A BRIGHTER DENSIFICATION

A concpet by qualitativ and quantitative research

Chalmers University of Technology
Erik Marklinder

CHALMERS

Master thesis in Architecture and Urban Design
Matter Space Structure
Department of Architecture and Civil Engineering
Chalmers University of Technology
Erik Marklinder
Examinator: Morten Lund
Supervisor: Jens Olsson
September 2019

Table of contents

Introduction

About the booklet

The booklet is a summary of a concepts and methodologies for my upcoming master thesis project during the spring semester 2019.
To make this thesis possible a collaboration with the Department of Architecture and Civil Engineering at Chalmers University of technology and teachers from the Studio Matter space Structure. The booklet is divided into four stages with an introductory discourse followed by method of implementation, design process and finally a proposal.

Student background

Contact details

Erik Marklinder
erikmarklinder@gmail.com
+46 725 772 888

Education

Bachelor studies
CHALMERS Technical University Gothenburg, Sweden
Sep 2013 - Jun 2016

Master studies
EPFL- Ecole polytechnique federale de Lausanne
Lausanne, Switzerland
Sep 2017 - July 2018
CHALMERS Technical University
Gothenburg, Sweden
Sep 2018 - 2019

Work experience

R-STUDIO for architecture
Architekture office, Gothenburg
Aug 2016 - July 017

Abstract

Light is not that which we see it is that which allow us to see. It is fundamental for our visual sense and thus important for orientation, wellbeing and health. We try to catch the light in the words of the poet, the brushstrokes of the painter and tools of the scientist.

Daylight has a major impact on our mental health and shows positive effects on humans for their everyday life. Considering the sun condition and the amount of sun hours in the nordic countries, an early planning for daylight is considered beneficial and crucial on a long term development. Our liability as architects to design a good living standard force us to rethink on how to provide and distribute daylight.

As a consequence of a new urbanization has made it more difficult to fulfill the requirement for good a daylight condition. Volume studies are calculated instead of designed to achieve the high density in the prevailing circumstances for the lack of dwellings.

The work investigates a methodology for how to work with natral daylight in the process of an architectural design in different scales and how the capacity from a facades can be enhanced by the configuration of building volumes. The housing block is developed through quantitative studies by simulations to measure solar radiation and spatial configurations for the immeasurable experience of light.

The thesis investigates strategies on how to design high dense dwellings according to better daylight condition in terms of natural light. Changeable parameters of the building volumes in relation to materials and facade design have a decisive effect on both the experienced and amount of direct sunlight and should therefore be used to a greater extent in the development of today's high density housing development.

To avoid contextual adaptations, the iterations during the process are applied on a concept prototype that is finally placed at a current location in Gothenburg. The purpose of the prototype is not to find an ultimate shape with maximum values but rather to demonstrate differences and conceptual proposals for alternative designs of high dense-housing development.

Figure 1. Pantheon - Rome

Thesis background

The dominating low standing sun in the nordic countries results in a critical amount of direct sunlight for dwellings in cities with higher density. The urbanization makes more people live on smaller areas and that results in new arrangement of the buildings. The experienced daylight of an environment is affected by buildings relation to each other and the configuration of the urban fabric.

In Sweden during the last century has daylight been a decisive factor in how the arrangement of building volumes is designed. The design-requirements have automatically controlled the density for their time, but in line with an increased population in the cities has the requirements been regulated to allow the urbanization.

Until the 1960 were the requirements for daylight regulated by distance and heights of the buildings to guarantee enough light. The distance and height did not only provide a good amount of daylight but also controlled the density for the cities. From the 1970s and forward was the design of buildings regulated by a daylight factor (DF) that allowed buildings to be placed at less distance from each other if the light emission of at least 1% skylight from the outside was achieved on the inside. This abstract rule from Boverket, which has been supplemented in the form of window sizes in relation to the floor area, has been shown by the prevailing climate crisis of prevented larger window openings to be difficult to interpret and difficult to achieve for some of today's new constructions.

Claim

Higher densification has a majord impact on access of daylight in dwellings and surroundings. Decisions about height, typology and materials gives varied light conditions and should be investigated carefully in new constructions.
This thesis explores the possibilities of designing building according to new rules to handle the daylight issue from a new perspective. The immeasurable light environment has a crucial role for the final experience and the responsibility lies with us architects to include strategies for this in the design process.

Question

How can we as architects work with and combine qualitative and quantitative methods in the process of daylight design?

Field of discourse

This Master's thesis is about lighting conditions in high utilization for new buildings. The thesis examines methods in different scales on where improvement and potential for improved daylight condition can be developed. The study is not about producing a volume with the most exposed facade surface of solar hours, but rather investigates the concept of qualitative and quantitative light.

Criticism is directed at a time of an urban fabric that has met the requirements for new constructions according to given demands of natural light but which still do not deliver a good daylight conditions in an urban context.

Building volumes and materials have a major impact on the perceived light and adapted to meet the requirements for new construction. By exploring the shapes of different building volumes, the conditions for facades to reflect and be exposed to light change. During the process, the properties of the developed volumes will be utilized at a detailed level in facades that together can show potential possibilities with daylight design.

The design of the proposed concept is supported by theoretical analysis's and investigations about the phenomena of light. The thesis aim to inspire and contribute to a discussion about how to include daylight design in the process from a sustainable perspective.

Delimitations

The focus is on the development of a prototype based on studies of different types of light. The prototype is not intended to be a proposal for the given site or to take into account the actual quality for the dwelling, but rather examines parameters where there is a potential improvement of light conditions. To narrow it down do not the thesis take into account other realistic issues of structural calculations or economic constraints. An optimization of massing and facades will only be investigated according to an improved daylight condition for the exterior.

Keywords

Daylight, urban density, skylight, diffused skylight, daylight simulation, solar reflections, material, facade component, light contrast.

Theory

Figure 2. Johanneberg, Gothenburg

Figure 3. Palazzo del lavora, Turino

Figure 4. Gårda, Gothenburg

References

Construction regulations have changed over time to adapt buildings to their time and needs. We live in a time when the requirement for daylight is something that must be met in a city that is expanding.

The references give a look on how ideals and buildings have been influenced over time and how architects have worked with the issue of daylight in dense urban environments.

The chosen references for further analysis is a combination of projects from the past relevant to issues of the today and modern experimental architecture according to daylight condition.

Some examples of how architects today work with conceptual projects in which daylight is explored in conjunction with high density.

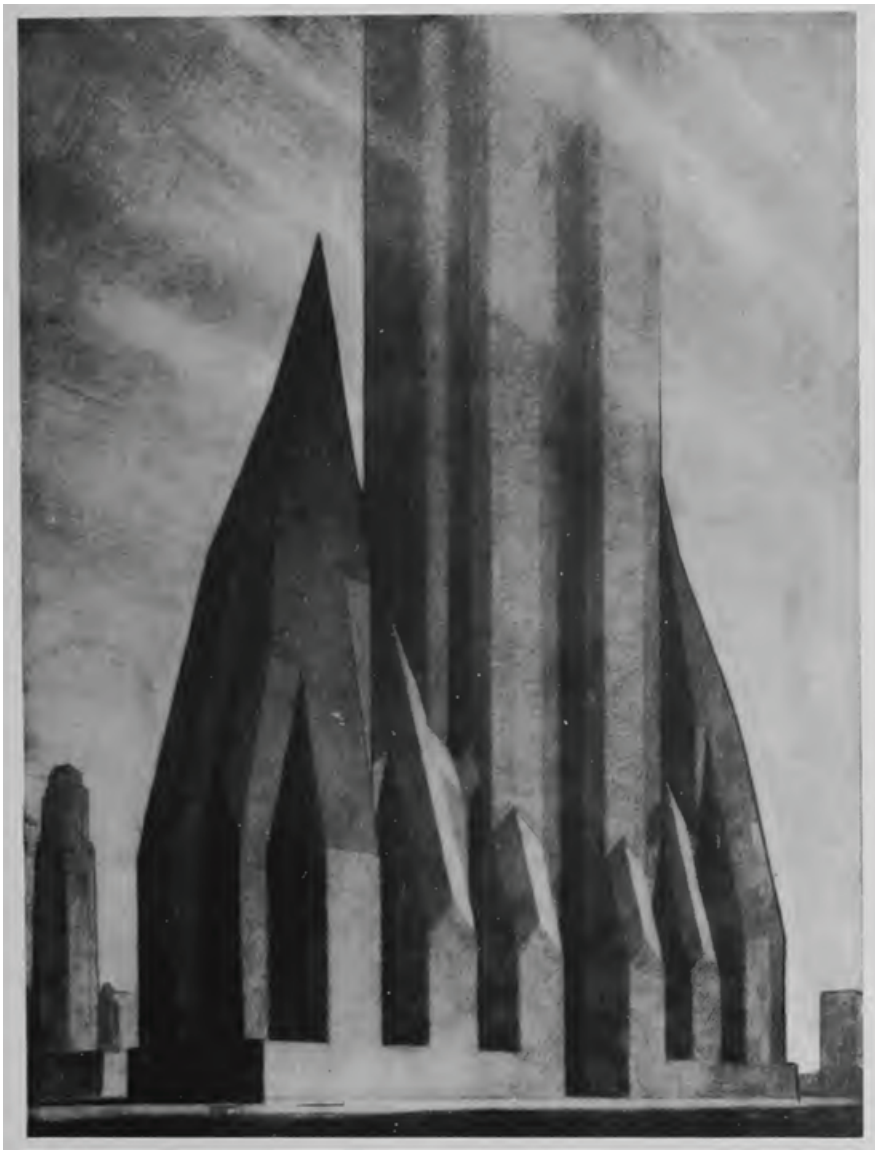


Figure 5. Illustration by Hugh Ferriss from "THE METROPOLIS OF TOMORROW"

From 1875

A period between 1875 and 1960 were the requirements for daylight expressed by the distance between the houses and height of the buildings.
As an earlier example before 1875 in Gothenburg is Haga, a district that were supposed to provided workers with a home. The density of the block was regulated in height for constructive reasons but lacked requirements for daylight.

Figure 6. Haga, Gothenburg

1930-

In 1931 came the rules for height and distance to be change and required that height shouldn't exceed the distance to the surrounding houses to retain a standard of direct sunlight. The houses were built no deeper than 10 meters and the distances created low shielding angles for better access of direct sunlight.
The Low-rise houses didn't answer to the need of higher density in cities but fulfilled the requirements for a good daylight condition.

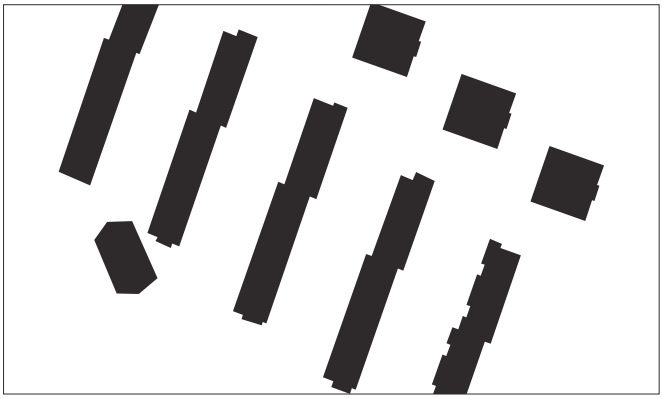


Figure 7. Doktor westrings gata, Gothenburg

1970-

During the modernist time with freestanding houses and ideals of light, space and sun were determining in the decisions on how to develop new dwellings. The housing authority took decisions on minimal requirements for the amount of light and sat the footprint. Building were formed according to the new daylight factor rule of having 1% of the skylight reaching the interior.

Figure 8. Gårdsten, Gothenburg

Today

Postmodern quarters in cities are compromising with daylight to meet today's need for higher density. The ideal of varied building heights creates better sun- and daylight conditions and an impression of more spacious courtyards. The heights of the volumes are adjusted according to the sun but the limitations of window openings and ceiling heights from today's energy crisis limit the availability of sufficient daylight.

Figure 9. Kvillestaden, Gothenburg

Architect: SeARCH + CEBRA + JDS + Louis Paillard Architects
The variation of shapes derives from a simple algorithm of low points meeting on the opposite side high points. The hierarchy of height increases from the front to the outer back according to the sun path. The high reflection value of the chosen white material with a matt surface diffuses the light on its surrounding.

Figure 10. Perspective of the Ice berg project, Aarhus

Figure 11. Perspective of the environment, Aarhus

Architects: MVRDV

The Agora project is a result of a collaboration between architects and engineers. The form is a result of design process of iterations with parameters like daylight, favorable floor area, facade exposure and view. Calculations from computer simulations has simultaneously design the aesthetics.

Slanted facades enable a larger facade area to be exposed for solar radiation.

Figure 12. Perspective of the Agora project, Unbuilt

Figure 13. Perspective of the environment, Unbuilt

As an example of a method for high density cities is a calculation model formulated from Hugh Ferriss concept illustrations in 1916 to ensure better lighting conditions.

Huge Ferriss (1889-1962) was an American architect and writer who, with his illustrations, contributed in 1916 to New York's new regulatory provisions. Through zone cover studies and regulations for air and light against the streets, Manhattan's skyline got its current silhouette with stepping-down house tops.
The features of the new regulations have now also laid the foundation for many innovative cities with urban landscapes of high density.

Depending on the Zone and permissible degree of exploitation, the provisions of New York City zoning laws are that the length of the street should determine the maximum height for the escalation limit. As an example, lower manhattan, which allows maximum exploitation, has a permissible height of 2.5 times the length of the street. This means that if a street is 50 m wide, the stepping-down starts diagonally from the center of the street and 150 m in height.

Necessarily, the number of hours of sunshine is not decisive for the light condition of a city, but rather light unaffected of the whether from the sky.

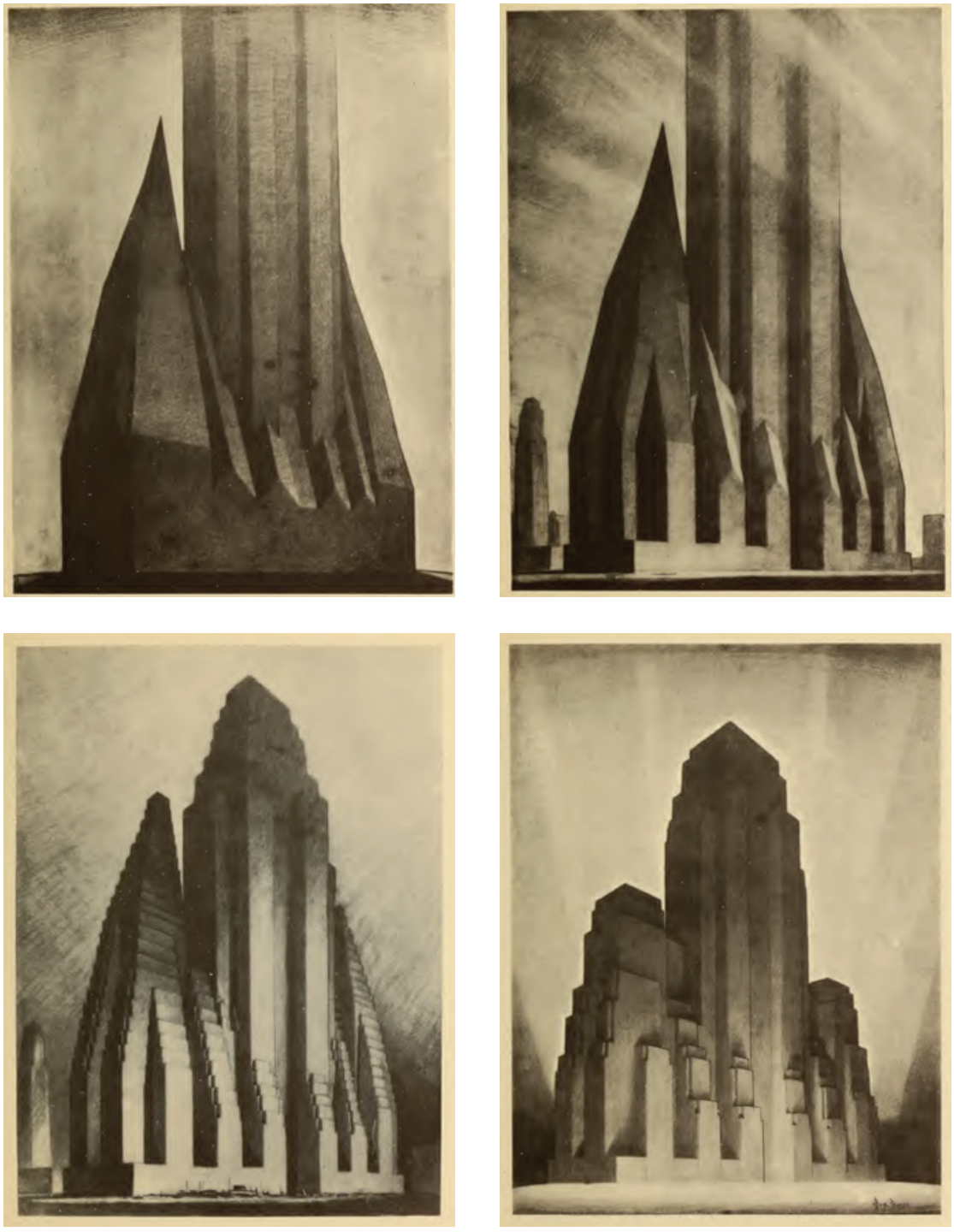


Figure 14. Hugh Ferriss illustrations in "The Metropolice of Tomorrow"

After the Equitable building was built in 1915, the "city" realized that increased exploitation would prevent daylight from reaching the street level. Equitable building at ‹120 broadway' with completely vertical facades and height of 164 m was considered too massive for its context. With the drawing Ferriss made he contributed to the new 1916 New York City zoning laws for maximum mass permitted.

Figure 15. Illustration of Equitable building, Manhattan

Manhattan's zoning for the regulation of maximum building height. The subdivision shapes the city's possible expansion in a vertical direction depending on the conditions of the streets.

Figure 16. Hugh Ferriss illustrations of different stages of a concept deisgn

The height limits of the street line. Depending on zone the diagram shows the different levels of inclination from the street level to the limitation/beginning of the step-down.

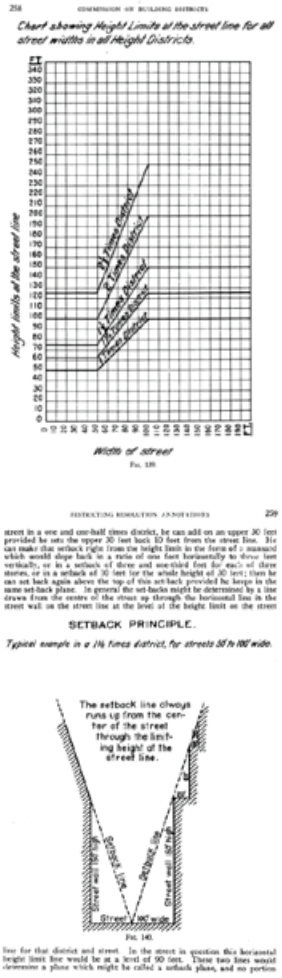


Figure 17. Hugh Ferriss illustrations of different stages of a concept deisgn

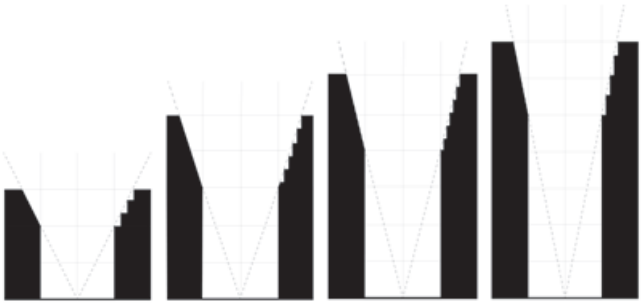
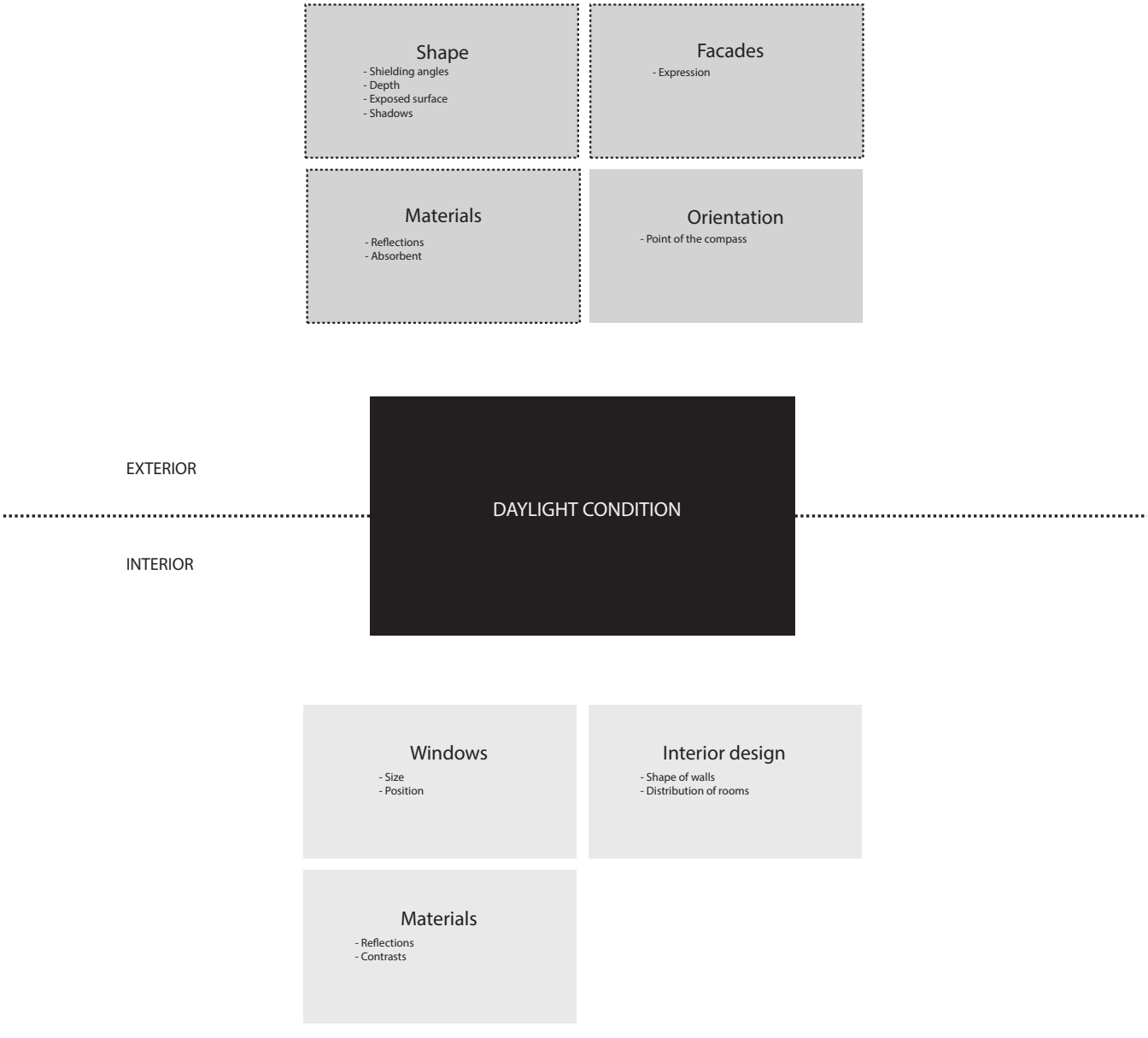


Figure 18. Hugh Ferriss illustrations of different stages of a concept deisgn

Method

Focus area

To improve the ratio of light, it is possible to influence the construction on different scales and grade. The building volumes change the conditions for the interior and depending on how they are designed, the interior must be adapted to meet the requirements for sufficient amount of sunlight inside of the building. The focus on the exterior, excluding the orientation of the volumes, will explore the possibilities of improved light condition in different scales from volume to facade materials. This is to create a relationship between volume and detail to investigate how they could influence each other.


Shape
- Shielding angles
- Depth
- Exposed surface
- Shadows
Facades
- Expression
Materials
- Reflections
- Absorbent
Orientation
- Point of the compass
EXTERIOR
INTERIOR
DAYLIGHT CONDITION
Windows
- Size
- Position
Interior design
- Shape of walls
- Distribution of rooms
Materials
- Reflections
- Contrasts

Prototype

The iteration from the investigations will be applied on an prototyp that later will be put in a context as a concept. By designing a prototype iterations can be applied without taking into account the parameters from a realistic urban planning perspective. By not embed the prototype as a proposal, the applied results of the surveys can give a clearer picture of the concept.

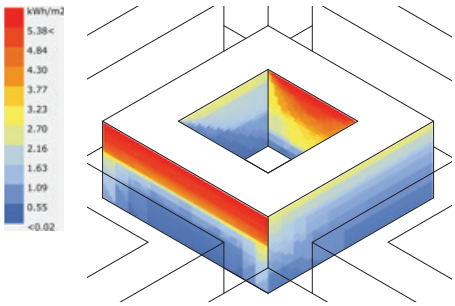
Digital tools

Digital tools are used for investigations of quantitative values and efficiency in the comparison of shapes.
Grasshopper® uses generated algorithms for designer to explore new complex shapes and control parameters without remodeling manually. The graphical algorithm is integrated with Rhino 3-D as a modeling tool and requires no pre-knowledge in programming script.

For daylight simulations and solar ray analysis additional plugins are used developed by Grasshopper.

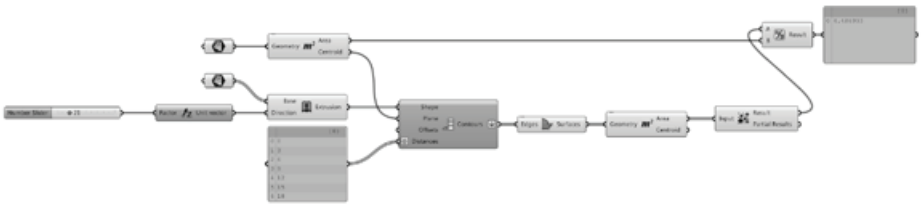
Solar radiation model

The figure shows a solar radiation diagram used in the volume studies of digital models and indicates the amount of direct sunlight from which the facades are exposed. The table shows a value (kWh / m2) in varied colors depending on the amount that also can be seen with the same color in the model.

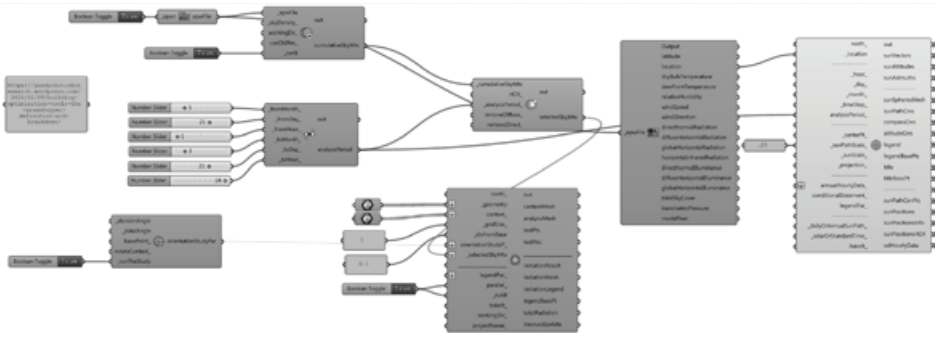


Analogue tools

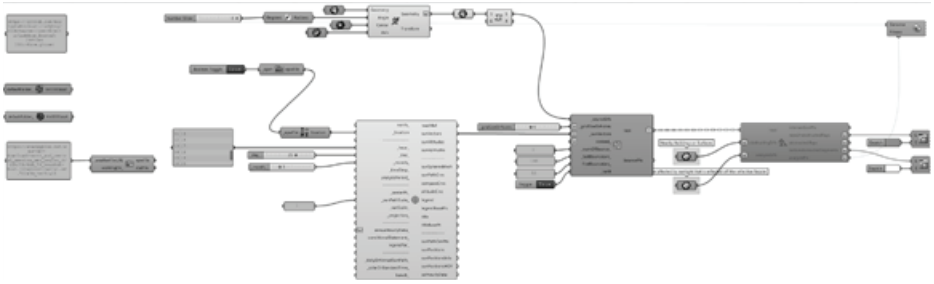
Light is a complex phenomena and values can not be measured by calculations. The method of analogue calculations is ment to broaden the understanding of experienced light qualities for the human eye. Since scale is irrelevant for the investigation, rescaled physical models of proportioned volumes will be analysed and measured from a qualitative perspective of the human eye.



Grasshopper script of floor area and volume



Grasshopper script of solar-radiation with data from EnergyPlus



Grasshopper script of Solar rays with data from EnergyPlus

Simulations

For this thesis to measure direct solar radiation in the digital investigations is the access for sunlight on the facades. The simulation measure the amount of exposed area from the sun on the facades during a given time. The tool requires information about the geographical location, a context and an orientation for the building/environment. The result is an indication of how the volumes will meet the requirements for the ratio of daylight.

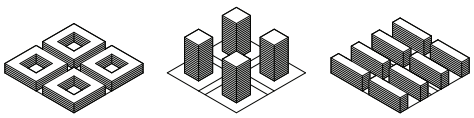
The script for daylight simulation is a plug-in that uses weather data from EnergyPlus that collects data arranged by World Meteorological Organization and Country. The data is used for all investigation based on the sun-path of Gothenburg.

Shape

Grasshopper script that are used for the investigations

Grasshopper script of floor area and volume

Grasshopper script of solar-radiation with data from EnergyPlus



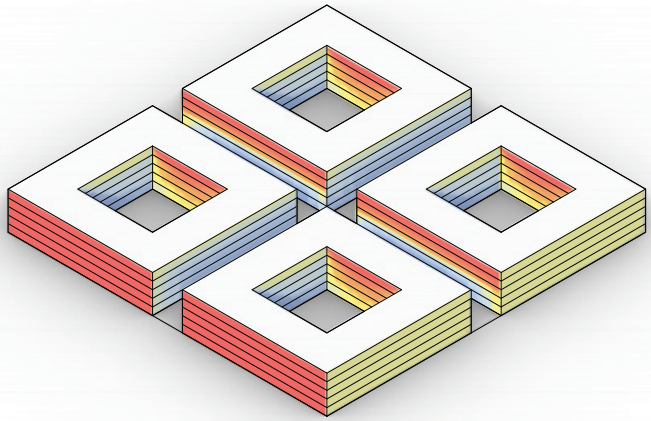
Typology

The definition of urban density can be measured by the number of inhabitants per area unit or level of activity. The study of common typologies addresses how direct sunlight affects different morphological designs of urban patterns.

The base form combines the three typologies as a parable of the build area in Kvillestaden in Gothenburg. The base shape with changeable parameters of height and width creates a flexible block formation for adaptation.

City block

The scale of a city block is directly related to scale of its context. The city block involves a relatively high degree of privacy. The building height justify the number of levels according to plot size and context, usually a range of 4 to 7 levels in terms of ideal energy footprint and daylight condition.



Tower block

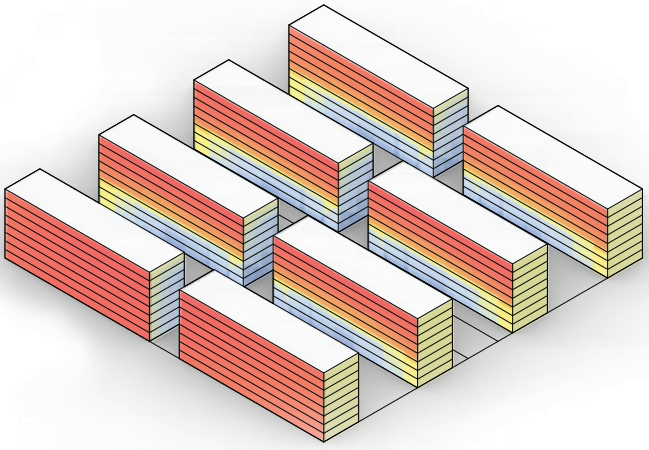
The tower block is represented as a tall building consisting of multiple levels. There is no clear definition of floors that determines the building its status. The impact on the neighboring of is high and the main disadvantaged of the tower block typology is shading and differences of the urban texture depending on its context.
The tower block is an adaptation of typology according to high density and justified by economic consideration.

The block tower is a common model in high dense cities. The limitation to maintain a good daylight condition on the inside is the depth for the floors. Of the three investigated typologies this is the only one without a limitation of height.

Linear block

The linear block is a block freestanding on its plot. It represent a number of individual units combined in a quantitative size. The height of the block usually differs from 3 to 5 levels but has been investigated on higher. Traditionally justifies the number of levels how convenient it is for walking and urban fabric.

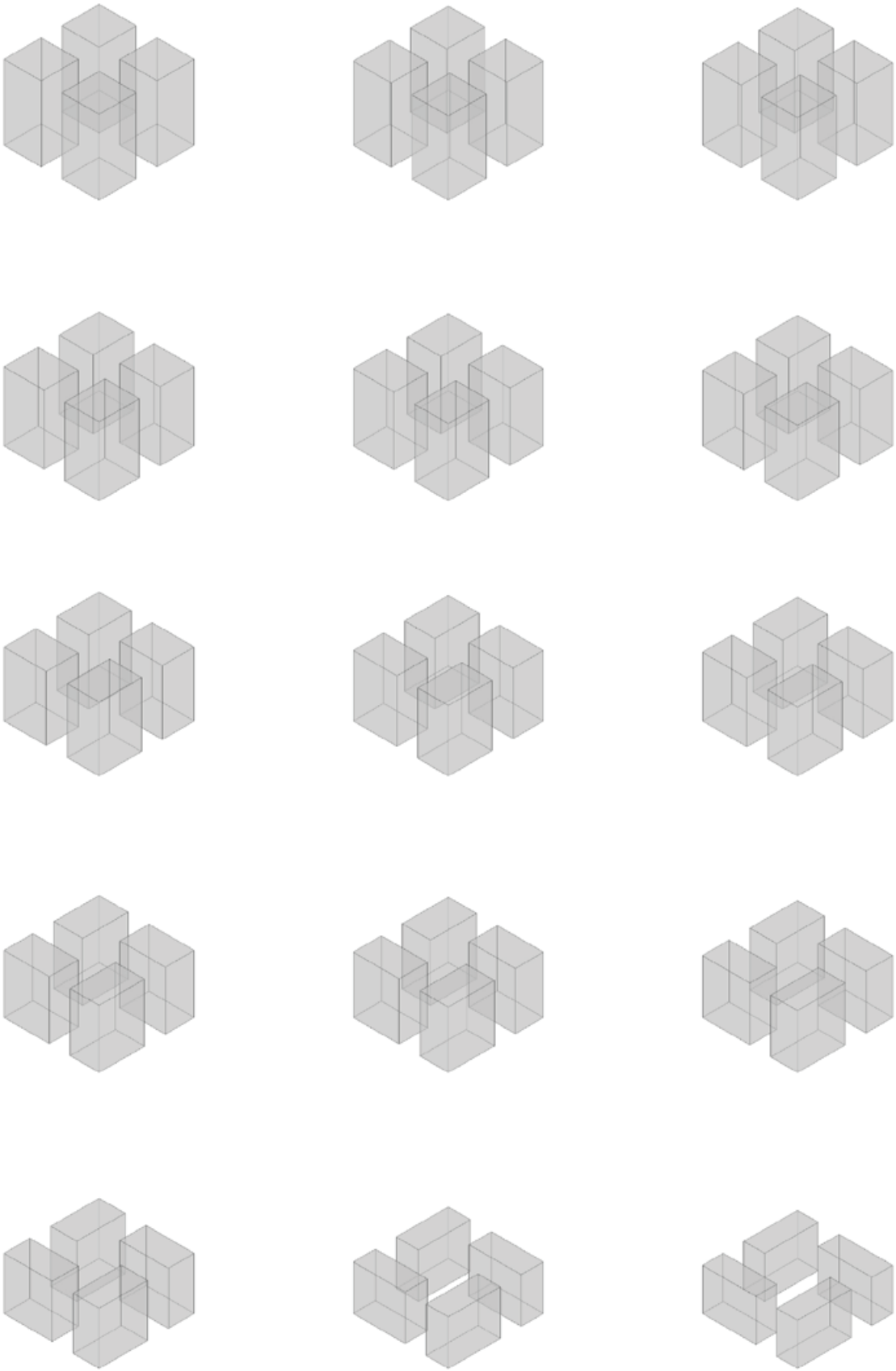
The free side of the block enable the typology to be assembled in groups or continue as an extension of existing buildings. The block typology has a large amount of exterior facade and possibilities for openings of windows in two directions.

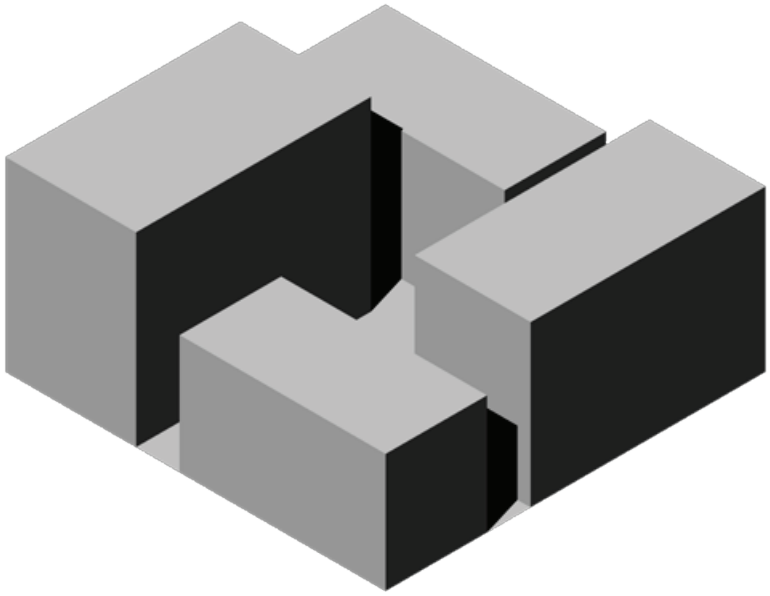


Typology mix

The base form combines the three typologies as a parable of todays post-modern quarters in Gothenburg. The base shape with changeable parameters of height and width creates a flexible block formation for adaptation. A quarter structure has a limitation to height while a high raised tower block is debatable in cities with a lower average height.

The typology for this investigation is a high dense quarter structure in combination of potential tower blocks to enable higher buildings within the quarter.

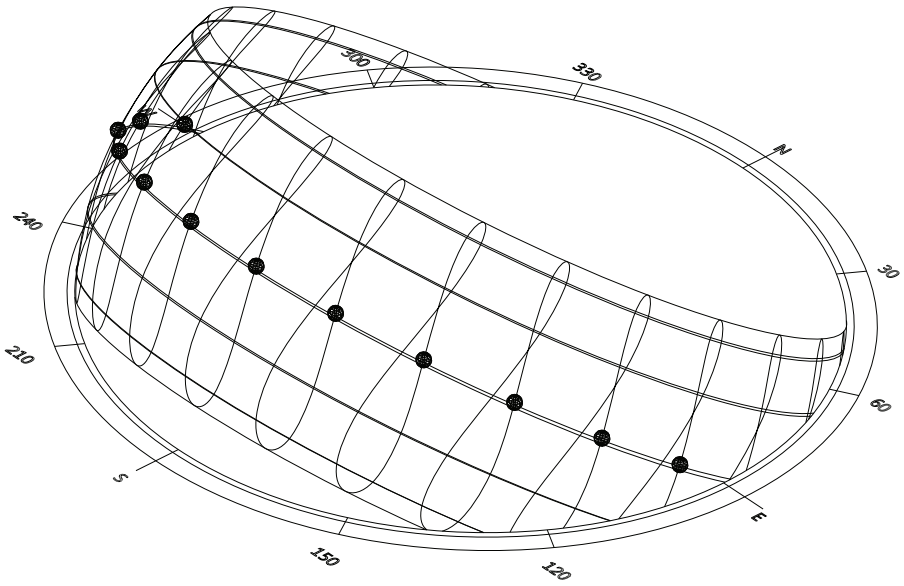




Base shape

As a foundation for further investigation, the base form is a mix of building types from the analysis of typologies and a comparison of today's buildings with postmodern neighborhoods. The transformation will gradually develop the block but retain the base formation of four volumes in a city block structure. Height is based on the typology mix and is limited by the depth of the volume.

Parallel studies on shapes and other features will be investigated and interpreted before application.



Vernal equinox

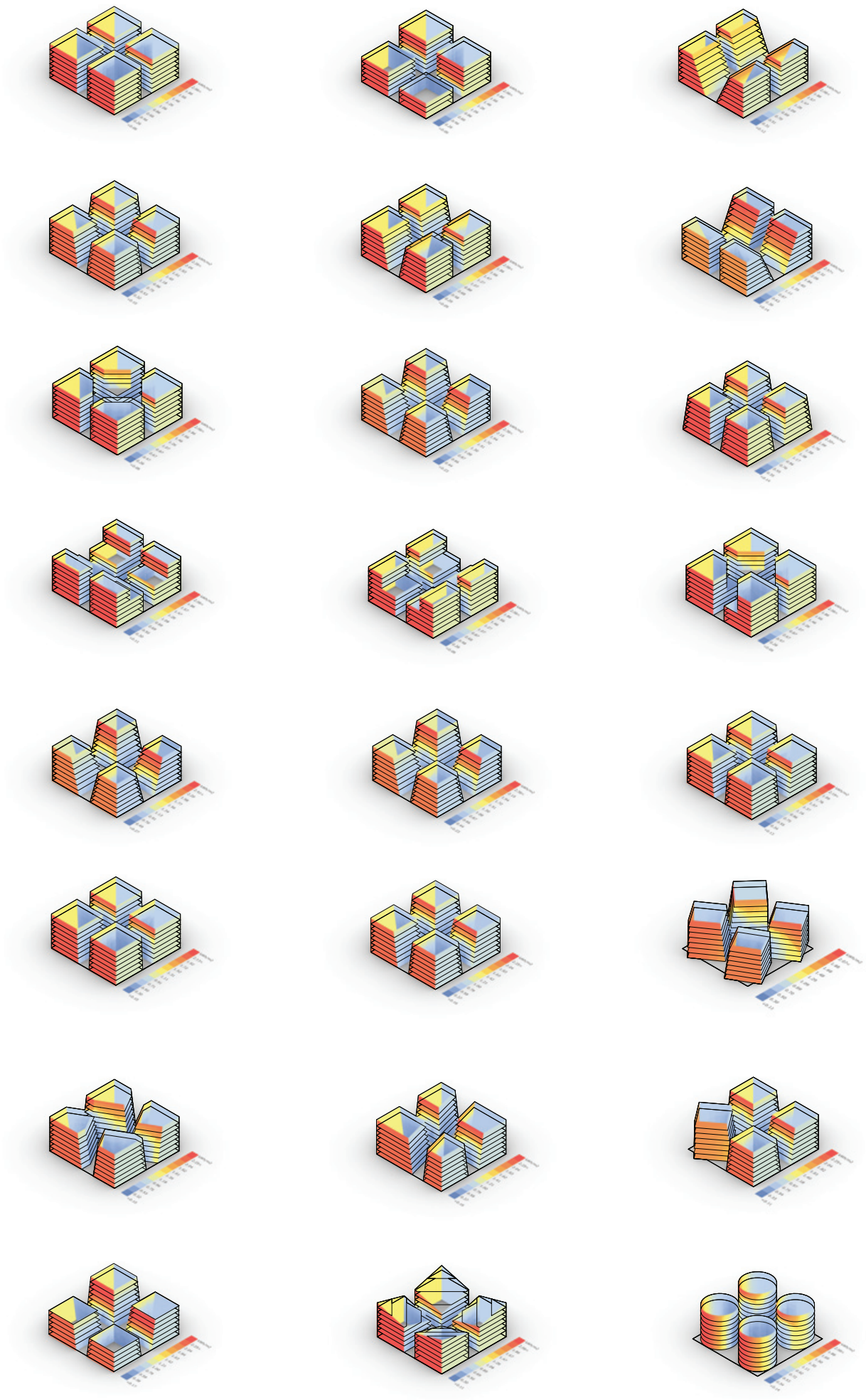
The grasshopper script for measuring solar radiation uses a component to locate the geographical positions sun path. With a location in Gothenburg is the timespan sat to vernal equinox as a median value of the whole year for quicker simulations. The given time is during 24h to simulate the sun path from morning til evening.

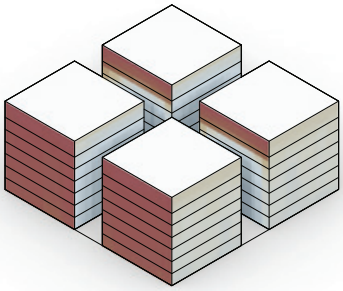
Simulations

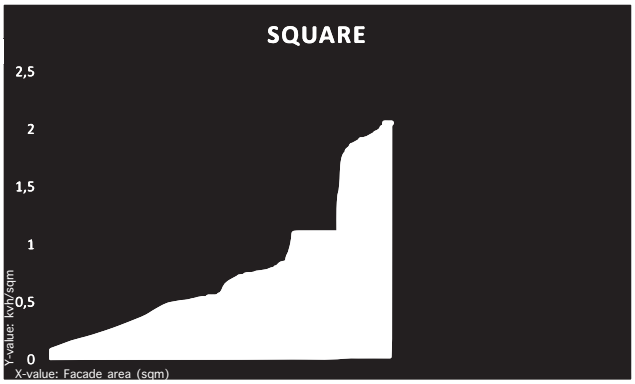
As a first step in the quantitative light study, a variety of volumes have been investigated by digital simulations. The study has taken into account FAR (floor area ratio) in relation to the amount of sun hours reaching the exterior facade. All investigations on quantitative lighting conditions are done during a 24h timespan at vernal equinox.

Further selection from the quantitative light study has a balance between volume and the number of exposed solar hours. To make studie relevant the same investigation was accomplished with the equal mass. No limitation of height is set but the plot size remains.

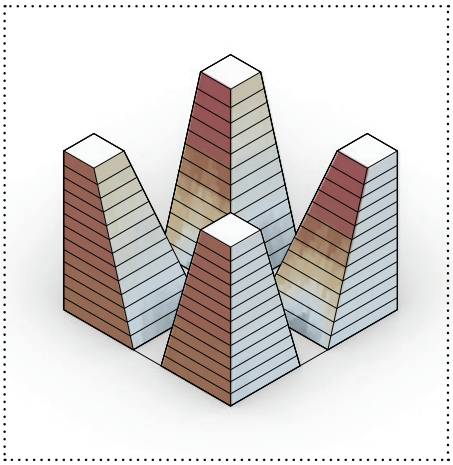
The quantitative analysis of the shapes describes the number of solar hours and area exposed by the sun based on the sun's orbit in Gothenburg. The X-value in the graph shows the number of square meters of exposed area that, regardless of the amount of sunlight, reaches the facade. The Y value indicates the number of kwh / m2 of one day at vernal equinox.

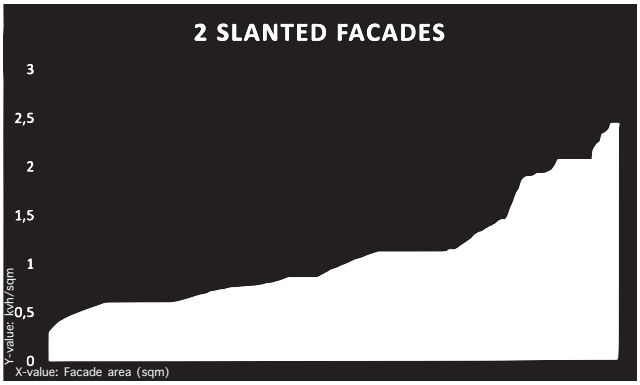




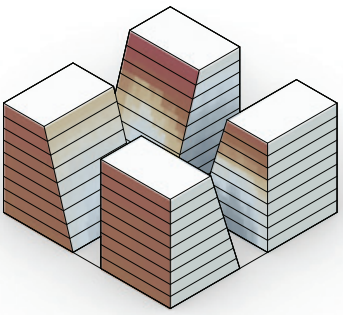


The high dense prevents the solar radiation to reach the narrow space between the volumes. Figure 1 has the highest amount of exposed facade area with values below 0,5 kmh/m2 since the density is causing the smallest void.





Adding height with maintained total volume creates a void for the solar radiation to expose the facades. The diagram show the highest amount och solar radiation and exposed facade for the sun. The figure also shows the lowest amount of surface exposed for radiation below the limit of 0.5 kvh/m2. The high number of facade area is not necessarily the best solution in a realistic point of view.



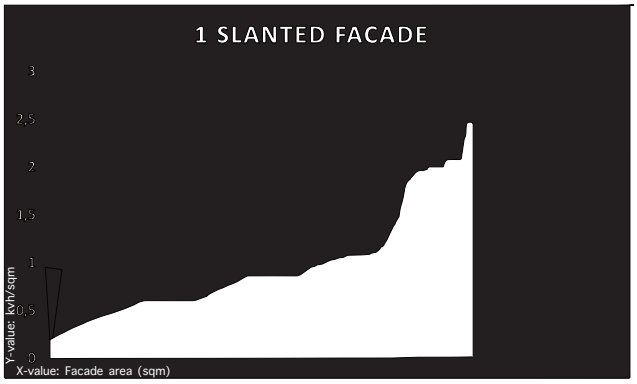
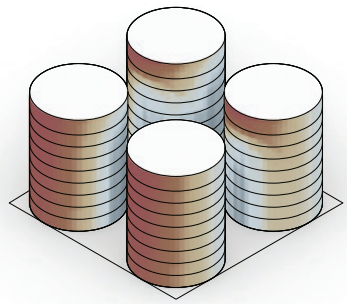
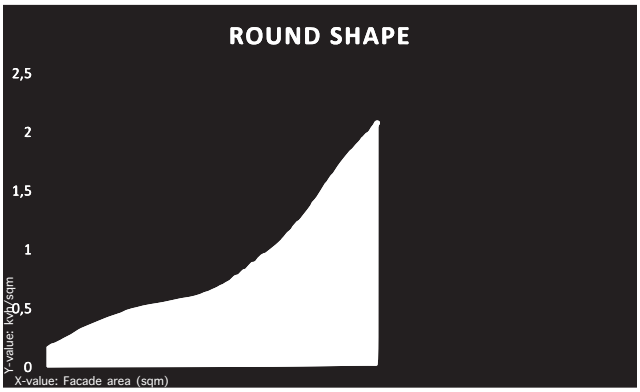
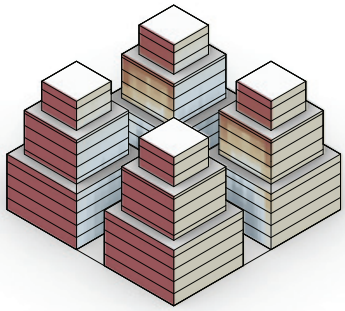


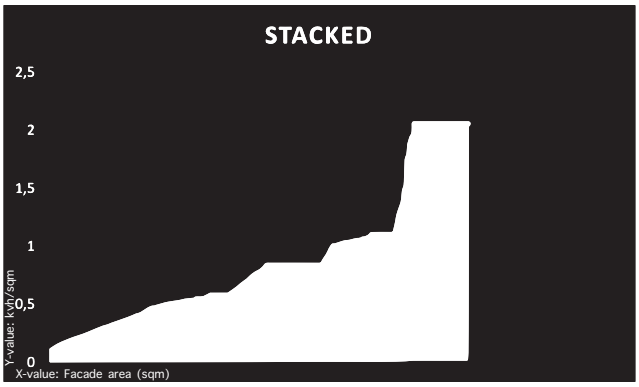
Figure 3 has similar features as figure 2 of larger voids and fewer low-valued facade m2.



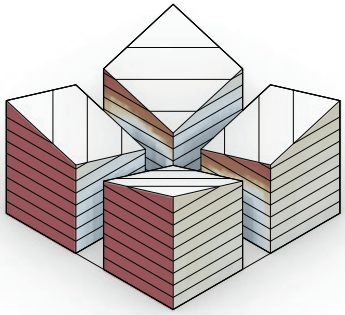


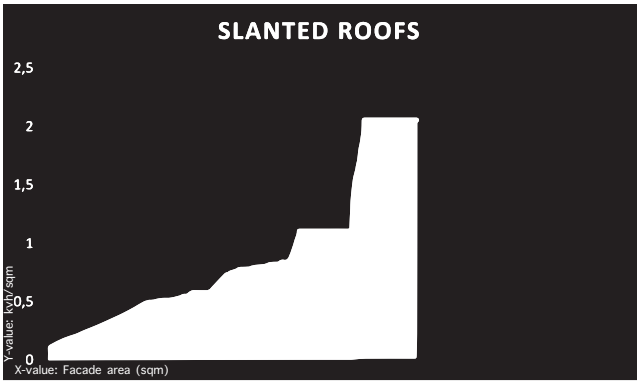
The curved corners reduce the total amount of exposed facade area and has a comparable high value of solar radiation. The radius of the corners makes the radiation reach closer to the middle of the four volumes. The least exterior surface would in a realistic



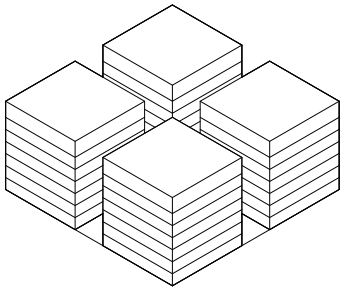


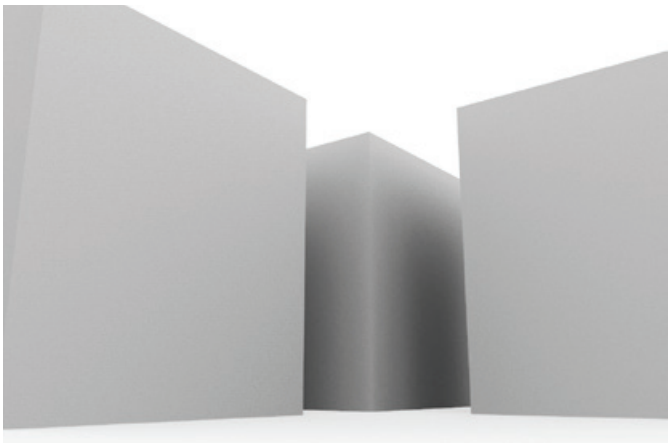
The stacked volumes shows divided features with high values on the smaller parts and low values for the lower foundation. The result of the low values is comparable to figure 1 with the highest dense.



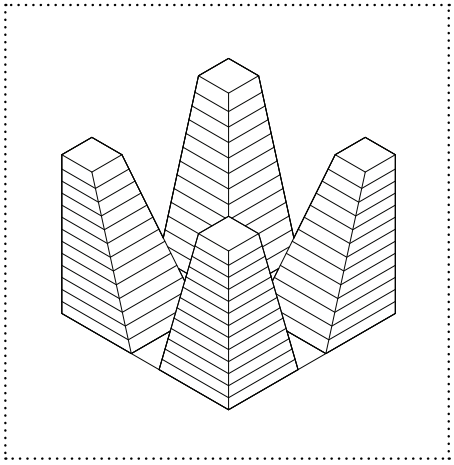


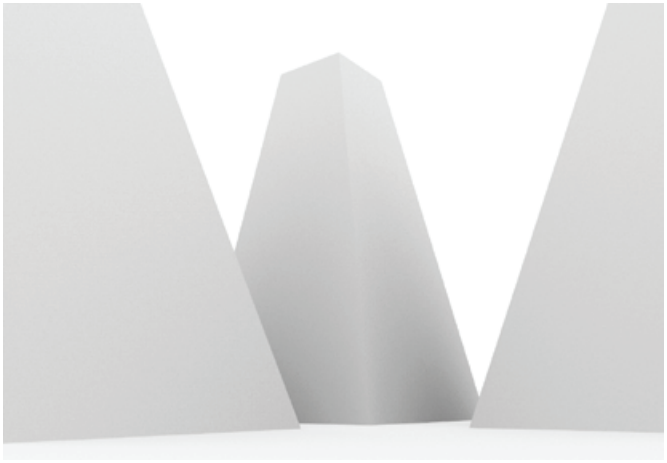
The slanted roofs allow the solar radiation to partly reach the narrow space between the volumes with maintained density. The low values are critical depending on the total height and narrow space.



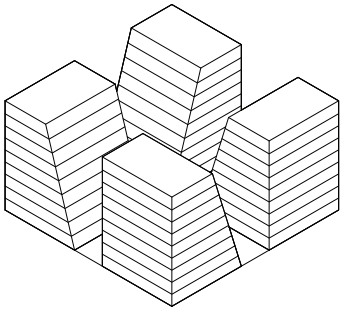


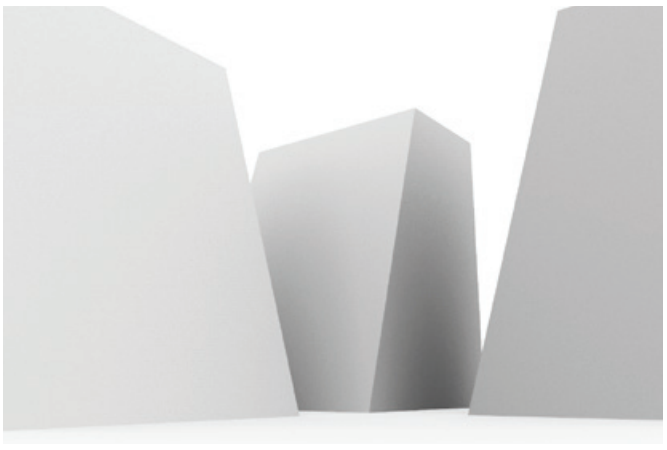
The square shaped blocks has the highest density for its height and therefor having the most narrow void abetween the volumes.



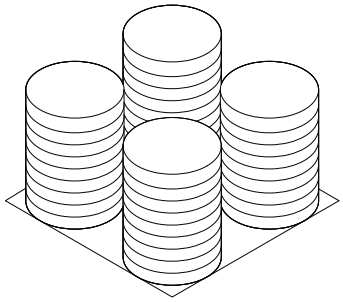


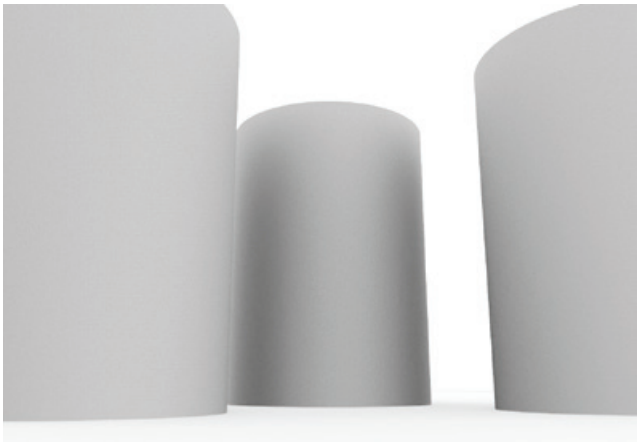
To incline the facades increases the height to maintain the same volume. The larger void creates a spacious gap and visibility to the sky. The critical aspect is a higher volume.



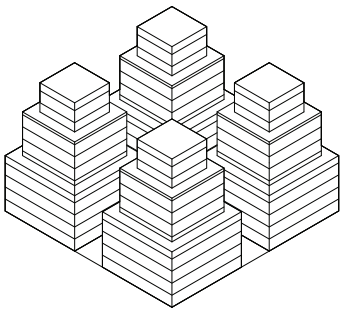


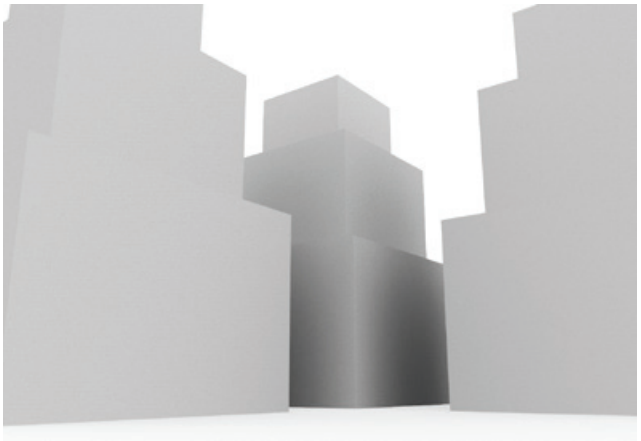
Like ”figure 2” is the inclining facades efficient for the visibility of the sky. One inclined facade reduce the critical aspect of height but keep the issue of vertical surfaces.



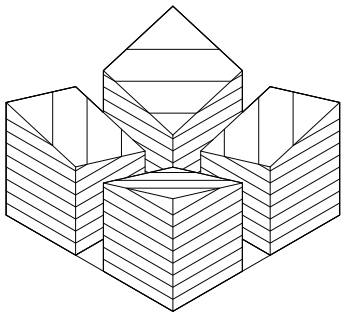


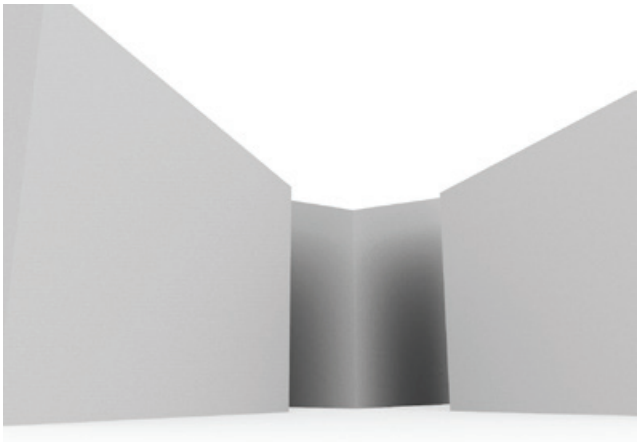
The round shape free the corners to its extent that only one part in the middle becomes as narrow as the squared volumes (figure 1). Since the corners are removed new sight lines emerges from a non-axial perspective.





LIke ”figure 2” the stacked volumes free space for the sky but keep the narrow foundation. The amount of visible sky depends on the size of the stacked volumes.





Slanted roofs has no impact on the average height for the volumes. The slanted roofs reduces height at particular areas but for the visuality of the sky can only be seen where the diagonal of the angel hits the ground.

Further investigations based on the idea of wider the viewer angle to let mot skylight in and create a more spatial environment.

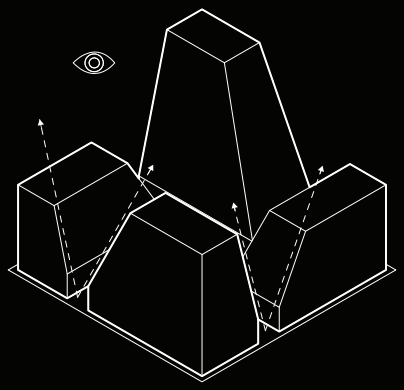


Diagram - View of sky as a result of inclined facades

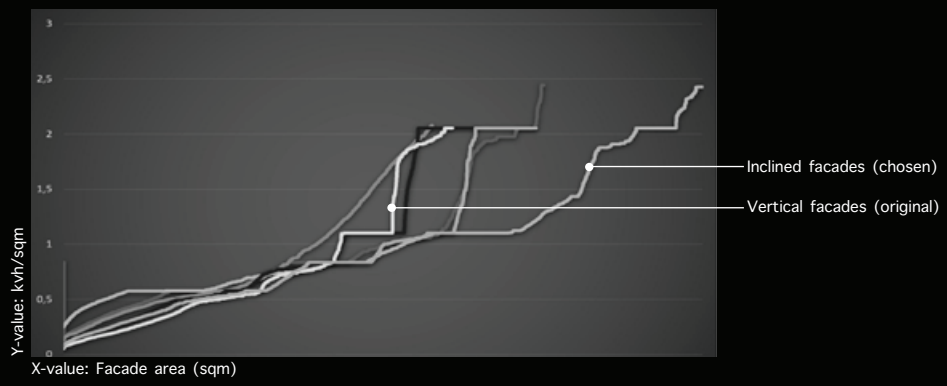


Diagram - Graph of all investigated shapes from the solar radiation analysis

Inclined facades

The volumes are examined with a light source comparable to the orbit of the sun at a certain time with a clear sky. The investigation is searching for advantages och disadvantages according to mass and light. The varied inclined models result in different abilities for reflections, potential density and access to skylight. The models examine the formation of airspace and light in relation to surrounding volumes.

In a future development of the shapes, the inclination of the volumes would vary within the block depending on the orientation. This is not an investigation of finding the ultimate shape for maximum solar radiation but the advantages of inclined facades and an awareness of how it affects the total mass.

The cut is made to improve the shielding angle and the amount of direct sunlight and form a balance of light and mass.

From the inclined facades creates a gap for direct sunlight to reach a wider area of the facades.

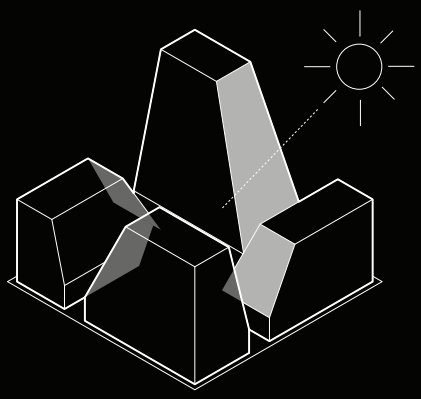


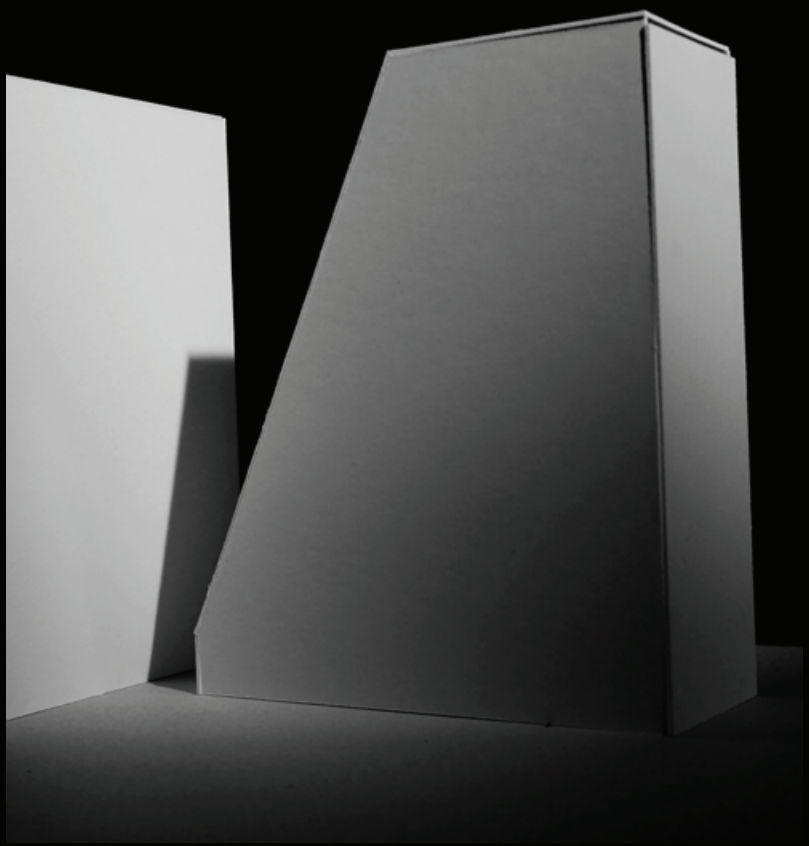
Diagram - Slanted facade for investigation

A sharp inclined shape forms a larger airspace that access a larger amount of light. The opposite facade has, depending on the slope's shielding angle, the volume's full exposure to the sun. The balance between gradient and amount of light emitted limits the height of the volume and density.

45 ^{0}

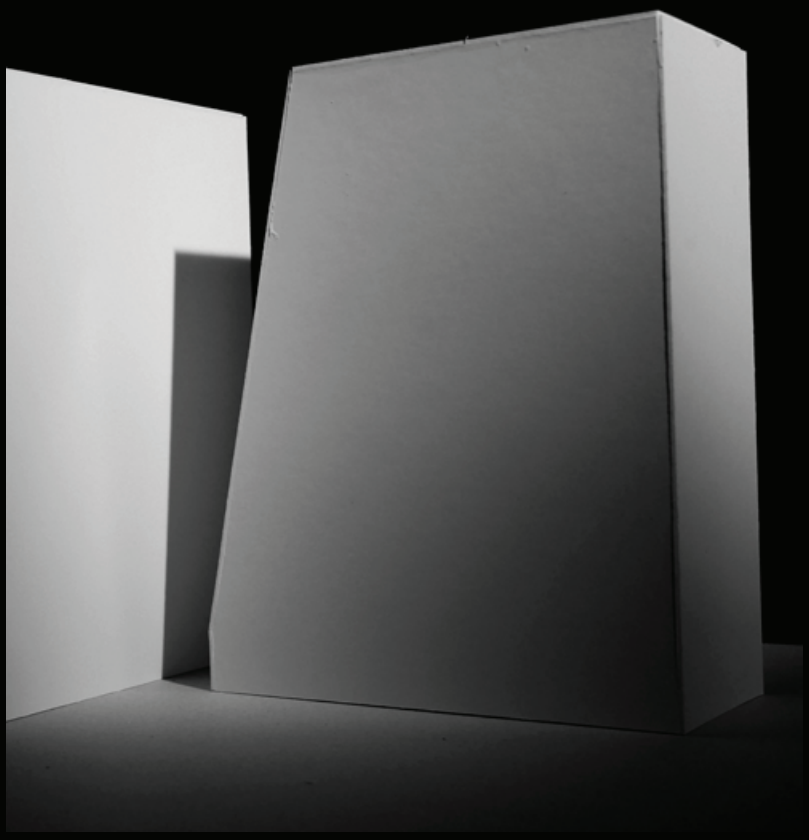
The figure shows a balance between light and density. The volume has the ability to expand vertically while access to sky light and sunlight radically changes the light image.

30 0

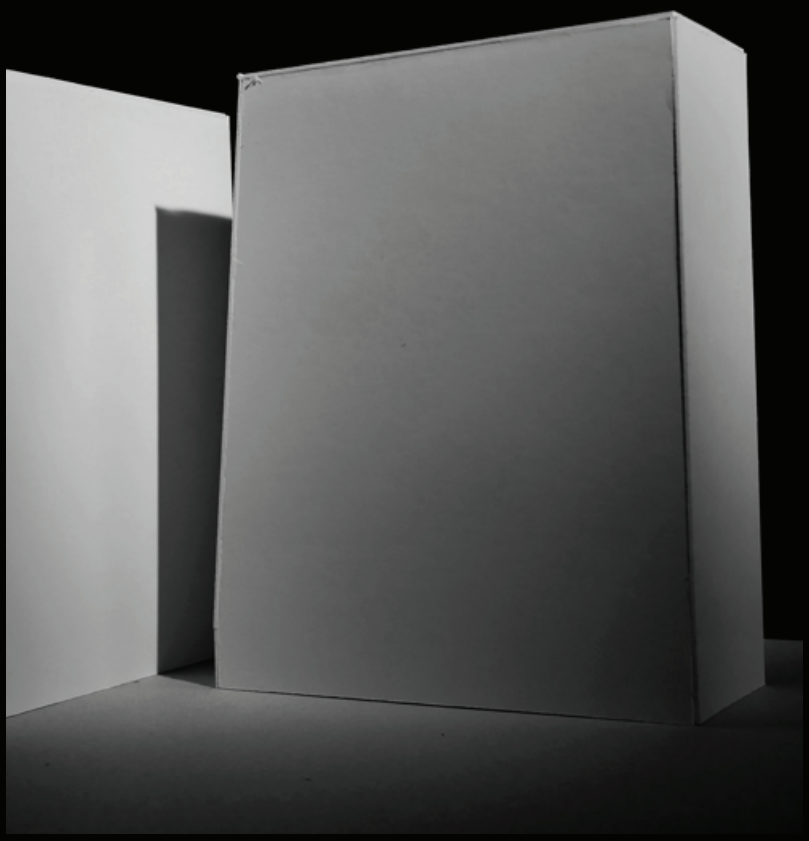


22,5 0

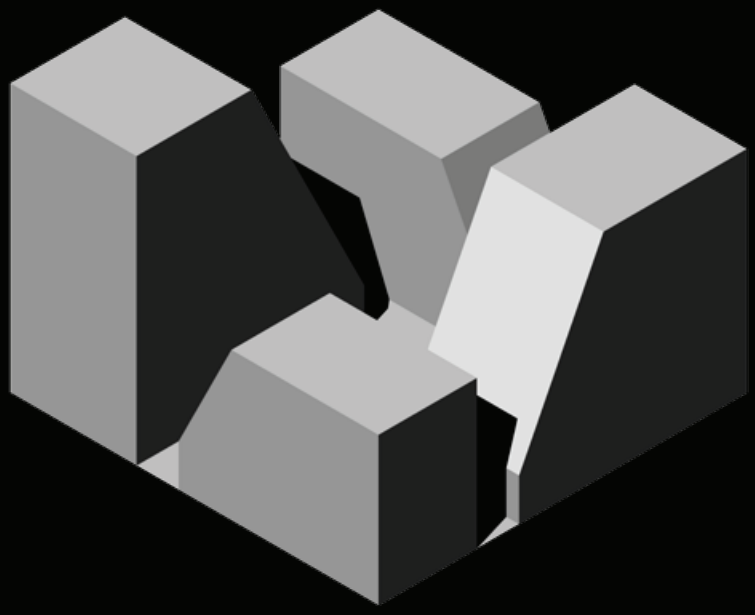
A slight difference in slope has a greater impact on the perceived light from the sky rather than the actual solar radiation. A reduced slope constantly reduces the light input along with an increased shadow image.



10^0



5^0



The inclined facades is capable of increase the amount of direct sunlight by lower shielding angle and maintain the mass. The purpose of the investigation is to address the quantitative and qualitetive values of inclined facades.

Cuttings

Depending on how the cut is made, the facades' character will change from a quantitative and qualitative point of view. The models examines an illuminated surface of the cut exposed from a directed light source and vertical skylight. The models examine how the volumes could be shaped to reduce the experience of the mass and enhance illuminated facade area. The variations will be based on previous studies and use the advantages of inclined surfaces for a wider opening towards the sky but aim to reduced the cut for minimized the loss of mass.

The second inclined facaded reflects the incoming light on the surface. Clearer contrasts to the vertical surfaces are created and the light appears.

Figure 1 - 45 degree large cut

The exposed round shape reduces the contrast to the vertical surface and forms a softer transition.

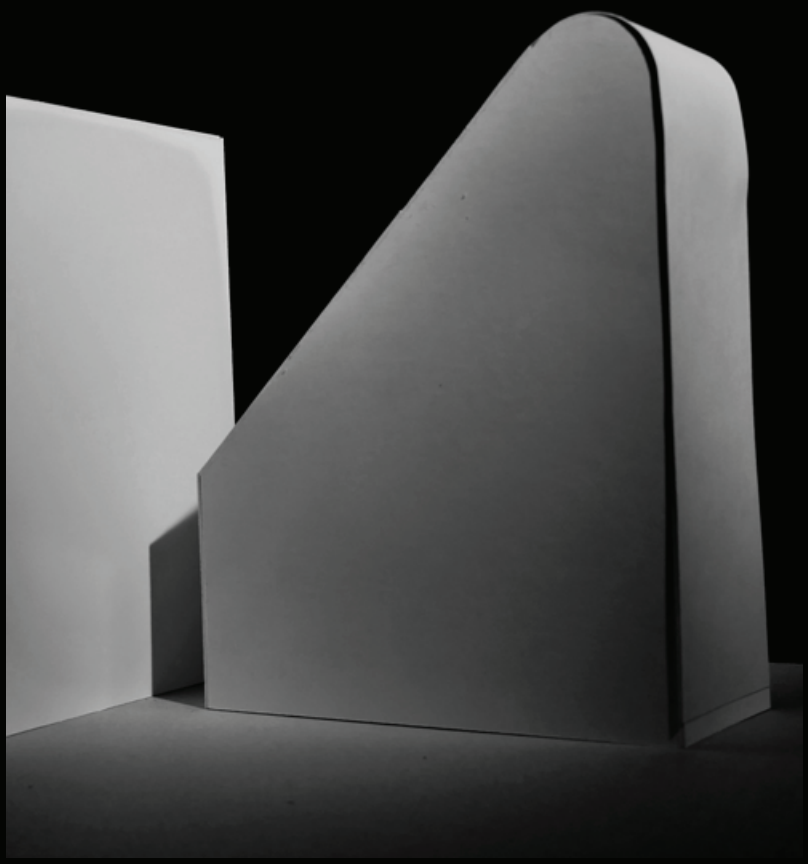


Figure 2 - Rounded edge

As in figure 1, the second inclined side gives reflections that illuminate the surface.

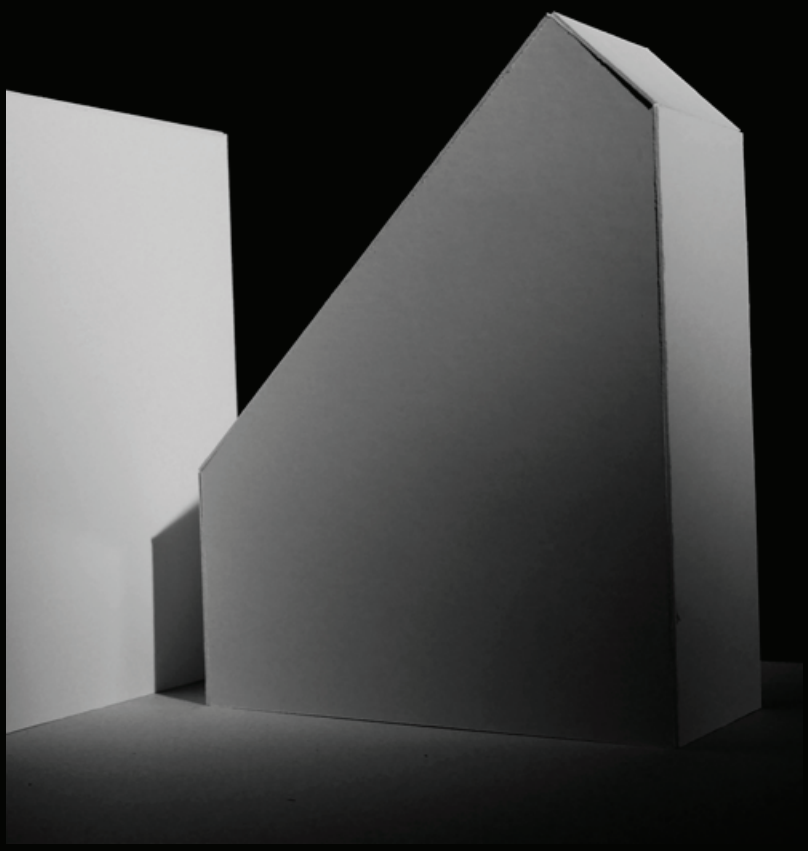


Figure 3 - 1 cut on one surface

The change has a minor effect on the amount of direct sunlight or the shadows on the opposite volume, but changes the qualitative value of the light image.

Figure 4 - 1 cut on two surfaces

By adding a more inclined angle, the direct sunlight can reach lower on the opposite volume.
Figure 5 is a comparison model to figure 6 to investigate the difference on a vertical surface and slightly inclined.

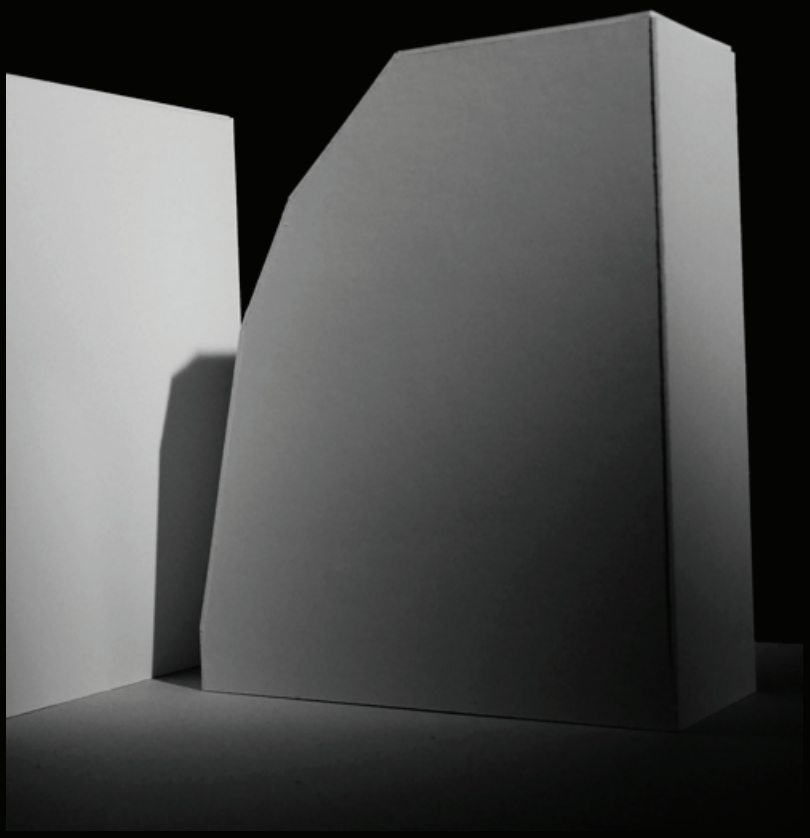


Figure 5 - Two cut on inclined surface

Compared to figure 5 with the same base shape, figure 6 shows a difference in reflected light which also illuminates slightly inclined surfaces. The change has a minor effect on the amount of direct sunlight or the shadows on the opposite volume, but changes the qualitative value of the light image.

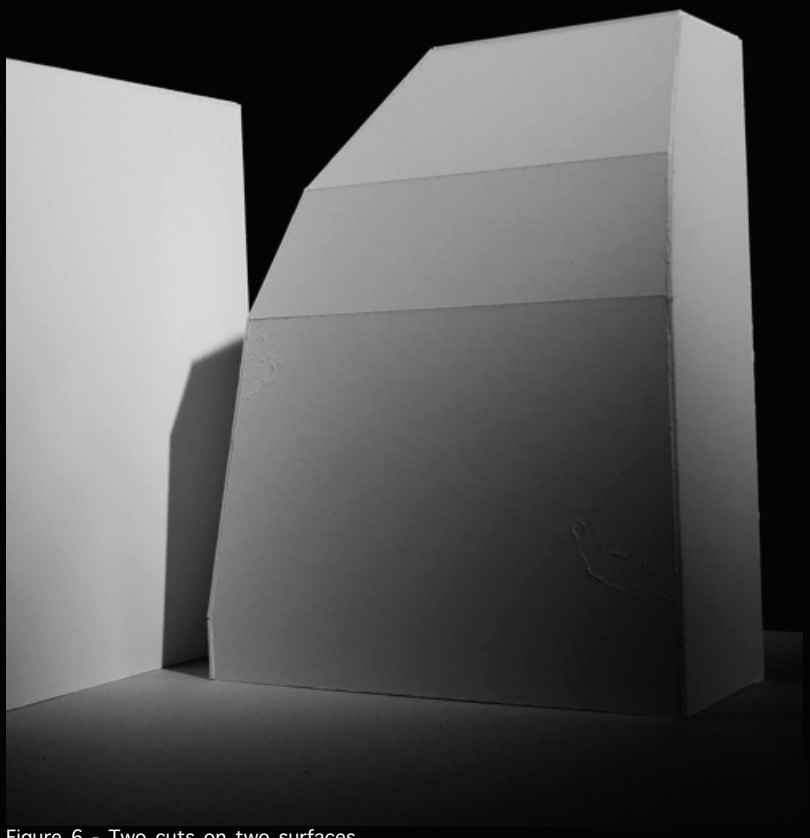


Figure 6 - Two cuts on two surfaces

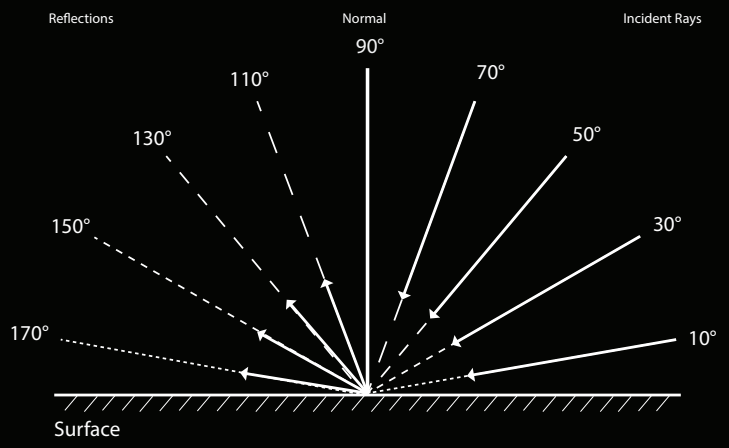


Diagram - Incident rays and reflection angle

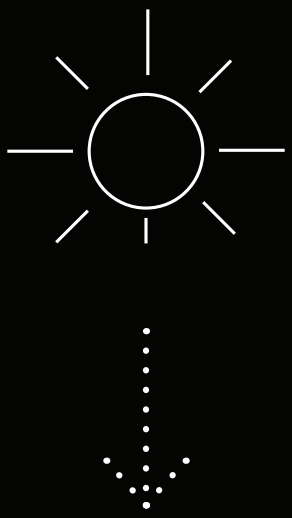


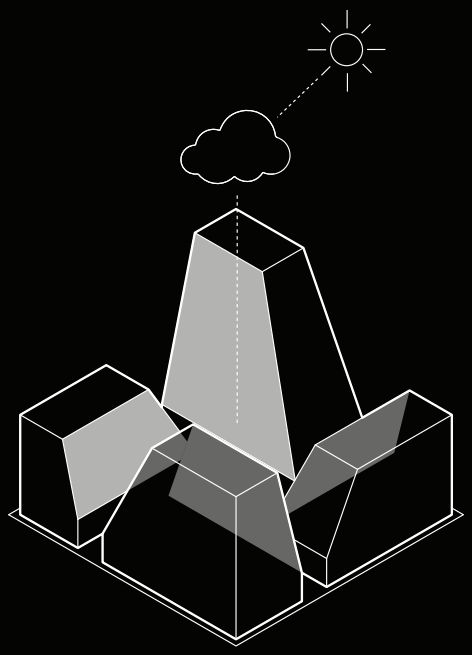
Diagram - Vertical skylight

Diffused skylight

Several measurements are taken into account in measurements of daylight condition. The direct sunlight is mainly the strongest light source, but in the Nordic countries, with fewer sun hours than latitudes further south, is the skylight as important. Same models from the direct sunlight study are analyzed with a diffused light to show the advantages of a reflecting surfaces inclination.

A merged assessment of the models with the two different light sources proves that a slope can increase the direct sunlight but also provide advantages in reflected surfaces by skylight from a qualitative perspective.

The inclined surface has an incident angle in the direction of the sky and reflects the light on its surrounding. The contrast from the sky to the ground becomes less blinding since more nuances creates lower differences.



The slanted surface has an incident angle to the sky and reflects the light. The contrast from the sky to the ground becomes less blinding since more nuances creates lower differences.

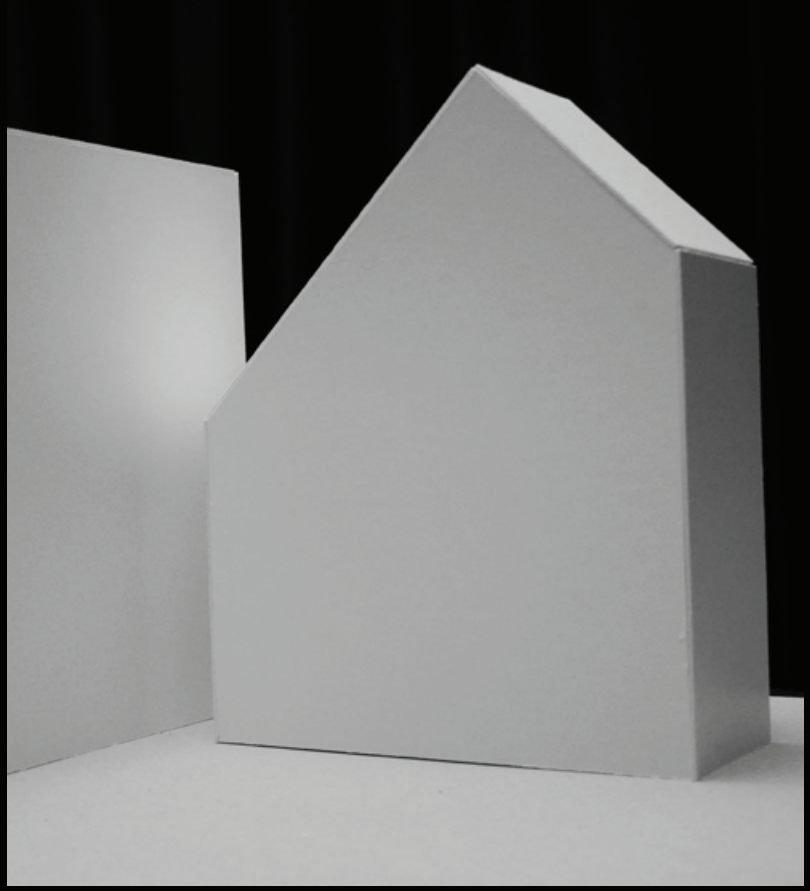


Figure 1 - Slanted surface on short edge

The rounded edge diffuse the transmit the light and diffuse the contrasts from the top. The vertical surface is not effected by the rounded edge so it is only beneficial if it would be observed from a distance. The differens between the sky and volume is reduced by not having a strong contrast.

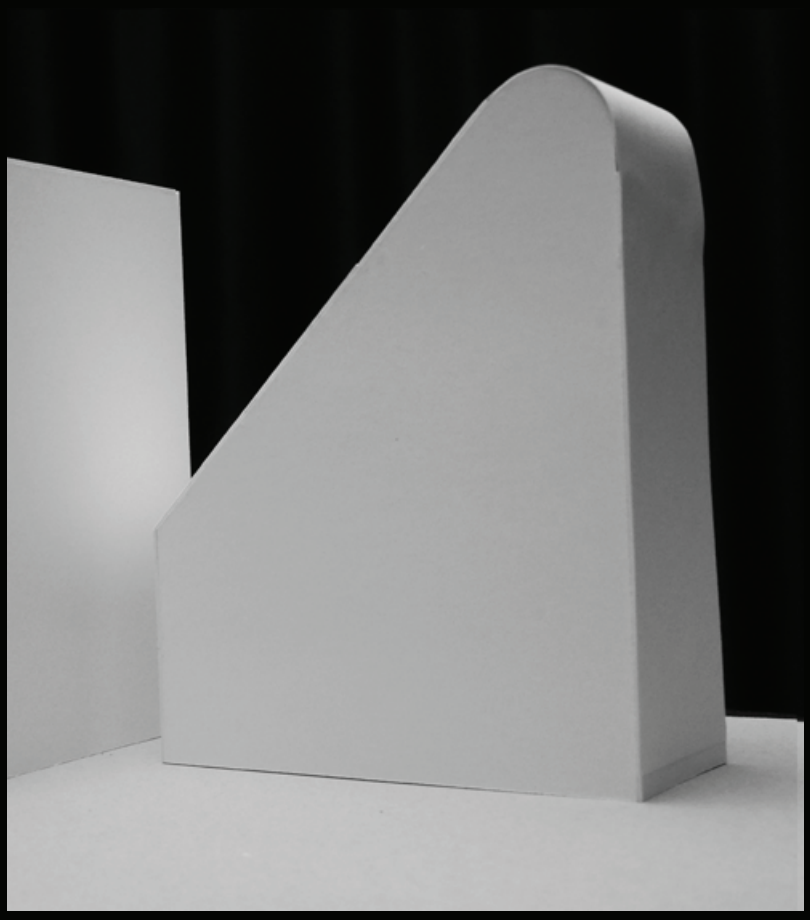


Figure 2 - Rounded top on short edge

The two slanted surfaces makes a clear difference compared to the vertical once in reflected light. Like figure 1 and 4 is the contrast between the slanted and vertical constantly increased in relation to its angle.

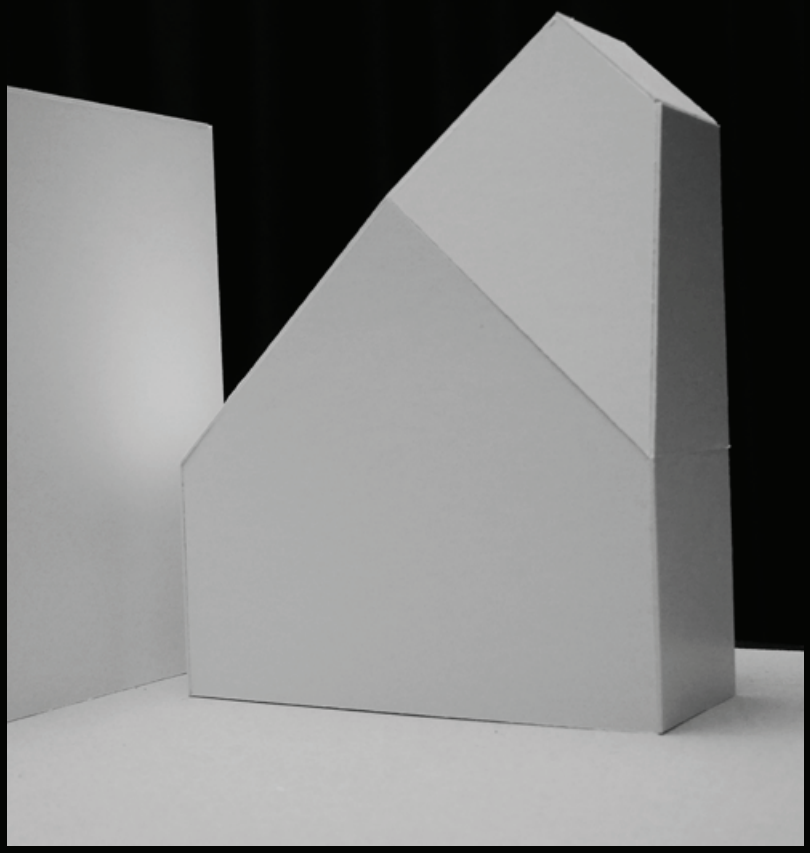


Figure 3 - Slanted surface long side and short side

Like ''Figure 1'' has the slanted angle an incident angle to the sky and reflects the light. Smaller surfaces results in less light.

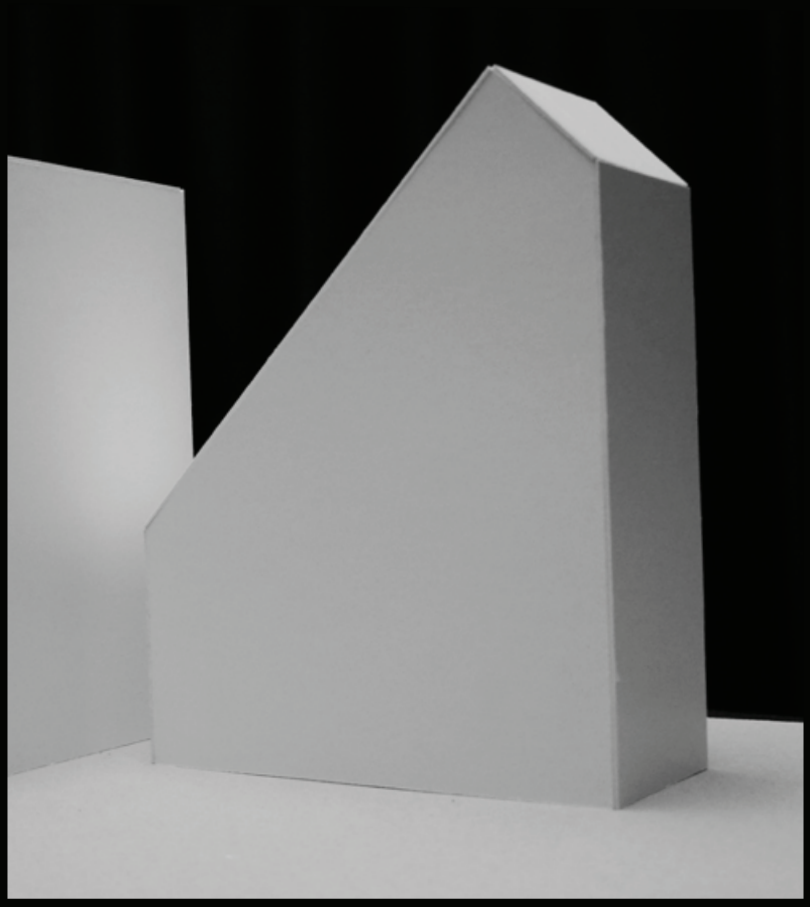


Figure 4 - Small slanted surface on short edge

The vertical light effect the slanted facades in relation to the incline of the surfaces. Similar to the model in ''corner and Cuttings'' is amount of reflected light constant in relation to the light value from the light source. The nuances of light reduce the high contrasts between the sky and volume. The incident angle for the surface and sky decides where the reflections are pointed. By increasing the incline angle of the surface less light will be reflected

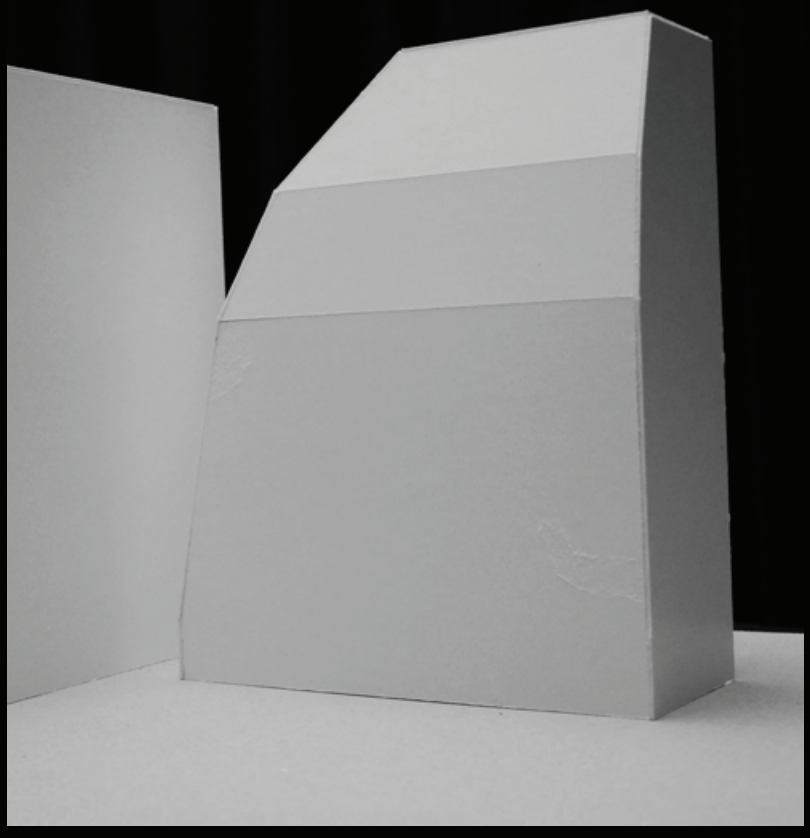
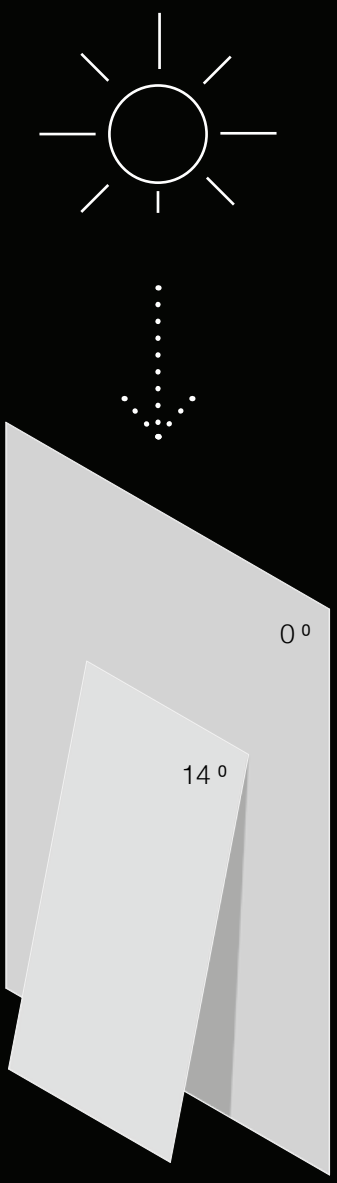


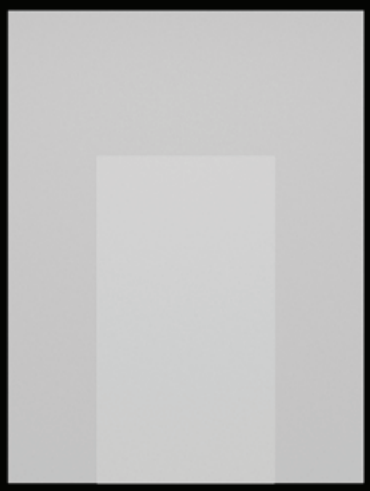
Figure 5 - Two slanted surfaced on long side



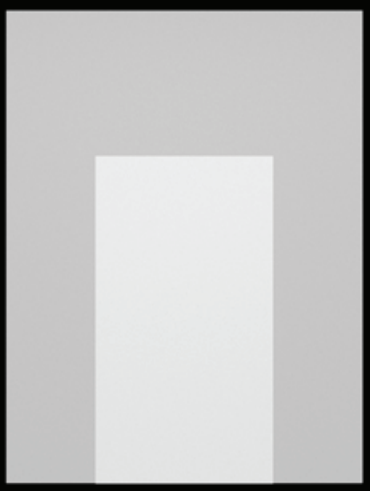
Diffused light angle

The vertical skylight reflects according to the diagram of incident ray, objects with a surface exposed with an angle directed at the sky. The investigation of diffused light angle tests different inclined surfaces illumination in comparison to a vertical background.

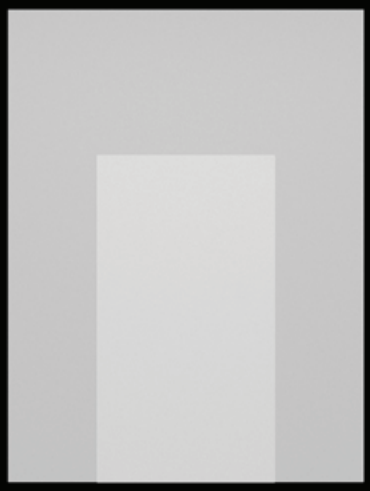
The human eye capture the contrasts between and exaggerate the differens. If an illuminated surface becomes brighter does our brain perceive its background darker compared to the given example of figure 1 in the investigation 3,5 ^{0} with more equate illuminated surfaces.



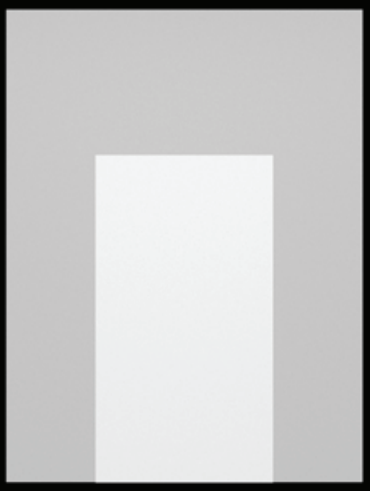
3,5 °



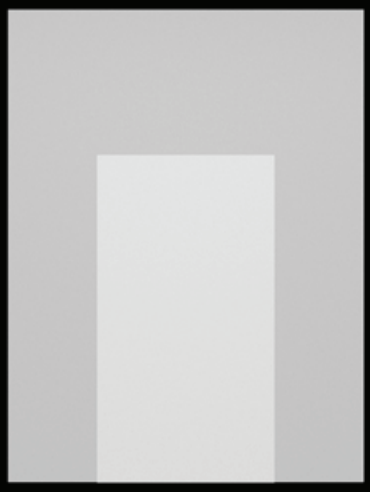
14 °



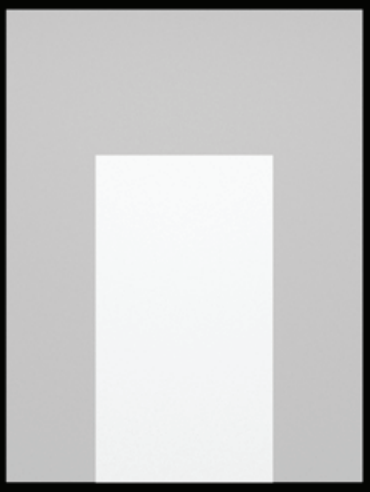
7 °



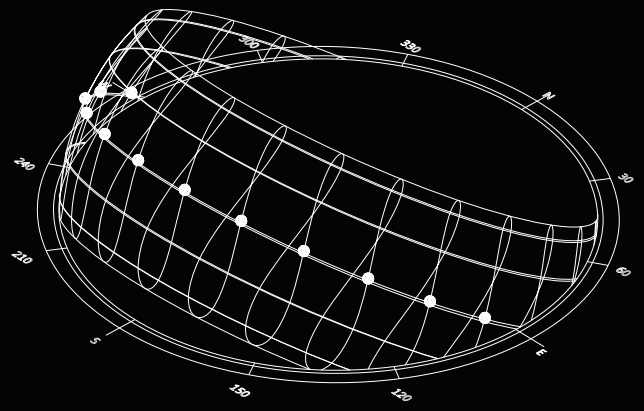
17,5 °



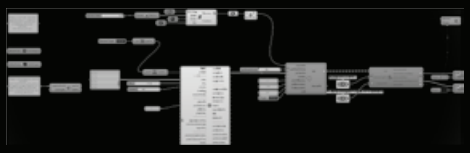
10,5 °



21 °



Sun path for Gothenburg at vernal equinox used in the investigation of reflection angle



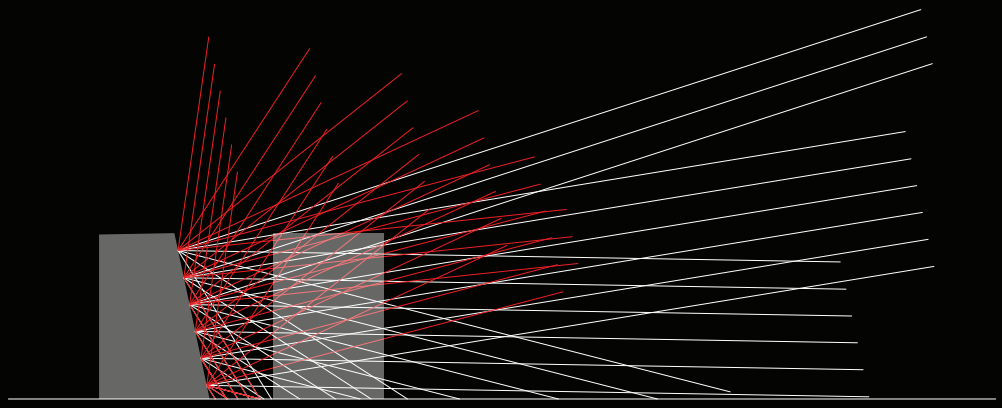
Grasshopper script of solar rays

Reflection angle

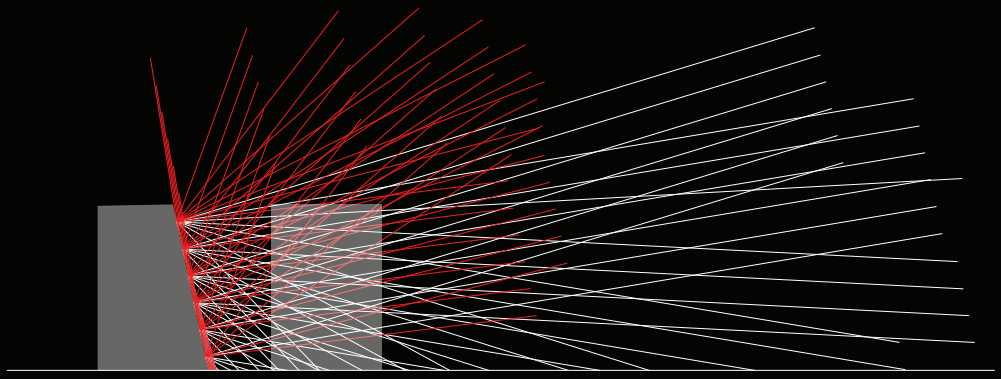
Reflections explain shapes and materials and gives the environment its character. The position from the light source reflects along the movement of the eye. Bad positioning of reflecting materials can creates difficulties for people with visual impairments. The awareness of how the materials and shapes will reflect would reduce the risk of blinding problems.

The investigation aim to understand the incident ray and reflection angle between volumes according to the sun path of Gothenburg.

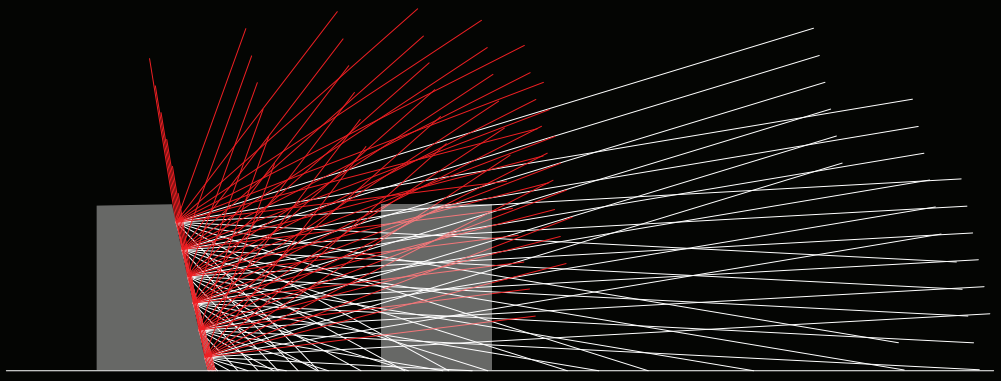
An average of 14° from the diagrams will be finally in a balance of previous investigations decide the angle for the inclined facades towards the courtyard.



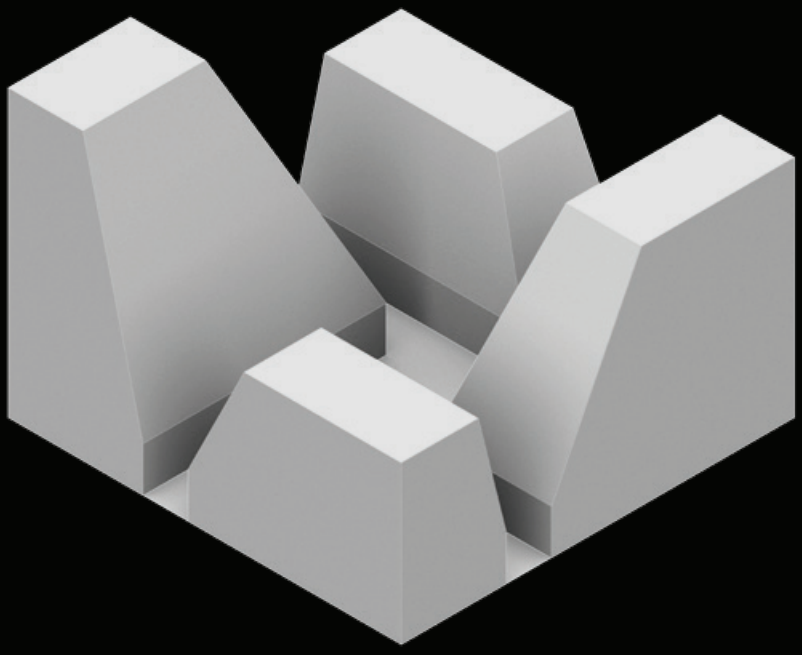
A 45 degree clockwise rotation of the volumes result in most reflected rays at the opposite volume at 12 degree vertical leaning for the incident rays hit.



A 45 degree counterclockwise rotation of the volumes result in most reflected rays at the opposite volume at 15 degree vertical leaning for the incident rays.



The amount of reflected rays hits the opposite volume horizontally and is not depending on the distance in between.



Axonometric veiw of final shape

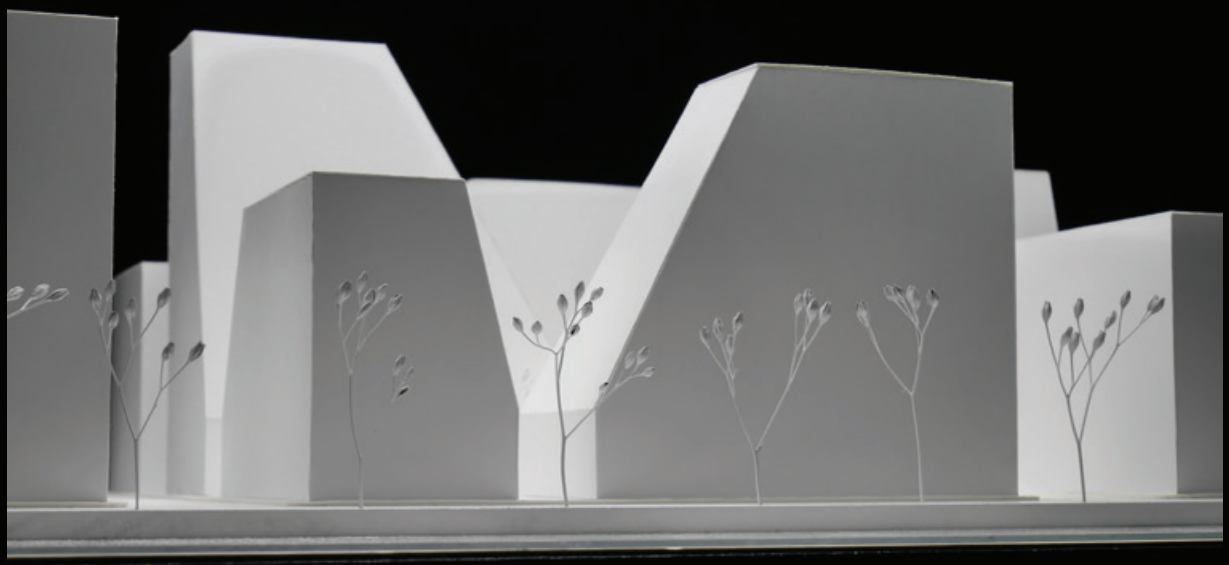
Final shape

The final concept model shows a transformation from a time-typical typology to a prototype based on a vision of improved light quality. The volumes are shaped by qualitative and quantitative evaluations decided through a collaboration of digital and analog research.

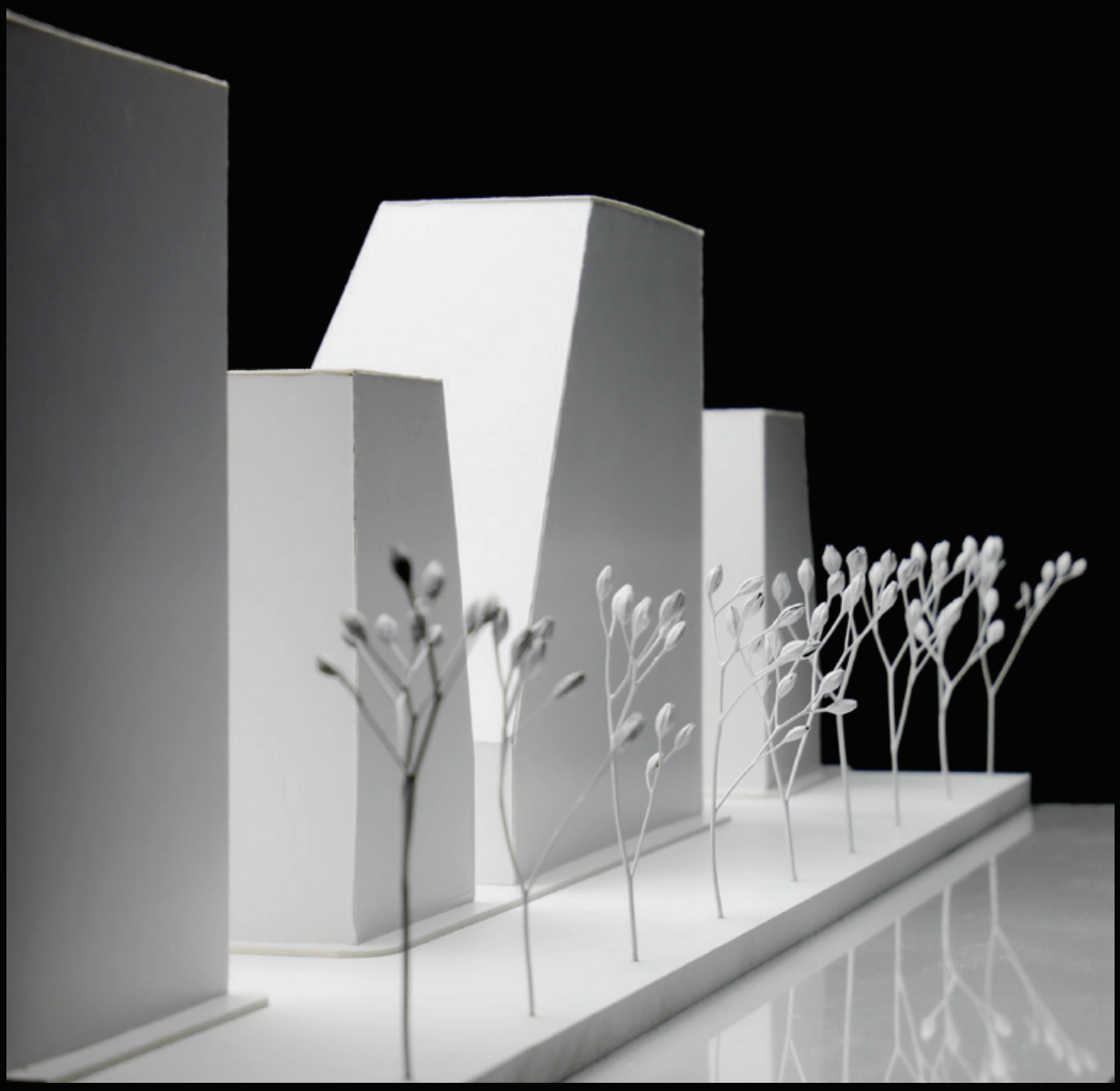
The final evaluation of the model is documented through a series of images taken with lighting conditions similar to sky lights in vertical direction. A comparison of the prototype with a closed block of the same density is finally compared by a qualitative and quantitative analysis.

The significant features of the investigations result in a prototype of quantitative and qualitative improvements in concrete calculations of solar radiation and experience of light. A simulation of the prototype indicates an increased exposure of sunlight compared to the typical city block. The lower inclined surface reflects the skylight and extend the viewer angle of the sky and creates a more spatial environment. The prominent angle for better shielding angle and the inclination towards the courtyard expand the void and follow the principles of the calculation model of Manhattan's stepping-down volumes.

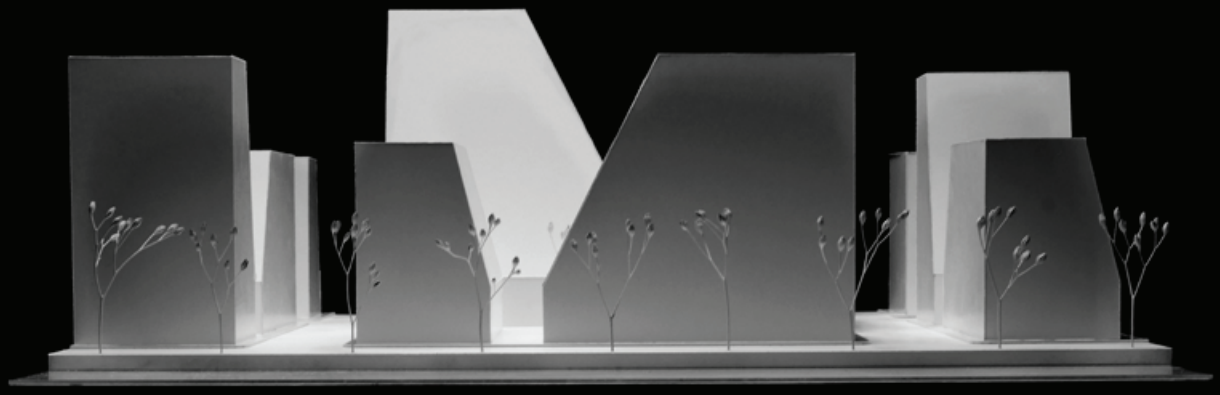
Section
Scale 1:750



Perspective - Final shape



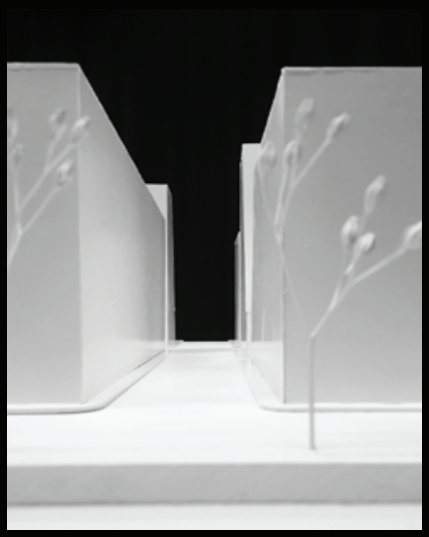
Perspective - Vertical facades and slanted, view from side



Perspective - Slanted facades in relation to vertical facades

Perspective - Groundfloor in relation to the sky

City block

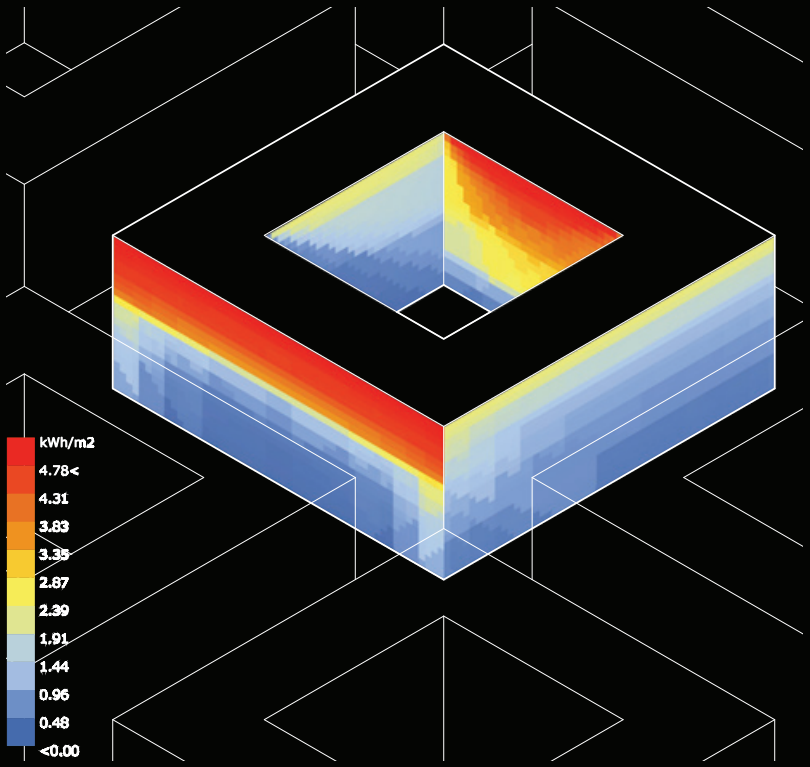


Perspective from street

Qualitativ analysis of a closed block

The lower height of the block blocks shading on surrounding buildings but forms dark corners through its closed unit. Depending on the height of the block and a smooth shadow image is created which can be critical for longer floors in the surrounding context.

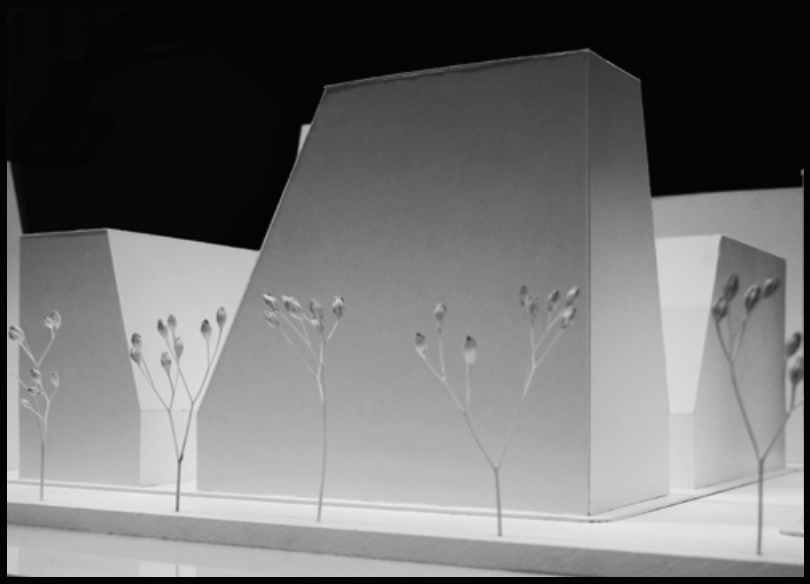
Perspective from courtyard



Quantitativ analysis of a closed block

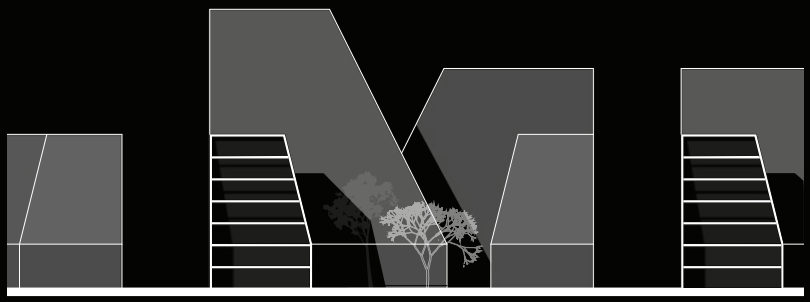
Proposed final shape

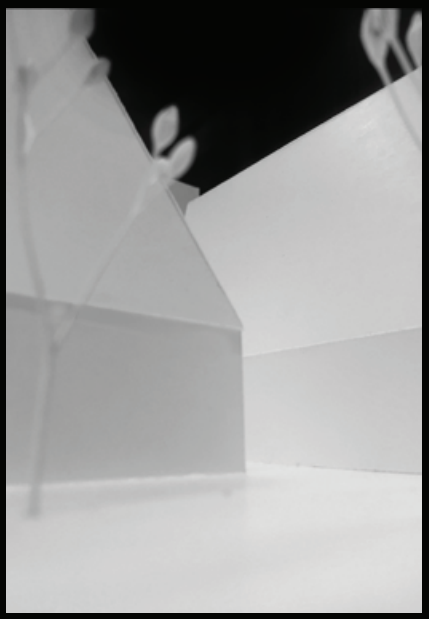
Perspective from street



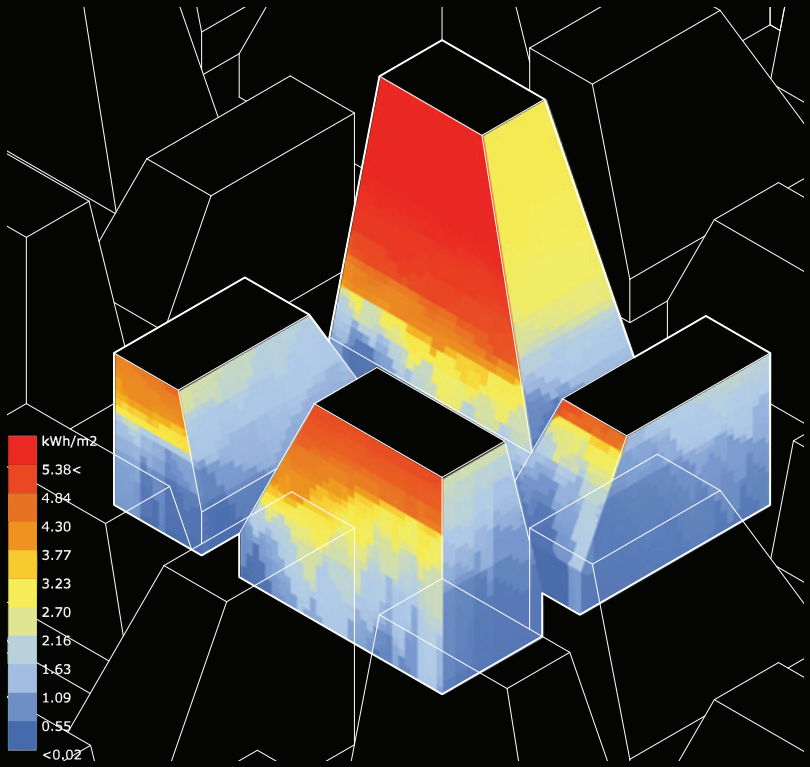
Qualitativ analysis of the prototype

The inclined facades are exposed by direct sunlight through the overlapping volumes and improved shielding angle from the inclined facades. Height is crucial for increased direct solar radiation but gives a longer shadow image on surrounding buildings. The digital simulation model shows a higher average of exposed facade surface with fewer square meters of critical low exposure.



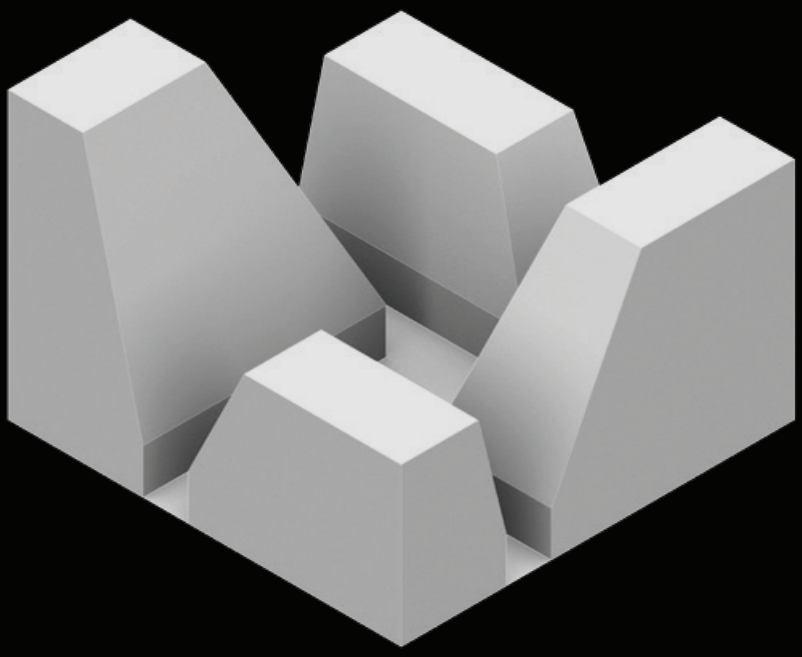


Perspective from courtyard



Quantitative analysis of the prototype

Facade



Model - Final shape

Transmitted light

Shadows and contrasts in different scales are equally important to navigate space and necessary for the eye to observe and understand shapes.

Shapes reflect and transmit light from the opposing surfaces and light source with a sharp or soft contrasts. A low contrast reduce the perception of high and low values of light but reduce the issue of blinding. The differens in light is a way of separating sequences and could be used as a design element for architects.

The aim of the study is to create an understanding for light and its transmission of different shapes. The features will be compiles into patterns based on the achieved features for further investigations.

Rectangular shape
The light from the exposed surface distributes equally according to the light source. Faded reflections hit the nearest edge on the unexposed surface. No major change happens from the different angles of light source.

Light coming from the left

Light coming from the right

Cut corners

The cut of a 45 degree angle reflected light from the exposed surface and illuminate the cut. Contrast from the non exposed surface and the cut corner dominate the light picture and creates a visually larger opening.
The reflected light of the cut surface appear when the opposing surface is exposed for light or when it is exposed itself.

Light coming from the left

Light coming from the right

Negative curved surface

Similar to the 45 degree cut the negative curve reflected light from the opposing surface. Variations in distributed light is depending on the angle of incidence from the light source. Because of the curved surface the light will transmit from the two edges with low contrast within the curve.

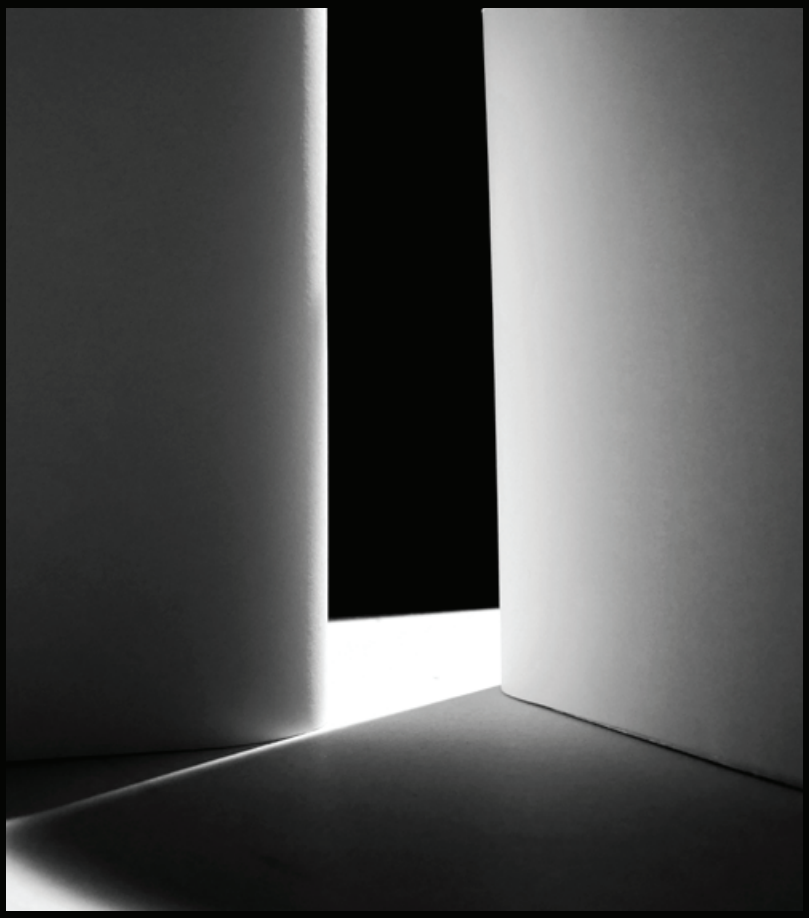
Light coming from the left

Light coming from the right

Large round corner

The curved surface reflects light from the opposing surface and transmit the light with fading contrasts. The features is not depending on the direction of the light source and creates a softer character for the volume. The low contrast reduce the perception of high and low light values but reduce the problems of blinding.

Light coming from the left



Light coming from the right

Small round corner

The small rounded corner shares the same features as the large rounded corner with low contrasts. The scale of the radius change the character for the volume but maintain the feature of a diffused transmitted light with fading transmission.

Light coming from the left

Light coming from the right

weaved surface

The weaved surface creates a variation of light expression and increase the amount of exposed area. The low contrasts reduce the risk of blinding and creates a soft character of the volume.

Light coming from the left

Light coming from the right

Saw cut surface

Depending on the direction of the light source the exposed surfaces will create higher contrasts to the non exposed surface. The contrast exaggerate the differens and the illuminated surfaces experienced brighter. Depending on scale for the element there is a risk of blinding if the eye will perceive too large surfaces and high contrasts.

Light coming from the left

Light coming from the right

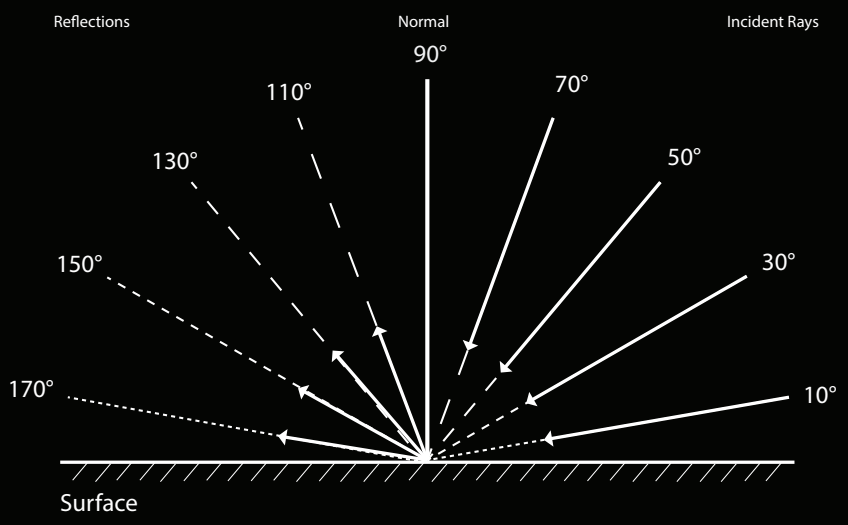


Diagram - Incident rays and reflection angle

Facade pattern

The facade constitutes an important reflection surface and a distributor of openings for the interior. The issue of preventing the facades to be exposed for the daylight depends on size of the building volume and its materials. Different expressions of lights differs if the facade is leaning, vertical, bent or folded.

A vertical facade is justified by having a plane surface in a 90 degree angle. Axiality in sight lines and lined up facades are beneficial for lower directed sunlight compared to high standing. But the efficiency of vertical facades result in difficulties to achieve a good daylight condition.

The aim is to establish the features from previous investigations to intercept reflections on a vertical and inclined facade exposed of skylight.
The developed patterns will be applied on the volume prototype and examine features in an inclined and vertical condition.

The importance of contrasts is to be able to distinguish distances and shapes,. Materials or shapes with higher contrast can mentally highlight objects in front of a lower illuminated background and is used for the upcoming investigation to take advatage of skylight in a vertical and inclined condition.

The significant features of the investigations result in a prototype of quantitative and qualitative improvements of light. A simulation of the prototype indicates an increased exposure of sunlight compared to a typical city block. The lower inclined surface reflects the skylight and extend the viewer angle towards the sky together with the surrounded inclined surfaces. The prominent angle for better shielding angle and the angle for diffused skylight expand the void and follow the principles of the calculation model of Manhattan's stepping-down volumes.

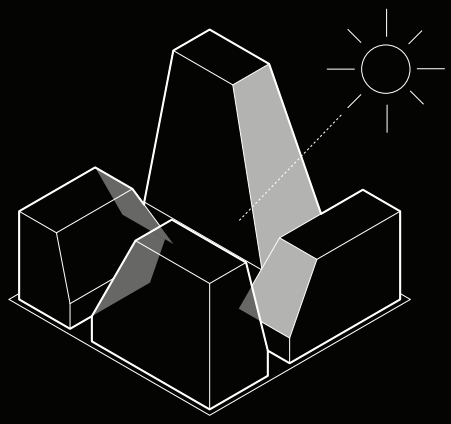


DIagram - Sunlight

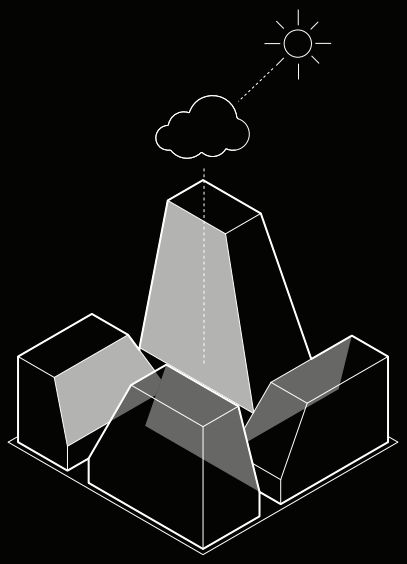
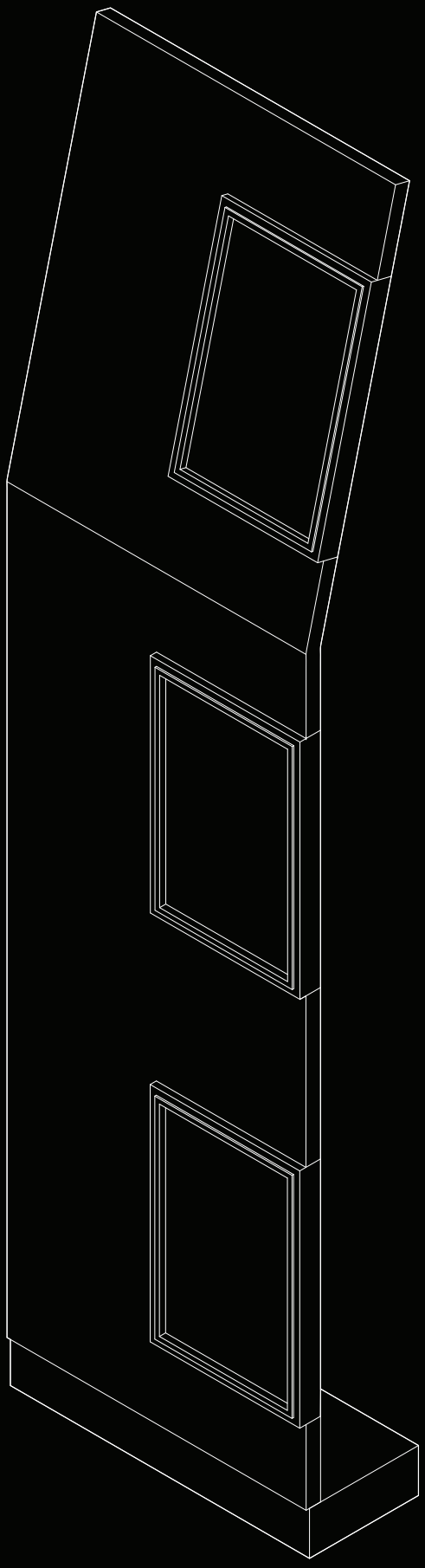
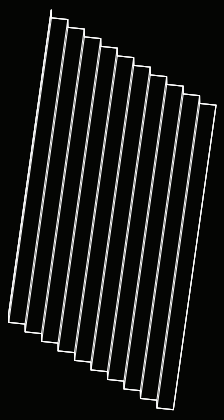
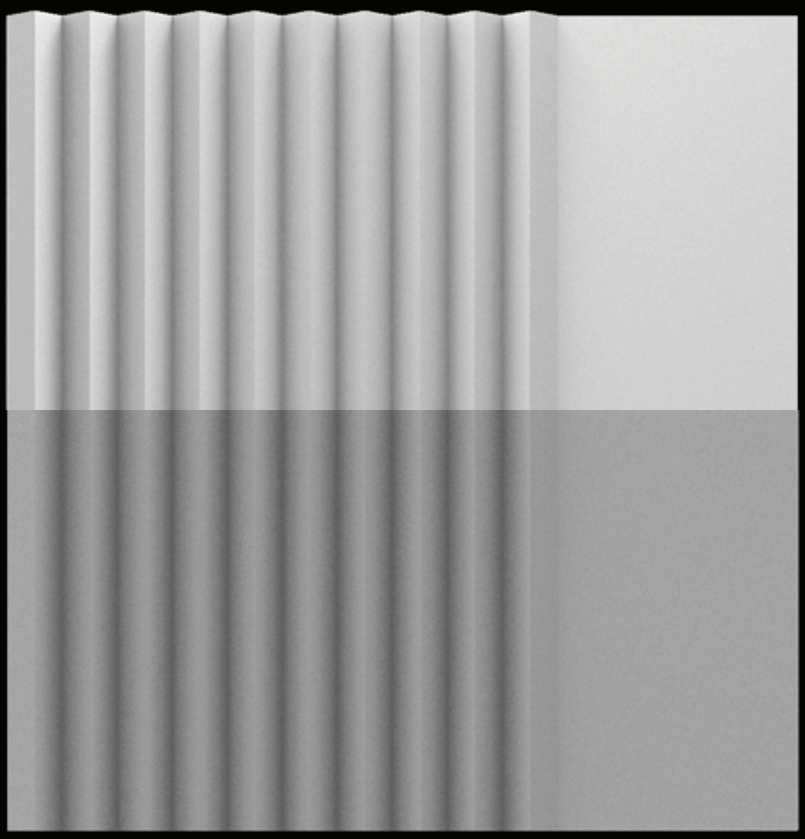


Diagram - The showed facade in the mockup for upcoming investigations

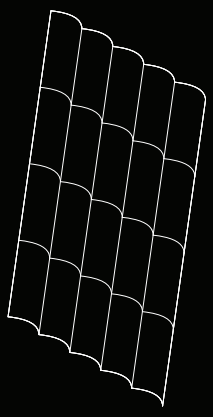


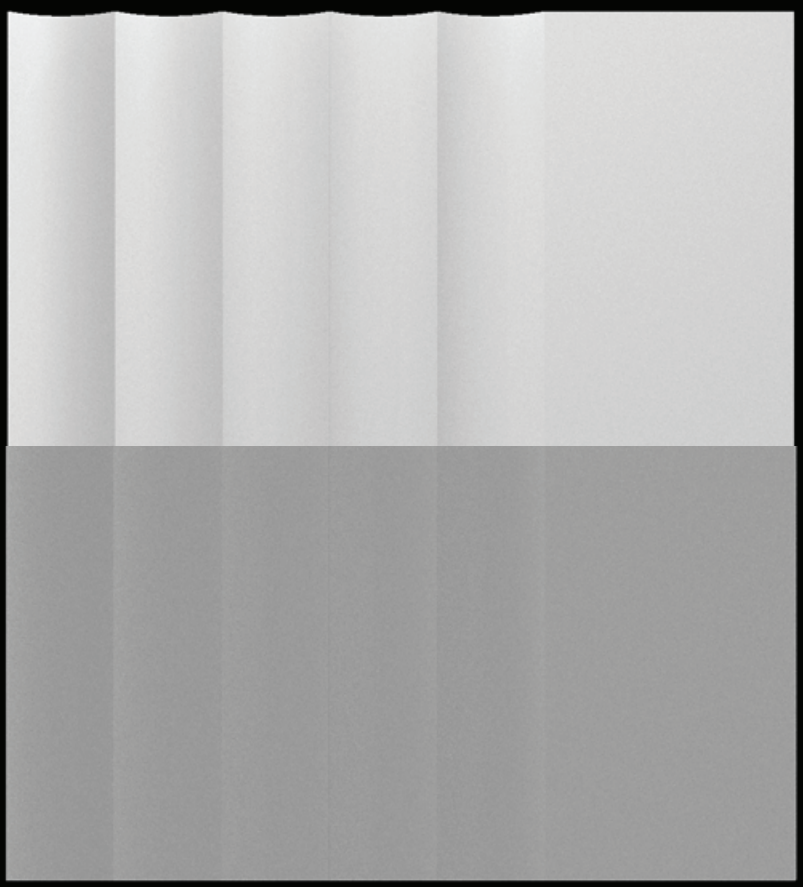




Folded

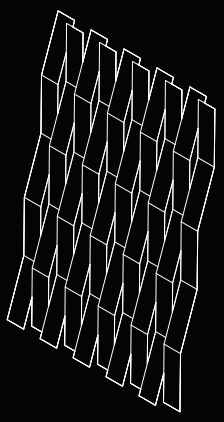
The features of the sick sack facade from the vertical skylight is not improved. The reflections from the sun-path would improve it's performance considering the two-sided facade.

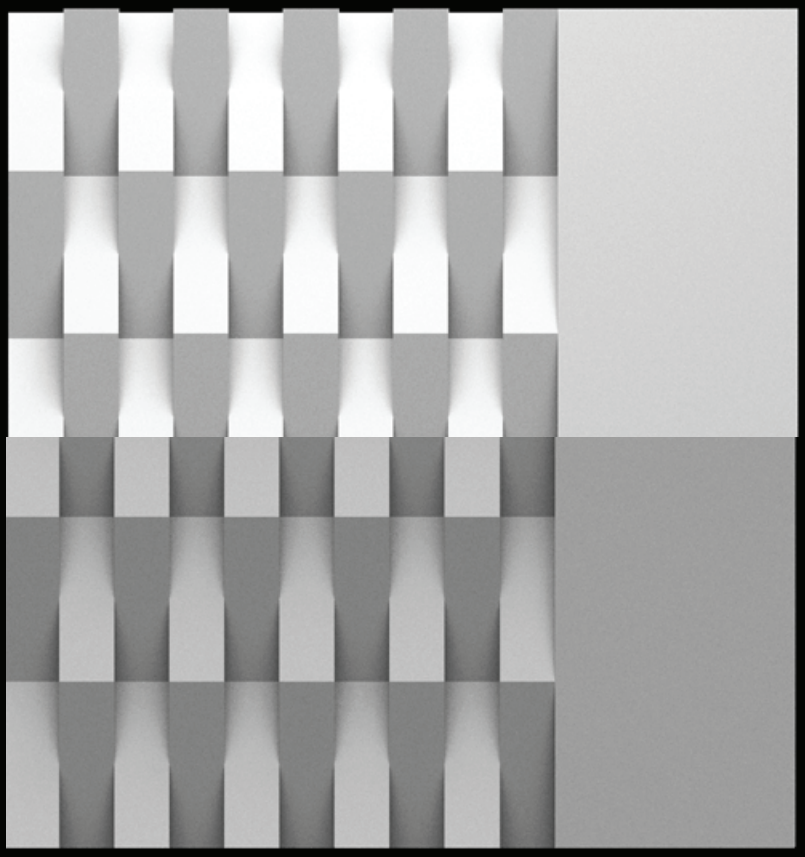




Negative Curve

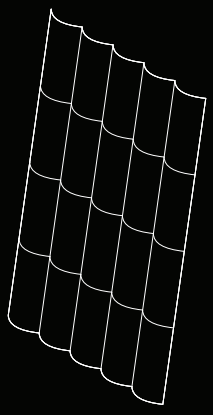
The vertical skylight lighten up one side of the negative curve on the inside with additional contrasts. The curved surface reflects from one angle of the incident ray into a spread out of angles for the reflected rays.

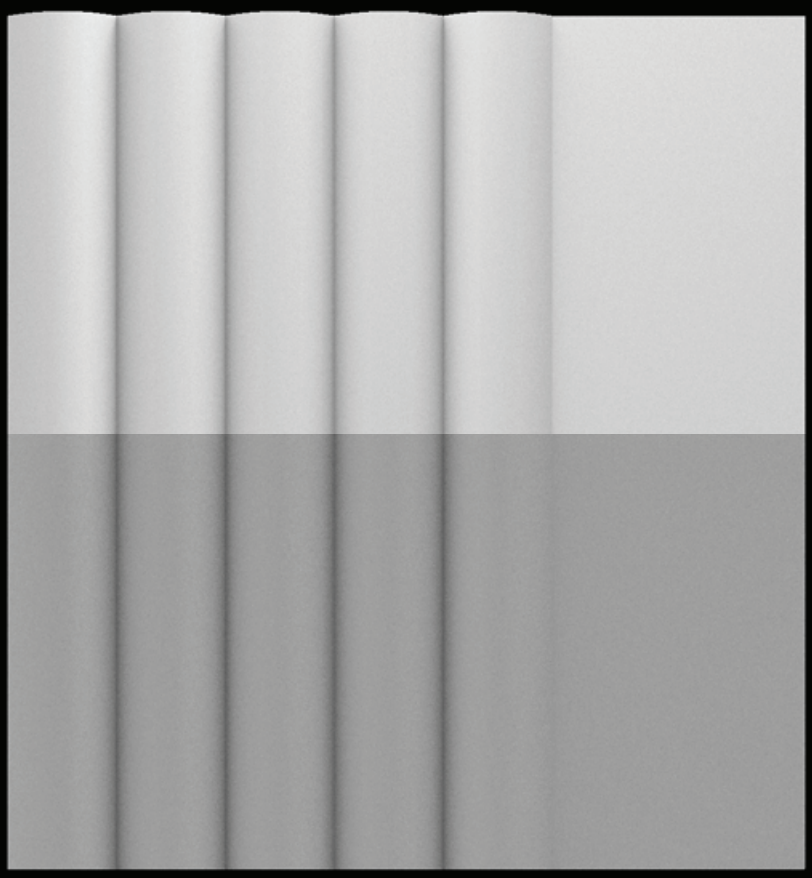




Braided

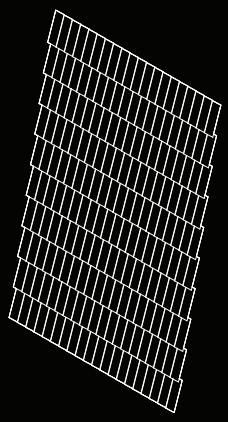
A braided facade panel in a vertical direction reflects the skylight and create a clear distinction of contrasts.



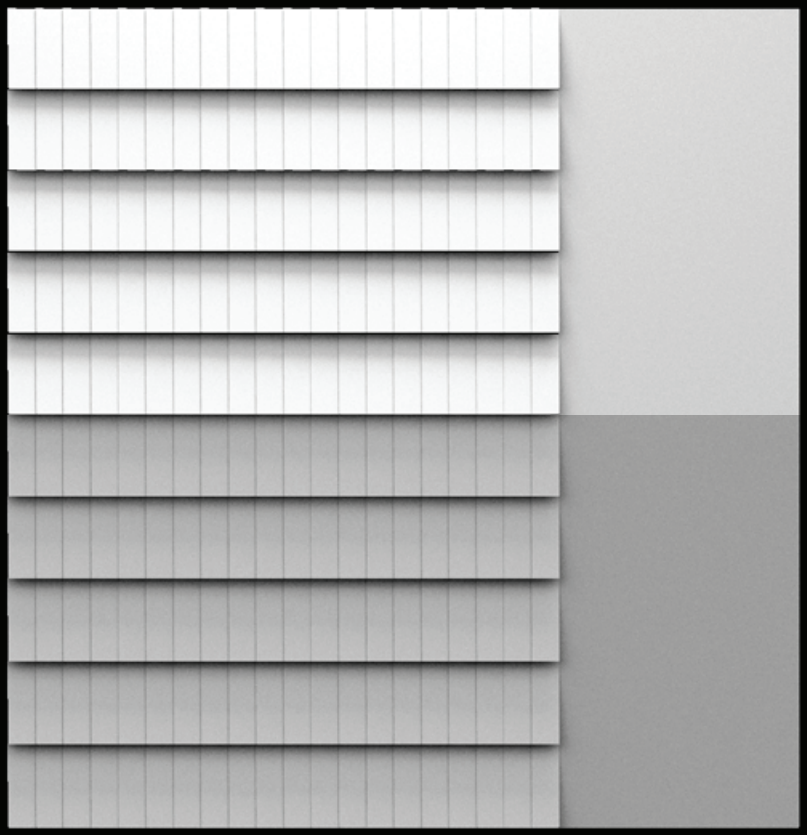


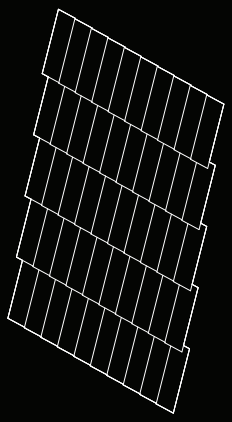
Round

The round surface from the physical model investigation has a limitation of sharpe contrasts. The curved surface reflects from one angle of the incident ray into a spread out of angles for the reflected rays.

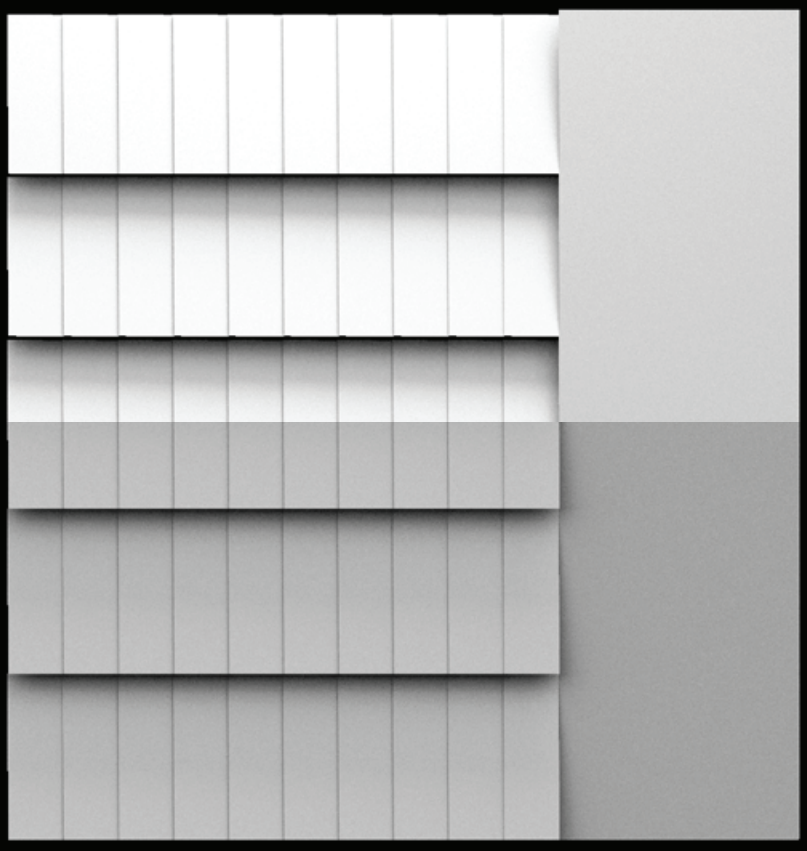


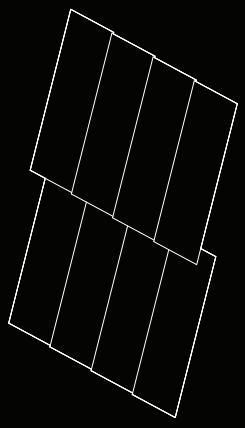
Small sized panels, vertical rotation
The vertical skylight reflects on the panels. The gap from the lower part of the panel creates a shadow and a sharp contrast between the two panels. The amount of light is not depending on the size of the panel.



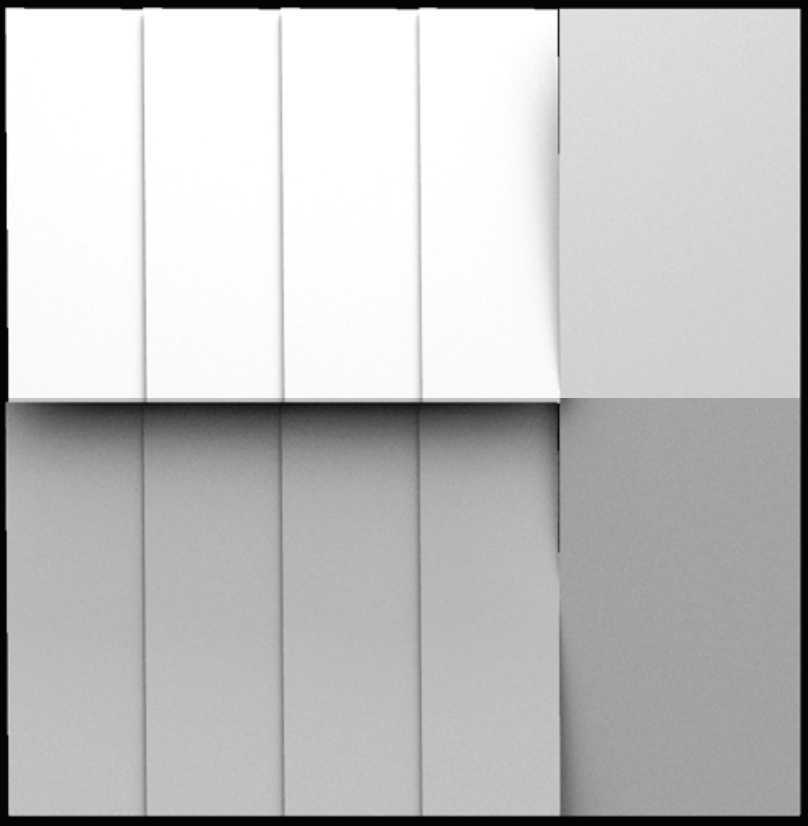


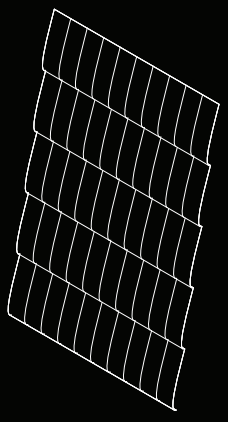
Medium sized panels, vertical rotation
Medium sized panels vertical rotated.
The medium sized panels has the same features as the small sized panels. Larger panels creates mentally a larger contrast.



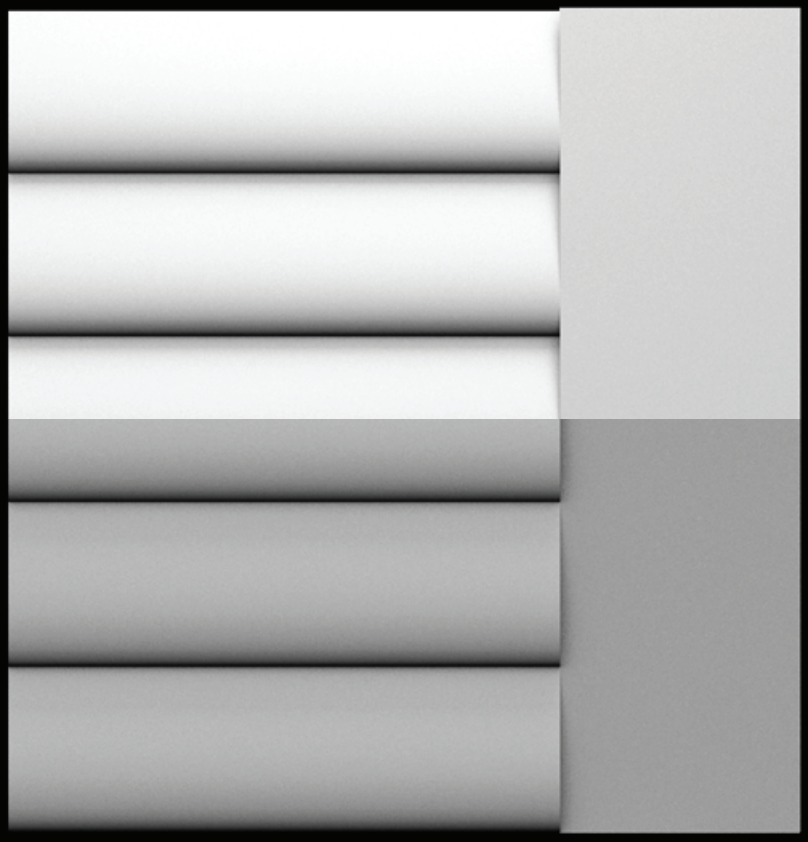


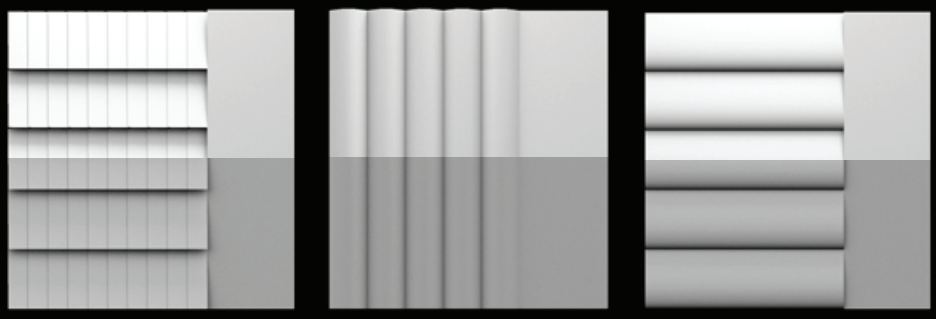
Larger sized panels, vertical rotatation
Depending on the size of the panels the our mind will think that larger panels are reflecting more light. The reason is an observed increased contrast between the surfaces.





Medium sized panels with round lower part. The vertical rotated panel capture the skylight. The rounded edge of the lower part remove the sharpe contrast. The less sharpe contrast does not make the panel perceived brighter but softer.





Selected designs that, together with previous investigations, proved effective for the purpose

Component

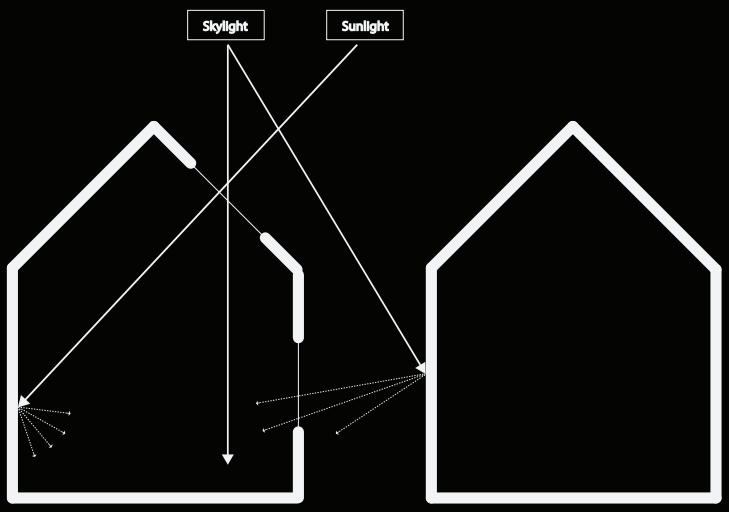
For a more detailed examination, the previous analyzes have been broken down into a scale of a component containing more abilities to then be a multiplied pattern on the facade.

The final expression aim to give a soft impression and reduces sharp contrasts in a horizontal direction to avoid blinding from direct sunlight.

The component is a result of previous investigations and compiles the features that have been shown to be effective for the purpose of an improved lighting environment.

The result contains several characteristics from previous investigations and has been compiled based on theoretical evidence and subjective decisions.

The component contains several char-

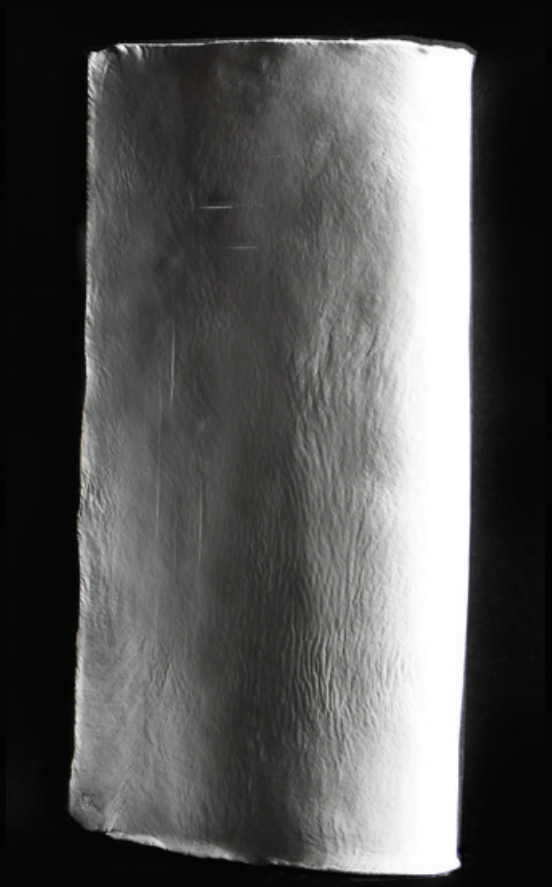

Skylight
Sunlight

Component 1

The slanting surface captures the diffused skylight from above by not being vertical. The light travels to the lower edge and transmit the light with a low contrast. As a larger assembly result in horizontal expression with abilities to intercept light from above. The rounded shape of the lower edge, according to the investigation ''physical models of transmitted light'' shows the low risk of blinding because of the low contrast.

Component 2

The vertical component does not have any certain abilities to absorb skylight. The main feature is to lower the contrast by transmitting the light sideways. The features of the component is based on light according to the sun path and causes vertical variations in the facade. The rounded shape of the lower edge, according to the investigation ''Transmitted light'' shows the low risk of blinding because of the low contrast.



Component 3

The cone shape transmit light because of its round shape with low diffused contrast from non vertical skylight. The three-dimensional shape reflects/absorb light in a 180 degree angle and captures vertical skylight by the inclined angle of the surface. The lower edge creates a high contrast in an assembly of many and depending on size of the components there is a risk of blinding.
Depending on the material a round shape creates a variation of reflection angles that with a glossy surface would avoid glare on opposite side.

Component 4

The three-dimensional shape has the same features as ”component 3” but differs from the low contrast of horizontal transmutation of light. The sharp vertical edges increases the contrasts and creates a sharper expression for the facade. The critical issue of blinding from the strong contrast is depending on the size of the component.

Section of component

View of component from the right

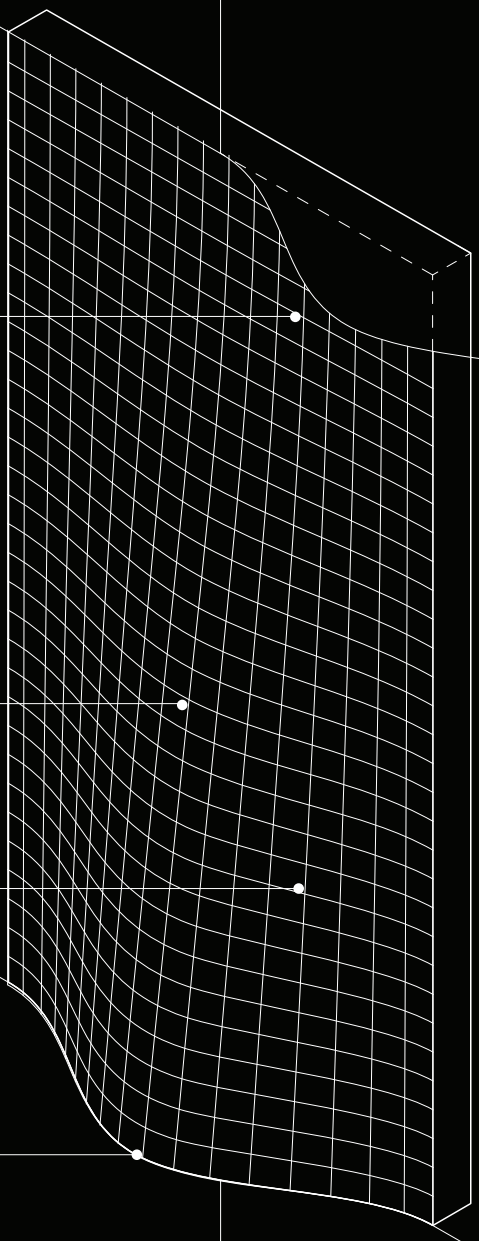
The proposed component in meant to be an investigated proposal with the features applied from previous iterations. Scale of the component is only relevant for the expression of the facade and as earlier mentioned in the chapter ''Facade patterns'' a high contrast of two larger surfaces will create a risk of blinding.
No material is applied at this point and depending on reflection value for the selected layer the features of the component will change.

The upper facade components curved part will cast a shadow on the surface below and create a high contrast. The high and low lightness exaggerate the differens and highlight the lit surface.

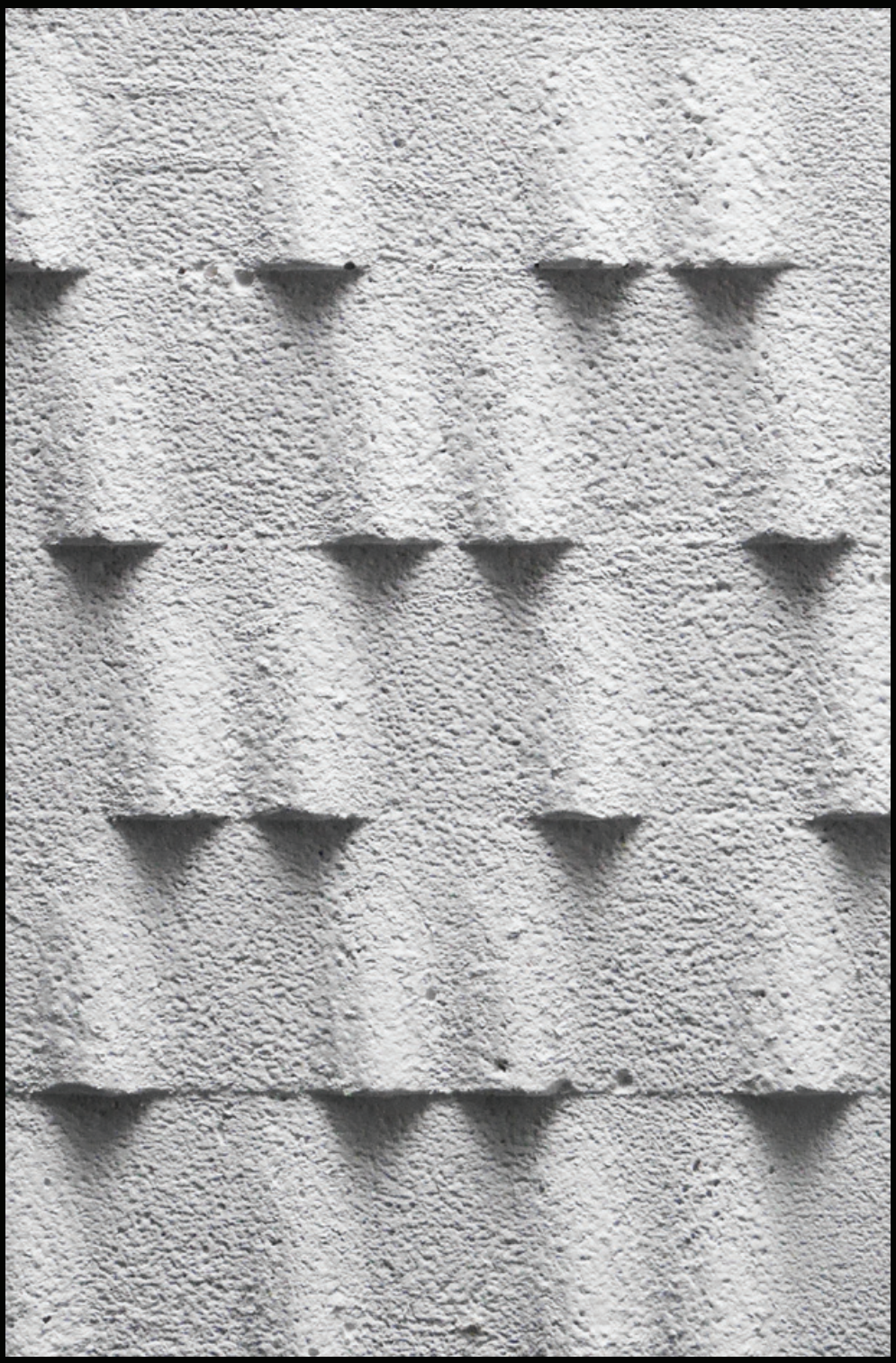
According to the ''diffused light'' investigation, reflections from the skylight will lit the leaning surface.

The three dimensional surface is able to reflect light coming from a 180 degree angle of the sun path.

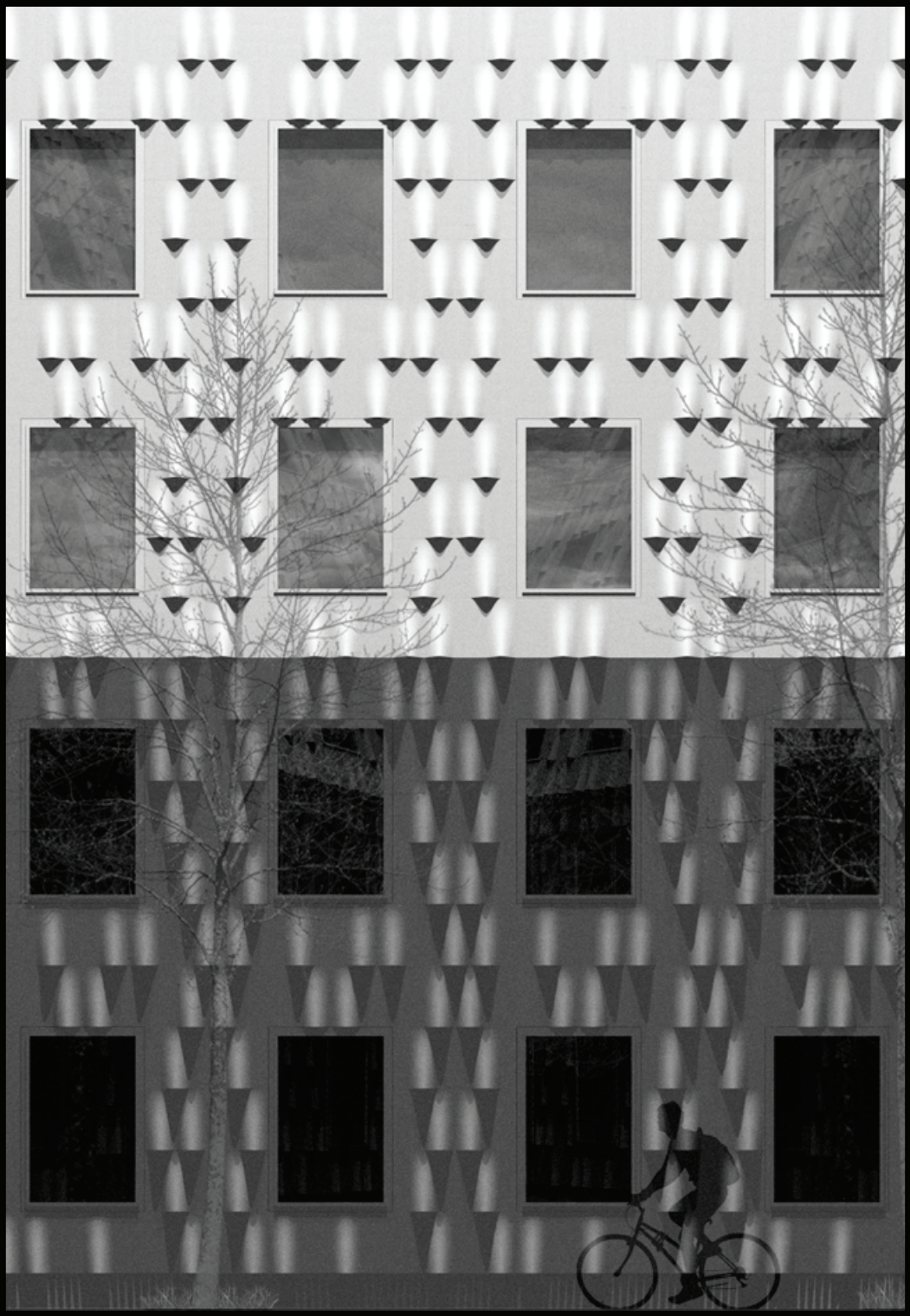
The curved surface creates a softer transition and a variation of lit areas for a more lively facade expression.



Axonometric view of suggested component

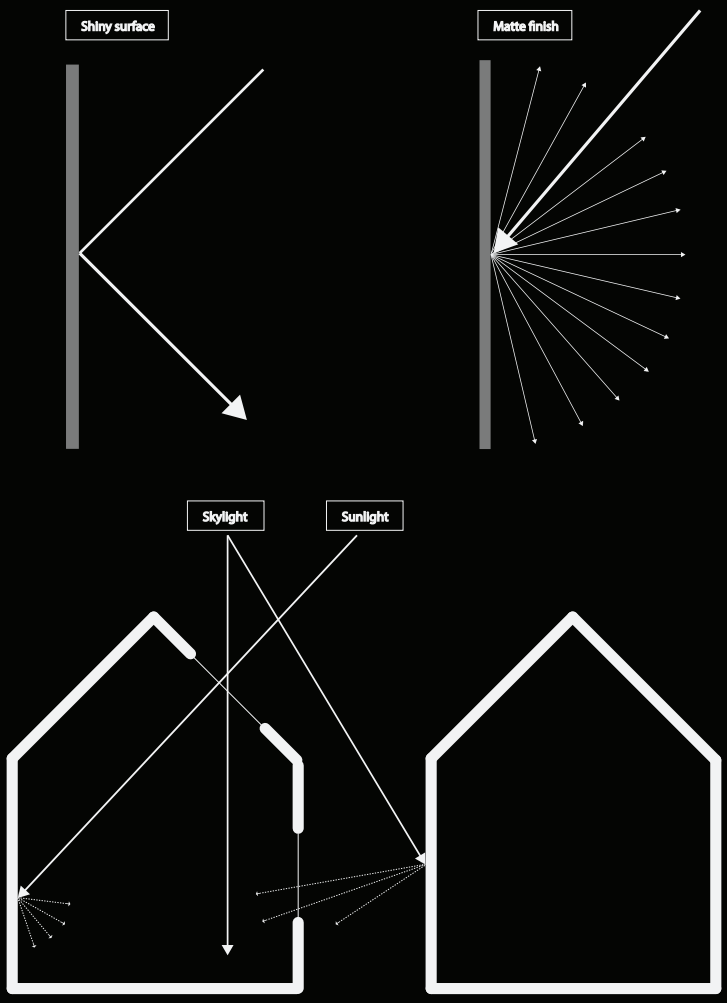


Facade pattern from component



Suggested proposal for facade

Materials



Reflection value

Reflections enhance the visual experience by telling us about the nature of the material and its shape. By using reflections in a context it creates a sense of the room by movements. When our position is being shifted the reflections from the light source change and reflects against our eyes as we move.
Reflective materials in an environment means an increased risk of glare. To reduce vision impairment is it important for the light to reflect in right direction. Reflections explain shapes and materials and gives the environment its character. The position from the light source reflects along the movement of the eye. Bad positioning of reflecting materials can creates difficulties for people with visual impairments. The awareness of how the materials and shapes will reflect would reduce the risk of blinding problems.

Reflection value of different materials

- Aluminum, pure, highly polished 80 - 87
- Aluminum, anodised, matt 80 - 85
- Aluminum, polished 65 - 75
- Aluminum, matt 55 - 75
- Aluminum coatings, matt 55 - 56
- Chrome, polished 60 - 70
- Vitreous Enamel, white 65 - 75
- Lacquer, pure white 80 - 85
- Copper, highly polished 70 - 75
- Nickel, highly polished 50 - 60
- Paper, white 70 - 80
- Silvered mirror, behind glass 80 - 88
- Silver, highly polished 90 - 92
- Oak, light polished 25 - 35
- Granite 20 - 25
- Limestone 35 - 55
- Marble, polished 30 - 70
- Plaster, light 40 - 45
- Plaster, dark 15 - 25
- Sandstone 20 - 40
- Plywood, rough 25 - 40
- Concrete, rough 20 - 30
- Brick, red 10 - 15
- Paint, white 75 - 85
- Paint, medium grey 25 - 35
- Paint, dark blue 15 - 20
- Paint, light green 45 - 55
- Paint, dark green 15 - 20
- Paint, light yellow 60 - 70
- Paint, brown 20 - 30
- Paint, dark red 15 - 20

The list of reflection values derives from: www.engineeringtoolbox.com

Matte Surface

The matte surface reflect solar radiation or skylight and diffuses the light. The lit surface reflect light without glare and the variation of high and low values will be distributed differently depending on shape the material is applied on. A risk of over exposure is possible with a larger surface or bright color.

Semi-glossy surface

Glare appear when the eye has difficulties to adapt to contrasts. A disturbing glare for the eye is when a large light area is too bright for its context but by increasing the surrounding light or level the light surface the glare can blend in.

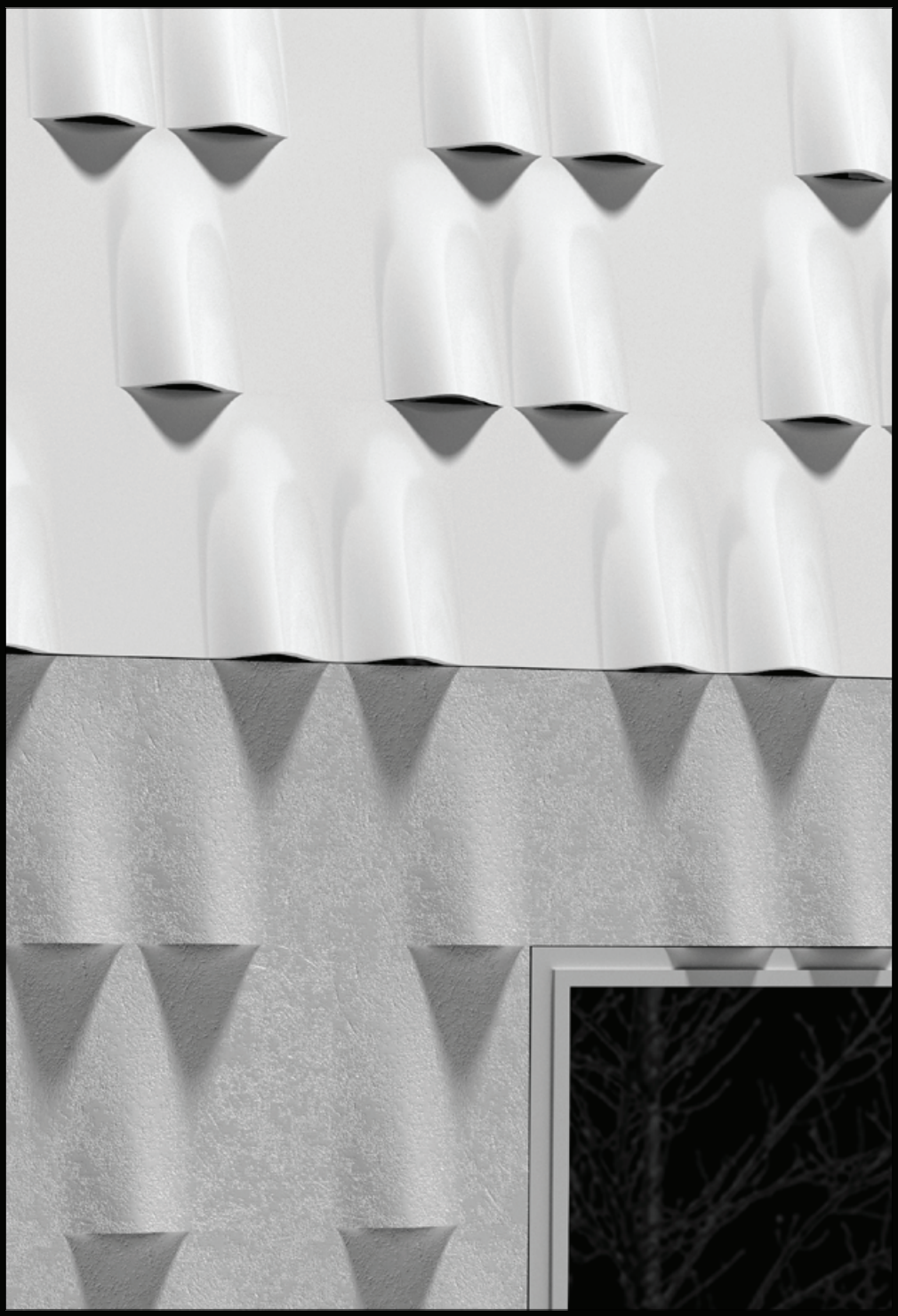
Also has the semi-glossy surface the ability to reflect solar-rays with reduced glare depending on the reflection value of the materials and facade expression, see figure for reflection value.

Glossy surface

Glare appear when the eye has difficulties to adapt to contrasts. A disturbing glare for the eye is when a large light area is too bright for its context but by increasing the surrounding light or level the light surface the glare can blend in.

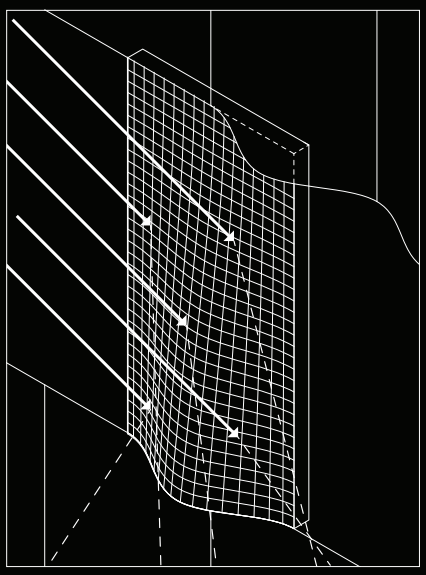
Matte surface with pattern

A rough surface reduce the blinding from the shaded pattern. Depending on the distance of the observer the small variations on the surface blends together. A glossy surface would reduce blinding from reflections because of its irregular layer.

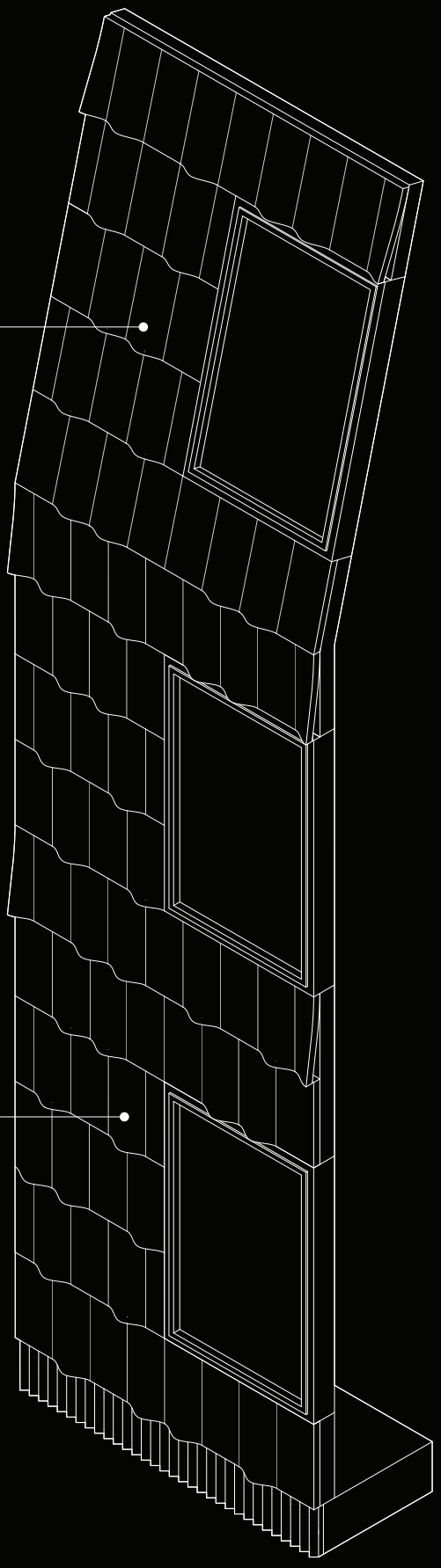


Materials - The inclined facade with a semi-glossy material in relation to the vertical with a matte/rough layer.

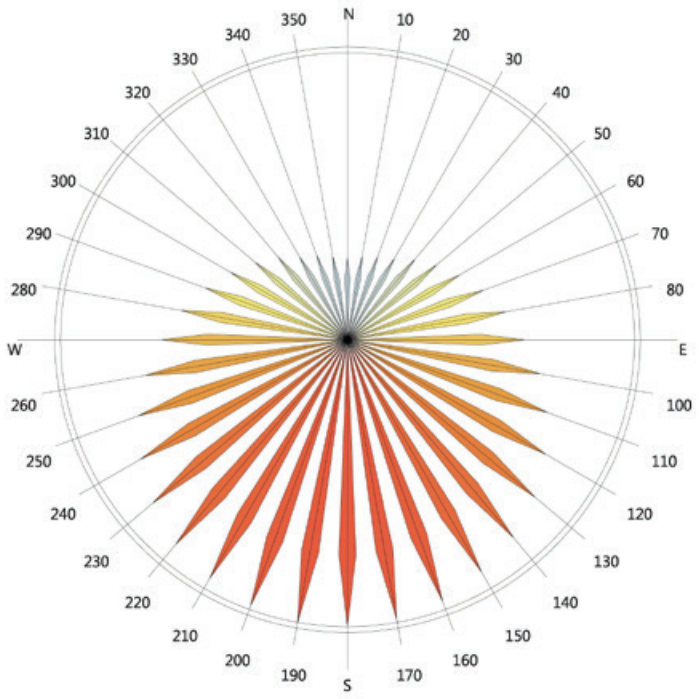
To enhance the abilities of the different facades, different materials have been applied depending on function. The inclination is capable of reflecting direct sunlight from buildings on opposite side and intercept vertical skylight. The inclined facades make up a major part of the buildings exterior and should therefor avoid a too glossy material for the risk of glare. A semi-glossy material with the ability to reflect and illumination would, depending on the reflection value be the crucial balance of an asset or blinding surface.



The chosen material for the vertical surface of the building's foundation has a rough matte layer to illuminate the non-exposed surface from skylight. A complete matte surface depending on reflection value would pose a risk of over exposure from direct sunlight.



Proposal



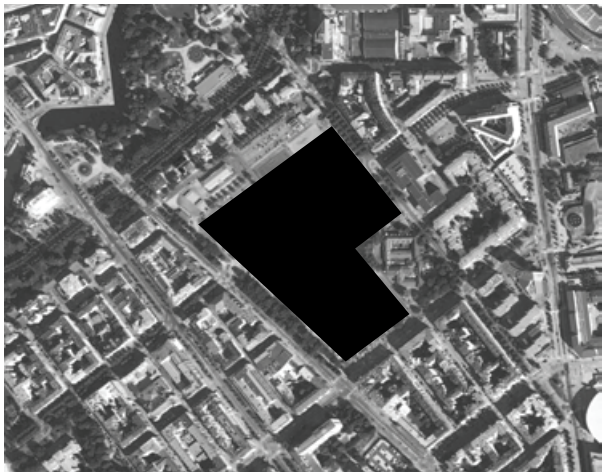
Distribution of solar radiation for Gothenburg

Site

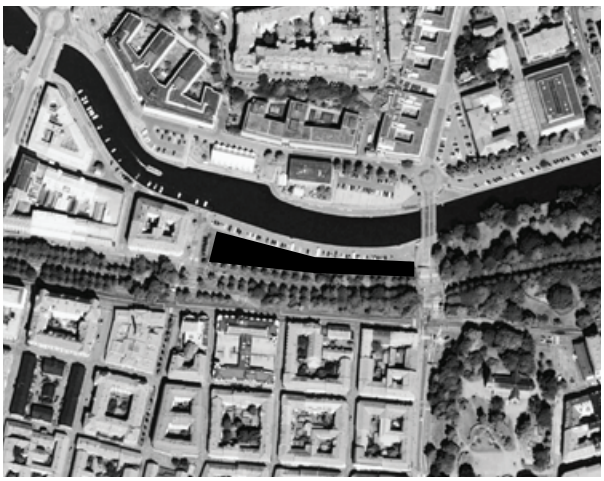
The best location for the prototype to be placed would be in an already crowded area considering its high density. The chosen site at Frihamnen in Gothenburg is a current site where new construction is planned.
The site is located where its necessary with high floor area ratio and especially for affordable dwellings.

Defining the foot print will be decided depending on the sites boundary. The site could be divided into individual areas where freestanding volumes could be placed or the site could consist of the prototypes "pattern" depending on the level of wanted density.

Frihamnen, Gothenburg



Heden, Gothenburg

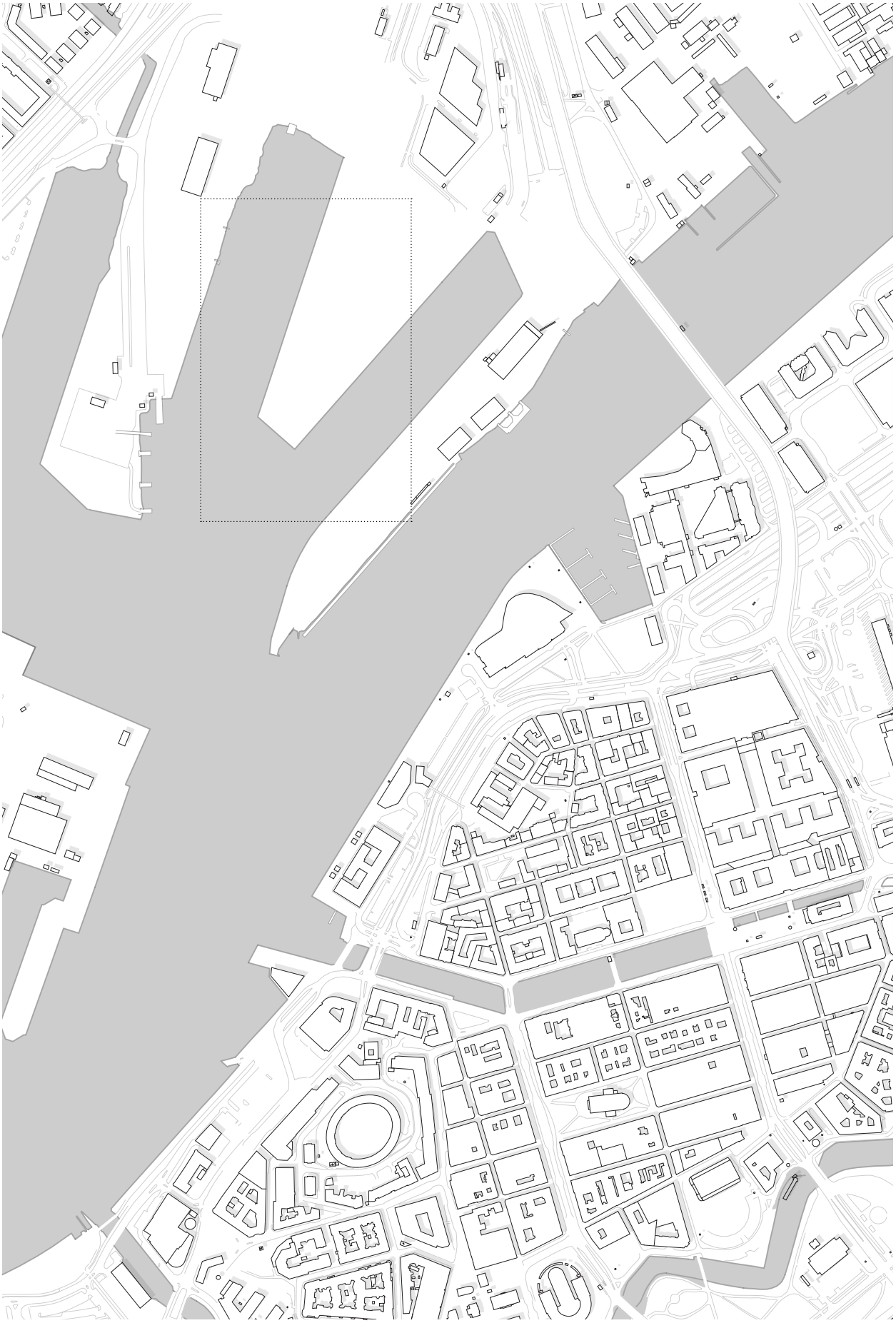


Masthuggskajen, Gothenburg

Suggested proposal

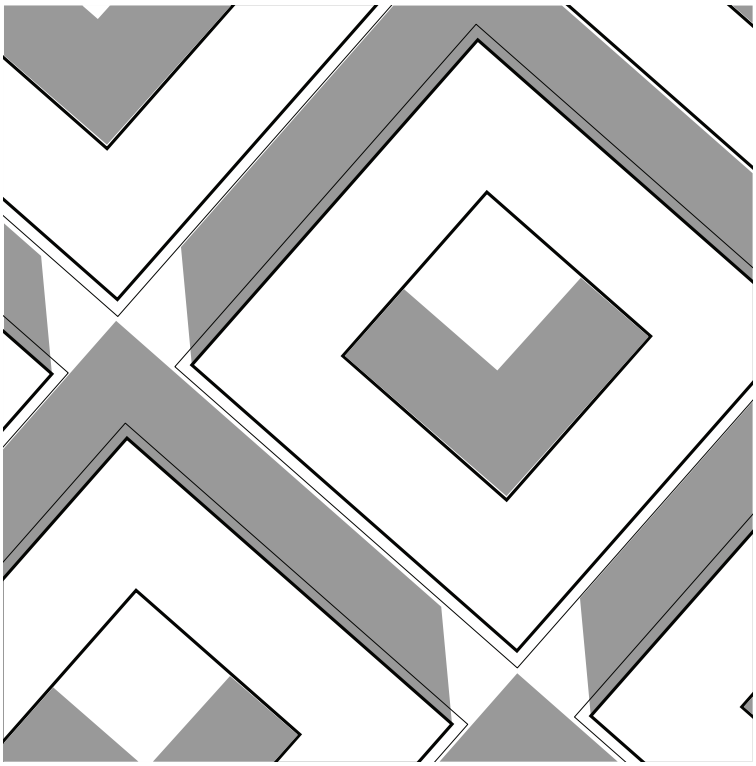
The proposal is a result of the methods that show how the different iterations could be applied. The methods from the investigation are intended to inspire and propose possibilities for improved daylight design in new constructions. The applied prototype is not an alternative for the prevailing proposal but rather a suggestion for implementations on a concept level.
The thesis is about the methodology and process but put the prototype in a context and realize it on a current site.

The final prototype would in a further investigation deal with contextual issues and develop from a concept to a real proposal. The current status of the proposal is a result of investigations only for the purpose of improved daylight condition



Areal view of Gothenburg and site
Scale 1:10000

The typical city blocks constitutes a solitude with large shadows with openings for low directional light only between the blocks. The overall lower height compared to the given prototype has a shorter throw length of the shadows but darkens larger areas.

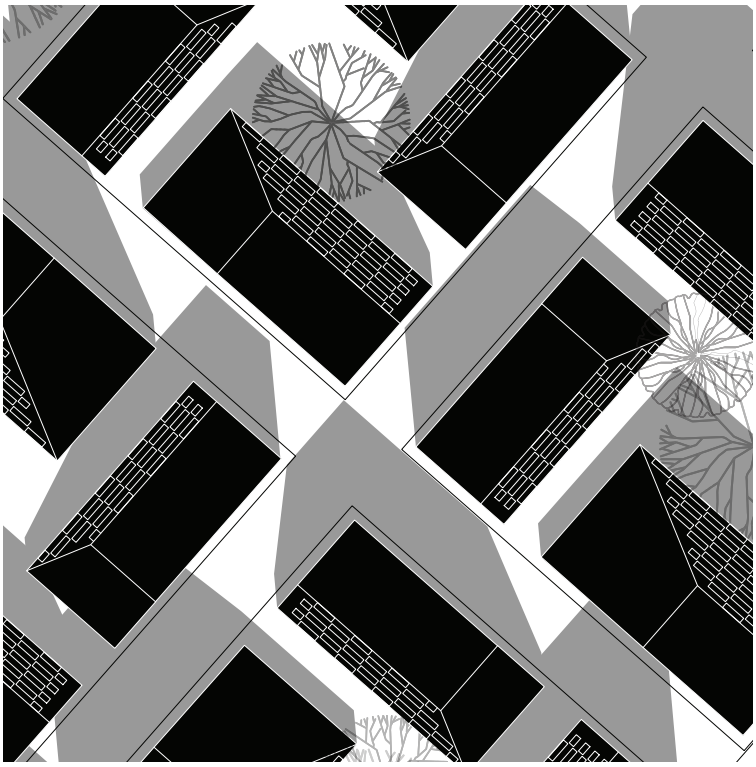


Typical city block
Scale 1:1000

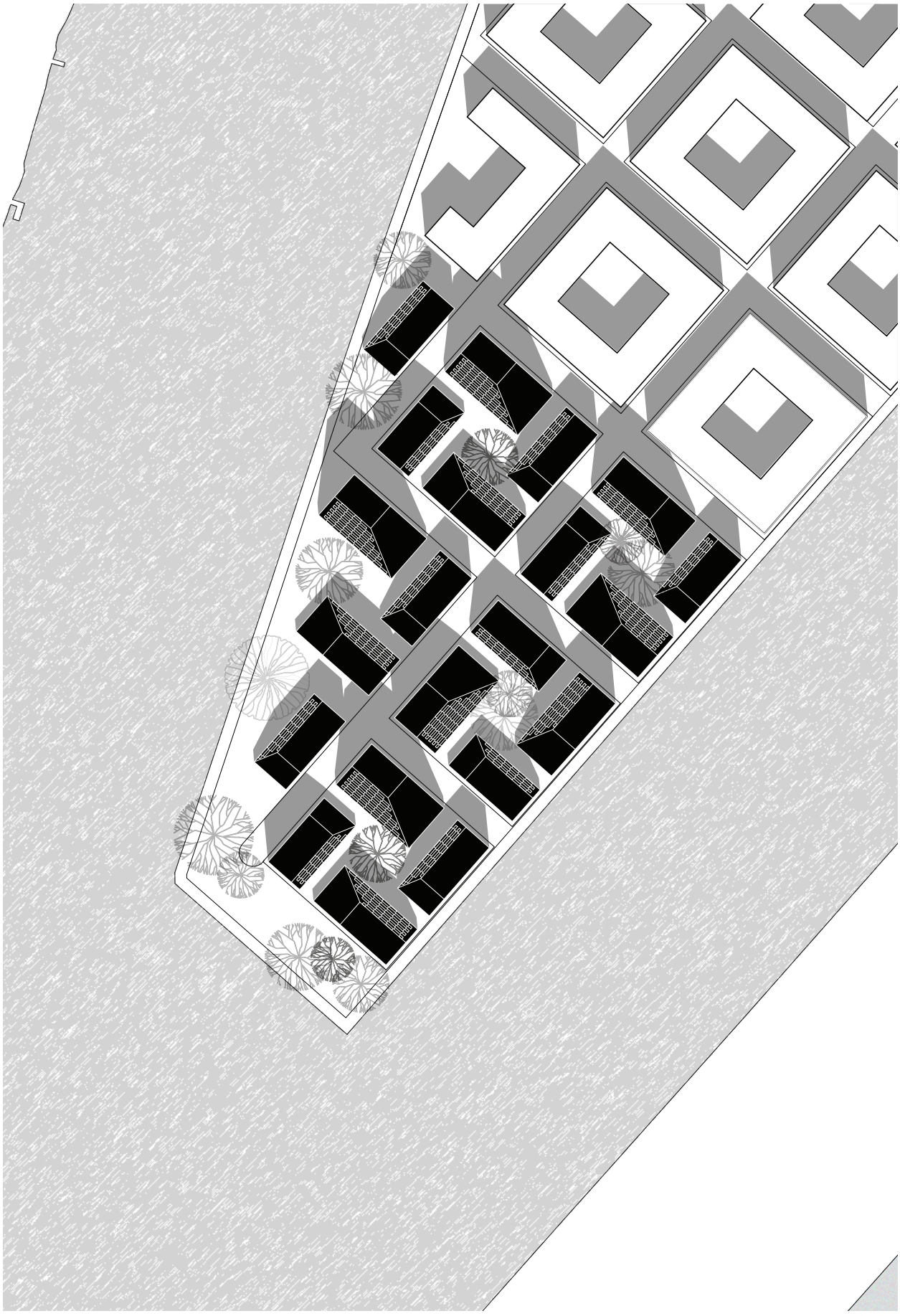
The prototype provides a varied shadow image and more openings for the direct sunlight to reach surrounded buildings. Shadows from the higher buildings have a longer throw length but for a shorter period for each individual dwelling. The inclined facades reduce the throwing length of the shadows and the opposite building gets higher exposure to the direct sunlight.

As a subjective assessment, the proposed prototype has a wider wide angle from the courtyard to the sky and is therefore perceived as a more spatial place.

The advantages of a typical city block are the low height and width of the volumes compared to the prototype's wider foundation. What has been reduced from the city block is the corner of the courtyard which provides hard-to-reach spaces for light to reach. These corners in the prototype have been replaced with vertical openings with inclined facades that constantly increase the distances between the volumes parallel to the height.



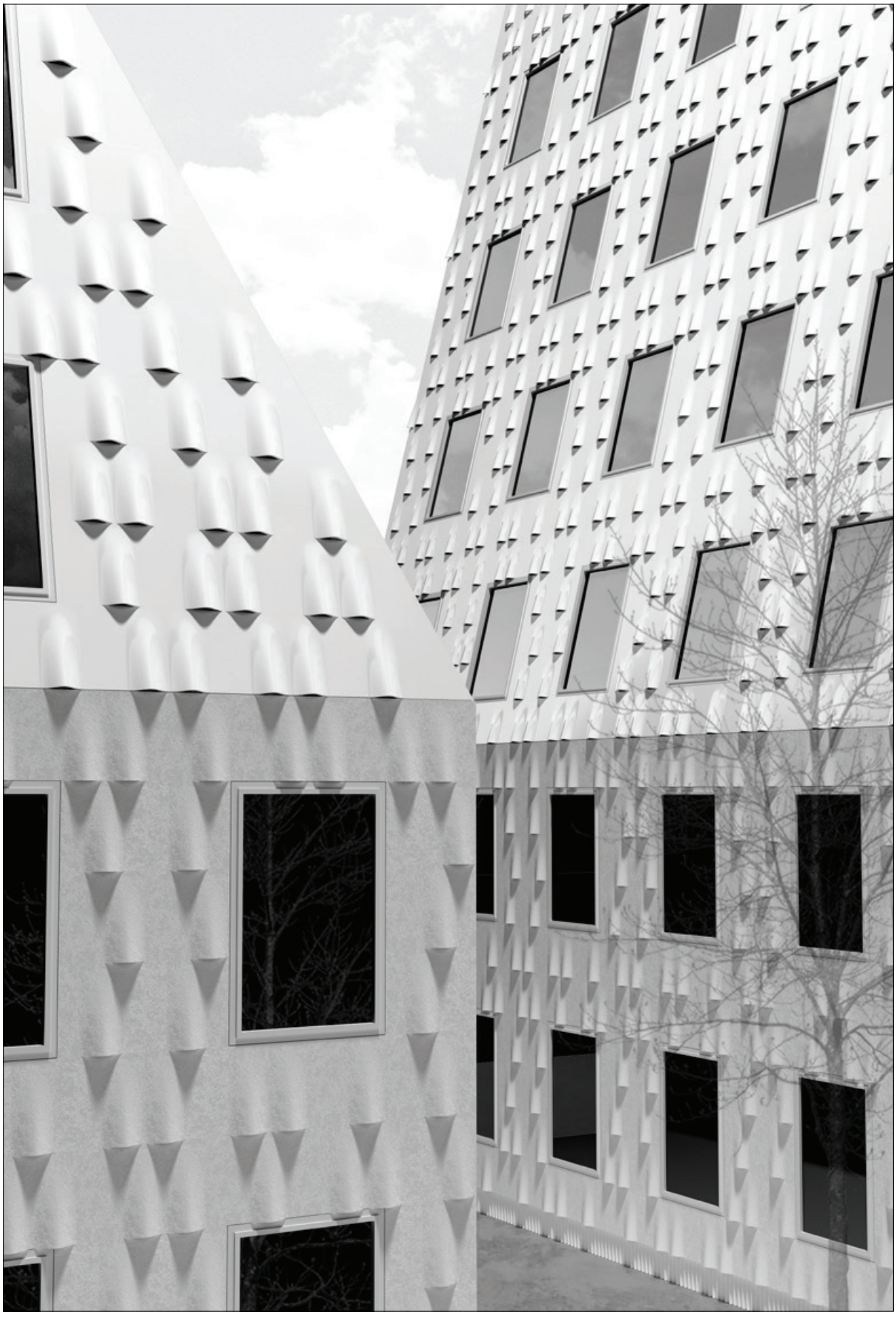
Proposed typology
Scale 1:1000



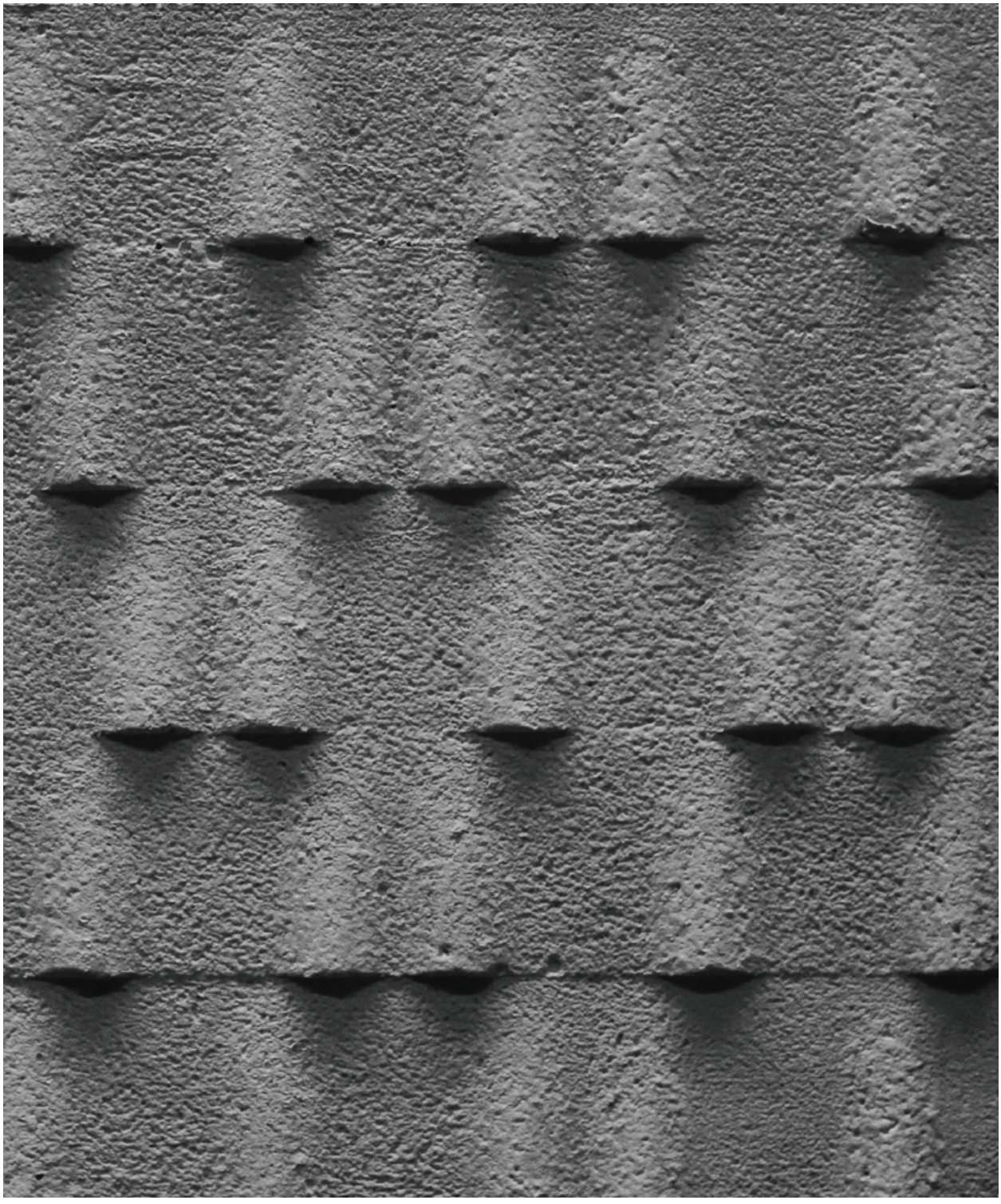
Proposal for Firhamnen in Gothenburg
Scale 1:2000

Facade exposed for skylight

Facade exposed for sunlight



Perspective of proposal



Facade expression and materials

The importance for the thesis and further work is that the aim of the surveys does not lead to a form of a practicable building. The results are conceptual interpretations of the phenomenon of light rather than a proposal of an architectural concept.
The given proposal will still be far away from any final result and the strategies and the scope in a future extension requires a greater refinement and adaptation than is here evident.

Final thoughts

Final thoughts

A densification is the ideal of an urbanization from a social, economical and ecological perspective. A higher density of buildings will increase the population, prevent segregation and reduced distances for functions with easier access within the city.
Larger cities are extended both horizontally and vertical to provide the urbanization but from an increased densification emerge problems of not having access to enough daylight. The result of the city's expansion of today could according to Boverket (2016) have a negative effect both on our health and environment in the future.

The early work of Hugh Ferriss for manhattans zone regulations shows that visibility of the sky enhances the experience of a brighter environment. A verticality in an area is not necessarily the main cause of not having enough light but rather how dense and narrow buildings are standing next to each other.
A larger void between buildings gives better access towards the sky and results in a better access for daylight. This thesis investigates the benefits of using inclined surfaces and how skylight can become a tool for better daylight condition in relation to the exterior.

This thesis is an investigating ''design by research'' project of different methodologies applied on a prototype for dwellings. The result is based on daylight condition from investigations of quantitative/qualitative data and strategies for potential improvements on how building volumes can interact with exterior surfaces.
Finally the prototype examine differences compared with a typical city block in term of concrete values and spatial experiences.

The angle of the facades does not only affect the direct sunlight but also changes the condition for reflected light. Reflections are taken into account when new building are being planned in terms of materials with better reflection value to attain the requirements. But the potential of using diffused light in a greater extent creates a tool to apply in any scale.

The exploration of new forms may be necessary to meet the urbanization of the future. But if future requirements for lighting conditions in new buildings constitues of qualitative assessments, then the awareness of daylight design becomes decisive for architects.

Litterature

Print

Lobell, John. 2008. Between Silence and Light: *Spirit in the Architecture of Louis I. Kahn*. Colorado: Shambhala Publications

Ferriss, H. 1929. Metropolice of tomorrow. New York: Ives Washburn. E-bok.

Sundborg, Bengt. 2010. Ljus i bebyggelsen : *om stadsplanering och arkitektonisk utformning.* Värnamo: Fälth & Hässler AB, Svensk byggtjänst

Tregenza, P, Wilson, M. 2011. Daylighting: *Architecture and lighting design*. New York: Routledge

Articles

Alenius, Malin, Dahlberg, Johan, Lundgren, Marja, Cederström, Caroline. 2019. Dagljus i stadsplanering. Stockholm: White arkitekter AB.

Bâldea, Maja, Dumitrescu, Cristian. 2013. Upplevt och uppmätt. High-Density Forms in Contemporary Architecture., University of Timisoara (Published online)

David W. Dunlap. 2016. Zoning Arrived 100 Years Ago, Changing New York Forever. The New York Times. July 25. https://www.nytimes.com (Hämtad 2019-05-10).

Ettelva Arkitekter. 2017. Lathund för dagsljusberäkningar & Artificiell belysning.

Reports

Ruck, Nancy. 2000. Daylight in Buildings: A source book on daylighting systems and components. En rapport av IEA SHC Task 21/ ECBCS. Berkeley: Lawrence Berkeley National Laboratory.

Alenius, Malin. 2018. Upplevt och uppmätt. En ARQ-rapport om dagsljus. Stockholm: White arkitekter AB

Esseys

Iskandarova, N, Svensson, T. 2019. HUR TÄTT ÄR RÄTT? : En studie om samexistens mellan dagsljus och förtätning. Examensarbete., Jönköping universitet.

Janram, Tommy. 2019. Solen ljus och förtätning: Ur ett socialt hållbarhetsperspektiv. Kandidatarbete., Blekinge Tekniska Högskola.

Litterature

Webb

https://www.grasshopper3d.com/

Weather Data. U.S, 2019. Department of Energy's (DOE). https://energyplus.net/weather (Hämtad 2019-02-10)

MVRDV. 2017. Ijburg Agora. https://www.mvrdv.nl/projects/299/ijburg-agora (Hämtad 2019-05-10).

JDSA. 2014. Tad/Iceberg. http://jdsa.eu/tad/ (Hämtad 2019-04-10).

Engineering ToolBox, 2012. Materials - Light Reflecting Factors. https://www.engineeringtoolbox.com/light-material-reflecting-factor-d_1842.html (Hämtad 2019-02-05).

Illustrationer

Figure 1-4, 6-9: By Author

Figure 5, 14-17: https://www.nytimes.com (Hämtad 2019-05-10).

Figure 6-9: By Author

Figure 10-11: http://jdsa.eu/tad/ (Hämtad 2019-04-10)

Figure 12-13: https://www.mvrdv.nl/projects/299/ijburg-agora (Hämtad 2019-04-10)

Master thesis in Architecture and Urban Design
Matter Space Structure
Department of Architecture and Civil Engineering
Chalmers University of Technology
Erik Marklinder