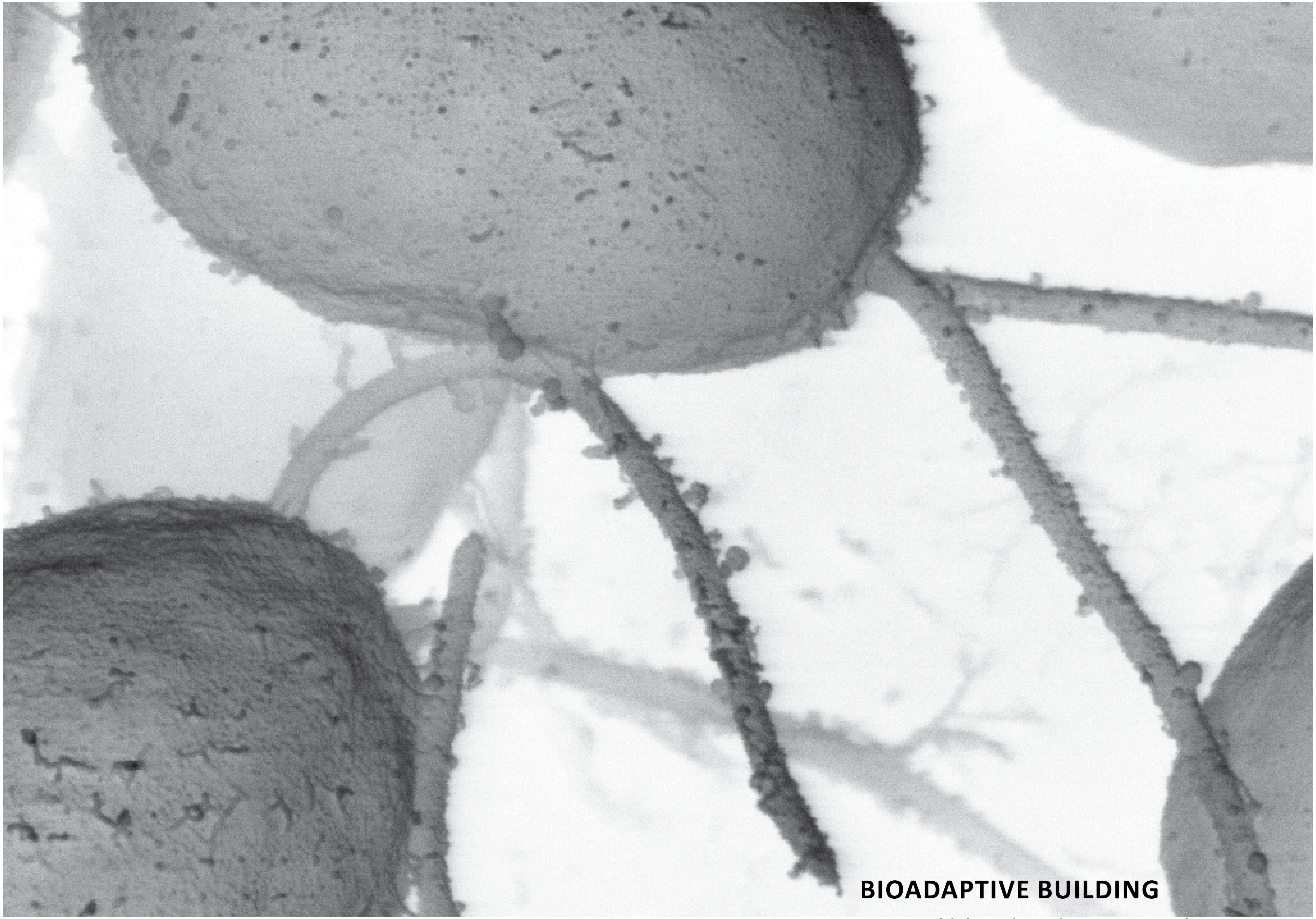

BIOADAPTIVE BUILDING

Jesper Hildebrandt Andersen, ma4-ark19, June 2011

Summary
This project regards an investigation in the field of bioresponsive element in building implementing and the use of active components in the development of a adaptable sustainable building. The building is made so that each room can change in form and comfort to suit different cases. Sustainability is achieved by making a component structure that enables to be dissembled without bounding of materials and with a system where no heat or cooling is necessary to put in.

Project Case
The project is based on a case in Billund, Denmark, of an office building which needs to be adaptive to its function and fits under the Danish 2015 norms. The focus area in this project is not to solve the direct given case, but to face some of the issues in these buildings with multifunctional rooms, by making an adaptive building.

Semester
4th, Master thesis, Architectural Design
Department of Architecture, Aalborg University

Project title
Bioadaptive Building

Theme
Biology, adaptive and sustainable

Project period
1. Feb. - 31. May.

Main supervisor
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BIM specialist, Asbjørn Levring

Jesper Hildebrandt Andersen

CONTENT

INTRO

Foreword

This project is created as a 4th semester master thesis from a student at Architecture and Design, Aalborg University. It is developed during the Spring semester, from 1st February to 31st May of 2011, and reflects the individual student work and ideas during that time.

The project is presented in a chronological way, doesn't necessarily have happened this way. The use of an integrated design approach, as further explained, allowed a continuous loop and iteration during the process.

Readers guide

References throughout the report have been made in accordance to the Harvard Method; for books and articles (Author, year) and for web pages (designated name). Regarding illustrations, if nothing else is indicated the illustration is own production. Otherwise, illustrations are numbered within the chapter and its reference can be found in the end of the report, with the link to the chapter headline and illustration number.

Complete references for books, articles and web pages can also be found in the end of the report.

Motivation

"Our innate ability to adapt and change is a core element in shaping how our environment can continue to be developed with an increased responde to these emerging environmental factors." (Kronenburg, 2007)

It is the idea that the central nerve in a society development is based on its ability to adapt to a changing future. This fast moving development of technology and the flexibility of data in IT systems provides control of a more fluted datastructure than seen before.

Where I see a conflict is in the creation of building with less flexibility to achieve the low energy norms and a longer life span. This gives architects a task where they have to create an adaptable space, in a fixed boundary.

Here I see it's important to try out new technology, to create buildings which can have their function changed and their material is able to be removed or reused in another case.

I believe the use of more adaptive component could help in providing more suitable tools for creating buildings for a more adaptive evolving environment.

To enable the use of adaptive component, in a more suitable way, I see the use of biointegrating component, together with technical surveillance as a more efficient way to achieve adaptive reactions.

Method

The project takes advantage of integrated design through the topics biology, kinetic movements, parametric and form finding. Here the Integrated Design Process (IDP) is ideal for its continuous loops and testing iterations. A method also used is the building process called (IDEEB) Intelligently Designed Energy Efficient Buildings, which considers the energy loop of all the building components in its operation.

Furthermore, by connecting a top down approach with a parametric design software, it was possible to keep the flow in the design process and to evaluate the influence of the component changes in the final proposal.

Tools

Different software and tools were used during the process.

Design software used in the parametic design phase:

Rhino (3d drawing) plugins

- Grashopper (parametric tool)
- Geco (sun simulation)
- Kangaroo (physic simulation)
- Vray (render engine)

Simulation tools

- Ecotect
- Bsim
- Virtual Environment

Adobe Master Suit was used during the sketching and report making, to have constant update in the report through the analysis and sketching phases.

Analog tools as drawing and modeling were used creating iterations and form understanding through the process.

Project Brief

To enhance the use of adaptive component by combining mechanic, biology and manual systems into an overall concept, which enhances the sustainable aspect in a building performance.

PROJECT STRUCTURE

The process of creating an adaptive system is an approach of connecting system elements, which its creation balances out to each other. So the process of its creation is a constant loop between systems and values, which make the process of the project a more flat structure where there is a constant need to be made consideration. Below is the description of the chapters, but it has to be taken into account that there has been a flow of information between each chapter.

Context
Analyse of the building case, for an understanding of a modern office, which needs to be adaptive and reach a high energy standard. Billund, Lego and the local climate are also brought in for analysing for achieving and understanding.

Integrated design
The architectural reason for adaptive understanding and how adaptive building is both a benefit in function and understanding.

Principle
To get an idea of what a building should be, and how it should interfere with the users and the environment is some principles brought in for understanding.

Cases
To get an idea on other research and form inspiration, is some cases looked into concerning facades and biology.

Investigations
Elements and systems which can be used in the concept development of the project is brought in early for and understanding of their implementation in the concept development.

Initial Design
Based on the investigation, is the initial ideas and system sketched. Finding the behaviour of the building.

Concept
The idea of the collaboration between component and system is implemented in a concept for further refining.

Respond
How the building should react in different situation.

Equation
Heat and cooling balance, is figured for finding the benefit from each component in archiving a good comfort.

Construction/Facade/Floor/Internal
Each element in the building is solved with a continues loop in between for finding the final form and construction principle.

Presentation
3d views of the design, plans and sections.

Conclusion/Reflection/Perspective
Evaluation and consideration on the process and project.

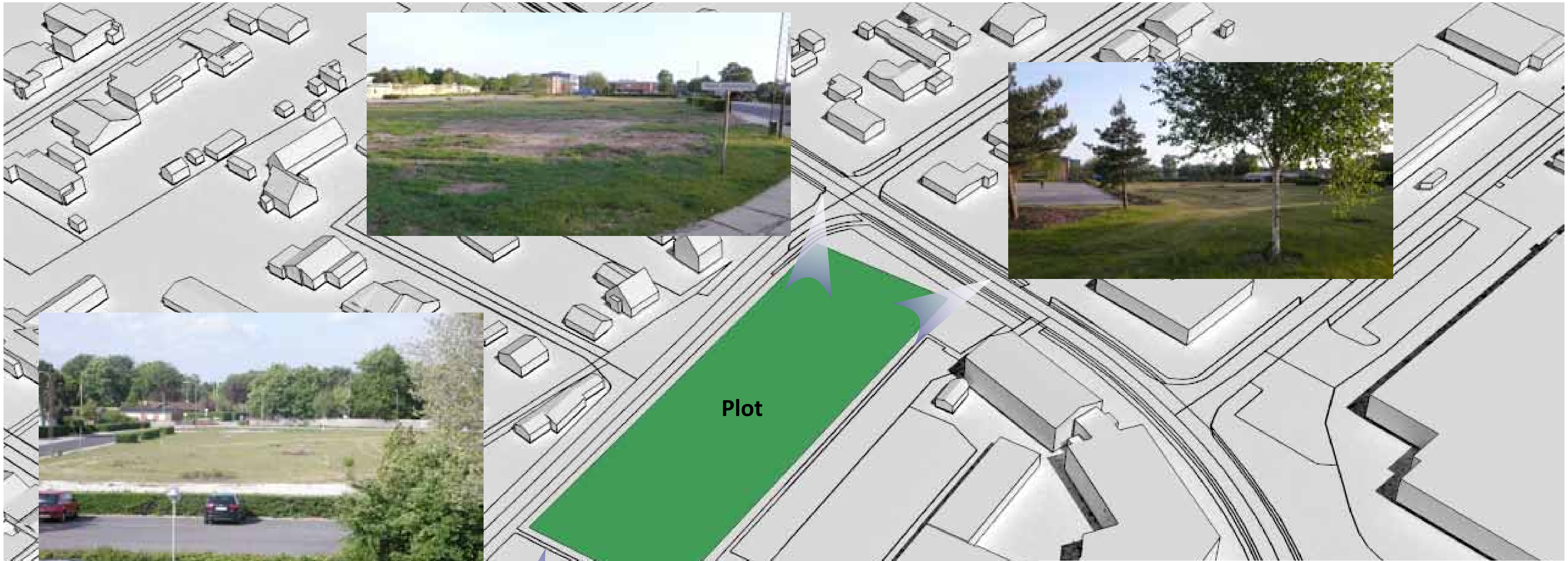
CONTEXT

Billund

Billund is a town in the centre of Jutland. It has developed around Lego, which has given Billund a lot of industry, including an airport, Lalandia and Legoland. Besides the industry, there is also space for green. Årstiderne has a urban project plan concerning Billund centre, dragging the green active environment into the heart of Billund.

The plot is located right on the other side of the centre, and it could enhance this pathway through the town.

Ill. 2



Lego

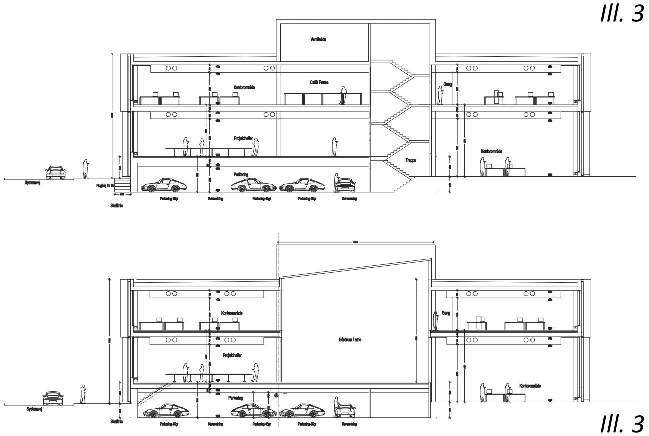
The word comes from “leg godt”, which means play well. The Lego philosophy is to play and learn, through creative stimulation of your mind.

The idea of Lego can be brought into component design as one brick can be the solution for many requests. It’s the system in which the components work together that enables the solution.

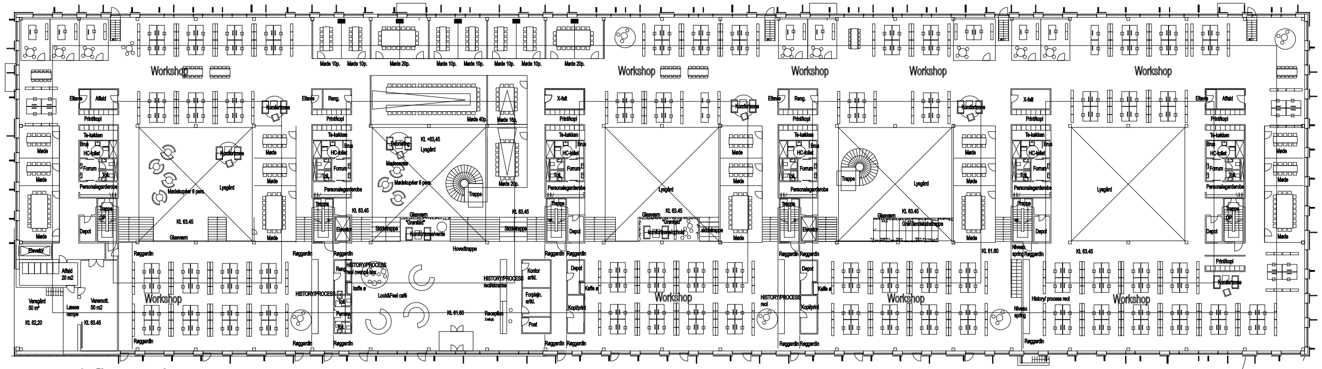
As part of the traditional Lego brick, there is also mindstorm robot, on the edge of the combination between physical modelling and computer based system. This toy is a good example of an adaptive design, as the adaptive component is controlled by the users control of the systems sensor input, and by that able to solve different tasks.

Ill. 3

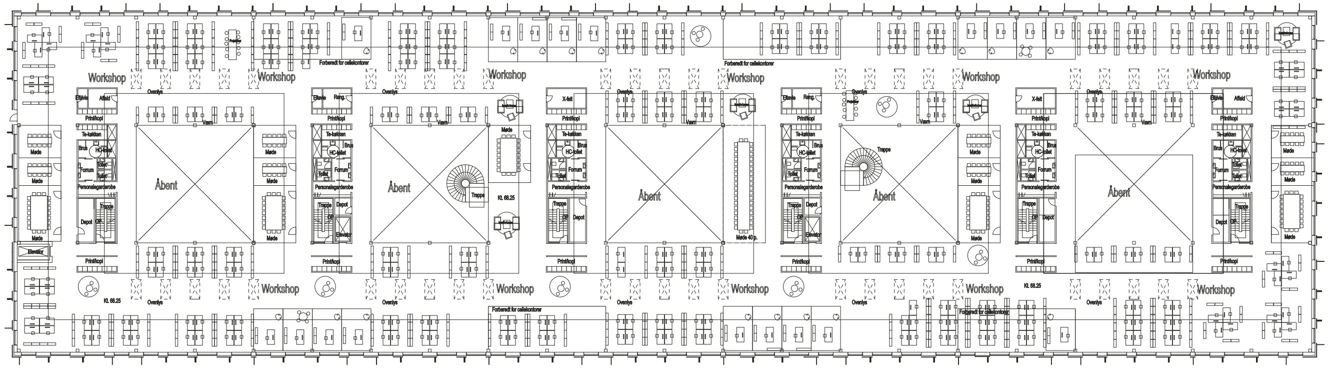
Ill. 3



Ill. 3



Ground floor plan



1st floor plan

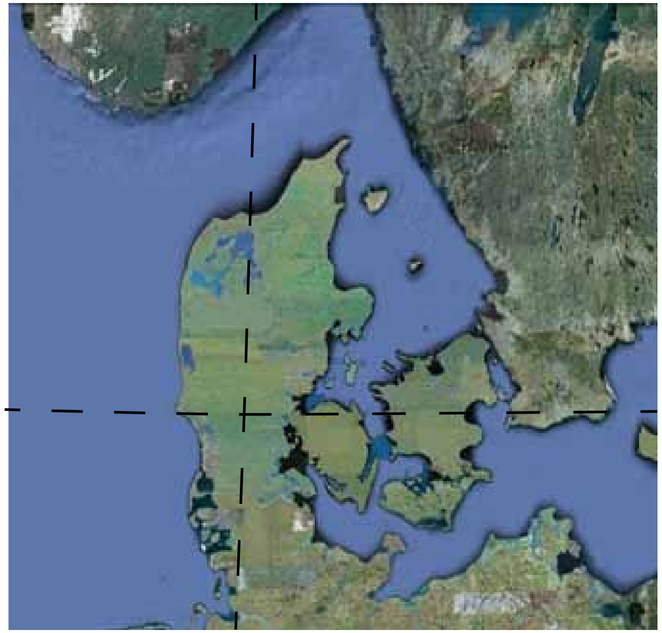
Ill. 4

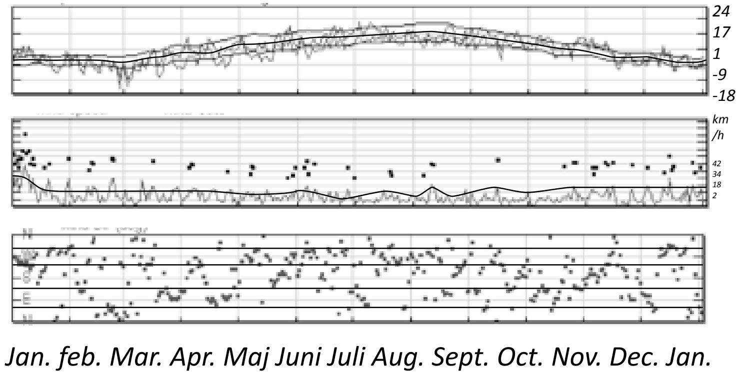
The information in this page - illustrations, program and construction details - relates to Arkitema's proposal for the building. The plans and sections have been changed to fit into the format of the report.

Area	
Basement	5.083 m^2
Floor plan	6.593 m^2
Atrium	58 m^2
1st floor	5674 m^2
Roof	423 m^2
Total	17.831 m^2

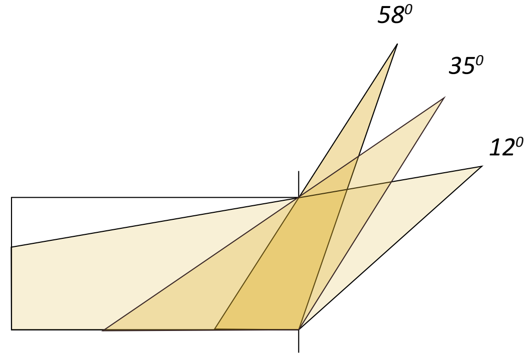
Main points from the program are:

- Glass U-value of 0,6 W/m^2K.
- U-value of external wall 0,12 W/m^2K.
- Building ratio 70 %
- Low effective lightning
- 2015 Danish energy norms
- Atrium is indoor none heated
- Office walls is made flexible
- Facade is both sensor and manual controlled
- The facade and roof contain pv-cells
- Facade elements redirect sun into building

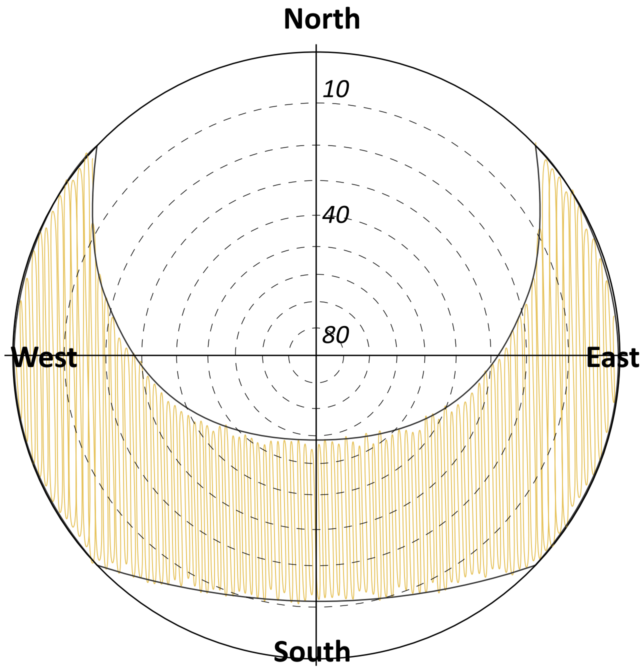




Data from weather-station in Billund over the past 5 years



The sun at the highest, lowest and average time of the year, in the middle of its path.



The Arkitema's project is built up on high energy demands norms and still in the need of good working condition. The use of traditional method such as atrium, high ceiling and skylight provide the daylight needed and still keep the building with a high insulation value.

Besides the light, the atrium allows the use of ventilation shaft, for cooling during the summer time. The facade element is going to be controlled and the inwards bend aluminium should help sun being redirected into the building.

Pv-cells on the roof help to get the power needed, and extra pv-cells are placed on the facade to give an idea of a green building to visitors. Internal green walls are used as ornament and to give a contrast in the building. The square shape of the building, furniture and rooms is based on the flexibility needed in the rooms, being able to change and stack different room functions.

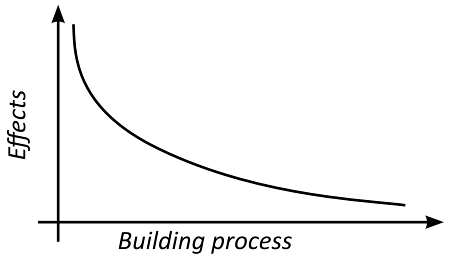
Each Segment of the building is build so that it is able to work as itself, so that if Lego is no longer in need of a segment, can it be rented out to other interested.

The context around the building is in brick and concrete blocks, approximately from the 1980th to 90th, and there isn't really any landmarks of interest.

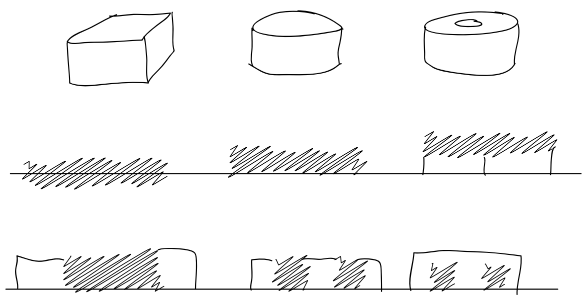
Climate in Denmark is normally quite stable not changing much, due to the high contact of ocean around, but the tendency is that the changing is getting bigger due to climate change.

The light is important in Danish building and to use it well. The sun is weak but is there during a long time of the day. The winter sun is able to get deep into the buildings because of its low altitude. The wind in the area is generally unimportant since there are other buildings in the area that blocks it.

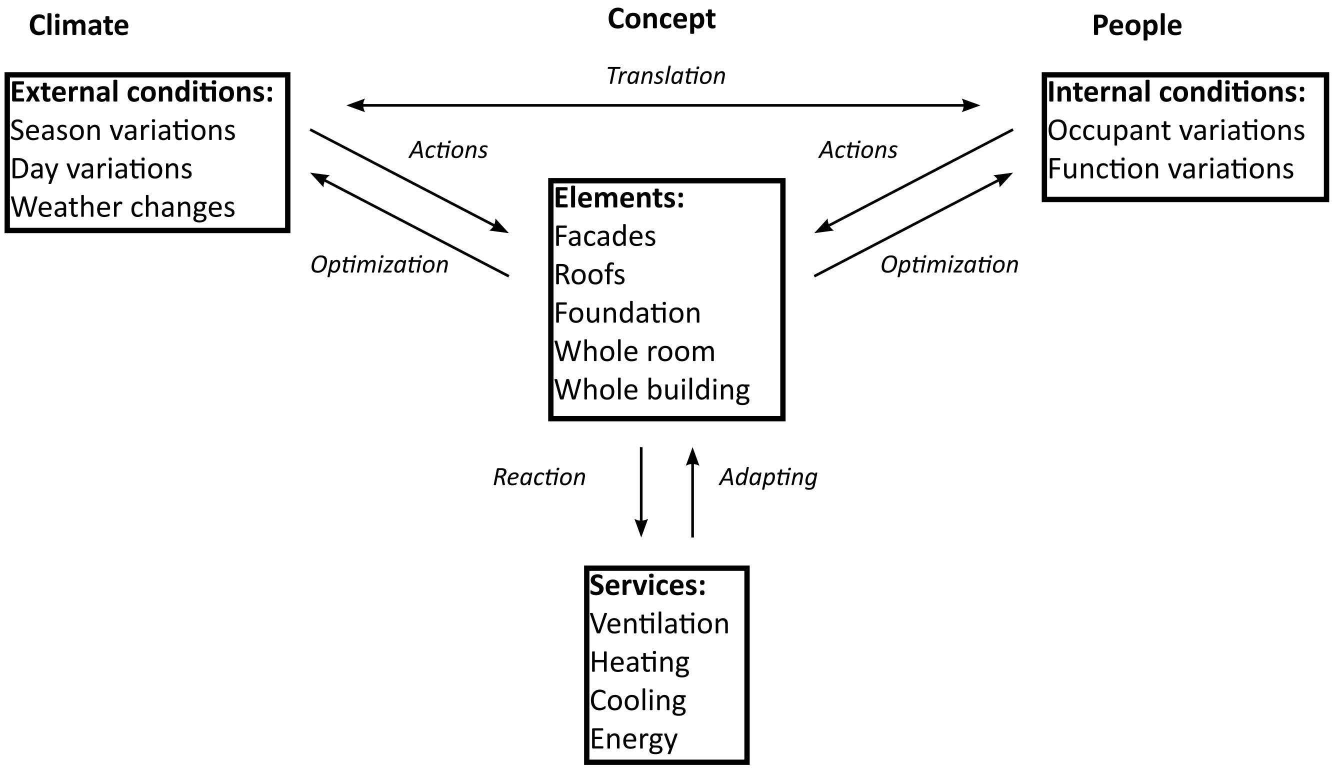
INTEGRATED DESIGN



The integrated design approach is an early implementing of principles into the design process, in this case sustainable principles. The earliest this sustainable issues are brought in, the biggest effect they have in the final proposal.
When sketching the initial shape, three main factors had to be considered, surface area contra floor area, placement of building core and placement of openings.



Also according to sustainable issues, reactive building element is brought in through an early understanding on their impact in the system.
It’s been seen that the flow of data through the reactive elements, from the control of the condition they are reacting to, is not just a one way data flow.



This flow of adapting systems gives a transparency through the system, between how the building reacts on external condition and how it enhances the indoor experience. This makes the barrier between the internal user and the external conditions melt together in the concept of the responsive elements in the building. *(http://www.ecbcs.org/docs/Annex_44_SotAr_Vol_1.pdf)*
For achieving this there is a need of a clear beneficent actions and the understanding of the outside environment, through the system. This will make the reactive component a clear transactor from its function to its users.
This is seen as a reason for bringing in adaptive environmental solution into the design development of a building concept, both for the design and for the comfort inside the building.

OTHER DESIGN APPROACHES

"We can't solve problems by using the same kind of thinking we used when we created them." Albert Einstein

This page presents innovative design approaches , considered during the design process for inspiration and to enable different perspectives.

Cradle to cradle

"Waste equals food, whether it's food for the earth, or for a closed industrial cycle. We manufacture products that go from cradle to grave. We want to manufacture them from cradle to cradle." William McDonough, cradle to cradle

Cradle to cradle is defined as not to produce waste but produce food, so every time you have a system makes sure that the system of the next chain is able to use the leftover product. This concept makes it possible to have a continuous flow of material, if powered by renewable energy sources.

Borrow

As introduced by Philips the borrowed light idea, the concept is based on the idea that you no longer buy products, but rent the function from them. This gives the product producer a constant flow of product. So this gives them a higher focus on long lasting service, and more efficiency, where only the decay of the building has to be covered by the rent.

Adaptive

"It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change." Charles Darwin

To enable a constant evolution there is the need of being adaptive to the changing in the needs and the condition. The need of houses is not necessarily the smartest or most resistent building but a building that can be changed for adapting to different situations. We have been able to use tools that enable us to adapt the surroundings to us. In the case of houses, could maybe be smarter if they were made more able to adapt to the surroundings instead and over time.

Summary

This new visions and our ways to respond and think are brought into this project to provide tools for a rethinking in the way we solve problems of living.

The things built, as part of the civilisation growth, are the essential problem in the resources being used. For solving this problem there is a need of a new way of thinking, in building not bounded in the resources used, but in the knowledge to build them.

Ill. 5 A Mongolian eaglehunter, riding on his mule, with his golden eagle. He is maybe better suited for adaptable changing, with his knowledge and the use of recycle materials.

CASES

To understand the movement, biology and comfort strategies, some cases are following presented.

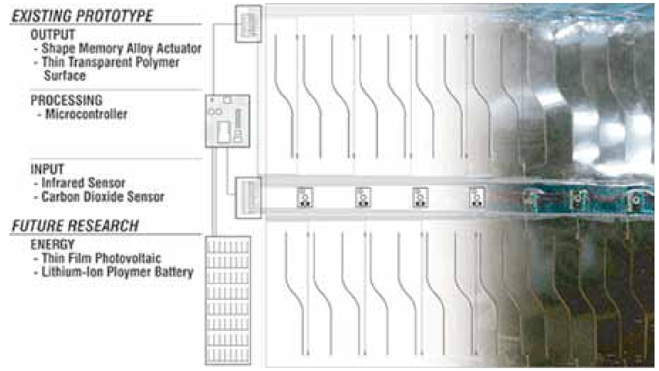
The first examples, the ones in this page, regard mechanical movement structures to get inspiration in design using motion and its benefits, both in shape and comfort.
The examples in the next page relate to comfort strategies, to how they work and how they are integrated in the design.
At last, the cases in page 15, concern the implementation of biology in buildings, in order to get a background in what can be done and in which way it could be beneficial.

Milwaukee Museum art museum *Ill. 7*
The wings open in the morning to let in light on the exhibition, the motion has a huge dramatic effect on the buildings light and internal experience.
(http://www.calatrava.com/)

Sliding house *Ill. 8*
The insulation material is moved over the house when it's to cold. When its moved away it provides a terrace, open bathroom and outdoor space covered.
(http://inhabitat.com/residence-sliding-house-drmm/)

Ill. 6

World Trade Centre, Bahrain
What I would likto enhance in this project is not the design of the facade, but the use of the production of sustainable energy in the shape of the building. This gives a clear image of the reason for the building shape, provides a huge dramatic reaction to weather change.

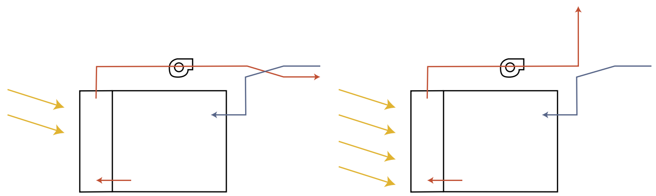


Silicon facade *Ill. 9*
This facade is able to open when activated from a given input. The movement is created with embedded memory steal, which subtracts when electrified. *(http://www.omnispace.org/art/)*

Sun shades *Ill. 10*
Each shade is controlled with an actuator, what makes it capable of turning each shade individually and create effects. The shades take inspirations from the look of leafs and how the wind moves them, producing shadow. *(http://www.hoberman.com/abi.html)*

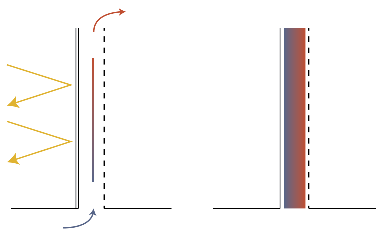
Facade ventilation

An example of an advanced integrated facade, is found in the Environment Park, in Turin. The outlet air temperature is increased through the double facade before entering the HVAC. If the ventilation is for cooling the outlet air is disconnected from the HVAC system.
(http://www.ecbcs.org/docs/Annex_44_SotAr_RBE_Vol_2A.pdf)

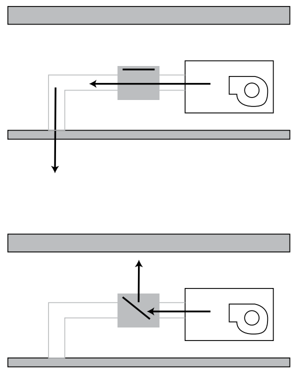


Facade blinds

Integrated blinds system for facade is used in the SOMEC headquarters building, in Italy. It's a double facade, with a integrated solar reflected blind which is automatically controlled, when it's getting too warm. The double facade enables to prevent heat loss in the Winter, and in the Summer reflects the sun. This is an efficient way to block from overheating, since the heat is blocked away from the building envelope.
(http://www.ecbcs.org/docs/Annex_44_SotAr_RBE_Vol_2A.pdf)



Night cooling



Kanden, a multistorey office building in Japan, takes advantage of night ventilation due to its massive thermal mass, by implemented a switch which changes the ventilation direction from day to night. In the day it's let out on the employes and at night it's switched for cooling the thermal mass of the building. *(http://www.ecbcs.org/docs/Annex_44_SotAr_RBE_Vol_2A.pdf)*

Embedded water pipes

ZUB (Center for sustainability) office in Kassel, is using a water pipe system embedded in each floor and roof in the building. The pipe is a 20 mm pipe every 150 mm. The temperature drops between 5-6 degree, and the water flow goes 600 kg/h. The building achieved to go under the energy norm of 20 kwh/m^2 down to 16.5 kwh/m^2. *(http://www.ecbcs.org/docs/Annex_44_SotAr_RBE_Vol_2A.pdf)*

Phase Changing

The use of phase changing materials, makes it possible to store more heat energy in a material, when it changes from solid to liquid. An example of this is the 3-Litre house in Germany, where they implemented new insulation layer in a old house, the insulation contained phase changing materials (BASF Micronal) which have a melting point of 24 C and a latent heat of 180 J/kg. *(http://www.ecbcs.org/docs/Annex_44_SotAr_RBE_Vol_2A.pdf)*

Smart texturing

The use of a textured transparent element is used in the case of a south facing facade in the elderly centre Domat EMS building. The facade is made of four layers of different glass, which gives a lot of solar and light gain. To avoid overheat one them is made with textured surface, so it blocks the sun at summer altitudes. *(http://www.ecbcs.org/docs/Annex_44_SotAr_RBE_Vol_2A.pdf)*

Wall ventilation

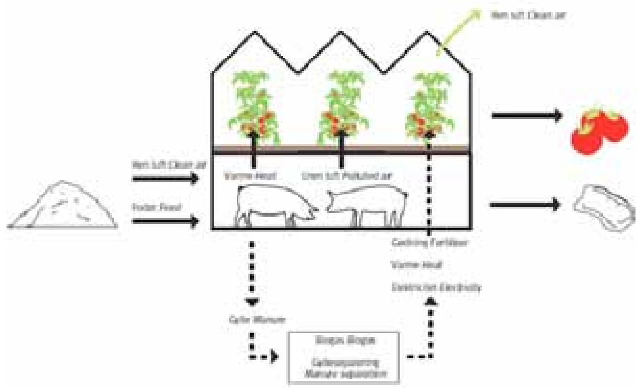
By ventilating the air through the wall, the insulation can clear out some of the particles from the air. By making the airflow through the wall a one way directional flow, it can optimise the wall insulation, by eliminating some of the air cycle flow in the insulation material. *(http://www.ecbcs.org/docs/Annex_44_SotAr_RBE_Vol_2A.pdf)*

Earth coupling

The ventilation docks goes through pipes in the earth, for using a stable temperature, either for cooling or heating. An example from Austria with pipes of 50 m, buried 2m deep and a volume flow of 500 m^3/h. This provides a preheating in Winter from -11,5 to 0,2 and a cooling in Summer from 29,4 to 19,6 degrees. *(http://www.ecbcs.org/docs/Annex_44_SotAr_RBE_Vol_2A.pdf)*

Window farms *Ill. 11*

The concept is on how to grow vegetables in apartments in dense cites. The water for the plants is provided by using air bubbles in tubes. The apartments benefit in shading, moisture and food.
(http://www.windowfarms.org/)



Pig city *Ill. 12*

The idea is to combine the production of pigs together with the production of tomato, so they enhance each other in a ecosystem. The waste from the pigs is absorbed by the plants and the plants provide the pigs with cleaner air.
(http://www.pig-city.dk/)

Greencurtains *Ill. 13*

A Japanese company, Kyocera Group, has planted greencurtains, as an extra layer of facade, on all their IT facilities. It covers at the moment 32,570 square feet an it had made a positive changing in the indoor climate on up to 15 degrees, in the summer. *(http://tokyogreenspace.com/)*

Greenwall *Ill. 14*

For indoor ornaments, plantwall is a innovative system. The plants are specially picked for the specific indoor climate situation. The system is made easily with the plant on a dry mull and a water system supplying for it.

Greenroof *Ill. 15*

Can help absorbing rainwater and clear it for any heavy materials, provide insulation both in Summer and Winter, create a habitat for wildlife and help cleaning the air. The negative side is that there is a need for a bigger supportive structure.
(http://www.trskablog.com/green-roof/)

Summary

The use of moving element in the building concept can enhance the building experience, with a good connection between the user and the conditions. But the amount of resources and energy used for creating this effect is not always appropriate for the given effects.
The implementing of biology solution in buildings is having a positive influence in the environment and it is still a solution which can be changed since it decomposes. The use of plants growing cycles for shading, where they have leafs in the Summer and none in the Winter, I see as an easy solution to controll the shading. The use of biocycle in the pigcity, where the plants and pigs are enhancing each other, could be an efficient way for comfort.

INVESTIGATION

For a better understanding on how to integrate green elements and how they could work in a building design, five cases are considered, listed here below:

Ken Yeang, in his creation of integrating green in building design.
ETFE because of its use in the Eden project, and for understanding the material properties.
Plantwall, how they are operated and if it has any influence in the indoor comfort.
Algae house, a house where the use of algae is integrated in the facade, to provide energy.
Algaebioreactors, how different algaeculture is held and how ideas from this could be used in a building design.

Ill. 20

Ken Yeang

The use of vertical planting, for the architectural benefit is seen in the high rise by Ken Yeang. The green element shapes up the building and is used as shading in the south facing facade. The idea of building dense is to enable a good use of the foot print, and bringing plant up in the light.

ETFE

Ill. 21

The use of ETFE is being implemented in many projects where there is a need of light construction with a good light transmittance, such as the Eden project and the OL Beijing swimming hall.
Due to its lightweight, installation cost can become 24 to 70 %, cheaper than a normal glass and steel construction. It transmits up to 95% of light, in the entire spectrum 380-780 and in the ultraviolet range 320- 380 nm, giving its benefit in growing plants and vegetation underneath.
It's placed normally away from humans because of it can be damaged by sharp object, but if damaged it can easily be repaired.
ETFE is 100% recyclable and doesn't seem to have any decay over time - so far only tested in laboratory and it should stand without any chance of decay for 50 years.
A single ETFE membrane has a U-value of 5.6 w/m²°K, a three layer cushion can achieve a U-value of 1.96 w/m²°K. More layers can be added to improve U-value. It is possible to achieve a U-value down to 0,3 with the use of Texlon nano from Vector. The G-value can be reduced to 0,48 for 2 layers, and with 3 layers down to 0,35.
ETFE can be made in two ways, either it's made with air cushion - with the use of an airpump keeps its pressure - or its suspended between two constructions. In the use of multilayered ETFE a printed pattern can block some of he sun when in a sudden angle.
(http://www.vector-foiltec.com)
(http://www.architen.com/technical/articles/etfe-foil-a-guide-to-design)

Plantwall

Ill. 19

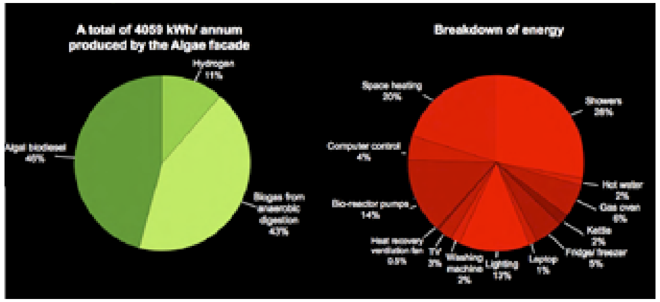
Mounted plant walls have been used in different cases to provide indoor area with green without the use of big floor spaces. Greenfortune is a company which uses a textile structure of 10 cm deep, where the plants are mounted; the water supplied for the system is from a normal water supply and 4 spots of 70 watt give the plants the amount of sun needed. (www.greenfortune.com)

Summary

The use of green is mainly being used in the creation of ornaments by its contrast with the building. The benefits from it on building are mainly related

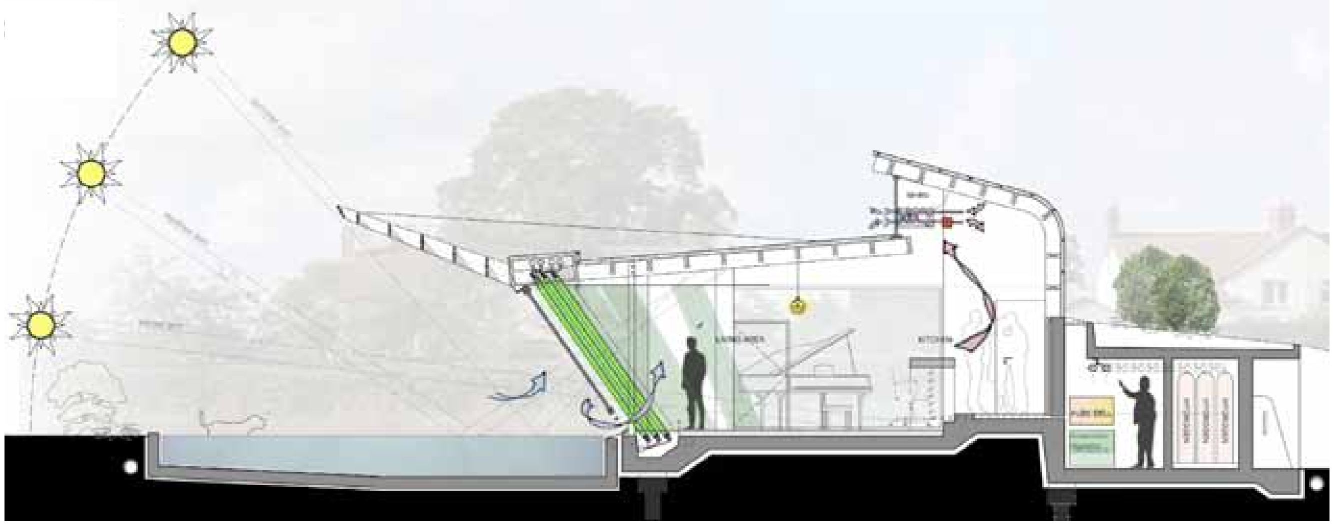
Algae House

A student project from Cambridge University, putting bioreactors on a house facade to provide the house with energy for its demands.

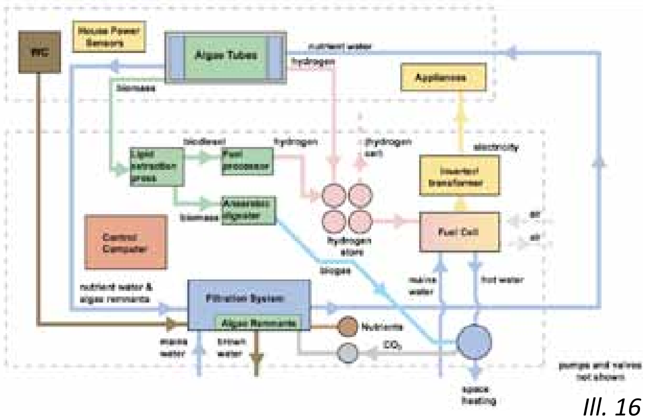


Ill. 16

The project aim is to supply the household demands from the grow of the algae in the bioreactor unit, with the production of hydrogen, biodiesel and biomass.



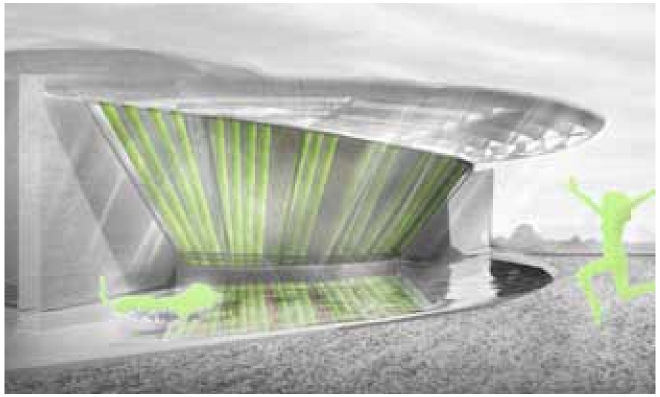
Ill. 16 The high sunlight in the summer is blocked by the overhang to prevent overheatting of the algae. The pool reflect the sun waves absorbing before reflected up at the facade. With a lower sun angle, the sun heat direct the algae, and is empowered by its reflection in the water.



Ill. 16

The bioreactor is connected to the wastewater from the house for nutritions, together with main water supply. Hydrogen is made from the biodiesel, giving hydrogen and biogas. The biogas is then burned and give back CO_2 to the process.

The Hydrogen is used in the production of electricity. This process gives back water and air for the household. The water in front of the house is used for reflecting the sun and for absorbing some of the heat waves preventing the algae from getting too warm.



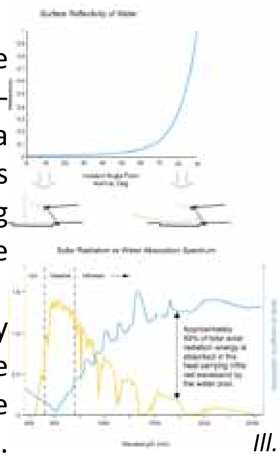
Ill. 16

In the summer the overhang blocks the sun, so only the reflected sun is hitting the algae.

The bioreactor used in the project a tubes enables a good even distribution of the light getting to the algae.

Summary

The idea of absorbing the heat waves in the water and reflect waves in a higher spectrum seems as an efficient way of having good living quality for the algae during the year.



Ill. 16

The production of energy through hydrogen can be hard to control, because of the small sized atoms.

There could be a bigger use of the algae as an ornament in the facade instead of having them inclosed in tubes.

Algae

Micro Algae has been the main field in research in Algae Culture, mainly regarding its fast reproduction.

It's the most effective transformer of sunlight converting 3-8 % of the sunlight to energy, while landplants can only convert 0,5 %. Algae produce around 1,87 ltr. pr. m^2 of oil, where the closed land plant palm produces 0,6 ltr. pr. m^2. *(Ole Terney, Bio-Nyt: Alger energi- og fødekæde)*

The algae can either grow or reproduce. When they grow they will produce oil. They will only grow if there is a lack of nitrogen. The reaction is based on the simply photosynthetic formula, creating glucose building bricks from CO_2, water and light.

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$
$$\Delta h = 2870 \text{ KJ/mol}$$

(http://en.wikipedia.org/wiki/Algae_bioreactor)

During the algae growth there is besides CO_2 a need of nutritions such as nitrogen, phosphorus, and potassium. This can come from industry or human wastewater.

The energy comes in three forms, hydrogen, oil and biomass. Hydrogen can be taken out in the chain in the photosynthetic reaction. Oil is produced in starvation of nitrogen as feedstock. At last, the biomass of the algae can be used in bioethanol.

(http://en.wikipedia.org/wiki/Algaculture)

Average algae facts

Light 18 hours a day, red/blue spectrum.

Temperature between 16 - 27 degrees, various from algae to algae. Lower than 16 will slow down growth, and higher than 35 will be lethal.

Mixing it at all time is necessary.

Light 1000 lux , Direct sunlight is often too strong for algae.

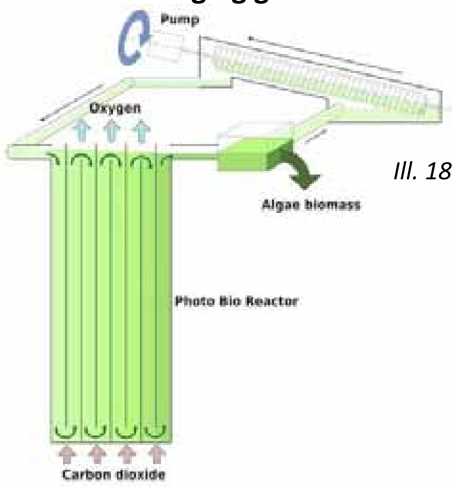
Depths of algaeculture 76–100 mm.

(http://www.growing-algae.com/algae-growing-conditions.html)

(Ole Terney, BioNyt: Alger energi- og fødekæde)

(http://en.wikipedia.org/wiki/Algaculture)

Ecuduna´s hanging gardens



Ill. 18

An example of a photobioreactor is the Ecuduna's hanging garden. Its a turning algae membrane which turns to watch the sun during the day, enabling a higher effect of algae production.

The field in which they want the system implemented is in the production of raw biomass, purification of water and air purification from industry smoke. The system is running on a constant flow of algae through the system, enabling a constant feedback of biomass from the algae. (*www.ecoduna.com)*

NASA´s seamembrane

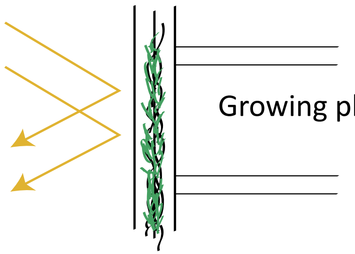
As an invention for spacetravel NASA invested in a offshore algae membrane, which enables biomass production on open water. The concept is a plastic permeable membrane with filled sewage water and algae. The clean water runs out while the salt in the ocean keeps the water from running in. CO_2 is moved through the membrane using osmose, and clean air is let out of the membrane. When the process is over, the bags are moved onshore and the biomass is used to produce fuel.

(http://biomassenergyjournal.com/nasas-project-omega/)

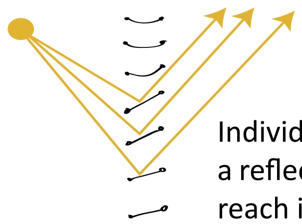
Summary

Algae is the most efficient plant in converting solar energy and it can use a lot of nutritions. The fact that micro algae is placed in water makes them easy to move around in the building. The algae flow from the Ecuduna's project, with the constant output of oxygen and biomass and its adaptive movement - its bioreactor turning to watch the sun - is a good responsive behaviour for having a changing function. The use of a passive membrane material which filters the water and air would make it easier to enable a constant flow of air through the membranes providing air for the indoor environment.

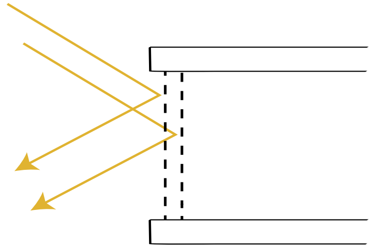
INITIAL DESIGN



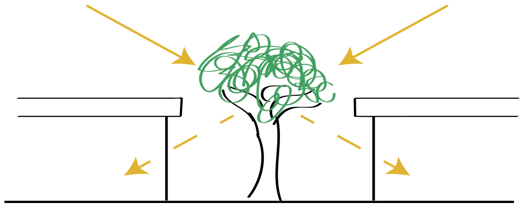
Growing plants cover from the sun.



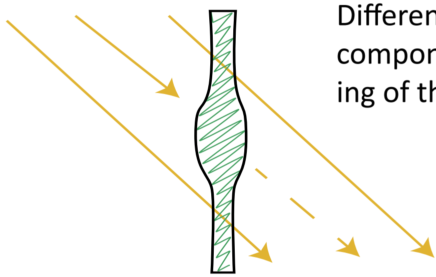
Individual controlling shades, create a reflection of the sun to enable it to reach into the building.



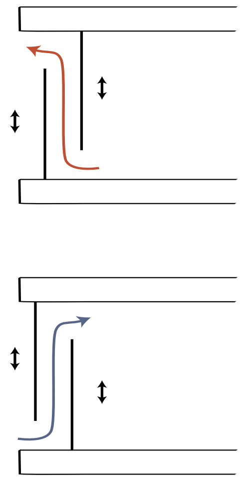
Different patterns block sun at giving angles.



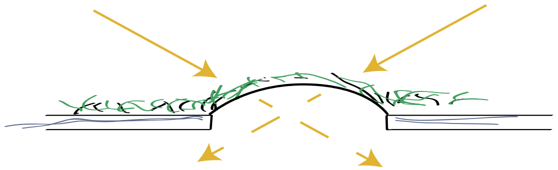
Tree blocks from the sun in an atrium.



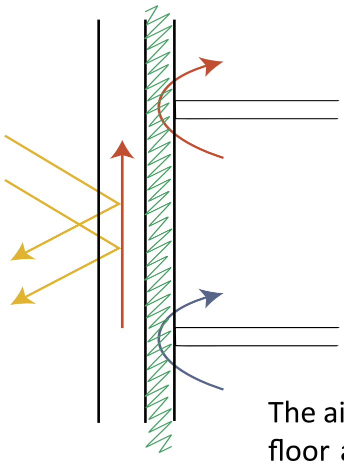
Different thickness on the facade component enable, different diffusing of the sunlight.



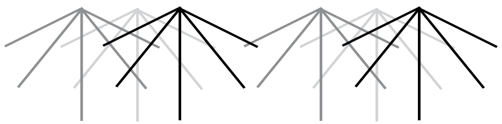
Moveable elements enable air to go either from inside out or outside in.



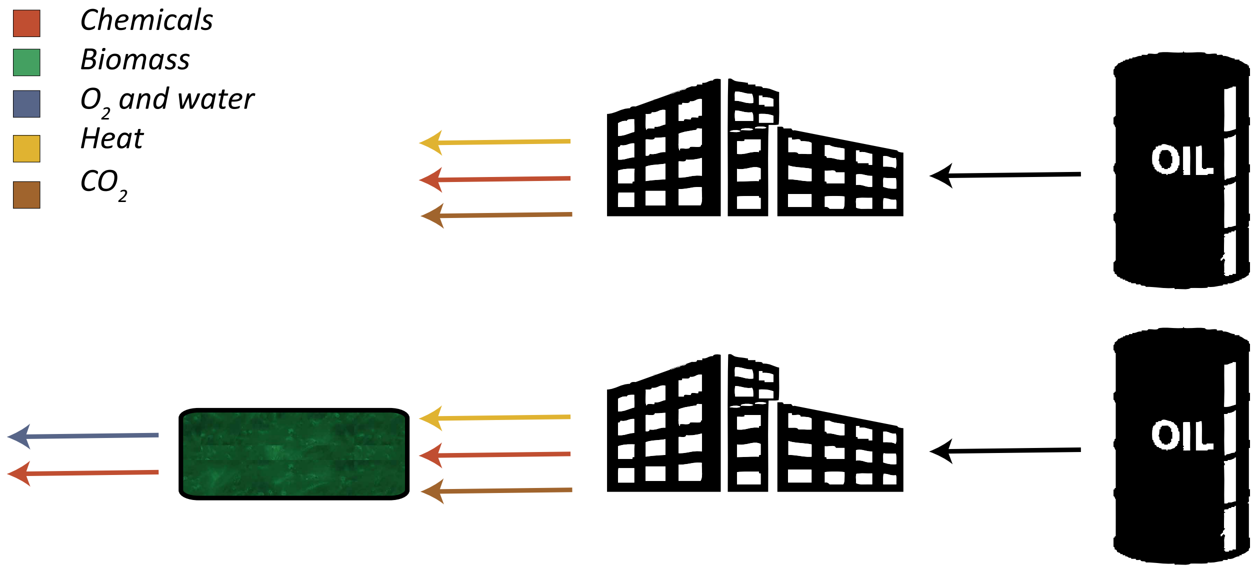
The moisture from the greenroof keeps the heat load down.

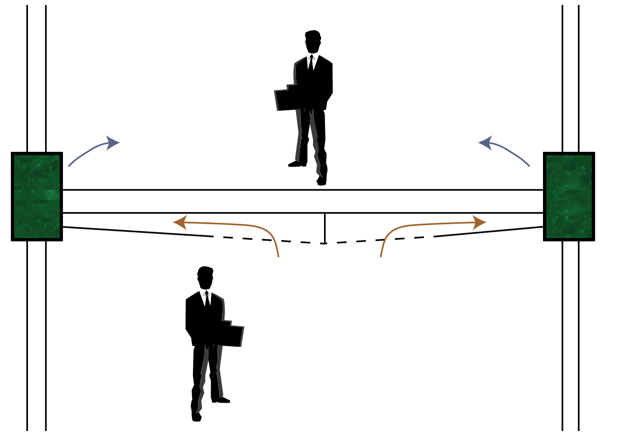


The air is cleaned when moving from each floor and up. A double facade creates an airshaft for heating or cooling.



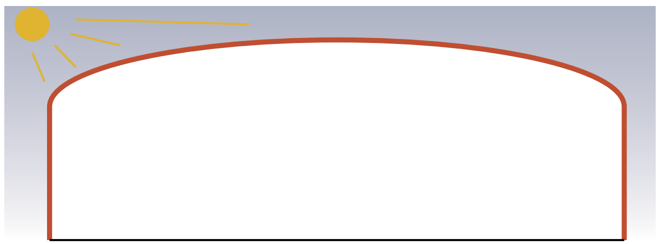
Overlayering shades creates a diffuse light into the building.

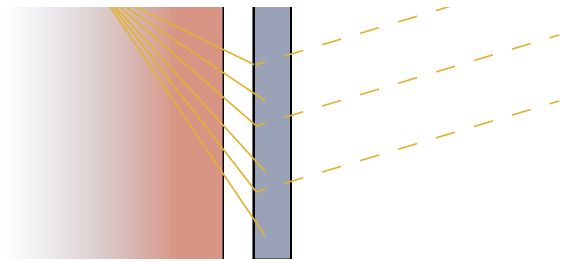




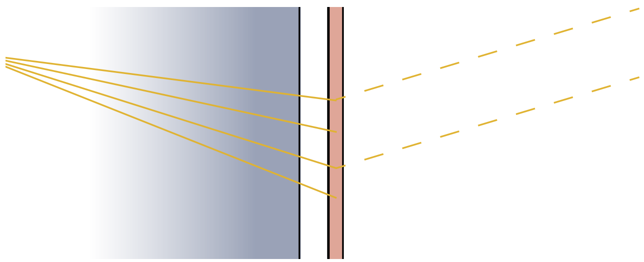
CO_2 moved from the below room through a green space which changes it to O_2 from photosynthetic.

Industrial production using oil, leaves out heat, CO_2 and chemicals. This is later absorbed by the environment, and converted back into biomass. This process is able to be fast forwarded, with the implementation of algae. By letting the smoke from the industrial plant go through a algaereactor, here the chemicals, heat and CO_2 are absorbed by the algae. This enables the algae to reproduce itself from the energy, and later they can be harvested for biomass.

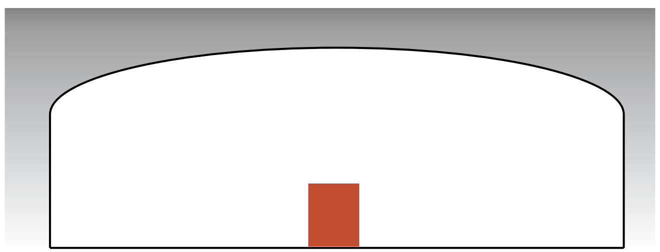




The facade concept in the Summer time regards an external transparent insulation that blocks the heat transfer through conduction but still enables heat transfer through radiation. The sun heat is absorbed by the internal wall, and the light is diffused into the room.

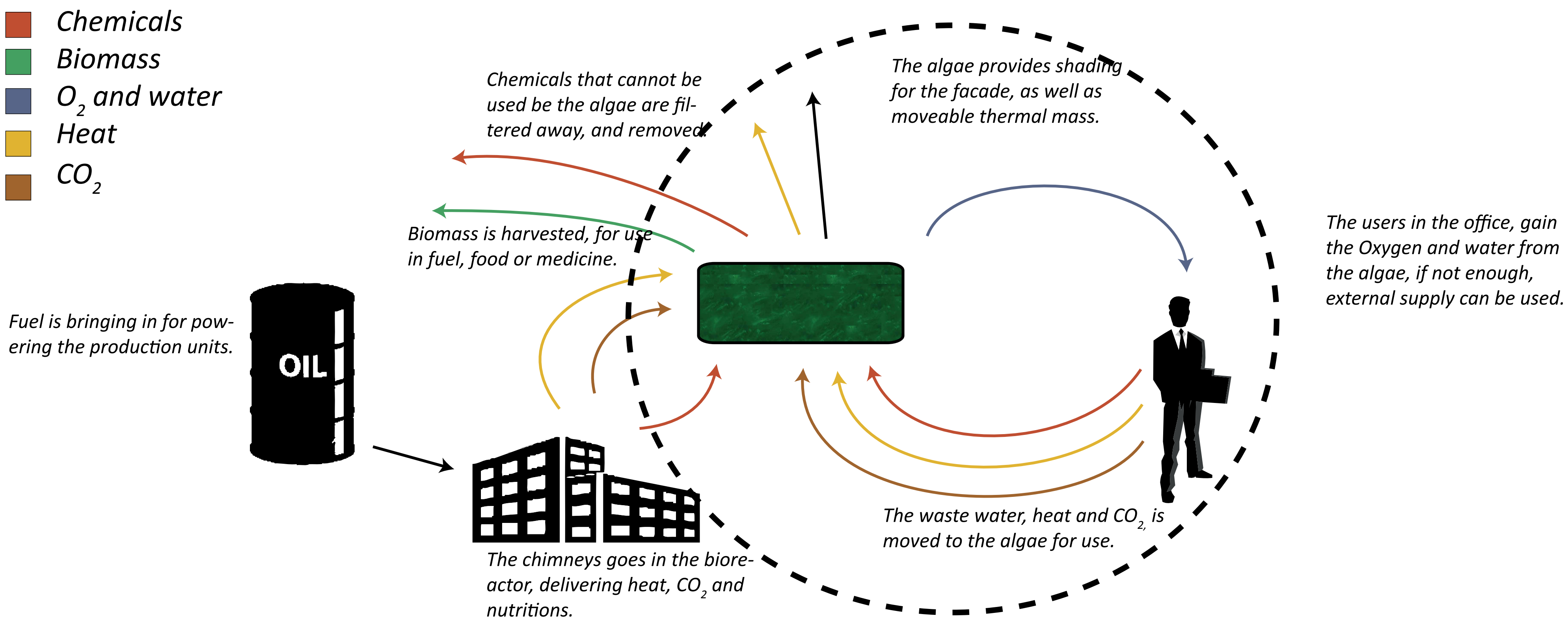


In the Winter, the internal walls are made thinner to enable the same amount of diffuse light into the building. The heat in the internal wall is kept with a higher flow to enable the right climate comfort.



The thermal mass can be moved to the facade and heated during the day. During the night is moved to the core of the building to keep it warm until next day. The stored heat is moved to the facade in the morning for heating up the building.

CONCEPT



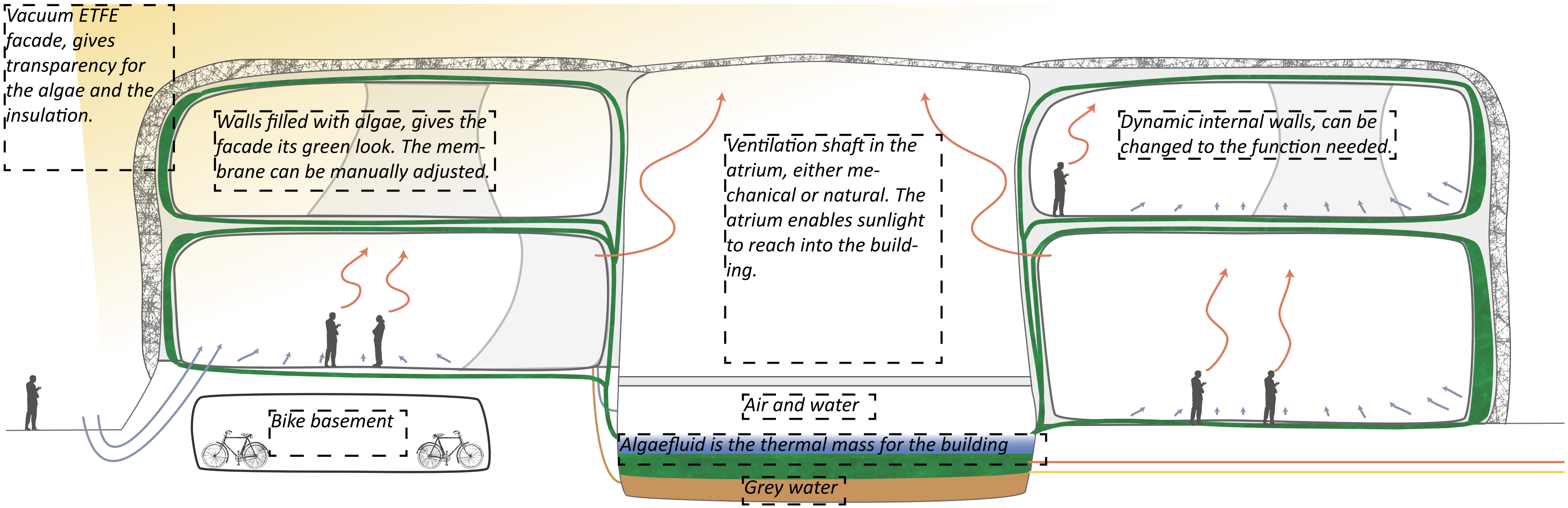
In the concept the algae are used in enhancing the building envelope. Micro algae is used because they exist in water and have a fast reproduction, what will enable a bigger impact in the building, when compared with the use of other plants.

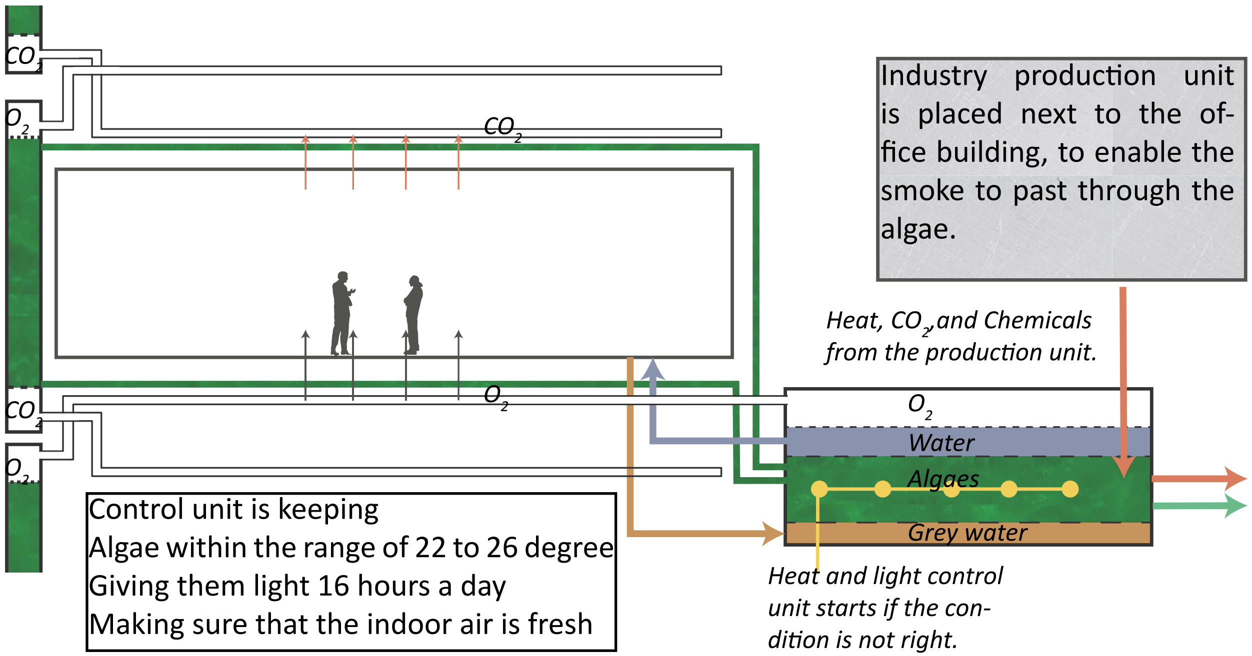
The concept is that the algae is connected to an industrial unit that produces polluted air, what will feed the algae with CO_2, nutritions and heat.
The polluted air is cleaned by the algae, while a membrane blocks all the chemicals from entering the building. The heat in the smoke is mixed with outside air for not overheating the algae.

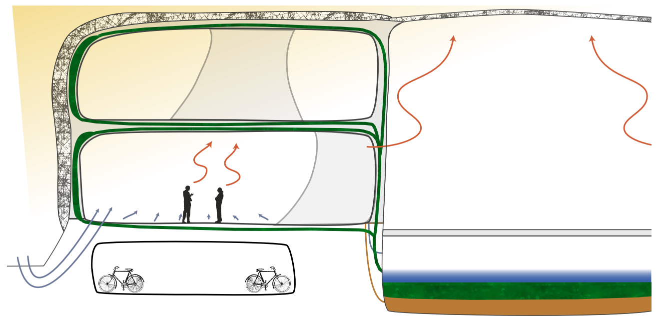
The use of algae is also benefic to the inhabitants as they can be used as shades, diffusing the sun and as dynamic thermal mass, moving from the facade to the centre of the building.
Wastewater and CO_2 from the inhabitants is moved down to the bioreactor unit where they are used as nutritions by the algae. The rest is let out.

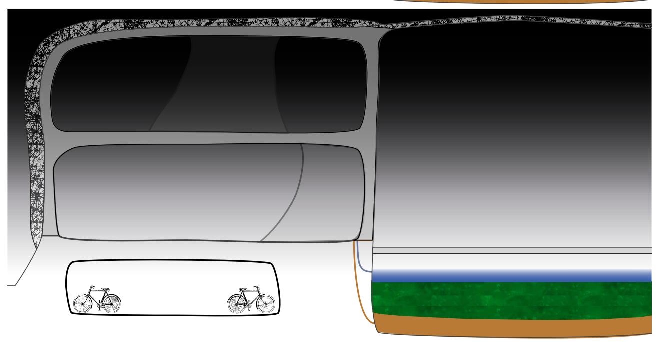
The building concept is a light and transparent construction that enables the maximum feedback from the algae mass and light transmittance for the algae.
To get a feedback from the algae flow on the building, its envelope is made with using flexible construction. This enable the building to move according to the flows inside - both from users and algae. The outside conditions, wind and rain, are also reflected in the transparent skin and in the flexible structure.

The construction is build in a way so that it can be dissembled again without a big waste of bounded material in the building. This allows not only to adjust to the day and the function, but also to adapt over time, being able to change completely.

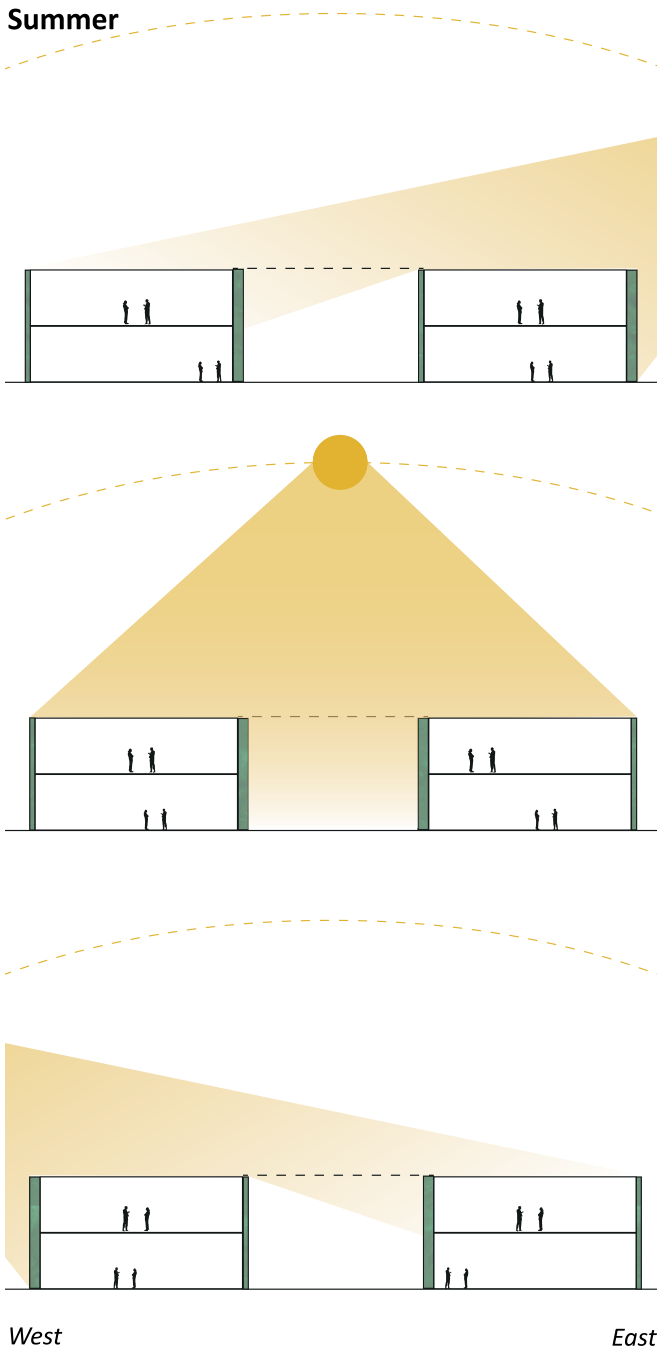

Vacuum ETFE facade, gives transparency for the algae and the insulation.
Walls filled with algae, gives the facade its green look. The membrane can be manually adjusted.
Ventilation shaft in the atrium, either mechanical or natural. The atrium enables sunlight to reach into the building.
Dynamic internal walls, can be changed to the function needed.
Bike basement
Air and water
Algaefluid is the thermal mass for the building
Grey water


CO_2
O_2
CO_2
O_2
CO_2
O_2
Industry production unit is placed next to the office building, to enable the smoke to past through the algae.
Heat, CO_2, and Chemicals from the production unit.
O_2
Water
Algaes
Grey water
Control unit is keeping
Algae within the range of 22 to 26 degree
Giving them light 16 hours a day
Making sure that the indoor air is fresh
Heat and light control unit starts if the condition is not right.



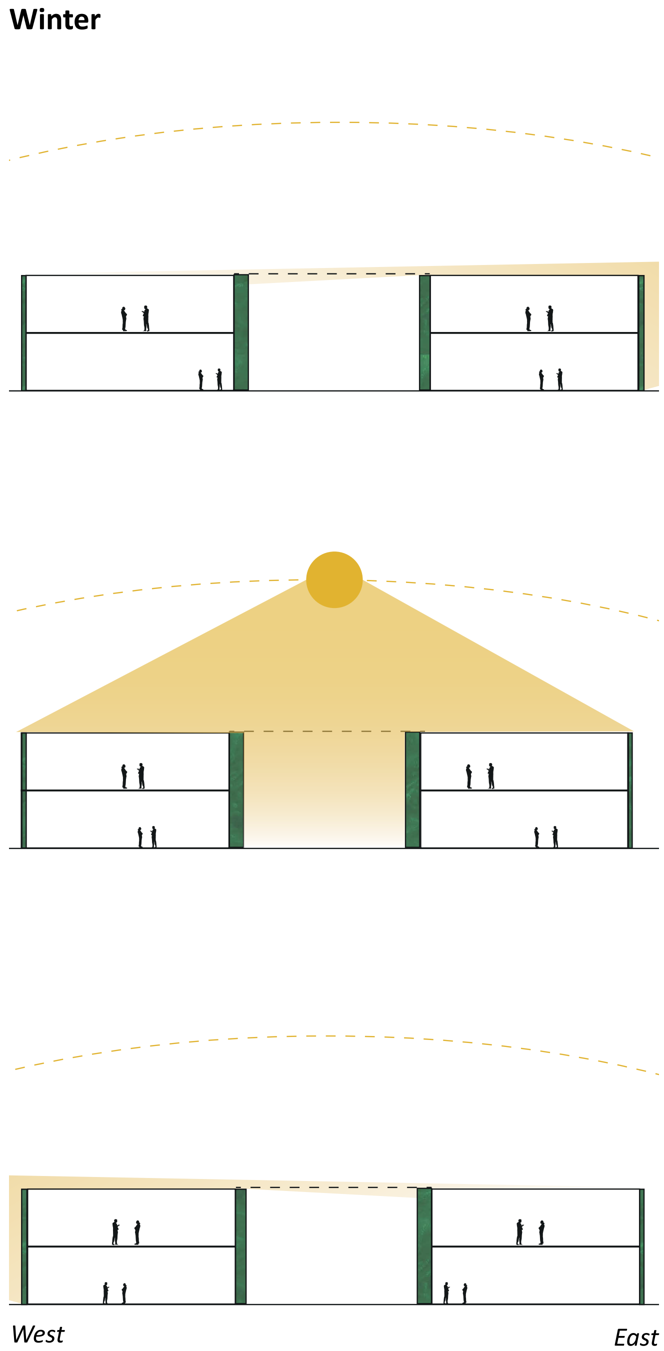


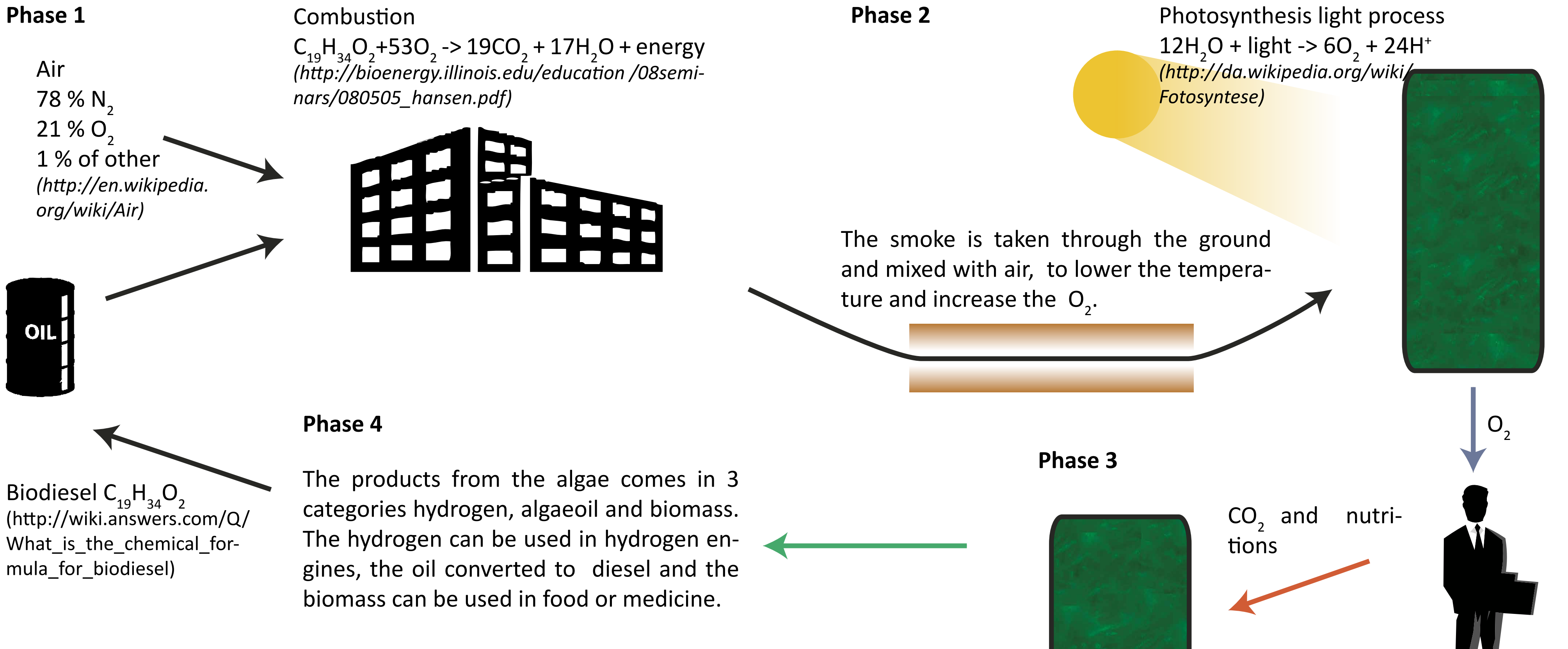
RESPOND

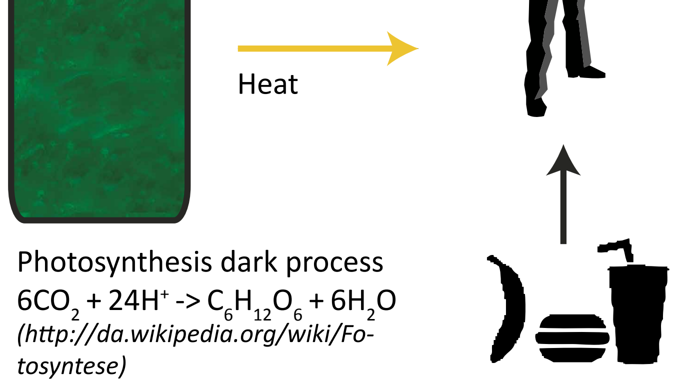


To enable a faster respond and shading in the atrium, the bioreactor is moved from the floor to the wall, in the atrium. This makes the algae able to receive sunlight through the day, and the concept can easier be implemented in higher buildings.
The different states of the facade system are presented in the diagrams in the left and right hand side, for Summer and Winter respectively.
The algae concentration can change so that there is a higher concentration in the Winter. This enables the pump to move less water to achieve the same amount of sun light diffusing than it else would need. The higher concentration makes it easier to have constant cycle of algae in facade, to enable a more constant temperature.
In the Summer the algae concentration is lowered enabling a higher absorption of heat through the during the day. The reproduction of algae is also increased due to a higher amount of sun light, this makes the algae have the need of more water to grow in.

Morning: The algae is moved to tahe east face to diffuse the penetrating morning sun; in the west facade some algae are moved out, this is only to provide the heat needed in the morning.
Noon: The algae are moved away from the east facade to let in daylight and is stored in the atrium where it catches part of the midday sun.
Afternoon: The algae are moved from the atrium to the west facade, to diffuse the evening sun light.
Night: In the night all the algae are stored in the central walls of the atrium.







Phase 1
Air and fuel are brought into combustion to generate power for the engine. Methyl Linoleate is used as an example for a biocombustion process, generating $C0_2$ and water. Enough oxygen is brought into the process for achieving a complete combustion.

Phase 2
Here the smoke from the fabric is transported through the earth and mixed with outside air, in order to lower the temperature of the smoke and increase the amount of oxygen.

Phase 3
The air infiltrated through the algae is used by the workers. CO_2 and wastewater from the workers are then absorbed by the algae. The algae learn the day cycles and start to store sun energy, so the process of reproduction can continue during the night time, where some of the chemical energy is released into the water.

Phase 4
The algae mass is harvested into biomass and algae oil. This can be used for biofuel, medicine or high food value product.

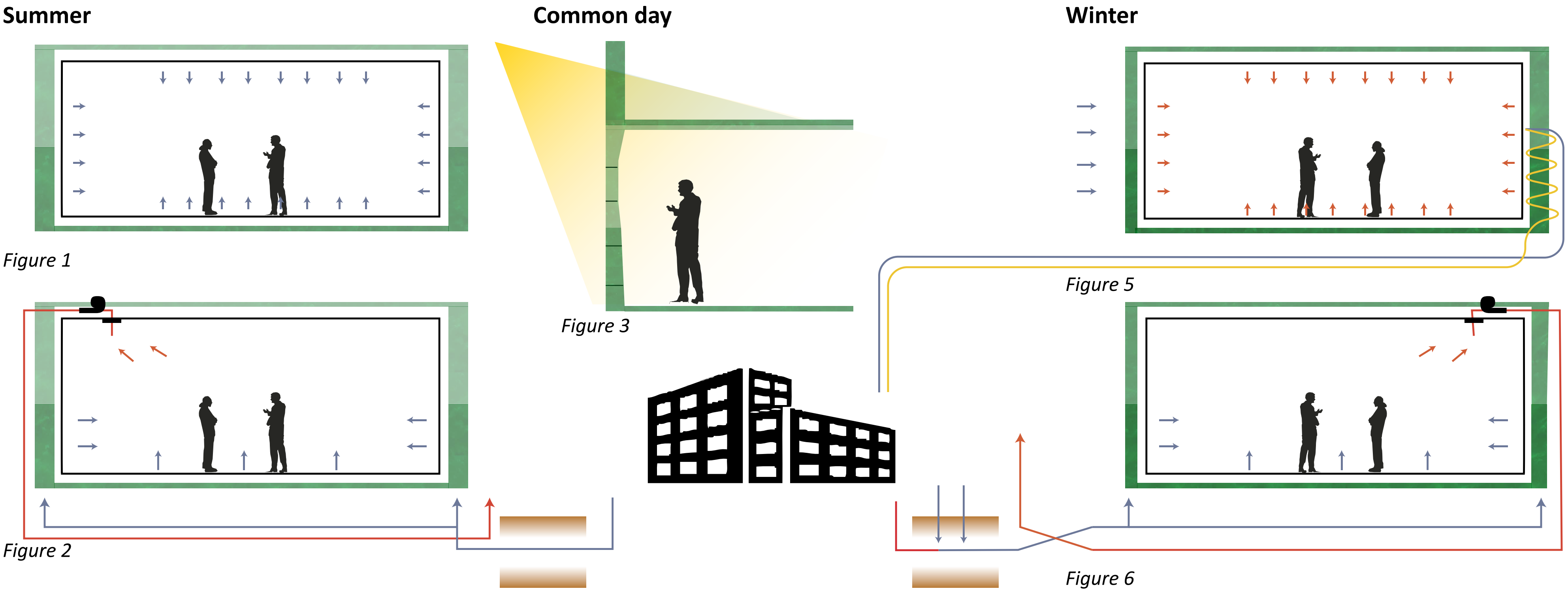


Figure 1
The thermal mass in the algae is cooled down during the night and it's pumped out through the day for cooling the building.

Figure 2
The inlet air is cooled down using earth coupling before being ventilated in through the facade. This provides inlet air that enables cooling of the building.

Figure 3
Manual control of the membrane thickness enable the users to directly control the light diffusing into the building.

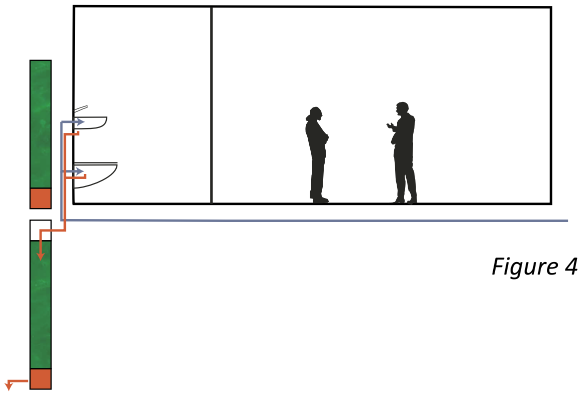


Figure 4
The wastewater from the toilet and sink is transferred to the algae to provide nutritions. The algae can grow during the night.

Figure 5
The algae reactor is connected to the cooling water from the production plant. This provides the heat the algae need in the Winter time.

Figure 6
The polluted air from the production plant is mixed with air from the outside, to lower the temperature and increase the oxygen amount in it. After, it's connected to a heat recovery unit which increases the air temperature, so it can be used for inflation.

EQUATION

	Activity	Occupancy	Category	Summer temp.	Winter Temp.	Summer flow	Winter flow	Ventilation rate
One person office	1,2	0,1 pr. m²	A	24,5 +/- 1,0	22,0 +/-1,0	0,18 m/s	0,15 m/s	2,0 l/s · m²

CR 1752:1998

To refine the concept of the algae, some design tools are considered in order to enable an integration between the design and performance of the building. To simplify, only a section of 1 meter deep cut of the building is considered. The standard values above are taken from CR 1752:1998, for a one person office in category A. The use of this here is wrong, but since this is the hardest to achieve it's used as a guideline and further adjustment can be made.

Data for a section of 1 meter deep, and 12,5 meter width, with one wall facing the atrium and the other facing the outside:

1,25 person

Heat load DS(3.8): *(Ventilations stabi, 7.2) (Ventilations stabi, 7.8)*

204 W pr person and one PC of 140 W. =

1,25 · 204 W + 140 W = 395 W

CO_2 production (Fig 7.13 ventilations tåbi):

0,02 m³CO_2/hperson · 1,25 = 0,025 m³CO_2/h

Light *(Fig 7.5 ventilation ståbi):*

200 lux in 0,8 m height

O_2 use *(http://en.wikipedia.org/wiki/Breathing)*

0,09 l/s

Facade U-value:

1 W/m² · K

The ventilation is made so that the inlet air is coming from the outside through the facade and the outlet is through the atrium.

Algae

To get an understanding on how a algae work, Niels T. Eriksen and Torben Hansson were involved and informed about some average facts on algae and bioreactors.

1 m² of algae surface, generate around 20 - 30 g of algae pr. day.

40 - 50 gram CO_2 use pr. m² pr. day.

Constant harvesting.

Algae concentration from 0,5 g - 2 g pr. ltr. of water.

Niels T. Eriksen, Associate Professor, Aalborg University, Department of Biotechnology, Chemistry and Environmental Engineering)

Through the growth of algae the balance between O_2 and CO_2 is 1:1

The mixing of algae will be enough with bubbles.

The photosynthesis process in algae demands CO_2 and light at the same time.

The DNA of an algae can learn over time and adapt to the cycles of a day. This enables the algae to keep its process during the night.

In a dense algae fluid a membrane of 3 -4 cm thick can block the light on a sunny day.

(Torben Hansson, Lektor, Institut for Kemi-, Bio- og Miljøteknologi)

Ventilation

To determine the ventilation needed for the building, the CO_2 and olf balance are calculated.

Ventilation needed to keep the CO_2 concentration under 0,5 %. *(Grundleaggende klimateknik og Bygningsfysik, 1.4.2)*

4,3 m³/h pr person · 1,25 · 7 h = 37.625 L

Ventilation needed to keep the decipol under 2. It is calculated with an olf of 0.1 pr. m², 0 load from inventar and 0,3 decipol in the outside air. *(Grundleaggende klimateknik og Bygningsfysik, 1.17)*

$$c = 10q/V + c_i$$

2 decipol = 10 · 0,1 olf/m² · 12,5 m² / V + 0,3 decipol

V = 12,5 olf / 1,7 decipol

V = 7,35 l/s

7,35 l/s · 3600 · 7 s = 185.220 L

This is higher than the previous value, so the rooms need to be ventilated because of smell.

Winter case heating
The heat balance for a given room is that the heat in is equal the heat out.

$$\Phi_t + \Phi_v + \Phi_{inf} = \Phi_{load} + \Phi_{heat} + \Phi_{sun}$$

Where
Φ_t = Transmission lose
Φ_v = Ventilation lose
Φ_{inf} = Infiltration lose
Φ_{load} = People and equipment load
Φ_{heat} = Heating system in building
Φ_{sun} = Sun heat transmission

Because all air goes through the facade the Φ_{inf} can be calculated as 0. Because the calculation is performed in the winter period it makes $\Phi_{sun} = 0$.

$$\Phi_t + \Phi_v = \Phi_{load} + \Phi_{heat}$$

Transmission lose
(Ventilations stabi, 6.3.1)

$$\Phi_t = U \square A \square (t_i - t_u)$$

Where
U is transmission W/m² □ K
A is the area of the surface
t is the temperature in or out

1 W/Km² □ 2,2 m² (22° -(-8°))
= 66 W

Ventilation lose
(Ventilations stabi, 6.2.2)

$$\Phi_v = \square \square c_p \square q_v \square (t_i - t_u)$$

tWhere
□ = 1,188 kg/m³
c_p = 1,007 KJ/kgk
q_v = 0,00735 m³/s from before
t_i = 22° in winter
t_u is the temperature ventilated in.

Temperature in inlet air
(Ventilations stabi, 16.3)

$$t_i = t_{cold} + \square(t_u - t_{cold}) + t_{cold} + t_{smoke}$$

Where
□ is the heat recovery effect
t_u is the temp of the outlet air
t_{cold} is the outdoor temperature
t_{smoke} is the temperature gained from the smoke

Temperature in outlet air
The Φ_{load} and Φ_t is calculated within the t_u.

7,35 l/s □ 1,188 kg/m³ □ 1,007 KJ/kgk = 8,8 J/Ks

It is calculated with a heat load on 204 W pr person and one PC of 140 W. The heat transmission is subtracted from the internal heat load.
(Ventilations stabi, 7.2) (Ventilations stabi, 7.8)

(204 J/s □ 1,25 - 66 J/s + 140 J/s)/ 8,8 J/Ks = 37°

Temperature gain from the algae
45 gram CO_2 absorbed times the facade area 2,2 m². Molar mass for CO_2 40,011 g/mol.
(http://en.wikipedia.org/wiki/Carbon_dioxide)

45 g/m² □ 4,4 m² / 40,011 g/mol =4,948 mol

To get it in litre the following conversion is used.
(http://members.shaw.ca/tfrisen/how_much_oxygen_for_a_person.htm)

22,4 L/mol □ 4,948 mol = 110,8 L

The amount of energy stored in the smoke.

1,017 KJ/kgK □ 0,815 kg/m³ □ 110,8 L □ 100/P_{co2} □ t_p
= E

Where
t_p is the temperature in the smoke.
P_{co2} is the CO_2 % in the smoke

A case whit smoke containing 10 % CO_2 and is at 160°.

1,017 KJ/kgK □ 0,815 kg/m³ □ 110,8 L □ 100/10 □ 160⁰ = 147 J

The temperature increases because of the gain from the amount of algae absorbing smoke

t_{smoke} = 147 J / 1017 J/kgK □ 0,815 kg/m³ □ 185.2 m³
t_{smoke} = 0,001°

Result
Inlet air temperature can now be calculated from the previous formula. The calculation is made with t_{cold} of -8° and a heat recovery effect of 0,75.

$$t_i = -8 + 0,75(37 + 8) - 8 + 0,001 = 17,751°$$

The heat lose during to ventilation can then be calculated.

Φ_v =1,188 kg/m³ □ 1,007 KJ/kgk □ 0,00735 m³/s □ (22° - 17,751°) = 37 W

From the heat balance before is $\Phi_v = \Phi_{heat}$ so in the winter time there is a need for heating pr. m² 37 W/12,5 m² on 2,96 W/m². This heating is achieved from the flow of algae in the heated core.

Summer case cooling
The same equation is used as before.

$$\Phi_t + \Phi_v + \Phi_{inf} + \Phi_{bio} = \Phi_{load} + \Phi_{heat} + \Phi_{sun}$$

Where
Φ_t = 1 W/Km² $\cdot$ 2,2 m² (24,5° -(25°)) = -1,1 w

Ventilation lose, due to natural ventilation.
(Ventilations stabi, 6.9)

$$\Phi_v = 3{,}4 \cdot n \cdot V \cdot (t_i - t_{varm})$$

Where
n is the airchange rate
0,00735 m^3/s / (12,5 m² $\cdot$ 2,2 m) = 0,96 h^{-1}
V is the volume
t_i is the required indoor temperature.
t_{varm} is the outdoor air

$$\Phi_v = 3{,}4 \cdot 0{,}96\ h^{-1} \cdot 27{,}5\ m^3 \cdot (24{,}5^o - 25^o) = -45\ w$$

Heat load Φ_{load} is the same as before.

$$204\ W \cdot 1{,}25 + 140\ W = 395\ W$$

Heat load Φ_{sun} is found from the ventilation ståbi fig 6.8. For August there is an average value of 350 W/m² that is used. The shading factor used is 0,8 which represents the structure and ETFE pattern shading

$$350\ W/m^2 \cdot 2{,}2\ m^2 \cdot 0{,}8 = 616\ W$$

The Φ_{bio} is the energy needed to bind the glucose in the algae.

$12H_2O + 6CO_2$ + light -> $6O_2 + C_6H_{12}O_6$
Energy = 4184 J
(Algae: Anatomy, Biochemistry, and Biotechnology, 3.5)

$$4184\ J \cdot 4{,}948\ mol / 6\ mol = 3450\ J$$
$$3450\ J / 7 \cdot 3600\ s = 0{,}14\ W$$

The equation from before is then.

$$-1{,}1\ W - 45\ W + 0{,}14\ W = 462\ W + 395\ w + \Phi_{heat}$$
$$\Phi_{heat} = -1057\ W$$

This heat gain is reduced using the thermal mass in the water, and by changing the air steam from outside to ground ventilation.

Earth coupling - see p14, a case from Austria where a 50 m pipe embedded in earth reduce 10 degrees - makes a cooling of 7 degrees seem plausible in this case.
(http://www.ecbcs.org/docs/Annex_44_SotAr_RBE_Vol_2A.pdf)

The ventilation then become.

$$\Phi_v = 3{,}4 \cdot 0{,}96\ h^{-1} \cdot 27{,}5\ m^3 \cdot (24{,}5^o - 18^o) = 583\ W$$

Φ_{heat} Then become - 1057 + 45 - 583 = - 519 W

This cooling is then calculated from the amount able to be absorbed in the water. The water is cooled down to 17 degrees during the night, and able to absorb heat until reach t_i.

Energy pr day

$$365\ J/s \cdot 7 \cdot 3600\ s = 13079\ KJ$$

Energy in water pr. m^3.

$$4{,}1820\ KJ/kgK\ (24{,}5^o - 17^o)\ 998{,}2\ kg/m^3 = 31309\ KJ/m^3$$

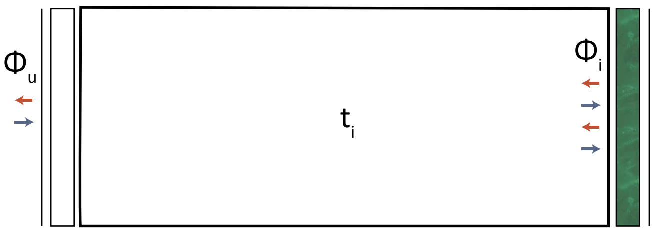
Amount of water needed

$$13079\ KJ / 31309\ KJ/m^3 = 0{,}42\ m^3$$

This will give the bioreactor a dimension of 0,42 m^3 / 2,2 m^2 = 0,19 m, this seems plausible to have in the building.

Summary
It is seen from this two sceneries that it is possible to achiee a comfortable working zone, but the effect from the algae reactions is almost minimal, the only part where it plays a bigger role is in the absorption of heat during the Summer.
The main provider for a comfortable climate is the heat recovery unit in the Winter and the earth coupling unit in the Summer.
The formulas used here to calculate the algae benefit only focus in some of their reactions. Further investigation in the reactions could reveal other benefits.
Besides, other benefits from the algae haven't been implemented in or tested in these cases, such as the thermal storage in Winter and the diffusion of sun light in the Summer, which enables to cut in the use of artificial light and allows the production of energy through hydrogen, biodiesel and biomass.

Thermal storage in the winter



Where

$\Phi_u = 1\ W/m^2k \cdot 2{,}2\ m^2 \cdot (t_i - (-12^o))$

$\Phi_i = 2\ W/m^2K \cdot 2{,}2\ m^2 \cdot (22 - t_i)$

Temperature lose in water over 12 hours

Where

Heat in water

$0{,}43\ m^3 \cdot 4{,}1820\ kJ/kgK \cdot 998\ kg/m^3 = 1794\ KJ/K$

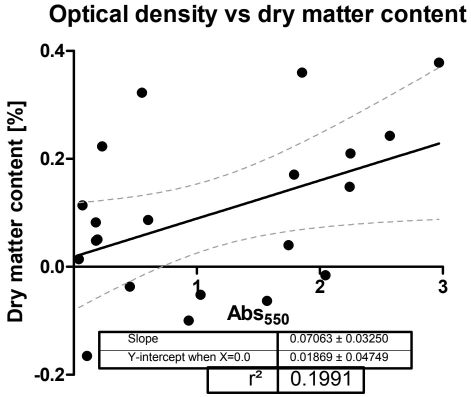
Heat in air

$12{,}5\ m^2 \cdot 2{,}2\ m \cdot 1{,}188\ kg/m^3 \cdot 1{,}007\ KJ/kgk = 33\ KJ/K$

Excel was used for calculating the temperature lose doing 12 hours, with an outdoor temperature of -12. (Se appendix on page 49)

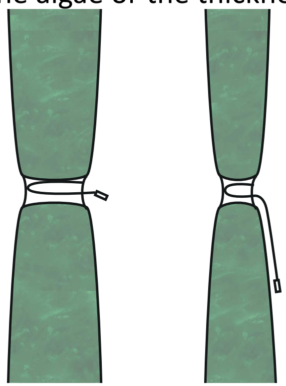
The water temperature was found to be 21,79° and the indoor air to be -0,29°. This heat in the water is then the next day, moved into the building where it conduct its heat, in 1 before the building is operational. (Se appendix page 47)

Shading



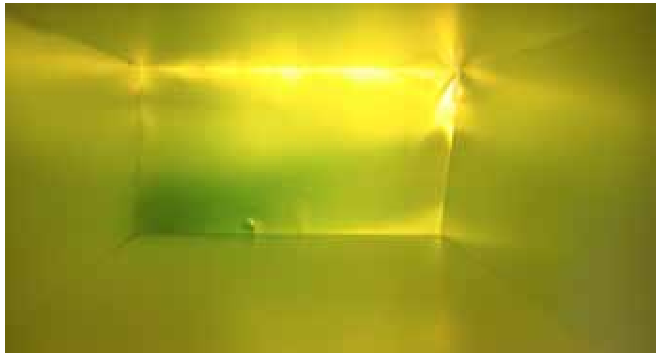
(Project in development; Analytical methods, calibrations and correlations by Anders Fjeldbo)

The graphic shows how the algae content can have a huge impact in the light transmittance. This gives the facades the possibility to adapt to any light situations, either by controling the concentration of the algae or the thickness of the membrane.

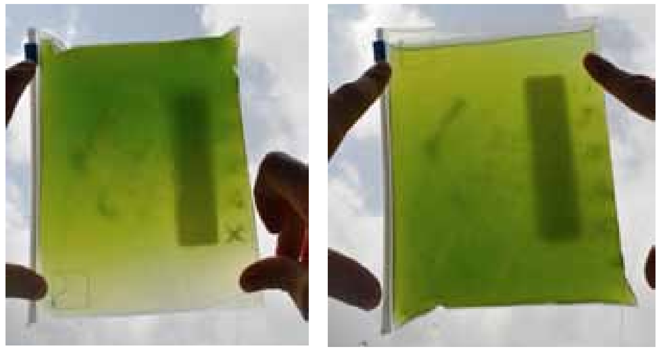


The algae concentration is adjusted in Winter and Summer, by being more dense or light concentrated respectively. To enable a high heat absorption in the Summer they should be less concentrated, so there is a higher percentage of water.

For a manual adaption the facade is able to adjust in thickness, by using a grid over the facade and through an hydraulic system. The workers are able to adjust the membrane thickness in each part of the grid. In the illustration above, the system is presented as a principle.



An algae bag on a box, hold up in front of artificial light. Can see different light transmittance, compared to membrane thickness.



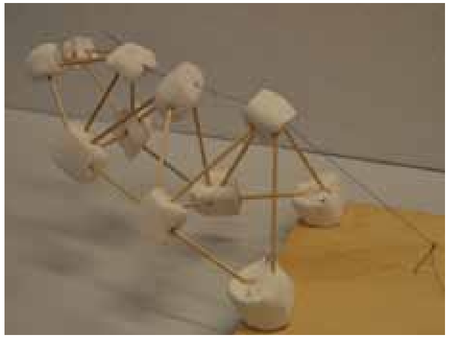
The algae bag in front of a window, its seen that be pushing in on the bag is the algae becoming more transparent.

Energy

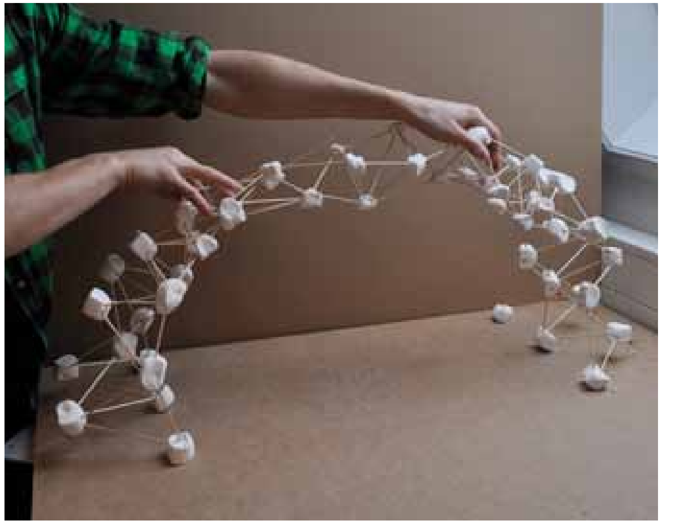
The gain from hydrogen, biodiesel and bioethanol is not further detailed, since precise information on its calculation is not easy to access. But it should provide a higher amount of energy gain than the one from the pv-cells. The algae in the entire facade should produce roughly around 10 kg of biomass each day.

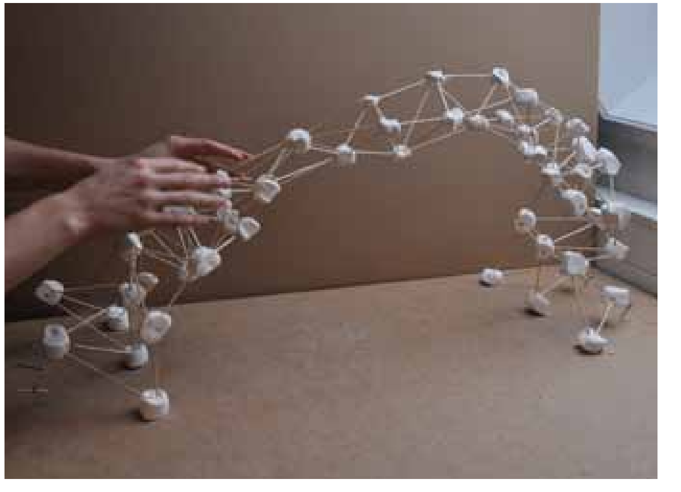
CONSTRUCTION

The carrying structure is external to keep its thermal mass outside, so that the building can stay light and easily being heated in the morning times. The first construction idea was based on a static construction, with a flexible wire structure spanning between them for holding the building skin. The construction got too big and not flexible, and was against my concept of a construction that is able to be dissembled and changed to another place or another function.
A trusses construction was tried out instead, where all the parts could be taken apart. The joints were made as released joints, enabling a transparency of the construction, where the users, the algae and wind will be seen as small motion in the moving of the structure.

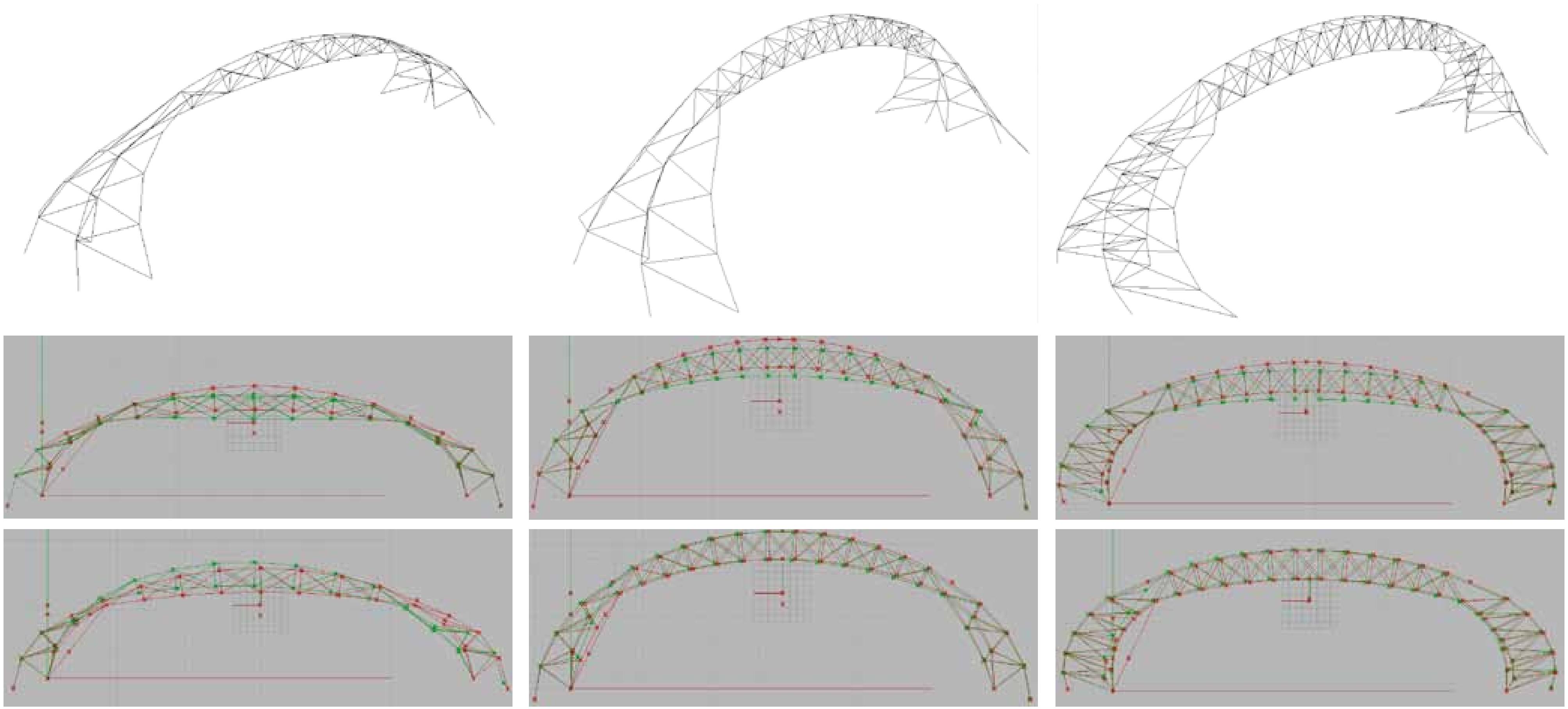


The model was made with the use of woodsticks, a common string and marshmallows to test out the principle.
Letting the woodsticks take compression, marshmallows work as released joint and the string take tension. The model was able to take forces in one direction, where the string was holding and move in the other.
The structure was made in the complete span to try out the idea of a construction which will have a deformation and how it would change.
The model only gave a rough idea of the motion, since it became too unstable with the construction materials used.
But the principle with the placement of the strings worked and that each side was supporting each

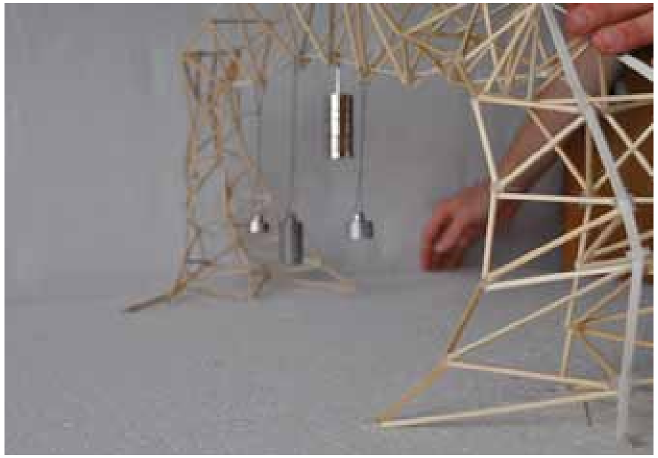


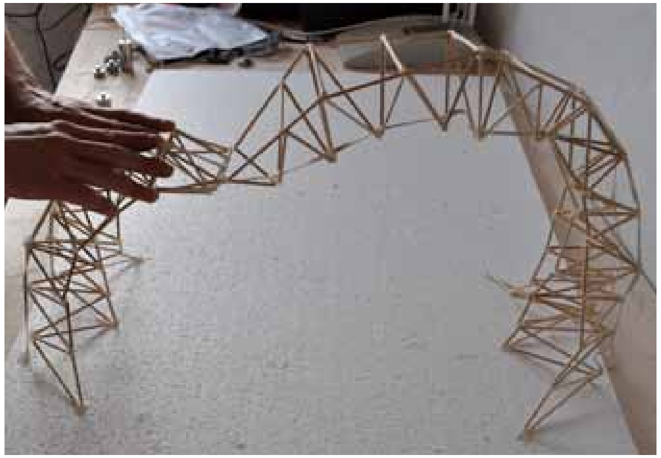


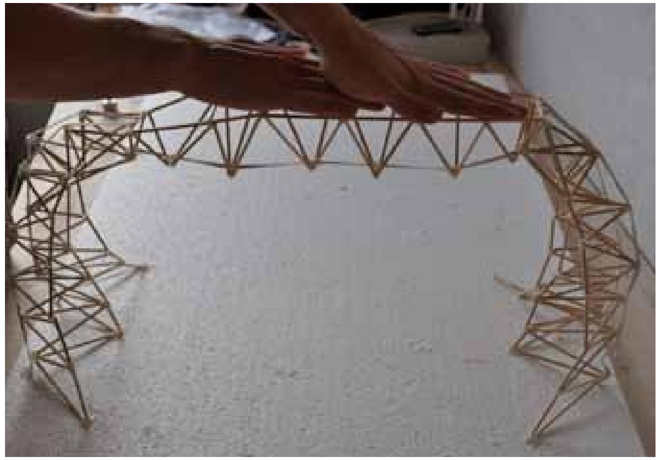
other against horizontal forces. The model was able to take a good amount of vertical load.
For further testing the model was made in 3d software for a digital analyses of it.



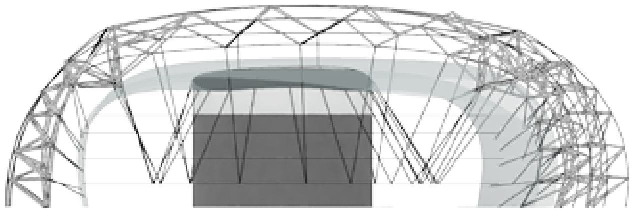
The model was buil as a parametric model in grasshopper to enable to adjust the shape of all components. Kangaroo was brought in as a physics simulator to use as a comparing tool, for the different shapes generated in grasshopper. Kangaroo finds the forces working on each subject, with Newton's second law to get each acceleration, and integrates the resulting differential equation of motion over time to find the new positions for all the parts.
(https://docs.google.com/View?id=ddpv99dx_44f88c75fh).
The aim was to continue testing and optimizing the shape to find a shape which reacts to external forces, and still is capable to take the load.
The process is not to be compared with the finite element method, in which the elements dimension are found, this is simply to compare the different solutions.
Two simulations were made for each width, a relative forces horizontal and vertical. The element of the structure was split into three configurations, trusses, cables and beams, where the amount of energy stored in an element extraction is biggest in the beams, smaller in the trusses and smallest in the cables.
Above there are three examples from the process, which is part of many examples simulated during the project.
The last examples were chosen because of its rounded shape, the flow of the structure from the ground and up, the stiffness and the rhythms in the beams and trusses. (Se appendix page 48)



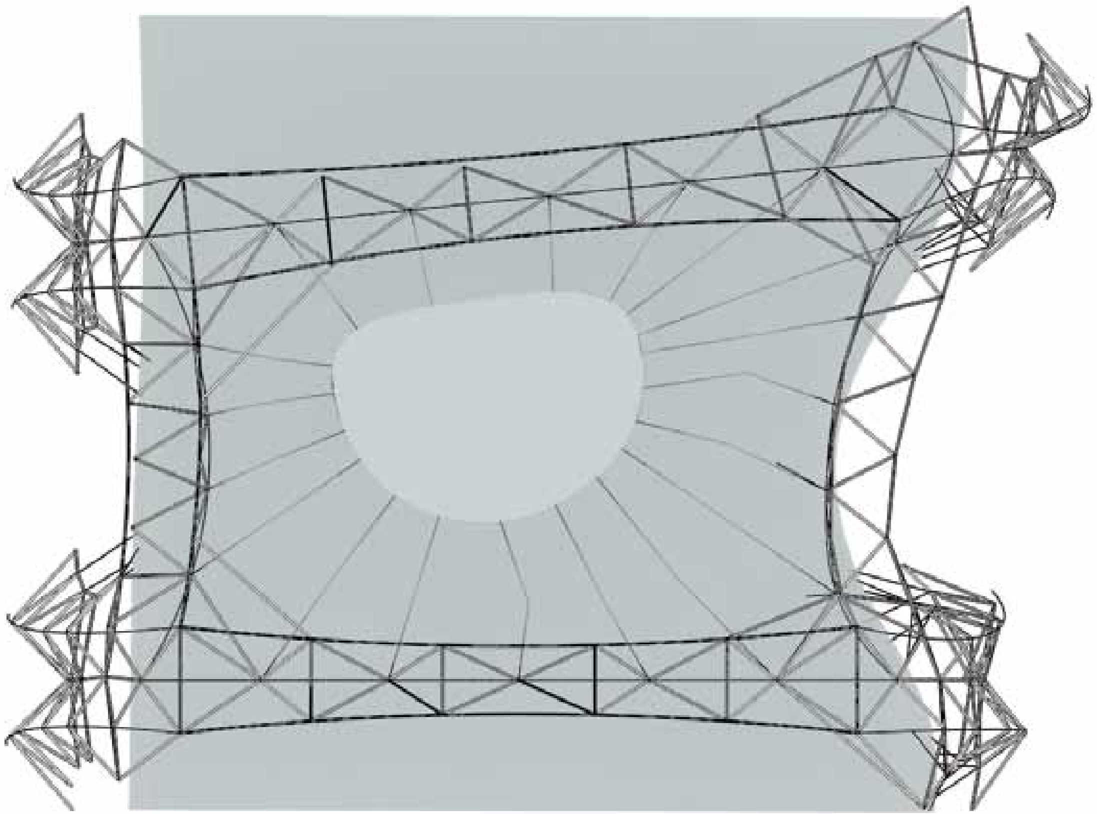




The illustrations above present the final model built, based in grasshopper results. Glue is used as released joints and rubber bands for the tension cables. The walls around the atrium are made stable. This is both to carry the floor and to support any other function which cannot be build on the other structure.



The floors are carried by using tension cables. The cables are placed so there is an even span, in which the cables are connected to the floor. (see illustration above and on the right hand side)

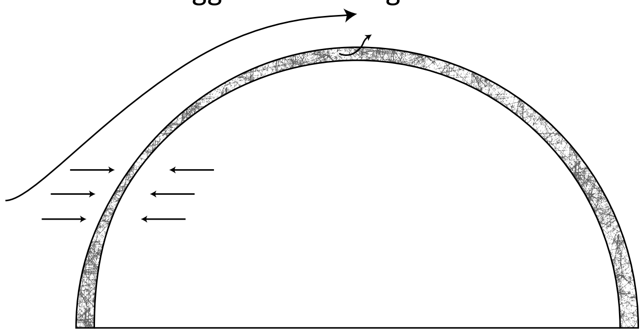


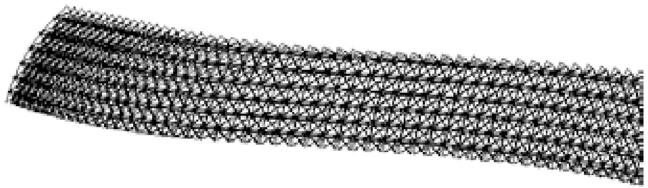
FACADE

For the facade, biology is used as inspiration, by applying the tensegrity concept - structural system of cell biology.
When applying the tensegrity structure into larger scale, there is a problem with the way it takes outside forces, since gravity has a bigger impact and an uneven amount of pressure on specific parts of the structure is stronger.
The concept used for the facade is based on the quad tensegrity structure, it turns from the ground and up 45^0 . By having two of this it´s possible to make it turn 90^0, this enables an equal surface structure on both sides internal and external.

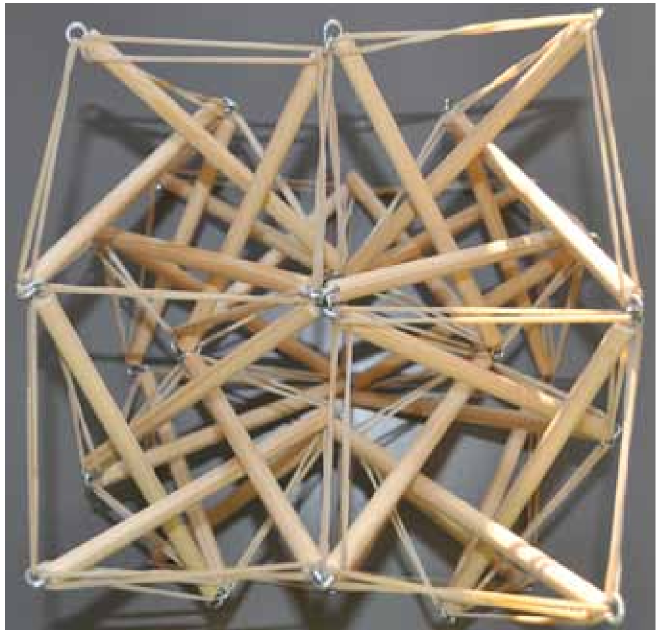
This structure is used to achieve a facade with a low U-value and still a good light penetration factor.
The use of ETFE, as described before, is ideal for a light construction and ETFE let in a wide range of light waves.
To achieve a low U-value the use of vacuum in the facade is applied. This lets light and heat waves pass through but blocks heat transmission.
Tensegrity structure is used as the support structure between the ETFE surfaces. This enables a strong structure which still can have a reaction/motion from wind and load.
The tensegrity enables a connection between the two surfaces with no fixed connection, making it possible for a facade with no cold bridges from the facade to the inside of the building.
Double layer or triple layer use of the facade element could apply, to improve the facade. For the previous calculation there was an U-value of 1 W/m^{2}K, this seems plausbile to achieve in this case.

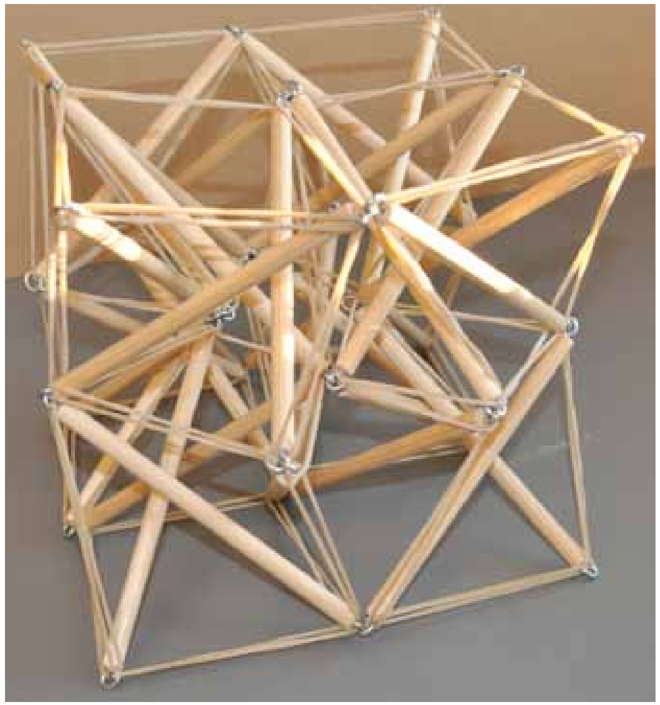
The vacuum in the tensegrity structure is kept using a one way air ventail placed at the top, (see illustration below). Wind applies pressure on the tensegrity and the shape creates a dragg at the top. With the action of these two, the air in the structure is dragged out through the ventail.



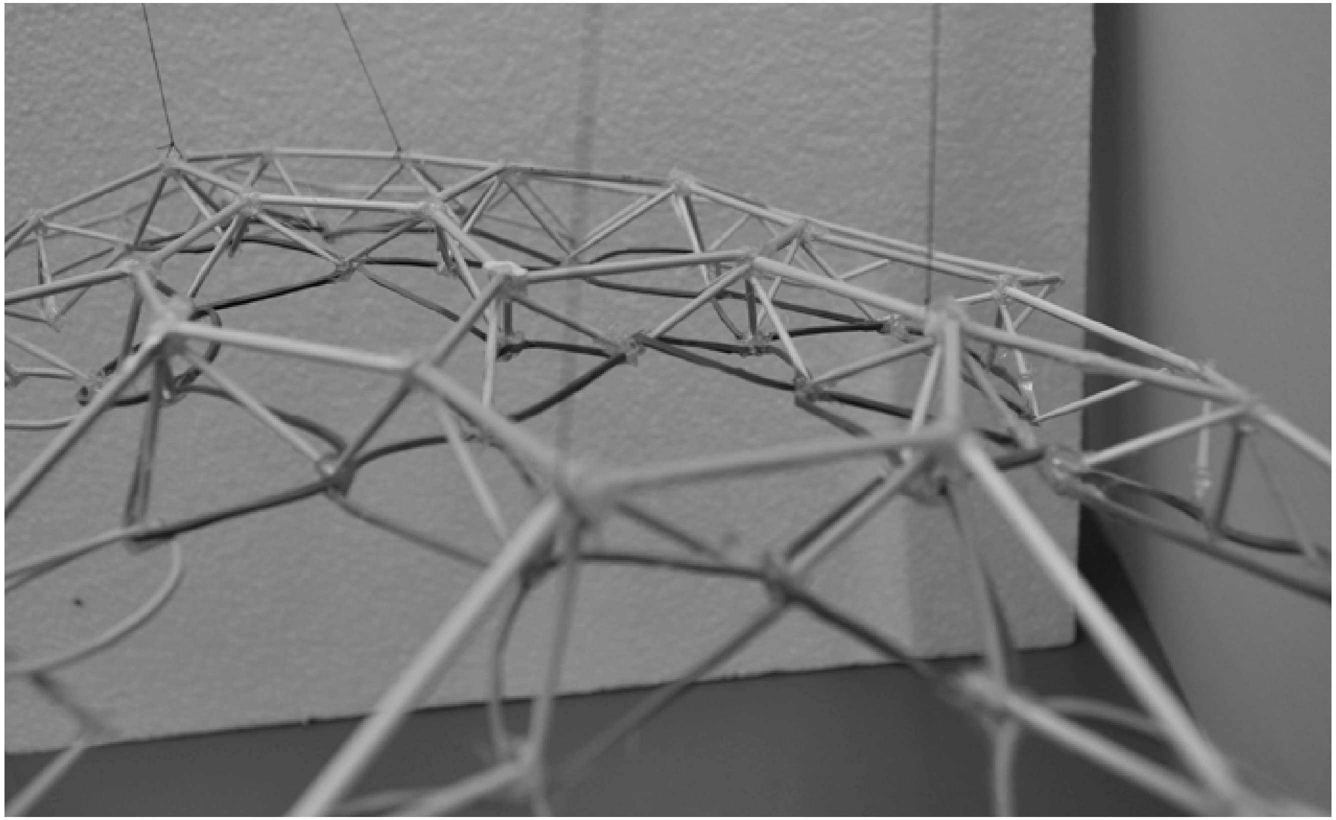


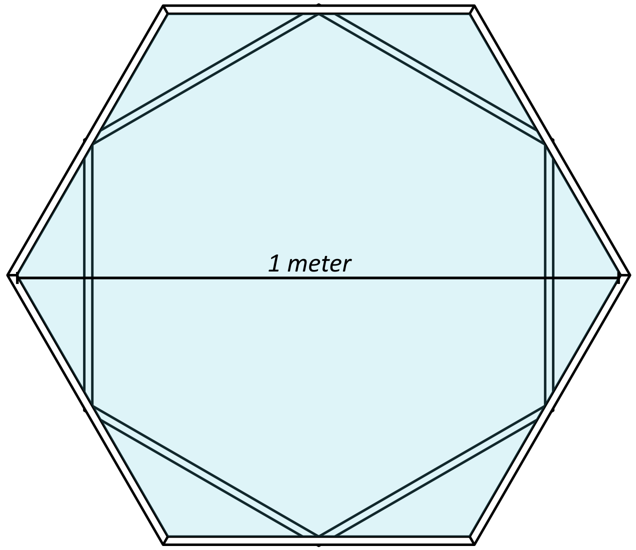
A grasshopper file was made to test and apply the tensegrity grid to a double curvature surface. This allowed to develop faster the final model. (see illustration above)

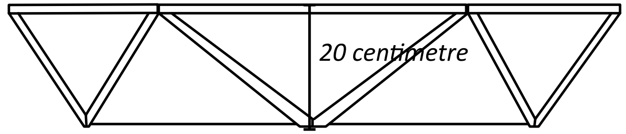




FLOOR



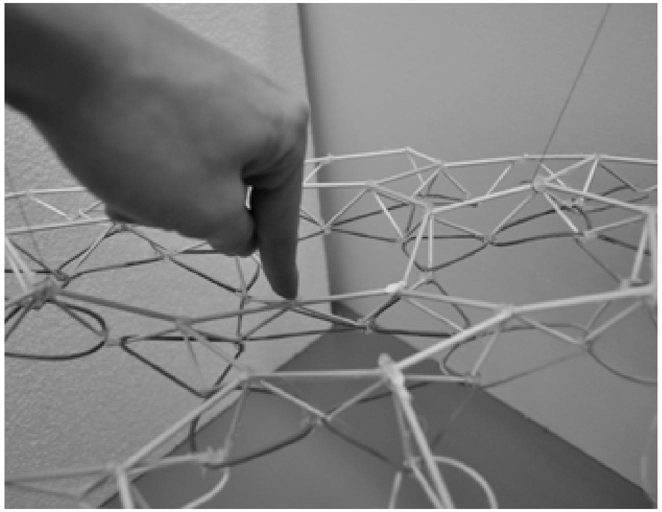




The floor structure is made taking inspiration from the honeycombs, where a minimal structure is used to cover a largest span. In the project, the floor structure is made using only released joints, like the external structure, which enables it to move.

The surface of the floor is made in a transparent material, such as silicon or textile, which can take the load from the workers. Steelwire is integrated in the surface, blocking any cuts or big hulls.

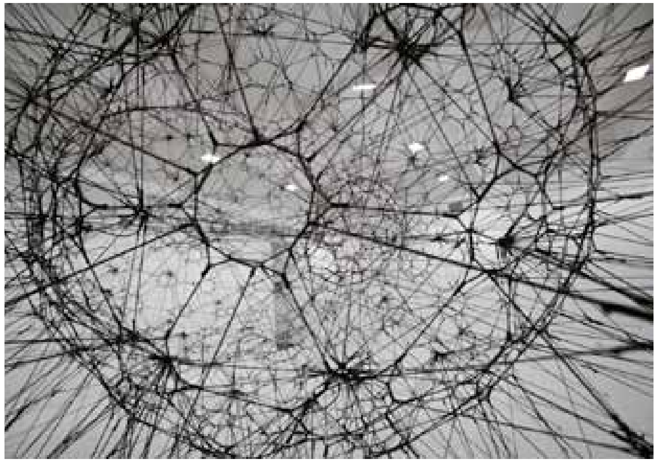
Tubes for the algae are made under this surface, running in the construction from the atrium walls to the facade.



INTERNAL

Ill. 22

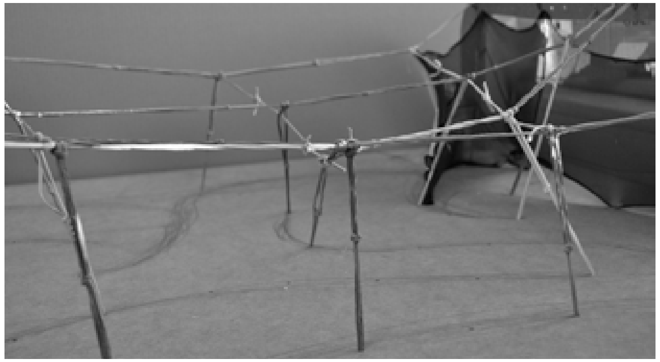
Ill. 23

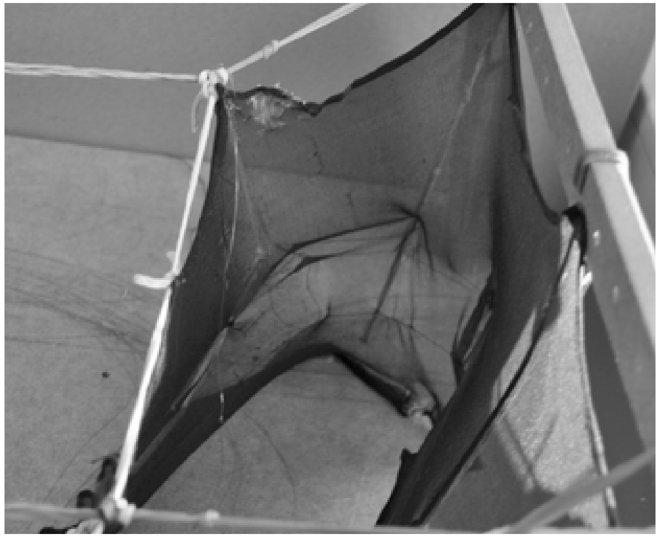


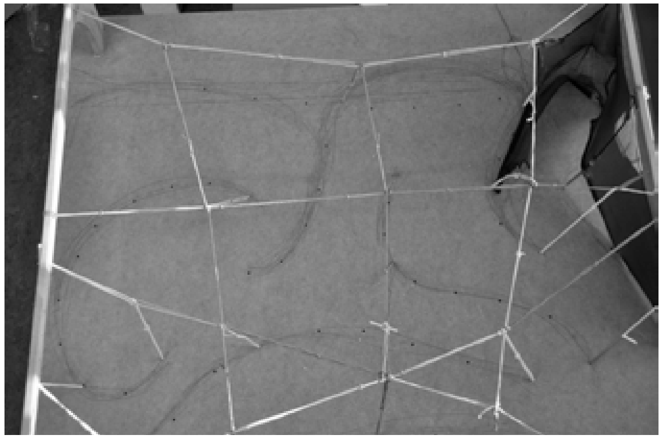
Ill. 24

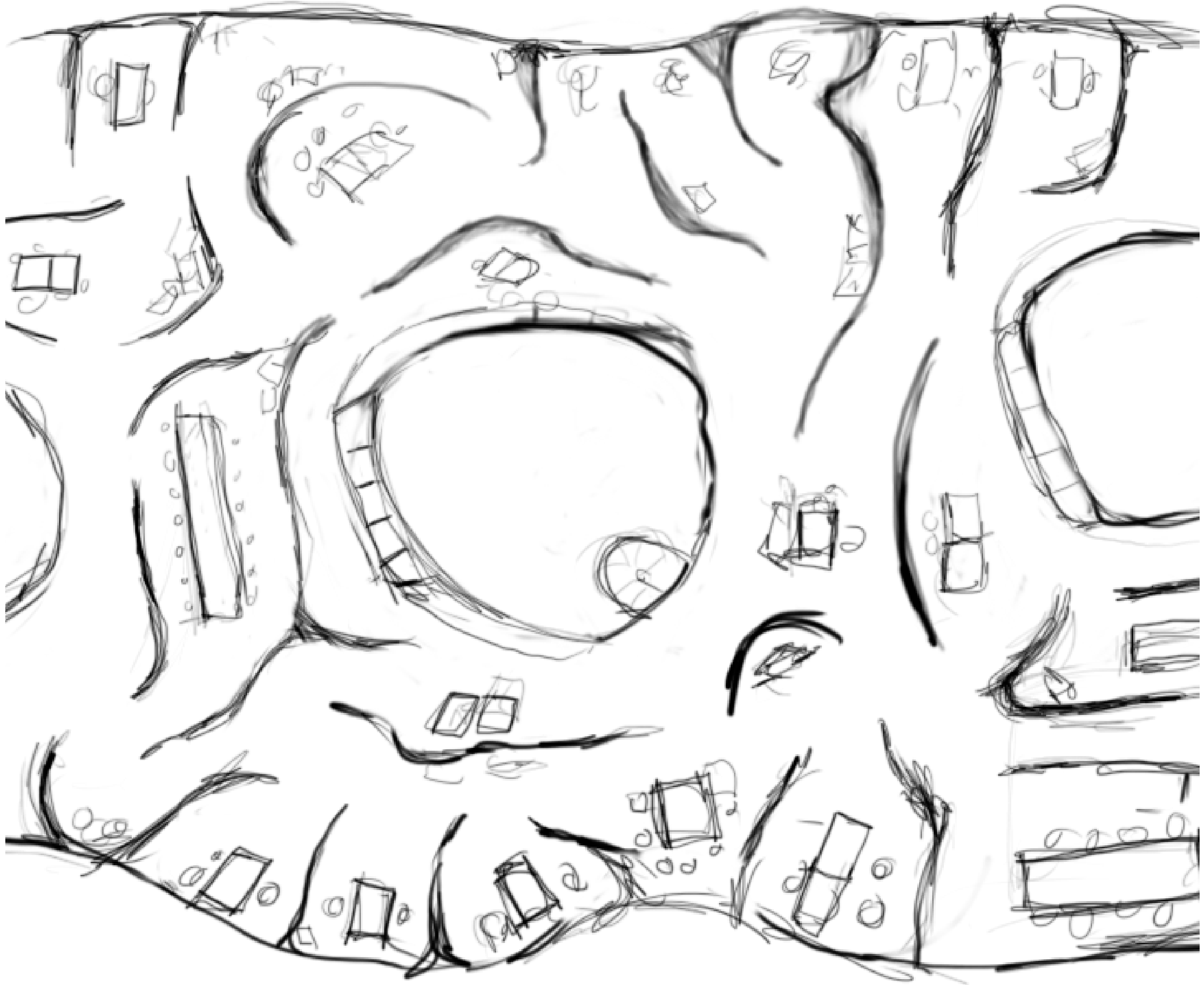
Inspiration for the internal organisation is taken from Tomás Saraceno, in his work “Lighter than Air”, concerning the topics on how we dwell together and how we coexist with the world. These ideas of ultra light structure and transparent complexity are seen as tools to create a space with both the feeling of inclosed in complexity but also still a transparency in the building. This complexity and changes, is also experienced in nature, where a natural relaxing atmosphere for the brain is offered.

In the creation of internal spaces for my project, the idea of a transparent membrane structure is developed further. The first model was a trial with a total membrane structure, expanded from the facade to the atrium and supported by a carrying structure. (see the two pictures on the top, right hand side corner) The model was made in tape, which gave the feeling of a transparent structure and how it could create different room shape for the internal. The idea with the total membrane structure was skipped because of its unfunctional rooms and the need of putting in another element. An easier model was made with the membrane being suspended between floor and ceiling. (see illustration above) This suspended membrane should then be able to take shape according to different functions, such as couch, storage and others, with the use of wires connecting to the ceiling.



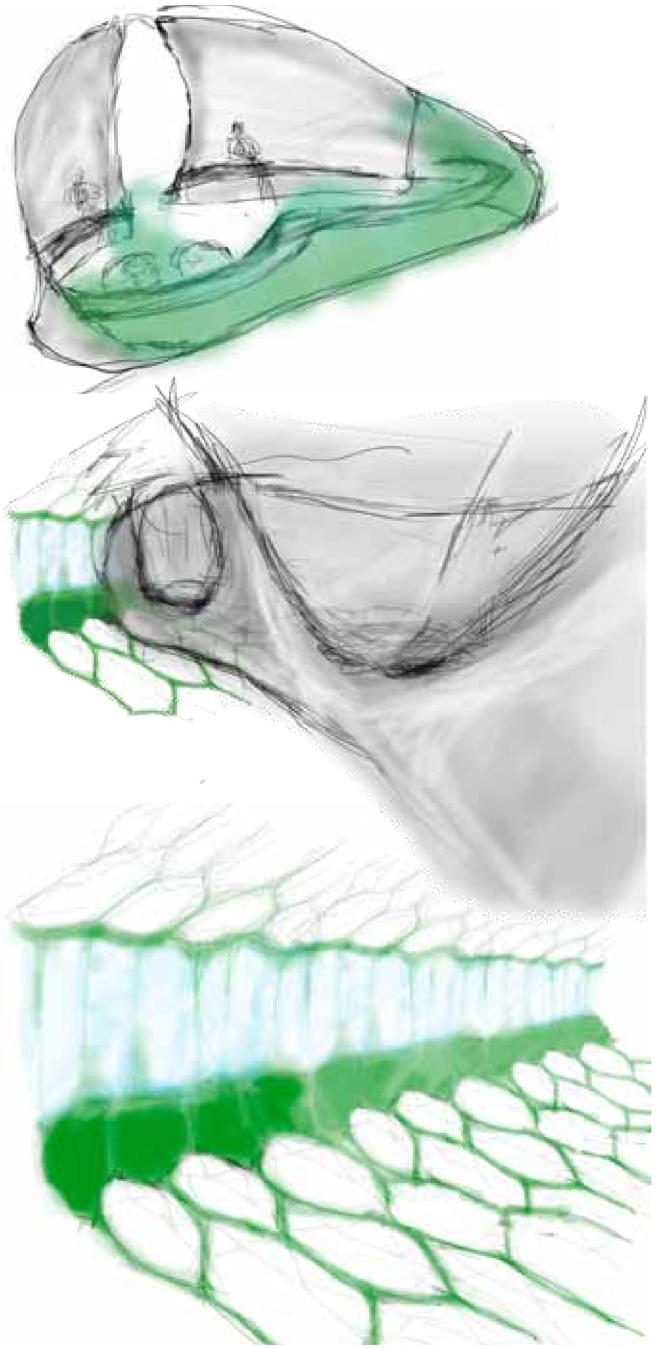


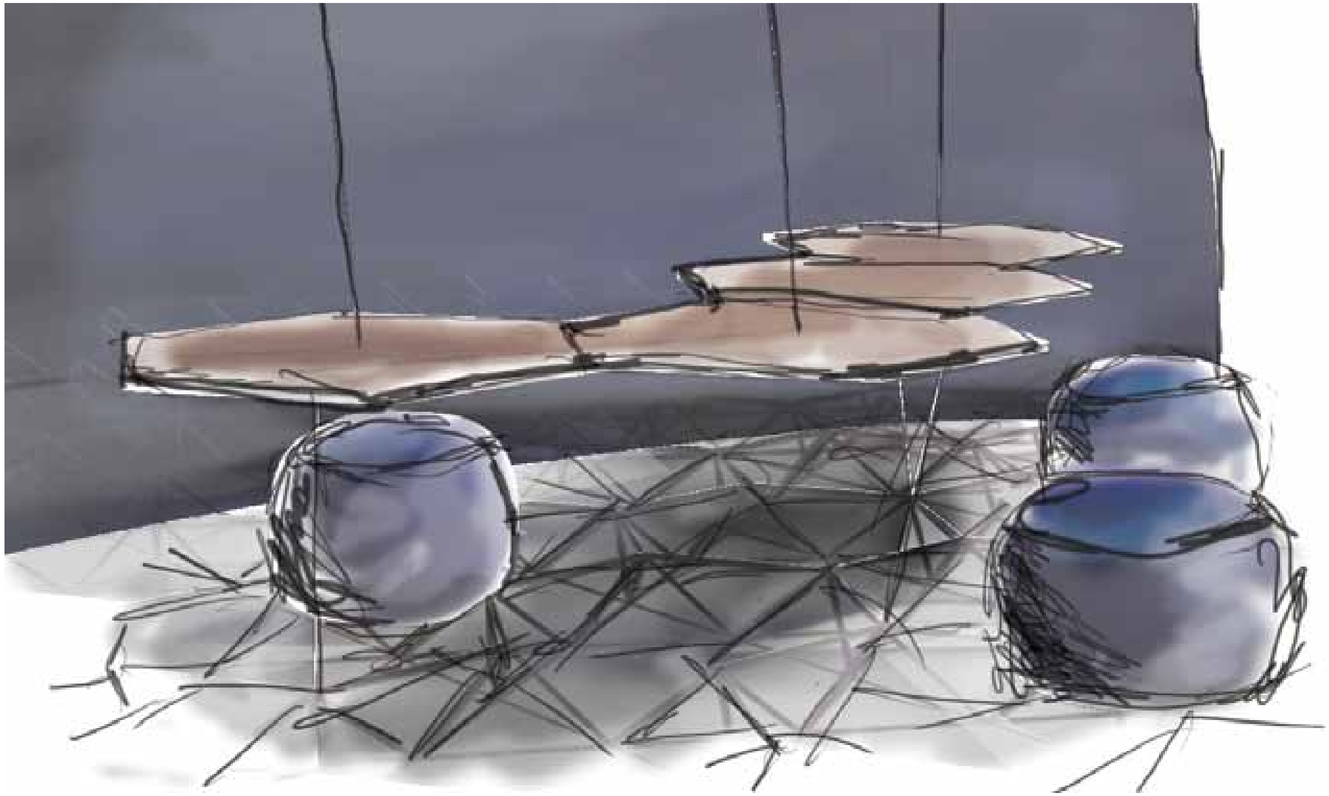




In the development of the interior space, part of the floor plan is made in scale 1:20. The model was used as a tool to develop further the ideas for rooms and their organisation .
The model was also used in finding the way in which the outside structure, internal structure, and the creation of internal space should connect.

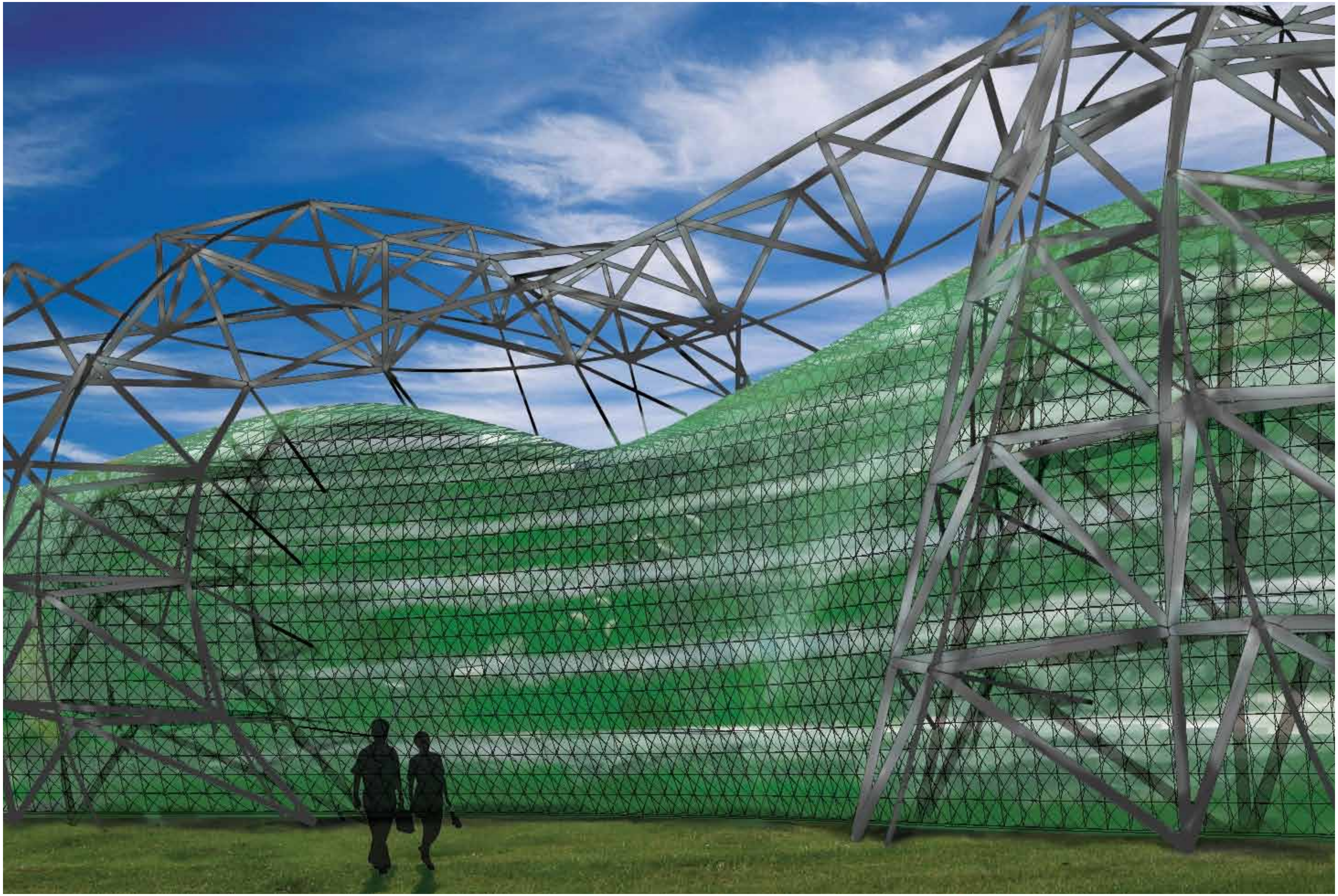
The plan is designed so that all fixed function such as kitchen and toilets, are placed connecting to the atrium. Working spaces are made at the edge of the building and big meeting rooms are placed in the middle of the building.





The internal walls were changed so that they only work as walls. This enabled them to be only connected to the floor and ceiling in few spaces, making them easier to move.
Tables and shelves were made by having them expanded between the floor and ceiling instead. The shape of tables is made in the same hexagon grid as the floor making it able to fit into different parts of the building.
Chairs and other furniture are made in soft materials with no sharp edges, enable them to stand on the floor without penetrating it.

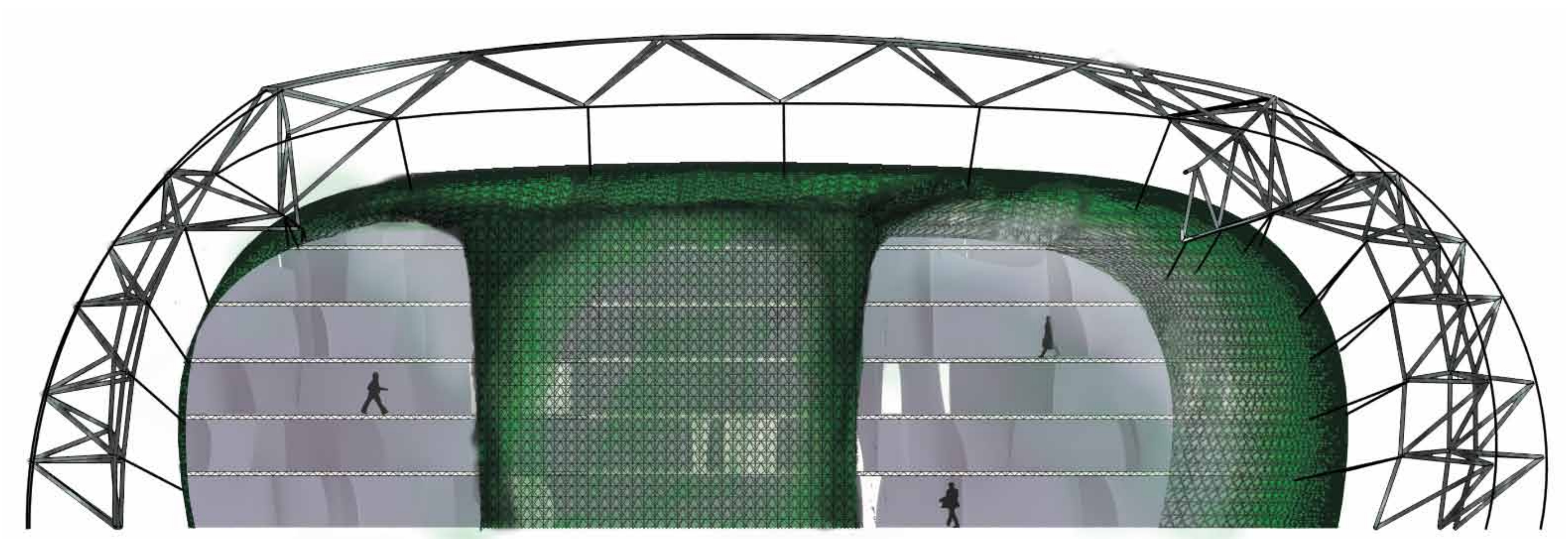
The facade was made so that the amount of algae stored in it can be changed manually by the users. This makes it possible to get light in and view out in the places needed. The algae will by itself also move to the bottom part of each facade, giving a better view out in the height of a normal window.

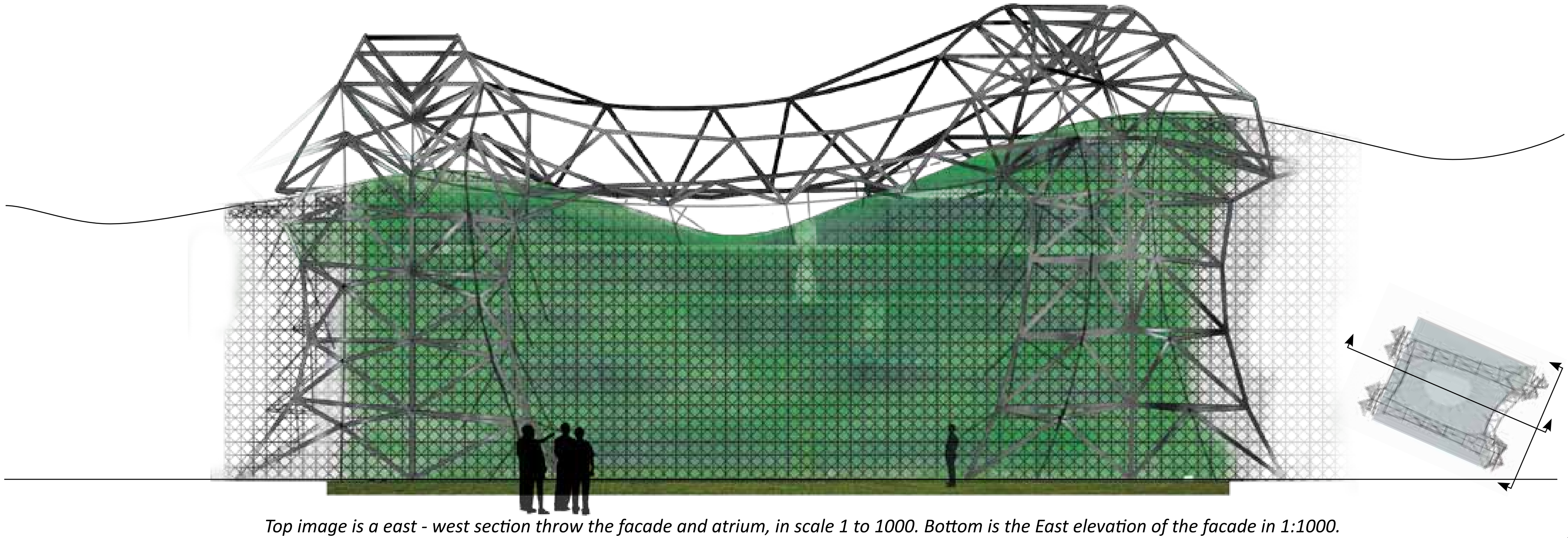


The East facade, with the construction going over the building, keeping the facade in place.

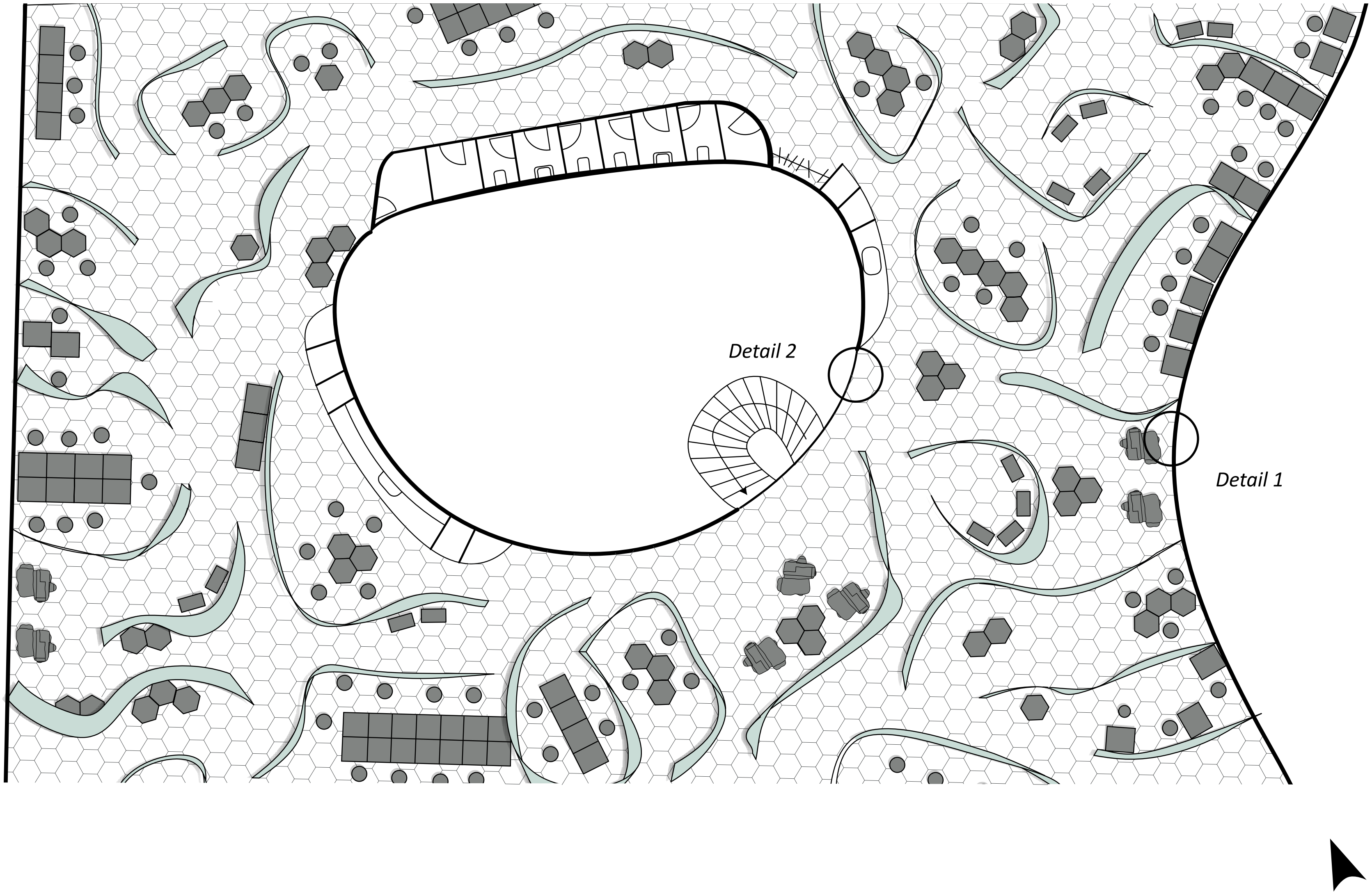
The internal space created behind the changing facade.

Internal rooms showing the flexibility given be the membrane walls, and the transparent floor structure.





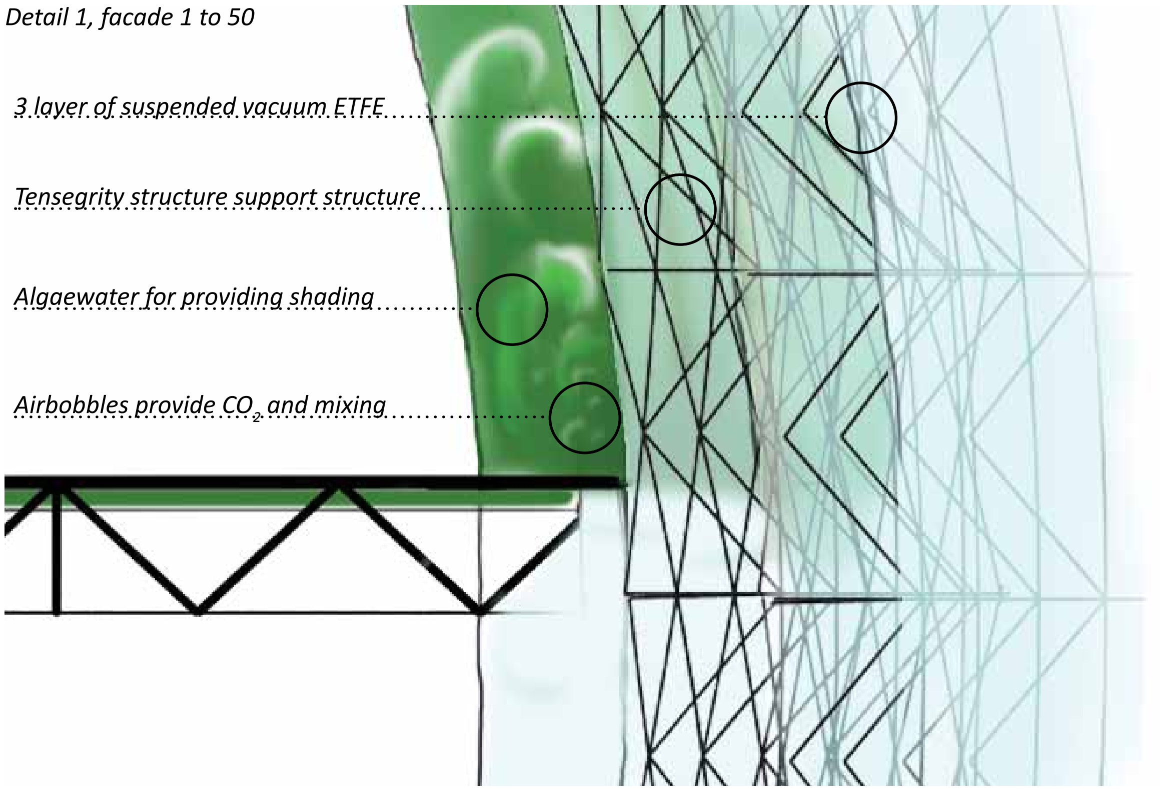
Top image is a east - west section throw the facade and atrium, in scale 1 to 1000. Bottom is the East elevation of the facade in 1:1000.



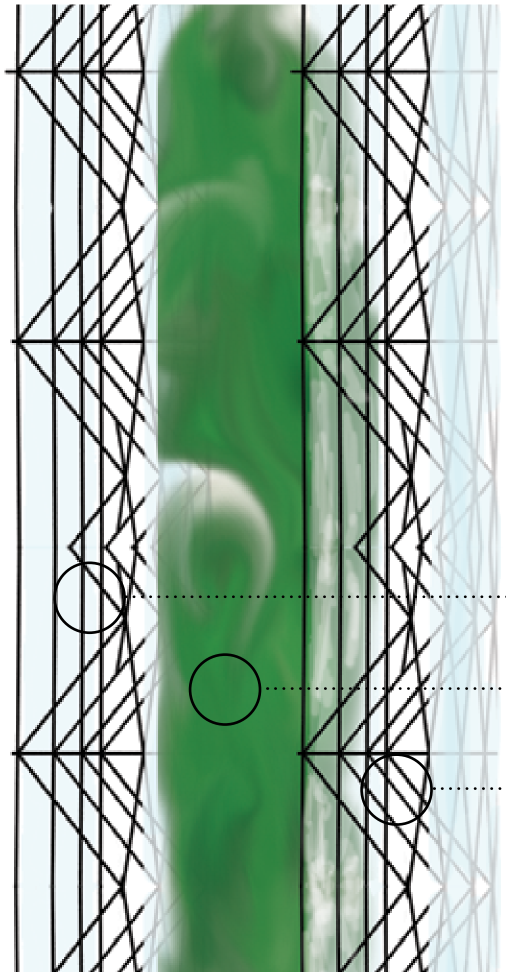
1 to 1000: An example of how the room can be organised one of the floors in the office. The plan is based on a separation of the room into flexible group rooms, individual working zone, relaxing zones and a few big meeting rooms.

DETAIL

Detail 1, facade 1 to 50



Detail 2, atrium 1 to 50



CONCLUSION/REFLECTION

Project aim

The project aim was to try the use of active component, to look at the sustainable building design in another perspective.

By using a specific case, the project for Lego headquarters in Billund from Arkitema, it was possible to compare the concept I was developing with a more expected solution that takes less use of active components.

The concept developed into combination of elements, in order to make a system where their interplay allows a more efficient response.

The use of algae integrated in the building together with both manual and mechanical control, enabled to achieve a concept where comfort, climate and outdoor conditions are connected.

Besides the use of responsive components, the way the building should coexist with the users was also considered, so the creation of adaptable comfort comes together with the creation of spaces which can change in function and shape.

Comparing to Arkitema´s proposal, the main difference is in the facade, in two points. First point, by enabling more light and the users to manually control the amount of diffusing light entering the building. This enabled each floor to be built with a lower ceiling height, and therefore less building surface compared to indoor floor space.

The second point regards the control of the dynamic mass of the water. This enabled the water to either work as heat or cooling storage. By having the water stored in an isolated container in the building, it was possible to control the amount of heat or cool that was necessary to conduct with the moving of the water.

To conclude, the aim of rethink the problem in sustainable building was achieved in the listed ways below:

- The building could adapt in comfort to climate and function change;
- The organization of the building is able to change, making it more functional;
- The component in the building is easier to dissemble, making it adaptable over time;
- By combining biology with mechanics, a more efficient solution was allowed, compared to the energy it uses.

Process and Learning Goals

I was interested in investigating the field of biology and how it could connect to a building design. I was specially interested in the field of algae culture, since they are the most responsive and efficient comparing to land plants. Here I could see potential for bioimplementation in building. The development of the responsive algae system should have been achieved through the integration of form and function. This wasn’t possible to be accomplished in the given time, because of the complexity in the algae behaviour and reactions. Therefore, it was hard to get a good flow of information iterating. The initial plan was to find a specific case of algae and develop the building design according to the specific reactions of this algae. That wasn’t possible, so instead I had to work with a building that could suit the general properties of algae. More average facts were studied and the concept went to a building which would have a high adaptive behaviour accordingly to the applied system. This encouraged to investigate a wider range of adaptive responsive form languages and integrate them in the project.

Reflection/Perspective

In the equation chapter, could be verified that the use of the algae reaction for the comfort is in this building case almost unnecessary. The amount of air which needs to be changed because of pollution from smell and equipment is much higher than the amount needed for CO_2. This makes a heat recovery unit much more effective than the cleaning of the smoke. It would make more sense to build it into a facade where there is a higher pollution in CO_2 than in the olf.

The project case bounded me to a given shape and spot. I realized that the shape of the building is, as stated in me analyses, the main driver on achieving a sustainable building. Because of the given case, was I very limited in that aspect. So I think that the system I built could have been more suitable in another shape, in another context, a warmer place, and maybe in another building materials such as bamboos.

I believe this case with the office integrated with a production unit could have been taken further, in a complete integration. If the concept could have evolved into a biodome, covering a multifunctional space with offices, industry and dwellings. This would have made a bigger span of the algae, the heat from the factory could easier have been used for heating in the offices and the motion with all this things would have given a great dynamic to the experience of the room.

APPENDIX

Illustration list

Ill. 1 http://www.natures-desktop-hd.com/desktop-hd/desktop-hd-trees.php
Ill. 2 Architectural company Aastiderne
Ill. 3 Architectural company Architema
Ill. 4 Architectural company Architema
Ill. 5 http://forum.santabanta.com/showthread.htm?t=221952&page=2
Ill. 6 http://www.tenos.co.uk/projects_list.asp?cat=offices
Ill. 7 http://paulparsons.wordpress.com/2008/08/15/the-eight/
Ill. 8 http://inhabitat.com/residence-sliding-house-drmm/
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Ill. 10 http://www.hoberman.com/abi.html
Ill. 11 http://permacultureforrenters.com/the-p4r-blog/tuesday-roundup-peeing-in-gallon-jugs-balcony-aquaculture-and-window-farming/
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Ill. 14 http://www.greenfortune.com/plantwall-dan.php
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Ill. 20 http://forbescomm.wordpress.com/recently-published-features-new/future-for-city-dwellers-not-pleasant-unless-youre-rich/
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Ill. 22 http://www.ecofriendlymag.com/tag/sustainable-transportion-alternative-fuel/
Ill. 23 http://www.kulturklik.dk/media/87216/smk_bobel_tomas%20saraceno%20_x-rum%20og%20skulpturgade%202010.jpg
Ill. 24 http://www.groveloejer.dk/sangild/kunst/

Source list

Web page

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Paul Jespersgaard, Kemi 2, 1990
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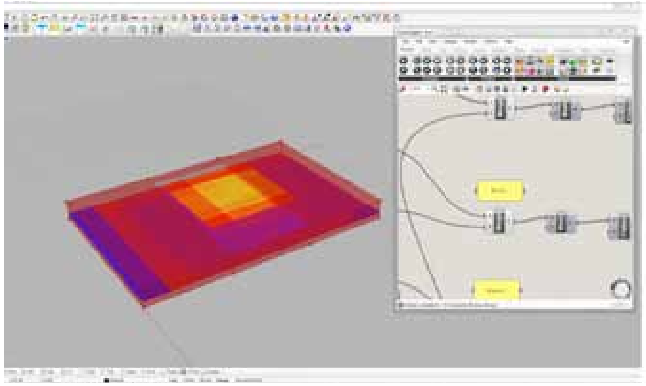
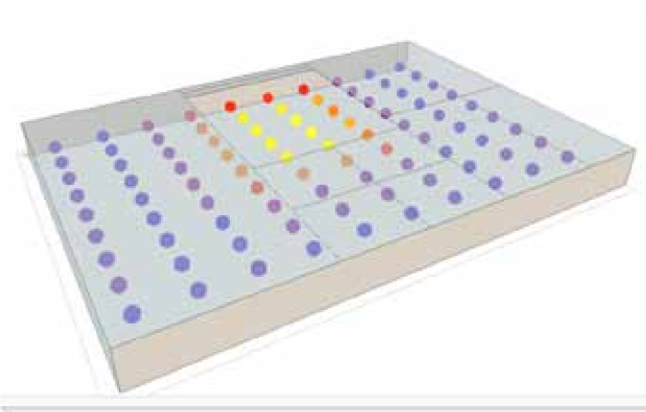
- (Table C.l - Design criteria for spaces in different types of building)
- (Tabel A.6 -Forureningsbelastning fonJrsaget af personer)

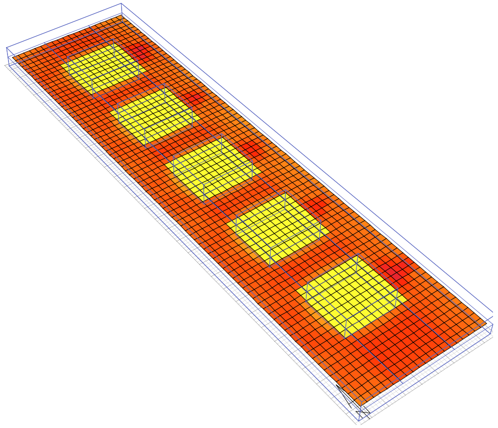
Different software was tried out to use as a design tools along the form and comfort finding.

Ecotoct/Geco/grasshopper
The directly collaboration between this software, seem as good tools, but the result from geco/ grasshopper was not fulfilling.



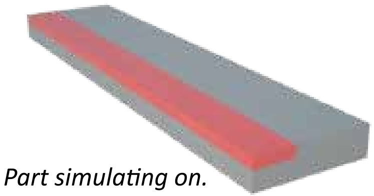


For the light simulation did it work, but when for the internal heat balance didn't the zone management giving enough flexibility in the heat flow as needed in this project.



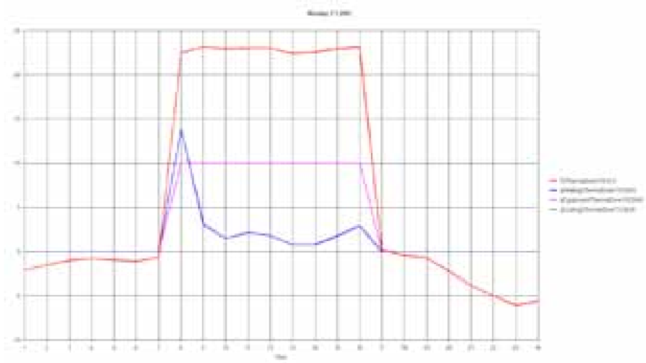
Ecotect
Was used for light calculations, but because of the transparent structure was it not capable of providing any result, cause their wouldn't be any blocking of daylight anywhere.

Bsim
The Bsim simulation was used as a rough simulation of the effect of the water pumped throw the system in the morning



Part simulating on.

Data input for Bsim
160 m width
12,5 deep
3,5 high
Facing west
Material data for the ETFE membrane
U value 0,4 W/m2 K
Solar heat transmittance 0,2 W/m2 K
Density of 0,2 kg/m3
Equipment and people load of 10 W/m2
Heating system in roof and floor
Ventilation



Air 1,04 m3/s
Recovery rate of 100 %
Heating system in floor and roof
Set point of 23 C
Surface area of 23 C
Max effect of 7 W/m2

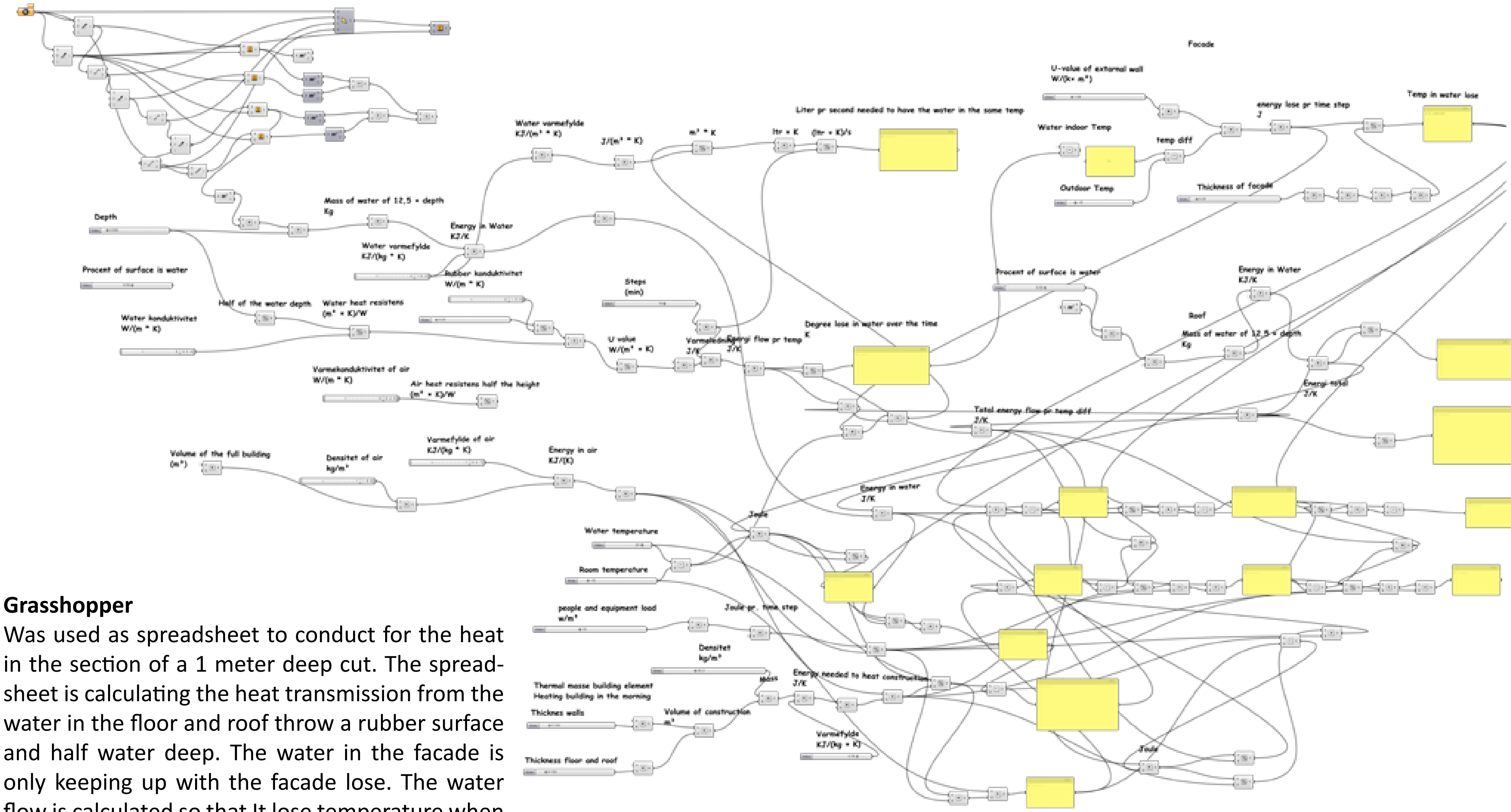
From the day with the highest need of heating Monday the 7th of January, is the maximum amount of heat for heating the building found to be 1,6 kwh.

If a lose of 1 degree in the water system do we get an energy in water of
419.000 ws/m3

1,6 kwh / 160 · 419000 ws/m3 = 8,6 l/s

Seems plausible, to have in the morning.

Bsim was used throw the process, and the value here is just an example of one of many simulations.



Grasshopper

Was used as spreadsheet to conduct for the heat in the section of a 1 meter deep cut. The spreadsheet is calculating the heat transmission from the water in the floor and roof throw a rubber surface and half water deep. The water in the facade is only keeping up with the facade lose. The water flow is calculated so that It lose temperature when going from roof to facade to floor. The thermal and heating load is added as input.

Since the heat transmitted is linear increasing with the heat difference, is their made a loop of interval where the change difference is taken in to account. For simulating the amount of time it takes for the system to heat up the building in the morning before the building is taken in to use. The following main input is used, the input from before is still in use.

Building mass 85 kg

Internal load 5 w/m²

Time steps 15 minuet of 4 loop, total 30 minuet

Indoor heat result

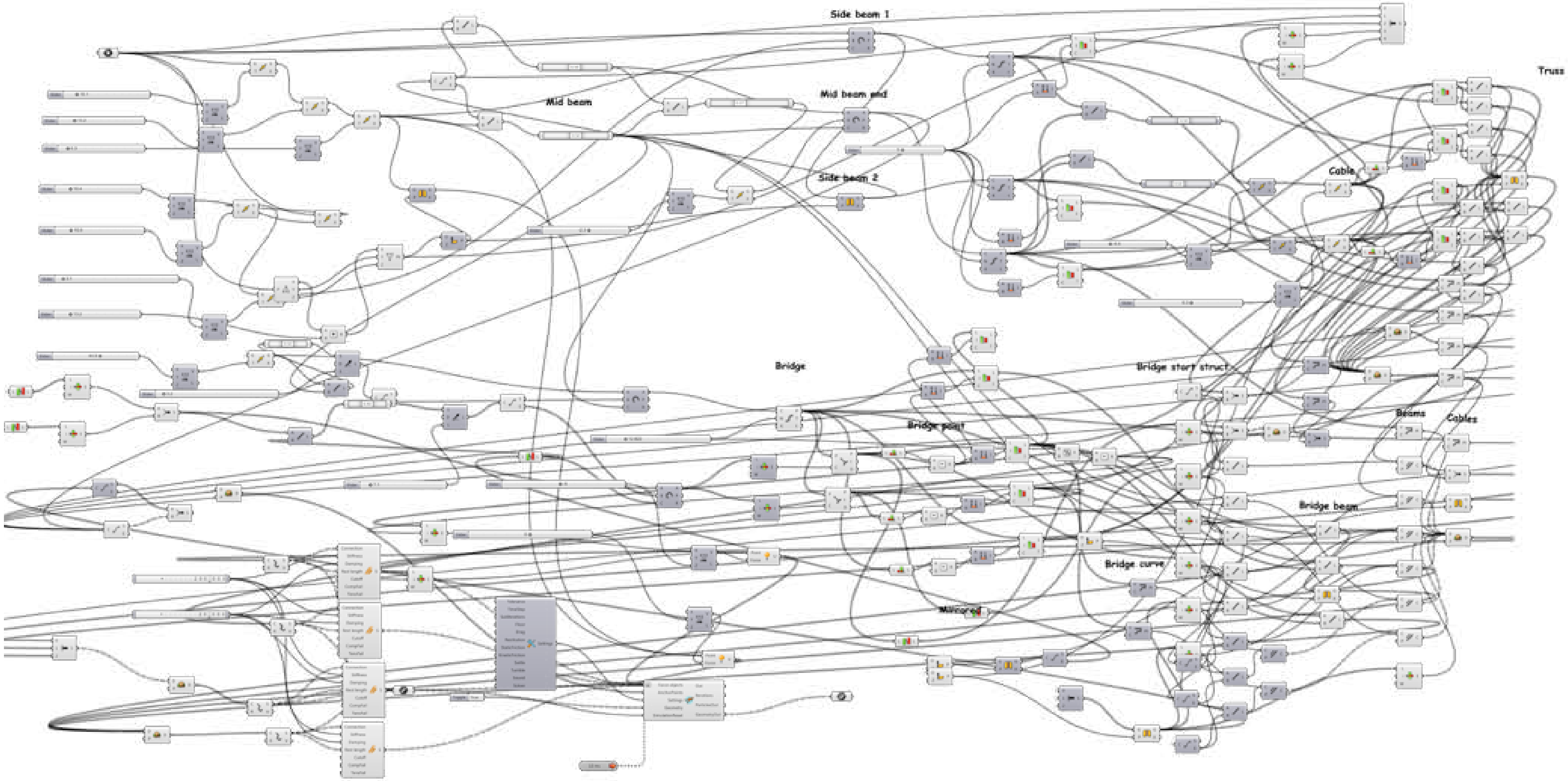
0-15 min from -15 to 1,1

15-30 min from 1,1 to 10,67

30-45 min from 10,67 to 16,3

45-60 min from 16,3 to 19,6

This seem to be fine for the pump system starting one hour before the building is taken in to use.



The grasshopper file used for kangaroo on the construction finding.

Water							Air									
	Heat akkumilated		templost	temp	tid	energy			Heat akkumilated		templost	temp	tid	energy	Energy with the water	Timestep’
	0	0	22	1	0			74,8	0,014	22	1	748	448,8		10	
	149,6	0,000	22	2	299,2			74,770	0,032	21,986	2	1495,402	1046,604		20	
	149,599	0,000	22,000	3	448,798			74,700	0,050	21,955	3	2241,009	1642,617		30	
	149,598	0,000	22,000	4	598,393			74,591	0,068	21,905	4	2983,632	2235,648		40	
	149,597	0,000	21,999	5	747,983			74,442	0,086	21,837	5	3722,088	2824,519		50	
	149,595	0,001	21,999	6	897,569			74,253	0,103	21,752	6	4455,207	3408,059		60	
	149,593	0,001	21,998	7	1047,149			74,026	0,121	21,648	7	5181,838	3985,117		70	
	149,590	0,001	21,998	8	1196,721			73,761	0,138	21,528	8	5900,846	4554,562		80	
	149,587	0,001	21,997	9	1346,284			73,457	0,155	21,390	9	6611,124	5115,286		90	
	149,584	0,001	21,996	10	1495,839			73,116	0,172	21,235	10	7311,592	5666,210		100	
	149,580	0,001	21,995	11	1645,382			72,738	0,188	21,063	11	8001,199	6206,285		110	
	149,576	0,001	21,995	12	1794,914			72,324	0,204	20,875	12	8678,930	6734,498		120	
	149,572	0,001	21,994	13	1944,433			71,875	0,220	20,671	13	9343,809	7249,871		130	
	149,567	0,001	21,992	14	2093,938			71,392	0,235	20,451	14	9994,898	7751,470		140	
	149,562	0,001	21,991	15	2243,428			70,875	0,250	20,216	15	10631,305	8238,403		150	
	149,556	0,001	21,990	16	2392,901			70,326	0,264	19,966	16	11252,182	8709,824		160	
	149,550	0,001	21,989	17	2542,358			69,745	0,278	19,702	17	11856,732	9164,936		170	
	149,544	0,002	21,987	18	2691,796			69,134	0,291	19,425	18	12444,208	9602,992		180	
	149,538	0,002	21,986	19	2841,215			68,494	0,304	19,134	19	13013,914	10023,301		190	
	149,531	0,002	21,984	20	2990,613			67,826	0,316	18,830	20	13565,213	10425,223		200	
	149,523	0,002	21,983	21	3139,990			67,131	0,328	18,514	21	14097,521	10808,177		210	
	149,516	0,002	21,981	22	3289,344			66,411	0,339	18,187	22	14610,311	11171,637		220	

	149,056	0,005	21,876	55	8198,106			37,197	0,367	4,908	55	20458,558	12112,522		550	
	149,036	0,005	21,872	56	8346,036			36,390	0,360	4,541	56	20378,331	11884,425		560	
	149,016	0,005	21,867	57	8493,906			35,598	0,353	4,181	57	20290,622	11648,908		570	
	148,995	0,005	21,863	58	8641,713			34,821	0,346	3,828	58	20196,173	11406,715		580	
	148,974	0,005	21,858	59	8789,458			34,061	0,338	3,482	59	20095,719	11158,580		590	
	148,952	0,005	21,853	60	8937,138			33,317	0,330	3,144	60	19989,981	10905,227		600	
	148,930	0,005	21,848	61	9084,754			32,590	0,323	2,813	61	19879,668	10647,365		610	
	148,908	0,005	21,843	62	9232,303			31,880	0,315	2,491	62	19765,473	10385,689		620	
	148,885	0,005	21,838	63	9379,784			31,187	0,307	2,176	63	19648,072	10120,875		630	
	148,862	0,005	21,832	64	9527,197			30,513	0,299	1,869	64	19528,122	9853,581		640	
	148,839	0,005	21,827	65	9674,541			29,856	0,290	1,571	65	19406,261	9584,447		650	
	148,815	0,005	21,822	66	9821,814			29,217	0,282	1,280	66	19283,103	9314,088		660	
	148,791	0,006	21,816	67	9969,015			28,596	0,274	0,998	67	19159,242	9043,098		670	
	148,767	0,006	21,811	68	10116,144			27,993	0,266	0,724	68	19035,247	8772,048		680	Hours
12																
	148,742	0,006	21,805	69	10263,199			27,408	0,258	0,458	69	18911,663	8501,484		690	
	148,717	0,006	21,799	70	10410,179			26,841	0,249	0,201	70	18789,009	8231,926		700	
	148,691	0,006	21,793	71	10557,083			26,293	0,241	-0,049	71	18667,779	7963,869		710	
	148,665	0,006	21,788	72	10703,910			25,762	0	-0,290	72	18548,440	0		720	

The excel sheet used for calculating the temperature lose in water, over a winter night.

Summary
This project regards an investigation in the field of bioresponsive element in building implementing and the use of active components in the development of a adaptable sustainable building. The building is made so that each room can chance in form and comfort, for suiting different cases. Sustainability is achieved in both with the making of a component structure that enables dissembled without bounding of materials and with a system where no heat or cooling is need to put in.