Fresh Air. Fresh People.

eBook for Architects

Why and how to use natural ventilation in your building design

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Content

Preface

Natural ventilation has always been at the heart of WindowMaster. By making buildings breath and bringing fresh air into schools, workplaces and other buildings, WindowMaster has helped to focus attention on what really matters: A sustainable and healthy climate – inside as well as outside.

By implementing natural ventilation to almost all types of buildings, we have created spaces of high quality and increased the well-being of occupants all whilst increasing the room for design and actual usage by reducing the area needed for mechanical installations. Today, we experience that WindowMaster's products and solutions are more pertinent to the market than ever before. Together with aesthetically designed rooms, health and well-being constitute one of the most important agendas of the future together with an increased focus on energy savings.

In recent years, the public discourse on sustainable architecture, and sustainability in general, has revolved around energy, CO_2 emissions and the efficient use of resources. These are all crucial for our life on this planet; yet they only compose three factors on the whole spectrum of issues facing us in our pursuance for living good, viable lives.

A comfortable indoor climate with the optimum amount of fresh air is equally important for our health and well-being. And with our health and well-being making up essential parameters to the overall quality of our lives, it is of utmost importance that we make indoor environment part of the public discussion and raise it to the same level as the questions pertaining to the human impact on outdoor environment and sustainability.

With natural ventilation, indoor and outdoor environmental issues can be addressed concomitantly while putting full focus on the architectural design of a building.

WindowMaster project: Gentofte Hospital

WindowMaster project: Frederiksberg shopping center

Introduction

Why consider natural ventilation?

Imagine you could reduce a building's area used for ventilation by 90%[1], what would be the impact on your design and final performance of that building?

This eBook has been written to address some of the issues and opportunities that Architects worldwide face when designing buildings that needs to be ventilated and meet sustainable requirements. Chunky ventilations taking up space that could have been used for more aesthetically designed rooms, unnecessary energy consumption as a result of ventilation systems, high maintenance costs and noisy mechanical fans. If these issues sound familiar, this e-book is for you.

With this e-book, we aim to share our knowledge on sustainable ventilation architecture by offering specific advice and documentation on the effects and advantages of WindowMaster products. You will learn how natural ventilation can be used to create beautiful, healthy buildings that are good for both the indoor and outdoor climate. You will discover ways in which natural ventilation can be applied to new as well as old buildings, to make them more sustainable. And you will learn how to use the principles of natural ventilation architecture to make complete use of your space, reduce construction costs and increase your green energy rating.

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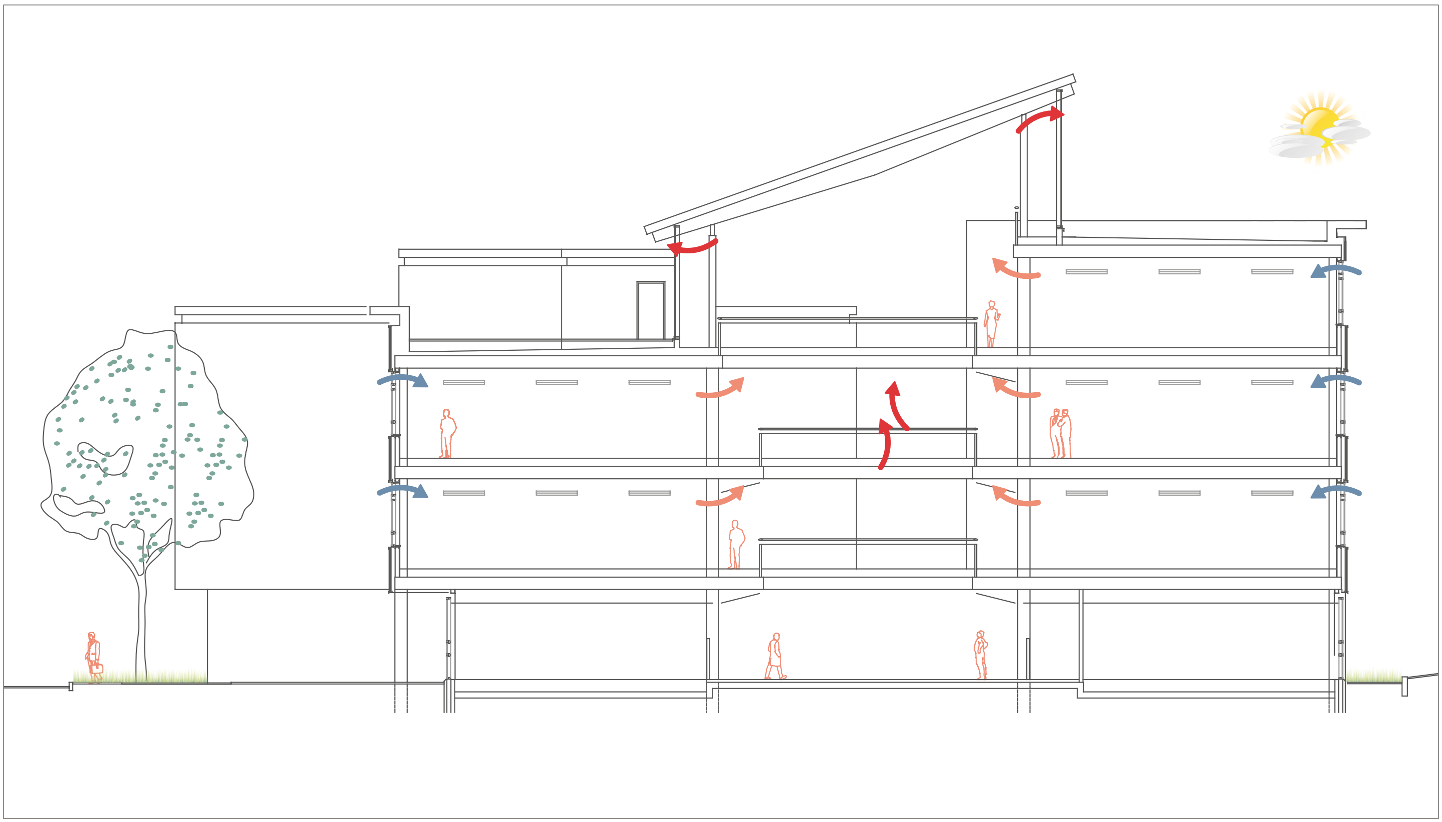
Natural ventilation

So, what is natural ventilation?

Natural ventilation is the use of natural forces, including both wind and thermal buoyancy, to regulate a building's indoor climate. These forces are created by temperature differences between the interior and exterior environment, thermal displacement within the building and winds around the building. Buildings using intelligent natural ventilation take advantage of the fact that warm air rises. When air rises, it can escape through vents, which in turn lowers the internal temperature.

The air inside a naturally ventilated building is kept fresh by controlling air change, typically by using actuated windows in the building's facade and/or roof. Ideal ventilation is achieved by an intelligent system that automatically opens and closes windows depending on numerous conditions inside and outside the building, including outdoor temperature, wind speed, wind direction, rain detection, indoor temperature, relative humidity and CO_2 level in the room.

Go to page 18 to read more about the design of natural ventilation



WindowMaster project: West Suffolk House, drawing of ventilation principle

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Indoor air quality indicators

Natural ventilation is an efficient way to control the indoor air quality. To better comprehend the impact of indoor air quality and why it is important to control, consider the amount of air we breathe per day. An average person consumes 2 kg of food and liquids per day, but breathes approximately 15 kg of air per day (corresponding to 12,000 liters). 90% of our time is spent indoors, meaning that most of the air we breathe comes from an indoor environment[2].

According to Professor Jan Sundell of the International Centre for Indoor Environment and Energy at DTU (the Technical University of Denmark) *"there is much evidence that the indoor environment, especially dampness and inadequate ventilation, plays a major role from a public health perspective, and that the economic gains to society for improving indoor environments by far exceeds the costs"[3].* Accordingly, it is vital to look at metrics that indicate the quality of the indoor air to be able to read and control the air we breathe.

Indoor air contains many pollutants and can be affected by gases (including carbon monoxide, radon and volatile organic compounds), particulates, microbial contaminants, or any mass or energy stressor that can induce adverse health conditions. Source control and the use of ventilation to dilute contaminants are the primary methods for enhancing indoor air quality in most buildings.

An average person breathes approximately 15 kg of air each day compared to consuming 2 kg of food and liquids

Today, several indicators exist to measure indoor air quality and the level of those pollutants. Greenhouse gas emissions or Carbon dioxide (CO_2) is one of the most commonly used indicators, measuring the CO_2 produced by human breathing and emitted by appliances. Other indicators include humidity and volatile organic compounds (VOCs).

TOP TIP: To design a building with a comfortable indoor climate make sure to keep down levels of VOC, CO_2 and humidity

Natural ventilation advantages

As already stated in the beginning of this e-book, natural ventilation comes with many advantages ranging from environmental benefits to improved design and lastly an enhanced indoor air quality that battles high levels of CO_2, VOCs and humidity. In the following sections, we will sum up some of the key reasons why every architect should not design a new building or retrofit an old building without first considering implementing natural ventilation.

The advantages in a nutshell

1. Beautiful architecture
No unsightly pipework or duct penetrations and no bulky ventilation units. Ceiling heights can be increased, as natural ventilation does not require suspended ceilings. More daylight and transparency, including the use of atriums for natural ventilation.

2. Lower energy consumption
Natural ventilation consumes less energy than a comparable mechanical ventilation system. The use of mixed mode ventilation can potentially reduce energy consumption even further.

3. 100% use of space
Natural ventilation enables full utilization of the building floor plate and floor to ceiling height, as there's no need to devote space to large air handling units and equipment rooms.
A mechanical ventilation system occupies up to 6.5% of a building's floor area compared to only 0.2% for a natural ventilation system.[4]

4. Green profile
Globally, commercial buildings account for up to 40% of all energy consumption.
Natural ventilation has a very low energy consumption, and thus very limited carbon emissions.
It is possible to achieve a 24-71% reduction in carbon emissions by using natural ventilation instead of mechanical ventilation.[5]

5. High user satisfaction
With a natural ventilation solution from WindowMaster, it's easy to divide your building into different zones, for instance separate office spaces, in order to address a range of different needs.
Users always have the option to override the automatic control, ensuring high user satisfaction.
In air conditioned buildings, only 50% of occupants are satisfied with the indoor temperature at one time, whereas in naturally ventilated buildings, 77% of occupants are satisfied.[6]

6. Gentle refurbishment
With natural ventilation, it's possible to create a good indoor climate in historical buildings without the need to break through walls and ceilings to make way for ducts and large ventilation units.

Natural ventilation is the obvious choice when replacing old windows with new ones simply by installing actuators to control the ventilation process.

7. Fast renovations
With natural ventilation, the renovations can be completed very quickly, thus causing minimal disruption to the lives of the building occupants. Often it is also possible to avoid having to relocate the occupants of a building during the renovation period.

8. Lower costs
The need for fewer and less expensive components and construction work makes natural ventilation a cost-effective option for achieving a better indoor climate.
Over a building's life cycle, capital costs, operating costs, and maintenance costs are 5 times lower with natural ventilation compared to mechanical ventilation and 2.5 times lower with hybrid/mixed mode ventilation.[7]
Our systems pay for themselves within less than a year, resulting in an average ROI of at least 120% for natural ventilation and mixed mode systems, thanks to energy, health, and productivity gains.[8]

9. Minimal maintenance
No filter replacement. No dirty ducts to be cleaned.

10. Better indoor climate
Studies show that people who spend time in buildings equipped with natural ventilation have fewer building-related symptoms, such as headaches, eye irritation, etc.[9]
They also show productivity gains of 3-18% compared to mechanical ventilation and savings on health costs of 0.8-1.3%.[10]
Finally, SBS symptoms can be reduced by more than 65% with a natural ventilation solution.[11]

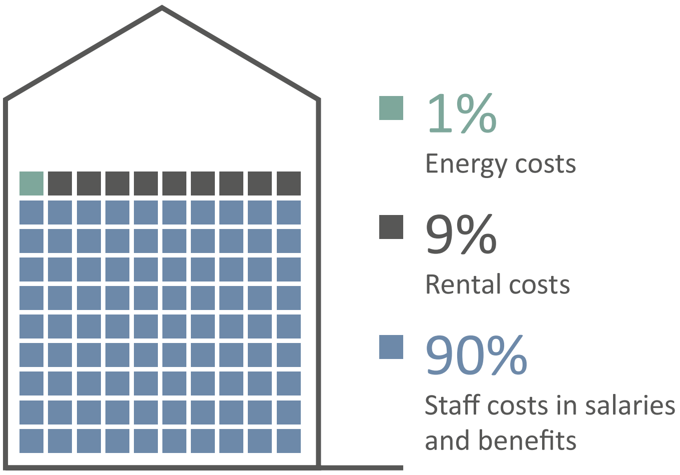
Go to page 18 to read more about designing buildings with natural ventilation ⇒

Go to page 33 to see examples of projects that have benefitted from natural ventilation ⇒

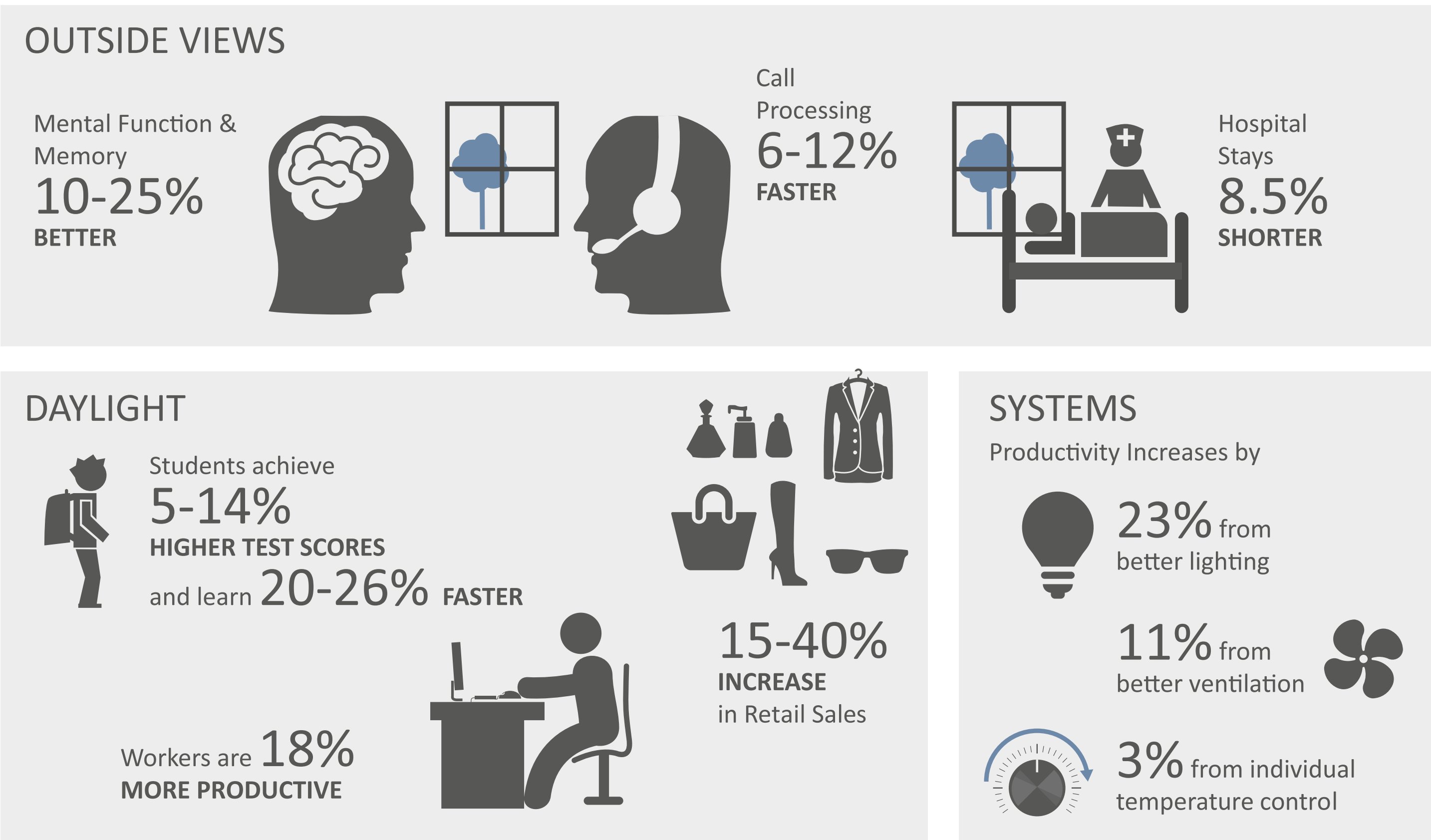
Productivity and Health benefits

The World Green Building Council (GBC) has published a comprehensive report on health, wellbeing and productivity in offices. Here, it was pointed out that staff costs, including salaries and benefits, typically account for about 90% of the business' operating cost[12]. It follows that the productivity of staff, or anything that affects their ability to be productive, should be a major concern for any organisation. An improvement in employee health or productivity can have a crucial financial implication for businesses – one that is typically larger than other financial savings associated with an efficiantly designed and operated building.

From a business perspective, there are therefore strong incentives for improving employee health and productivity. There are numerous ways to improve employee health, including exposure to daylight and access to outside views. Several certification programs such as LEED, BREEAM and DGBN exists **(read more about green certificates on page 32)** to guide the design, construction and operation of high performance buildings. Points for excellence are distributed across different categories, one of which is Indoor Environmental Quality.



Typical business operating costs[13]

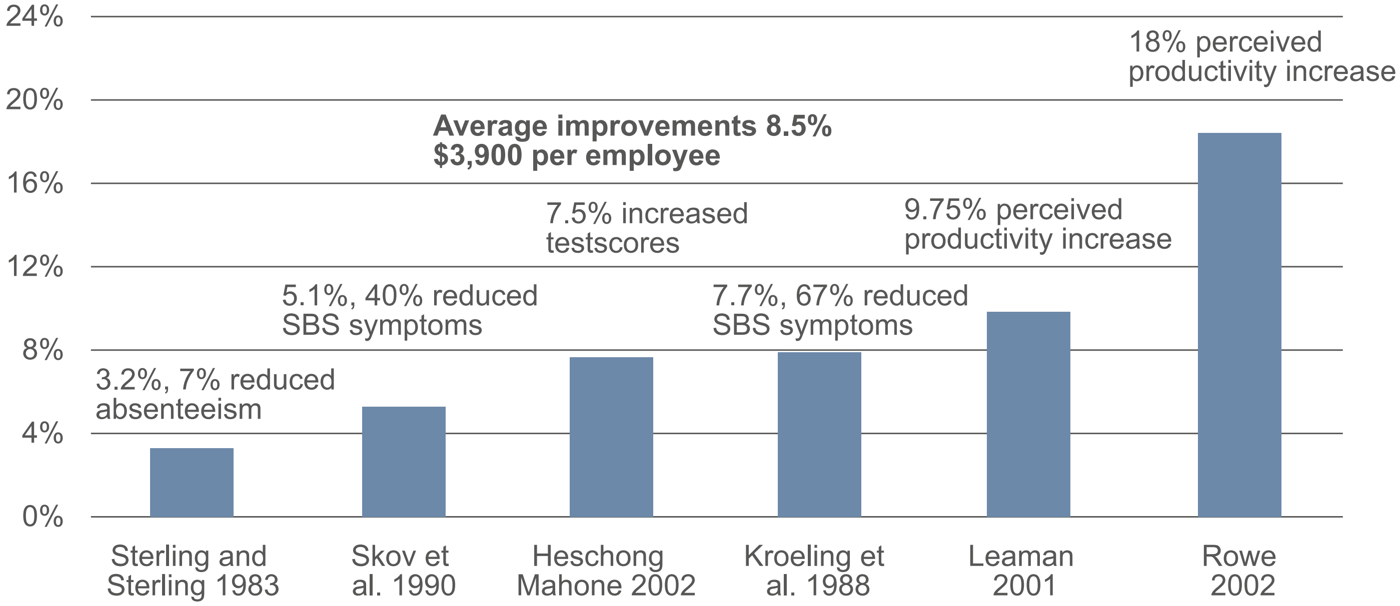


Net present value analysis of the operational cost and productivity and health benefits of LEED certified buildings

Several studies have investigated productivity gains, Sick Building Syndrom (SBS) and the health impact from natural and mixed-mode or hybrid ventilation. The illustration below highlights the results from different studies from the past 30 years, showing productivity gains ranging from 3.2% to 18% as a result of natural and hybrid (mixed-mode) ventilation being implemented.

Also from an educational perspective improving the indoor air quality will have profound effects on productivity. Studies have shown that an improved indoor climate influences the students' performance. According to a study by Fraunhofer Institute for Building Physics, enhancing ventilation, bringing down the level of CO_2 and increasing daylight will improve the indoor climate and thereby the students' ability to learn[14]. All of these things are directly linked to natural ventilation; enhanced ventilation is achieved by automatically controlled windows letting in the optimum amount of fresh air; an ideal air change rate will bring down indoor CO_2 levels; and light is allowed to enter the building through windows as opposed to having mechanical systems blocking the light.

Natural and hybrid ventilation can lead up to 18% productivity gains[15]

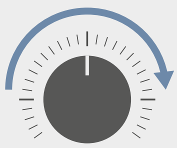


Annual Productivity Gains from Mixed-Mode Conditioning and Natural Ventilation[16]

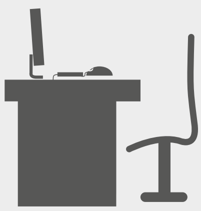
Improved indoor climate with natural ventilation can:

Maximize attention span

Improve performance with 2.8-15%



Hinder absence



Cause students to progress 7-8% faster (regardless of whether the classroom also has air conditioning)[17].

Productivity and Health benefits – the practical implications

Knowing that intelligent natural ventilation has the direct potential to increase the health and productivity of employees and students, it is time to analyze the practical implications.

Linking back to previous chapters regarding indoor air quality and the measures of these, the indirect benefits of using an automated, intelligent natural ventilation system in relation to health and well-being can be summarized to:

- The decreased level of humidity means that building occupants will feel refreshed and are less likely to suffer from asthma or allergies.
- The low levels of VOCs will decrease unpleasant smells and the risk of long-term health issues.

Buildings with operable windows and natural ventilation have 3.2% reduced absenteeism compared to sealed buildings with air conditioning[18]

- Lower CO_2 emission means less pollution in the rooms, which in turn means clean, fresh air for the occupants.
- Fresh, odorless rooms decrease the risk of headache and other illnesses.
- Fewer headaches and other health related issues will lead to decreased absenteeism in schools, which in turn will lead to fewer days off work for parents.

Economic impact of natural- and hybrid ventilation

Having already established that a better indoor climate can potentially improve both employees and students' productivity and health, it is time to put this into perspective by adding the economic gains to the equation.

A comprehensive analysis by Carnegie Mellon[19] of eight studies concluded in 2004 that natural- or hybrid ventilation could achieve 0.8 – 1.3% savings on health costs and between 47 – 49% in HVAC energy savings for an average ROI (Return on Investment) of at least 407% for new constructions and 120% for retrofits. Apart from the decreased cost on health, the analysis also showed that natural ventilation and mixed-mode systems can pay for themselves in less than one year due to energy and productivity gains.

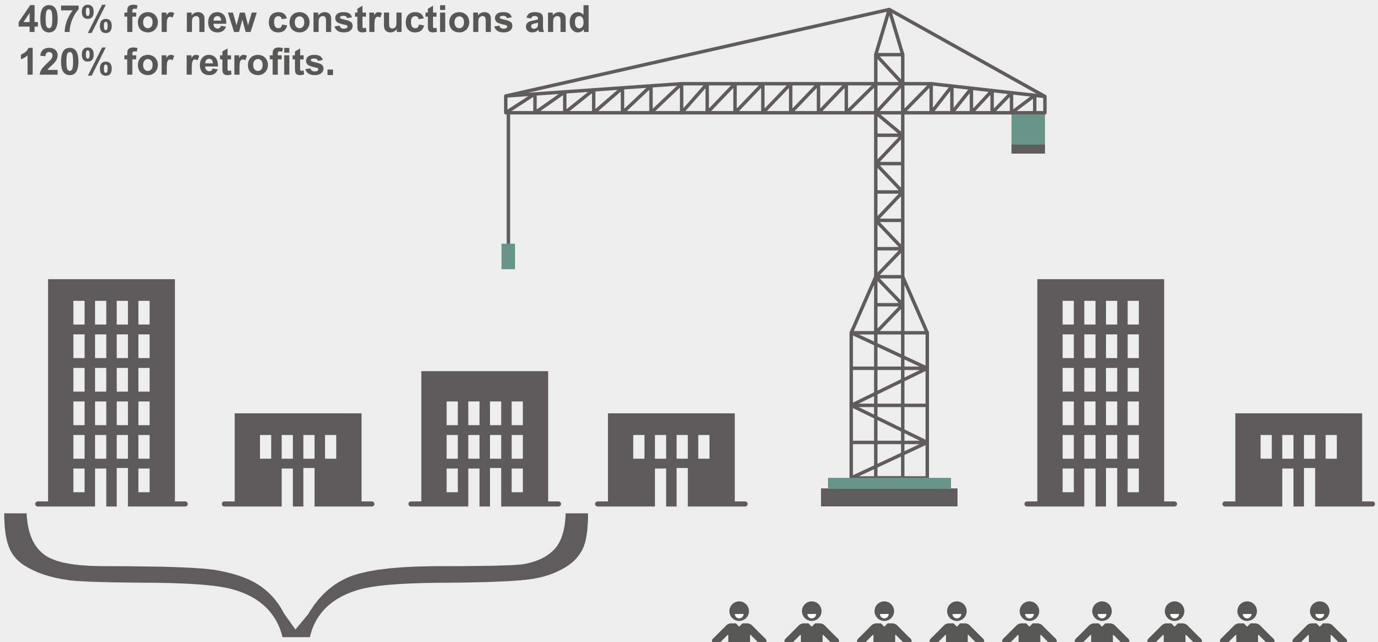
8 studies have shown that natural ventilation and mixed mode systems can pay for themselves in less than 1 year

Natural- and hybrid ventilation systems yield:

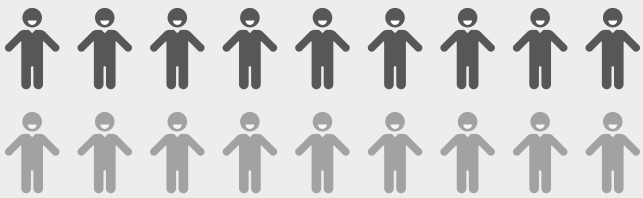
· Annual energy cost savings per employee : $110
· Health cost savings per employee : $60
· Annual productivity gains per employee : $3,900

Total savings per employee annually : $4,070

The average ROI for an investment in natural- or hybrid ventilation is 407% for new constructions and 120% for retrofits.



In the U.S. office sector this would mean more than $6.4 billion in energy savings each year. If only half of thise buildings used natural- or hybrid ventilation, over 40 billion kWh would be saved each year.



Given the average productivity and health benefits of 3,900 and $60 per employee respectively, the total savings achieved by providing half of the U.S. workforce with natural- or hybrid ventilation would amount to more than $118.9 billion annually (equivalent to 1% of the U.S. GDP in 2003).

Improved use of space

Using natural ventilation means no unsightly pipe-work or duct penetrations and no space consuming ventilation units. When opting for natural ventilation you also get the possibility of increased ceiling heights, as natural ventilation does not require suspended ceilings.

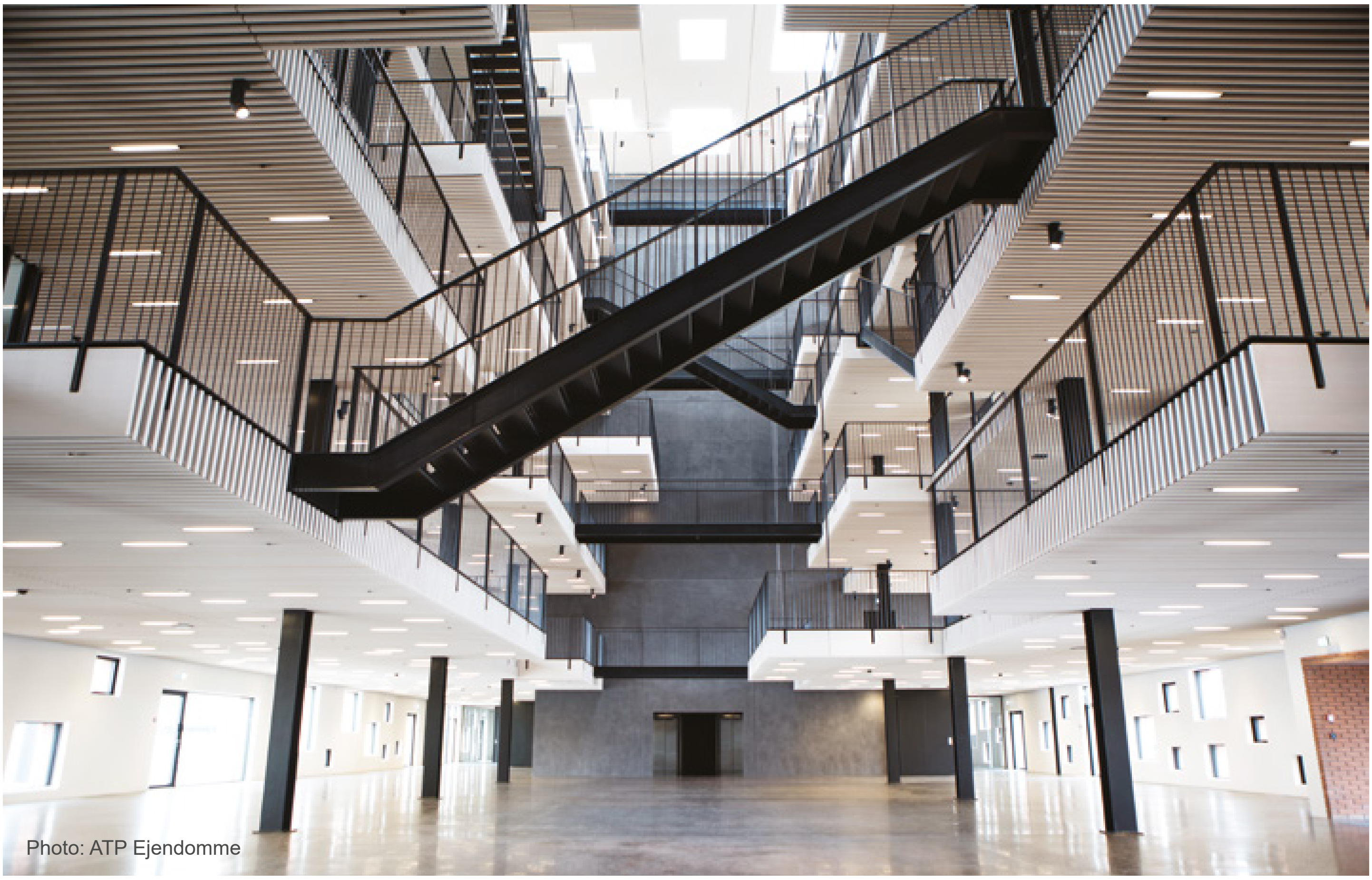


Photo: ATP Ejendomme

Case: Pakhuset gains extra floor with natural ventilation

In Copenhagen, a new 16,400 square meter office building (Pakhuset) has recently opened. The developer, ATP Ejendomme, wanted to create a sustainable construction and consequently chose natural/hybrid ventilation for their indoor climate along with thermo-active building systems and groundwater cooling. It is expected that the hybrid solution will reduce energy consumption with 80% compared to a traditional cooling/heating system.

Air intake for the natural ventilation goes through canal locks in the façade, which has automatically controlled dampers installed, so that air strikes the thermos-active structure when the dampers are open. From here, the air distributes in the office and subsequently escapes through openings in the roof and exhaust fans.

> ***"Because no pipework for mechanical ventilation was necessary, the architects were able to gain ½ meter per floor, which has allowed them to use the space to add a whole extra floor to the building."***
>
> Svend Kristensen, Senior Operations Manager, ATP Ejendomme

What kind of buildings can benefit from using natural ventilation?

Almost all buildings can benefit from natural ventilation including office buildings, schools, shopping centers, hospitals and sport halls.

All these types of buildings, including atriums and common rooms are ideal for creating attractive solutions with natural ventilation, as the natural ventilation system does not require large space for mechanical equipment. All it requires is an adequate number of openings in the roof or façade. Not only does this let a great portion of light into the room, it also provides architects with much more space to work with. In large areas, natural ventilation is very effective and has proven capable of completely or partially replacing mechanical air-conditioning with night cooling (night purge ventilation).

Click to see examples of buildings with natural ventilation

WindowMaster project: Elephant House, Copenhagen Zoo

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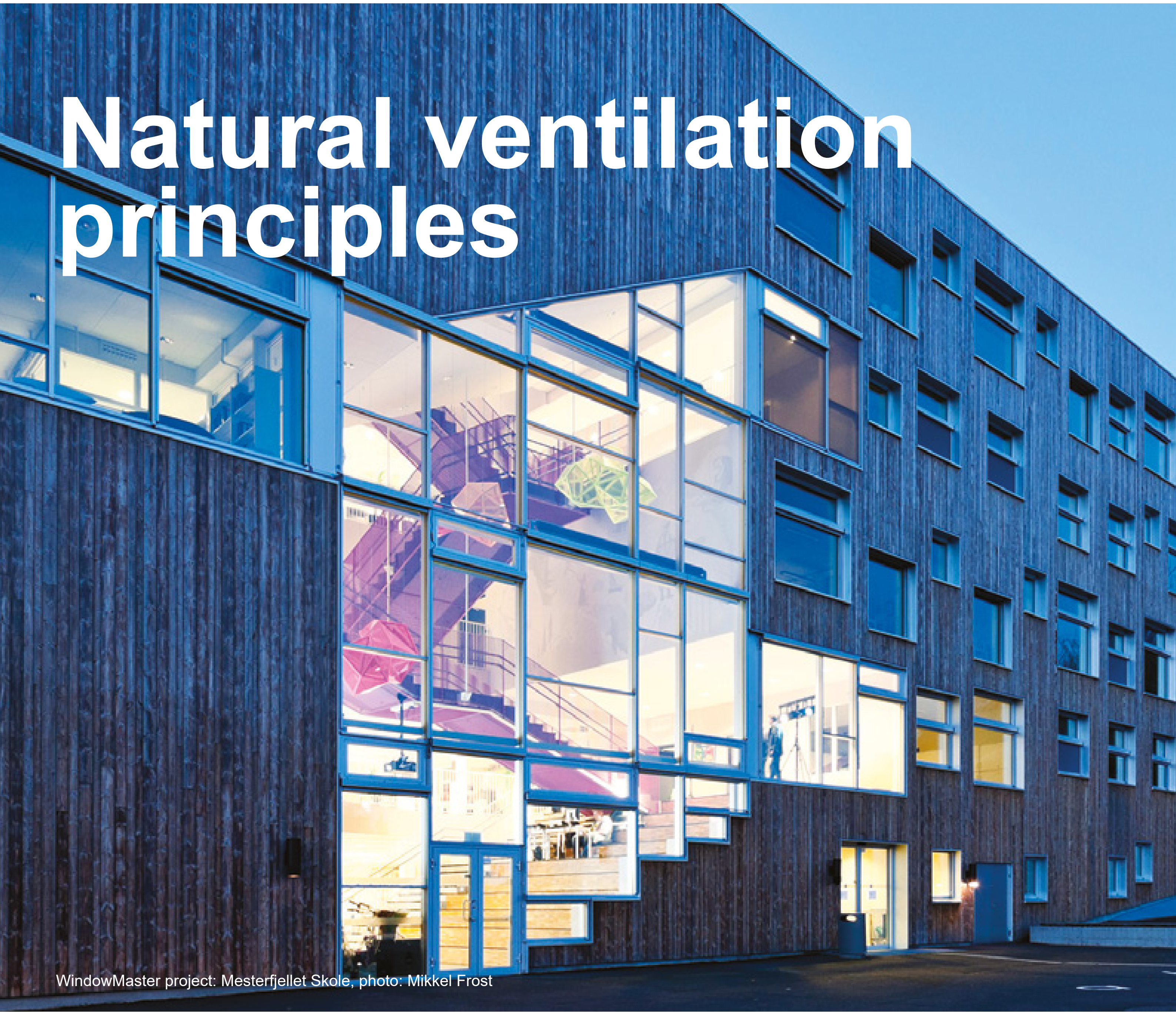
Natural ventilation principles



WindowMaster project: Mesterfjellet Skole, photo: Mikkel Frost

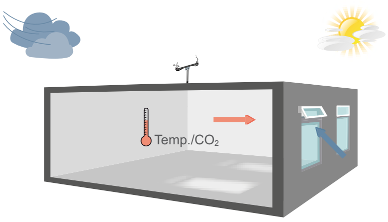
Apart from knowing that natural ventilation can be applied to almost all building types, it is also important to understand how the design of a building influences the performance of a natural ventilation system.

A building's natural ventilation can be based on a variety of different ventilation principles. A ventilation principle shows how natural ventilation works based on the design of the building, internal thermal loads and the positioning of openings (typically windows).

All WindowMaster's natural ventilation principles are based on the overall principle of ensuring healthy and comfortable indoor climate through minimal energy consumption and at minimal cost.

In general, our ventilation system designs are based on the following three fundamental principles:

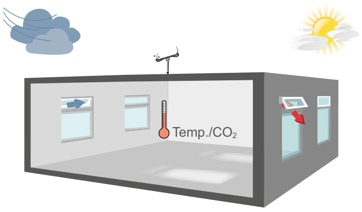
· Single-sided ventilation
· Cross ventilation
· Stack ventilation



Single-sided ventilation

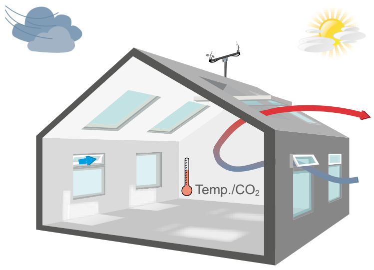
The illustration shows a typical situation in an office with single sided-ventilation, i.e. a room with windows on only one side. The example shows the room during the winter months. The surrounding air is often cold in the winter, meaning that windows cannot be opened for longer periods. To overcome this problem pulse ventilation is used. Windows are opened for short periods of time ensuring that the air in the room is replaced quickly.

Because cold air creates draughts even at very low wind speeds, the windows are quickly closed again after a set period of time. High wind speeds and low outdoor temperatures further limit the amount of time that the windows are open.



Cross ventilation

The illustration shows the cross-ventilation principle. Cross ventilation is achieved using windows on both sides of the room, creating a current of air across the room. If the windows on both sides of the room are open, the overpressure on the side of the building facing the wind and/or low pressure on the opposite sheltered side will create a current of air through the room/rooms from the exposed side to the sheltered side. To ensure optimal airflow with as few draughts as possible, the windows on the side of the building that is facing the wind are not opened as much as the windows on the sheltered side.



Stack ventilation

The illustration shows the stack effect that arises as a consequence of temperature differences. Warm air rises because it is less dense than cold air. When warm air rises to the roof of a building it creates a slight vacuum in the building's lower levels, which in turn pulls fresh air in through windows in the ground floor. This creates a natural airflow. This physical process depends on the height difference between the windows that are used to let outdoor air in and the windows used to exhaust 'used' air.

Windows in the roof are used to let the 'used' air escape and the windows in the lower levels are used to let fresh air into the building. In the illustration, the stack effect is combined with the wind direction. Wind direction determines which windows are used to let air in and which windows are used to exhaust air from the building. The ground floor windows on the sheltered side are opened more than the windows on the wind-exposed side, whereas only the windows in the sheltered side of the roof are opened.

Natural ventilation design

The following section will dive into how a perfect natural ventilation solution can be designed. Besides natural ventilation principles, several other factors must be taken into account when preparing a building for natural ventilation and below guidelines will highlight key aspects of the ideal design.

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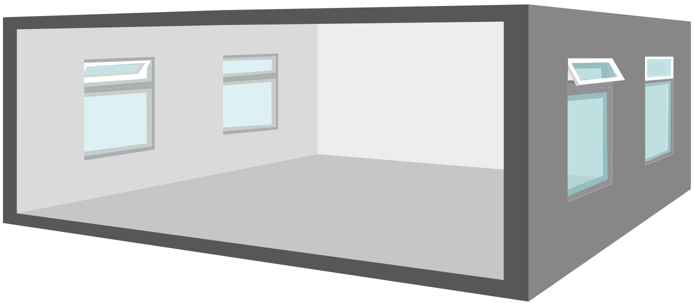
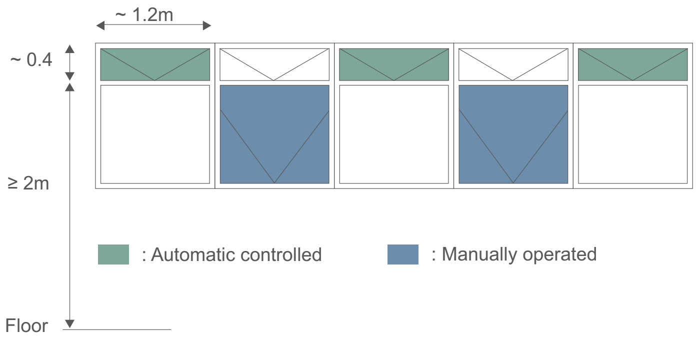
Geometry of space
- Good room height – the room must be at least **2.5 m** and preferably **2.7 m** or more.
- Single sided ventilation – the room depth should not exceed **2.5 times** the room height, and never more than **10 m.**
- Cross ventilation – the room depth should not exceed **5 times** the room height.
- Stack ventilation – the distance from the facade to the roof lights should not exceed **5 times** the room height.



Window opening
- Highly placed openings/windows in the facade – preferably **2 m** or more above floor level and with sufficient clearance between the top of the vent and ceiling for inward opening vents so the achievable opening area is not limited.
- Bottom hung inward windows or top hung outward openings in the facade.
- Window height, facade: Approximately **400-600 mm.**
- A window width of approximately **1.2-1.4 m** is often optimal, since you often need two window actuators if the width exceeds **1.2-1.4 m** (subject to window profile material and type, due to frame flex with single pull point).
- Openings evenly distributed.



WindowMaster project: Rungstedgaard

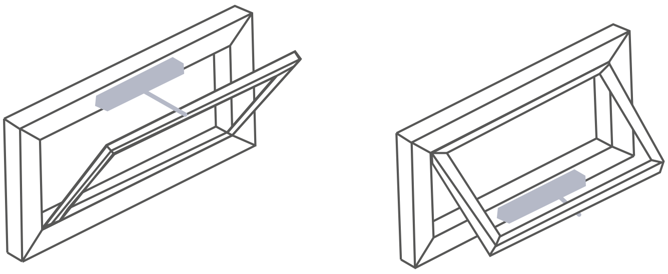
Other natural ventilation guidelines

· Optimized natural night cooling.
· Preferably include thermal mass for optimum benefit of night cooling.
· User control e.g. timed override facility by local keypads.
· Preference for cross ventilation, stack ventilation or hybrid ventilation in high occupancy spaces e.g. in classrooms.
· Preferably a minimum 7m^3 per person in e.g. classrooms.
· Maximum air changes:
  Winter: Approximately 2.5-3 h^{-1} (average during occupied hours).
  Summer: Workstations: 4-6 h^{-1} can easily be accepted.
  Atriums and similar transient spaces where people stay for shorter periods: 10-15 h^{-1} can be accepted.

Specifically for supplementary mechanical exhaust

· In most cases the capacity of the exhaust should be at least the minimum required air change.
· The exhaust should be controllable by variable speed.

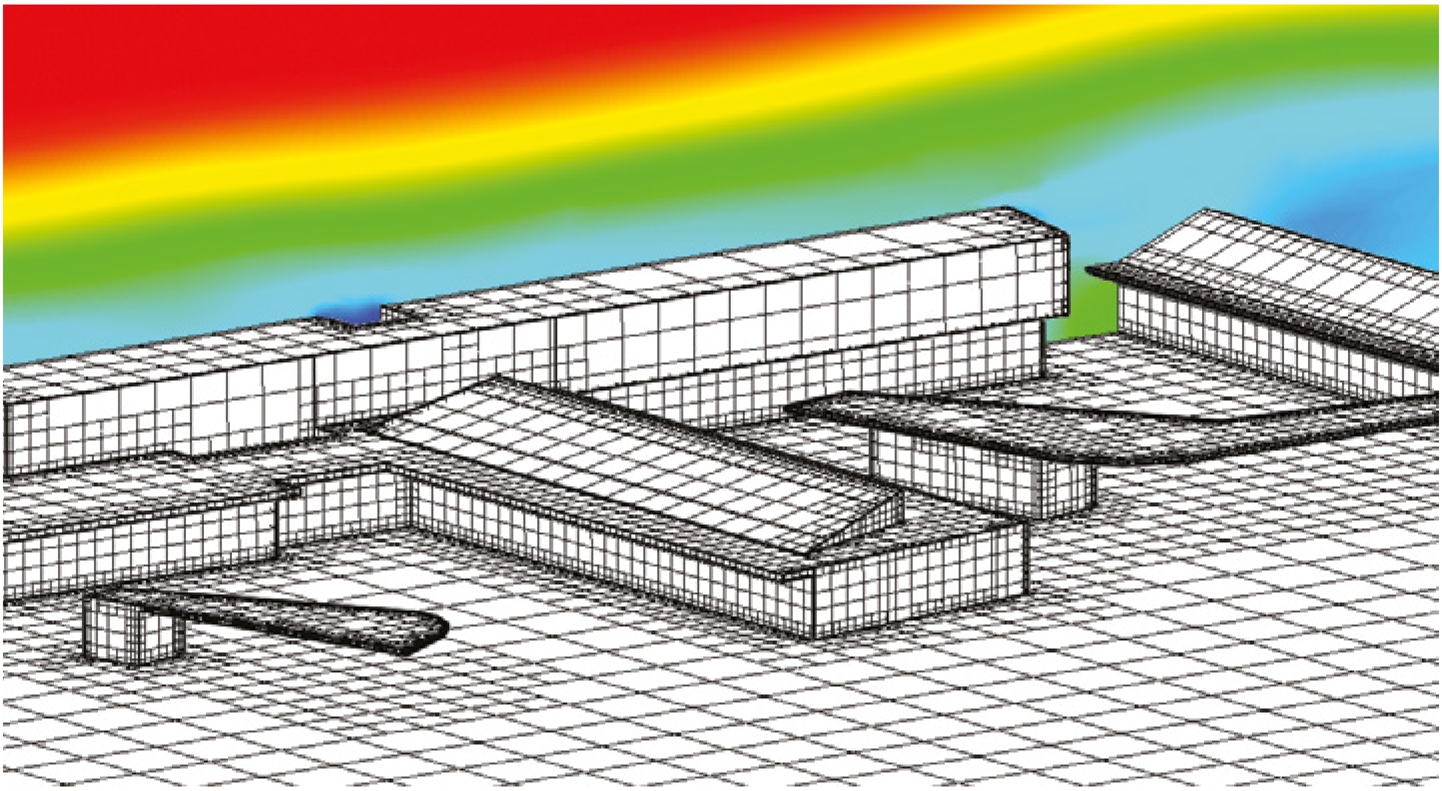
If in need for advice or assistance with evaluating your buildings' potential for intelligent natural ventilation, we have a dedicated team of professionals ready to share our knowledge and know-how on this topic.



Our services

· Ventilation proposals
· Air change calculations
· CO_2 level calculations
· Dynamic simulations of the indoor climate
· CFD analysis

Read more about our natural ventilation calculation and how we can help on our website



WindowMaster project: Kulturwissenschaftliches Zentrum
(Centre for Cultural Studies) of Georg August University

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Intelligent control systems for natural ventilation

Acknowledging the importance of how a building is designed is first step in achieving an optimum indoor climate. However, the performance of a natural ventilation system is not limited to the design of a building; how the system is controlled is equally important. And if there are not enough openings in a building to create ideal conditions for air change, you may even have to combine natural ventilation with mechanical ventilation (called hybrid- or mixed-mode ventilation). All WindowMaster's natural ventilation solutions are based on BACnet, KNX, LON, and MotorLink® technologies, making them easy to combine with other mechanical ventilation systems and integrate into any BMS system.

Based on analyses and empirical data, we have designed three control systems to meet market needs and the varying requirements that different buildings ask for based on their size, location and purpose.

NV Solo®
NV Solo® is our simple yet cost-effective control system for a single zone, where the automatic opening and closing of windows is based solely on indoor temperature.

NV Comfort®
NV Comfort® provides an optimum indoor climate in up to 8 ventilation zones based on the automatic opening and closing of windows. It comes with a touch screen panel.

The automatic opening and closing of windows is based on:
· Indoor temperature
· CO_2 level
· Relative humidity
· Outdoor temperature
· Rain detection
· Wind speed

NV Comfort® can also control sunblinds, lighting, heating, and mechanical ventilation.

NV Advance®
NV Advance® is our top-of-the-line solution based on a computer interface. Ideal for large buildings with more than 8 ventilation zones.

The automatic opening and closing of windows is based on:
· Indoor temperature
· CO_2 level
· Relative humidity
· Outdoor temperature
· Rain detection
· Wind speed
· Wind direction

NV Advance® can also control sunblinds, lighting, heating, and mechanical ventilation.

WindowMaster project: Aller Domicile

Night purge ventilation

In a typical new office building with normal heat loads generated from people, lighting and computers etc., cooling may be needed even at outdoor temperatures below 0 degree Celsius. This is an example of how the new building regulations, lowered U-values and the continued focus on the heating usage in buildings have resulted in a decreased need for heating but increased the need for cooling.

Passive cooling measures can play an important role in improving the energy efficiency of a building by reducing or even eliminating the need for auxiliary cooling. One passive cooling technique, commonly used in private, public and commercial buildings, is night purging ("night flushing"). It is the removal of heat from a building by bringing in cool night time air without the use of active HVAC cooling and ventilation. Night purge ventilation is a critical component to enhancing the performance of any naturally ventilated building that is used during the summer time and in need of cooling even during winter.

Night purging using natural ventilation – how does it work?

Natural night ventilation is a passive cooling method, driven by the natural forces of the wind and/or thermally (stack) generated pressures. The heat absorbed by a building's exposed thermal mass during the day is released to the indoor air at night, after which it is purged by night ventilation. Meanwhile, external fresh air cools down the thermal mass, which then acts as a heat sink

during the following day. The night flushing involves automatically operable windows or louvres being opened for a pre-set period of time over night, allowing a natural air flow through the building.

Why should night purging be incorporated into your building?

Night purge ventilation can help reduce the building operating costs, with hot and stale air being replaced with fresh night time air. This reduces the need for the HVAC system to be activated as soon as the building is occupied in the morning. The thermal mass of the building will be cooled, providing a fresher and cooler environment for occupants.

If hot and stale air is not removed, not only will the room feel stuffy; airborne pollutants, such as carbon dioxide, may reach alarming levels. This can be potentially harmful for the occupants with symptoms such as headaches, dry and itchy eyes or a sore throat. Consequently, this can have a negative effect on both the productivity and well-being of the occupants.

In which climates is night purge ventilation most effective?

The efficiency of night cooling depends on the thermal properties of the building and on the local climate conditions, i.e. night-time wind speed and the temperature swing of the ambient air.
It is particularly effective in climates that have cool night time temperatures as there will be a greater difference between internal and external temperatures. This is not to say that night purging cannot be effective in warmer climates. Even when internal and external temperatures are very similar night flushing can still provide a means for airborne pollutants to be exhausted and allow fresh air to enter.

Common concerns with night purge ventilation

Security is a somewhat common concern when night purging is considered. This concern is alleviated by selecting small, high level openings, which poses tasking to access. Moreover, insurance companies generally prefer small openings at a high level if night cooling is applied. The risks from entrapment can be lowered by using intelligent actuators, which have an inbuilt pressure safety function. Furthermore, by using an intelligent actuator in combination with an intelligent control system you are able to control your openings very precisely, as the windows normally do not have to open fully during night purging to secure an effective cooling. The intelligent control system should include wind and rain sensors that can detect when rain and wind speed limits are exceeded and then send a close signal to the windows to avoid potential water damage.

All in all, passive night purging is a safe way to ventilate and cool down a building for improved well-being of the occupants while reducing energy consumption and the concomitant energy bill.

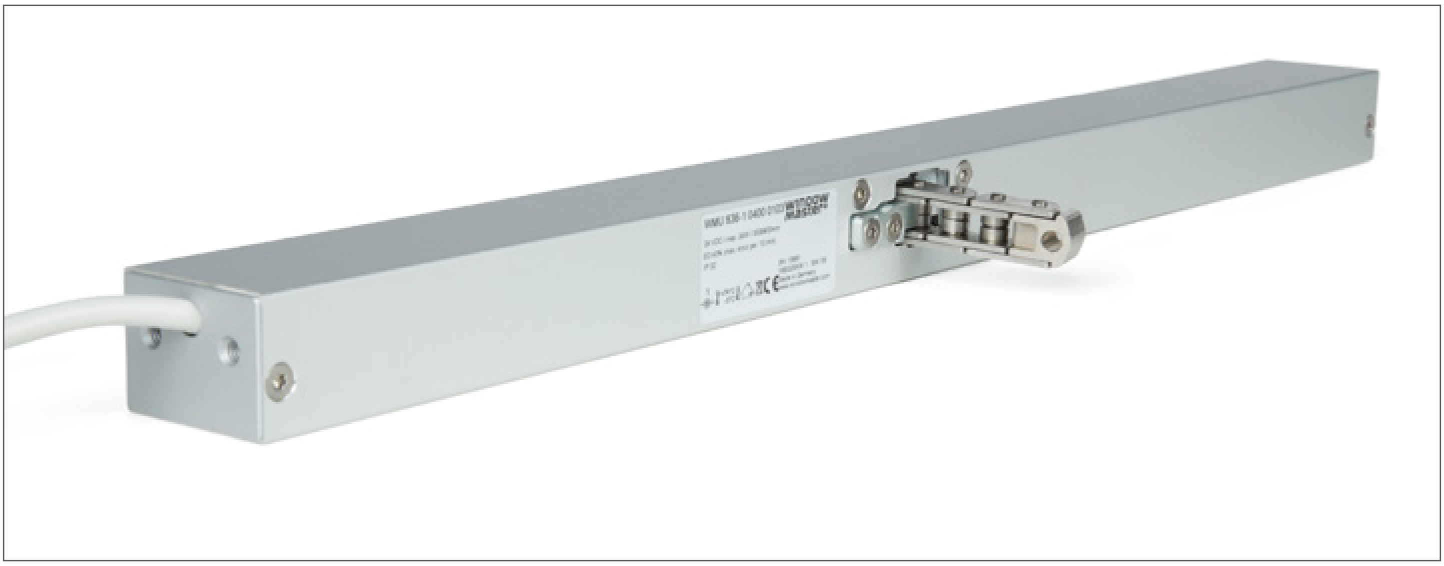
Selecting the right window actuators

WindowMaster project: IT University

As an architect, you are the expert in planning, designing, and reviewing the concept and construction of buildings but also in identifying those variables that give great aesthetic pleasure.

Seen from a ventilation point of view, this means selecting silently operated window actuators that fits the correctly sealed windows. When this requirement is met, you will be happy to find that your building has low heating loads, no excessive cold draughts and near to silent, synchronized operation of the windows.

In the following section, we will elaborate on the purpose of window actuators, what differentiates the varying types of actuators and how to select the correct type in relation to the needs of a particular project. Additionally, it will be discussed why wiring routes and concealment need to be thought in already in the design phase, like power options, opening areas and window orientation also need to be factored in.



What is an actuator and what is its purpose?

The actuator is essentially what pushes the window open. Most façade window actuators are chain types and are typically used for three main reasons. Firstly, they deliver automated ventilation and are increasingly chosen to add ‘intelligence’ to the building’s ventilation, helping it breathe more effectively on its own. Secondly, actuators are also used to provide ventilation via out of reach openings, such as roof windows. Thirdly, they may be used to provide smoke ventilation to improve building safety in the event of a fire.

How do actuators differ?

There is a large number of actuators on the market of varying quality and capability. This has a direct effect on building performance, overall costs and client comfort and satisfaction.

Most standard actuators have little or no intelligence. They consist of a glorified bike chain designed to bend only in the required planes, a motor and set of gears. Without any intelligence, they are often operated in large, poorly controlled ‘chunks’ of opening distance, which is associated with heavier oscillations around comfort set points, uncomfortable draughts, excessive energy consumption and potentially shorter actuator life. In addition, many actuators do not have pressure safety functionality. Typically, actuators have a closing force of around 200N, which is not inconsiderable when applied to the leading edges of two metal profiles, particularly when a hand or finger finds its way between those edges.

Most standard actuators also have a factory-set speed of operation, which in many instances can be noisy, disruptive, cause complaints and lead to other widespread building performance issues. These cannot be easily adjusted for quieter operation once installed.

Choosing intelligent actuators, such as those with MotorLink® technology, allows essential functions like speed control to minimize noise. Position feedback offers accurate positioning even for minimum opening areas, which are commonly required for comfortable ventilation. Likewise, the technology ensures that openings for night cooling remain within allowed security limits and the pressure safety functions will be the defining factor that reduces a potential severe injury to a minor pinch.

Wiring routes and concealment

The visibility of wiring routes for windows are rarely considered during the specification and tender process. Nevertheless, paying attention to this detail in the specification and preparation for concealment can reduce cost and improve aesthetics in subsequent stages of the building process.

Oftentimes, a window profile can be used as a conduit for 24V actuator wiring. It may require some co-ordination during installation but the specification erases the need for surface-mounted trunking that can potentially spoil the overall look of the window system. If vents are at a high level, simply preparing the mullions to allow cables to be pulled through will enable cables to be hidden on top of the transom thus limiting their appearance on the face of the façade or windows. Alternatively, a matching cover profile may be considered.

In certain windows (i.e. VELFAC windows), the actuator can be hidden inside the profile. Other aluminium systems also allow for this solution but low profile systems usually offer little room to hide the actuators, which will therefore be surface mounted. Accordingly, actuator colour- and finish need to be considered already in the specification.

On high load applications, such as large roof lights with pitched opening, spindle actuators are usually used. The solid spindle housing hangs down into the space when closed, which many designers and clients find unsightly. New high capacity WMU 888 chain actuators from WindowMaster can address this issue and offer a powerful and neater solution.

Most actuators used for natural ventilation are 24V DC, which gives higher torque capacity and makes them electrically safer when using the window profile for containment. There are 240V actuators on the market, but these are generally designed for occasional use and are prone to overheating if used regularly, so are therefore normally avoided.

When addressing the wiring routes, the window or curtain walling fabricator should prepare the profiles for these with grommets and draw wires, using the frame as containment. If at high level, a route should be provided through the mullions without having to bridge the inside face of the profile. If this cannot be avoided, consideration should be given to a matching cover profile.

WindowMaster project: Frederiksberg courthouse

Multi speed operation

The actuator must provide two-way communication with the control panel to enable it to operate at a very slow speed when in the automatic mode. Operating in slow speed reduces noise significantly to near silent when opening/closing a window, meaning that the ventilation system will not cause disturbance to the building occupants. Two-way communication will also enable the motors to operate at a faster speed when activated by the manual keypads, for example, to provide an immediate visual response to the user. The motors will operate at full speed during smoke clearance in the event of fire. WindowMaster actuators are the only ones in the market with the ability to operate at three different speed levels.

Pressure safety function

The actuator must have the ability to monitor for entrapment on specified windows by communication via the microprocessors installed within the actuator and by monitoring in real-time the amount of electrical current being drawn and the precise position of the window to an accuracy of less than a millimetre. The MotorLink® actuator will detect if an object becomes trapped in the leading edge of the window and prevent it from closing by monitoring the amount of current being drawn and then reversing the actuator to release the obstruction.

The sensitivity of the pressure safety must be adjustable, as the pressure safety function is a factor of the closing force of the actuator combined with the size and weight of the window, as well as the configuration of the window, its hinges and the rigidity of the profile itself. Therefore, the overall performance and sensitivity of the system is dependent on all these factors combined and needs to be monitored and adjusted as the required forces can change during the life of the building.

Actuator position feedback

The actuator must provide two-way communication with the control panel to enable feedback to the control software on the exact position, for precision of opening and control (mm by mm) as well as a security indicator for open windows.

Synchronised actuators

Where opening vents are about 1.200mm wide or more, the window or curtain walling supplier shall check whether two actuators are required. This should be checked with the profile systems house as it is dictated by frame flex and the capacity to achieve a seal at the edges with a single pull point. If required, the actuators must use MotorLink® to synchronise speed and time of operation.

The actuator must provide two-way communication with the control panel to enable feedback to the control software on the window status and an early indication of any errors with the actuator operation or the wiring.

Opening areas

Actuators come with different standard chain lengths: 250, 400, 500, 600 and 1.000 mm. Using the smallest actuator possible will keep the unit size and cost down. The longer the chain, the bigger the links are needed to maintain integrity and therefore also the bigger the housing to hide it when it is withdrawn. To reduce the size and cost and improve aesthetics, use a 250mm chain where possible.

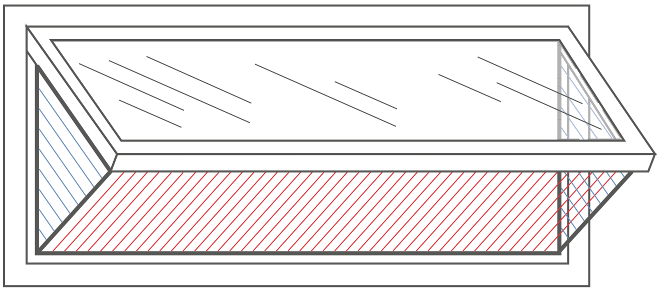
There are many schools of thought on calculating the opening or free area. A typical profile will use around 40mm of chain to bridge the profile from the actuators fixings to the sash. Therefore, a 250mm chain will give around 210mm clear opening depending on the profile and mounting arrangement.

If you want guidance on calculating the chain length and opening areas, feel free to contact WindowMaster, who has a team of specialists ready to assist.

WindowMaster project: Helsingør Kulturværft

TOP TIP: Common-sense guidelines for opening areas

- Calculate the geometric free area by using the rectangle or throat at the leading edge of the opening sash first. If slightly bigger areas are required, then consider the triangles at the sides if they are allowed to be included. For example, a standard 250mm chain gives approximately 0.210m clear opening x 1m window width gives 0.210m^2 clear opening per opening window.
- Consider any reveal or sill that might limit the actual clear opening achieved (Building Regulations, Approved Document B, 2007). High level top-hung outward opening windows can avoid the reveal or sill limiting the achievable opening areas.
- Triangles at the side of the opening should not be included if it is a string of opening windows (adjacent open vents effectively cancel out the triangles).
- Many window suppliers, or WindowMaster, offer support with these calculations.



WindowMaster project: St Wilfrid's Catholic School

Window orientation

Research suggests that a high level (typically two metres and above from floor level) top-hung outward opening windows are the most effective overall solution for natural ventilation. Their opening areas can be supplemented by manually opened low level windows if required for operation on hotter days. These are often limited to 100mm openings due to the risk of falling, and the risk of obstruction if opening onto a thoroughfare.

Selecting high level openings minimises a number of risks. Draughts when controlling CO_2 in winter are reduced because the small amount of cold air that is introduced at high level mixes with warm air and travels further into the room before falling to body height. Avoiding side-hung windows removes the risk of a scissor action at body height, which can present a safety hazard. In addition, the lower element of the opening can introduce cold air at body height.

It is important to note that different window profiles have different requirements for the number of operating handles. This applies to actuators too. This is normally associated with the rigidity, or flex of the window profile around the pull point(s) and the frame's capacity to maintain a seal around the perimeter of the vent. It is less associated with actuator power or opening/closing ability and is therefore dictated by the vent fabricator or profile supplier. The vent width limit for a single actuator can vary from 700mm to 1.500mm, though for aluminum profiles 1.200mm is normally used as a rule of thumb. It is important to get confirmation of this if more actuators are required as this not only affects actuator costs but also associated power supplies and wiring. If in doubt, consult WindowMaster or fabricators early on in the project.

Compiling a specification to avoid common complaints

Most quality actuators look similar, but while aesthetically important, this has no bearing on how the actuator will deliver on its requirements. When creating the specification, any expectations you have for the benefit of the project and client should be made explicit. Decide which of the following points are important for the project and your client:

- Low noise during automation to minimise disruption
- Enhanced safety to help protect occupants in case of entrapment
- The capability for accurate control to prevent draughts and energy problems
- Minimised visual impact of wiring/cables on the windows
- Synchronised motors for wider windows to help protect the sash from distortion
- A special colour requirement
- Real time indication to the building owner of faults.

Green certifications

Intelligent natural ventilation is a major contributor to achieving a green profile and certification of the building.

WindowMaster's natural ventilation solutions can contribute to:

· Reducing the energy consumption and the total resulting CO_2 emissions.
· Having a good thermal comfort during summer and winter.
· Using free cooling by introducing night cooling.
· Reducing the amount of material used compared to mechanical ventilation, which is beneficial for a building's life cycle assessment.
· Reducing the capital cost compared to mechanical ventilation, which is beneficial for a building's life-cycle cost.
· Giving a precise and accurate control of the actuators by using MotorLink® technology.

Several sustainability rating systems exists to guide the design of sustainable, high-performing buildings and they recommend natural ventilation as the best solution to air quality and minimal environmental impact.

Click to read more about how WindowMaster can help you ensure that your buildings achieve a green building certificate

BREEAM
WindowMaster's indoor climate solutions can influence up to 42 BREEAM points.

DGNB
WindowMaster's indoor climate solutions can provide up to 80 DGNB points.

LEED – Leadership in Energy and Environmental Design
WindowMaster's indoor climate solutions can provide up to 22 LEED points.

Project examples

HouseZero, Harvard University – Center for Green Buildings and Cities

Innovative and Holistic Design Approach
In collaboration with the Norwegian architectural firm, Snøhetta, and Skanska Technology WindowMaster Control Systems has designed and will supply the natural ventilation system for Harvard University's Center for Green Buildings and Cities' new headquarters. The goal was to create a design space to support the creativity and productivity of the occupants. The 1940s-residential building situated on Harvard's campus was chosen to showcase and inspire others how old and conservative design, can be renovated to an ultra-efficient facility with ambitious performance targets. The building is anticipated to be completed towards the end of 2017, and will house research dealing with global climate change and sustainable building design strategies.

Highlights
· The building will be 100% naturally ventilated supplied by WindowMaster to achieve minimal energy consumption.
· The WindowMaster system, NV Advance®, will also control the sun screening and the underfloor heating and cooling throughout the building.
· In addition to the natural ventilation, it will include 100% daylight autonomy, zero carbon emissions and will achieve Net Zero Energy for its heating and cooling needs.
· Actuators containing the intelligent MotorLink® system is used for precise, two-way communication, three speed operation, pressure safety function and reversing function to protect weather seals.

A healthy indoor climate
By monitoring indoor CO_2, humidity and temperature, the automated natural ventilation system can manage air flow through the building's window openings and the chimney and thereby create an optimum indoor environment. To accurately measure the airflow through each individual opening given wind direction and speed a Computational Fluid Dynamics simulation was carried out. The building and its surroundings were modelled by an advanced software program, so that the airflow through the individual openings could be calculated precisely based on the wind pressure coefficient for different wind directions.

Professor of Architectural Technology at the GSD, founding director of the Harvard Center for Green Buildings and Cities and the creator of the HouseZero project, Ali Malkawi, stated:

> ***"Before now, this level of efficiency could only be achieved in new constructions. We want to demonstrate what's possible, show how this can be replicated almost anywhere, and solve one of the world's biggest energy problems — inefficient existing buildings."***[20]

The Tower at PNC Plaza, Pittsburgh

The Tower at PNC Plaza is a 800,000 square feet headquarters for the PNC bank in Pittsburgh, Pennsylvania.

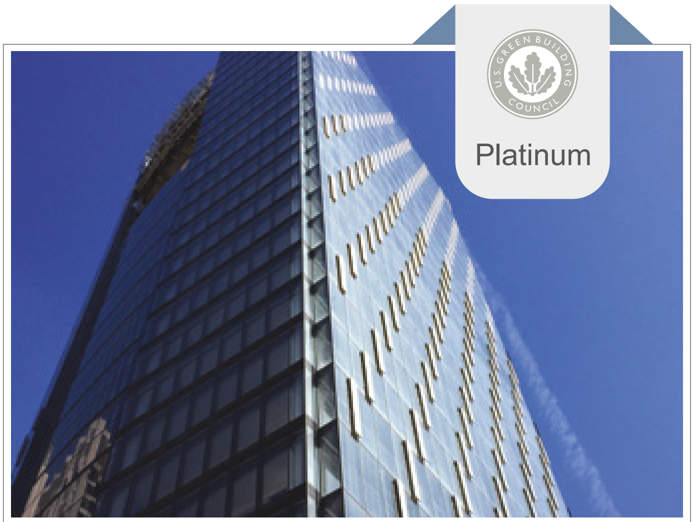
Planned as a landmark building, both with regards to design and in terms of environmental friendly solutions, the 33-story tower has a construction budget of approximately $240 million. Incorporating state-of-the-art green technology, including a double-skin facade and solar chimney, the building was designed to exceed LEED Platinum certification and to be the greenest office tower in the world.

The WindowMaster Solution
WindowMaster has delivered more than **6300 actuators** to control 700 parallel windows in the outer double skin façade and 1450 automated air vents in the inner facade.

From its one-of-a-kind, breathable double skin to its innovative workplace strategy, The Tower drives performance to new levels. The building “breathes” with a double-skin facade: a natural ventilation system that has a glass outer weather and air barrier and an inner layer with automated air vents, a wood curtain wall, and manually operated sliding doors. A series of automatic sensors on both layers open up the building for air when the weather permits.

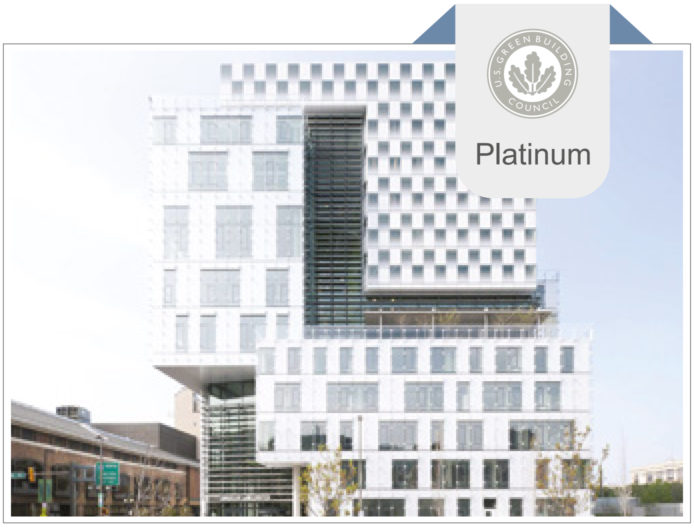
The main reason for choosing WindowMaster as a supplier for this project is the MotorLink® technology that enables genuine synchronization of four actuators on one parallel window and exact position control and feedback via the BACnet BMS.

> ***“The research told us that 45% of the time we would be able to open our windows for fresh air and essentially turn off the mechanical ventilation in the building.***
> ***We had to create a double skin that operated through a building control system that would open during the optimal weather days…”***
>
> Doug Gensler, Managing Director | Gensler Boston

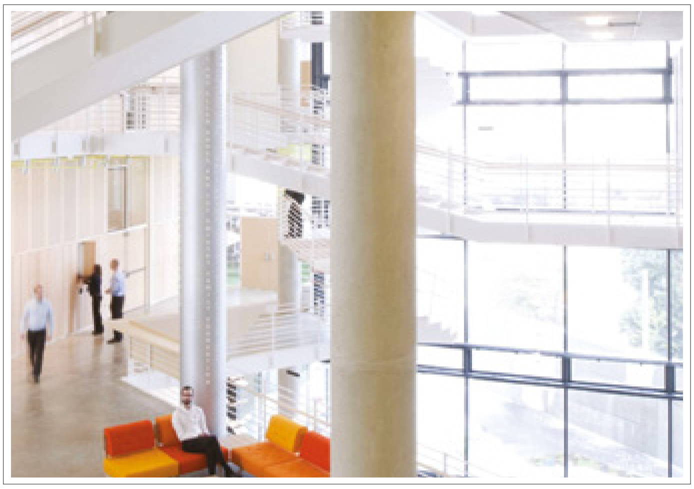


The University of Baltimore School of Law, Baltimore

The new home of the John and Frances Angelos Law Center at 192,000 sq. ft. unites classrooms, faculty offices, administrative space, and the law library under a single roof for the first time in the history of the school. The building, located at the prominent intersection of Mount Royal Avenue and Charles Street, functionally and symbolically defines the Law School as an academic and social nexus, offering state-of-the-art teaching and learning facilities.[21]



The WindowMaster solution
WindowMaster has provided more than 1000 MotorLink® actuators integrating the intelligent facades with the LONworks Buildings Management System. This enables full control of each motorized window. The windows will then be automatically closed when the aircondition is on and made available for the users to open and close at will by the manual override switches, when the aircondition is off.



Operable windows are provided in regularly occupied spaces, allowing users to have direct control of their environment. Occupants have local control of operable windows in all office, teaching and library spaces, and are notified of favorable outdoor conditions by means of a green indicator light that communicates appropriate times to open a window. Atrium operable windows are fully controlled by the building automation system based on the quality of outdoor conditions. Atrium smoke exhaust fans are activated at low speed in natural ventilation mode to guarantee good cross ventilation through all spaces, and acoustically protected and fire-protected transfer openings are provided from perimeter spaces to the atrium.

Outdoor temperatures in Baltimore are appropriate for natural ventilation about 40% (red. 5 months) of the year. Therefore, a mixed mode approach to the interior climate is taken, with mechanical ventilation, heating, and cooling during the extreme seasons and natural ventilation during spring and fall. **The law center does have a conventional HVAC system, but it is less than half the size of one that would be required for a normal building of its size.**

The Bullitt Center, Seattle

The Bullitt Center is a high performance urban office building, demonstrating a commercially structure with essentially no environmental footprint is possible. The six-story, 52,000 sq. ft. building was evaluated toward the goal of net zero energy, water and waste – resulting in an unprecedented EUI of 10kbtu/sf/yr.

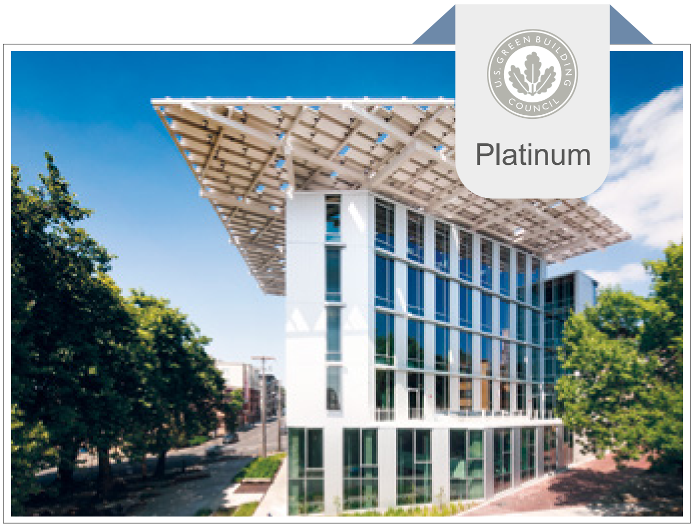
The Bullitt Center is all about changing the norms of design and construction for a typical office building. The challenge PAE, the project's mechanical and electrical engineer, accepted was to design the ventilation system to keep the occupants comfortable while using radically less energy compared to a standard office building. The three principle strategies used to create a comfortable office environment are a high-performance envelope, passive cooling through motorized windows, and a radiant slab to heat and cool the space.

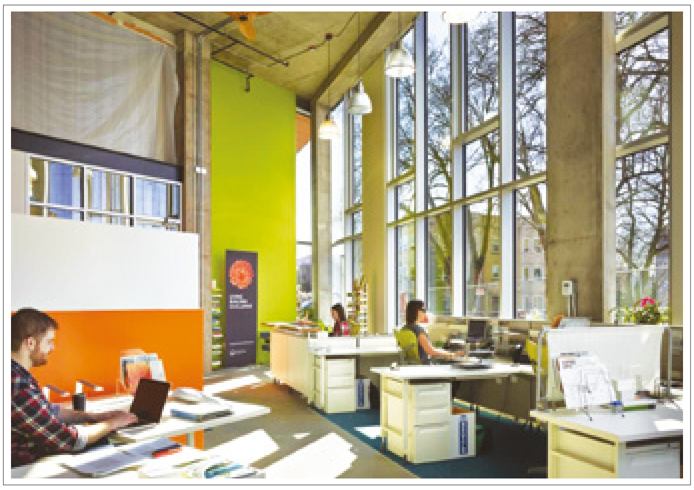
The WindowMaster solution

Justin Stenkamp of PAE feels that the new norm should be to have the occupants and the building operator sharing the strategies to support the efficient operation of the building. The occupants need to buy-in to the goals and understand how to optimize the energy efficiency of the building. At the Bullitt Center there is an override for the control of the windows on each occupant's computer and a hard switch in each tenant space.

In a standard office building there is a disconnect between the weather outdoors and the interior temperature. We all are familiar with the chill when stepping into a typical office building from the summer street. The old style is to have the building maintain a standard temperature all year regardless of what is happening outside. At the Bullitt Center it's different. In summer the interior will be a bit warmer and will suit your summer clothing. This last summer was a hot one for Seattle and the building was able to maintain a maximum indoor temperature of 78° F. even when it was in the 90's outside.

The interior spaces are controlled by a computer that acts as the brains of the building, translating the outdoor environmental conditions into reactions at the envelope of the building – such as employing the exterior louver shades or opening the windows, as heating or partially cooling the radiant slab at each floor.[22]





"To help cut energy consumption to 23 percent the amount of a traditional building its size, natural light will account for 82 percent of all lighting, thanks to oversized windows and higher ceilings that help get light farther inside. And so will air, as the building's electronic 'brain' automatically opens and shuts the windows based on temperature needs, eliminating the need for air-conditioning units."

Source: Time Inc, June 2012

University of San Francisco John Lo Schiavo, San Francisco

The University of San Francisco (USF) needed to replace its cramped 1966 Harney Hall, built when science enrollments were just half of today's levels. Construction of a new state-of-the-art science building (S.J. Center for Science and Innovation) located in the center of the USF main campus, immediately adjacent to two existing buildings. Classrooms include chemistry wet-labs with fume hoods, physics labs, lecture halls, computer labs, and community spaces. The 61,610 sq. ft.building had a budget of $43M and was awarded LEED Gold.

The WindowMaster solution

A green feature of the mostly glass building are the climate-controlled windows, which open or close depending on the temperature and have features to prevent reflectivity and use ambient heat to help control temperature. In line with the campus' wind patterns, the building is designed to accommodate natural ventilation. Piping systems embedded in the concrete run water hot and cold, which helps control the building's temperature.[23]

Gold

42% savings from title 24 baseline

Passive ventilation
Natural ventilation /
Radiant Floor System

Active ventilation
Type 1: Intensive Lab Space
100% Outside Air
Type 2: Overhead / Displacement
Type 3: Underfloor Air

Green Lighthouse, Copenhagen

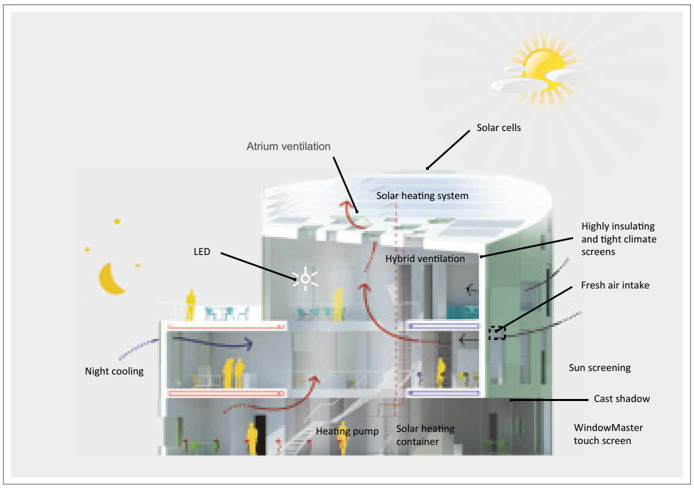
Green Lighthouse was Denmark's first certified sustainable building, having become the first building in the country to achieve a LEED Gold rating.

Green Lighthouse, a faculty building for the Faculty of Science at the University of Copenhagen in Denmark, is designed to optimize the well-being of the people working in the building as well as being CO_2 neutral.

The 10,000 sq. ft. (950 m^2) was built as a demo building in connection with the UN Climate Conference, COP15, held in Copenhagen in 2009, with a sharp focus on energy consumption and renewable energy.

The WindowMaster solution
An important element in achieving CO_2 neutrality is using technology that reduces the use of electricity. Traditional ventilation systems are usually one of the great electricity consumers. Automatic window control (natural ventilation) has therefore been installed to ensure fresh air in the building. Mechanical ventilation is only in operation for a very limited part of the year.

NV Advance® from WindowMaster ensures that the building is at all times using the most efficient form of energy. This is done by continuous measurement of room temperature, CO_2 and light levels and using the weather station records of outdoor temperature, wind speed and direction, sunshine and rain. Based on all these data, NV Advance® determines which type of ventilation is optimal and whether there is a need for heating or additional electrical lighting.



For most of the year, ventilation is provided solely via the automatic control of windows that are opened and closed in each room/area depending on the need for ventilation and fresh air. On cold days, mechanical ventilation with heat recovery is used. On warm days, cooling is provided in the large meeting rooms.

Two years after Green Lighthouse at the University of Copenhagen opened the doors, it became the first building in the country to be certified as a sustainable building. Green Lighthouse was given a LEED Gold rating. Furthermore, the building was chosen to become a pilot project in order to test the Danish certification system, DGNB-DK, and was awarded with DGNB Silver.

Prime Tower, Zürich

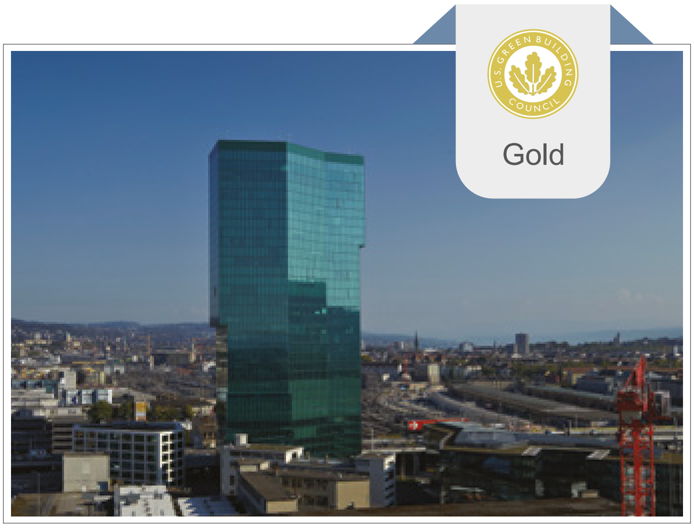
Zurich's 126 metre high 430,000 sq. ft. (40,000 m^2) Prime Tower, the tallest building in Switzerland, has been designed by architects Annette Gigon and Mike Guyer to be at the forefront of sustainable building technologies.

The development houses offices, restaurants and bars, retail outlets and support facilities. As part of the sustainable construction of the building it features natural ventilation controlled by the MotorLink® automated window control system.

The WindowMaster solution
Schüco, in partnership with façade designers Emmer Pfenninger Partner and façade manufacturer Dobler Metallbau, delivered an installation of **6,910** WindowMaster chain actuators for the automation of 1,382 parallel opening windows including one espagnolette locking motor for each window. These MotorLink® actuators are connected to MotorLink® MotorControllers to provide power and control primarily for natural ventilation.

The windows in Prime Tower are large rectangular parallel opening windows, which weigh approximately 360kg. To safely operate under load each window is equipped with four WindowMaster chain actuators and one special espagnolette/locking actuator.

The window actuators communicate with the MotorController via digital MotorLink® technology. Exact feedback concerning position as well as accurate synchronisation of the actuators is therefore ensured. The chain actuators and other components were tested and approved according to strict performance standards.



Qualcomm Campus Building AY & Building AZ, San Diego

Qualcomm's Pacific Center Campus consists of Building AY, an approximately 357,000-sq-ft, six-story office/ laboratory facility and Building AZ, an approximately 67,000-sq-ft, two-story multi-use facility that includes a learning/conference center, kitchen/café, a health/fitness center and a theatre. The buildings are being designed to achieve LEED gold certification.

Sustainable features include an architectural bioswale designed to remove silt and pollution from surface runoff water in the interior courtyard, natural daylighting and a state-of-the-art façade that controls heat and glare. It is also one of the largest naturally ventilated buildings in the country. These high-performance features create a high-quality work environment.

The WindowMaster Solution
WindowMaster has supplied almost 1000 actuators for two buildings at the Qualcomm Pacific Centre in San Diego, USA.

'The buildings are designed to optimize passive design strategies to achieve high-performance results and provide a high-quality interior workplace environment to boost employee productivity. The buildings' east/west solar orientation and narrow floor plates promote natural ventilation and daylighting, and a high-performance façade design controls heat gain and glare.

Photographer: Chad McDonald
Source: www.flickr.com

San Diego Continuing Education Mesa College Campus, San Diego

The facility has been awarded LEED silver certification by the U.S. Green Building Council, making it the district's fourteenth LEED certified facility. Natural ventilation and daylighting played a big part, while sustainable construction materials and high-efficiency plumbing and mechanical systems also contributed to the green qualifications.

This $22.5-million school project consolidates programs such as English as a second language and disability support into a bright and airy two-story learning center of 37,700 sq. ft. (3500 m^2). Project engineers have incorporated sustainable features such as natural ventilation and natural lighting to reduce the building's energy use by **43% compared** with state requirements.

The WindowMaster solution
The natural ventilation occurs via high-level automated façade windows in the classroom. In the back of each classroom, there are high-level automated vents, which can lead the air into the common areas (hallway) where the air is ventilated out through the high-level automated windows in the clerestory.

Each teacher controls the classroom temperature through a single switch on the wall that offers the choice between natural and mechanical cooling. When the temperature falls within the comfort zone (as it does the majority of the year), the natural ventilation system disengages the mechanical air conditioning and automatically opens the windows.

In the design discovery process, teachers told that they love to open the windows and doors. This building encourages that behavior, so it is expected that the teachers will choose natural ventilation most of the time.

WindowMaster was selected to supply the more than 100 motors for the natural ventilation solution for its MotorLink® technology. MotorLink® is a digital data communication technology designed to provide improved control and functionality where automated windows and natural ventilation are part of a building management system.

43% reducement of the building's energy use, compared with state requirements

Get in touch

Want to stay updated on similar topics and future trends within natural ventilation? Sign up for our newsletters or contact us directly if you have feedback or any questions about the company or intelligent natural ventilation.

You can also follow us on Facebook, Twitter and LinkedIn or share our book with your fellow architects.

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