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Natural vs. mechanical ventilation and cooling.

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NATURAL VS. MECHANICAL

Ventilation and Cooling

Weighing the benefits and the drawbacks of each type of ventilation system helps the building occupants, owners, and the technicians integrating and monitoring each concept become a unified force.

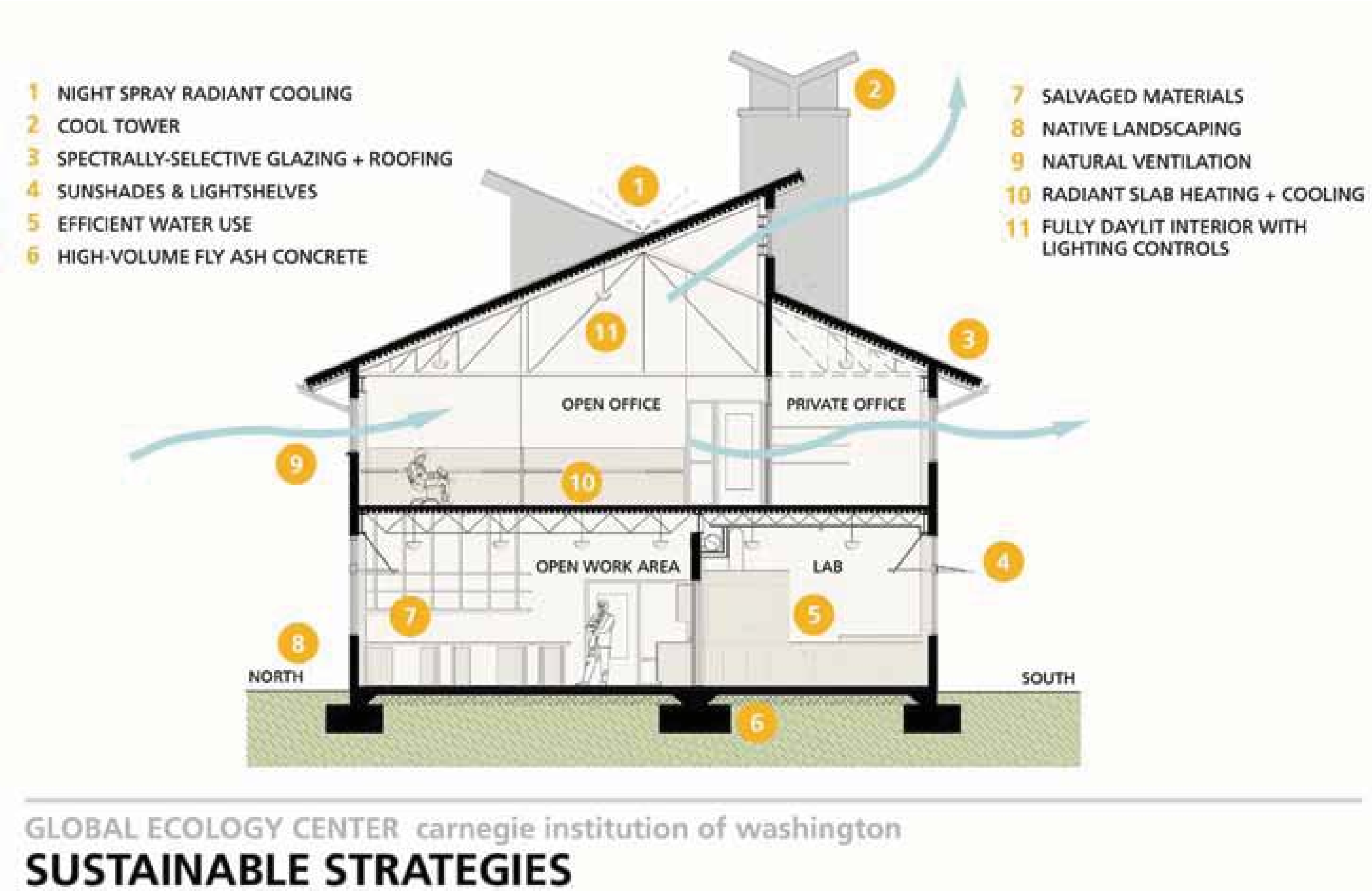
The benefits of natural ventilation for occupants in commercial buildings are well-documented, but not without limitations. Shown here is an example of a naturally ventilated building, the Kirsch Center for Environmental Studies at DeAnza Community College in California. Image courtesy of Cody Andresen, Arup.

BY GAIL S. BRAGER, PETER ALSPACH AND DANIEL H. NALL

Natural ventilation and cooling

Definition: In the strictest sense, "ventilation" refers to the exchange of outdoor air for the purpose of diluting contaminants and maintaining acceptable indoor air quality. But in practice and typical lexicon, "natural ventilation" usually refers to a multitude of functions, combining both the ventilation and cooling effects of outdoor air exchange, including cooling people, cooling the space during the day, or cooling the building mass at night. While this can occur through various types of openings in the building envelope, this article will primarily focus on operable windows.

Potential benefits: Ask anybody if they would prefer to have an operable window in their office that they can open and close as they wish, and chances are, few people would say "no." The most obvious benefit to using operable windows to provide natural ventilation and cooling is to reduce or eliminate the energy use associated with mechanical ventilation and cooling, with associated reductions in greenhouse-gas emissions and operating costs. The amount of these reductions depends on climate, cooling loads and building type. There also can be significant first-cost savings in situations where the equipment needed for mechanical cooling generation and distribution can be eliminated, and these



The more energy-efficient buildings include several sustainable strategies into their designs, including the examples illustrated above.

savings can be used to offset the added cost of operable windows and other envelope upgrades, such as solar shading.

The benefits to occupants are significant and well-documented. ASHRAE Standard 55 prescribes a comfort zone—a set of conditions that 80% of the occupants would find acceptable—but many people would argue that the industry should do better than allowing 20% to be unsatisfied. Given the inherent variability of an individual's thermal preference, it is likely that the only way to do better is to provide people with some means of personally controlling their own local thermal conditions. Operable windows are one way of doing that.

The thermal environments in naturally ventilated buildings are typically more variable and less predictable than those found in air-conditioned buildings, but not necessarily less comfortable. ASHRAE Standard 55-2004 includes an "adaptive comfort zone," based on 22,000 sets of data collected in approximately 160 buildings on four continents. This research clearly showed that occupants of naturally ventilated buildings are comfortable over a much wider range of indoor temperatures compared to occupants of air-conditioned buildings, primarily because the higher degree of personal control shifts their expectations, as well as allowing them to fine-tune their thermal environment to match their own personal preferences. To enable these benefits, buildings need to be designed with what is sometimes termed "adaptive opportunity," which would include not only access to operable windows but perhaps other forms of personal control, such as flexible dress codes.

Research also has shown that naturally ventilated buildings have reduced problems associated with IAQ. One of the most extensive studies was a cross-sectional analysis of 12 field studies from six countries in Europe and the United States, totaling 467 buildings with approximately 24,000 subjects. Relative to naturally ventilated buildings, the air-conditioned buildings (with or without humidification) showed 30%–200% higher incidences of sick-building-syndrome symptoms.

Potential limitations/challenges: Natural ventilation is not without its limitations. Its applicability clearly depends on building type and climate, and especially humidity. High humidity can limit the potential for both daytime cooling, and also nighttime cooling if overnight dewpoint-temperatures are high enough to cause moisture to be absorbed by porous materials. Climatic constraints include both minimum

temperatures that would be unacceptable to introduce directly into the occupied zone, and maximum temperatures above which technicians would likely only be heating the space or people further. Climatic limitations can be stretched by providing locally enhanced air velocity—such as via ceiling fans—which also may help ensure adequate distribution of ventilation.

Natural ventilation has a more limited load capacity than mechanical cooling, and therefore it is even more important to design carefully to limit internal and envelope loads, such as including solar shading and day lighting, as well as thermal mass in some cases so that direct ventilative cooling during the day might be combined with nighttime cooling. There also are potential challenges if the area has unusually poor outdoor air quality, or high degrees of outside noise.

Natural ventilation works best when the building owner and occupants are well educated about what to expect about the building performance, and be willing to become an active and integral part of the building operation.

Mechanical ventilation and cooling

Definition: Mechanical ventilation refers to the exchange of outdoor air provided by mechanically powered equipment, such as a fan. Mechanical cooling refers to removing heat from the space through a chilled medium (usually air or water), which has been created using some form of external energy (typically, but not always, via compressive or evaporative cooling). Mechanical systems can either combine the ventilation and cooling functions, or keep them separate. While not as common, some buildings utilize mechanical ventilation but not mechanical cooling, either relying on natural cooling or simple fresh air exchange.

« While there is more operational control of mechanically ventilated buildings, occupants often suffer from their drawbacks—such as subjecting many people to one non-adjustable setpoint.

Potential benefits: Mechanical HVAC systems are the most prevalent approach to conditioning modern buildings for many reasons, key among them being:

- → **Load flexibility—**the ability to meet most any thermal load imposed, either through internal or façade loads;
- → **Architectural flexibility—**mechanical systems allow for greater freedom of architectural expression as the physical constraints of passive systems are relieved;
- → **Operations—**the ability to centrally control and manage facilities, schedule operations and ensure performance; and
- → **Climatic independence—**the ability to provide a comfortable and well-ventilated indoor environment regardless of exterior climatic conditions.

While often scorned for their energy consumption, well-designed mechanical systems can be very energy efficient. Mechanical ventilation systems can provide the opportunity for controlled free cooling for all exterior conditions below a specified design supply dry-bulb temperature, even down to temperatures below the lower threshold of operable window cooling. At extreme conditions (very high temperature and humidity or very low temperature), energy recovery can mitigate the energy impact of providing minimum levels of ventilation for human health and comfort.

In many climates, the energy benefit of precise metering of outside air delivery and of energy recovery from the exhaust stream can offset the energy cost of fan-forced air delivery. Advanced control approaches can be used to mitigate some of the conventional energy impacts of mechanical conditioning, including automated demand response, pressure and temperature reset, and demand control ventilation—all helping to reduce consumption significantly compared to older systems. Increasingly, these features are becoming required by building codes and standards, including ASHRAE Standard 90.1.

Mechanical systems also allow a designer to ensure the proper distribution of ventilation air to each and every occupied space and that indoor pollutants are exhausted sufficiently to ensure a healthy indoor environment. Building pressure control also is only achievable through mechanical ventilation systems, allowing for infiltration control and moisture management—both significant contributors to good IAQ.

Potential limitations/challenges: While mechanical systems are capable of delivering tightly controlled thermal conditions, they also are often derided for poor thermal control. This typically results from overly large thermal zones that subject too many people to a singular, often non-adjustable setpoint, and controls and equipment that often do not allow for user interaction and adjustment. Some of these problems can be remedied through design and equipment selection, including various personally controlled conditioning devices—though often with an increase to system cost and complexity.

Mechanical systems also can suffer from poor ventilation effectiveness, resulting in over-ventilation due to supply short-circuiting, typically when in heating mode. Engineers try to address this challenge through better zoning, as well as selection of system characteristics such as system type (ceiling versus floor supply/return locations), heating supply-air temperature, and heating approach (radiators versus all-air heating).

Noise also is a common complaint for mechanical systems, and here again these challenges can be mitigated through careful system design and equipment selection and location.

Mechanical systems do have a significant effect on the architecture as well, requiring space both in plan and in section that can result in potentially increased costs. These cost impacts, as well as the costs of mitigating the other common issues with mechanical systems, must be factored into the overall systems design and project decision-making; especially when considering mechanical systems versus natural ventilation and cooling solutions.

Best of both worlds: mixed mode

Definition: "Mixed-mode" refers to a hybrid approach to space conditioning that uses a combination of natural ventilation from operable windows (either manually or automatically controlled), and some form of mechanical cooling. A well-designed mixed-mode building begins with intelligent façade design to minimize cooling loads. It then integrates the use of mechanical cooling or ventilation only when and where it is necessary, with the use of natural ventilation whenever it is feasible or desirable, to maximize comfort while avoiding the significant energy use and operating costs of year-round air-conditioning. There does not seem to be a "standard" mixed-mode approach in practice today—each building continues to be unique. Yet there are a number of classification schemes that describe the integration of natural ventilation and air-conditioning control strategies, usually in terms of whether they exist in different spaces (zoned); exist in the same space and operate at the same time (concurrent mode); or switch on and off at different times (change-over mode).

Potential benefits: Mixed-mode buildings are less climatically dependent than purely naturally ventilated buildings, as well as being feasible in a wider variety of program types. Ideally, the building operates in naturally ventilated mode for as long as possible as weather and loads allow, and then the mechanical ventilation and cooling is there for the hours or days when natural ventilation alone cannot meet comfort conditions or is not the optimal energy solution.

Other approaches include a zoned approach where mechanical ventilation ensures minimum rates of air turnover for problematic spaces within the building (such as spaces with sporadic dense occupancy, remote from the window wall or isolated within the building infrastructure). Mixed-mode provides the designer with a lot more flexibility in being able to provide operable windows, without worrying as much about precisely sizing those windows to provide sufficient air flow for extreme conditions or adding the expense of automation of openings. Mixed-mode also provides for "passive survivability," meaning that the building is much more likely to coast through power outrages or other periods of minimal power availability without shutting down the entire building.

Potential limitations/challenges: Such flexibility comes with a cost, however. By having dual systems (natural ventilation plus mechanical equipment), there is less opportunity for first-cost savings, and the financial incentive is primarily focused on operational savings (which is clearly maximized in situations where the mechanical cooling is used less frequently during the year). Some people fear that the occupants might become confused, not always knowing when the mechanical system is on, when they should open the windows, etc. Because of this, achieving operational energy savings in a mixed-mode requires sufficient occupant education.

Occupants need to understand when conditions are suitable for "free cooling" and need to be encouraged to not reach immediately for the HVAC controls even if they are available to them. There may be some hours of the year when energy use could potentially increase, if mechanical heating or cooling is being operated while windows are open. Others argue, however, that even if this does exist, those number of hours may be far outweighed by the amount of time during the year that the mechanical cooling is never turned on in the first place.

> **"An innovative control strategy that is becoming increasingly common in mixed-mode buildings is "signaling systems," such as those that contain red/green lights or "open window" signs."**

An innovative control strategy that is becoming increasingly common in mixed-mode buildings is "signaling systems," such as those that contain red/green lights or "open window" signs. These directly engage the occupants in becoming an active participant in the smart management of the building's environmental control. This approach may actually be the tip of the iceberg in future trends in building design and operation—where educated occupants become the low-hanging fruit for enabling the industry to reduce energy use while simultaneously providing comfortable indoor environments.

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