Design Principles...

...to optimize urban areas regarding the Urban Heat Island effect

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Content

URBAN FOREST 3
MEADOW 6
STREET TREES 8
GREEN ROOF AND WALL 10
URBAN WATER 12
PAVEMENT FOUT! BLADWIJZER NIET GEDEFINIEERD.
CITY SIZE 18
BUILT FORM 19
WIND 22
SHADING 24
(ANTHROPOGENIC) HEAT STORAGE 26
REFERENCES 29
Urban Forest

An urban forest or a park is a green area within an urbanised environment. These areas have a lower air and surface temperature and thus form a PCI (Park Cool Island). The characteristics of the green area that lead to cooling are evapotranspiration\(^1\) of plants and trees, shade, evaporation of surface water and/or moist in the soil. During the night the high sky view factor of open fields make these areas cool very fast.

Effects

The temperature difference between a park and the surrounding urban area is generally about 1-4.7\(^\circ\)C according to a comparison of studies by le Comte and others (le Comte, et al 1981). The size of a green area has not to be big in order to generate a cooling affect, according to a study in TelAviv a park of only 0.15 ha had an average cooling effect of 1.5 \(^\circ\)C and at noon reached 3 \(^\circ\)C difference (Shashua-Bar, et al 2000). Another study in Göteborg shows that a large green area does generate a big cooling effect, here was measured a maximum difference of 5.9 \(^\circ\)C in summer in a green area of 156 ha (Upmanis, et al 1998).

An urban forest could serve as a cool spot during the hottest periods for people to take shelter. More interesting when designing with green is the cooling effect it has on the surrounding urban area. In Tel-Aviv the cooling effects of small parks was noticeable till 100 from the border of the green. In the large park in Göteborg the effect reached out more than one kilometre.

On both the temperature difference and the cooling effect on the urban surroundings, the local climate, geography, city structure and city size have a great influence. The influences of many different variables makes all researches have different outcomes:

- Vancouver (3-53 ha) PCI: average 1-2 \(^\circ\)C, max 5 \(^\circ\)C. (Oke, et al 1998)
- Sacramento (2-15 ha) PCI: average 5-7 \(^\circ\)C. (Oke, et al 1998)
- Tokyo (60 ha) PCI: > 2 \(^\circ\)C and at noon the park can reduce a busy commercial area 1 km down wind by 1,5 \(^\circ\)C. (Ca, et al 1998)

In the temperate zone, the transpiration of evergreens is in general lower than the transpiration of deciduous trees. Wetlands vegetation has the highest capacity for

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\(^1\) The evaporation and transpiration of vegetation
transpiration. On a sunny day in the temperate zone with sufficient water available, natural flora achieves transpiration values of several mm (several litres per square meter per day), values above 5 mm being considered high.

Some plants, as long as they have sufficient water available, are able to evaporate in the course of a sunny day more than 20 litres of water per square meter. On developed land, evapotranspiration on sunny days is mostly limited by a shortage of water, so that the values of actual transpiration are markedly lower than those of potential transpiration. When a PCI needs to have a cooling function the availability of water is critical (Kravcik, et al 2007)

Small and spread green is cooling more area than large parks with the same size in total.. (Kuypers et al. 2008).

Potential benefits
- Air pollution reduction of ozone and particulate matter
- Wind dispersion
- Attractive urban landscape
- Less heat-related deaths
- Habitat for animals and other organic life.
- Energy saving: an increase of 1.0 °C outdoor leads to 6.6% extra electric energy demand to cool indoor (Hiroaki, et al 2003)
- Protecting valuable soil from being sealed completely by buildings and pavement. In cities soil provides the following services: water filtering, carbon capture and in some cases food production. (Vrscaj et al 2008)

Comments
- Space for green could be scarce
- Trees take time to grow and generate effect
Applicability
- Realizing large green areas within the existing urban structure is only possible when an area is restructured on a large scale. Even then the urge for new building development within the city will in most cases reduce green.
- For new development areas there is a great opportunity for green to be combined with highly urbanized areas.
Meadow
During the day open fields with a natural grass surface do not cool the city as the same space filled with trees would. Though at night an open grass field does cool better than a forestry area. At daytime an open field catches a lot of sun that causes the soil to evaporate the moist quickly, followed by warming up. During the night this reverses as the accumulated heat can radiate fast into the atmosphere since there are no obstacles to reflect or retain the heat.

Effects
As sketched above, open grass fields warm quite fast. To minimize the transition of solar radiation into heat, the soil needs to contain a lot of water. The more water the more solar radiation can be used for the cooling mechanism called evaporation. As the graphs underneath show; in order to keep temperatures low a meadow should not be drained or mowed too often in summer.

(Kravcik, et al 2007)

Potential benefits
- An open grass field can be combined with many different functions; play ground, soccer field, area for dogs, picnic area, fishing spot, festival area etc.
- Habitat for small animals/insects/organic life.
- A meadow can be used as water infiltration area (wadi)
- As parking space using ‘semi-paved’ materials. Less effective because the cars minimize the heat reflection, but better than an asphalt surface that retains heat for a long time and cannot absorb water (cooling by evaporation).
- Open spaces in parks can contribute to safety
- Protecting valuable soil from being sealed completely by buildings and pavement. In cities soil provides the following services: water filtering, carbon capture and in some cases food production. (Vrscaj et al 2008)

**Comments**
- An open grass field might be seen as a low quality green.
- Soccer fields are large green fields with a cooling effect, in the images below the southern field has a light blue colour. Because of the low maintenance requirements more and more grass fields are replaced by synthetic fields. These do not cool, but turn out to accumulate heat even more than the housing areas, see the dark red colour of the northern field.

![Image](image1.png)

(Arrau 2005)

**Applicability**
- Because of the on going growth of the amount of cars in cities, more and more space in streets is occupied by parking places. You might combine these by making use of ‘half verharding’.
- Since there are many possibilities in combining an open field with facilities that are necessary or an extra value in a living environment the implementation will not be too difficult.
- An open grass field is relatively cheap to realise, though the space can generate much more money with other types of land use like housing, offices, commercial functions, etc.
Street Trees

Street trees might seem to have a low impact on the temperature within the city because they are so dispersed, but since they are so many they actually have a big impact. The characteristics of a tree that leads to cooling are: evapotranspiration, shading and reflecting sunlight. Their position in a paved area make them soft and vulnerable elements, and therefore add another dimension to the hard surfaces of the street and buildings.

Effects

Transpiring plants, especially trees, are the perfect air conditioning system of the Earth. Let’s imagine a large, independently standing tree with a crown of about 10 meters in diameter. On the crown of this tree, which has a surface area of 80 m², there falls each day about 450 kWh of solar energy (4-6 kWh/m²). Part of the solar energy is reflected, part is absorbed by the soil and part is converted into heat. If such a tree is well stocked with water, it evaporates (transpires) some 400 litres of water each day. For the transformation of water from a liquid state into water vapour, 280 kWh is consumed. This amount of energy thus represents the difference between the shadow of a tree and the shadow of a parasol with the same diameter. In the course of a sunny day, then, such a tree cools with a power equal to 20-30 kW, power comparable to that of more than 10 air-conditioning units. The tree is at the same time "fuelled" only by solar energy, is made of recyclable materials, requires a minimal amount of maintenance and emits water vapour that is regulated by millions of stomata which respond to the heat and humidity of the surroundings. The main thing is that the solar energy bound up in water vapour is carried away and is released by condensation in cool locations. It thus balances temperature in time and space, unlike a refrigerator or air-conditioner, which release heat into its nearby surroundings. A tree, unlike a refrigerator or air-conditioner, is also completely noiseless, absorbs noise and dust and binds CO₂. (Kravcik, et al 2007)

So trees seem to cool the earth, but are they also suited to cool the city? As in many Mediterranean cities the narrow streets create shadow and usually do not contain trees. But according to Nickson planting trees is more effective than implementing the structure of Mediterranean cities in the Netherlands. (Nickson, Hot places - Cool spaces, 2007)

The value of projected benefits when planting trees is nearly three times the value of projected costs. Payback periods for trees in Chicago for example range from 9 to 18 years. Trees in residential yards and public housing have largest benefit-cost ratio: they are relatively inexpensive to establish since the yards contain less cables and other
functions, trees have a low mortality rate, vigorous growth and large energy savings. (McPherson 1997)

**Potential benefits**

- Energy saving: shading buildings can reduce energy use for cooling by 25 to 80% (Meier 1991)
- Energy saving: an increase of 1.0 °C outdoor leads to 6.6% extra electric energy demand to cool indoor (Hiroaki, et al 2003)
- Air pollution reduction of ozone and particulate matter
- Wind dispersion
- Attractive urban landscape
- Less heat-related deaths
- Habitat for birds and other small animals/insects/organic life
- Trees are cooler than their environment during warm weather and warmer than their environment during cold weather
- Protecting valuable soil from being sealed completely by buildings and pavement. In cities soil provides the following services: water filtering, carbon capture and in some cases food production. (Vrscaj et al 2008)

**Comments**

- Street trees need a lot of care in comparison to trees in parks
- Trees in a street canopy form a cover of leaves; these leaves can prevent airflows to clean the street canopy from car emissions. At the same time these leaves can clean the air from particulate matter and avoid spreading them over the city and into the atmosphere.
- When planting street trees make sure they can reach enough water and have enough space to grow in height and width, above and under the ground
- Street trees are often combined with parking; for this purpose select trees that do not produce too much resinous liquid that forms a sticky layer on cars
- During the night trees block heat to radiate into the sky

**Applicability**

- In cities, there are two types of locations in which trees can be planted: on sidewalks, “curbside” or squares where they shade impervious surfaces, and in open spaces, where they shade grass. A previous study for New York showed that replacing all urban grass with trees could reduce Manhattan’s air temperature by up to 1°C in the afternoon (Luley, et al 2002).
- Planting trees in grassy open area is a third of the price of a curbside tree (Rozenzweig 2006). Even more cost effective is the planting of trees in private gardens as is done in Chicago.
- Because of the on going growth of the amount of cars in cities, more and more space in streets is occupied by parking places.
Green roof and wall
Covering roof or façade with vegetation has a cooling effect on the urban environment and the building itself. The responsible cooling mechanism are: evapotranspiration from the leaves, evaporation from the soil, shadow from the vegetation. The indoor temperatures also reduces because of the high isolation value of the green package.

Effects
In terms of urban warming alleviation and cooling energy saving a big difference is made by vegetative facades of buildings in residential canopies. This measure indicated daily and spatially averaged decreases in near-ground summer air temperature of $0.2-1.2\, ^\circ\text{C}$. The simulations also suggested these temperature decreases could result in the buildings cooling energy-savings of $4-40\%$, indicating remarkable savings in residential canopies. (Yukihiro, et al 2006)

In a test done by M. Schmidt it is proven that plants evaporate considerably more when they have a surplus of water available compared to the evaporation values when they are lacking water. In the summer months July until September 2005 the water consumption for the well developed *Wisteria sinensis* increased up to 420 liter per day for 56 planter boxes. This represents a cooling value of 280 kWh per day for one of the courtyards. Mean evapotranspiration between July and September 2005 for the south face of the
building was between 5.4 and 11.3 millimeters per day, depending on which floor the planters were located (Figure 9). This rate of evapotranspiration represents a mean cooling value of 157 kWh per day. (Schmidt 2006)

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**Potential benefits**
- Reduction of energy use of buildings
- Slow down drainage
- Air pollution reduction of particulate matter and ozone
- Lengthening the life span of roofs
- Wind dispersion
- Attractive urban landscape
- Less heat-related deaths
- Habitat for birds and other small animals/insects/organic life
- Combination with grey or recycled water systems

**Comments**
- Extensive greening on a facade or roof is expensive to realize, especially when the construction has to be reinforced to carry the load of the roof.
- Green facades can require more maintenance, this depends on the type of greening, form of facades and roofs and climate circumstances

**Applicability**
- Green roofs are applicable on flat roofs and slanted roofs. The maximum angle is around 45 degrees. A flat roof (or a maximum angle of 6 degrees) is cheaper.
- Especially green facades influence the appearance of a building, this is not always the desired appearance.
Urban Water

Cities were often built along rivers and canals because these were important transport routes, so was the sea. But water also brought the danger of flooding. The Netherlands, as no other country, has a long history of water management. This history has lead to an enormous variation in water applications.

Water can reduce temperatures by evaporation, by transporting heat out of the city and as a buffer that slowly absorbs the heat. This is already occurring in the Dutch cities because of the already existing applications.

Water applications in general are more effective when water is moving or dispersed as done by a fountain. The effect of cooling by water evaporation depends on the air flow that spreads the cooled air through the city.

Effects

A study in Japan shows air temperature measurements on the leeward side of a fountain with a reduction of approximately 3 °C at 35 m distance. The measured effect of the water system can be felt from 14.00 to 15.00, other times of day show lower temperature reductions. (Nishimura, et al 1998)

Another study done in Bucharest showed a cooling effect of a pond of 4*4 m, see images underneath. This was about 1°C at a height of 1 m, at 30 meters distance. (Robitu, et al 2004)
In the figure above is shown the amount of solar energy reaching the earth by radiation in one year in relation with the energy flux of the total amount of evaporation in one year. This energy flux is enormous in comparison to the world’s energy consumption of one year. (Schmidt 2006)

**Potential benefits**
- Water storage combination
- Water recycling combination
- Storage of heat
- Water playground combination
- Attractive urban landscape
- Water as a place for citizens to cool themselves; artificial beach, water/haze spray machine
- Transportation over water
- Nutrition for plants and trees
- Habitat for all kinds of organic life

**Comments**
- Water in the city can cause health problems, especially with warm weather
- Water can cause flooding

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2 To improve biodiversity in urban water R.A. Francis and S.P.G Hoggart suggest the following: a complex river wall from brick or bolder with a rough surface, added ledges and timber frames entourages plant growth. Frequent maintenance does not endanger the organic life. (Francis, et al 2008)
Applicability
- Cooling facades and thus electrical energy saving
- Dutch cities often have a history with water in the form of harbours, rivers or canals. Re-introducing or re-designing this history enriches the city.
Materials

In cities the soil is covered with artificial pavement, in rural areas mostly with natural greenery or agricultural crops. There is a big difference in the temperature flux between these materials. The hard materials in cities do not absorb water and therefore do not cool by evaporation. The other missing cooling mechanism of plants is evapotranspiration. Instead of cooling the hard materials accumulate heat. Not only at the surface as in rural areas, but also in the third dimension, facades, the heat is absorbed.

One aspect of the accumulation of heat in hard materials is depending on the colour. A light colour will reflect solar radiation, while a dark colour absorbs it. This reflectivity is called albedo by climatologists.

Another aspect is the time in which a material releases heat. Materials like brick have a long time lag, which results in radiating heat into the air during night time until sunrise. During heat waves the temperature in cities can be cumulative day by day when there is no cooling wind or enough green to compensate.

Effects

A test in a street gorge in central London (Watkins et al, 2002) resulted in a decrease of surface temperature of 6-10°C for matt white surface instead of dark coloured surface. Simultaneous measurements of the near ground air temperature showed a decrease of 3-4°C for the matt white colour instead of the dark. (Watkins et al, 2007)

A study in Tel-Aviv measured the temperature difference between the material of the urban and a park with the size of 0.6 ha. The highest temperature of the ground surface of the grass field in the park was 40.3 °C, which was 19 °C lower than that of the asphalt surface or 15 °C lower than that of the concrete surface in the parking or commercial areas. Soon after sunset, the temperature of the ground surface at the grass field in the park became lower than that of the air, and the park became a cool island whereas paved asphalt or concrete surfaces in the town remained hotter than the overlying air even late at night. (Ca, et al 1998)
A research project in Singapore focussed on the difference in temperature on building facades due to dark or light colours. A maximum temperature difference of 8°C and 10°C on the external wall was measured during 13.00 and 16.00, see diagram above.

The façade material has influence on the time it takes to cool. Three types were tested; the brick wall had the longest time lag, followed by a concrete wall and a hollow block wall. (Wong Nyuk 2007)

Roofs are usually dark coloured and therefore heating up the indoor climate. Extra isolation for roofs is often hard to realise in existing dwellings. Here preventing the accumulation of heat is more feasible. By using light reflective roofing the temperature of the roof can be reduced with 37°C. (SPS)

When less heat is absorbed by outside materials during the day, the radiation of heat back into air at night will be reduced. And the indoor climate will stay cooler. On a sunny day a light roof keeps the indoor air temperature lower by 1.5°C compared to a building with dark roofing. (Peutz 2009)

**Potential benefits**
- When a material for cladding, roofing or paving needs to be replaced by new ones, there is a chance to apply light and ‘cooler’ materials.
- Permeable materials will drain and evaporate more water
- Semi-paved surfaces will drain and evaporate more water and form a habitat for small organic life

**Comments**
- Materials with light colours need to be cleaned to retain their reflectivity. When a colour turns just a little less light the albedo diminishes fast.
- The materialization of roads, roofs and facades depends on many factors; structural characteristics, erosion proof, water proof, sun proof, appearance, costs, etc

**Applicability**
- Light surfaces require an area many times greater than green roofs to achieve comparable cooling (Rozenzweig 2006).
- Light surfaces and light roofs have lower costs per temperature reduction as well as per on-peak MW reduction than other instruments like, green roofs, street trees, etc. (Rozenzweig 2006)
- Changing the colour of pavement, roofs and facades is relatively easy to do, but it is not always desirable from an aesthetic point if view
- In some occasions materials and colour might be the only possible design principle to work with
City size

The larger the city, the bigger is the UHI effect. This phenomenon has been proven by many studies all over the world. Heat accumulates in cities due to the absence of trees, the big surface covered by pavement, wind obstructing buildings and human activity like traffic, industry, cooling buildings, etc. T.R. Oke has developed a prediction method of the UHI effect for a European city. With the following formula the maximum difference of the rural and the urban temperature can be predicted according to the amount of inhabitants; $\Delta T_{u-r(\text{max})} = 2.01 \log P - 4.06$. (Oke, 1973)

\[
\Delta T_{u-r(\text{max})} = 2.01 \log P - 4.06
\]

**Utrecht:**
$\Delta T_{u-r(\text{max})} = 2.01 \log 300.000(P) - 4.06 = 6.9^{\circ}\text{C}$

**Den Haag:**
$\Delta T_{u-r(\text{max})} = 2.01 \log 450.000(P) - 4.06 = 7.3^{\circ}\text{C}$

**Potential benefits**
- A recommendation for new settlements, for example: when a maximum of 2°C difference is required, a settlement should not exceed the amount 16.000 inhabitants.

**Comments**
- Besides the amount of inhabitants other aspects might have more influence on the UHI effect; city size in actual m², land use, city structure

**Applicability**
- The government can influence the growth of cities, the regulating instruments usually control the growth rate, it is hard to stop a city completely from growing or shrinking.
Built form

Built density, and built form are composition variables that combine parameters like the area of exposed external surfaces, the thermal capacities and surface reflectance of built elements, and the view of sun/sky view factor of surfaces.

Effects

External surface area
Compared to flat open ground a building has a larger external surface on which solar radiation can be received. This is more than three times the annual amount of radiation that would have fallen on ground equal to the area of its base. (Yannas 2001)

View of the sun
The view of the sun indicates the overshadowing by neighbouring buildings. This increases with latitude and is largest in winter. The view of the sun is mainly determined by the built form and density, street widths and orientation. (Yannas 2001)

Wind
The built form has a direct influence on the wind climate within canopies. Large spacing generates a better mix of air layers and therefore on cooling.

In an investigation into the link between urban morphology and energy demand two types of buildings were used to simulate solar radiation on different building compositions:

- Type A opposite Type A H:W = 1.1
- Type B opposite Type B H:W = 2.2

The final H/W ratio is associated with the asymmetric city streets formed by Type A(B) opposite Type B(A). The average H/W here is 1.7.
The results pointed towards a relationship between energy loads and overshadowing. The height to width ratio with the lowest CO2 emissions was found on buildings number 9 to 17. This street canyon consisted of Type B building opposite Type B. This configuration received the lowest percentage of external isolation during the late afternoon, when temperatures are beginning to rise.

It showed that **tall buildings opposite tall buildings, in street canyons with the highest height to width ratio, use less energy when cooler internal temperatures were desired than a street canyon with a variation in height or with low rise buildings. This reduction in energy use was a result of a larger surface area of the building being shaded.**

*Does an optimum height to width ratio exist that permits the internal cooling load to be reduced?*

Although subjective the results showed that by manipulating the height to width ratio you can influence energy use, and that greater height to width ratio may have a positive effect on energy by reducing the demand for energy for cooling by overshadowing.

- **Wide streets and other open spaces encourages air flow**, which improves the opportunity to ventilate the inner parts of a city and reduce temperatures, but not on still days or days with very large air mass formations.
- **The taller the buildings and the narrower the streets, the less long-wave radiation is received.** Building proximity to each other determines the amount of reabsorbed longwave radiation from their immediate environment. (Johnson and Watson, 1983).
- **Dense urban fabric** (high height to width ratios) **provides solar shading** at street level but also **traps heat** resulting from multiple solar reflections, reduced albedo, and anthropogenic heat.
- Height to width ratios, have to be taken as a function of orientation, due to the Intensity and direction of isolation received on a face at any given time. (Futcher 2008)

**Potential benefits**
- Less solar radiation will lead to energy reduction of air conditioners because the indoor spaces do not warm-up and the outdoor façade stays cool.
- Natural ventilation generates a cooling effect on the air in canopies, which also leads to energy reduction.
- Natural ventilation cleans the air from pollutants.
**Comments**
- Solar radiation in winter is important in the Netherlands for comfort and as extra heating. By shading buildings with buildings in summer, there will be even less sun in winter. Shading buildings with deciduous trees does not have this negative effect in winter.

**Applicability**
- For new development areas there is a great opportunity to re-structure the area in a heat resistant urban environment.
- Re-structuring an existing urban area is only possible when the area is renovated on a large scale. Even then the historical and geographical elements might be constraining aspects in realising an ideal situation.
Wind

Designing with wind can lead to effective methods for buildings and urban areas. In many warm countries wind is an important cooling factor. Though in the Netherlands it is a dangerous measure for cooling. This is because the main wind direction is South-West, but in winter we have the coldest wind from the North-East. Generating wind for ventilation in summer means a very unpleasant situation in winter.

![Wind Diagram](image)

**Effects**

- Slanted roofs improve affective natural wind ventilation. This is a much more effective means for improving natural ventilation at the ‘mouth’ openings of urban street canyons than increasing building spacing. (Rafailidis, S., 1997)
- The canopy layout has influence on wind patterns in between buildings. To design with wind the height/width ratio can be taken into account, see images underneath. This measure counts for wind directions that come more or less perpendicular to the streets.

![Wind Effects](image)

*fig 17 twee co-roterende wervels bij H/W=0,17 (boven), een hoofdwerp met kleinere wervel bij H/W=0,5 (links) en twee contra-roterende wervels bij H/W=2 (rechts) (Xiaomin, 2006)*

(Oke 1988)
Potential benefits
- Slanted roofs can be combined with PV
- When designing a street layout the H/W ratio can be optimized for wind, but also for solar radiation.
- When designing a street layout elements like trees can be used to weaken or change wind flows

Comments
- Slanted roofs offer fewer possibilities for green roofing and terraces.
- With higher wind speeds windmills can produce more electricity, on the other hand high buildings have already very powerful wind speeds at the top.
- Wind is extra cold in winter and can become uncomfortable and dangerous.

Applicability
- The choice for slanted roofs is usually made because of constructional, practical or aesthetic motives. The advantage of improving the ventilation in the canopy could be an extra convincing aspect in the decision making
- When extra ventilation for warm periods is generated by a design, the winter situation needs to be considered. In the open air school from J. Duiker for example is the possibility to give lessons in the open while the heating in the floor gives enough warmth for the children to work.

Open air school Amsterdam, J. Duiker, 1929-1932
Shading

The sun view factor on buildings influences the amount of solar radiation accumulated by the facade and the amount of solar radiation warming the interior of buildings through glass. When a building is shaded by another building in summer to reduce heating, the building will be even more shadowed in the winter situation in the Netherlands. Since winter is the time of year when solar radiation is lacking, shading buildings by buildings should be avoided.

Other measures to shade buildings are trees and green walls which are green in summer and transparent in winter. Also canvas or other kind of materials can be used to shade buildings, these can be easily removed in winter. If the facade has a high albedo of itself than measures for the indoor climate can be sufficient. To keep solar radiation out you can think of all kind of screens on the in- or outside (last one is more effective), even applications within the glass panel that can be adjusted by the user. A fixed element could be a shading device for vertical solar radiation in summer that does not stop horizontal solar radiation in winter, see right image underneath.

Potential benefits
- Less solar radiation will lead to energy reduction of air conditioners because the indoor spaces do not warm-up and the outdoor facade stays cool
- Solar radiation can be transformed in electrical energy while shading, see image on the right
- Solar radiation can be transformed in electrical energy and heating while shading, like a so-called ‘PV-Thermal system’
- Solar radiation can be transformed in electrical energy while controlling the incoming light. The darker the glass, the more electricity is produced. (Smart Energy Glass 2008)

J. Chambers, Barcelona

Comments
- Solar radiation in winter is important in the Netherlands for comfort. By shading buildings with buildings in summer, the winter situation becomes unhealthy and uncomfortable. Shading buildings with deciduous trees or removable applications does not have this negative effect in winter.
Applicability
- Adjusting the height/width ratio in the Netherlands just to create shadows on neighbouring buildings has more negative implications than the positive effect on energy demand for cooling. Building with a high density also implies heat accumulation because of more solar reflection, reduced albedo, a lower sky view factor and less ventilation.
(Anthropogenic) heat storage

The heat that is produced because of human activities is anthropogenic heat. This can be the heat production of air conditioners, cars, buildings, humans themselves, etc. For the colder periods of the year waste heat is a welcome extra heat source, while in summer we need to get rid of this. To cool buildings we use air conditioners, this is a contrasting device since it blows more heat to the outdoor than it cools the indoor. During the last decade buildings in the Netherlands start to manage their internal heat distribution by storing heat underground in summer and using this in winter. This principle is called WKO; warmth and cold storage in an aquifer\(^3\).

Effects

Average: increase of 1.0 °C of the outdoor temperature leads to 6.6% extra electric energy demand (Hiroaki, et al. 2003)

In the cities of United States, the urban warming is surmised to increase the peak electric energy demand by 3 to 6% with 1.0 °C temperature rise (BRETZ et al., 1998). This increased rate of demand is estimated up to 3%/°C in recent years in Tokyo, and about 1.6 GW of new demand is required as the daily maximum temperature increases by 1.0 °C in the greater Tokyo area (SAKAI and NAKAMURA, 1999). Most of this huge demand of summer electricity is caused by the air-conditioning systems, and is considered to be one of the common characteristics in big cities of Asian countries.

From the viewpoint of the reduction of CO2 emission to mitigate the global warming, this huge demand should be reduced through the control of the urban warming. (Hiroaki, et al. 2003)

The average daily contribution of anthropogenic heat release on local urban micro-climate and the boundary layer structure is 43.6%. This heat release intensifies the UHI effect, especially during the evening and at night. (Chen, et al. 2008)

A study in Tokyo analysed the influence of the heat discharge to the environment by simulating the mesoscale climate with no anthropogenic heat discharge. Below (figure 6) is first given the situation. The analyses showed the highest influence of anthropogenic heat late at night and early in the morning. Actually when there was no strong solar radiation. The maximum difference of 3.4 °C was obtained at midnight. The differences were larger at the places with higher anthropogenic heat discharges.

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\(^3\) an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be usefully extracted using a water well.
Four different simulations of a winter period in Central Europe are carried out to investigate the principle effect of anthropogenic heat release from the highly industrialized and populated Ruhrarea region (Germany) on regional climate conditions. The results reveal a permanent warming due to anthropogenic heat emissions over affected areas ranging from 0.15 K over land area with an additional 2 W m\(^{-2}\) anthropogenic heat flux up to 0.5 K over the Ruhrarea with additional 20 W m\(^{-2}\) anthropogenic heat flux.

Energy consumption is a major source for regional and global warming either directly by the anthropogenic heat release itself or indirectly through the anthropogenic greenhouse effect. The direct effect discussed in this paper is smaller than the expected warming caused by increasing greenhouse gas concentrations [Houghton, 2001; Keuler et al., 2003]. But anthropogenic heat will become more important in the future, because of the steadily increasing worldwide energy consumption and the growth of population and urban areas. (Block, et al. 2004)
The storage of heat underground using an aquifer is illustrated underneath.

### Potential benefits
- WKO installations reduce energy consumption by 40-80%
- Housing in combination with greenhouses with heat storage in the earth (WKO)
- Re-using the waste heat from traffic and industries

### Comments
- WKO installations are not applicable at all sites, in the Netherlands 90% of the soil is fit for the purpose. Determining are the thickness of the earth layers and the permeability of the earth. There are also constraining juridical factors;
  - dispersion of pollution;
  - danger for ecological values;
  - interference with groundwater absorption;
  - interference with other energy storage systems;
  - salination of sweet water or sweetening of salt water;
  - danger for subsidence;
  - not aloud in drink water source areas
These last factors leave only 27% of the Netherlands free for the installation of WKO installations. (Zwart 2007)

### Applicability
- A solution for the air conditioners problem may be to put a tax on heat that is produced, for the industry this tax will imply another restriction next to the CO2 emissions, but can also lead to innovations and big savings
- During the design of a building and it’s surrounding the use of air conditioners can be avoided, this leads to a better in- and outdoor climate and saves energy for cooling
References

Books

- 

Thesis’s and PHD’s

- 

Reports


Journals


**Symposiums**


**Articles**


Design Principles for Urban Heat management

Lectures

Maps

Designs

Internet
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