affected much. However, cognitive skills that require more advanced application of information, like crisis response, information usage and strategy, are affected the most. The study shows clearly that handling more advanced tasks becomes much more difficult when the indoor carbon dioxide levels rise.

When comparing good indoor air quality of 800–1,000 ppm of $CO_2$ to the normal level of 1,500 ppm in office buildings, it's easy to see why indoor air quality is an emerging topic. Accurate measurement of indoor air and better ventilation are vital to cognitive abilities of people working in offices.

When taking a look at the typical operating costs of an office building, we can see that energy costs stand only at 1% and rental at 9% of the overall costs, whereas employee costs stand at 90% (**Figure 3**). So is it relevant to minimize the energy

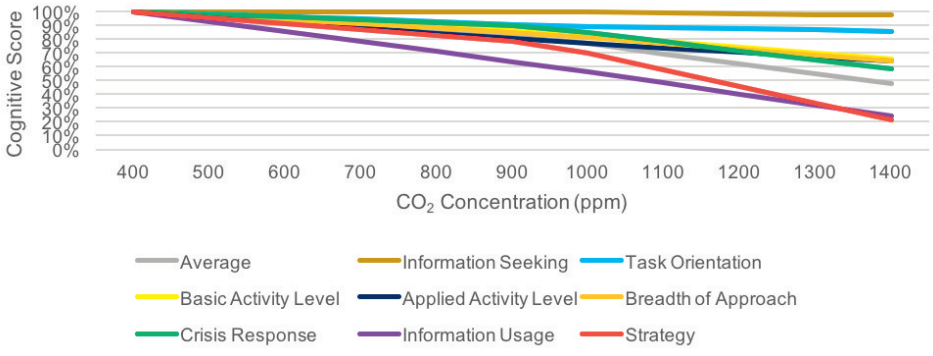


***Figure 2.*** *Impact of changes in $CO_2$ levels on employees' cognitive abilities.*

[(1)] https://wwf.fi/en/green-office/

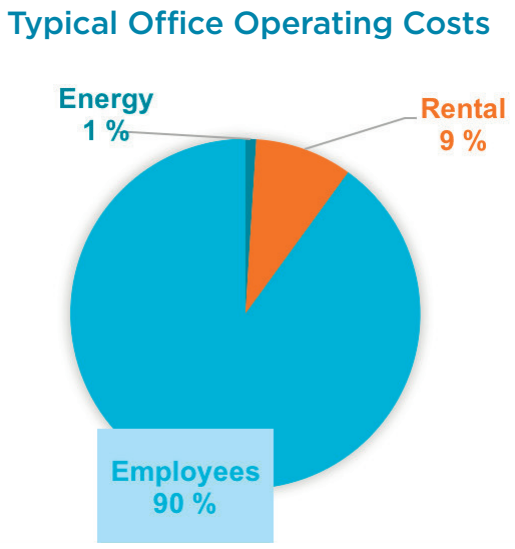


***Figure 3.*** *Typical operational costs of an office building.*

costs with strict HVAC control? Even at the expense of employees' well-being? And even when too high a concentration of $CO_2$ indoors has major impact on the cognitive skills and productivity of the employees?

## Better Productivity through Employee Well-Being

Now that we know how carbon dioxide really affects people, what does this mean on a company-wide level? Let's take a closer look at the three cognitive abilities affected the most by $CO_2$ concentration: crisis response, information usage and strategy. Firstly, a decrease in the ability to manage crisis response leads to mistakes and maybe even to dangerous situations. Secondly, decreased ability to use information has a negative impact on employee learning and productivity. Thirdly, decreased ability in strategy may lead to belated or poor decisions. In the long run, continuous insufficient ventilation may lead to many problems regarding employee well-being and increased costs, both directly and indirectly (**Figure 4**).

Many of these effects are difficult to quantify. For example, lowered employee learning has far-reaching disadvantages and effects in human resources. Also, bad and late decisions can have consequences within organizations that are impossible to evaluate in direct costs, not to mention the possible consequences of mistakes and potentially dangerous situations.

Productivity, on the other hand, can be measured. Studies indicate that better indoor air and ventilation have a positive impact on productivity. The Continental Automated Buildings Association (CABA) conducted a comparison between better buildings and other employee strategies, like workplace health programs and bonuses. With a meta-study of 500 different studies, they found out that better buildings increase productivity by 2–10%. The Federation of European Heating, Ventilation and Air Conditioning (REHVA) state that decreased ventilation lowers productivity – typing speed, for example – by 10%. The US Green Building Council commenced a meta-study in 2003 and concluded that delivery of fresh air and reduced levels of pollutants improve productivity by 11%. Furthermore, according to the analysis of the Carnegie Mellon University, better ventilation improves productivity by 3–18%.

To sum it up, the productivity gains of better ventilation range between 2% and 18%, with many studies revolving around 10%. How does

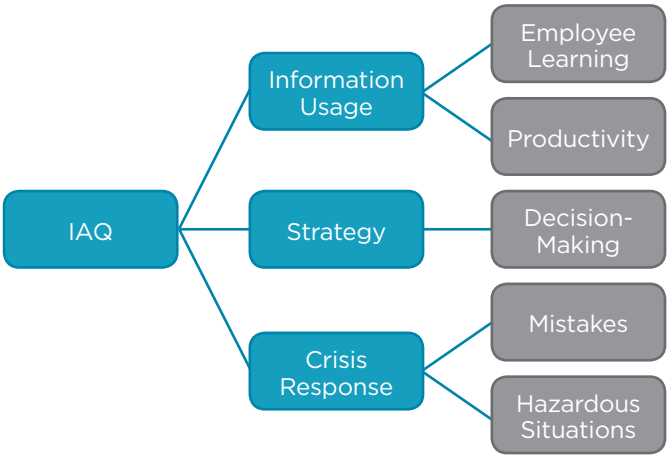


***Figure 4.*** *Continuous insufficient ventilation may have negative effects on employee well-being and increase costs.*

this finding affect costs? Assuming that an average employee costs 50,000€ a year for a company, the cost benefits of better ventilation are 1,000–9,000€ per year per person, with productivity gains of 2–18%. The annual cost savings for companies with 100 employees are 100,000–900,000€. Companies with over 1,000 employees reach savings worth millions of euros, even with the most careful estimates. And these numbers are only the cost savings in measurable productivity.

Coming back to the typical operating costs of an office building, where employee costs stand at 90%, whilst energy represents 1% of the total costs, it is easy to understand the importance of ensuring good indoor air quality over unnecessarily strict energy management. The magnitude of the difference between energy and employee costs is definitely immense. Of course, energy efficiency is as important as before, but when optimizing the HVAC systems, occupants' well-being needs to be considered even more carefully.

## Ventilation Control Today and Tomorrow

To achieve both energy efficiency and good indoor air simultaneously, accurate measurement is the key. As people's cognitive skills are affected even when the $CO_2$ concentration changes only by 100 ppm, the $CO_2$ measurement sensors must be accurate at all times, even in spaces occupied 24/7.

The energy efficiency of a ventilation system is most affected by the measurement sensor when the system relies on measuring $CO_2$ levels based on occupancy. Vaisala's sensors stay accurate throughout the years, ensuring correct measurement, efficient energy usage and fresh air for the people also in the long run.

As the impact of indoor air quality on employees' well-being is one of the emerging issues, Vaisala aims to serve the customers in the best possible way in that area as well. At Vaisala, we believe that energy efficiency will remain important in building automation also in the future, along with the developments of smart buildings and smart cities. The focus will shift more towards people's health and well-being through ensuring indoor air quality.

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