A research on climate responsive design in the transformation of buildings in the Netherlands

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1.1 Fascination
My fascination is climate responsive design and how this strategy could be applied in the Netherlands in the transformation of (office) buildings. In climate responsive design the main goal is to make buildings sustainable by means of building shape and orientation. Climate responsive design is architecture that has a connection to nature. Building designs that take into account climate and environmental conditions to help achieve optimal thermal comfort inside. It deals with design and architectural elements, avoiding complete dependence on mechanical systems, which are regarded as support. Heating, cooling and lighting are regarded as the form-givers in architecture (Lechner 2001, p. 2). The climate is used as a form determinant for the architectural design.

1.2 Problem definition
Bioclimatic design or climate responsive design has a great history, it has been practised all around the world for centuries. Many examples exist but one of the most interesting is Pueblo Bonito in Chaco Culture National Historical Park, northern New Mexico. This semicircular village facing south contained of houses which were stepped up to give each home full access to the sun. The massive construction of the village stored the heat for night-time use (Lechner 2001, p. 142). Architects nowadays seem to have forgotten all about this design method. The form and orientation of buildings are now mainly decided by the urban context (houses f.e. seem to always face the road regardless the orientation) or the architectural style, not by its climatic surroundings. To solve the created climatic problems inside the building several installations are added to the design. As temperatures around the globe continue to rise and climates continue to change it has never been more important to sustainably design buildings. All choices we make have impact on our environment. When choosing for a sustainable low energy design, built to respond to the season, taking advantage of the sun, wind and on-site conditions a lot of valuable energy can be saved. It could naturally regulate heating and cooling and will minimise the impact on the environment. Caro van Dijk stated that you should design along with the climate and not against it. Façades should be designed according their orientation (Van Dijk, 2012).

Until the previous century the heating, cooling and lighting of a building was part of the profession of the architect. Since the 1960’s this situation has changed, mechanical equipment accomplished the heating, cooling, and lighting of buildings (Lechner 2001). Due to shrinking companies in the Netherlands about 15,4% of office buildings is vacant. This is partly due to the new working method which is popular in the Netherlands. This is a growing problem in the Netherlands. In 2013 the number of vacancy is expected to rise to 16%. Many researches are focussed on finding a new function for these office buildings. This thesis will try to find a way to transform vacant office buildings in sustainable buildings with a
new function using climate responsive design. The possibilities of the climate responsive design will determine the new function of the office building.

The research will focus on passive sustainable methods. Climate responsive design is something to be researched. The design itself and the architecture itself should create a highly efficient building. Electric light, heating, cooling and ventilation should be avoided/be unnecessary as much as possible. The direct context of the building is very important especially its climatic features. Sun, wind and light are the key to this research and design. By using these features in a smart way it could create natural ventilation, natural lighting and natural heating/cooling.

1.3 Research question

“How could a(n) (office) building in the Netherlands be transformed in a climate responsive way?”

Sub questions:
Which methods are known for
- natural ventilation?
- natural lighting?
- natural heating?
- natural cooling?

In what way could you translate these climate responsive design methods into architecture?

How to imply climate responsive design methods in an existing situation (building)?

1.4 Project goal

The goal for this research is to create a spectrum of possible architectural applications of climate responsive methods in the transformation of buildings in an urban context in the Netherlands. It will guide the designer in the possibilities of choices. It will show the benefits and downsides of the methods covered in this research. A literature study will be done about climate responsive design and current examples will be analysed on how these techniques are implemented in the architecture of the building. The research focuses on methods which are created by architectural elements. This means that the smaller techniques will not be dealt with. The methods which exist of architectural elements will be broadly explained. In the end this research is meant for architects, it will have to guide them in the choices they can make during the design process of the building.

An important restriction in this research is the fact that it focuses on buildings in an urban setting. Designing in a climate responsive way in an urban environment is a lot more complex comparing with areas where no attention needs to be paid to surrounding buildings. The design location is also located in a highly urban area.

1.5 Methodology

The methodology used for this research is mainly based on the literature study on climate responsive design methods and the analysis of
sustainable buildings on the climate responsive methods used in the designs.
The climate responsive methods will be explained extensively. Diagrams will clearly show how the methods work. Only the methods applicable in the Netherlands will be dealt with. The case studies will be clearly explained using diagrams as well.

Through case studies of vernacular architecture in the Netherlands and locations with a similar climate an overview will be created of techniques used in the past to achieve a comfortable indoor climate in dwellings. Which methods are used and how the shape and orientation of the building depended on it will be explained. Diagrams will show how these designs worked.

The case studies of modern climate responsive designs will show how the methods can be applied in modern buildings at this time. An important aspect in these case studies is how the methods are translated into architecture. The case studies are selected on relevance.

In addition to these case studies sustainably transformed building will also be covered. These will also be selected according to their relevance. These case studies are mainly located in an urban context and build after 1950. Before the year 1950 it was a lot more common to design in a climate responsive way. Climate installations were not used in buildings much yet. Therefore it is more interesting to research the buildings build after 1950 since these buildings were initially designed with no regard whatsoever on the local climate, since climate installations were expected to solve all climatic problems. The case studies will show how such a building can be transformed in a way that it does react to its local climate, which climate responsive design methods were used and how this is translated in architecture.

A conclusion will be drawn from the case studies and the literature study. A spectrum of useable climate responsive methods in the Netherlands in an urban area is created. Several important points will come forth to pay attention to when designing in a climate responsive way in the transformation of buildings in an urban context. The research is concluded with a plan of approach for designers to design in a climate responsive way. The process necessary for designing in a climate responsive way is explained.

**Boundaries**

One of the boundaries for this research is the fact that it will focus on urban areas in the Netherlands. The eventual design will be located in the Netherlands in an urban area. Another boundary is climate responsive design.

The third boundary is the fact that this research will focus only on the architect. The research is based on what architects can do in their design for naturally heat, cool, ventilate and light the building. So it will mainly be based on shape and orientation.

The research should eventually be a guide for making a design for the transformation of buildings in urban areas in the Netherlands in a climate responsive way.

**1.6 Relation research and design**

The research will function as input for the design. As explained in chapter 6 the research can be used to find inspiration and useable methods for the design problems found. The research is a design manual for architects wanting to design in a climate responsive way. This means that I, as well as other designers, will be able to use the content and outcome of the research as inspiration but also as a source of information. The case studies are mainly meant for inspiration. The chapter explaining all the methods gives the designer enough information and insight into the methods to be able to use and understand them. In chapter 6, a plan of approach is proposed to help the designer in the process of designing in a climate responsive way.
overview of research

case studies of vernacular architecture

climate responsive design methods

natural heating
natural cooling
smart sunshading
natural ventilating
natural lighting

case studies of climate responsive buildings

case studies of sustainable transformed buildings

conclusion & plan of approach
visual explanation of the project

name, place, architect of the project

textual explanation of the project

strategies used in the project

diagram explaining how the project works

strategies used in the project

visual explanation of the project

case studies
This chapter will focus on the application of climate responsive design methods or bioclimatic design methods in vernacular dwellings of the Netherlands. Whether the organisation, shape, orientation and landscaping of vernacular dwellings was influenced by climate responsive considerations will be researched. Some examples will be searched to represent the influences of these climate responsive considerations in the design of the dwellings.

The history of housing in the Netherlands, the Low Countries, starts with the earliest form of housing namely: the housing in caves. In some caves paintings are found of tents or cottages. This points out that people used to live in their own build structures in summer, but in winters still came back to the comfortable and effortless to heat caves (Rottier and Arnoldus 1988, p. 20). So in the early years people already sought for different types of housing in different seasons to be more comfortable.

The first settlement consisted of a group of approximately 6 tents or cottages. The positioning of the tents relative to the suns path, the prevailing wind direction and an acceptable water drainage had a great influence on the choice of the location of the settlement. Hence the evident preference for the south east sides of hillsides and river valleys (Rottier and Arnoldus 1988, p. 26). The disadvantage of tents was when sunny the temperature could rise quickly and in winter the tents wouldn't retain much heat, so temperatures would drop easily (Yanovshtchinsky, Huijbers et al. 2012, p. 17).

The ‘bandkeramische’ farming community lived in farms which weren’t positioned in the settlement following a certain plan. Nonetheless, the majority of the farms where oriented northwest-southeast to be better protected from rain and wind (Rottier and Arnoldus 1988, p. 33).

The earliest houses in the Middle Ages were build up from timber and straw which resulted in a short lifespan of those buildings. Therefore traces of these houses in the Middle Ages are quite scarce. Initially these early medieval farmhouses were very similar, but gradually regional types emerged. These regional types were among other influenced by the climatic circumstances of the location. The social, climatic and geographic circumstances determined the layout and shape of the buildings, while style and ornaments where not important (Rottier and Arnoldus 1988, p. 89).

The structure of medieval cities were very much influenced by the local climate. Especially during the period in which buildings were build from timber it was of great importance to bear in mind the climatic circumstances. For that reason most streets in coastal towns are oriented southwest-northeast and northwest-southeast. The typical medieval linkage of apartment blocks and the cohesion between these apartment blocks and streets, squares and public buildings is a direct result from the influences of nature (Rottier and Arnoldus 1988, p. 117).
As you can read most forms of housing are based on the shelter from wind. This is clearly visible in a more recent example like the ‘schaapskooien’ on the Dutch island Texel (Yanovshtchinsky, Huijbers et al. 2012, p. 16). The sloping roof is oriented to the west, which is the most common wind direction in the Netherlands. The openings or entrances of these ‘schaapskooien’ (sheepfold?) are facing east to be bothered less by the wind.

In the roman empire wealthy people would have build greenhouses for tropical plants in their houses. This shows that they already understood the principal of passive solar energy. Another example is the Roman heliocaminus. This was a room in a bathhouse which would be heated by the sun. The northside of this room was closed and the south side was opened to gain heat (Yanovshtchinsky, Huijbers et al. 2012, p. 18).

The main aim in the Netherlands is to gain as much sun as possible inside the building (Lechner 2001, p. 2). Gaining heat and to retain heat is very important too. Some archetypical solutions for the first one are large windows and bay-windows. These windows where used to capture as much light as possible. In winter it was hard to keep the heat inside with these very large windows which were made of single glass.

To retain the heat inside the building at night, for example after a sunny day when solar...
heat was gained through the windows, the windows contained shutters which would be closed during the night. This way gained heat would not leave the building as easily as it entered the building and the building would stay warm for a longer period of time.

Another vernacular climate responsive method is the placement of deciduous trees near the (south) façades of buildings. These trees are mainly planted at the south façade of a building but could also be placed at the east or west side of the building. The deciduous trees are covered with leaves in summer which results in a natural sun screen for the building. In winter at the other hand, the tree loses its leaves and the winter sun will be able to enter the building through the bare tree.
In New England some vernacular examples show the fact that orientation was already important in those days. The colonial buildings called salt boxes had a two story wall on one side of the building and a one story wall at the other side. The two story wall would face the south and contained a big number of windows to catch as much wintersun as possible (Lechner 2001, p. 144). The one story wall faces the north and has a big sloping roof containing a small number of windows. This side of the building would deflect the cold winter winds. This type of building is much like the ‘Schaapskooi’ type explained earlier. It functions more or less the same. This shows that the same climate asks for the same measures.
In mild climates which are very gray during a great part of the year (very cloudy), like the Netherlands the main aim is to gain as much sun as possible inside the buildings (Lechner 2001, p. 2).

The architectural approach for the heating, cooling and lighting of a building is divided in three tiers according to Lechner (Lechner 2001, p. 7). To minimise heat loss in winter, heat gain in summer and to use daylight as efficiently as possible through architectural design is the first tier. The second tier consists of the use of natural energies by means of passive heating, cooling and daylighting methods. Architectural design is the medium to accomplish these first two tiers. The methods to accomplish these two tiers will be discussed in this research. The third tier will not be discussed, this tier involves the design of the mechanical equipment. This is mainly focused on the handling of the demand that remains after the first two tiers have reduced this demand as much as they can (Lechner 2001, p. 8).

**NATURAL HEATING** is mainly about using the sun as a natural source of heat to obtain a comfortable indoor climate in buildings. Mass and orientation are of great impact on naturally heating a building. In chapter 2.1 explains all about natural heating.

**NATURAL COOLING** To naturally cool a building the thermal heat sinks can be used. In the Netherlands not much natural cooling is needed, since most of the year temperatures are fairly low. Everything about natural cooling is explained in chapter 2.2.

**SMART SUNSHADING** is all about keeping the sun out of the building, to retain the building from heating up to much. There are many interesting vernacular examples of smart sunshading as well as modern interpretations of the subject. Chapter 2.3 explains many methods considering smart sunshading.

**NATURAL VENTILATING** mainly makes use of differences in pressure as well as differences in temperature. Methods for natural ventilation are based on these two principles. Careful consideration of the orientation is very important for natural ventilation. Chapter 2.4 explains natural ventilation.

**NATURAL LIGHTING** is all about bringing natural light as deep as possible inside the building. The main goal is to create a comfortable indoor light climate and to reduce the need for electric lighting as possible. Chapter 2.5 deals with natural lighting.
2.1 Natural heating

To achieve natural heating you will have to meet with some requirements. The requirements for natural heating are solar radiation, architectural elements and internal loads. There are several classical passive types for natural heating. They are divided in three different groups: Direct gain systems, indirect gain systems and isolated systems (Bainbridge and Haggard 2011, p. 45). These three groups are subdivided in 6 subgroups. The direct gain system consists of distributed mass and concentrated mass systems. The indirect gain system consists of thermal walls and thermal roof systems and the isolated systems consist of sunspaces and thermosiphons. These systems can be used in various combinations and are best not regarded as pure systems but as components which can be used in combinations. For natural heating the three functions, thermal collection, thermal storage and thermal transfer and control must be provided for.
2.1.1 Direct gain systems

Direct gain systems are systems in which the thermal transfer occurs in the interior of the building. This means that the heat will be captured inside the building instead of at the building envelope as is the case in the indirect gain systems or like the isolated gain systems: outside the building envelope via a separate architectural element (Bainbridge and Haggard 2011, p. 45). The thermal collection is provided by means of the openings in the building which introduce the sun directly into the interior of the building. The heat is stored in the mass of elements in the interior, the transfer of heat is realized by the radiation from the elements which store the heat to the surrounding spaces. The control of the heat is also realized in a spatial way, architectural elements should control the amount of heat stored and transferred. The direct gain system is the most efficient of all the systems when energy collection and first costs are the main concerns (Lechner 2001, p. 149). The direct gain systems are subdivided in two groups: distributed mass and concentrated mass. These two will be explained more extensively below.

Spread mass systems
This system is most suitable for balanced heating and balanced cooling. In this system the thermal mass is spread around through the building in relatively thin layers. This thermal mass is only located in the interior space. For the best performance the mass should have a light colour. The mass will gain heat from either:

//How it works
Mass is spread around the building in relatively thin layers, e.g. in floor or walls. This mass is heated by solar radiation. The heat is captures in the mass and will be distributed when the surrounding turn colder.

//When to use
Use this system when solar radiation is wanted for heating as well as for natural lighting of the building.

//How to apply
Orientation: SOUTH is best. East and West orientations could heat the building respectively in the morning or afternoon.

Materials: Concrete, masonry, gypsum plaster or phase change materials

Placement: all around the room you want to be heated and has preferably south oriented windows

//Strategies to apply in transformation
This strategy could be used in the transformation of buildings when the building consists of a sufficient amount of mass and has proper orientation. Mass could be added by adding gypsum plaster to the existing walls or by adding solid walls with high mass to the building.

//Related projects
The Jacobs II House, Solar Hemicycle house, Frank Lloyd Wright (Columbia University 2014)
ther direct solar radiation or by re-radiation or convection from warmer areas (Bainbridge and Haggard 2011, p. 58). The down-side of giving the mass a light colour is that it will reflect a great part of the solar radiation, this will reduce the direct absorption. But thanks to this increased reflection light will be transported to a bigger area of the distributed mass. The light colour of the mass also enhances the natural lighting of the building thanks to this reflection.

For this system to work best it is preferable to have a south (equator-facing) facing solar opening in all rooms in the building. Of course this is mostly impossible, so one should think carefully of which rooms should have a priority on facing south/the equator. The thermal mass which is distributed in the interior space should be of a considerable amount. The materials used for this thermal mass are mainly concrete, masonry, gypsum plaster or phase change materials (Bainbridge and Haggard 2011, p. 59).

Table 1 shows the rule of thumb for the amount of distributed thermal mass needed in combination with the area needed for openings in the façade.

New materials can increase the effectiveness of this direct gain system with distributed mass. Transparent insulation for example could increase the amount of transparent or translucent openings in the façade with less conductive heat loss than glazing. Phase change
materials are another promising new material. This material can be added to materials like masonry or gypsum to increase the thermal storage capability.

Concentrated mass systems
As the title says this system works with mass which is concentrated in the interior space. One could think of a water tank or a masonry wall. Because of this concentrated mass the efficiency is much greater. The most efficient thermal mass material is water. Water has a high heat capacity, it is 2.7 times more effective at storing energy than concrete by volume and 6 times more effective by weight (Bainbridge and Haggard 2011, p. 58). The concentrated mass systems are smaller in size than distributed mass systems. They cover less surface in the interior, for this reason the element could be a darker colour since this will not affect the lightness of the interior too much. The other surfaces in the room could be a light colour to give the space a more light character and help with natural lighting.

For this system it is very important to consider the placement of the mass carefully. Following the new phase change materials water is the most efficient thermal mass. So far when applying this system large amounts of water are used in an architectural way. One of the applications used are steel water tanks below the standard windowsill on the south wall (Bainbridge and Haggard 2011, p. 64).

Table 2 shows the rule of thumb for the amount
//How it works
This method captures heat in the envelope of the building. In the façade of the building heat is captured and heats the behind lying wall, due to the time lag -only after the wall itself has substantially warmed up heat can exit at the other side of the wall- the rooms behind the wall will be heated at night.

//When to use
Use this method when only the solar radiation is wanted for the heating of the spaces and not for the lighting of the spaces.

//How to apply
Orientation: Best to the SOUTH since most solar radiation can be captured in this orientation
Material:
- translucent material: glass or f.e. translucent Fiberglas
- solid materials: concrete, brick, stone or water
Wall needs to be quite thick: about 30 cm
Placement: at the facade of the building

//Strategies to apply in transformation
Old masonry buildings can benefit in several ways by having a glass-curtain wall built over their south facade, which then becomes a thermal wall. (Lechner, p. 156)

//Related projects
University Building Lawrence USA, studio 804 (www.holcimfoundation.org)

For the Netherlands the third column is most comparable. So a thermal mass will be needed which is as big as 8-12% of the area of the openings facing south in that room.

2.1.2 Indirect gain systems
Indirect gain systems consists of two different approaches. The indirect gain system could either be applied to the façade or the roof of the building. Examples for indirect gain systems are the double façade, the thermal wall applied in the façade and roof ponds. (pag 67 solar architecture)

Thermal wall or thermal envelopes
The thermal wall functions in a way that the outer layer of the façade heats up, the air behind this layer heats up simultaneously after which this air will be brought into the space behind the façade. Thermal walls can be designed as a double façade as well as a water wall and many other types. Norman Foster has developed the thermal wall into a thermal envelope which includes more functions of daylighting and natural ventilation (Bainbridge and Haggard 2011, p. 68).

Thermal roof system
This system can be used for heating in winter as well as for cooling in summer. The system consists of two parts, the first is a large amount of thermal mass which is attached to the roof and the second is movable insulation (panels).
Thermal roof system

//How it works
This method captures heat in the mass located on the roof during the day. The movable insulation is moved on top of the mass at night to keep the heat in the mass which will radiate to the rooms below.

//When to use
Use this system when the construction is strong enough to bear the extra weight of the mass. And use it when there is enough space on the roof to apply the method.

//How to apply
Orientation: as long as the southern solar radiation can reach the mass the orientation is ok.
Material: usually water in waterbasins, but phase change materials are applicable too
Placement: on top of the roof

//Strategies to apply in transformation
This system is very hard to apply in the transformation of existing buildings. The system asks for a very thorough integration of the system into the architectural design of a building, for this reason it is hard to implement the system afterwards.

//Related projects
The winters house, Jon Hammond, Living Systems (Bainbridge and Haggard 2011, p. 103)

In winter the thermal mass is exposed to the sun during the day and at night the movable insulation will move over this mass to conserve the gained heat. This heat will heat up the building.

In summer the system works the other way around; the thermal mass will be shaded during the day by the movable insulation and at night the thermal mass will be opened up towards the night sky. This enables heat-radiation to the night sky which cools the building (Bainbridge and Haggard 2011, p. 70). These systems are mainly realized with roof ponds filled with water, but with new technology water could be replaced by phase change materials.
Sunspaces

//How it works
Heat is captured outside the building via a separate architectural element. The heat is transported in the building through openings in the walls.

//When to use
When there is need for an extra space outside the building. Which can be oriented either to the south, west or east of the building.

//How to apply
Orientation: The orientation could either be south, east or west. East and West will respectively heat the building in the morning or afternoon. Landscaping is needed for the necessary shading in summer at these orientations.
Materials: The sunspace consists mainly of glass.
Placement: Outside the building envelope.

//Strategies to apply in transformation
Sunspaces could be added towards the outside of the building. For this reason it is quite easy to apply this method in the transformation of existing buildings.

//Related projects
Westraven Utrecht by Cepezed (Koekebakker 2008, p. 55)

2.1.3 Isolated systems

Sunspace
A sunspace is an added space at the side of the building which faces the equator, for the Netherlands this would be the south side. This space can be closed off from the building, this way heat losses at night can be prevented. There are several types of sunspace such as the seasonal sunspace and the solar greenhouse.

The seasonal sunspace is mainly applied as an addition to an existing building. Often it is applied in a part of the house which already consists of walls and a roof. This type of sunspace is also applicable at the west or east side of the building. At these orientations it functions as a heater in winter, as well as early spring and late fall. If it faces east it will heat-up the building in the morning, a west orientation enables heating in the afternoon. The down-side of these orientations is that it will cause overheating in summer if the seasonal sunspace is not shaded. Landscaping could ascertain a solution to this problem.

The solar greenhouse could also be added to an existing building. This type consists of more glazing; the (sloped) roof also consists of glass, like a greenhouse has. This type also works best when applied with a south orientation. Due to the higher amount of glass surface this type will generate more heat and light, but this also means that there is a greater risk of overheating in summer. For this reason it is needed to add shading for summer situations, large vent
areas to the outside is also a necessity. These vents should be located at the lower parts of the greenhouse as well as at the higher parts. To be able to bring the heat inside the house in winter, it is important to have vents to the house as well. To improve the ventilation towards the house a fan or thermal mass could be added. To prevent from cooling down at night the greenhouse could be supplied with insulation; one could think of insulated shades or curtains.

Table 3 Heat capacity of materials by volume (Lechner 2001, p. 165)

<table>
<thead>
<tr>
<th>Material</th>
<th>Heat Capacity per Volume (BTU/Ft²oF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>62.4</td>
</tr>
<tr>
<td>Steel</td>
<td>59</td>
</tr>
<tr>
<td>Wood</td>
<td>26</td>
</tr>
<tr>
<td>Brick</td>
<td>25</td>
</tr>
<tr>
<td>Concrete (stone)</td>
<td>22</td>
</tr>
<tr>
<td>Foam insulation</td>
<td>1</td>
</tr>
<tr>
<td>Air</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Table 4 Comparison of various heat-storage materials (Lechner 2001, p. 165)

<table>
<thead>
<tr>
<th>Material</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>- Quite compact</td>
<td>- A storage container is required and can be expensive</td>
</tr>
<tr>
<td></td>
<td>- Free</td>
<td>- Leakage is possible</td>
</tr>
<tr>
<td>Concrete (stone)</td>
<td>- Very stable</td>
<td>- Expensive to buy and install because of weight</td>
</tr>
<tr>
<td></td>
<td>- Can also serve as wall, floor, etc.</td>
<td></td>
</tr>
<tr>
<td>Phase change material (PCM)</td>
<td>- Most compact</td>
<td>- Most expensive</td>
</tr>
<tr>
<td></td>
<td>- Can fit into ordinary wood-frame construction</td>
<td>- Long-term reliability is not yet proven</td>
</tr>
</tbody>
</table>
2.2 Natural cooling

Since global warming causes more heat waves (Bainbridge and Haggard 2011, p. 86), also in the Netherlands natural cooling becomes more and more important. Many buildings build in the past will not meet the needs for future climate features especially when it comes to cooling. The cooling demand is influenced especially by unwanted solar heat gain and internal heat loads. For natural cooling it is very important to also consider the relative humidity and wind speed of the location.

The orientation of a building is of great importance for passive or natural cooling. The orientation of windows influence the capability of natural cooling greatly too. The best orientation for natural cooling is conveniently the same orientation best for natural heating, namely south facing (equator facing) (Bainbridge and Haggard 2011, p. 86). This orientation will collect the most heat in winter and in summer it is the best orientation to block the sun and keep the building cool for example by designing an overhang.

East and west orientations on the contrary can cause overheating of the building in late spring, fall and summer. The position of the sun at these orientations is quite low which makes it more difficult to block it from entering the building.

Natural cooling can be achieved by using the three thermal sinks of cool night air, night sky radiation, and evaporation from wet surfaces.
Natural cooling is very important in natural cooling, almost all natural cooling principles use natural ventilation. Passively cooling a building will bring a very low electricity demand and simultaneously will provide a more comfortable and healthy living condition. The humidity of a place influences the potential of naturally cooling a building, because it influences the difference in temperature between day and night. When very humid the temperature differences are small because the humidity works as a sort of blanket which blocks the heat from radiating to the night sky. For this reason a building on a location with a low relative humidity is easier to naturally cool (Bainbridge and Haggard 2011, p. 87).

To be able to efficiently naturally cool a building it is very important to also consider the skin of the building. A few things are very important to think of when naturally cooling a building; insolation in the building and internal heat gain from for example machines. The insolation could be controlled by architectural means, for example smart sun shading etc. Internal heat gains have more to do with the amount of people in the building and the amount of electrical appliances which generate (waste) heat, for example light bulbs or refrigerators. Smart design for natural lighting could reduce the heat gain from electrical lighting (Bainbridge and Haggard 2011, p. 88).
Landscaping
Elements in landscaping can help the building from overheating. These elements can help controlling the solar radiation which enters the building. Trees can be used very effectively for shading, but one should be careful that the tree doesn’t shade too much in winter too. The branches etcetera could block the much wanted sun from entering the building in winter. For this reason it could be best to place trees at the southeast and southwest sides of the building instead of placing them exactly on the south side. This way the sun will be blocked in summer but will be able to enter the building in winter on the south façade, which can be very pleasant. Trees have the same shading coefficient as an overhang; a shading coefficient of 0.2 (Bainbridge and Haggard 2011, p. 92).

Night ventilation cooling
This method uses the same aspects as the direct gain-spread mass method for natural heating. Thermal mass is used to cool the building at nights through ventilation with cool night air. During the day the building is closed, to gain as little heat as possible. The building should be cooled down enough during the night to keep the building cool during the day. For this reason it could be best to place trees at the southeast and southwest sides of the building instead of placing them exactly on the south side. This way the sun will be blocked in summer but will be able to enter the building in winter on the south façade, which can be very pleasant. Trees have the same shading coefficient as an overhang; a shading coefficient of 0.2 (Bainbridge and Haggard 2011, p. 92).

Ventilation cooling
This method is mainly used in hot and humid climates. So for the Netherlands this wouldn't be very useful. It is mainly about maximizing

//When to use
In the Netherlands this method is very well applicable since summer night tend to be much cooler than summer days. Use this method when cross ventilation is possible in the building.

//How to apply
Orientation: windows are best to be placed in a way that cross ventilation is enhanced (see cross ventilation)
Materials: Concrete, masonry, gypsum plaster or phase change materials
Placement: The mass should be placed all around the rooms you want to be cooled

//Related projects
The Jacobs II House, Solar Hemicycle house, Frank Lloyd Wright (Columbia University 2014)
Radiation cooling

//How it works
Mass is applied on the roof of the building. The movable insulation is closed during the day -to gain as little heat as possible- and open during the night to radiate heat from the mass to the cold night sky.

//When to use
Use this system when the construction is strong enough to bear the extra weight of the mass. And use it when there is enough space on the roof to apply the method.

//How to apply
Orientation: oriented to the cold north sky could cool the building during the day too. If only applied for night cooling the orientation is not important.
Material: water is very useable because of the good thermal capacity and the warmest water will always move to the radiant surface
other materials could be used too, like concrete, stone, phase change materials provided that they have high-mass

insulation material for the movable insulation panels
Placement: on top of the roof of the building

//Strategies to apply in transformation
This system is very hard to apply in the transformation of existing buildings. The system asks for a very thorough integration of the system into the architectural design of a building, for this reason it is hard to implement the system afterwards.

//Related projects
The winters house, Jon Hammond, Living Systems (Bainbridge and Haggard 2011, p. 103)

Radiation cooling
This system makes use of the cold night sky and the cool north sky in the day. Radiation cooling is very similar to the principle of the thermal roof systems for natural heating. It only works the other way around. During the day the roof will be covered with insulation and at night it will be opened and the heat from the roof will radiate to the cold night sky. The sky can be about 5-22 degrees Celsius colder than the air temperature (Bainbridge and Haggard 2011, p. 101). For this reason when exposed to the sky elements could cool down by radiation. Roofs with only a high mass and no insulation already benefit from the night sky radiation. The only problem with high mass is that this mass will be heated during the day, which is no problem in the beginning of the day since it has a lot of mass which will block the heat from entering the building below. But at the end of the day when all mass is heated the spaces below will be overheated. For this reason it is best to work with movable insulation panels. For this system water is very useable, like for the thermal roof system for natural heating, especially because water has the property to move the warmest water to the surface, which will radiate to the sky. Other materials could off course as well be used, like concrete and phase-change materials or other materials provided that they have high-mass.

This system works when there is more outgo-
ing radiation than incoming radiation (from the sun for example). During the night when there are no short-waves from the sun, the long-wave radiation from the earth is more powerful than the radiation in the opposite direction, this makes that the elements will cool down since more radiation flows to the night sky than will flow towards the elements.

Studies done by Tod Neubauer, Richard Cramer and N.R. Ittner have shown that the cool day sky is most effective when the elements which are to be cooled are sloped 65 degrees facing north. White panels even stayed below the air temperature during the day when facing north with a slope of 60-70 degrees. In this research even vertical walls which were exposed to the sky at night had an average temperature of about 3 degrees Celsius cooler than the air temperature (Bainbridge and Haggard 2011, p. 102).

This system works best when the sky is little cloudy. This system is most effective during periods with clear skies and low humidity (Bainbridge and Haggard 2011, p. 102). Also trees, buildings etc could block or limit the night sky radiation. Most of the radiation, about 80% flows towards the area of the sky which is 30 degrees above the horizon. At the same time the most outgoing radiation goes from the object straight upwards, directly overhead. Shortly said it will work best when horizontal surfaces are exposed to a cloudless sky with low humidity and no obstructions.
Evaporative cooling

The change of phases of a material can absorb or discharge a lot of energy. For example during the phase change of water into water vapour a lot of energy/warmth is absorbed by the water.

In very hot climates the evaporative cooling has been applied already centuries ago. These mainly used the water vapour in the air to cool, by spraying or sprinkling. This is in the Netherlands hardly necessary, there are only a few weeks in a year that it could be really warm in the Netherlands, for this reason this part of evaporative cooling will not be explained extensively.

Landscaping and plants could help cool the building and surroundings in an evaporative way. Usually a city suffers from the urban ‘Heat Island effect’. This means that it gradually becomes warmer when approaching an urbanised area. Landscaping and plants can contribute to decreasing this effect because it is caused by a lack of evapotranspiration (Magee, Curtis, & Wendler, 1999, p. 39). This is mainly due to a lack of vegetation. According to Honjo and Takakura, small green areas with sufficient intervals are preferable for effective cooling of surrounding areas (Honjo & Takakura, 1990/91, p. 446). A small green area effectively decreases the downward temperature, which is shown in the figure on the next page (Honjo & Takakura, 1990/91, p. 446). A green area has a cooling effect in the surrounding atmospheric environment, this is called the “Park Cool Island” (Ol-
The air quality of an area can be improved by plants (Oliveira et al., 2011, p. 2186). Parks and green spaces in urban areas can minimise the effects of Global Warming and Urban Heat Island, by creating a cooling effect and providing fresh air supply (Oliveira et al., 2011, p. 2186).

This method could also be used on the scale of a building itself. The evapotranspiration of plants could help cool the building. Plants could for example be added in a conservatory.

Thermal effect of an urban green area (Honjo & Takakura 1990/91, p. 443)
2.3 Smart sunshading

As explained in the vernacular architecture chapter in the past farms in the Netherlands sunshaded their buildings by using deciduous trees. These trees would be full of leaves in summer and lose their leaves in winter. This means that in summer the buildings would be shaded by the trees and in winter the trees wouldn’t block much of the sun.

Bainbridge and Haggard give an example of a solar-control plan for a house or commercial building. They suggest to plant tall trees to the southeast and southwest to shade the walls and roof. The south façade should be provided with a pergola or arbor with deciduous vines above the windows. To prevent the building from overheating due to reflections from the ground, the ground at the south façade should be covered by plants too, for example grasses. At the north side shade plants could be planted. These will help by reducing the Urban Heat Island effect. Small trees could be planted at the north side of the building to the east and west side of this façade to block the morning and evening sun in the hot periods of the year (Bainbridge and Haggard 2011, p. 92).

Modern examples show that with architectural elements the solar radiation can be smartly blocked in summer but not in winters. This way in winter the buildings can still be pre-heated by the solar radiation.
Deciduous trees block most of the solar radiation in summer. In winter the trees lose their leaves which results in the solar radiation entering the building and pre-heat it.

**How to apply**

**Orientation:** The trees could be placed at the South side to block the South-sun effectively but more to the East or West are good orientations too

**Placement:** in front of the facades

**Strategies to apply in transformation**

It can be applied in projects where the surrounding area could also be designed. The trees need to be planted in front of the facades to be able to block the sun.

**Related projects**

Typical Dutch farm (Rijksmonumenten 2012)
Shading by architectural elements

//How it works

By using the fact that the sun has a very high position in summer and a low position in winter, in the design of sunshading elements the sun could be blocked in summer and allowed to enter in winter.

//When to use

When the building needs shading in summer but solar radiation in the building in winter.

//How to apply

Orientation: The most shading is needed in the South. This is also the orientation where the sun is at its highest position and so the easiest to block in summer. In winter this is the position where the building can gain the most heat from.

Placement: at the facade of the building.

//Strategies to apply in transformation

This method could be applied to the facade. The shading elements should be mounted to the existing facade.

//Related projects

DUO office in Groningen by UN Studio (van der Woude 2011)

case study 4.3
2.4 Natural ventilation

Air flow is very important for naturally cooling a building as well as for designing a comfortable and healthy building. Natural ventilation will ensure natural cooling in summer and in winter it will provide the building with fresh air.

There are two causes for the flow of air. One is the differences in pressure. The other is differences in temperature(Lechner 2001, p. 255). This principle depends upon the buoyancy of the warmer air causing the air to rise and leave the building from a higher outlet. This is also called the stack effect, see figure 6. The heavier cooler air is replaced by outdoor air via a lower inlet(Bansal, Hauser et al. 1994, p. 138).

Urban designers should incorporate the benefits and importance of wind in the design of an urban plan. The design should regard the wind direction to protect the natural breezes which could cool the buildings in summer. In the past the windmills in the Netherlands where protected with the “wind rights”. Until the end of the 18th century landlords owned the wind, the owners of windmills had to pay for a permit to receive the “wind rights”. These “wind rights” assured them from obtaining enough wind and protected them from wind-obstructions being build in their surroundings(Molen 2013). Something similar could be incorporated in the cities of the country for assuring natural ventilation in buildings.
Cross ventilation

//How it works
Air will move from places with high pressure to places with low pressure.

//When to use
Use this method when natural ventilation is wanted and when it is possible to place windows in a way that cross-ventilation is enhanced.

//How to apply
1. Placement of windows (plan/section)
   - Inlet and outlet should be the same size. If this is not possible, the inlet should be smaller than the outlet. (Lechner, 2001, p. 263)
   - Cross-ventilation between windows on opposite walls is so effective because air flows from strong positive-pressure to strong negative-pressure (Lechner, 2001, p. 260), as you can see in figure 4. The best orientation for the room for this cross-ventilation would be oblique to the wind direction (Bainbridge and Haggard, 2011, p. 118).
   - The ventilation from window adjacent to each other can be either good or poor. This is mainly depending on the wind direction causing pressure distribution (Lechner, 2001, p. 260). The best orientation for this type is directly facing the wind (Bainbridge and Haggard, 2011, p. 118). Height difference between the inlet and outlet window could help generate more natural ventilation during still times.

2. Sizing of windows
   - The speed of the interior airflow is largely determined by the size of the outlet in relation to the inlet window (Bainbridge and Haggard, 2011, p. 119)

3. Using architectural elements to enhance airflow
   - Fin walls can increase the natural ventilation through windows on the same wall significantly (Lechner, 2001, p. 260). When a greater positive pressure occurs on one side of the window the airstream will be deflected in the wrong direction. A great part of the room would remain unventilated (Lechner, 2001, p. 261).
   - Fin walls can be used to direct the flow of air through the centre of the room (Lechner, 2001, p. 261). A solid horizontal overhang causes the air to deflect upward (Lechner, 2001, p. 261).
   - A louvered or an overhang consisting of a gap between the facade and the overhang will permit the airstream to straighten out (Lechner, 2001, p. 261).

4. Using landscaping elements to enhance airflow
   - Vegetation used to provide wind protection
   - Vegetation used to improve natural ventilation

//Strategies to apply in transformation
This method is fairly easy to apply in transformation projects. The only measure needed to take is to ensure that several openable windows are implemented in the building. The best is to have windows on opposite sides.
This is different for windows located on one side of the building. The ventilation in this situation can vary from fair to poor depending on the location of the windows, even though there is no pressure difference (Lechner, 2001) p. 260).

There are some measures which can have great influence on the natural ventilation inside the building. First of all the placement of windows and the shape of the exterior surfaces. The inlet location and the exterior surfaces have great influence on the air patterns inside the room, this is shown on the previous page (Bainbridge and Haggard 2011, p. 118). The second measure which can be of great influence is the size of the inlet opening versus the outlet opening, this determines the speed of the airflow inside of the room. Changing the direction of the air flow will result in a greater spread of the air in the room and the speed of the airflow in the room will be reduced. The previous page shows more information on this topic. The last measure to influence the natural ventilation inside the building is landscaping elements. If the building can not be oriented in the optimal direction for natural ventilation landscaping elements can help enhance this natural ventilation. The elements can lead the wind into the building or could help protect the building from strong winds. Some examples of how to enhance natural ventilation by landscaping elements are shown on the previous page.
**Stack ventilation**

**//How it works**
When air heats up it will become less dense and will rise and move to a higher position. The surrounding cooler air will then be drawn into the building and replace it ((Hollo 2011, p. 43)

**//When to use**
Use this method when open stairwells or atria are present in the building. And there is a sufficient height difference between the inlet and outlet.

**//How to apply**
- **Orientation:** SOUTH is best but a west or south-west is very good on summer days since the sun has a very high position on the south at summer.
- **Placement:** the inlet and outlet openings should be as far away from each other in height as possible. Min. distance = 1.5 meter. Preferred distance is 4.5-6 meter.

**//Strategies to apply in transformation**
Open stairwells could be extended to become a tower for stack ventilation. Also atria could be used for the stack effect. They should contain windows to warm up the inside air for the stack effect.

**//Related projects**
- Westraven Utrecht by Cepezed (Koekebakker 2008, p. 55)

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**Stack ventilation**
This type of natural ventilation uses the property of air to become more dense when warmer and less dense when colder. The air movement is induced by the fact that air will move from the high density to the place with low density. It works best when the intake opening is as low as possible and the outlet as high as possible. Of course it is important that the intake air is taken from an area with cooler air than the air at the place of the outlet. This air could for example be taken in at a shaded courtyard with a fountain. When the outlet air is warmer than the outside air the stack effect works best. The bigger a building the better the stack effect becomes. The best effect is achieved when the inlet and outlet openings are as far away from each other in height as possible. The minimum of this distance is 1.5 meters, preferably this distance would be between 4.5-6 meters. For this reason buildings with more floors will have a greater potential for stack-effect ventilation. Stack ventilation could enhance or even replace cross-ventilation (Bainbridge and Haggard 2011, p. 121).

**Design guidance for natural ventilation**
Open floor plans are best —> cubicles and partitions can interrupt the flow of window-driven cross-ventilation and may limit natural ventilation benefits unless floor vents are used.

Atria, open stairwells, ventilation shafts, or courtyards are well suited for stack effect cooling. Openings are off course needed to provide flow paths where the warmer, lighter air can
escape through the higher openings and the cooler more dense air can flow into the building at the lower parts to make up for the escaped warm air (Bainbridge and Haggard 2011, p. 121). As said before, bigger buildings can have a better stack effect.

The combination of cross ventilation and stack ventilation is very convenient. When the simple applications of these methods are not enough for the amount of ventilation needed the effect can be enhanced by special methods. For example solar chimneys or wind catchers.

**Solar chimney**

The solar chimney is a very interesting design using the stack effect. It increases the stack effect without heating the indoor climate (Lechner 2001, p. 259). This is achieved by heating the air after it leaves the building as shown in figure 3. Many different solar chimneys exist, the most basic example is a black pipe on the roof of a building. But more mature examples consist of a glass face and a black interior. A solar chimney generally consists of glazing on the south side, an air channel, and black thermal mass which collects and stores solar energy. This collection and storing of heat enhances the draft of air upwards and enables natural ventilation in the building. A west or southwest orientation of the solar chimney could be best on hot summer days, this ensures an optimum gain of ventilation in the afternoon.

In the Middle East wind catchers and wind towers have been part of the design of buildings

//How it works

The solar chimney increases the stack effect without heating the indoors. The chimney heats up due to the solar radiation. For this reason air is drafted from below upward to the solar chimney and will be released there. A natural upward draft is formed. Fresh air will be introduced in the building at the lower level.

//When to use

When natural ventilation is wanted and the building consists of an atrium or a stairwell all the way up to the roof of the building.

//How to apply

**Orientation:** SOUTH is best but a west or southwest is very good on summer days

**Material:** glazing on the south side, an air channel, and black thermal mass to collect and store solar energy

**Placement:** on top of the roof above an atrium or stairwell

//Strategies to apply in transformation

Open stairwells could be extended to become a tower for stack ventilation. Also atria could be used for the stack effect.

//Related projects

case study 4.1

Cityhall Venlo, Kraaijvanger (Venlo 2010)
//How it works

Wind catchers are usually mounted on top of a building to catch the wind and bring it inside. This way the building is naturally ventilated.

//When to use

When natural ventilation is wanted in the building and the roof has possibilities of the application of this catcher.

//How to apply

**Orientation:** Towards the main wind direction. If there is no main wind direction, multiple directions can be used. Below two examples are given.

**Height:** Most effective height is 3.60 meters.

Multiple direction wind catchers in Yazd, Iran (Dahl 2010, p. 108)

Single direction windcatcher in London (the catcher is adjustable to changing wind directions (Dahl 2010, p. 110)

//Strategies to apply in transformation

These wind catchers could be applied on the roof of existing buildings. Some grave measures are to be taken in the rooftops and channels will have to be applied in the building to bring the caught air in the spaces.

//Related projects

The Lighthouse, UK by Sheppard Robson Architects (Phillip 2008)

for centuries already. They were mainly applied in areas where winds are common. They were used to naturally ventilate and cool the buildings in this very warm climate. There is a difference between wind catchers and wind towers. Wind towers were used in areas where the wind direction was very variable. Wind catchers were used in places with a main wind direction and were fixed on this direction to catch the wind and bring it inside the building.

Wind catcher

Wind catchers could be used in the Netherlands as well, they could naturally ventilate and cool the building in warm summers. When the wind almost always flows from the same direction fixed wind catchers can be used. Usually a wind catcher is mounted on the top of a building to reach into the stronger and more laminar flow winds (Bainbridge and Haggard 2011, p. 123). Studies were done researching the most effective height of a wind catcher. The height of traditional wind catchers appeared to be the most effective which is a height of 3.60 meters. Existing examples mostly are used in commercial buildings but they could also be applied in residential buildings (Bainbridge and Haggard 2011, p. 124).
2.5 Natural lighting

The importance of natural light for people
Natural light can be of great importance for the well being of people. It is proven that the amount of natural light received by a person can influence their performance, the state of mind, the energy of the person and their health (Bainbridge and Haggard 2011, p. 136). The more daylight a person receives per day the more positive the aforementioned conditions will be. Research has even shown that at working environments the productivity increases and people calling in sick has reduced substantially. It has also shown that it is commonly preferred to have natural light and desired to have a view to the outside as well as the possibility to control and adjust the amount of daylight received (Bainbridge and Haggard 2011, p. 136).

If people receive too little natural light for a long period of time it could cause seasonal affective disorder (SAD), this mainly occurs in areas with short winter days in the higher latitudes, like the Netherlands. SAD is a depression which is distinguished by laziness or lethargy. This disorder occurs because due to a lack of natural light the pineal gland doesn’t receive the signal which comes from natural light to stop producing melatonin. Melatonin is a hormone that the body releases, normally it is only released at night when the amount of natural light received reduces, to help the body rest. In this case the hormone is released during the day as well, which makes the person feeling lethargic or passive. Due to the hormone the body is in a state of rest. This disorder, SAD, can even occur in summer with people spending much time in buildings with inadequate natural light (Bainbridge and Haggard 2011, p. 137). It is one of the main symptoms of sick building syndrome. Some other diseases are linked with a lack of natural light too, like bone disease which occurs due to a fail of vitamin D which is received by the body from natural light. Multiple Sclerosis for example occurs much more often in northern countries which have short winter days. It is believed that MS is linked to a lack of vitamin D.

Use of natural light
As said before natural light can function to comfort people. The colour of light also influences the state of mind of people. Colour of light can influence the perception of temperature. Rooms with warmer coloured light (reddish colours) are perceived as having a higher temperature than rooms with cooler colours (bluish colours). Cooler colours make people more calm and it could even change the perception of time while warmer colours make more alert and is mainly experienced as more appealing (Bainbridge and Haggard 2011, p. 139).

Capturing natural light
Natural light is of course obtained by the sun. Just a small part of the sun’s radiation is received directly, the rest is received as indirect or diffuse light. To receive enough daylight in a building the orientation and the design of a building is of great importance (Bainbridge...
and Haggard 2011, p. 137). Some other important factors are the micro climate of the location and the solar altitude. Of course the atmospheric clarity and the amount and type of clouds influence the incoming natural light as well.

Methods to enhance natural lighting

There are two approaches for receiving natural light in buildings. Natural light could enter buildings via the envelope of the building from the top or the side of the building. For this reason the methods are described in both top lighting and side lighting. Of course the footprint of the building influences the amount of natural light entering the building too. Thinner buildings will have more natural light entering the building compared with thicker buildings. The problem with thicker buildings could be solved by adding a central atrium from which natural light will also reach the inner spaces.

Side lighting

Every building uses this method of natural lighting since every building consists of windows in the façades. Unfortunately the depth of reach is very limited. But some of the methods mentioned below can increase this depth of reach. This is shown in the following

Light shelves

Light shelves can increase the depth of reach of the natural light entering from the windows. The goal of a light shelf is to reflect the light entering the building further into the room. Light shelves can be applied on south façades
but also on the east and west façade. It is possible to apply the light shelf at the north façade but there will be little benefits from it. It is best to have a light shelf with a high reflective surface, so white coloured surfaces are preferable. It could also help when the ceiling of the room has a light colour and so has a high reflective surface. There are two types of light shelves. The first is the one applied on the inside of the window. The second is applied at the outside. They can also be applied in combination. This will help reduce glare and will increase the depth of reach of the natural light (Bainbridge and Haggard 2011, p. 154).

The interior light shelf is often opaque or translucent but can also be materialised with a diffuse reflective top surface, some examples even use mirrors to improve the depth of reach of natural light and the quality of the reflected light. The shelves can be freely shaped to increase the performance. More width can be added to prevent the room from glare throughout the year. An extra benefit of the interior light shelves is the fact that it can easily be used in the retrofitting of buildings.

The exterior light shelf works more or less the same as the interior light shelf, the only difference is that the exterior light shelf could simultaneously function as a sun shade. The position of the light shelf can influence the way it functions. If tilting the shelf towards the building the shelf will introduce natural light into the building in summers with high summer sun too. But if the shelf is tilted down

//How it works

The lightshelf reflects the light deeper into the building. This way the depth of reach of natural light increases. There are two types of light shelves: the interior light shelf and the exterior light shelf.

//How to apply

**Exterior light shelf**

**Orientation:** South, east or west

**Material:** light colour of material with a high reflective surface. When the ceiling of the space has a light colour too the effect increases.

**Placement:** outside the building at the facade

Extra benefit: this light shelf could simultaneously function as a sun shade (Bainbridge and Haggard 2011, p. 154).

If tilting the shelf towards the building the shelf will bring the light of the high summer sun in the interior too

When the shelf is tilted down to the outside it will block the hot summer sun and increase the amount of light entering the building in spring and autumn

**Interior light shelf**

**Orientation:** South, east or west

**Material:** light colour of material with a high reflective surface. When the ceiling of the space has a light colour too the effect increases.

**Placement:** inside the building

Extra benefit: this light shelf can easily be applied in the transformation of building

//When to use

When rooms are very deep and natural light can only reach part of the room.

//Strategies to apply in transformation

**Interior light shelves are easily applied in the transformation of buildings. They can just be mounted on the inside of the façade. Exterior light shelves are harder to apply in transformation projects.**

//Related projects

DUO office in Groningen by UN Studio (van der Woude 2011)

**case study 4.3**
**Interior apertures**

//How it works
Transparant or translucent walls are applied in the interior of a building to increase the depth of reach of natural light in the building. The behind lying rooms will receive natural light through these openings.

//When to use
When the space needs to be separated by separating walls but the back room doesn’t receive any natural light from another orientation.

//How to apply
**Orientation:** the windows where the light will come from are best to be oriented either to the south. Another possibility is the north. East and West will easily cause overheating.

**Materials:** The openings in the interior could either be completely open or covered with a translucent or transparant material like glass.

**Placement:** inside the interior at places where separating walls are wanted and the penetration of natural light into the back room is wanted.

//Strategies to apply in transformation
This strategy is easily applied in the transformation of buildings, since the only measure will be the introduction of translucent/transparant walls. Another idea is to create openings in existing separating walls.

//Related projects
Westraven Utrecht by Cepezed (van Houdt 2008)

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to the outside it will help the building to block the hot summer sun and it will increase the amount of light entering the building in spring and autumn, since the sun will be at a lower angle at these times of year.

Since this light shelf is mounted at the outside of the building rainfall should be taken into account. One should give the shelf a slope towards the direction where the water should be directed to. If the angle is not right the building could suffer from leaks. Another solution could be to add an small gap between the light shelf and the building, so the water will fall down there and ventilation through this gap is possible.

**Extra possibilities** Light shelves can also be applied in an adjustable way. It could for example be a canvas which can be rolled out and in to adjust to the amount of natural light needed.

**Apertures in the interior**
If walls or doors are transparent or translucent in the interior of the building the depth of reach of natural light will increase. This way the northern rooms can be lit by the light entering the southern rooms via openings in walls. These openings can be completely open or can be covered with glass for example. The surface of the glass can be transparent or translucent when more privacy is preferred.
Top lighting

The approach of top lighting is very diverse in different scales of buildings. Every scale asks for another approach to top lighting.

Clerestory windows

Clerestory windows are windows located on a high level in the façade. They improve the natural lighting of the central or north side of the space.

It is best used to light the inner rooms of a building which are not adjacent to the outer façade. It will enable natural light to enter the building deeper and will even naturally light spaces on the north side of the building (Bainbridge and Haggard 2011, p. 149).

The window could best be placed 2.5 to 3 times the height of the wall where the sun will enter the building. So for example when this wall is 3 meters high, the clerestory window will be placed about 9 meters further inside the building. With the use of light shelves in the lower windows these windows will be able to provide the space in between from natural light. The clerestory windows should be placed on a height of about 3.75m to 4.5m. These clerestory windows will provide the space behind up to a depth of 9 meters further in the building from natural light.

This method is best used in one or two storey building with relatively open floor plans.

//How it works

Clerestory windows are located on a high level in the façade. Through these windows light will enter the central or north side of the interior space.

//When to use

When the design of the building allows for the application of clerestory windows as shown in the drawing above.

Apply this method when the building is quite deep and therefore the deeper rooms will be fairly dark. It is best used in 1-2 storey buildings with relatively open floor plans.

//How to apply

**Orientation:** South when winter heating is desirable
North when winter heating is not desirable. Avoid east and west due to overheating

**Material:** transparant or translucent materials

**Placement:** on a high place in the facade. It could also be used in an atrium. In the picture below the optimal placing of the windows for best daylight distribution is shown.

//Strategies to apply in transformation

This method is only applicable when the architecture of the building allows it. Otherwise a part of the roof should be lifted to introduce the clerestory window.

//Related projects

Clerestory windows in Westraven, Utrecht by Cepezed (Koekebakker 2008, p. 106)
Roof monitors

//How it works
This method is also applied to the roof and consists of an extra volume added to the roof. The roof monitor faces more than 1 direction and is operable.

//When to use
When it considers a deep building and the inner spaces do not receive any natural light. Only the spaces directly under the roof benefit from the roof monitors if no atria, courtyard or light well is applied. This means that single floor buildings are best suited for this method.

//How to apply
Orientation: South when winter heating is desirable, North when winter heating is not desirable. Avoid east and west due to overheating
Materials: Roofing materials and of course transparent or translucent material for the entering of light. Glass is mostly used.
Placement: On top of the roof. An extra volume is added to the roof. Best location is to place the roof monitors on top of a staircase, hallway or central room to simultaneously enhance natural ventilation (stack ventilation).

//Strategies to apply in transformation
This method could quite easily be applied to the roof. It must be considered whether the construction of the roof allows creating the holes for these roof monitors. Attention must be paid to the fact that only the spaces directly under the roof benefit from this method.

//Related projects
Case study 4.8 Church or Riola Italia (www.alvaraalto.fi)

Roof monitors
This method is very much comparable with clerestory windows. In this method an extra volume is added to the roof of the building with windows (preferably facing south).

The best location for a roof monitor is on top of a corridor, a staircase, a hallway or a central room in the building. Placing the roof monitor in these locations will provide good natural lighting as well as it will enhance the natural ventilation of the building.

The roof monitor can cause glare. This glare can be controlled and minimized by using difusers, for example vertical baffles or curtains.

Extra benefit These roof monitors can enhance natural ventilation as well as heating and cooling, because they allow warm air to rise further up. The roof monitor will have to have operable windows or there should be a reversible ceiling fan located.

Limitations The roof monitors have to be applied on the roof of the building. It is best to be used in small buildings.

Best use For the best result the roof monitor should face the equator and be combined with side lighting in the lower parts of the building. The light coming from the roof monitor can be transported to the lowest parts of the building by creating an atrium, courtyard or light wells.
Sawtooth roofs

Sawtooth roofs are commonly used in industrial buildings in the past. They were applied south facing as well as north facing. The north orientation has the benefit of introducing very stable northern light which will not create glare in the building. South facing sawtooth roofs can also contribute to the solar heating of the building. Many old industrial buildings with these kind of roofs are now to be reused and transformed.

//How it works
This method is applied to the roof. Actually the method consists of the whole shape of the roof.

//When to use
When it considers a deep building and the inner spaces do not receive any natural light. Only the spaces directly under the roof benefit from the roof monitors if no atria, courtyard or light well is applied. This means that single floor buildings are best suited for this method.

//How to apply

Orientation: South when winter heating is desirable
North when winter heating is not desirable. Avoid east and west due to overheating

Material: transparant or translucent materials and best is to add reflective roofing materials

Placement: this method will be the roof of the building. The best dimensions of the sawtooth roofs are shown below.

2.5h  2.5h  2.5h
  h

//Strategies to apply in transformation
This method can not be applied in the transformation of buildings since the method consists of the whole roof structure. Unless the whole roof needs/will be replaced this method is not applicable.

//Related projects

Bedrijfspand Zwartsluis B+O architectuur en interieur (BNA 2013).
//How it works
This method adds horizontal windows to the roof.

//How to apply
When it considers a deep building and the inner spaces do not receive any natural light. Only the spaces directly under the roof benefit from the roof monitors if no atria, courtyard or light well is applied. This means that single floor buildings are best suited for this method.

//When to use
Materials: translucent or transparant materials such as glass and windowframes.
Important adjustment: To reduce glare it is important to add diffusers, for example baffles as shown in the 'how it works' diagram.
Placement: In the roof. Best location of the skylights are shown below.

//Strategies to apply in transformation
This method could quite easily be applied to the roof. It must be considered whether the construction of the roof allows creating the holes for these skylights. Attention must be paid to the fact that only the spaces directly under the roof benefit from this method.

//Related projects
Woonboerderij Goigarijp, Jelle de Jong Architekten (www.jelledejongarchitekten.nl)

Skylights
Skylights are windows placed in the roof of a building. They are mainly used to light the inner part of large open spaces. Sky lights can also be used to light interior walls, to wash these interior walls with light. This will help to brighten the space adjacent to this wall. There are several shapes of skylights, such as curved, pyramid or flat skylights. It the height of the ceiling is little the skylight can best be applied in an angle, this way light can be distributed to a larger space.

Best location of skylights
The general rule is to place the skylights in a row on the ceiling of the room. The first skylight should be placed at a distance of the wall with no windows of a half the height of this wall. So if the wall is 3 meters high the first skylight will be placed at a distance of 1.5 meters from this wall. The next skylight will be placed at a distance equal to the height of the room from the first skylight.

Important adjustments
To reduce glare it is important to add diffusers, for example vertical baffles.
This method is applicable in the retrofitting of buildings.

Light tubes
Light tubes or pipes consist of a clear acrylic dome on the roof which is connected to a circular aluminium tube or pipe which is covered on the inside with a mirroring surface. At the end of the tube a diffusing-light emitter is placed which introduces the light in the space.
A light tube introduces natural light from the top of the building into lower spaces in the building through a circular aluminium tube or pipe covered with mirroring material. On the roof a clear acrylic dome is located which brings the light into the tube and on the ceiling of the ‘to be lit spaces’ a diffusing-light emitter is located.

//When to use
When small fixtures of natural light are wanted in the darker spaces of a building. The tube could reach further down dan only the space directly under the roof so it is applicable for multistory buildings.

//How to apply
Materials: the tube usually is made of aluminium. The dome is made of an acrylic material and the light emitter is made of an acrylic or glass material which diffuses the light.
Placement: the dome is placed on the roof to catch natural daylight. The tube connects the dome to the emitter which is located in the spaces which need to be lit.

//Strategies to apply in transformation
This strategy is easily applied in the transformation of buildings. The product is even sold for the purpose of applying it in existing buildings. The roof structure needs to allow for making holes for the dome and tube.

//Related projects
UK Pavilion, Shanghai Expo 2010, Heatherwick Studio (www.heatherwick.com)
Atria and courtyards introduce daylight in the heart of a building. This results in a better daylit building. The natural light enters the spaces through the atria at the place where otherwise no light would have entered the spaces.

//How to apply

**Material:** the material on the top to bring the light in should be made of a translucent or transparant material.

**Placement:** at the places in the building where otherwise no daylight would have entered.

The top left figure shows the availability of daylight in a building with standard window arrangement. Full daylight is only received in 51% of the building. When adding an atria this percentage will rise to 100% when the depth is about 9m.

The top right figure shows a longer thinner building, which is better considering daylighting. Still only 59% receives full daylight. Also in this example an atria or light gallery will improve this percentage considerably.

//Strategies to apply in transformation

To add an atrium to an existing building is quite a serious measure. The construction of the building should allow the cutting of the floors to introduce the atrium. A thorough inspection of the construction is preferred. An example where this has been done is the Gasterra building in Groningen, re-designed by de Zwarte Hond.

//Related projects

The Gasterra building in Groningen by de Zwarte Hond (DeZwarteHond 2013)
Chapter 4 // case studies of climate responsive buildings
Location

The location of the building is in the centre of the city Venlo. The building location is near the river Maas. At the north side the building is adjacent to the road Eindhovenseweg which crosses through Venlo. At this moment the building is not completed yet. The building lies in a very urban context. The building is surrounded by many building and infrastructure. At the other side of the Eindhovenseweg the heart of the centre of Venlo is located. This is the location where most shops are to be found.
Climate responsive design methods

The design is mainly focussed on creating a building which is designed Cradle to Cradle. Nevertheless the design also consists of some climate responsive design methods. These are mainly focused on naturally cooling and ventilating the building. Natural heating is generally unnecessary since it concerns an office building. Office buildings contain many appliances which generate heat and it houses many people on few square meters. Altogether offices mainly suffer from overheating and seldom have to deal with a high heating demand (Raaij 2013).

Natural ventilation

On top of the building Kraaijvanger designed a greenhouse which induces natural ventilation. Fresh air is brought into the building through this greenhouse and gets moisturised by the plants. The air will be pre-heated by solar radiation in this green house. The offices are supplied with this fresh, pre-heated and moisturised air.

On the other side of the building top a solar chimney is designed. In summer this solar chimney ensures a natural draft of air upwards. Via this solar chimney the used air will leave the building. This solar chimney is connected to the atrium which connects all floors of the building.

When the solar chimney doesn’t work, because of a lack of insolation for example, the air will be mechanically ventilated towards the green
should be transparent and which shouldn’t be transparent. It appeared that the lower 80cm of the façade didn’t necessarily have to be transparent. This part of the façade doesn’t do much for the amount of daylight entering the spaces behind while it does cause a lot of unwanted heating of the adjacent floor. From 80cm to 220cm a transparent surface is wanted for the view and natural lighting. Light-screens are mounted at this window part, this reduces glares from the sun. These light-screens are mounted in a closed part which is extended for 120cm to the outside of the façade and contains PV-cells at the south part of the building.

At the height of 240-290cm a second window is designed. Below this part a daylight shelf is located. This shelf reflects the daylight further into the room. This shelf creates indirect lighting entering the room. The direct light will therefore be mostly blocked which reduces the need for sunscreens. Which makes additional electric lighting less necessary(Raaij 2013).

Naturally constraining air pollution
The designers say that about 30 percent of the NOx in the air around the building will be captured by the green façade which is located at the façade which faces the highway. The lower part of this façade will capture the fine particles released by the cars on this high way(Raaij 2013).

Natural cooling
The green façade and roof will protect the building from overheating. The plants function as extra insulation. The plants in the façades also cool the building by means of evapotranspiration. This also counts for the plants in the greenhouse. Evapotranspiration stands for evaporation and the transpiration of plants(Perlman 2013). Evapotranspiration can be defined as the sum of the evaporation of water from the ground surface and the transpiration of plants. The transpiration of plants in essence is the evaporation of water from the leaves of a plant.

In summer the solar chimney will induce natural ventilation which causes the draught of warm air towards this chimney. Due to this draft fresh air will be drawn into the spaces.

The inner garden is planted with trees which function as sunscreens for the façades there.

Natural lighting
A lot of brainstorming about natural lighting was done for the design of this building. The designers researched which parts of the façade
Plants have the capacity to capture gasses in their leaves. For example NOx can be captured, the plants use this gas for their own growth. This way the gasses are captured from the air and used in a natural and beneficial way. The fine particles which are released by for example cars will stick to the leaves of the plants. When it start to rain the fine particles will be released from the leaves and will fall to the ground. This reduces the amount of fine particles in the air which could be inhaled by people (Anrijs 2013).
Location
The building is located just outside the town of Hoofddorp in an area office park. The building lies at the border of this park. The building is surrounded by other office buildings in the direct context.

Climate responsive design methods
The building’s orientation is one of the most important aspects of this design. It is designed with an optimal north south orientation. The designers have searched for the most efficient shape for the building. The building consists of a U-shaped volume. In between the two sides of this volume an atrium is designed. The façade facing north is completely transparent resulting in a maximum amount of daylight in the indoor spaces (Ligtenberg and Brands 2011). The design for this building is part of the ‘Planet me’ program of TNT with which TNT Express wants to achieve the goal of becoming the first express company in the world that operates emission free (AgentschapNL 2011).

Natural ventilation
The designers claim that natural ventilation is implemented in the design. The only measure taken for this natural ventilation is the fact that windows are operable. Mechanical ventilation is controlled by CO2 level monitoring (Ligtenberg and Brands 2011). Another way of natural ventilation applied in this building is the fact that the air in the atrium will be heated naturally after which this air can be introduced in the adjacent offices without a need for extra
The concept for this building in a sustainable point of view is not only focused on the environmental sustainability but also focused on the social sustainability of the building. The atrium ensures great visual interaction between the different departments as well as interaction between people in the atrium itself. The position of the stairs and the elevators stimulate the visitors to use the stairs rather than the elevators. The atrium is the core of the building where people meet and communicate. It creates great value to the building in an environmental sustainable way as well as a social sustainable way (Ligtenberg and Brands 2011).

Natural lighting
Natural lighting of the building has been achieved by building the office in the optimal north-south orientation. The north façade is completely open and covered with glass. This results in a high amount of natural light entering the building, which reduces the amount of electric light needed. The south façade is less transparent and contains sun blinds just like the west façade (AgentschapNL 2011). The atrium which is located in the middle of the U-shaped volumes around it introduces light from the inside of the building in the offices. Electric light is hardly needed in this building due to these measures.

Natural cooling and heating
There is no real natural cooling but the south and west façade as said before will keep the strong summer sun out of the building by means of a smart design of horizontal sun blinds. The winter situation results in the exact opposite. The horizontal sun blinds will not block the winter sun from entering the building due to the low angle of this winter sun. This way the building will be natural heated in the south and west façade. The atrium will also gain some heat due to its transparency. Of course additional heating will still be necessary. The additional heating is done by a climate ceiling which heats by means of low temperature and cools by means of relative high temperature.

Social sustainability
The north façade (Agentschap NL 2011)
CITY CENTRE OF GRONINGEN

3// DUO office
UN studio
Location

The office is located just outside the city centre of Groningen. It is located in the new area of Europapark. This area consists of office buildings as well as dwellings and recreational buildings and places. At one side the building borders a small wood which is called 'het Sterrenbos'. The other sides border either a residential area or other office buildings.

Climate responsive design methods

The climate responsive methods for this design are mainly focused on the wind and sun. Studies have been done to find out how the façade could be designed as efficient as possible to use the sun and to reduce the influences of the wind. The studies for wind are mainly focused on how the design could reduce the wind velocities around the building. The location suffers from a dominant North-West. If a building was designed without considering this dominant wind direction, the wind would fall down at the façade of the building and will create a very strong and unpleasant wind at street level around the building. The surrounding area would suffer from this wind. The designers wanted to reduce this downwards draft of wind which can be a burden on the street level. For this reason the building has been designed in an aerodynamic way. The round edges, terraces and the fins create a wind draft which will run over the forest which is located next to the building. This prevents the trees and soil of the forest from dehydrating due to the high wind velocities. Another important goal was to reduce the drifting wind around the façade of
the building (DUO and VROM 2013).

Natural ventilation
The drifting winds around the building are reduced by the shape of the fins which are designed in the façade. The fins are designed with different angles and different depth according to the location considering wind and sun direction. When the wind runs along the building, the fins will function as windbreakers and change the direction of the wind which creates a very low velocity of the wind around the building. For this reason windows are openable throughout the whole building. Even the windows on the top floor can be opened. People working anywhere in the building can adjust their own desired amount of ventilation (Allin 2011).

Natural cooling and natural heating
The depth of the fins vary along the building. The depth depends on the location of the fins towards the location of the sun. The fins block the sun in summer which reduces the heating of the building. For this reason there will be a lower cooling demand.
In winter this principle works the other way around. The fins are designed in a way that the sun does enter the building in winter. Due to the fact that the sun does enter the building in winter the heating demand of the building is substantially decreased. Having the sun entering a building in winter is generally speaking experienced as desirable (DUO2 2011).
The concept for the natural lighting in this building is also focused on the natural lighting of the surroundings. The floors are designed in such a way that the installations and tubes are integrated in these floor constructions in a very efficient way. Thanks to this smart solution the thickness of the floors could be reduced significantly. This resulted in a lower building which ensures a better insolation of the surrounding area and buildings.

The fins are clad with white panels which contribute to the indoor climate control in several ways. First of all these panels reflect light deep inside the building. This is due to the direction of the panels, the shape of the fins, and the reflectivity of the panels. In summer the high and intense light is blocked which reduces unpleasant glare inside the offices. The shape of the panels vary along the building due to the position of the sun compared to the building. The fins also ward off views inside the office from street level (Allin 2011).
Natural heating
This building by Frank Lloyd Wright was designed on a hemicycle plan. The design is focused on the local climate. The northern part of the building is build in a berm with earth piled up against the north wall, this functions as insulation. The southern side of the building consists of two-storey glass windows and doors. In winter this facade faces directly into the desired warmth of the sunshine. Due to the shape of the building, based on the hemicycle, a maximum of solar radiation is captured (Brooks, Gössel et al. 2007, p. 154). The walls in the building consist of irregularly laid stones. These supply the thermal mass for the natural heating of the building. Simultaneously these walls relate the interior with the natural environment (Lechner 2001, p. 144). The concrete floor slabs also stores heat for the night and prevents the building from overheating during the day (Lechner 2001, p. 144).

Smart sunshading
To the south of the building a 2 meter overhang is designed to block the high summer sun (Lechner 2001, p. 144). This overhang will not block the lower winter sun. This overhang prevents the building from overheating in summer (Brooks, Gössel et al. 2007, p. 154).

Natural ventilation
Windows are designed on the opposite sides of the building. This allows cross-ventilation in the building in summer (Lechner 2001, p. 144).
The sawtooth roof in this building assures the natural lighting of the whole building. This creates a comfortable working environment as well as a reduced need for electric lighting (Architect 2012). Even the very core of the building receives natural light coming from the north-east. This orientation assures that overheating in summer will most probably not occur.

It gives the interior of the building a special feature. The interior is mainly white which, together with the sawtooth roof, makes that the interior is very light and bright.
The pavilion is naturally lit by 60,000 slender transparent fibre optic rods, each 7.5 metres long. The pavilion is completely perforated with these fibre optic rods which allow daylight to enter the building in a very special way. During the day, daylight is drawn through these fibres towards the inside of the pavilion to illuminate it. This is a very special example of a method similar to the light tubes explained earlier.

An extra benefit of these fibres is when wind moves past the building the fibres gently move along with it to create a dynamic effect (Jordana 2010).
A glass facade covers most of the south facade. Behind this glass facade a thermal wall is designed. This 250mm thick thermal wall consists of 150mm thick concrete masonry units filled with sand and clad on both sides with limestone (50mm thick). This wall sits 760mm behind the glass facade and provides much of the building’s heat during winter (HolcimFoundation 2012).

An interesting fact of this project is the limestone cladding used in the facade as well as in the thermal wall. It is created from cottonwood limestone tailings which is the waste product from the manufacturing of stone.
This church in Riola, designed by Alvar Aalto, makes use of roof monitors to make natural northern light enter the building. These roof monitors collect constant and cool north light (Lechner 2001, p. 394)

Interior of the church (www.alvaraalto.fi)

Exterior of the church (Lechner 2001, p. 394)

Interior of the church (www.erikademartino.com)

Natural lighting - Roof monitors
In this design of Jon Hammond, bags of water are placed on the roof covered by movable insulation. In summer the insulation panels are opened during the night to initiate cooling by night sky radiation. During the day the panels are closed to retain the coolth. By reversing this operation the roof can be used for natural heating in winter too. The insulated panels will be opened during the day to capture solar radiation in the water bags to heat the building. At night the insulated panels are closed to retain the warmth (Bainbridge and Haggard 2011, p. 103).
In this design drums filled with water are used as thermal mass to be heated by solar radiation. The sides of the drums facing the glazing are painted black. The interior is completely white. This is a fine example of a direct gain - concentrated mass system; only the drums in the interior are used as thermal mass and will heat the building when the water inside the drums is heated by the solar radiation.

Some insulated shutters at the outside of the building can close the building at a winter night or during a hot summer day (Lechener 2001, p. 153).
This house is the first net zero carbon house in the UK (Phillip 2008). On top of the roof of this building called the Lighthouse, a windcatcher is designed. As explained in Chapter 3 a windcatcher functions in a way that it, as the name indicates, catches the wind on a high point of the building and brings the fresh air into the building below. Through a lower outlet the used air can be released and replaced by the fresh ventilation air.

In the bottom left image the numbers correspond with the explanations below:

1. Wind catcher, for summer ventilation
2. Solar array at back of house for hot water and electricity
3. High-level of wall insulation
4. Biomass boiler
Chapter 5// Case studies of sustainably transformed buildings
5.1.1 //location
Westraven is located in the business district Kanaleneiland which is part of the city of Utrecht. There are some high buildings in the surrounding area but it is no real urban context. As you can see in the image at the right the building is surrounded with quite a big space without any buildings. The building lies in between the centers of two cities; Utrecht and Nieuwegein. The buildings stands right beside the highway A12 and the Amsterdam-Rijnkanaal.

5.1.2 //climate responsive design methods
By designing the transformation for this building one of the main themes was to make the building perform as good as possible on its own, without the help of climate installations. The installations for heating and cooling should only have a corrective function.

The amenities to achieve this were mainly the proper sun protection and the use of ventilation air in a smart way.

In the following pages the climate responsive design methods are described separately. These sections will provide a more detailed story on the different methods used in this building and how they are translated into architecture.
Natural ventilation

The different climate zones makes that every zone is treated differently also considering ventilation.

Natural ventilation in the entrance hall
The main entrance is part of the climate zone which is called the ‘rough’ climate. This entrance hall is naturally ventilated through grates which are integrated in the floor. These grates are installed at the inside as well as at the outside of the façade. An aluminum ventilation grate is installed right under the façade. Fresh air will flow through this ventilation grate inside the entrance hall. This entrance hall is not heated, this means that the temperature in this area will be more or less the outdoor temperature. This entrance hall has an east orientation. Due to this orientation the hall can be heated in the morning by solar radiation. This space is covered with ETFE-cushions which will keep rain and wind out. The upper façade as well as the roof contains these cushions. The lower façade is made of glass panels because of the risk of damaging the ETFE-cushions in this part of the façade. The entrance hall works as a buffer zone to the areas behind. This means that the areas behind will need less energy to heat up.

Natural ventilation in the conservatory
The office wings are located inside a spacious conservatory. The offices are shaped like volumes which encase into the conservatory. The conservatory is naturally ventilated in summer. In summer a sunscreen can be rolled down on
the inside of the façade of the conservatory which creates a small space in between the glass façade and this sunscreen. The air in between the two parts will heat up and will generate an upward flow of air due to the stack effect. This results in a ventilated cavity. This ventilation creates a draft of air which draws fresh air inside the space. Hot air from the conservatory will move towards the air exhaust in the top of the façade. The movement which is created ensures ventilation of the inside air.

Natural ventilation in the offices adjacent to the conservatory
The offices in the building which are located in the conservatory are ventilated with the air from the conservatory. Some panels in the façade of the offices can be opened to naturally ventilate the spaces behind. Extra channels for the supply or discharge of air aren't necessary thanks to this conservatory. The conservatory works as a buffer area for the adjacent offices. It buffers the offices from the outdoor climate. The inlet air for the offices is already pre-heated in the conservatory, for this reason no extra installations are needed to pre-heat the incoming air of the offices. Even if the panels are closed ‘used’ air will be discharged towards the conservatory through perforations in the panels. These panels simultaneously work as soundabsorbers for the conservatory.

Natural ventilation in the tower
In the old tower windows couldn’t be opened. This was mainly due to the high wind velocity in the higher part of the tower. Cepezed de-
signed a second skin which is attached to the existing balconies. This second skin consists of textile. It is a teflon-coated glass fibre cloth. This second skin is applied to the south, west and east façade of the building. The north façade needed an extra measure to block the noise of the highway A12 which runs right next to the building (as you could see in the picture). For this reason as well as for the reason that the north façade doesn’t need any sun protection the second skin for this façade consists of glass panels. This second skin creates the possibility to open the windows of the offices in the tower. This way every office can be naturally ventilated. The teflon-coated glass fibre cloth has a black colour, this ensures that the cloth doesn’t seem very closed, you can easily see through the cloth. This openness is achieved eventhough the skin keeps 50% of the sun load out.
Natural cooling

The design for natural cooling is mainly focused on protecting from overheating due to solar radiation. This is realised through sun screens and buffer zones.

Natural cooling in the tower (by smart sun-shading and natural ventilation)
As said before the design for the transformation of the tower added a second skin which on the three sunny sides of the building consists of a teflon-coated fiberglass cloth. This cloth keeps 50% of the solar radiation which hits the façade out. This way the offices behind this façade will not heat up that quickly due to solar radiation. The second skin also enables the inner façade to have openable parts. This means that the offices behind can be cooled with the cooler air from outside and the cool air from the space in between the two façades.

Natural cooling in the conservatory (by a bufferzone and natural ventilation)
The conservatory first of all works as a buffer for the spaces behind. This means that the spaces behind will have an extra protection from overheating and undercooling. In summer a sunscreen can be rolled down on the inside of the façade of the conservatory which creates a small space in between the glass façade and this sunscreen. The air in between the two parts will heat up and will generate an upward flow of air. This results in a ventilated cavity. This ventilation creates a draft of air which draws fresh air inside the space. Hot air from the conservatory will move towards the...
The conservatory works as a buffer between the offices and the outside climate. As said before in summer the heated air in the conservatory will be exhausted through the valves in the top of the façade of the conservatory. This ensures that the adjacent offices will not overheat.

**Natural lighting in the entrance hall**

The façade of the entrance hall is covered with ETFE-cushions, these cushions are translucent. The lower part of the façade consists of glass panels. The roof is also covered with ETFE-cushions which results in every façade being either translucent or transparant which makes this entrance hall a very light space. Electric lighting is hardly needed during the day. The long façade of the entrance hall is facing east.

**Natural lighting in the conservatory**

The façade of the conservatory is made of glass panels with a very light steel tubular profile column. The conservatory is designed to be very transparant, in between the office wings the roof is also made of glass panels. This ensures that enough daylight will enter into the offices. The conservatory hardly ever needs any extra electric light during the day. The roof of the conservatory, apart from the parts in between the offices, is covered with steel air exhaust in the top of the façade. This will result in a cooling effect of the conservatory because cool air will be drawn into the space.
Natural lighting in the offices adjacent to the conservatory

As said in the part on the conservatory, the roofs in between the office wings are made of glass panels. Because of this natural daylight will enter into the offices. But this is not the only feature made to create natural lighting in the offices. Every office wing consists of one atrium. This atrium goes all the way from the roof down to the ground floor. On top of each atrium the installation floors are located. These floors are raised somewhat more so a strip of glass could be implemented to provide the offices from natural light. This results in every office from the top to the bottom receiving extra daylight from the inside of the office floor as well as from the outside of the office floor.

Natural lighting in the tower

The offices in the tower also have atria just like the offices in the conservatory. Every office floor is adjacent to one of the atria. As you can see in the section on the next page. These atria creates a deep permeation of daylight inside the building, as a result the offices which lie in the heart of the building will receive natural light as well. The walls of the offices located at the façade of the tower are made of glass panels. The light entering the building will also reach the inner part of the building behind the offices.
these offices. Common workspaces where people have a place for deliberation are located at this inner part of the building. The second skin added to the building blocks part of the natural light but still is very transparent whereby the offices behind will still receive a sufficient amount of daylight. Due to the fact that the textile has a black colour the view towards the outside doesn’t get much blocked. The dark colour prevents from reflections from the inside and makes the lighter background more visible. The picture at this page clearly shows the visual transparency of this cloth (AFB). The north façade of the tower is not covered with a second skin of textile but with a second skin of glass. For this reason more daylight will enter the spaces at this side of the building.
The climate responsive methods implied in this building mainly create the transparent appearance of the building. The atria designed in the tower make the tower far more transparent than before. Also the new parts added to the tower have a high transparency rate.

The textile placed on the façade of the tower gives it a strong horizontal rhythm. Due to the fact that the textile is interspersed with a glass strip this horizontal rhythm is strengthened. Together with the spacious atria which are visible in the façade a strong architectural image is created.

The interior of the building is architecturally strengthened by these methods in a way that the building has become very transparent and light. For the people working there it is a much more pleasant place to work in an architectural point of view but of course also in a climate point of view.
Location
The building is located in the city of Groningen. The building is situated adjacent to the river Reitdiep which runs through the city. The city of the centre lies at the other side of this river. The building is directly connected to the centre via the bridge ‘Herebrug’. The trainstation of Groningen is located to the west of the building. Towards the east, along the river, a number of villas are located. The first row of buildings at the other side of the river are also build in the typology of the urban villa. Towards the south is a more dense part of the city. This part is seperated from the Gasterra building by the railtracks.

Climate responsive methods
Actually the only climate responsive method used in this design is the introduction of the atrium in the centre of the building. At the other hand the big windows in the façade also contribute to a better indoor climate by letting in a lot of daylight, but these windows where already there. The only change here is that the glass has been replaced by HR+++ glass.

This building is an example of how an added architectural quality can function as a climate responsive method at the same time. The atrium functions as a connection between the office floors, where people can meet and where the transparancy of the company is visible. The glass façade adjacent to this atrium generates great views towards the city and simultaneously gives the building a very transparant look from the outside.
The amount of technology needed in this building has been reduced drastically. For this reason the space formerly reserved for the machines is now transformed in a representative room with great views over the city.

**Natural lighting**
The transformation of the building mainly consists of the implementation of the atrium. It is designed in the middle of the building and at both sides where this atrium touches the façade a great view is created by means of glass panels.

This atrium creates a deep introduction of daylight into the building. Since the façades of the atrium are constructed by these glass panels the space inside is very bright.

The facilities are mainly placed at the end of the office floor at the closed façade. In this way the light from the atrium does not get obstructed much. In the middle of each floor an element is designed in which work places are designed where one can work when more concentration is needed. The meeting rooms are also situated in these elements.

**Natural ventilation**
Thanks to the transparant atrium towards the south the air in the atrium can be pre-heated before it will enter the offices. Also the atrium could function as a solar chimney. It could enhance the ventilation of the building by the stack effect.
The architectural quality of the climate responsive transformation

This building is an example of how an added architectural quality can function as a climate responsive method at the same time. The atrium functions as a connection between the office floors, where people can meet and where the transparency of the company is visible. The glass façade adjacent to this atrium generates great views towards the city and simultaneously gives the building a very transparent look from the outside. This atrium with its modern look transforms an old office building in a very modern building which is sustainable at the same time.
In the transformation of former farm buildings into a dwelling daylight is a main topic. In the transformation of this farm in Goïngarijp the architect did not want to perforate the characteristic closed roof surface. To allow enough daylight to enter in the core of the house the architect came up with the idea of a double ridge seperated by a strip of glazing of about one metre wide. A new construction is added to carry the roof (Bantal, Berg et al. 2010, p. 99).
In the transformation of this office building into dwellings all categories of climate responsive design were considered. All façades were treated differently. The local influences on the building as well as the local climate have led to the resulting design. The conservatory located at the busy side of the building keeps traffic noise and airpollution out of the building and dwellings. The climbing plants growing on the exterior of the conservatory façade will constrain some of the airpollution due to the fact that airpollution will stick to the leaves of the plants. The openings in the roof make natural ventilation through the dwelling possible since the main winddirection is perpendicular to the south-west façade.

The dwellings are designed in a way that natural lighting, natural heating and smart sunshading are possible. The set back of the façade make that the high summer sun is blocked out of the dwelling. The spacious vide designed ensures light to enter deep into the dwelling. The lightshelves in this façade will reflect the lower sun in winter further inside the dwelling. These shelves can be moved in different positions helping the inhabitant to adjust the façade however they like. For this reason in summer these lightshelves can function as sunshading.
To conclude this research a plan of approach for designers is created. This will help guide designers in the process of designing with climate responsive design methods. It will help the designer to make the best choices in the process.

The plan of approach for designers consists of the following steps.

1. analysis of the local climate
   1.1 find examples of vernacular architecture of the area.

2. analysis of local factors/influences

3. produce a map of the site with the aforementioned factors shown

4. analysis of the ‘local factors map’ and determine a number of starting points

5. Make a matrix of rough design solutions and rate them on climate responsive design elements

6. use the manual to find useable methods to apply in the design

The best way to start the design process is by analysing the site on the characteristics of the local climate. Find information about the main wind directions and the sundiagram of the location. Gather information on the common temperature year-round of the location. This will explain much of what measures are necessary and wanted to obtain a pleasant indoor climate all year round.

1.1 Find examples of vernacular architecture of the area
The vernacular architecture of the area generally shows how in the past (when there were no climate machines yet) building designs would respond to the local climate. Inspiration could be gained from these examples.

2. analysis of local factors/influences
The direct surroundings of the site can have great influences on the design of a building. Therefore it is important to analyse these factors before designing. These factors can either have a positive effect on the climate responsive design or a negative effect. A pond or small lake for example could be very positive for the design when the site is located in a hot and dry area. This could help cool the building. This factor could be used positively in the design. But a busy road near the site will influence the design in a more difficult way. The design will have to react to this factor and try to reduce the influence of this road on the indoor climate as much as possible.

3. produce a map of the site with the aforementioned factors shown
When creating a map with all the aforementioned factors shown, a clear overview can be created. When analysing this map, conclusions can be drawn which will be the starting points for the design.
4. Analysis of the 'local factors map' and determine a number of starting points

As said, the analysis of the map will conclude in starting points for the design. In the analysis you need to weigh all the factors carefully. Architectural factors and elements important for the function of the building could of course also be considered during this analysis.

5. Make a matrix of rough design solutions and rate them on climate responsive design elements

Apart from the analysis of the local factors map, a matrix of rough design solutions for the to be designed function for the building can be made. A rough design implies the overall organisation of the building. The designs should come forth from the future function. The designs deriving from this need to be analysed on climate responsive design elements. After doing this they can be rated and one of the rough designs can be chosen to be developed more.

6. Use the manual to find useable methods to apply in the design

When you know the overall organisation of the building you can dive into the smaller scale of the building. At this point the manual comes in handy. You know what factors are influential on the building and what measures are necessary and wanted to obtain a pleasant indoor climate all year round. Now you can search for the methods which could help you comply to the wishes of the location.
Towards the design

The research functions as input for the design. The research can be used to find inspiration and useable methods for the design problems found. The research is a design manual for architects wanting to design in a climate responsive way. This means that I will be able to use the content and outcome of the research as inspiration but also as a source of information. The case studies are mainly meant for inspiration and the chapter explaining all the methods gives the designer enough information and insight into the methods to be able to use and understand them.
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