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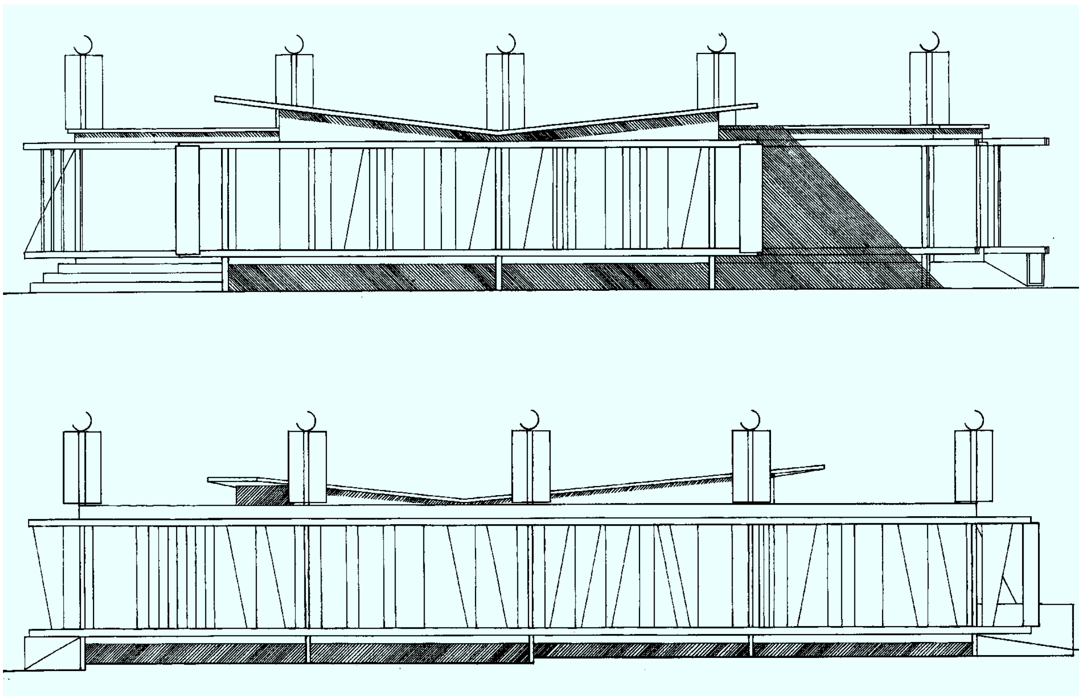

CLIMATE AND VENTILATION

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CONTENTS

Cover. A naturally ventilated building with wind enhanced solar chimneys.(Kuismanen, Viikki Club-house)

1 BUILDINGS, CLIMATE AND ENERGY

Building activities use globally about 50 % of the material resources, 45 % of energy, 40 % of water, 60 % of fertile land and 70 % of wood used by the humankind. The known oil fields will be emptied in 40 years and gas recourses in 60. That's why construction and use of buildings are central when saving natural resources and fighting climate change.(Edwards 2005: 11, 23)

Building sector is one of the greatest energy users; for instance in Italy about one third of the total energy consumption. For comparison: buildings are using 40,6 Mtoe (million tonnes of oil equivalent), industry 40,3 Mtoe and transport 41,2 Mtoe. In Italy the consumption of the building sector increased 18% between 1994 and 1999.

The placing, direction and wind protection have great effect on the energy use of individual buildings. In cold climates like Finland wind and cool air pools can cause temperature differences which can be as large as 10°C, the average being 1-2°C. The main contributors to energy consumption and pollution are heating and air-conditioning.(Gallo 10, Kivistö)

The Meteorological Institute of Finland has estimated that cold air lakes will cause, depending on the house type and place, 1.6-7.9 kWh addition to the heat consumption per square metre in a year. It has been estimated that warm south slopes will reduce annual heat consumption about 1.6-3.2 kWh per square metre. (Kivistö Raportti 2 p. 22, Pienilmasto)

Recent studies show that best results in energy saving can be achieved through passive design and recycling strategies. That means avoiding electro-mechanical devices and using the climatic conditions of the site locality as the starting point of architectural and house technical design. In practice this means the building's particular morphological organisation according to the climate and the solar conditions (see ECONO report on climate and architecture). Warming and ventilation modes determine building's life span impact. (Yeang 202)

According to Yeang the new green skyscrapers and intensive building types should seek to achieve energy use of about 100 kWh/m² per year or less, compared with 230 kWh/m² per year for fully air-conditioned – and in temperate zone heated – buildings and about 150-250 kWh/m² for un-air-conditioned offices.(Yeang 266)

The heat flow between a building and its environment takes place as conduction, convection and radiation through windows and the envelope of the building. There are many processes between the interior and the exterior of a building. The standard heat loss calculations assume mechanical ventilation and constant indoor and outdoor average temperatures. In most cases solar heat gain and the impact of the thermal mass of a building are not included in the calculations. The supply of the solar radiation affects the amount of free energy received, even though this point had not been taken into consideration separately in planning. When the amount of window area on the main facade increases, also the affect of their direction on the heat consumption will grow distinctly. With an about 25% window percentage in which case the window field includes nearly the whole façade, the difference between the best and the worst direction is already about 12 kWh/k-m², in other words less than 8%.

The total effect of the microclimate consists of the wind, sunniness and warmth of the building site. According to ASTA II study the difference of the relative heat consumption between the maximum cases and the minimum cases is 40 kWh/k-m² (28%) in small houses, more than 37 kWh/k-m² (27%) in multi-storey buildings and for tower blocks 35 kWh/k-m² (28%) in a year. However, it can be estimated that in real situations the maximum addition from the minimum to the maximum will be about 20 %. (Kivistö (2) p. 36)

According to the ASTA II study with planning which takes the microclimate into consideration it should be possible to lower the average heat consumption in residential areas 2.5-5%. On the basis of the study it can be estimated that in Finland within one area microclimate can cause at most an about 20% difference in the heat consumption of individual buildings. According to Glaumann and Westerberg in Sweden, about 10% of the heating need of buildings can be reduced when the wind conditions are taken into consideration in the design of structures and building form (Glaumann & Westerberg p 8 p 40-42 Kivistö Raport 2)

In addition to microclimate another phenomenon which affects the energy consumption is the forming of the heat islands especially in big cities. It has been stated that the annual mean temperature of big cities is usually about 1-2°C warmer than the temperature of surrounding areas. This means a difference of 5-15 kWh/k-m² in the annual heat consumption of similar buildings. According to this, the heating expenses in the centre of a big city can be 5-10% smaller than in its surrounding areas. (Kivistö p. 123-124, Mattsson p. 113-117)

2 WIND AND VENTILATION

Building ventilation has four functions:

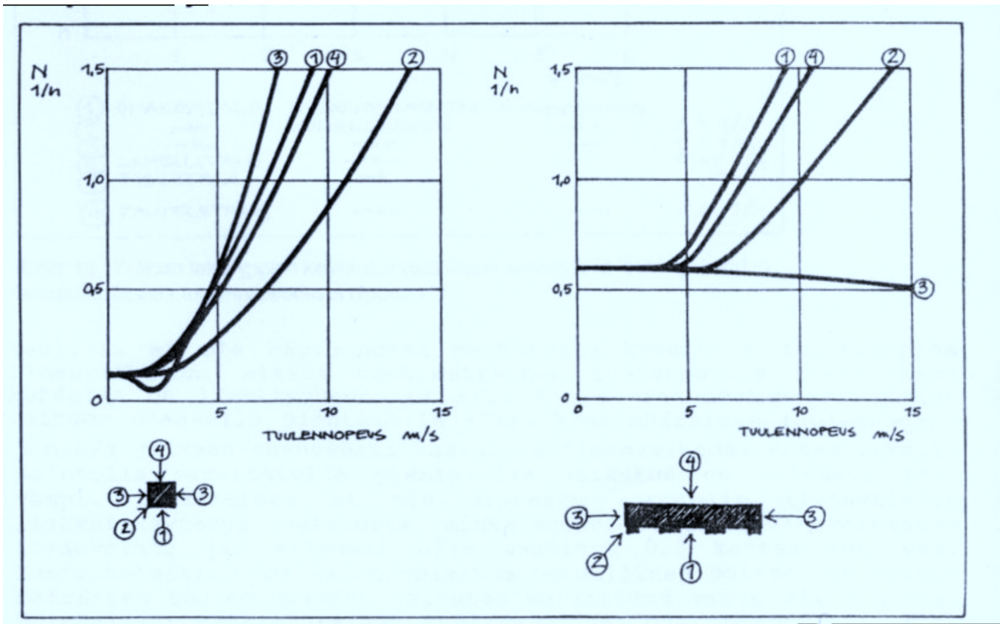
- To maintain indoor air quality: air change.
- To provide thermal comfort: air movement.
- To cool the mass of the building during the night.
- To warm the mass of the building during the day.

Winds cause pressure differences to different sides of a building, which usually tend to add ventilation and correspondingly heat consumption. According to the ASTA II study, balanced (mechanical in- and out-blowing) and stack (natural) ventilation are considerably more sensitive to the winds than one with only mechanical output. On the other hand, wind can be utilised in the operation of stack ventilation. (Climatic, Kivistö p 127-130)

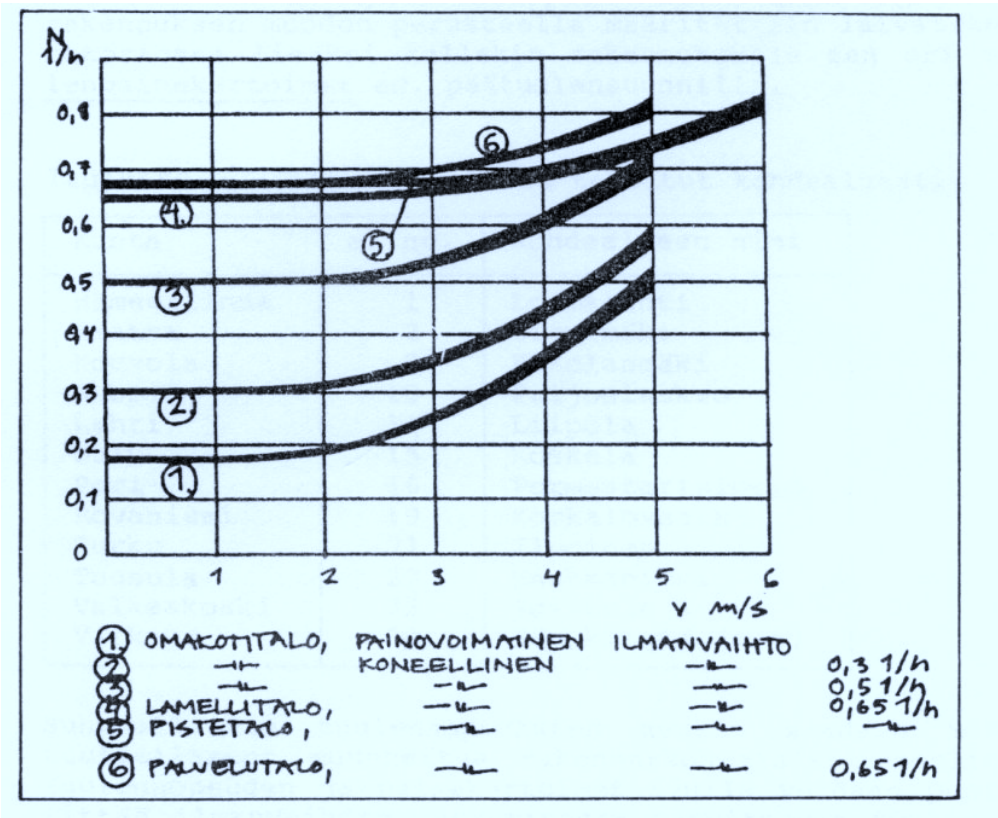
According to the results of ASTA II, wind begins to affect ventilation at more than a 3-5 m/s speed. Small houses are more sensitive to the winds than multi-storey buildings, because considerably smaller pressures in their blowers are used. However, the winds do not have significance to the ventilation of houses in practice, if the average wind speed around the building is less than 2 m/s in the heating season

In detached houses which have been equipped with stack ventilation, the difference between the maximum and the minimum will be about 30 kWh/k-m² in a year, in other words the wind causes an about 22% addition to the average heat consumption in the maximum case compared to the minimum. With mechanical output ventilation at 0.5 times in an hour wind increases the heat consumption of the same small house even about 15%. For the heat consumption of a multi-storey building and a tower block the effect of winds is a maximum of 12 kWh/k-m² only. So the relative addition to the heat consumption of multi-storey buildings caused by the wind is at the maximum less than 10%. (Kivistö (2)) p 26-28, 36-37.

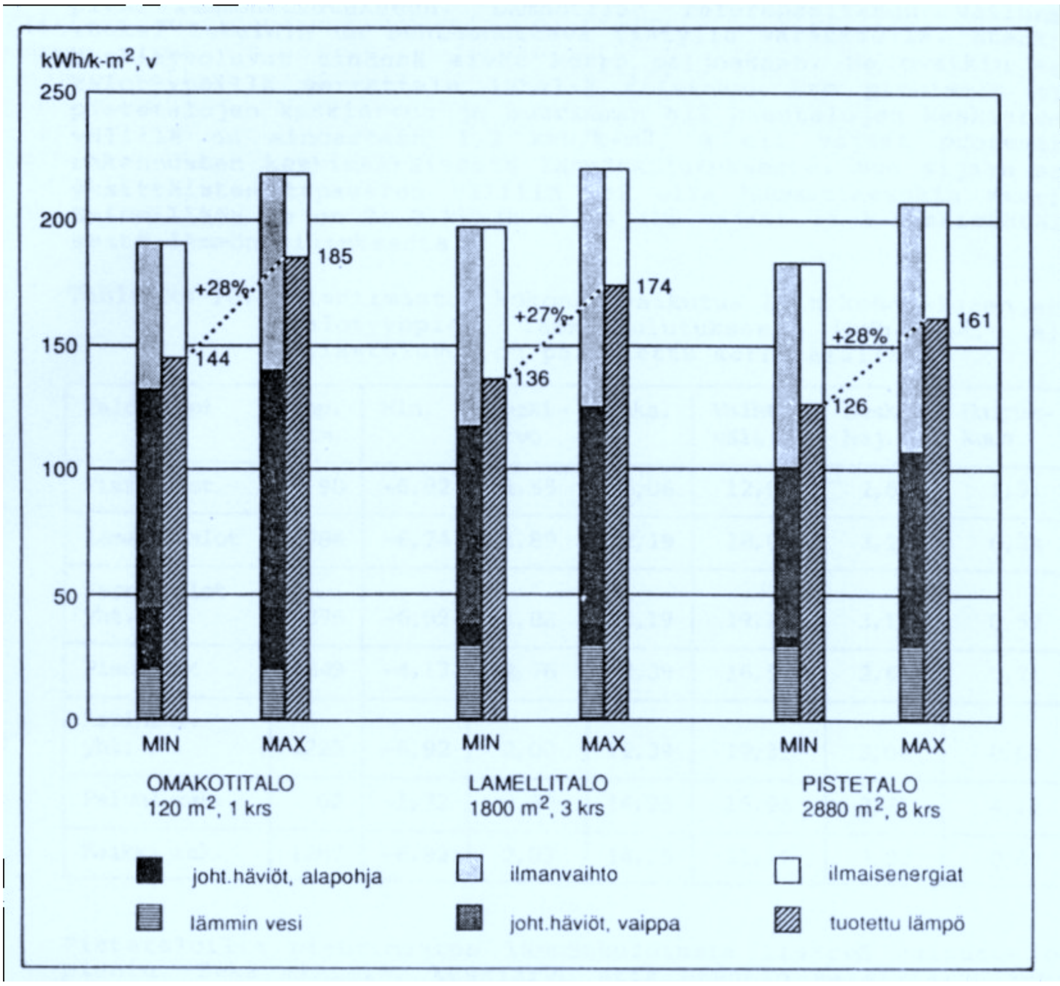
The effect of winds on the heat consumption of buildings in Finland is on average only 0.7 kWh/k-m² (0.5%) in a year. The building-specific differences in the effects of winds are considerably bigger than the average effect, over 10 kWh/k-m², in other words about 7% in a year. If in ASTA II calculations a more high-quality balanced air conditioning had been used, the effects of winds would have become bigger in that case. The Oulu district heating company has registered that the wind will raise the maximum heating power consumption during cold days by a few megawatts. According to Daniels, the growth of the average speed of the wind by 1 m/s increases the consumption of heat 4-9% depending on the place and the form of the building. (Daniels p. 165, Kivistö (2) p. 36-37)



The average ventilation amounts of some building types depending on the average wind speed of the heating season. (Kivistö Raport 2 p. 24)



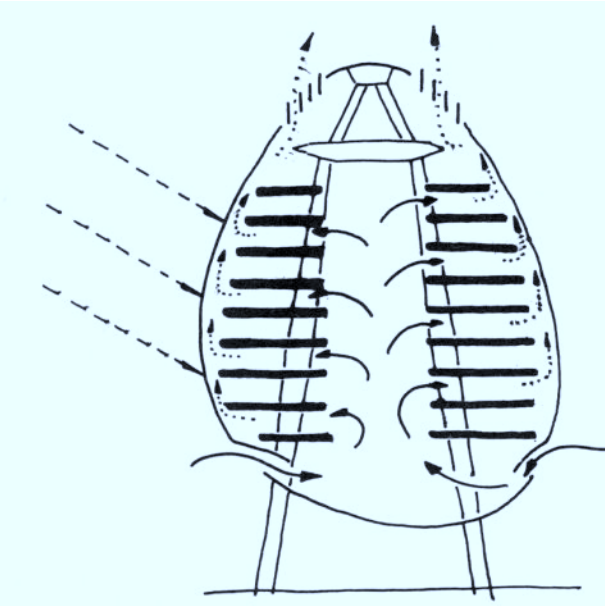
The average ventilation amounts of some building types depending on the average wind speed of the heating season (tuulennopeus = wind speed). (Kivistö Raport 2 p. 24)



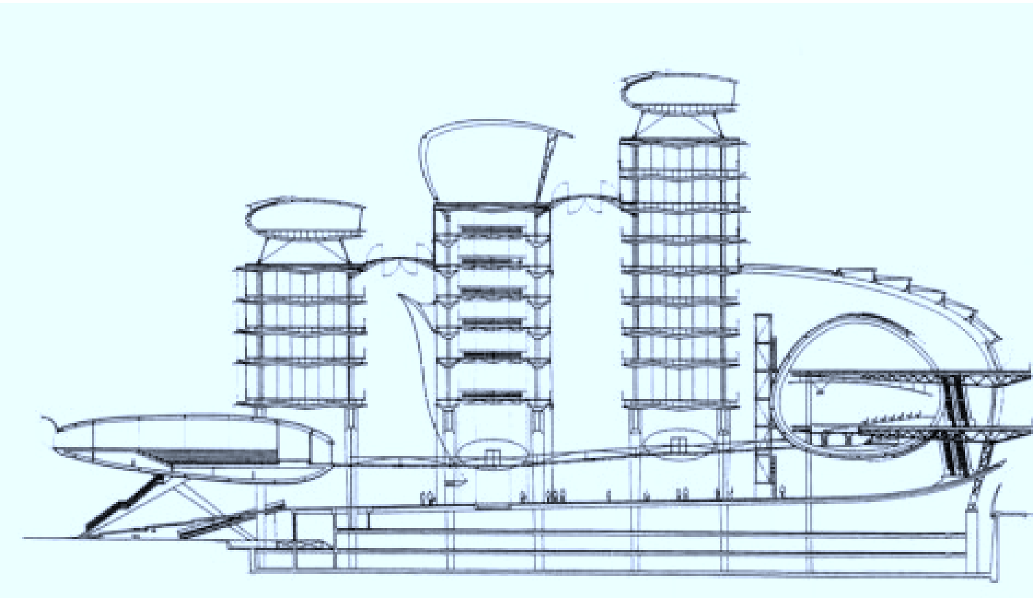
Heat balance of three different house types in regard to microclimate in a as good as possible and bad situations. (Kivistö Raport 2 p. 37)

Summary of the planning instructions:

- amounts of high wind speeds (more than 6 m/s) and high mean wind speeds (more than 4 m/s) affect the heat consumption of buildings
- on the heat consumption of a tight and well isolated house the effect of microclimate is smaller
- from the point of view of energy economy, in sheltered calm conditions the wind circumstances in designing of residential areas can usually be given fairly little attention
- in windy places, such as coasts, wide plateaus and high hills the effect of the wind is considerable, and in connection with the planning of the area wind analyses and model wind tests must be made, especially if the area is comprised of high building masses
- wind can be utilised in stack ventilation and the production of energy.



Solar facade as air conditioning system. (drawing Future Systems, cit. Oswalt p. 138)



Big building complex in which the ventilation of atriums is natural, Hotel du Department Marseille. (drawing Alsop & Lyall, cit. Oswalt p. 48)

3 NATURAL VENTILATION

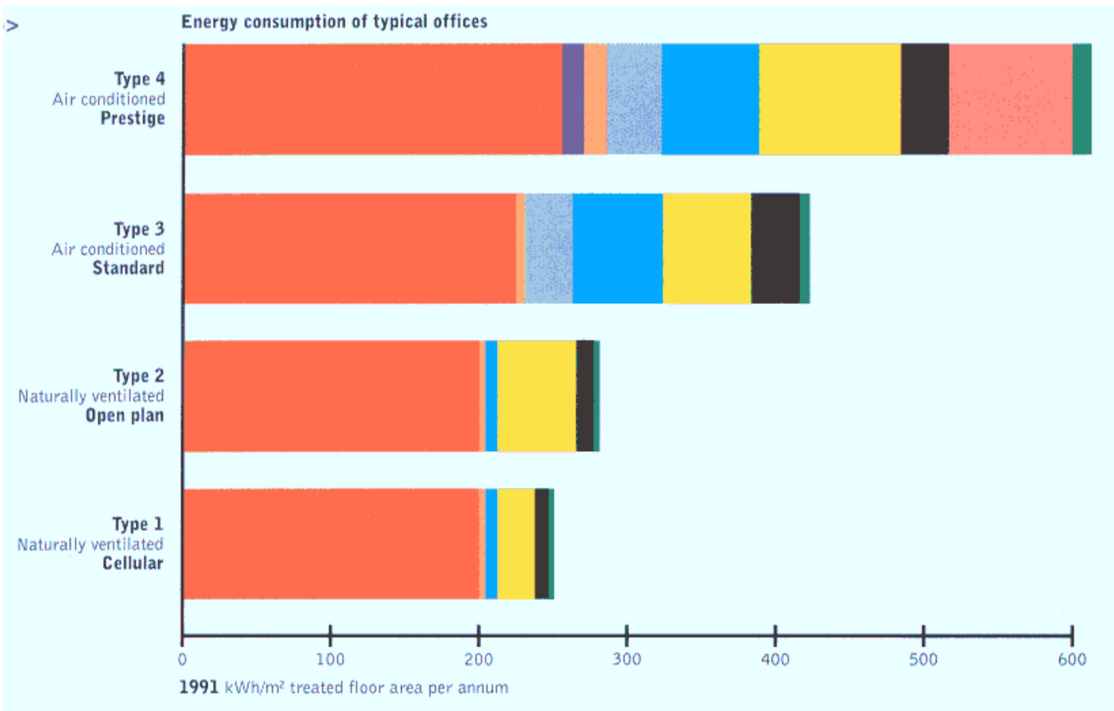
Air movement caused by temperature differences is utilised in the gravitational, in other words natural ventilation of buildings. In the lower part of a room the air is cooler than at the ceiling level, which makes the warm air at the upper part of the room flow out through ventilation shafts or high windows, and the room is ventilated. However, temperature differences which are big enough to change the air do not always occur in summer conditions. In that case natural ventilation must be intensified by the ventilation through windows, solar ventilation flues, with under-pressure ventilators or pressure differences caused by the wind on different sides of the building. (Climatic p. 63-66, Evans p. 1-4, Kossak p. 45-49)

Stack ventilation can be achieved in many different ways:
- cross ventilation at the same level
- chimney effect
- solar ventilation chimney or attic
- under pressure ventilator on the roof
- wind tower
- air flow caused by the evaporative cooling (patio or wet chimney).

Natural ventilation has become again interesting also in industrialized countries, because properly designed solutions can save both capital costs and energy. The energy consumption of buildings with natural ventilation is typically only half compared with air-conditioned ones. Also maintenance and renovation need are reduced, and there are fewer incidents of sick building syndrome.

	Typical air-cond. office (kwh/sq.m.) (kwh/sq.m.)	Good practice open-plan office with nat. vent.
Heating and hot water	222	95
Lighting	67	32
Fans and pumps	61	5
Refrigeration	33	0
Catering	7	4
Total	390	136

Comparison of energy use between an air-conditioned office and a naturally ventilated office.(BRECSU, cit. Yerang)



How energy is used in office buildings in temperate climate, like UK..(Jones)

Understanding the local wind patterns during the seasons and different hours of the day is the *conditio sine qua non* for the design of natural ventilation. Data about the diurnal temperature differences during the seasons is needed, too. For large buildings and skyscrapers the use of wind tunnel testing is recommended. Testing can be used to natural ventilation system design, façade design, structural calculations, demonstrate how smoke will behave in fire situations and shape the microclimate around the building. In ventilation design it is possible to determine the ventilating inlets and outlets, design wing-walls, test the functioning of double façades and design different ventilating devices.

Natural ventilation functions well when there are ventilation openings which have different levels of air pressure. This happens when the temperature of the outdoor air is lower than the indoor air, or when wind flow against the building causes such a difference. In hot dry climates the stack effect doesn't function during day time, but natural nocturnal stack ventilation can be used. The capacity of the building's materials to store heat/cold during diurnal temperature cycles in un-air conditioned buildings is important in areas with large diurnal temperature swings. In hot-humid regions natural ventilation caused by wind is desirable because it minimizes discomfort resulting from wet skin.

Pressure and temperature differentials between inside and outside are used to power natural and stack ventilating systems. The air near floors is cooler than the topmost layer near ceiling, and the warm air flows out through ventilation ducts or windows. The flow rate is quite small in summer, and summer ventilation by wind force or solar vents is needed. The effective vertical distance between inlets and outlets should be 5-7 meters, which can be difficult to obtain in low buildings. In winter and during hard winds there is the danger of over-ventilation. In large buildings hybrid ventilation systems are often the most effective.

On the skyscrapers façade wind performance grows exponentially as it moves upwards. Therefore a series of modified natural venting devices are needed for different height zones of the building's walls. Often in polluted city centres hybrid systems give the best results in tall buildings: natural ventilation for entrance halls, lift-lobbies, staircases and toilets, and mechanical devices for offices. For residential towers in warm climate natural ventilation is frequently used. In temperate climate each season should be treated separately, and the mechanical devices are used only during the coldest and warmest periods.(Climatic 63-66, Evans s. 1-4, Kossak s. 45-49, Matilainen, Yeang 245-256)

Placement and size of openings affects greatly the air flow pattern inside the buildings (picture …). Cross-ventilation can be made better by adding to each opening a single vertical projection - a wing-wall - to increase the air pressure (picture …). Enclosed central courtyards or atriums can be used to bring fresh air into the building and to pre-heating of the air. The body of a naturally ventilated house must not be too deep, and the rooms should open out or to an interior court. Rooms ventilated from one side only should not be deeper that 2.5 time their height. Cross ventilated rooms can be 5 times deeper. One residential unit should have openings both on the windward and leeward sides. Even with winds oblique to a wall up to about 60 degrees it is possible to use windows as inlets for the wind. In warm climates high interior spaces are recommended, because in them overheat has the possibility to rise, while in cold regions unnecessary cubic meters rise the need for warming energy.(Daniels s. 164, Kossak s. 45-49)

To make sure the functioning of ventilation and in fire situations the right dispersal of smoke it is recommended that the ventilation of deep bodied and high buildings is studied in a wind tunnel or in a climate laboratory with smoke tests. (Daniels p. 164, Kossak p. 45-49)

4 COOLING

In most countries over heat is a big problem for buildings at least during summer. Very often passive low-energy cooling systems can provide sufficient indoor comfort even in hot climates. These cooling options include:

- Daytime ventilation.
- High mass, with or without nocturnal ventilation.
- Direct evaporative cooling.
- Indirect evaporative cooling by roof ponds.
- Radiant cooling.
- Soil cooling.
- Cold water cooling.

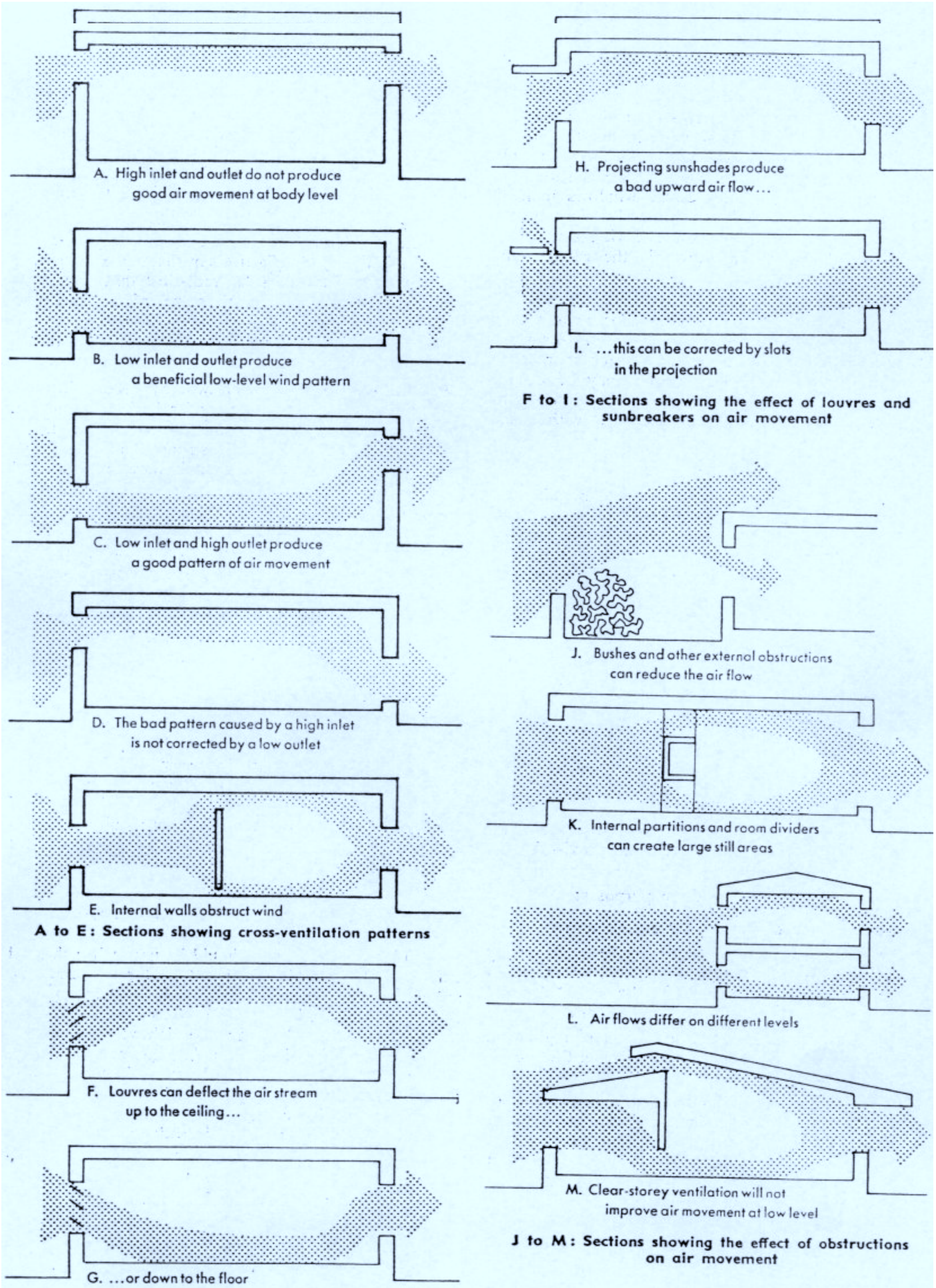
Ventilation has a direct effect on human comfort. In cold climates it brings fresh air in when indoor temperature is too high. In warm climates it provides higher airspeeds thus extending the upper limits of acceptable temperature and humidity.

Nocturnal ventilation can be used in such climates where night temperatures are lover than about 25°C. A building with high mass is ventilated during evening and night hours thus cooling the mass which absorbs the over heat during day time. In areas with cold nights warm air is ventilated in during the day and stored in the structure of the house or in special storage bins. During the following night hours the mass will keep the indoor temperature above the outdoor level.

In direct evaporative cooling the temperature of the outdoor air is lowered before it is led indoors. This can be done either by mechanical systems - like swamp coolers or desert coolers – or by passive means, such as cooling towers. In cooling tower fine drops of water are sprayed downward like a shower. The falling water creates an airflow down. The evaporation from the fine drops cools the water, as well as the air. This kind of cooling functions best with warm or hot dry climate, in tests in Saudi Arabia the outdoor maxima was +44°C and the indoor maxima about +28°C. Passive indirect cooling can be realised by providing a shaded water pond over an un-insulated roof.

All spaces with glassed roofs or even other un-insulated material, such as concrete, lose heat by the emission of long-wave radiation toward the sky. During the daytime the absorbed solar radiation counteracts the cooling, and operable insulation is needed against over heating. (Givoni 191, 198)

Temperature of the soil is almost constant the year round and the simplest soil cooling system is the traditional cellar. Cold ground water can be used for cooling by using cold radiators on the ceilings or letting a thin water layer flow down on certain surfaces outside or inside the building. The later system will increase the humidity of the indoor air, too.



The effect of different kinds of openings for wind force ventilation (climate s. 62)

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