DESIGNING A COMFORTABLE BREEZE

PETER MENSINGA

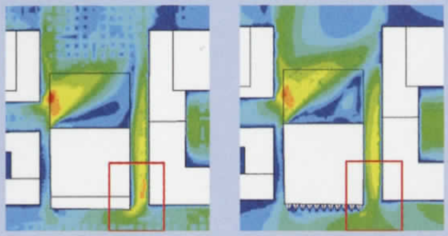
Peter Mensinga is a climate designer and environmental engineer with ARUP. He specialises in holistic sustainable planning in architecture and urbanism.

As I write this short essay about my relationship with wind in my professional life as a climate and sustainability engineer, the rain is being blown against the window. I am thinking about yesterday's wind which we tried to capture as best we could in our sails while sailing in the late summer sun. None of this would be possible without wind. Like the sound of the trees in front of my open window the day before yesterday, when I was listing some of my work that I would like to share with you in this essay. This selection of work, I hope, will show that wind is an interesting design parameter for architecture and master planning. Before sharing it with you, I would like to let you know that I am not a bona fide wind expert. My interests lie in rethinking our environment in terms of climate design and our use of resources to make it comfortable for us.

Air velocity, as we call wind in indoor climate design, is an important parameter for thermal comfort. The other parameters are clothing, rate of activity, air temperature, radiant temperature of surrounding surfaces and air humidity particularly in extreme conditions. The combination determines whether people feel comfortable or uncomfortable. For indoor thermal comfort the work of Danish researcher Fanger (1934–2006) plays an important role in building design. Type "comfort calculator" into your browser and you can play with the different parameters to understand the technology behind indoor climate design. Similar work has been done for outdoor thermal comfort. This is commonly referred to as "wind chill", used to warn of chilly winter days, while "heat stress" is for humid summer days. Strangely, in the latter, wind plays no role at all. Please type "weather calculator" in your browser to discover more. In scientific papers outdoor comfort is discussed, among others things, as physiological equivalent temperature and perceived temperature.

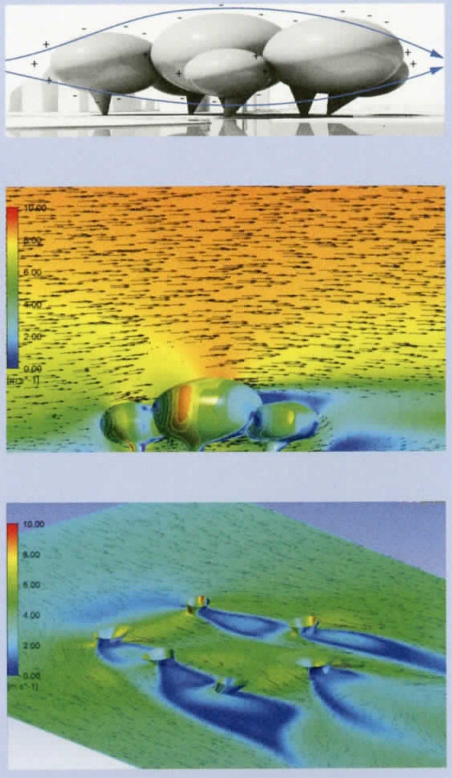
The first work I would like to share with you is from Dubai. We are all familiar with the temperature difference between air-conditioned indoor environments and the hot outdoors. In Dubai an extreme difference between indoors and outdoors occurs at least for four months a year.

For the major part of the year, however, this difference is less extreme. Outdoors the climate is actually very comfortable. Unfortunately, the four months of extreme climate is taken as the rule for the design of the contemporary buildings, which is focused on the indoor climate. The relation between indoor and outdoor is neglected.
Our design ambition was to create a building block for the typology with which we are familiar in (northern) Europe, where people are encouraged to go out on the street into the street rather than staying inside. For that reason we designed a thermal transition zone comprised of shade provided by trees, preventing direct solar radiation. An outdoor colonnade with a forced air flow uses exhaust air from the indoor space and entrance sludge. The perceived temperature gradually goes from 23°C inside to 28°C in a transition zone to 33°C and 37°C in the shaded peripheral areas of the building to 40°C in unprotected areas in direct sunlight. We irrigated the trees with waste water effluent.
In the same project we studied the air flow over the proposed urban fabric in order to predict comfortable places that were protected from the sun and with a likely gentle wind for outdoor terraces. Computer Fluid Dynamic (CFD) simulations were used to model the possible build up of sand in the proposed courtyards. We've studied a similar phenomenon, evaluating the consequences of new residential towers in a master plan, in this case a listed modernist centre constructed in 1950s. The new towers significantly reduced the wind and solar quality at street level, hence more gusts of wind and less sunlight. In contrast to Dubai, we looked for sunny and shaded places. For the local community and decision makers the study brought awareness of of the existing air quality and showed the counterbalance of increase of dwellings of our existing city centres.
Serious wind investigations are at stake when gusts of high wind are expected or, if we are unlucky, are already happening on a built project. This is the field of the real wind expert who possibly prefers making use of wind tunnels to prove whether he/she is right or wrong. Although CFD simulation is catching up, wind tunnel studies are still more advanced, particularly in studying small and large scale air turbulence. Personally, I've never been in such an urgent situation. I remember a project in Amsterdam, though, where we wanted to find out if a large curtain draped facade would have a positive impact on air flow at pedestrian level. It did have an impact, but much less than offsetting the building back from the street. The latter wasn't allowed, however, by the local authorities,



[Fig. 156.] CFDv study of the effect of a draped curtain wall on the air flow at pedestrian level.

[Fig. 157.] Dutch stamp to celebrate unbuilt smart architecture with augmented reality.



[Fig. 158.] Flow around the aerodynamic-shaped bubbles, the CFD images prove that the space underneath the building doesn't suffer from unpleasant wind gusts.

who were in favour of straight alignment of the buildings on the street. The curtain draped building was never built but instead was printed on a Dutch stamp to celebrate unbuilt smart architecture with augmented reality.

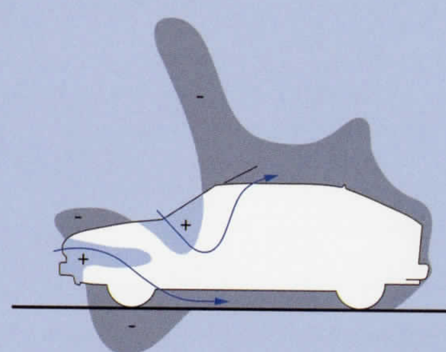
Sometimes wind becomes a major design parameter. This happened in the design of a comic museum in Asia. The architect quite literally suggested using the speech bubbles seen in comics to shape the building. The aerodynamic-shaped bubble hovers above ground level supported by the "tails", an important characteristic of a speech bubble. With the help of CFD, I proved that the space below and around the building would not suffer from unpleasant gusts of wind. Also, as a result of its aerodynamic shape, air pressure around the facade of the building would be homogeneous. The homogeneous flow results in a lower pressure which is very useful for creating a natural wind flow through the building. I've used the ventilation of a GS to illustrate how this works. Apart from two places, at the front and between the engine's hood and the front window, the car has a lower pressure area over the bodywork. Only at the front there is higher pressure, which is used to let the fresh air in. Extrapolating from this concept one need not bother about heat recovery because air leaves the building all over the facade. I lost sight of the project, as sometimes happens, but the building seems to be under construction. Incidentally, the architect owned a GS...

Moments of serendipity occurred more than once while studying air flows in and around buildings. Such a moment happened once while I was studying how to prevent uncomfortable wind flows through a green canyon, created between two or more building elements. Some time before, I had studied the active use of plants for indoor air-conditioning. It struck me that indoor greenery had a certain dullness. While working on the green canyon design I discovered that wind makes greenery come alive. Wind makes leaves move, which results in a pleasant noise. And when lit it also becomes a twinkling visual experience. From that day I starting advising that indoor greenery should always put in air streams near windows and doors, in front of ventilation grills or where I anticipate that thermal buoyancy will create air movement. For those unfamiliar with thermal buoyancy, this is air movement due to temperature difference in an enclosed space with a significant height. It is an interesting wind phenomenon. Please type "stack effect" into your browser to discover more about it.

Sometimes you run into unpleasant surprises while designing with wind. I once suggested a naturally ventilated velodrom. (Most velodroms are mechanically ventilated to control air flows and temperature.) We used computer modelling to try and convince the jury that natural ventilation would be very comfortable and incur minimal operational costs. It turned out that we rubbed salt in the wounds of the national cycling organisation, which years before had invested heavily in training with bicycles with closed wheels only to discover on the day of the competition that closed wheels did not perform well with the natural wind flow crossing the arena. In their minds they lost their competition because of unpredictable wind flows. We lost ours trying to prove that a comfortable breeze would not necessarily had have the reason they lost the competition.

Like all unusual design parameters, playing with wind comes as an addition to the traditional program of requirements. In order to allow the integration of wind into the design concept, it is likely that one has to compromise on other aspects of the design. Briefly, this is exactly what happened when I was involved in work on a museum extension. I was able to make the client invest in proper natural ventilation openings in public spaces by first saving significant money on the mechanical system, by connecting the extension to the existing mechanical system instead of investing in new equipment and costly basement space. It is best, when playing with wind, to look for the multiplier effect. I know of a wind-driven building design where the aerodynamic shape not only promised the opportunity for natural ventilation but also resulted in less air turbulence in the environment, which in turn meant that the local bat habitat remained undisturbed. With that, the aerodynamic shape became the licence to build.

In this essay I've tried to give you a glimpse of the richness involved in trying to design with wind in architecture and urban design. That it is a crucial parameter for creating the requisite thermal comfort. And that a better understanding of how a wind affects your design will result in new discoveries. Implementing these discoveries in built design requires: practical thinking, being lucky in finding the right multiplier effect; finding the right story for marketing purposes; daring to compromise; and designing with a proven backup. Not in the least because air flows are difficult to predict. The easiest way is to prevent wind disrupting your plans. But as you probably realize by now, I believe designing with wind is healthier and more inspiring, which is why this book is so important.



[Fig. 159.] Aerodynamics of a Citroën GS, used to explain the natural wind flow through a building.

IN THE NATURE OF FLOW

CHRISTOPHE DM. BARLIEB

Christophe DM. BARLIEB is an architect and currently Visiting Professor at the Technical University, Berlin. His work focuses on the fields of conceptual architecture and digital design.

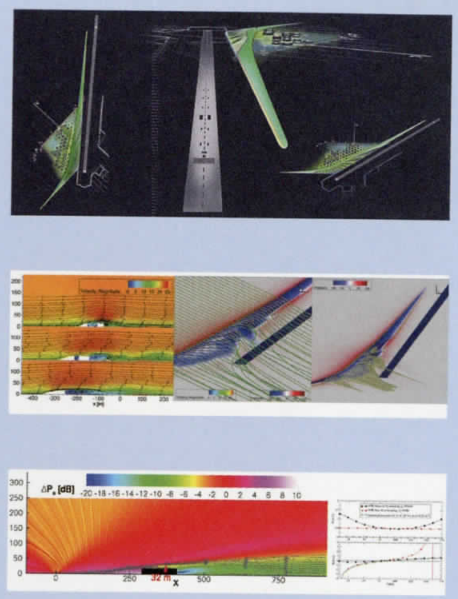
When looking at climate related designs where wind plays a central role in the architecture, they are often located in the Netherlands. In the early Dutch landscape paintings of the van Ruysdaels, van Goyen and other Dutch masters of the Golden Age, the lowlands are depicted as horizontal, flat, endless, filled with windmills, billowing clouds and sails along the horizon. The light is intense and the skies are crisp. One feels the force of the brisk winds in these pictures. The polder landscape is essentially devoid of vertical obstacles and thus the wind blows through the fields with the same ease as the farmers move through them.

A similar idea applied to the Docking Dunes project for the Rotterdam Architecture Bienniale in 2006. The proposal tied together four mineral transportation barges filled with fine white gypsum sand (literally from White Sands, the National Park and US Army missile testing site in New Mexico, U.S.A.) to create a large artificial dune landscape docked in Rotterdam harbour. The installation allows visitors to hide among the dunes, to play in the sand's soft undulating geometries while the sounds of the harbour are muffled by the air pockets found between the fine crystals.

With time, the dunes flow, change shape, move and eventually erode away. In essence the project is envisioned as a large horizontal hourglass, where gravity is replaced by wind. Time is no longer a constant measure of space, but rather flows like a river that rises and falls with the seasonal tides.

[Fig. 160.] Docking dunes.

Whispering Wind is a project proposal for a new noise reduction facility at Schiphol Airport. Airports appear to be natural wind roses. Ideally, aeroplanes take off and land in the wind, so runways are designed to align with local prevailing winds. In the case of Schiphol, though, there are several runways spread across the polder because the wind likes to dance about. The principal challenge of the design was: how does one make a 20 m tall structure appear 30 m to sound? The project avoids delving into complex structural engineering technology to solve the problem. To overcome extreme noise conditions found at the site (a runway used for take-off and landing operations generates extreme noise pollution carried by the wind onto the adjacent town) the project incorporated the wisdom of the ancient texts by Vitruvius describing acoustic resonators; today, these are better known as Helmholtz resonators and they allowed us to to explore sustainable design solutions inherent to the polder. The wind coupled with large resonating chambers, ideally carries noise up and away from the hard clay like fields that are the perfect medium for propagating the low-frequency noise associated with jet engines. Furthermore, the wing shaped, dyke-like structure aerodynamically holds airstreams together to avoid undesirable eddies on the runway.



[Fig. 161.] Whispering Wind project.

> **The Whispering Wind project has thus been named for its performance criteria, and derives from a desire to let nature flow, to let it find its way over geometries eroded by and attuned to the wind.**

The wind, the estuaries and Dutch culture, itself are moulded by the sea; without the wind no pumps would have come into being to move water out of the basins and no ships would have crossed the oceans, leaving the Dutch moored in the clay.

LET AIR IN, LET AIR OUT

OTTO KLEMM

Otto Klemm is Professor of Climatology at the University of Münster, Germany. His research focusses on processes within the atmospheric boundary layer. Topics include air pollution and turbulent exchange between the surface and the atmosphere, as well as the dynamics of atmospheric aerosol particles and fog.

Weather and climate at any specific location in the world are driven by macro-scale, meso-scale and micro-scale processes. The geographical latitude, temperature and precipitation regimes lead to well characterised "climates" or macro-scale climate zones. Passing over to the smaller scale, phenomena such as proximity to the nearest body of water (e.g., an ocean), altitude above sea level or the presence and type of vegetation, lead to more and more complex patterns in both the spatial and temporal domains. Eventually, at the micro scale, local conditions and processes modulate the local weather pattern enormously. How much of the incoming solar radiation is used to heat the surface? Are there a lot of air-polluting emissions? Is the air flow restricted or channelled by obstacles such as valleys or ridges, by tall vegetation, or even by buildings?

Any urban climate is altered in comparison to its adjacent rural environment:

Firstly, the heat conductivity of urban structures, i.e. buildings and roads, is much greater than that of a natural environment such as soil or vegetation cover. Therefore, heat energy penetrates the urban fabric better eventually leading to a higher energy content and higher average temperature.

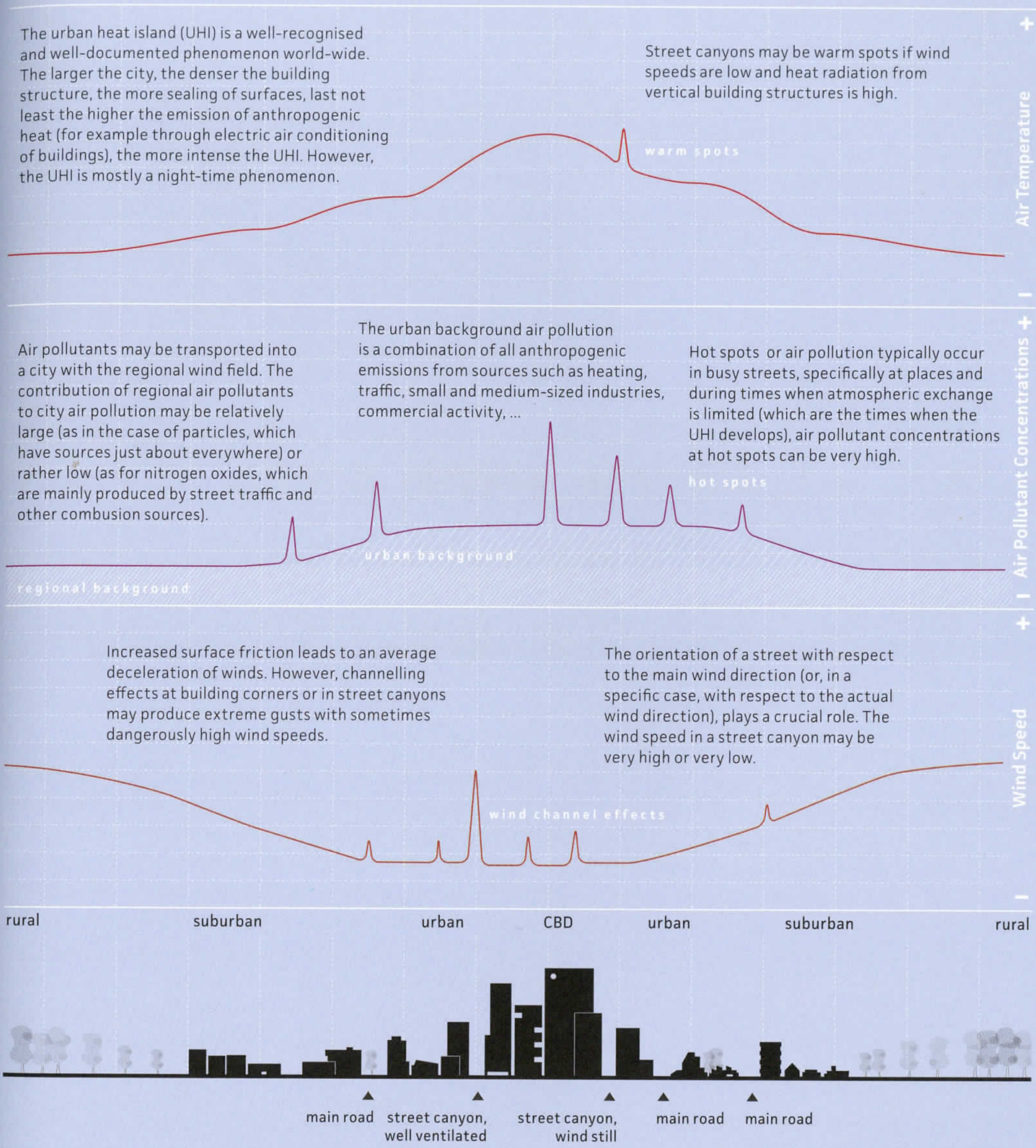
Secondly, the below-ground drainage of precipitation renders this water unavailable for evaporation or transpiration within the city. As a consequence, less of the available energy (heat, solar radiation) is used for the evapotranspiration process. The additionally available energy leads to a further increase in the urban temperature.

Thirdly, buildings lead to a modification of the wind field, with deceleration at most locations and the potential for gusts at other places.

Finally, cities are typically centres for the emission of air pollutants. Vehicular traffic, domestic heating and light industry lead to pollution levels that are in some cases very severe.

Most of the processes described foster the establishment of the "urban heat island" (UHI). Depending up on the size of a city, the ambient temperature may be 1 to 12 degrees warmer than that of the surrounding rural environment. However, the UHI is mostly a nocturnal phenomenon. Why?

[Fig. 162.] Opposite page: City climate and rural climates exhibit systematic differences. The issues of air temperature, a modulated wind field, and air pollution, must be considered together. The structure and physics of buildings are common drivers. The regional wind field is heavily modulated. When wind speeds are low, the urban air temperature is often higher than that of the hinterland. Many air pollutants exhibit high concentrations in cities. Actually, there are exceptions: ozone, for example shows higher levels in neighbouring rural regions. Intelligent design of urban structures can be utilised to allow good ventilation, mitigating the urban heat island and air pollutant hotspots. Let air in, let air out.



The urban heat island (UHI) is a well-recognised and well-documented phenomenon world-wide. The larger the city, the denser the building structure, the more sealing of surfaces, last not least the higher the emission of anthropogenic heat (for example through electric air conditioning of buildings), the more intense the UHI. However, the UHI is mostly a night-time phenomenon.
Street canyons may be warm spots if wind speeds are low and heat radiation from vertical building structures is high.
warm spots
Air Temperature
+
–
Air pollutants may be transported into a city with the regional wind field. The contribution of regional air pollutants to city air pollution may be relatively large (as in the case of particles, which have sources just about everywhere) or rather low (as for nitrogen oxides, which are mainly produced by street traffic and other combustion sources).
The urban background air pollution is a combination of all anthropogenic emissions from sources such as heating, traffic, small and medium-sized industries, commercial activity, ...
Hot spots or air pollution typically occur in busy streets, specifically at places and during times when atmospheric exchange is limited (which are the times when the UHI develops), air pollutant concentrations at hot spots can be very high.
hot spots
urban background
regional background
Air Pollutant Concentrations
+
–
Increased surface friction leads to an average deceleration of winds. However, channelling effects at building corners or in street canyons may produce extreme gusts with sometimes dangerously high wind speeds.
The orientation of a street with respect to the main wind direction (or, in a specific case, with respect to the actual wind direction), plays a crucial role. The wind speed in a street canyon may be very high or very low.
wind channel effects
Wind Speed
+
–
rural
suburban
urban
CBD
urban
suburban
rural
main road
street canyon, well ventilated
street canyon, wind still
main road
main road

[Fig. 163.] Typical situation in a medium-size city in Germany. The arterial highway is oriented into the main wind direction. Therefore, the street canyon can act as a channel for city ventilation. On the other hand, the rather intense road traffic leads to high pollution levels. An air quality monitoring station (yellow container) is operated on the pavement on the left-hand side. Concentrations are close to European limit values.

During the night, the atmospheric boundary layer typically cools, calms down, and stabilises. Urban structures release some of the heat energy that they had taken up during the previous day. There is not much exchange of air masses between the urban and surrounding rural environment – different characteristics develop. During daytime, turbulence is produced at the surfaces after uptake of energy from solar radiation. A regional wind field develops. Depending on the size and strength of the wind field, it penetrates the city, leads to more or less intense mixing of air masses and thus evens out the difference between the urban and rural climates. This is a very important process because it leads to an input of fresh air into the city and reduces the stress resulting from very high temperatures and calm conditions. Furthermore, recently emitted air pollutants can be flushed from the city, diluting the urban air and thus ameliorating air quality. The more intense the import and export of air masses, the fresher and cleaner the urban air is. In other words, the more the import and export of air is restricted by the building structure, the less comfortable city life is. Therefore: let air in, let air out!

The concept and importance of city ventilation is well recognised by many urban planners. Will they be able to act according to this understanding? Urbanisation is an ongoing process world wide, city compaction is one of

the consequences. Open space is increasingly becoming an expensive and limited, even a luxurious resource. For what purpose would an urban planner be able to keep open space? Even street and rail traffic are often relocated underground in order to create new space. Would this space be kept open "only" to allow fresh air to come in and polluted air to get out?
From another perspective, what is the role of climate change? Efforts to mitigate climate change call for energy-efficient buildings. Such buildings are well isolated and have a large volume-to-surface ratio. Compact and large structures are the logic consequence. In that sense, urban compaction meshes well with sustainable concepts. However, a compact structure is not likely to be well ventilated. How can this development be married with the need for good city ventilation?
Good ideas and concepts are welcome. Probably there is no single best solution. Cities are not alike but located in different climates on the macro, meso, and micro scales, with different histories and different structures. In any case, intelligent solutions are needed to foster good ventilation of the urban fabric whenever heat or air pollution is an issue. Urban climate and gives wind can be implemented as a key element in urban development, how architects and urban planners can realise solutions in which wind is among their main priorities.

DESIGNING WITH WIND

[Fig. 164.] Mitch Dobrowner, Bear's Claw, Moorcroft, Wyoming 2010.

Let air in, let air out!

Otto Klemm

CLIMATE WORLD MAP

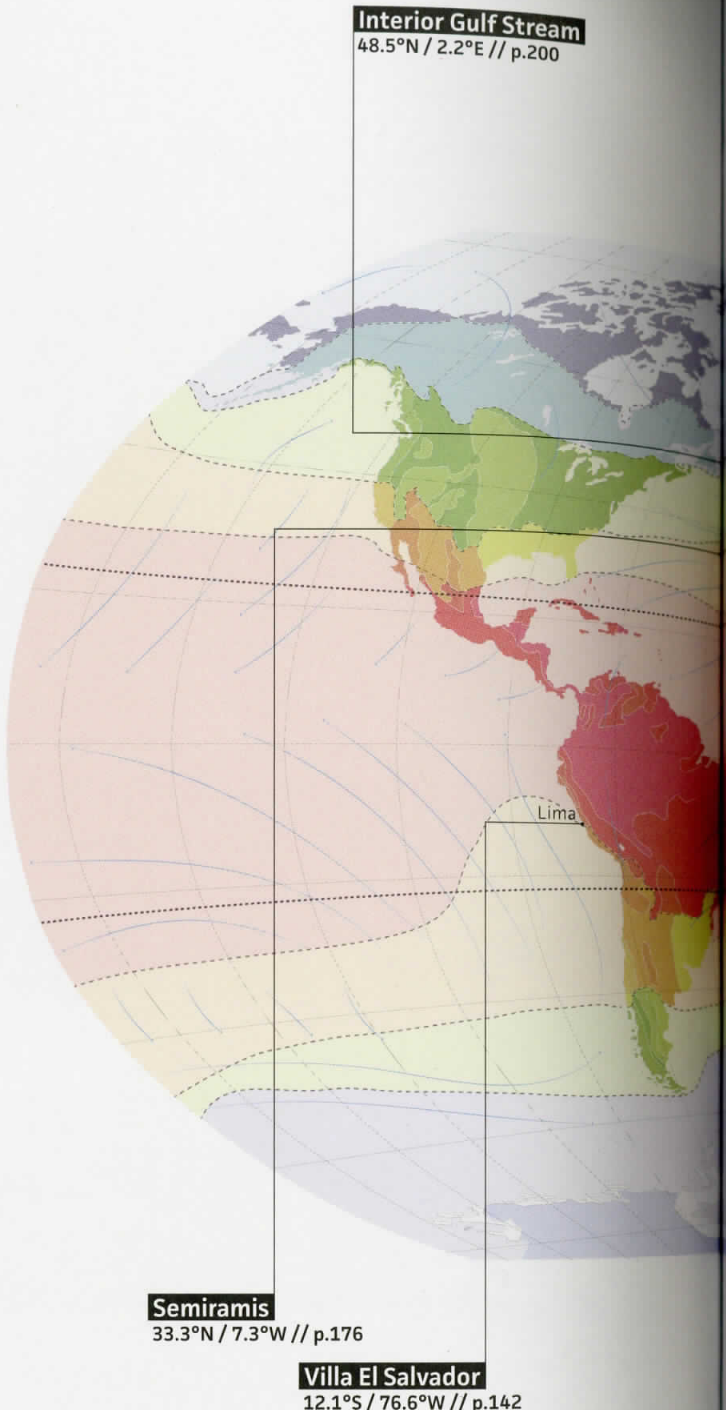
TROPICAL ZONE
- Tropical Humid Climate
- Tropical Semi-Humid Climate
- Tropical Arid Climate
- Tropical Desert Climate

SUBTROPICAL ZONE
- Arid Desert Climate
- Steppe Climate
- Mediterranean Climate
- Subtropical Humid Climate

MILD TEMPERATURE ZONE
- Desert Climate
- Steppe Climate
- Oceanic Climate
- Continental Climate

SUBARCTIC ZONE
- Subarctic Climate

ARCTIC ZONE
- Tundra Climate
- Polar Ice Climate

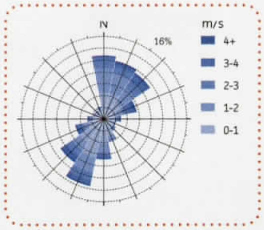


[Fig. 165.] Climate world map.


Sensational City
51.9°N / 4.3°E // p.152
Windscape City
51.9°N / 4.3°E // p.144
Climate Campus
51.9°N / 4.3°E // p.182
Jätkäsaari
60.1°N / 24.6°E // p.158
Flowmorphology
51.9°N / 7.4°E // p.148
Through & Beyond
51.9°N / 7.4°E // p.156
Lyceé Charles de Gaulle
33.3°N / 36.2°E // p.172
Druk White Lotus School
34.0°N / 77.4°E // p.168
Badgir
31.5°N / 54.2°E // p.164
Masdar City
24.3°N / 54.3°E // p.134
Xeritown
25.0°N / 55.2°E // p.138
Helsinki
Rotterdam
Münster
Paris
Madrid
Casablanca
Damascus
Ladakh
Cairo
Riyadh
Abu Dhabi / Dubai
Shenzhen
Hyderabad
Hanoi
Gando
Noumea
Tjibaou Centre
22.2°S / 166.3°E // p.186
Airtree
40.3°N / 3.4°W // p.190
Wind Scales
24.4°N / 46.6°E // p.192
Mangh
25.2°N / 68.2°E // p.162
Interactive Facade
22.4°N / 113.6°E // p.196
School Complex
11.5°N / 0.3°E // p.174
Malquaf & Dur Qa'a
30.0°N / 31.1°E // p.166
Space Block
21.2°N / 105.5°E // p.178

The CROSS HAIR locates the project on the world climate map according to the UTM coordinate system.

The ANNUAL WIND ROSE indicates the frequency (%), the direction (degree) and the speed (m/s) of the wind. Dark colours represent stronger winds.



GENERAL INFORMATION is indicated in black. Studies emerged from an academic context are highlighted in colour. Projects are now completed or in construction. Usually a large interdisciplinary team has been in charge. Detailed credits can be found at the end of the book.

SCHOOL COMPLEX

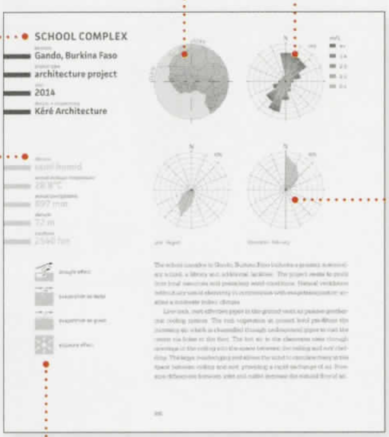
location
Gando, Burkina Faso

project type
architecture project

year
2014

design + engineering
Kéré Architecture

The DASHBOARD is always the first page of a project. It shows local climate and wind data next to general information.



climate
semi humid

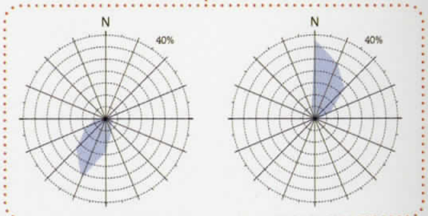
annual average temperature
28.8°C

annual precipitation
897 mm

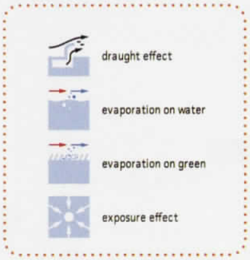
altitude
72 m

sunshine
2540 hrs

CLIMATE DATA is indicated in blue. The relation between temperature and humidity has a major influence on specific wind strategies.



Wind effects are explained in the chapter "A handful of principles". There are different classifications relating to aerodynamics and thermodynamics and also social effects. Red and blue relate to air temperature, "+" and "-" indicate pressure.



Additional WIND ROSES show seasonal or daily wind directions and frequencies.
Note: the colour does not reflect wind speed.

HOW TO WORK WITH WIND

This is a compendium of architecture and urban design which only refers to the climatic parameter of wind. Twenty-two projects and studies have been analysed to find evidence for the method and inspiration behind each approach.
There are two categories of projects. On one hand contemporary projects and traditional architecture relate to best practice. In these projects, usually designed in a holistic way, wind was one of numerous parameters for the design, but is of key importance for this compilation. On the other hand empirical studies trigger speculation enriching methodological variety and strategic thinking.
The "dashboard" – a format for local climatic and wind data on the first page of each case study – relates the project to the climatic context. The frequency of winds is shown in different scales for each case study. The annual wind rose is printed at the top, while additional wind roses below show specific seasonal or daily conditions. » Mapping Wind

Although wind is unpredictable, the mapping of prevailing winds leads to a site-specific wind regime which provides valuable information for climate strategies.

Working with wind offers unexpected potentials and benefits, for instance the optimisation of energy balances. Wind can be integrated in the design process in various ways: for example, in the Semiramis project natural air flow is used in order to optimize the ventilation and cooling performance of the building. The Druk White Lotus School uses thermodynamic principles with solar radiation. Wind catchers in Hyderabad are aligned precisely to one prevailing wind in order to exploit aerodynamic conditions, while wind catchers in Yazd are multi-sided, reacting to more than one prevailing wind direction.
When it comes to extracting principles for wind-specific design, the transfer of schematic guidelines to other places and projects has to be done with care, taking the complexity of all local parameters into account.

MASDAR CITY

location

Abu Dhabi, UAE

project type

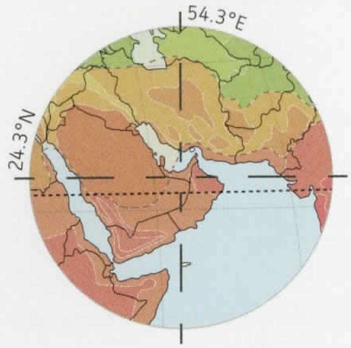
urban project

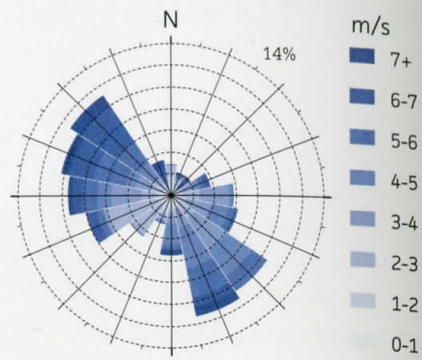
year

2007

urban design + climate engineering

Foster & Partner
Transsolar





climate

subtropical, humid

annual average temperature

26.8°C

annual precipitation

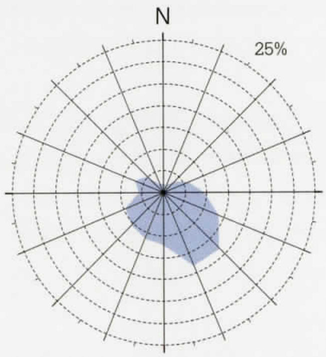
88.9 mm

altitude

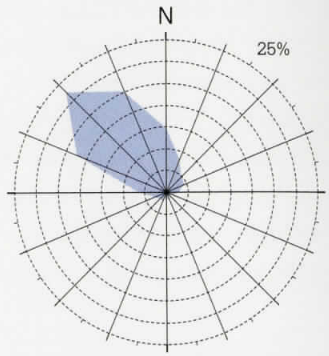
2 m

sunshine

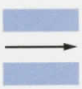
3609 hrs

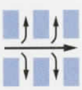


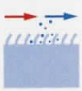
Morning

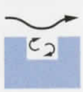


Afternoon / Night


channelling effect


diverting effect


evaporation on green


wake interference flow

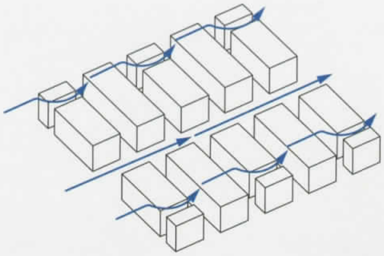

back pressure effect

Masdar City became synonymous for a sustainable eco-city. Comprehensive and ambitious design guidelines aim at the implementation of all the latest technologies such as electric people movers, sophisticated waste management methods and energy efficient systems fed by renewable resources. As well as high-tech applications, almost forgotten vernacular principles of climate adaptation have been re-introduced: these principles in particular make this project a prototypical study in relation to local wind conditions.

The car-free zone with narrow street profiles enables a high building density compared to traditional Arabic walled cities. The orientation and structure of the dense urban fabric reacts to daily varying wind directions of different temperature. Modern wind towers support the cooling of public spaces, providing them with a gentle breeze.

[Fig. 166.] Top: As traditional Arabic walled cities, Masdar has a defined boundary to keep out hot desert winds. The whole development is a car-free zone with narrow street profiles, enabling a high building density comparable to traditional urban patterns.

[Fig. 167.] Left: The orientation and structure of the dense urban fabric reacts to daily altering wind directions of different temperature. Hot desert winds are kept off the public ground. Fresh east winds are channelled into the structure with the help of modern wind towers which support the cooling effect on public space.



COOLING WITH GREEN CORRIDORS

The urban fabric is interrupted by two wind corridors with vegetation in order to reduce the urban heat island effect. Partially the corridors are about 80 m wide; orientation and profile are planned according to prevailing wind directions with a daily alternation. Hot north west winds can be cooled down by evapotranspiration, enriched with humidity and diverted into side streets.

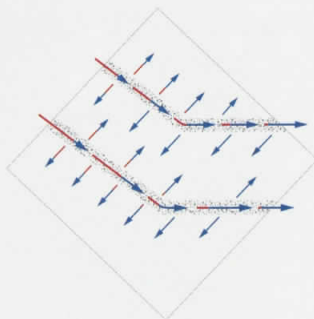
» pattern: 11 street orientation

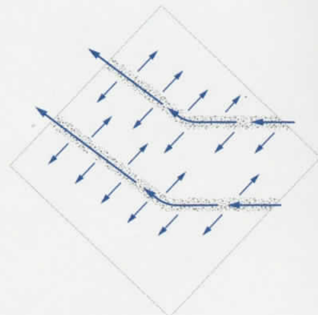
[Fig. 168.] Left: Hot north west winds during the day will be cooled down along vegetated corridors and diverted into side streets.

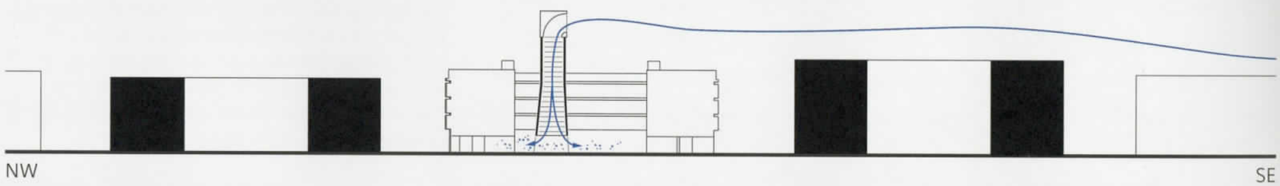
[Fig. 169.] Right: Cooler nocturnal winds enter the urban fabric and will be diverted into side streets.

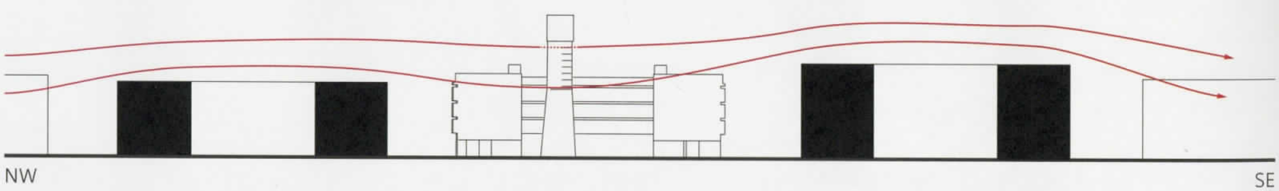
[Fig. 170.] Below: Section. Cold winds from SE are channelled to the public ground.

[Fig. 171.] Bottom: Section. Hot winds from NW won't enter the continuous urban fabric. Street canyons and public spaces are limited in length.





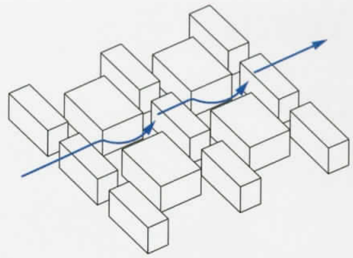




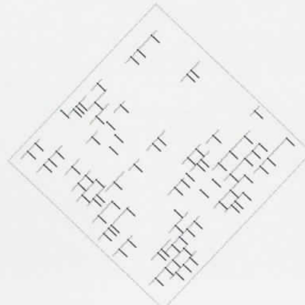
AVOIDING HOT WINDS ON STREET LEVEL

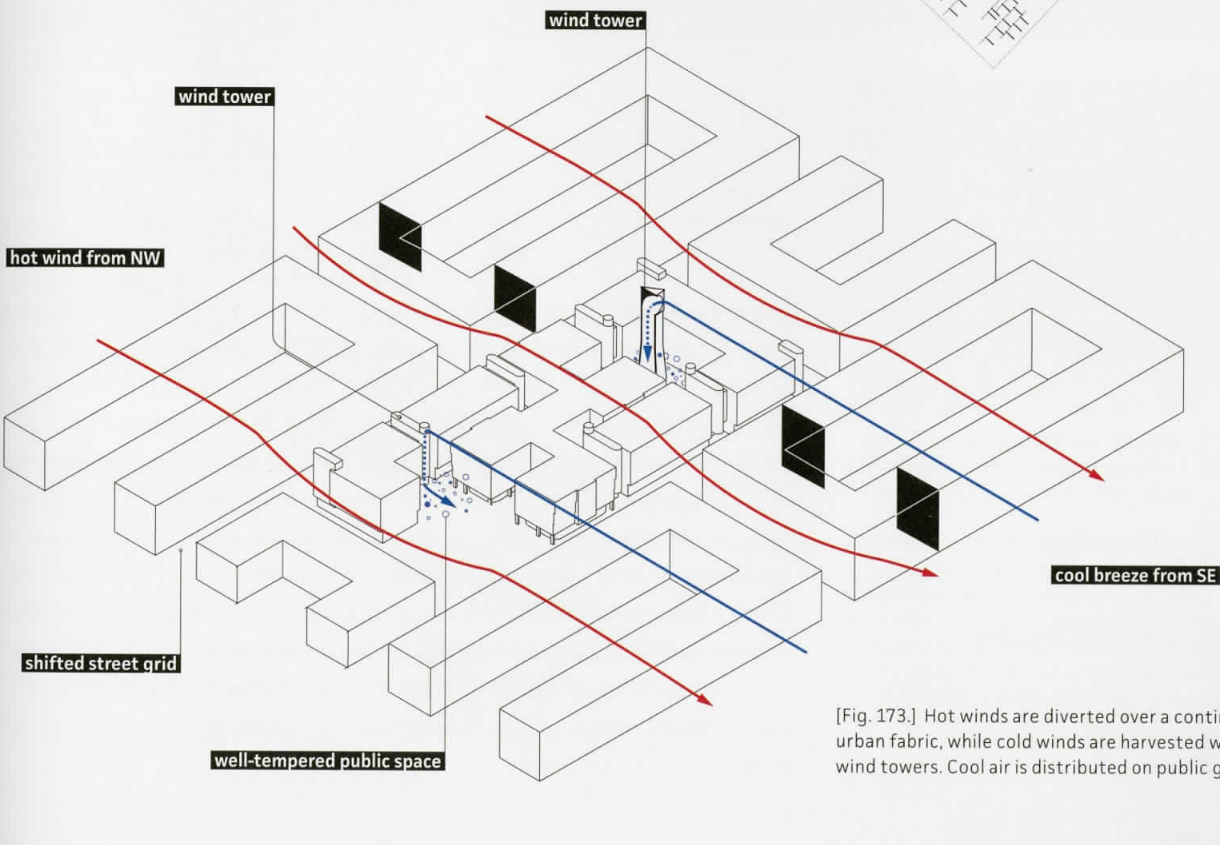
A shifted street pattern has an effect on descending air. During the day, the hot wind cannot fall into the streets due to the short street length of 75m. According to street canyon flow regimes, air exchange is reduced on ground level. At night, the wind is caught by the wind towers at the other end of every 75m-road and channels air into those streets and squares. Cooler night air forms a fresh layer on the ground. Disturbance is limited because of reduced air circulation at this time. The temperature is moderated at lower levels.

» pattern: 10 shifted street grid



[Fig. 172.] Below: Reduction of street lengths to 75m aligned to prevailing winds.





[Fig. 173.] Hot winds are diverted over a continuous urban fabric, while cold winds are harvested with wind towers. Cool air is distributed on public ground.

XERITOWN

location
Dubai, UAE

project type
urban project

year
2008

urban design + engineering
X-Architects
SMAQ S. Müller, A. Quednau
with J. Schultz-Granberg
Buro Happold

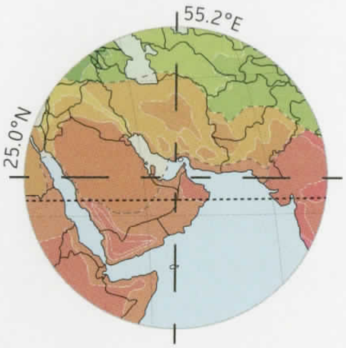
climate
subtropical, humid

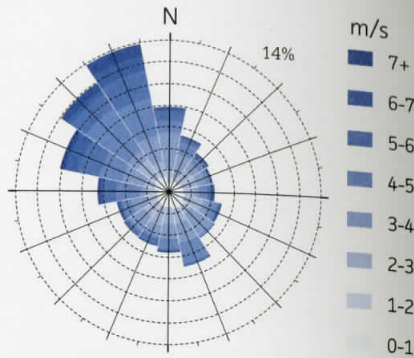
annual average temperature
26.9°C

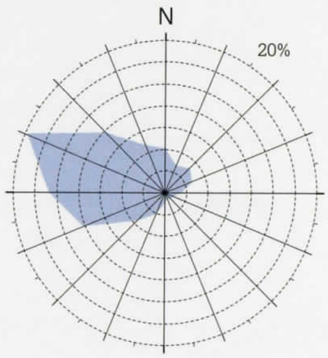
annual precipitation
94 mm

altitude
30 m

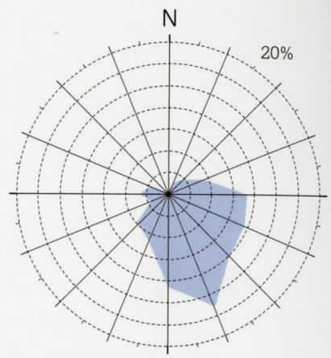
sunshine
3700 hrs



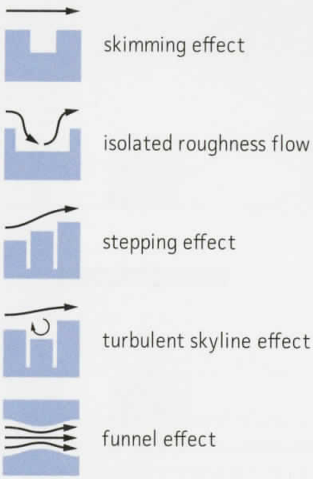




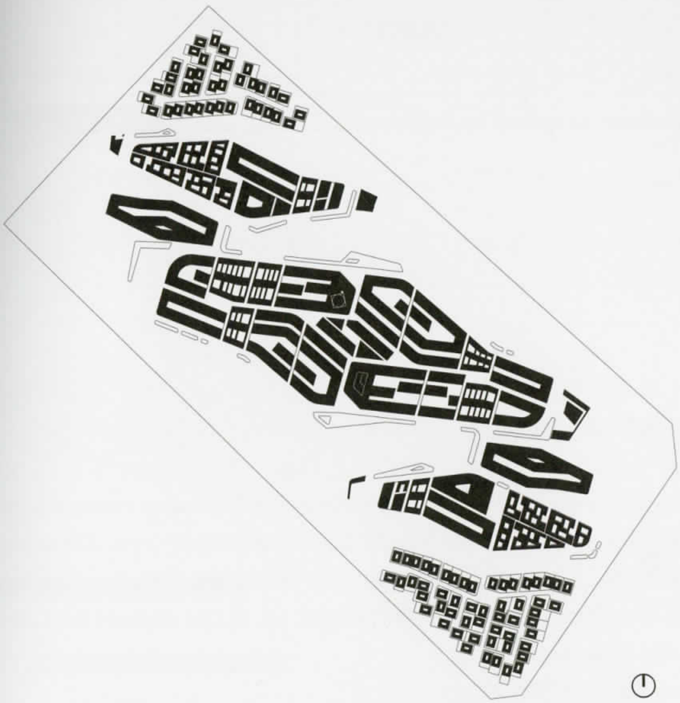
morning / day



afternoon / night



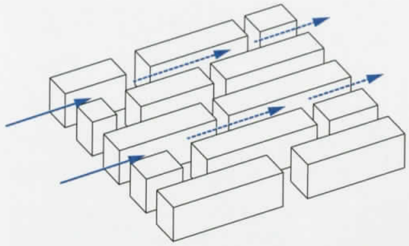
Xeritown is a 60-hectare sustainable mixed-use development in Dubailand, a proposed extension of the city of Dubai towards the hinterland of the sandy Arabian Desert. This project reacts to the local climate: the most frequently occurring winds informed the urban structure.
Elongated urban islands with a high building density, surrounded by an arid open landscape, reduce the sealing of the surface. Daily changing prevailing winds cross the site at an obtuse angle and meet a direction-dependent urban fabric according to street canyon flow regimes. During the day the cool breeze from the sea is channelled between the islands and through the longitudinal cuts in the urban fabric, while the hot night-time wind from the desert is diverted over the top of the buildings. Natural ventilation is enhanced by a rugged skyline breaking up airflows on the scale of both low rises and towers.



[Fig. 174.] Top: Aerial view. The landscape will mostly be left dry in order to reduce irrigation. A minimum selection of frugal plants prevents erosion.

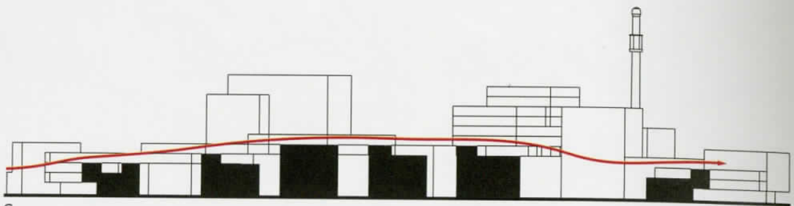
[Fig. 175.] Above: The regime of two reverse daily changing wind directions is reflected by a modest but obvious geomorphology of existing longitudinal dune formations on site. A careful observation and analysis of those correlations were the initial points for the design of the urban morphology and led to a series of wind tunnel studies and critical examination of local climate conditions.

[Fig. 176.] Left: Site plan.

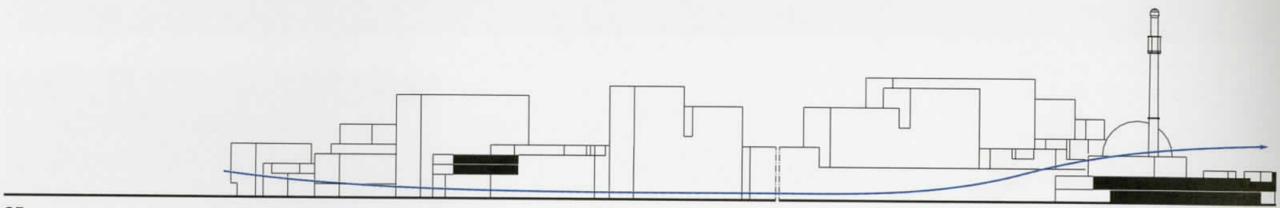


DIRECTIONAL STRUCTURE

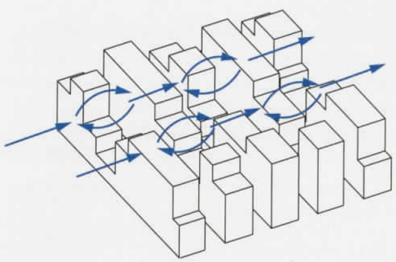
The urban fabric is a directed structure in relation to wind. Different street canyon flow regimes can be applied in relation to the two prevailing wind directions. Cooler winds are channelled by aligned building volumes and can enter the urban fabric.
Only public buildings (e.g. a mosque, a community house) are interrupting the air flow and offer opportunities for naturally supported interior ventilation for generous interiors.
» pattern: 12 comb



[Fig. 177.] Hot wind from the desert / N-S transversal section: Building volumes generate narrow shaded street canyons with a width-height ratio of more than 0.7. This results in a skimming flow – hot air will be diverted over the urban fabric. The open space on ground won't be directly exposed to the hot air flow.



[Fig. 178.] Fresh breeze from the sea / SE-NW longitudinal section: Long courtyards create continuous corridors. A width-height ratio above 2.4 causes an isolated roughness flow.



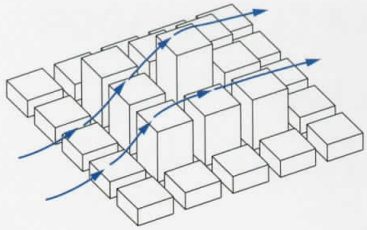
TURBULENT SKYLINE

A development of varied building heights from two to twelve storeys form a rugged skyline creating turbulences at the boundary layer between buildings and sky. As a result, local air flow ventilates the urban fabric. Polluted air from the ground will be purged up to the surface and exchanged with fresh air.
» pattern: 6 height differences

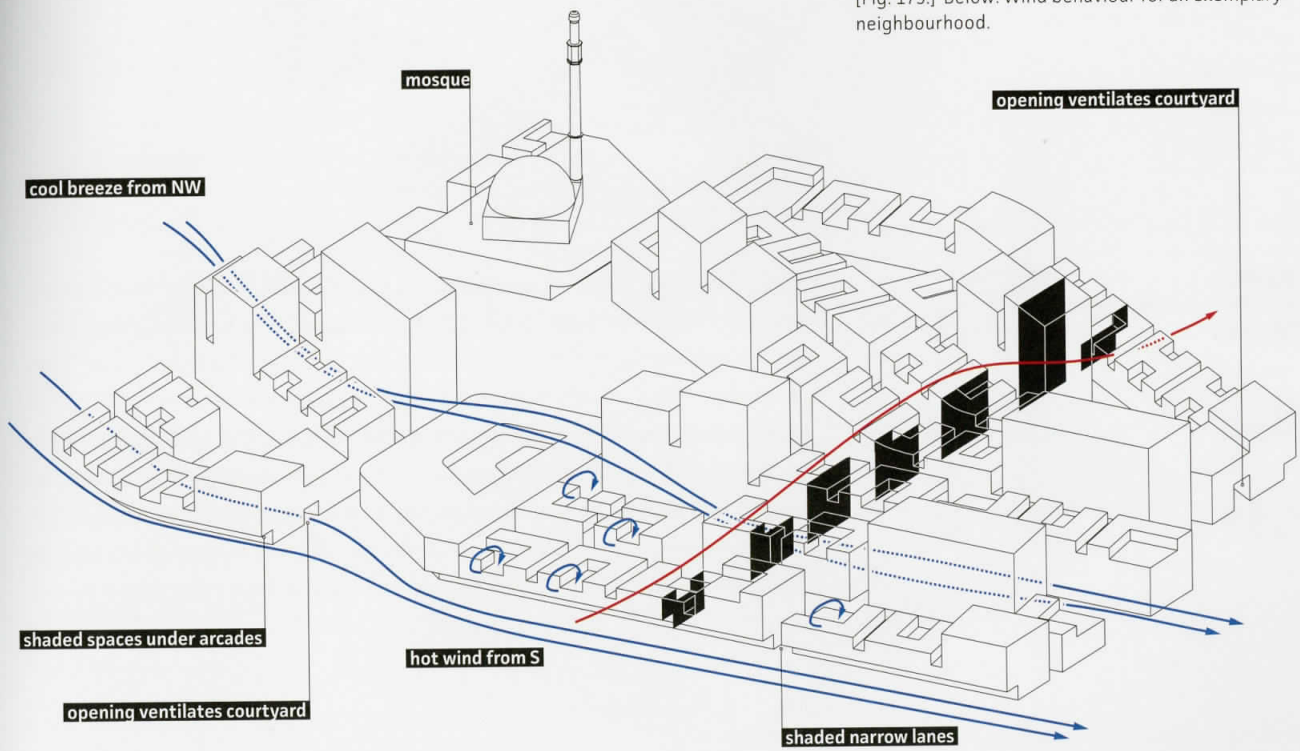
FORCING HOT WINDS OVER BUILDINGS

The edges of urban islands fall within a special regulation: buildings rise step by step towards the centre of each island. These rising edges face towards prevailing hot wind direction from SSE. As a result wind is channelled over the middle of urban islands and kept out of the public ground.

» pattern: 5 continuous stepping



[Fig. 179.] Below: Wind behaviour for an exemplary neighbourhood.



VILLA EL SALVADOR

location
Lima, Peru

project type
urban project

year
1971

urban design
Migual Romero Sotelo

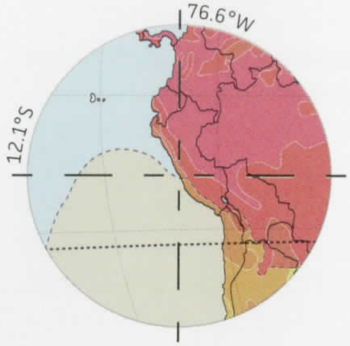
climate
subtropical, dry

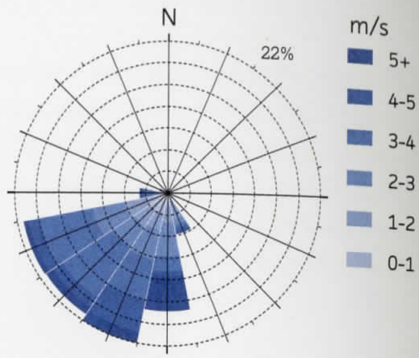
annual average temperature
19.2°C

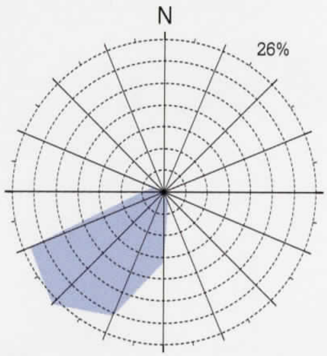
annual precipitation
15 mm

altitude
160 m

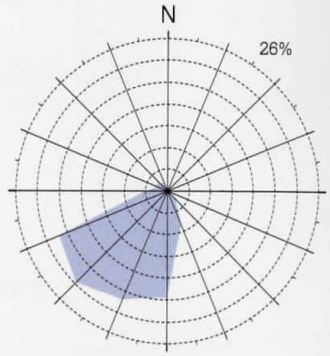
sunshine
1447 hrs



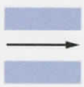


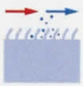


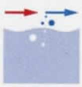
April



September


channelling effect

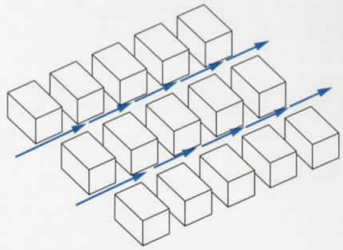

evaporation on green


evaporation on water

Villa el Salvador is an urban district in the outskirts of Lima which arose out of housing shortage in the 1970s. Although it is a mainly deprived, simple and partly self-built area, here the orientation of the urban grid coincides with a steady prevailing wind from southwest.
As air conditioning was not an affordable solution, the inhabitants were forced to draw on traditional opportunities. The strategy was to rely on natural ventilation in combination with evapotranspiration along adjacent green agricultural fields and green corridors. A steady sea breeze is cooled down and charged with humidity before it enters the urban fabric.

[Fig. 180.] Exemplary site plan for a part of the development.

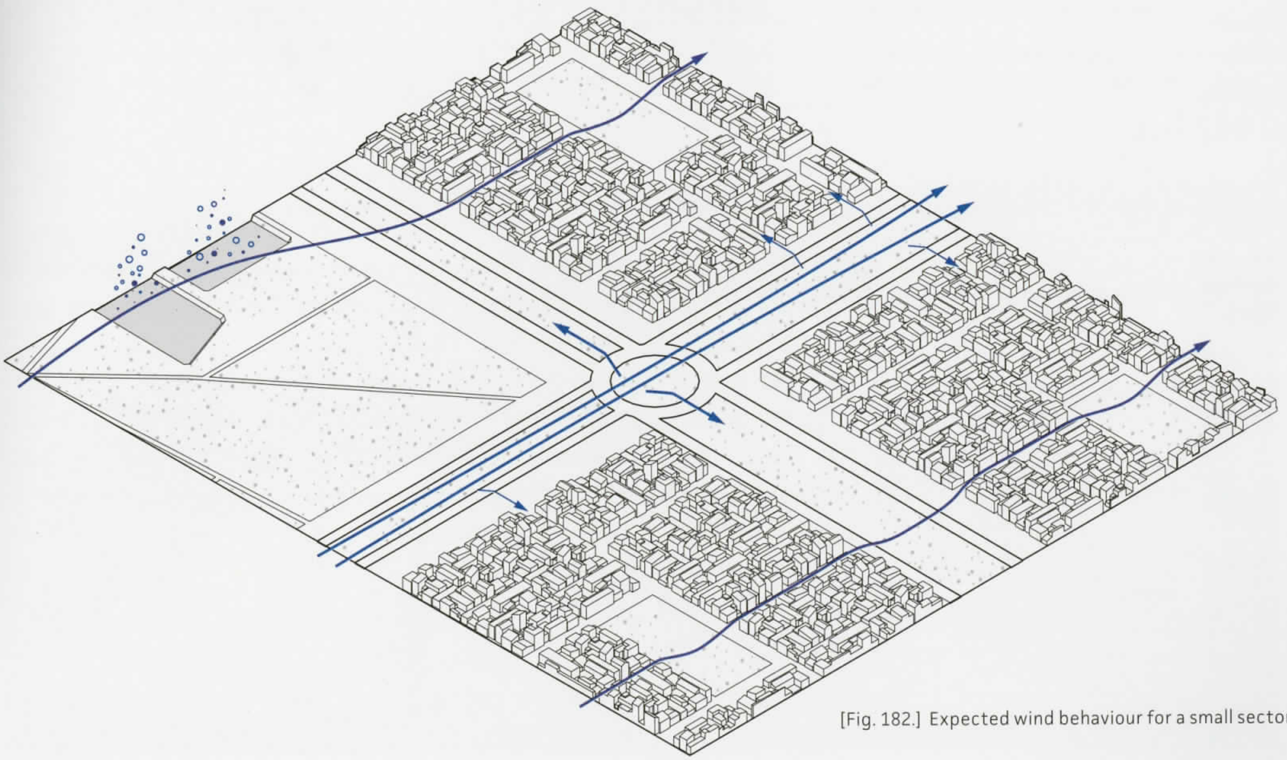
[Fig. 181.] Transversal section green corridor / street.



COOLING WITH GREEN CORRIDORS

Wide street profiles of about 50 m qualify the section for the channelling of wind. The urban fabric is penetrated; fresh air is able to circulate deep into the structure, improving the micro-climate and reduce the heat island effect.

» pattern: 8 aligned buildings



[Fig. 182.] Expected wind behaviour for a small sector.

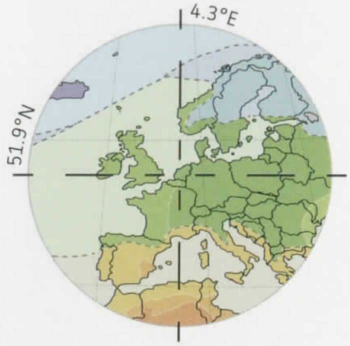
WINDSCAPE CITY

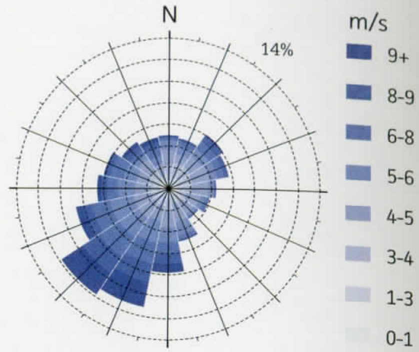
location
Rotterdam, Netherlands

project type
urban study

year
2011

design
Studio 51.9°N
Franse, Zoet





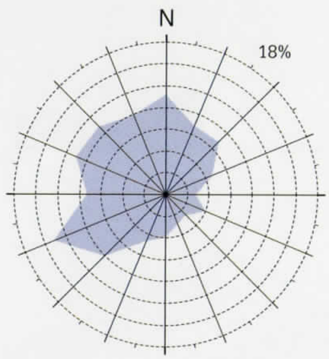
climate
moderate, oceanic

annual average temperature
10.3°C

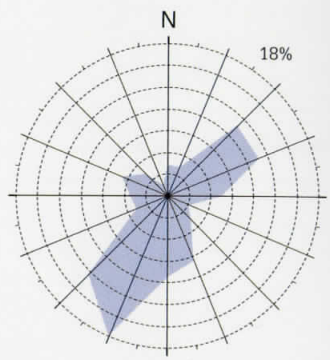
annual precipitation
825 mm

altitude
4 m

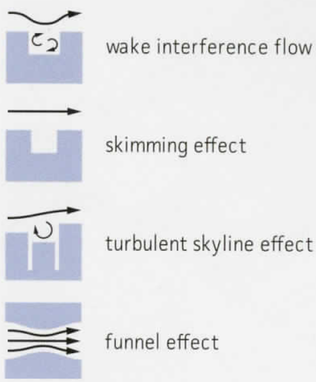
sunshine
1542 hrs



June - August

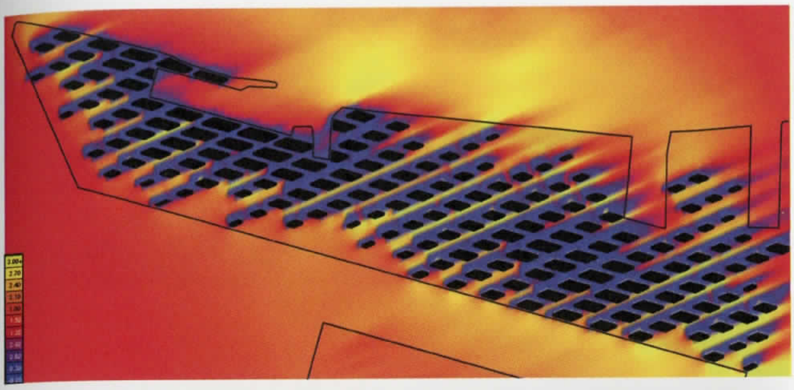


December - February

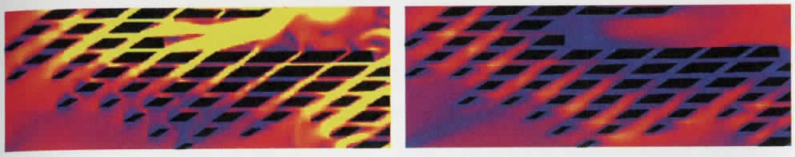


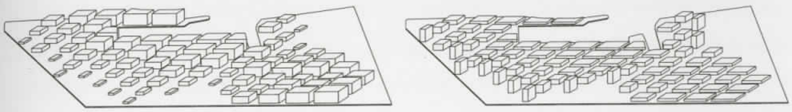
The wind conditions in Rotterdam are characterised by a moderate to fresh breeze from a prevailing southwest wind. Especially in winter easterly winds bring extremely low temperatures.

Windscape City is a design scenario for the Maashaven docks that are part of the city-port of Rotterdam and located in the immediate vicinity of the expanding city centre. At the moment the site is a working harbour. With the upcoming completion of the new mega-port Maasvlakte II, the area will change its current use and will undergo an intense urban transformation.



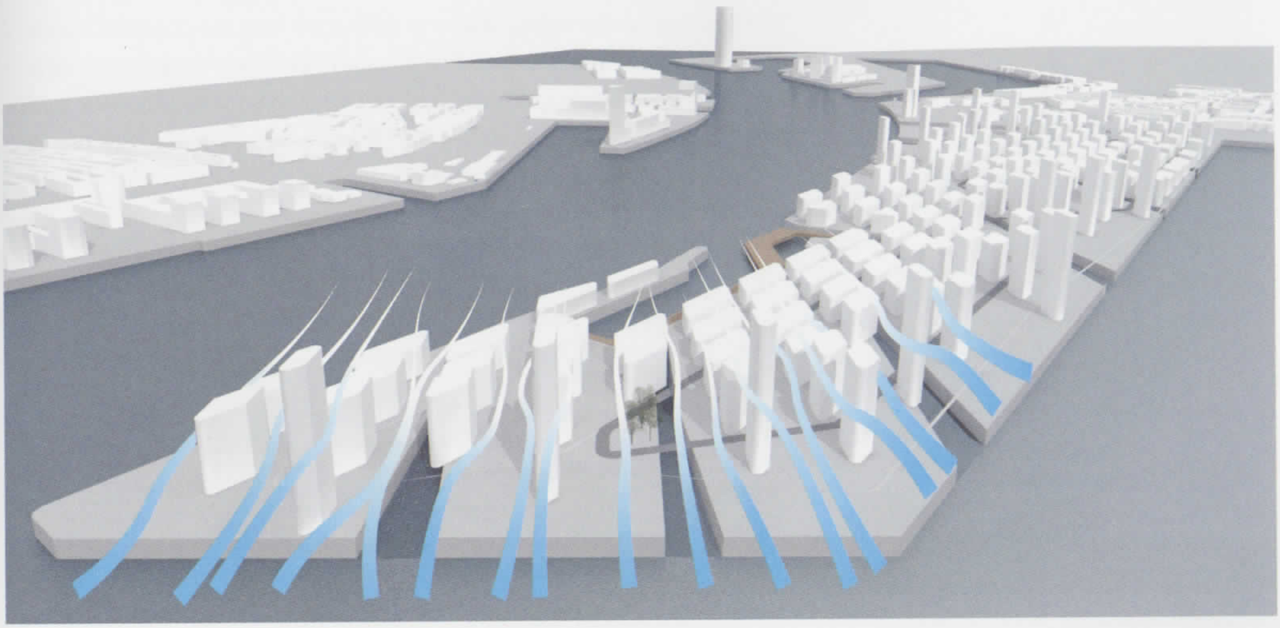
[Fig. 183.] Top: Optimisation of the design process: There is a clear difference between the open "windy"parts and the dense "protected" areas, resulting from the ratio between the height and distance of the buildings. Wake interference flow and skimming flow principles apply.

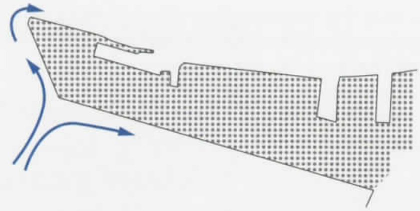




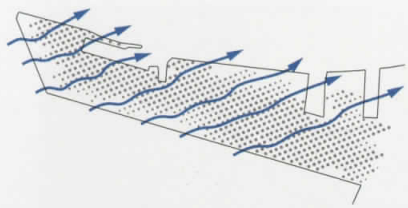
[Fig. 184.] Left: A parametric pattern study reveals a gradual capability of controlling the wind speed. Dark areas with a reduced wind speed have a higher urban comfort, but less air circulation.

[Fig. 185.] Bottom: The wind speed is gradually reduced by a varying ratio of buildings to open space.

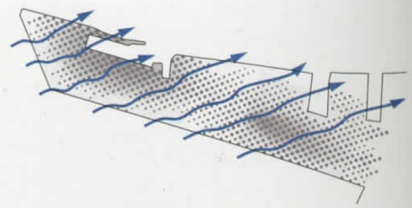




[Fig. 186.] High and dense urban patterns divert wind over the site.



[Fig. 187.] Ad-hoc pathways let the wind in and out.



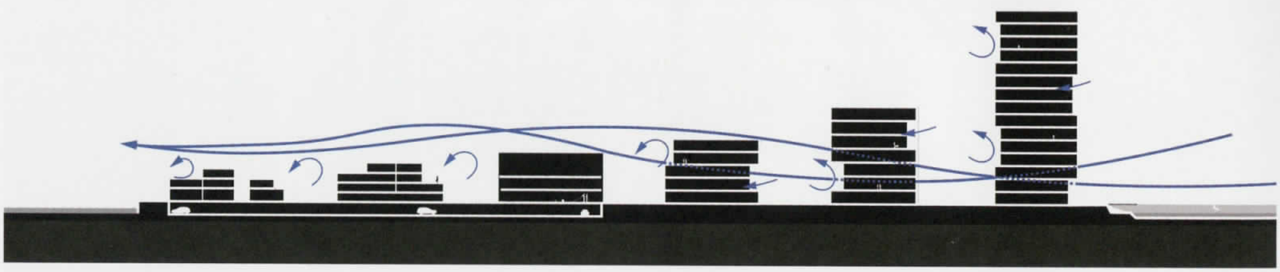
[Fig. 188.] The diversified density of the urban pattern creates a varying intensity of the wind.

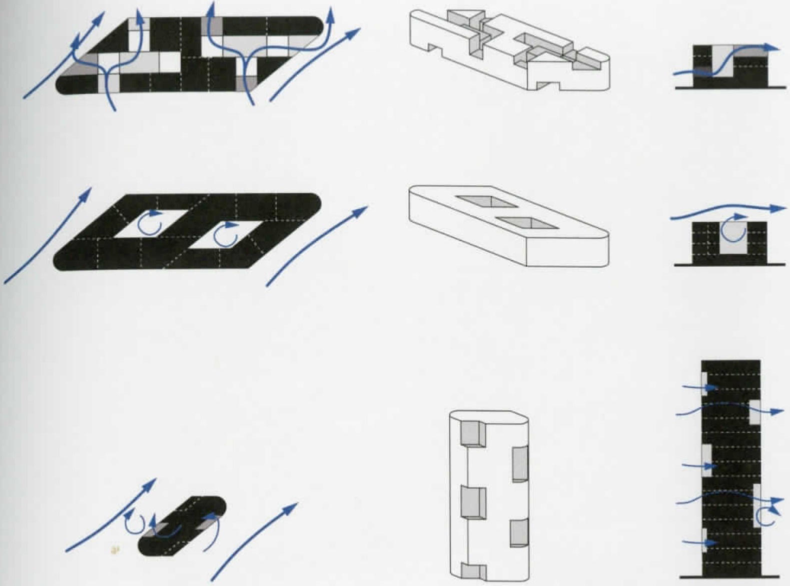
All buildings have the same volume but differ in height and ground coverage. This leads to an urban layout which presents a homogeneous density and continuously changing wind patterns, depending on the gradually varying porosity of the urban fabric. This project scenario plays with the different attributes of the prevalent wind in order to create specific wind related conditions within an urban fabric.

In areas of low-rise buildings and higher ground coverage, the stepping effect applies and the wind is directed over the buildings. In areas with high-rise buildings and a low ground coverage, the funnelling effect is deployed. Through the variation in the urban topography, different wind conditions are present that allow a wide range of architectural possibilities regarding different programs and functions in the urban plan.

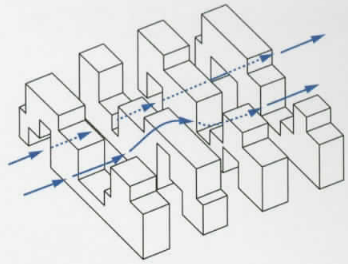
The porosity of the urban layout is converted into the physical shape of the architecture too. The low-rise housing blocks are designed to optimise natural ventilation in the buildings by means of courtyards, patios and loggias, whereas the higher and thinner buildings that are predominantly programmed for public facilities and offices have an enhanced ventilation provided by the roughness of the facade.

[Fig. 189.] Section.





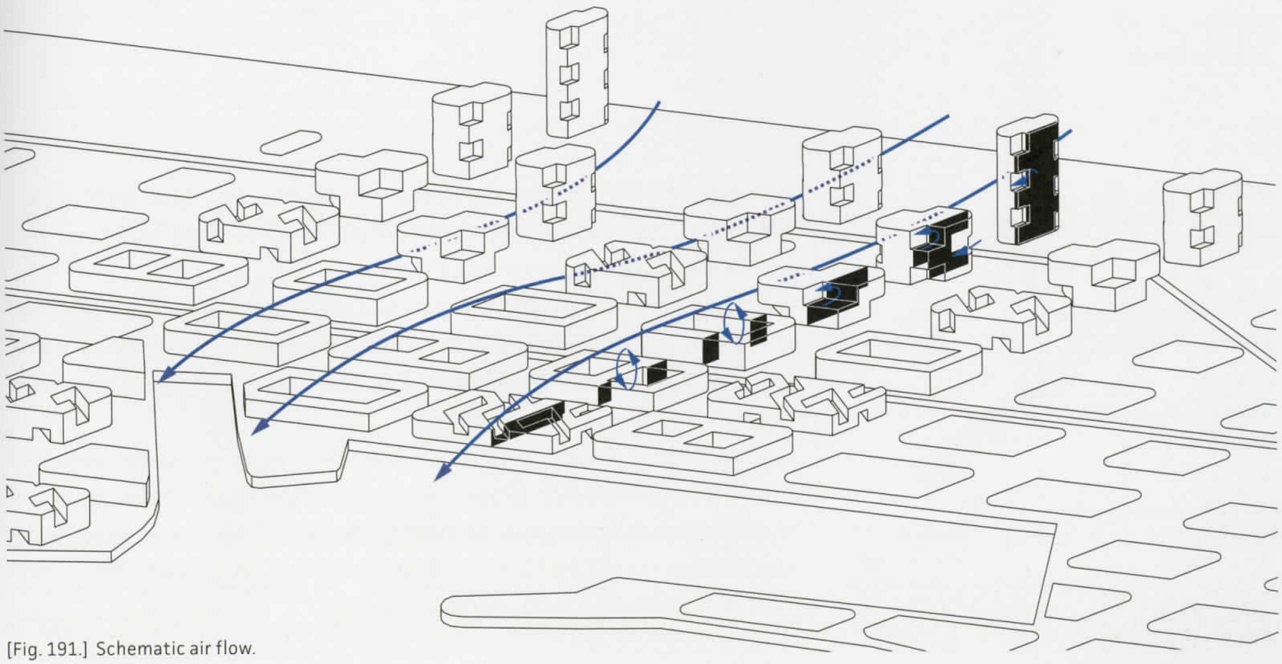
[Fig. 190.] Openings in the facades positioned at different heights enhance turbulences and encourage interior ventilation.



POROSITY POLICY

With density-related parameters, the porosity of the urban fabric can be adjusted specifically. The tall buildings with a small ground-coverage give way to the wind, the lower buildings with a larger ground-coverage force the heavy winds over the urban fabric, with slow winds between the buildings.

» pattern: 9 porous buildings



[Fig. 191.] Schematic air flow.