KHEPRI

From field to fork, and back again

School of Architecture, Design and Planning
Aalborg University

Preface

Khepri is developed as an Urban Design Master Thesis at the at faculty of Architecture & Design Aalborg University, Spring 2016 Denmark

The aim of the project was to investigate insects as a possible bio-converter within danish agriculture and to design/illustrate a building facilitating them

I would like to thank all the people that made Khepri possible

Abstract

Khepri is a visionary project presenting new developments within food production, systems in which the urban areas become an active part of recontributing to the agriculture. Through mimicking the natural cycles within nature, the implementation of insects, generate a complete food chain cycle within the agricultural production. The manifisation of the project is a building containing production, while also having educational functions.

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Introduction

Khepri is inspired by two major topics of the 21st century, farming and waste management. These are undeniably tied together, hence being the start and end product of feeding the population of the modern world. A population rapidly expanding, demanding and expecting the same resources as their ancestors, the only problem is that the globe is not expanding. The human species have to transform the current systems providing essential resources, in order to offer something for the next generation, while providing a sustainable chain of supply to the current one.

During the 20TH century the human species have turned into an urban species living in enormous cities, epicenters were the human race develops due to critical mass and knowledge exchange. Living in the city the disconnection to nature is obvious and seems indifferent. However the basic needs that we, as a species, have remains the same: air, water, warmth, shelter and finally food.

Currently the cities on the globe occupy only two per cent of the world's surface area, but are consuming 75 per cent of the earth's resources, and the amount of people living within cities is expected to double by 2050. The equation is simple, with the current needs and the way they are produced; we won't survive as a species unless we rapidly rethink our food system. (Girardet, 2008).

In other words, if designers are able to rethink and redesign the systems, which keeps cities running, in a sustainable manner. They would actively influence a major part of humanity, thus reducing our demand of nature's resources.

Khepri will take its departure revolving food, the cyclus of it and how the production of it might be improved. Turning the needs of people into an active part of the natural cycle in the world instead of disconnecting them from it.

The existing movement of food is incredibly linear, going from countryside to city and even from country to country. In other words transferring energy from increasingly distant fields to the urban areas into the stomachs of the inhabitants, at the cost of transportation. Because that's what food also is: Energy. Western societies have already started to turn its residues into value, often by incineration generating electricity and heat, while an option could be returning it to the nature. Resetting the cycle from which it came (Michael Braungart, 2009)

The scope of the analysis and design proposal will revolve Denmark, a country seemingly self sufficient in manner of food. Producing food in such an extent that it have become a key export, especially meat which is the most resource consuming kind of food to produce.(Rikke Lundsgaard, 2014)

Between delivering and keeping price rate that allows the Danish food to compete with other countries, the effects of intensive farming have started to surface in the rural lands of Denmark along with a growing demand of foreign animal feed. Contributing to a Danish agricultural which pollutes considerably compared to other countries. (CONCITO, 2014)

Alternative methods of protein production for animal feed is necessary if we want to bring down national pollution level which causes a large CO2 footprint relative to the size of Denmark. The problematic situation today and a possible production evolution will be described and illustrated in the following project,

Methodology

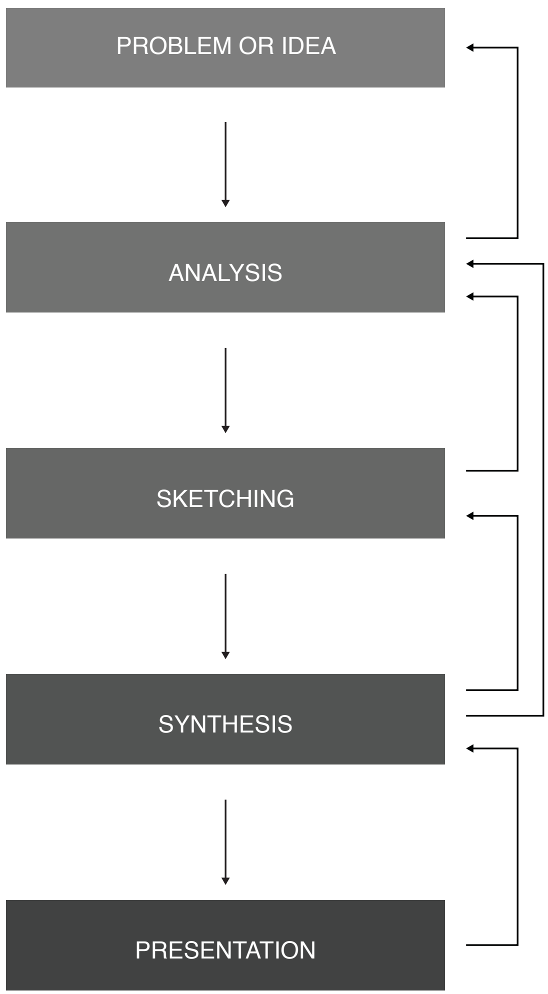
Ill.1:
The phases of the integrated design process. (Hansen & Knudstrup, 2005 : 895)

The methodical foundation of the project is combination between the educational model of Problem Based learning and Integrated Design Process (IDP), both methods used in the architecture & design department.

Using the IDP is integrating the knowledge from different disciplines, as engineering and architecture to gain a more holistic approach of problem solving. Creating a design, which is influenced from more than solely aesthetics. but also functionality and technique.(Hansen & Knudstrup, 2005) Since this project is concerned with amount and management of food and waste, it is essential to understand and work with the factors and calculations regarding the subject. Hence is the technical aspect deeply influential and will be a common denominator through the report.

The initial idea behind Khepri was intrigued by the rising debate about sustainability and food production, that are linking the two subjects with each other. Among the more publicly known medias discussing the matter are movies such as cowspiracy and food inc. But larger organisations like WWF and UN are showing increased interest in the subject, and the inevitable growing population are generating interesting questions.

It is a subject constantly discussed and a debate with several trenches of opinions, whether it's the wrongdoing of animals, deforestation or warmer temperatures they are all tied together by humanity. The analysis phase of the project will focus on researching a variety of the existing and suggested solutions. Gaining a general understanding of the subject is essential, hence deeming the investigation of the subject the same importance, as the final product.


PROBLEM OR IDEA
ANALYSIS
SKETCHING
SYNTHESIS
PRESENTATION

Ill. 1

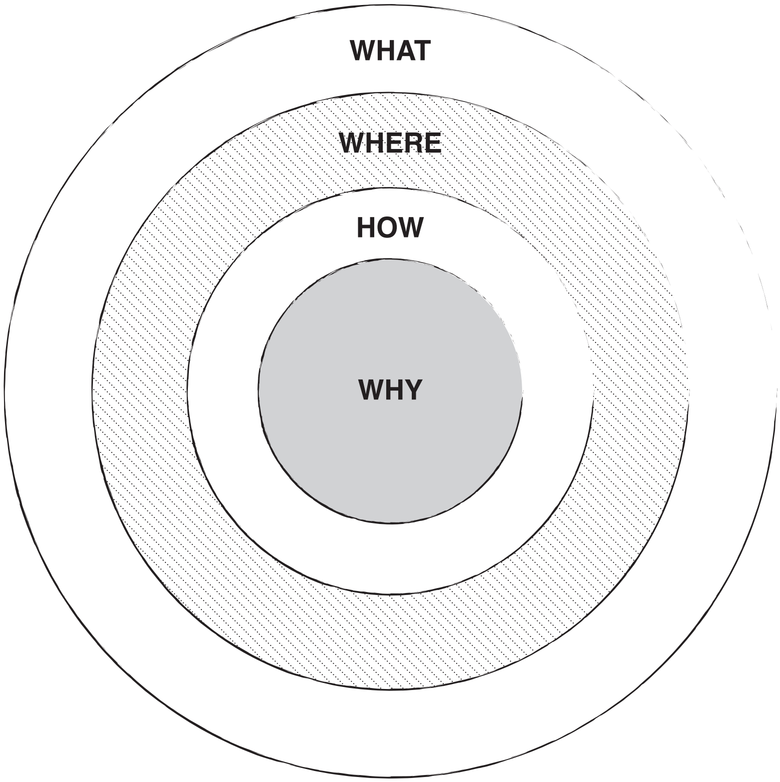
Ill.2:
A modified version of the golden circle, an approach where *why* is the rotation point. Introducing another circle *where*. (Inspired by Sinek, 2013)

The structure of the report is inspired by the golden circle by Simon Sinek, a view of design in which prior to the traditional approach of understanding what the problem is, is asking why the problem exist? (Sinek, 2013). The approach of gaining knowledge before uttering new information corresponds well with the IDP, but provides a more simplistic understanding of the report structure.

The why part of the project will serve as a theoretical foundation, while how will serve as a design manual of contributing to the food system, while also solving problems within it. Since this project is a master thesis in Urban Design, another circle is introduced: where, located between how and what, a chapter that are using mappings and tools to pinpoint a suitable location of the project. The where chapter is the finale component of the synthesis phase, along with the previous chapters culminates into design parameters.

The sketch phase is used during all parts of the project, the goal is to make complicated registrations understandable for every reader of the report. By showing diagrams and illustrative work, the complicated data sets is distributed to a larger audience.

Finally the presentation phase will present what a conceptual project of a possible building could look like. The qualities of the building and fundamental knowledge will be explained with drawings and illustrations. Followed by conclusion on the initial problem along with a reflection on possible changes and perspectives will be the final part of the official report.



Ill. 2

Demarcation

Khepri covers a large area, ranging from traditional building design to analysis of several elements of food production and waste distribution. All this are contributing to a conceptual design proposal. The comprehensive approach is dominant throughout the project, which results in a very pragmatic understanding of the issue.

The report is a research project that will examine and understand general terms to give an overarching explanation of our problems as a united humanity. Creating a suitable foundation from facts and understanding to start a more general debate on food- and environmental issues. This requires an immediate understanding of the wide range of topics, which are very complicated. There will therefore be omitted information in the report as they primarily will be shown as quick and easy explanations.

The intention of the project is to introduce methods to produce food from alternative sources, in this case organic waste. Therefore, the project will actively be part of the evolution of our food production, rather than presenting a revolutionary mindset. Both production of food and waste management consists of several rules and regulations, which are beyond the scope of this project.

There is a long way from concept to actual design, various technical issues must be addressed now the placement and logistic have been looked into, but the production requires an interdisciplinary understanding from several experts. Khepri is a possible solution to the food aspect within the combined picture of the problems regarding environmental issues, multiple decisions must also be implemented before the humanity can regard itself as being sustainable.

SECTION 1

Food waste or Waste of food

This chapter is a quick introduction to different aspect of our foodsystem and waste problem. Along with introduction to terms such as ecological footprint and foodmile. Towards the end of the chapter, there is an explanation of why Denmark are in its current environmental situation.

“There are people in the world so hungry, that God cannot appear to them except in the form of bread.”

Mahatma Gandhi

Metabolism of cities

In order to improve the cycle of the city, understanding the input and output is essential. The connector between these is referred to as the metabolism, much like living beings, a city needs fundamental resource in order for its inhabitants to exist.

The 20th century is defined by how people have emigrated from the countryside to the cities, in time making the cities the primary habitat for the human race. Now there is more than 50 per cent of the population in the world live in cities. In a sense we have unawarely turned ourselves into an urban species living within mega cities, containing millions of lives. The cities are attractive, because unity provides a wide range of assets such as education, infrastructure and better living conditions, that is what people are led to believe. At the same time higher densities of people creates health issues, especially in developing countries. Countries where urbanization is happening, due to growth within the industrial sector, but much like european cities in their early stages, the new cities are becoming unhealthy and downright dangerous places to be. But people are moving into them, not for a sustainable reason, but an economical one. They move towards a job, which will secure them benefits, that will be provided by the city. However these benefits are designed solely to serve humanity in order for them to maintain their comfortable state, unavoidably injuring the surrounding nature. (Girardet, 2008)

Cities, a structure created by humans for humans, of course the primary role has been deemed to humans. The city serving its inhabitants and the nature serve the city, the thought process has generated a linear metabolism of the cities. The essential resources are extracted from nature, transported to the city and consumed, disposed and then the process starts again with extraction. The linear food chain is induced by industrialization, a system in which speed and homogeneous is creating security. But at the same time removing the human from the equation, reducing nature to small packages of meat and groomed vegetables. Along with an improved infrastructure, cheap energy and technologies driven by fossil fuels, the city was able to distance itself from its hinterlands. But not removing itself from it, because now we are just as depended on nature as our ancestors, even more it's just not as visible. (Steel, 2008)

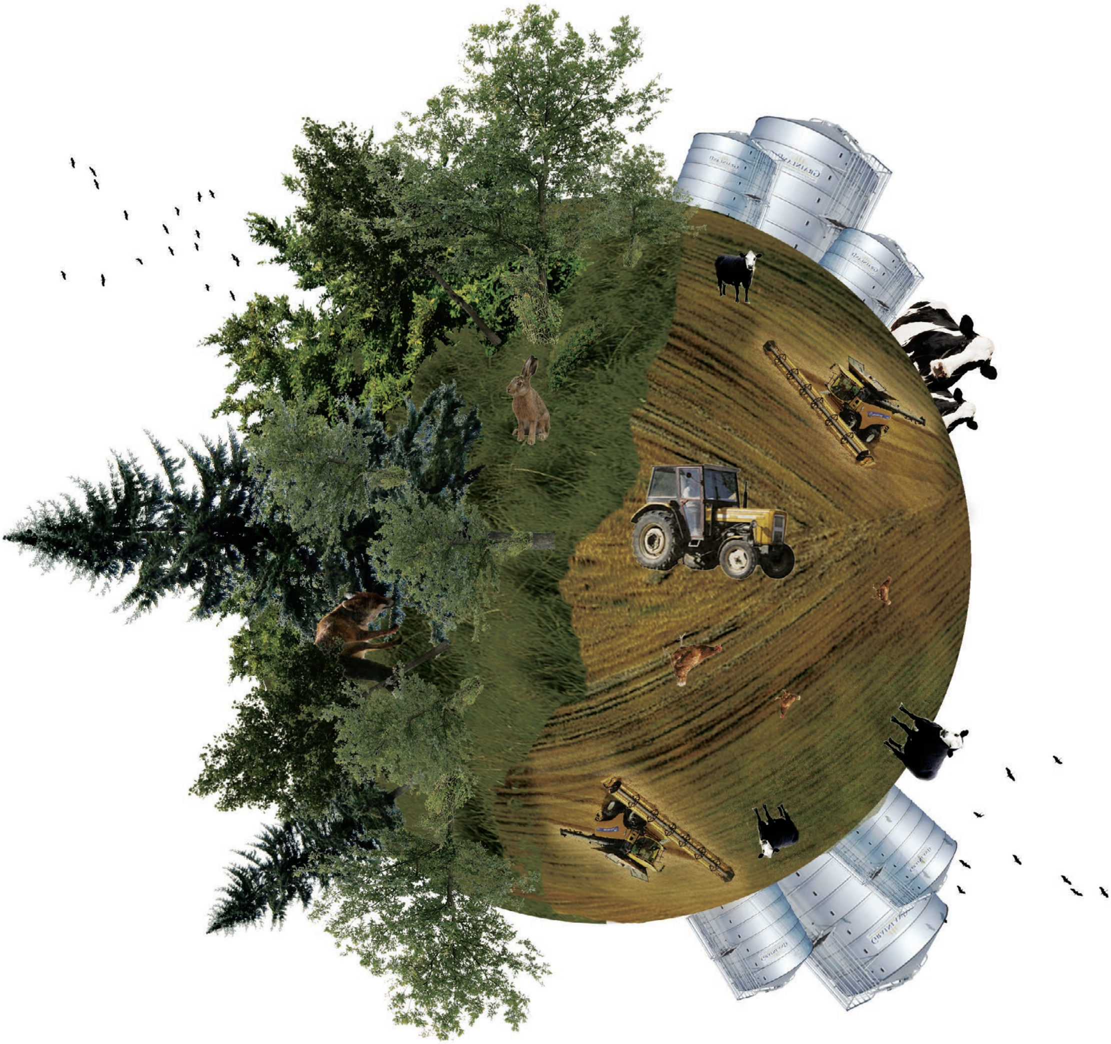
Removing nutrients and energy from the soil in the form of crops, is a more scientific explanation of the harvesting part of agriculture. However agriculture is not just removing, but replacing. When energy is extracted, new energy have to be introduced, otherwise the soil will slowly become infertile. Understanding of that is providing the crops with the needed resources and harvest its prosper. That fact was what created the first settlements in human history, instead of the being hunters, humans became farmers. The steady supply of food ensured the security for people to become stationary, returning their waste to the fields, thus resetting the system, which provided them with food. The density and better life conditions was the foundation for population growth and development, as the human species expanded as well as its needs. (Steel, 2008)

Ill. 3:
The modern view on nature in western countries. We rely on nature, but are constantly moving away from it. In a sense we are forgetting about it, while taking a greater toll on it. (Own illustration)

The problems regarding the urbanization, are the people inhabiting them are consuming to such an extent that the agriculture also had to evolve in order to provide the cities with the needed goods. The demand of goods changed as agriculture became influenced and enhanced by industrialization, allowing it to become a part of the linear food supply, technologies turned agriculture into an effective harvesting machine. By producing abundant amounts of crops, humans was able to feed large herds of livestock and turn meat from a luxury good into a commercial good.(Steel, 2008)

Humans are developing and becoming better at taking from nature, but on the other hand also generating mountains of waste, the end product of long linear line. This waste is still containing vital nutrients, minerals and resource, but instead of recycling or introducing it to the fields from which they came. Cities are hiding it away in landfills or even burning it. Instead cities should perform as an active role within the biosphere, giving back what it took in the first place creating a “chain of mutual benefits”. Returning and restoring the areas that a providing the much needed resources, that is the fuel of a city. In that manner a circle/eco system will form between city and countryside, as it used to be. (Michael Braungart, 2009)

While 20th century defined by man moving into cities, the 21th should or rather have to be how we will survive there without destroying the planet. (Girardet, 2008)



Ill. 3

Global food market

Ill. 4:
Traditional vegetables garden. Able to provide a family with fresh vegetables during spring and summer.

Ill. 5:
Conventional agriculture capable of feeding millions. Vast fields, which require large machinary to harvest.

This chapter will discuss food, and how it has changed during the 20th century. Why it ended up being provided by a global food production along with its distribution, consumption and what the consequences of maintaining it.

Prior to urbanization when humans was in immediate contact to nature, production of food could be provided by themselves, the traditional countryside farm with fields around it. However the urbanization removed people from the nature, thus removing them from growing their own food. This generated the need for food supply, the countryside provided food to the city. But as mentioned in the previous chapter more people within the urban areas requires more food. The food chain used consist of small producers; farming, distributing and selling the goods, but in a world where effectiveness has taken over, the smaller producers were forced to grow and even expand their area of interest. (Steel, 2008)

Industrialization and the discovery of fossil fuels created seemingly limitless possibilities for engineers at the time, which generated new inventions. In preindustrial times goods was transported on sailing ships, the industrialization enabled the steamship and the land based railroad. The food and products could be moved at a greater distance and more rapidly. (Michael Braungart, 2009)

With well developed infrastructure, the basic need of the food circulation was a reality and suddenly the hinterland to the cities was larger and the possibility of new goods was available. As new technologies was introduced and new parts of


Ill. 4


Ill. 5

Ill.7:
A typical food market, on the picture the variety of goods are displayed. The crops are mature on different time periods, nevertheless they are all available here.

Ill. 8:
Large container ships are supplying the world with goods and food

the world was discovered the supply rapidly expanded. This allowed cities to grow, and the appearances of today's cities is realised by industrialization. Places where the basic need for food is fulfilled, different demands arise such as food variety and food products season independent.(Steel, 2008)

Today the variety of goods available to the average city dweller would properly be unimaginable by their grandparents. The multitude of products going into a city have expanded over its hinterlands, being produced in distant countries and are traveling great distances. Giving birth to the terms global food market and food mile. (Steel, 2008)

Food mile, the distance food are traveling before it reaches the consumer, but also added the distance getting the food to a recycle station, incinerator or landfill. Demanding groceries that are produced on the other side of the earth, emits CO2 and pollution having huge impacts on the enviroment.(NRDC, 2007)

Providing food to inhabitants in the western world, is infused with fossil fuels from the very beginning. The cultivation, harvest, production, transportation and distribution, in a sense we are eating oil. The demand of foreign goods, seasonal independent products and cheap products, is distancing the customer further from the production. The educational value of understanding food and how it's produced is squandered on supplying a steady increasing demand, an ignorance that will create a larger gap between product and consumer.


Ill. 7


Ill. 8

Ecological footprint

Ill. 9:
The two main topics within ecological footprint theory. Ecological footprint and bio capacity. If the footprint is equal to the bio capacity the earth is in a sustainable state. (Own illustration)

This chapter will explain the notion of ecological footprint and why it is a necessary way of measuring countries demand. While also explaining bio capacity, how nature is providing the inhabitants of the earth.

Ecological footprint is a measurement of the needed land and water area to provide a nation, city or persons needs, and also the area absorbing the carbon dioxide generated by their activities. The unit for the footprint is global hectares, similar to global food market some countries are using hectares outside their own border, a hectare is equivalent to 10.000 m2. (Wackernagel, 2016)

The method is developed by the Canadian ecologist William Rees and his colleague Mathis Wackernagel. They wanted to create a system, where nations have an account and the bio capacity of the world, or in this case their country, equals the available capital to spent. Right now, humanity is using the regenerative capacity of 1,5 earth, which mean there is an overshoot of a half earth, if we continued along that path, bankruptcy is unavoidable. (McLellan, 2014)

WWF made a report in 2014, the Living planet report. The report divides the ecological footprint into continents and countries, along with the ecological footprint per capita. In the current state we use more than nature can replenish, in other words we eat, demand and emit more than the world can produce and convert.

Ill.9

Ecological footprint, is the combined land use required to supply the ecological goods and services, which is divided into timber, meat, crops and fish. Our waste and emission is other half of the footprint.(Wackernagel, 2016)

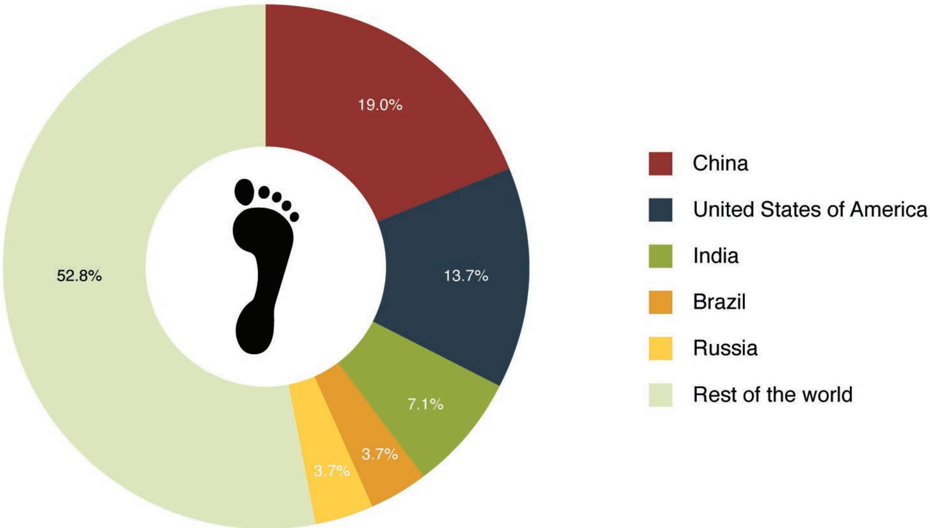
Biocapacity, represents the planets biologically productive land areas, which includes our forests, pastures, cropland and fisheries, thus serving as the supply. If these areas are left unharnessed, they can absorb more of the waste we generate, especially our carbon emission.(Wackernagel, 2016)

Ill.10:
The combined global footprint generated from humanity. Divided in percentage, the top contributor is China.
(McLellan, 2014 : 37)

During the last 40 years, the sum of humanity's demands has exceeded what nature can renew. The major factor changed during the 40 years, is the carbon emission. Technologies improving ecosystems, resources and energy have reduced parts of the footprint, but simultaneously been driven by fossil fuels. Understanding and improving the footprint is difficult, when looking at the combined world. The ecological footprint is the demand per capita multiplied by the population, both differs between regions of the world. Illustrating the difference between this is critical with a country like China, as seen in illustration 10. China has the largest footprint on the world with 19 per cent, due to their massive population. If divided by per capita, China is ranked 76th with a footprint below the world average. The second largest footprint is the USA, not due to their population but their demand. An average american citizens footprint is ranked as the 8th largest in the world. The reason for the USA having the second largest in the world, is not solely from a huge demand but more so since the population is a quarter of the Chinese. (McLellan, 2014)

The living planet report have calculated the footprint for all countries with more than 1 million inhabitants, among the countries with the largest footprint per capita is high-income nations. These nations are using ecosystems faster than their biocapacity replenish it, and even import products from other countries, thus benefiting from other nations bio capacity. The calculations expands with the additional transport, and the food mile adds to the importing nations footprint.

When looking at the upper part of the diagram illustrating footprint per capita (see appendix A) among the top candidates is some of the largest oil producing countries:



Ill.10

Kuwait, Qatar and United Arab Emirates, these countries is also in the lowest category of bio capacity, due to their countries being dominated by desert, Since these countries are providing large quantities of oil to the world, while having little nature to compensate, their location is understandable.

Ranking fourth as having the largest footprint is the first mentioned european country, Denmark. The same country that is honored further into the report, due to the rapid development in wind power. In 2013, wind turbines provided a third of the Danish electricity consumption and by 2020 the goal is 100 per cent within the transport and energy sector. Actively reducing the carbon footprint, the footprint was performed in 2014. Denmark is despite being the leading wind turbine country in the world, the country with the fourth largest footprint per capita. (McLellan, 2014)

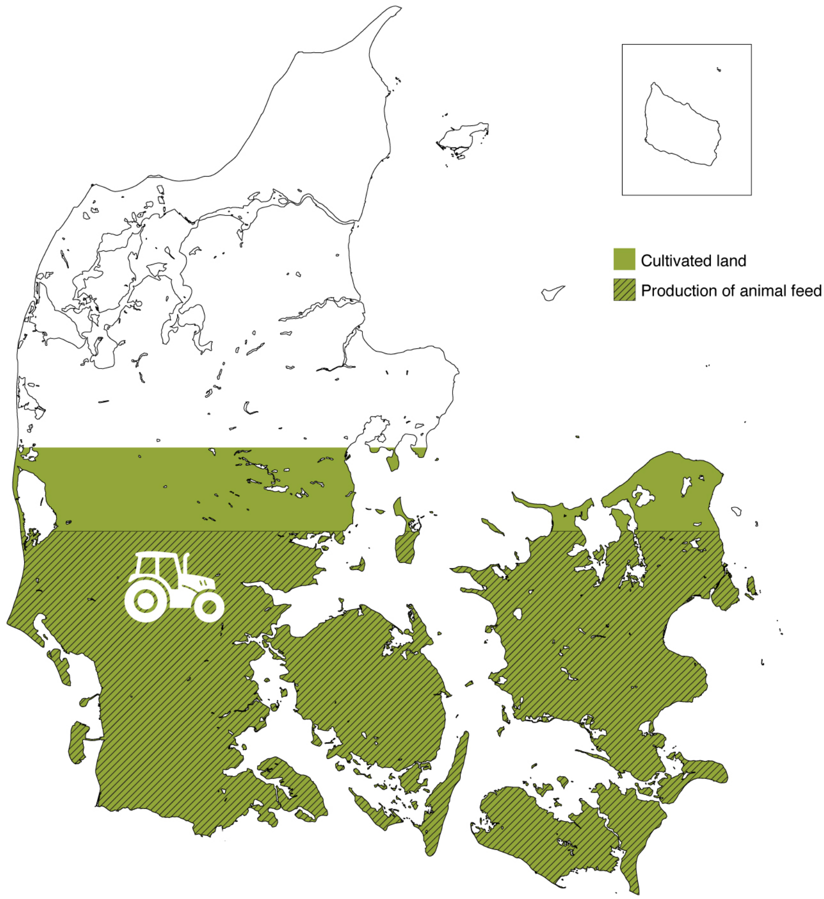
Denmark

Ill. 11:
A abstract illustration of the percentage of agricultural land use within Denmark. 62 per cent is cultivated, of which 80 per cent is used to feed livestock,
(Own illustration)

This chapter will explain why Denmark could have a large ecological footprint. The current state of Denmark and possible future developments.

Denmark is located In the Northern part of Europe. A small country, renowned for its leading position within different fields, such as renewable energy agriculture and etc. As seen on the diagram (see appendix A), a large percentage of the ecological footprint, is cropland. Denmark is considered being an agricultural nation, and is producing food for approx. 15 mio people, that's three times the population of the country. The food production has focus mainly on meat, which is one of the key exports from Denmark. Feeding of animals requires large quantities of land, which have turned Denmark into the most intensive cultivated country in Europe, in fact the whole world. (Rikke Lundsgaard, 2014)

As seen on illustration 11, 62 per cent of the area of Denmark is cultivated. The remaining areas are divided between, 14 per cent forest, 9 per cent open nature areas, 3 per cent small biotopes in farmland, 3 per cent lakes and creeks, the remaining 10 per cent is cities, infrastructure etc. Among the 62 per cent cultivated land, 80 per cent is used as animal feed. Spending crop land feeding animals is an insufficient way of feeding people, crops is energy, and the total energy is reduced when fed to livestock. If Denmark is looked upon using ecological footprint contra bio capacity, they are using 80 per cent of it to feed animals and only 20 per cent are fed directly to humans. (Rikke Lundsgaard, 2014)



Ill. 11

Ill.12:
Illustration explaining the distance from Denmark and the countries, where the soymeal are produced. Primarily in South america, and the countries Argentina and Brazil.
(Own illustration)

The intensive production of meat has a massive influence on the ecological footprint, the production as well as the livestock is generating emission. On the other hand, Denmark has an impressive bio capacity taking its size into account, the equation should add up.
An explanation could be, that Denmark have a significant import. The demand and production of goods exceeds the country's biocapacity leaving a large part of the danes's ecological footprint impact on other countries. This is due to import of raw materials and consumer products, also applying to the agriculture. Despite producing vast amounts of animal feed it is still not sufficient, protein rich crops particularly.(CONCITO, 2014)

Currently Denmark is importing protein rich animal feed from other countries, primarily Argentina and Brazil. The imported crop is soybean, which has become a key component in Danish animal feed. Animal feed for livestock can be construed as either forage or fodder. Forage is the main component in food for livestock, hay and grassland, while foder is more concentrated containing higher amounts of proteins, like the soybean. Animal feed is mixed of different crops from the two categories, depending on livestock fed and progression state. (Aske Skovmand Bosselmann, 2014)

Modern livestock used for meat production are divided into two categories, ruminant and monogastric animals. Ruminant animals, like a cow, have multiple stomachs, which means the cow is able to chew the consumed animal feed multiple times, thus gaining a better protein gain from grazing. Monogastric animals have one stomach, such as pigs and chickens require more proteinous rich feed, unlike the cow they are omnivore, able to consume nutrients and energy from multiple origins.

Ill.12

Hence forage is not sufficient for them, they need a high proteinous fodder such as the soybean meal. (Rikke Lundsgaard, 2014)

Denmark is mainly producing pork and chicken, hence the production or import of protein rich crops is vital. Of the imported soy meal, 80 per cent are used for pork production, and close to 90 per cent of the pigs are exported.(Aske Skovmand Bosselmann, 2014)

The soybean meal is transported by ship approx. 12.000 km, this has a huge impact on the environment. In a climate report, CONCITO identifies the problem as following: *Greenhouse gas emissions related to the Danish demand for soy proteins can be estimated to be around 6 million tonnes CO2 per year, which is equivalent to over 80% of the emissions from Danish cars, or almost half of the total emissions from the Danish agriculture.*(CONCITO, 2014:14)
The report suggests and explains the benefits of producing

Ill. 13:
The amount of imported soy meal in 2014 by Denmark from the main producers of soy meal. The size of the soybean fields within the country, and the size compared to the landarea of Denmark. Appendix D for calculations.
(Own illustration)

proteinaceous rich crops in Denmark, thus reducing or even stopping the import of soymeal. Traditionally Denmark has and is still growing proteinaceous crops such as; rape, peas and sunflower. producing these solve the need of protein need, maybe but unfortunately the yield of these crops is inferior to the soybean. Comparing the current price of soybean it would not be sufficient in an economical context. Producing crops with higher yield is necessary, the red clover and clover yield more per hectare, but is arduous for monogastric animals in larger quantities. A production line, able of extracting the protein from the clover would be necessary. (CONCITO, 2014)

As seen on illustration 13, the import of soybeans is close to 1.5 mio tonnes and grown on huge land areas, primarily in Argentina and Brazil the fields are former rainforest. A growing demand is actively increasing the deforestation of the rainforest, which means production of cheap meat in Denmark have directly influence on forests and nature on other continents. (Aske Skovmand Bosselmann, 2014)

Implementing the cultivated land in Denmark, would take up an additional 12,8 per cent of the land area, making close to one third of the country cultivated. In the calculation it's granted that soy can grow in Denmark, since it can't other crops would be needed, expanding the additional land area for protein production. (CONCITO, 2014)

ARGENTINA

Imported soybeans to Denmark: 781.319 tonnes

Size of soybean fields: 307.606 ha

Soybean fields compared to Denmark size: 7,1 %

BRAZIL

Imported soybeans to Denmark: 383.137 tonnes

Size of soybean fields: 129.438 ha

Soybean fields compared to Denmark size: 3 %

USA

Imported soybeans to Denmark: 256.558 tonnes

Size of soybean fields: 95.731 ha

Soybean fields compared to Denmark size: 2,2 %

Ill.13

Waste

Ill. 14:
On a daily basis vast amounts of food are thrown out in plastic bags. The combination of plastic and organic degradable matte makes it hard to reuse, hence incineration is often an general solution.

Ill.15:
A landfill, a place where waste and trash are piling up. Bulldozing it into the ground, will make it disappear temporarily. Places like these are heaven for scavengers such as seagulls.

This chapter will discuss what food eventually becomes, waste. Why it is becoming an increasingly problem and the consequences of it.

The linear metabolism of modern cities revolves around extracting resources from nature, that energy is pumped through the urban system in a steady and secure phase, then released into the nature again. After being through the urban system, the energy has been packed, injected and transformed, which makes it difficult for nature to reabsorb it. Simultaneously the demand of humankind has created a system, which reaps faster than nature is able to regrow.

Increasing quantity of goods going into the cities has consequences regarding waste, in every aspect of the production of food chain. In the primary production, fruit and vegetables are discarded if they have a wrong size, and the demand is difficult for the producer to decipher, which means that there always have to be plenty. In grocery stores food are thrown out, if any indication of decay appear even though the food is perfectly safe to eat. The grocery stores want people to find fresh groceries every day, year around, this means throwing out good edible food. Providing food for people has become a highly efficient business, the customers are faced with deals which promotes quantity. The other part of the chain is after the food is purchased, people are buying more than they can eat and share the same perspective on food as the grocery stores. (Miljøstyrelsen, 2014/2015)

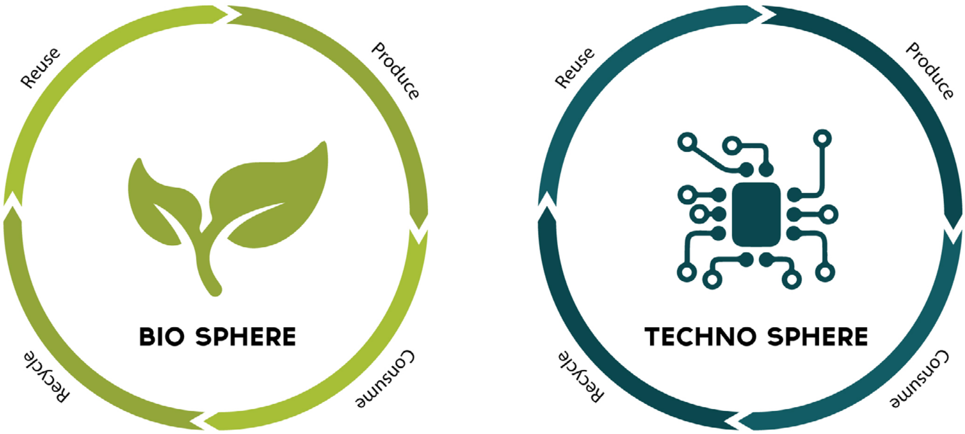
Ill. 14

Ill. 15

Ill. 16:
The two spheres in which all materials on earth are divided. The biosphere contains biodegradable materials while the remaining are within the technosphere.
(Own illustration)

The quantities of thrown out food are staggering, in Denmark 716.000 tonnes of edible food was thrown out in 2014. The primary contributor is the households, followed by the food industry. (Miljøstyrelsen, 2014/2015). People are living in cities, in which food and other materials always have been in abondances. It is difficult to teach how to recycle and reuse goods, when there are brand new ones, just 5 minutes away, after all what came easily is easily thrown away. The modern societies are aware of the waste problem, and new methods is being developed. Among the more popular are turning the waste into energy in the form of heat and electricity by incineration. Suddenly the mountains of waste have to started to decrease and do not need to be hidden away in landfills, a subtle solution for a brief moment. Burning the materials is not resetting the cycle of resources its ending it.(Michael Braungart, 2009)

The notion of craddle to craddle, a system where the waste of humans becomes nutrients for the nature. In a system like this, limits are removed, the term waste is redundant and a true abundance is possible. Basically everything can be divided into two spheres, in which they interact and becomes a part of the ecosystem. The biosphere is everything, which is consumable by microorganisms in soil or animals. That being food and other bio degradable products. The other sphere is the technical sphere, which consists of technical nutrients, such as metals and minerals. The extraction of these is expensive and the amount of them, if not recycled, limited. Recycling within each sphere is possible, but modern products are starting to become hybrids between these, mixing nutrients from each sphere. This makes it difficult to harness and are forcing us to incineration.(Michael Braungart, 2009)



Ill. 16

If people started dividing their waste, it could become vital components in other industries and cycles. Because people want new products and when they are done, they deem that no one else might want it. Which in a sense is understandable and even okay, because throwing stuff out, does not mean it disappears from this world. The waste may come of use for other people or organisms, as Carolyn Steel writes Waste, like beauty, is in the eye of the beholder. (Steel, 2008:260)

Humanity have to focus on creating a chain of mutual benefits, a cradle to cradle cycles is only possible if start reusing, re-cycling and reintroducing the materials into the production of new goods. If we keep burning our materials, there will not be anything to transform.

Summary

If humanity are to survive upon this planet, we have to accept that we are a part of the ecosystem, instead of viewing ourselves as something greater. As explained in this section our actions have direct influence on the environment and are currently destroying ours and other species living conditions.

A system of equivalent exchange must be established, a system where our footprint on this world, is minor compared to the bio capacity. Being sustainable is not enough anymore, the damages inflicted, needs care and time to heal. We have to be better than just sustainable, humanity must provide instead of only consuming. Like everything else in nature, our end products have to be nutrients for other organisms.

Living in cities, humanity has started to densify itself and people are being excluded from nature. Producing of food is still happening on the hinterlands, but as the population growth within the cities are exponentially increasing, so is the agricultural frontier. Biodiversity is being suppressed, so food can be produced. Accepting the impacts humanity has on the nature is important, if we ought to improve.

In the case of Denmark, the increased production of livestock has transformed the country into a big field. The fields are providing feed to mainly livestock, the actions has effects on surrounding nature areas, such as lakes and rivers. To reduce leaching from fields, regulations were implemented, reducing the amount of fertilizer legal to use on the fields. Hence the energy in the crops was reduced, and a chain of events was set in motion. If the meat should stay in the same nutritional state as before, additions to the animal feed had to happen. The soy meal was introduced and the level of protein in the animal feed was maintained, but at the cost of rainforest on a neighbouring continent.

Decisions like these, is the reason why humanity is facing such extreme problems, goods are shipped in and consequences shipped out. Either we discover new and renewable ways of providing the cities, which will exponentially decrease the footprint or the living standards will have to be reduced. Western societies have been through the industrialization and are currently starting to understand its consequences, but all the benefits from it are intact. Convincing the much more inhabitant intensive Asia, that industrialization have impacts on the world is a easier task, if we are able to present better solutions, without demanding them to stop evolving.

We are facing times, in which we have to choose. Do we want to have the same living conditions as the generations prior to yours or do we want become more environmentally sustainable. Because what we do, will always have an impact, there are no saints nor demons.

If cities was improving its ability to provide to the natural cycles, the footprint would be reduced. In the case of Denmark, the agriculture would emit 50 per cent less CO_2, if the country produced protein within its own borders. Controlling the production and harnessing the energy accumulated in the waste, could turn the cities into a beneficial part of the supply instead of only demand.Understanding the fundamentals, and immediate problems have made it possible to form a vision for the project and a initial problem question.

Vision

The aim for the project is to rethink our current food production system; turning the linear movement of food from countryside to urban areas into a more circular movement, a cyclus were the residues of the city becomes an active part of the production of food. Turning the cities into an active actor within a sustainable system, by contributing to their own food production, hence becoming an active part of the supply, while also ensuring a reduction in import of animal feed.

Ill. 17: The current linear movement of food from countryside to urban areas. (Own illustration)

Research question

"How can urban residues become an active part of the production of protein in danish agriculture, thus deeming residues more value in an economic, social and environmental sustainable context?"

Ill. 18: The proposed circular movement, where the urban area return nutrients to the supply. (Own illustration)

CHAPTER 3

Nothing ventured, nothing gained

This chapter is a quick introduction to circular metabolism and how it serve as the solution to the problems explained in the previous chapter. Starting out with explaining how designing with nature could be beneficial within food production.

"When the winds of change blow, some people build walls, others build windmills"

Chinese proverb

Nature as a design tool

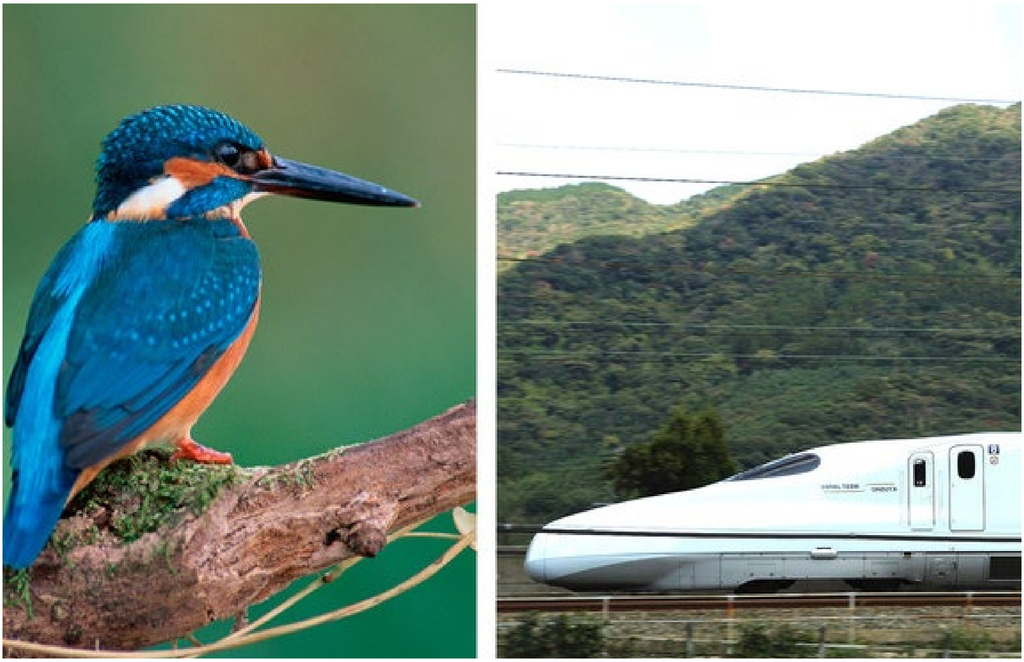
Ill. 19:
The designers making the bullet train in Japan was inspired by the beak of the kingfisher. This is biomimicry, a design where nature is copied.

Ill. 20:
In 2014 SLA designed the surrounding park of the new Novo nordisk building in Bagsværd, Denmark. Introducing wild nature to the built environment, tilted trees becomes habitants for bio isotopes.

Biomimicry is an approach, in which design seeks solutions by mimicking nature. The core idea is that nature's innovation already has solved many of the problems humans are facing. Nature is having an impressive ongoing design process, in which failures are extinct and the solution to survival surrounds us. The inventors and engineers are plants, microbes and animals, after billions of years they have developed solutions, which have generated sustainable living conditions for their species. (Benyus, 2002)

The notion of biomimicry was introduced in 1997 by Janine Benyus, her theory suggests that humanity's aspirations for new solutions should be guided by nature's designs. A student- mentor -relationship with nature, where we are learning from nature instead of exploiting it. Biomimicry encourages designs, that save energy and materials. In nature energy is a valuable resource, organisms have evolved in different ways, to harness it. This has created the cycle of nature, a true cradle to cradle system, in which organisms are adapting and contributing to the cycle. Waste does not exist in the natural system, waste is a phenomena created by man, in nature the individual organisms leave nutrients for others in a holistic system. (Benyus, 2002)

SLA, an architectural office in Denmark are designing with nature. Their method is called process urbanism, which basically means using nature when designing cities. The method combines scientific knowledge about nature, such as water, soil, vegetation, food chains, metabolism and CO2 with creative commitment to develop durable, sustainable and holistic design solutions for our cities. Their focus is not about the aesthetics of nature, but how it works. Leaving the traditional ideas of master planning behind, in favor of a more adaptable planning. Process urbanism does not view the city and nature as opposites, but as organisms within the same system.(SLA - Architects, 2011)



Ill. 19

Ill. 20

Ill.21:
The foodchain of all organisms on earth. Vegetation are able to harness energy through light, the producers. The consumers eat the producers and continues the circle, finally the waste of both groups are decomposed and reintroduced to the soil in the decomposer group.
(Own illustration)

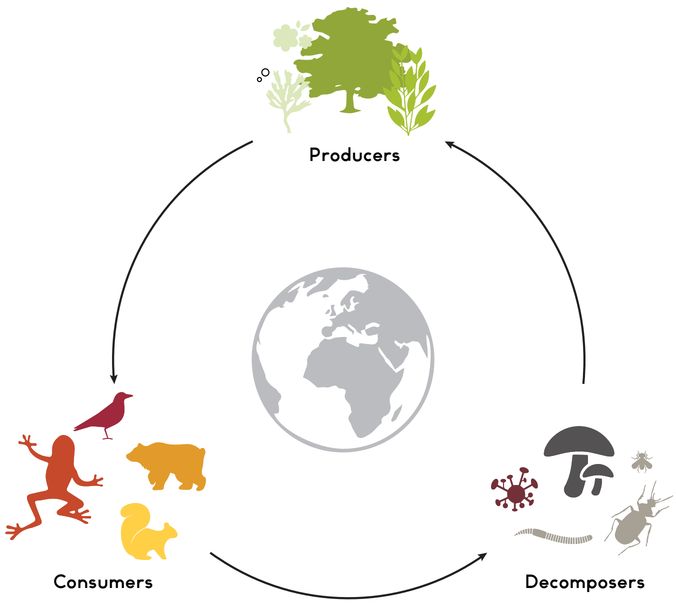
Ill.22:
The foodchain constructed by humanity is partially inspired from the natural one. The starting point is vegetation, grain, vegetables and fruit delivering energy through light. A narrow range of livestock is consuming these, hence providing a condensed food source for humanity. Afterwards only few parts of our waste is reintroduced to the natural enivorenment. Instead the waste is transfered to landfills and incinerators. Creating a ecological gap of resources between consumers and producers.
(Own illustration)

Nature optimizes instead of maximizing, this is the reason why nothing is wasted. Humanity has to accept that we are a part of the cycle instead of being apart from it, contributing to a system of mutual benefits. Biomimicry and process urbanism are both inspired by nature, and so should we look for inspiration in regard to the problem of waste as well.

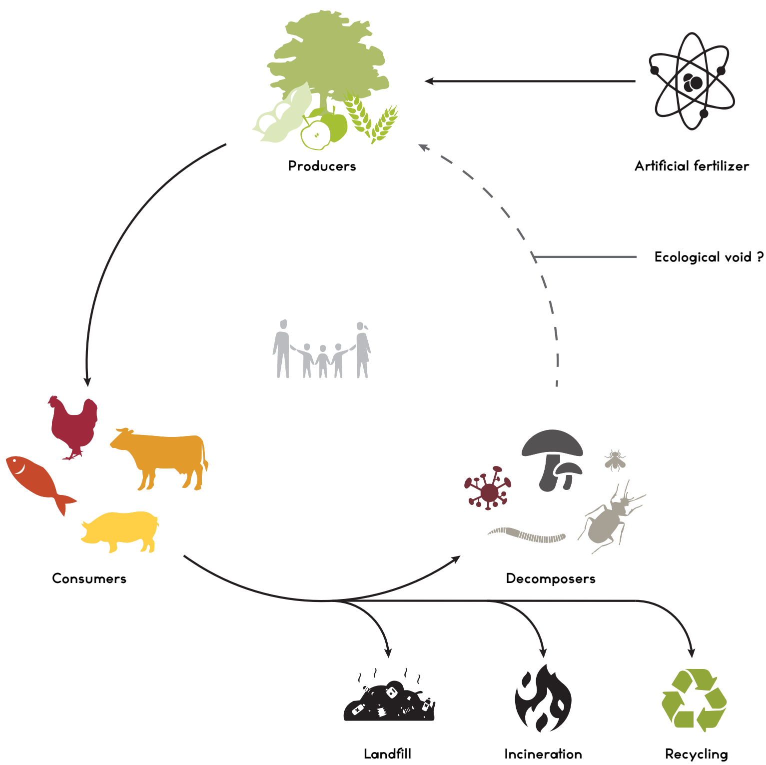
Earth's ecosystem is comprised of a great diversity of organisms that consume each other and organic materials in dense and complex interactions. Nutrition and energy are moved, transformed and released through several links, from one organism to another, which have made every step available to new organisms. (Michael Braungart, 2009)

All organisms within the ecosystem can be divided into three categories; *producers*, *consumers* and *decomposers*. *Producers* are plants and vegetation in general, they produce energy by means of photosynthesis using water, nutrients and sun. *Consumers* is divided into three subcategories, herbivore, carnivore and omnivore. None of these are able to produce their own energy, they have to consume. Herbivore consumes plants, carnivore consumes everything within the consumer's category and omnivore is able to consume both plants and other consumers. The third category of the ecosystem is *decomposers*, organisms in this category are able to absorb nutrients from dead organic materials. Bacteria, fungi and insects are the main components of this category, they consume waste and release nutrients into the soil that plants then can absorb. (Markfoged, 2012) (Mogensen, 2010)

The differences between the linear metabolism of our consumption and the natural ecosystems as seen on illustration 21 and 22. The waste produced through the various steps is being shipped out to landfills and incinerators, parts are recycled and reintroduced.


Producers
Consumers
Decomposers

Ill. 21


Producers
Artificial fertilizer
Ecological void ?
Consumers
Decomposers
Landfill
Incineration
Recycling

Ill. 22

Ill. 23:
The project suggest the implementation of insects into the existing food production. The insects will serve as a bio converter, transfering the energy from waste into themselves, thus becoming proteinous livestock feed. The remains are safe to reintroduce to nature, since it is the same procedure as is performed within the natural cyclus.
(Own illustration)

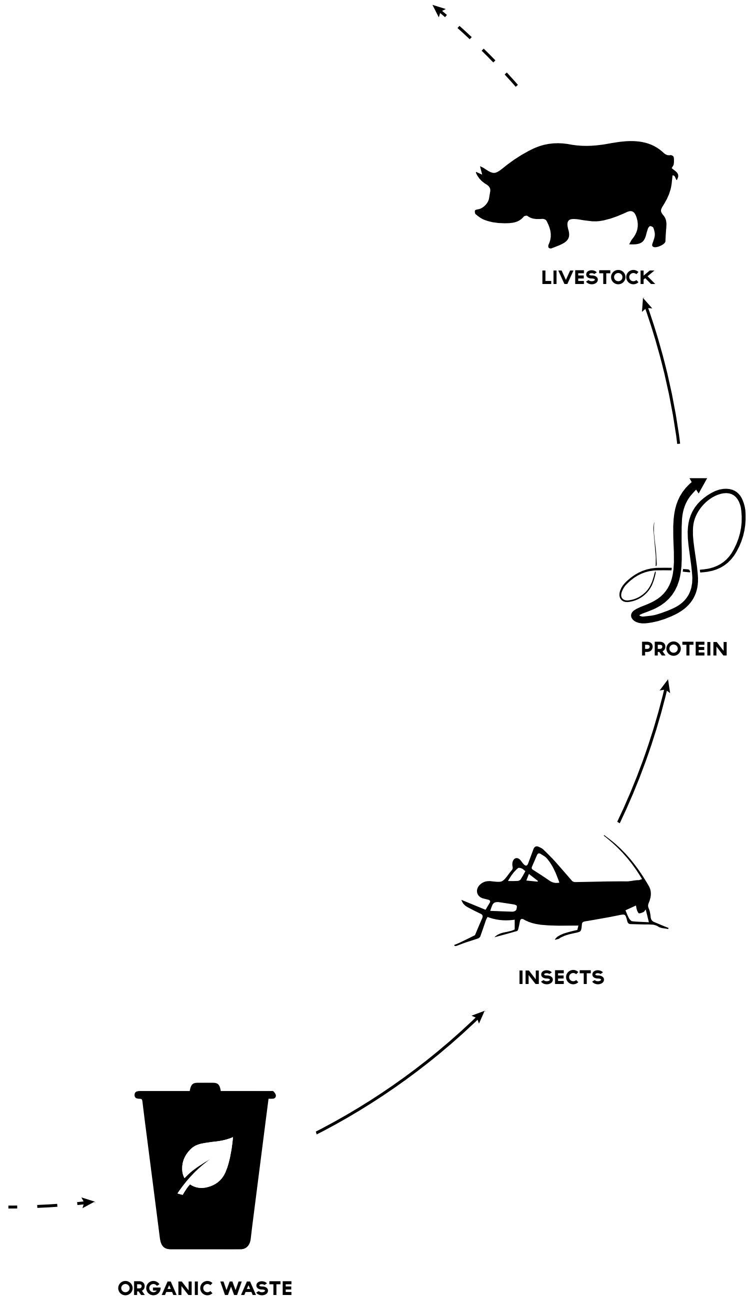
In the natural system waste from consumers is decomposed and the nutrients are returned to the soil. When we remove our waste from the equation, this action creates a gap, a gap of lost energy. Artificial fertilizers are added to the equation, so the energy of the remainder cycle is maintained. Modern agriculture is mainly focused on the *producer* and *consumer* spectrum, but if waste ought to provide more value to the food system the interest in *decomposers* should increase as well.

Besides being able to consume organic waste organisms within the *decomposers* category are also a vast source of food for the *consumers*. The source of food is primarily from the most bio diverse group within the *decomposers*, the insects. Among animals the ones that have insects as a natural part of their diet are wild poultry and pigs. (Dyrenes Beskyttelse, 2015)

If we turned insects into a viable part of our food system they would then be a very favorable supplement as a proteinaceous feed, which would reduce and recycle our waste, while also reducing the ecological footprint of meat production. This will also provide feed to an agriculture that is in need of new food consumption patterns. Feeding future generations requires alternative sources of protein for our livestock, but eventually also for us. (Arnold van Huis, 2013)

Design scope

Facilitate insects as a bioconverter, turning organic waste into animal feed in a Danish context



Ill. 23

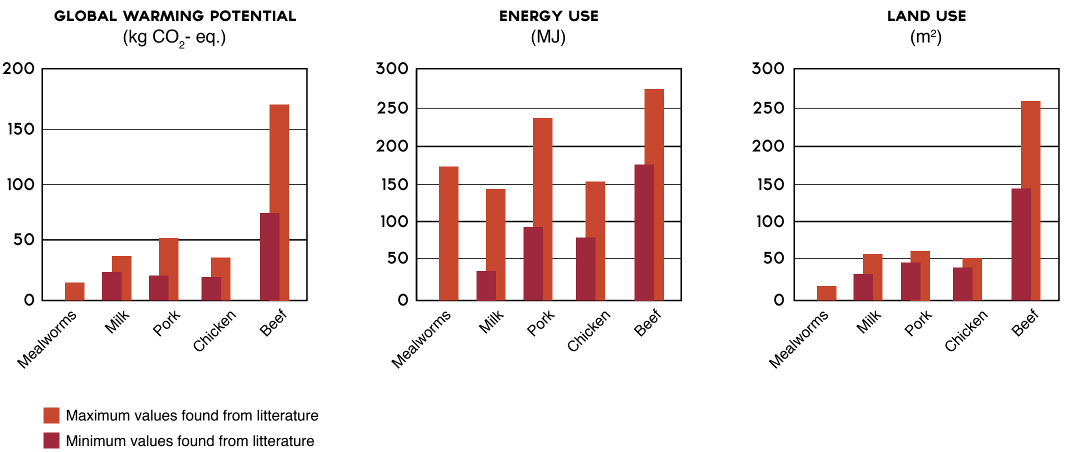
Insects

Ill. 24:
Comparing of different livestock and mealworms. The data are the report Edible insects made by FAO*. The numbers used are accumulated within the report. (Arnold van Huis, 2013 : 64)

The possibilities of multiple uses of insects are already in motion. The report Edible insects made by FAO, *the food and agriculture organization for the united nations*, proposes insects as a possible food for people in the future and as feed for livestock. Providing a growing population of demanding consumers requires an increase in food production. The current agricultural production is already limited, in sense of its resources, capacity, fertilizers and energy. An increased demand for food and particularly meat, will place considerable pressure on it, leading to more emission, deforestation and environmental degradation. As the report concludes it is an environmental problem in need of urgent attention (Arnold van Huis, 2013)

One of the largest barriers that prevents people from eating insects is determined by culture and has to do with the traditional cuisine and aesthetic preferences, that are norm driven and have to do with the feeling of “disgust”. In western societies insects were and still are regarded as pests, and eating them is still considered a taboo. There are however examples of agricultural utilization of bees, silkworms and insects used as dye. (Arnold van Huis, 2013)

In the report different livestocks have been compared in a life cycle assessment with the mealworm, representing as edible insect. The parameters or criteria for such assessment are as follows; the greenhouse gas production, energy usage and land use throughout the production respectively of 1 kg of protein(see ill.24). As graphs show mealworms produce far less emission and require little amounts of space. The energy usage is quite high, since mealworms and other insects are cold blooded, meaning it takes energy to keep them warm.



Ill. 24

The other animals are using energy on maintaining a constant body temperature, that energy is spent differently by each insect resulting in higher protein conversion and productivity. (Arnold van Huis, 2013)

A huge benefit is that insects are able to consume energy from biowaste, making the insects suitable as an alternative protein source. The insects are then processed and fed to pigs and poultry, which then are sold to the customer. The insect kingdom is by far the largest in the world (see appendix B), not all species are suitable for bioconversion. Species that excel in bioconversion are of further interest, among these species are the common housefly, mealworm and black soldier fly, as mentioned in the report these could collectively convert 1.3 billion tonnes of biowaste/year. (Arnold van Huis, 2013:61)

Larger productions of black soldier flies already exist, they are known as suitable animal feed, and since they already are being farmed, it is possible to gather information about rearing.

Black soldier flies

Ill. 25:
A photograph of a fully grown black soldier fly. Proparly resting before finding a mate. This is the last evolution stage of the BSF, within the production the larvae will be the main component.

This chapter will give a quick introduction to the black soldier fly (BSF), its life cycle and how it can become a part of a recycling system.

Unlike traditional livestock, insects have a very different lifecycle. Growth is happening through metamorphosis, a development where the fly radically changes its appearance and physical capabilities several times. The BSF changes appearance four times, starting out as fragile eggs for 4 days hidden in cracks until hatching as larvae (BSFL). Larvae is the primary state in the BSF cycle, while in this state only consumption matters, in fact it's the only state where the BSF is able to consume. After rapidly eating and growing for 2 weeks the larvae is fully grown and ready to pupate. It migrate from its siblings in order to find a safe and dry area to bury itself and pupate. After roughly 2 weeks a adult BSF emerge, during its life as a fly it survives solely from its storages as larvae, focusing only on reproduction in its 5-8 long life. (Newby, 1997)

Observing the black soldier fly in its natural habitat have provided farmers with the needed information to domesticate the BSF. Thus developing a foundation for data collection, which can be used for further calculations, such as production times, yield and feed consumption.

The majority of BSF life is during its larval state, where consumption is its primary trait. They eat organic material, and turn it into bulk. Effectiveness and consumption rate depend on temperature, since insects are cold-blooded. BSF do not spend energy on maintaining a certain body temperature which set expectations to their habitat. The consumption rate is impressive, one square meter of BSFL are able to consume 15 kg of organic every day. (BSF Farming, 2016)

Ill. 25

The larvae consists of 45 % protein, which is 10 % more than soybeans. (CONCITO, 2014:15) They are mobile, since migrating is apart of their natural cycle they able to harvest themselves without being handled by humans. Despite a short lifecycle the reproduction is massive compared to traditional livestock, a pair of BSF are becoming parents to between 500 and 900 eggs before dying. That cycle repeats itself every month, which means breeding certain capabilities is possible in a much faster rate than typical livestock. (BSF Farming, 2016)

BSFL are photophobia, they thrives in shade and bunched together, which makes them perfect for vertical farming. The vessel in which they are contained need a gradually rise towards the end, a path for migrating BSFL. In that manner the natural cycle of the fly becomes an active mechanic within the production unit, harvesting themselves.

Capacity study

Ill. 26:
Walk through of the calculations explaining the capacity of the production unit within a possible BSF factory.
(Own illustration)

In order to consider BSFL as possible animal feed a capacity study must be executed. The calculation will provide dimensions for the building. The data used is gathered from the various sources used through the foundation segment. Calculations available in appendix C

The focus of the building is the production mechanism, hence the needed area the larvae need to grow and become animal feed. As mentioned earlier Denmark imports close to 1,5 mio tons of soy meal every year, the amount of used soy meal depend on season. This calculation assumes that the demand is steady every month, thus 122.000 tons. The BSFL is able to consume 15 kg of organic waste per day and consists of 45 % protein, the production mechanism has 30 days to produce the needed protein.

Since the production mechanism needs to be a controlled environment, 60 ha is a tremendous size. If the facility provides a quarter of the needed protein, it becomes a realistic. Other similar facilities might be built or other forms for protein production to fulfill the demand.

Vertical farming is possible, if the area is stacking the production area reduces the footprint. Harvesting and rearing is a cycle determined, the maturing the BSFL takes 2 weeks. Dividing the production mechanism into 8, ensures harvesting every week.

In order to be able to design, the production mechanism must have a shape. In this case, the cylinder is preferred, since it has no corners. The larvae migration will only have one direction, to the edge.

PROTEIN NEED	$\frac{1.460.000 \text{ tonnes}}{12 \text{ months}}$	= 122.000 tonnes	
INSECT CONVERSION	$\frac{122.000 \text{ tonnes}}{(15 \text{ kg} * 0{,}45) * \text{m}^2}$	= 18.074.074 m^2	= 1.807 ha
TIME PER DELIVERY	$\frac{1.807 \text{ ha}}{30 \text{ days}}$	= 602.469 m^2	= 60 ha
FACTORY CONTRIBUTION	60 ha * 0,25	= 150.481 m^2	= 15 ha
VERTICAL FARMING	$\frac{15 \text{ ha}}{15 \text{ floors}}$	= 10.041 m^2	= 1 ha
AREA DISTRIBUTION	$\frac{10.041 \text{ m}^2}{8 \text{ silos}}$	= 1.255 m^2	
SILO RADIUS	$\sqrt{\frac{1.255 \text{ m}^2}{3{,}14}}$	= 20 m	
SILO HEIGHT	8 silos * 2 m	= 30 m	

Ill. 26

Spatial division

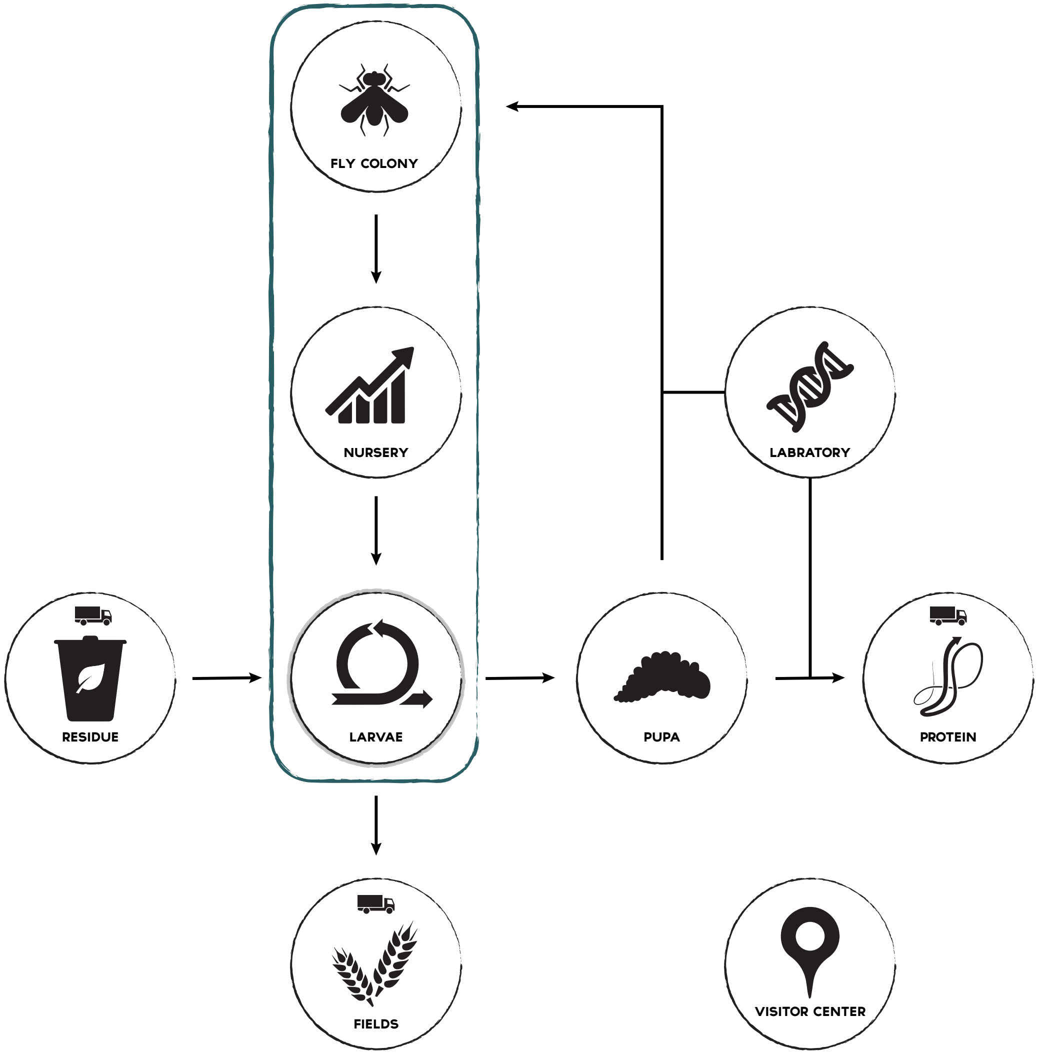
Ill. 27:
Illustration providing a spatial overview of the a possible division of functions within a BSF factory. The building will primarily be a combination between the cycle of entering residue and the life cycle of the BSF.
(Own illustration)

The building will be an intersection of two cycles, the life cycle of the BSF and the conversion of residues to protein. The three metamorphosis stages of the BSF needs secluded chambers, the main being the silos which contains the BSFL, marked with blue on illustration 27. The remaining parts are scaled proportional to it, and morphed to fit the functions of the specific stage.The eggs needs extra care and heat. While the fly colony must have a artificial tropical environment, in order for them to copulate. Since they are secluded, the transportation between them is the second most space consuming asset of the building.

The main function is feeding the larvae, hence the freight terminal is an important part. Arriving organic waste and departing protein and field mineral is the other cycle within the building. Pipelines and mechanics preparing the residues to be consumed needs to be in close relation to both the silos and the freight terminal. The mechanics harvesting and preparing the pupae also have to be in immediate connection to the freight terminal.

Research and development of the different cycles are of highest importance, creating an effective population of flies and a consistent understanding of the residue will ensure a steady production. A laboratory is connected and maintains primarily the selection and research of the BSF population.

A visitor center, that invites people into the facility will provide an educational and multifunctional purpose to the building. Maintaining a transparent understanding of the food production is important.


FLY COLONY
NURSERY
LABRATORY
RESIDUE
LARVAE
PUPA
PROTEIN
FIELDS
VISITOR CENTER

Ill. 27

Summary

Humanity fought nature until it seemingly tamed it and was able to harness it. Prior to the industrialization people thrived in a symbiotic relation with nature, but then due to centralization people gradually became more alienated from nature, and an industrialised society emerged which meant that all food production got streamlined . The waste products that are a result of our needs have to be recycled and reused in order to become a part of a more holistic symbiosis with nature instead of constantly trying to work against it.

We have an opportunity to create, a master and apprentice relationship with the ecosystems in nature, learning from them while interacting with them. We must acknowledge that we cannot avoid not being consumers , we are destined to consume,so the question is not whether we are consuming or not, but how we can be sustainable and do it in a cyclical way.

Our current focus within the production of food, is purely on certain species of livestock and a narrow variety of plants.This has allowed focused research and development, which results in a production mechanism that is able to produce vast quantities of food, but unfortunately also a lot of waste. As mentioned earlier we have to learn from nature, and this means for instance that we have to construct facilities that can convert waste into nutrients.

Large concentrations of BSFL are able to do that, with an end product that can safely be put out into nature again. Whilst serving as a possible environmental solution to waste problems, the production of BSFL will serve as an economical breathing space for Danish agriculture, allowing agriculture to evolve in a more environmentally friendly manner, which will ultimately reduce the import of animal feed from foreign countries.

A cyclical approach is a decision, we as consumers all have to come to terms with. The possibilities of such a system, depend on people's ability to divide the organic degradable waste from their residues. Introducing the public to the natural cycles are of high importance, responsibility and joint ownership are key to creating sustainable ecosystems.

The waste has to be gathered and transported to the facility, which inevitably makes the location of the facility of high importance. The building will serve as an energy connection between the inhabitants and the agriculture, and similar to traditional rearing the food supply is important, so the BSFL won't starve. The end product is inanimate, which allows storing, hence the building is best suited for a location with a large hinterland of consumers producing organic waste. Transporting large quantities requires an area with well developed infrastructure and roads that can serve heavy vehicles.

The BSF is not a natural insect in Denmark, which means it can't survive in the danish climate. This ensures an ideal failsafe, preventing the risk of any disturbances of the natural ecosystem. The fact of the alien habibat for the insect however complicates the maintenance that requires a preferable temperature in the production silos. During the summer months, attached solar panels could easily heat the silos, but during the winter extra energy would be needed. Other large industries produce their goods with high temperatures, through cooling and relocation of heat they provide surplus heat to their context. It would be beneficial to place the facility in immediate close relation to an industry of that sort.

The Triangle Area

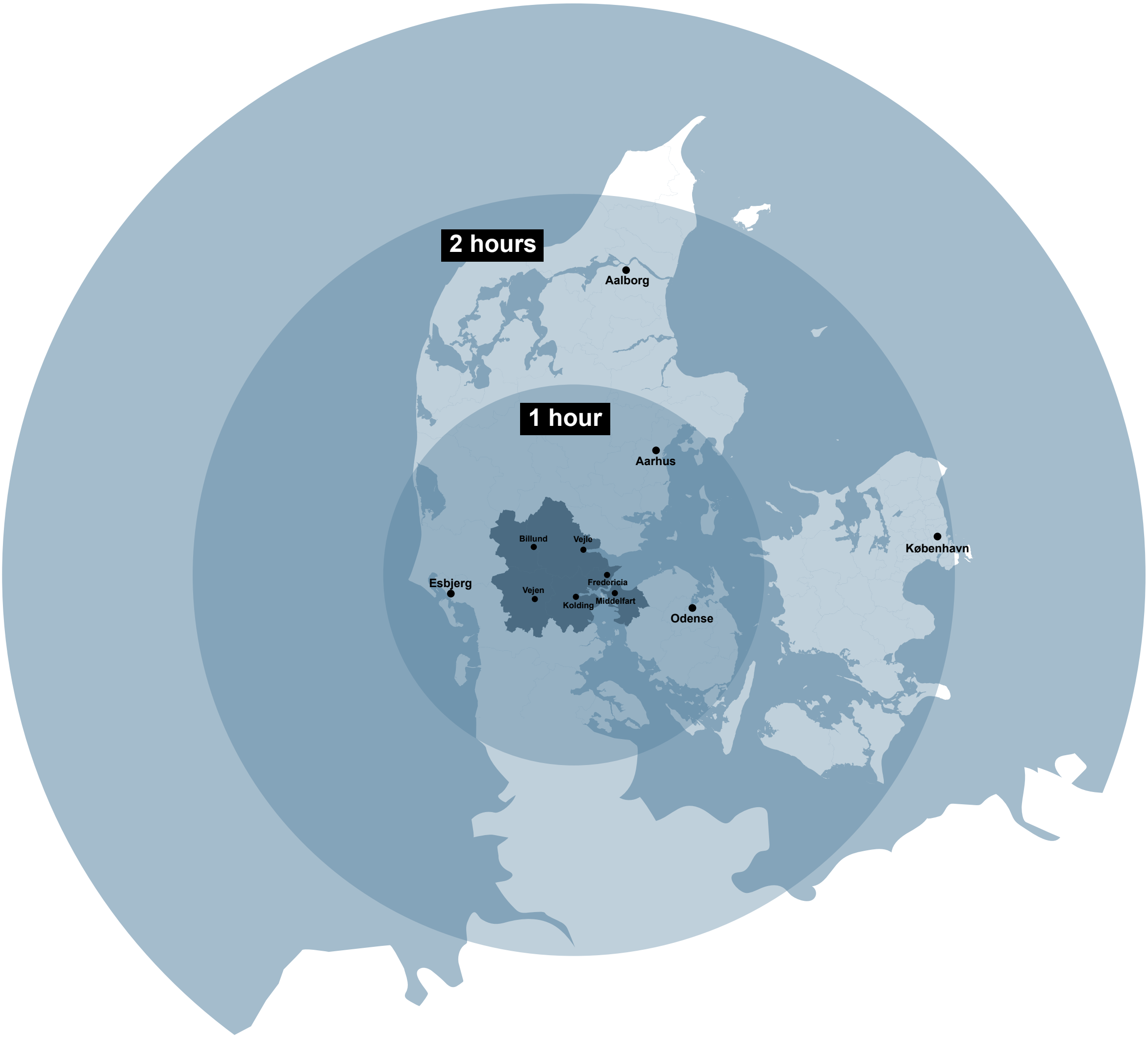
Ill. 29:
Illustration showing the distance from the triangle area to other parts of Denmark.
(Own illustration, inspired by Trekantområdet Danmark, 2016)

The triangle area is a geographical region within Denmark placed between Lillbælt to the east and the moorland of Jutland to the west, covered the notorious beech forests and varied landscapes, a beautiful part of Denmark. The triangle area is also the name of a union between seven municipalities: Billund, Fredericia, Haderslev, Kolding, Middelfart, Vejen and Vejle. With a combined population is 415.000 people, where 31.000 are working within the industrial sector. (Trekantområdet Danmark, 2016)

The area is known for its industry and central position in Denmark, creating an attractive setting for new developments. The areas leading position was achieved during the industrialization in the middle of the 1800 century, where the increased demand of steel and cotton turned the area into a wealthy region.

Today the industry is still strong and very present; the area has more workers employed within the industrial sector than the three largest cities in Denmark combined, without a doubt because of the geographical location in the center of Denmark. The triangle area is the center of the Danish infrastructure network. The two main highways in Denmark, E45 stretching from North Jutland to Germany and E20 from Sweden to the Triangle area are intersecting within the Triangle area generating formidable conditions regarding transport.

As seen on the illustration 29, the region is located in the center of Denmark and most of it is within reach in a matter of hours. This has created the foundation for well-developed infrastructure, which have the capacity to deal with future pressure from an ever growing industrial sector. Within the first hour drive Aarhus, Odense and Esbjerg is reached, summed in a total of approx. 1,8 mio citizens. One more hour away is Copenhagen, Aalborg and even Hamburg expanding the hinterland to approx. 7 mio people. (Trekantområdet Danmark, 2016)


2 hours
1 hour
Aalborg
Aarhus
Billund
Vejle
Esbjerg
Fredericia
Vejen
Middelfart
Kolding
Odense
København

Ill. 29

Fredericia

Ill. 30:
Marking of the municipality of Fredericia.
(Own illustration)

Ill. 31:
Diagrammatic overview of the neighboring municipalities.
(Own illustration)

Of the seven municipalities forming the Triangle area, Fredericia is the center point being the nearest municipality towards Fyn and Sjælland. The lillebælt bridge is situated within the municipality, and currently besides ferries and the older Lillebælt bridge, is the only connection to the rest of Denmark.

The municipality of Fredericia is 134,46 km2, with the primary city being Fredericia. The industry in Fredericia city is well known within Denmark, and the intersection of the two highways E45 and E20 makes the municipality an attractive place for new industries. (Fredericia Kommune, 2016)

The current town center of Fredericia resemble the old one, which was designed with a historical defence purpose, surrounded by ramparts. Even though its nearly 100 years ago it lost its purpose as a fortification point in Denmark, the development of the city is still following the guidelines that was decided at the given time. The industry within the city are mainly placed within the harbor area or on the hinterlands around the city.

Within the municipality the interest of recycling and reusing are becoming of greater concern during the last couple of years. A strategy ensuring more recycling and further information has been created and will become a part of the planning of the municipality towards 2024. The reuse of organic materials and nonorganic are already being discussed, and the goal is a reuse of 80% of the waste from the inhabitants of the municipality. (Fredericia Kommune - Affald & Genbrug, 2015)

Making the municipality a suitable location for the project, since most of the criterias is within reach.

Ill. 30

Ill. 31

Built area

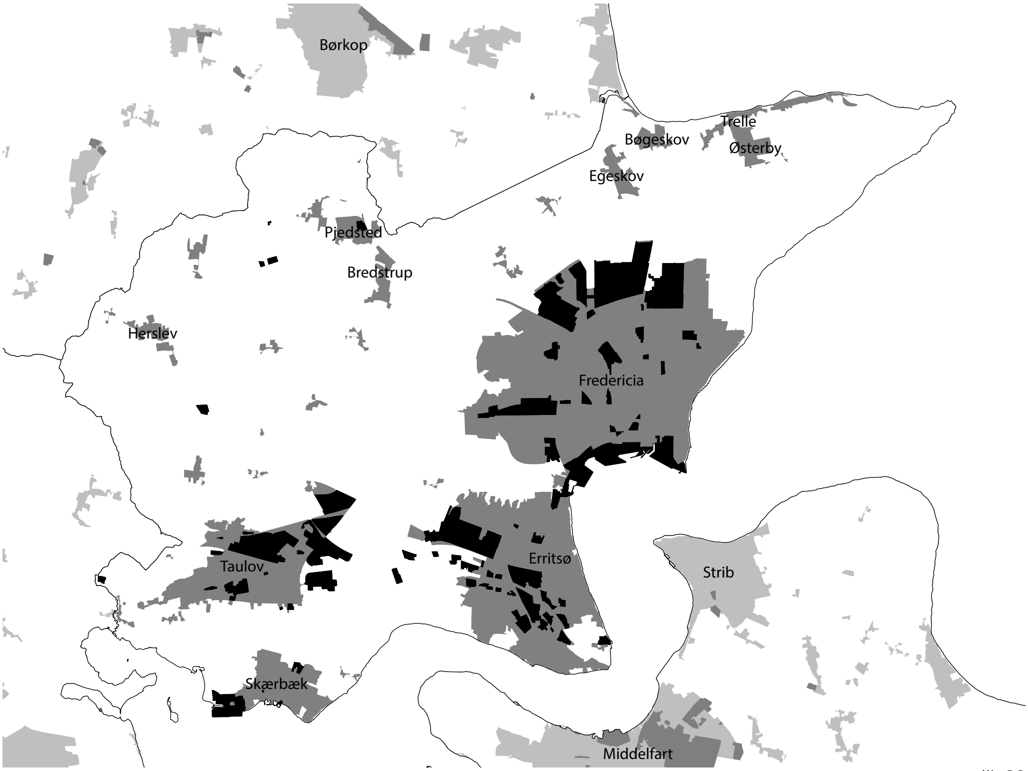
Ill. 32:
Illustration showing the built area within Fredericia municipality. The black areas a representing the industrial district of the various cities in the municipality.
(Own illustration)

Ill. 33:
Illustration showing the infrastructure of the municipality. The inner and outer ringroads are marked with red. The highways are marked in a thicker line.
(Own illustration)

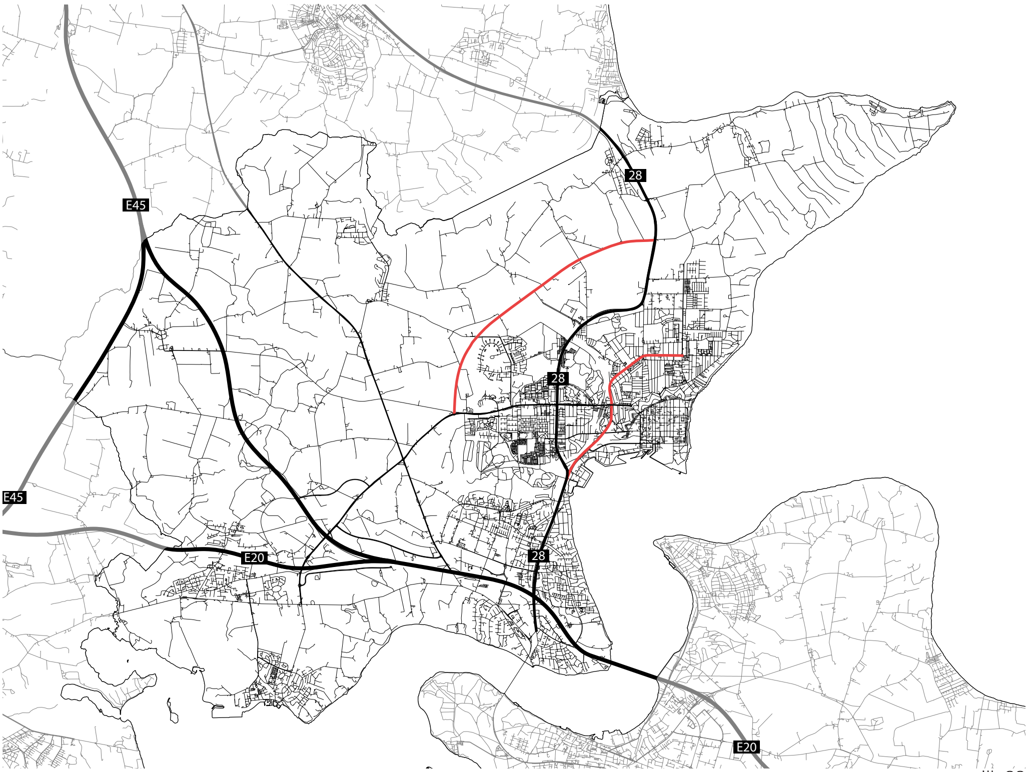
The building should be close to a larger city; when building larger industries the demands for water and electricity supply for example are enormous and only cities with well-developed grids can provide that. Furthermore hence the building will be of a factory like character, the site must be close or within the industrial areas of the cities. The noise and smell is best suited for the hinterlands of the city. An important location parameter is also the demand of surplus heat from other industries along with a sufficient area to build on.

Mobility

As mentioned earlier the closer the site is to the main highways, the better it will be connected to the rest of Denmark. However the locations closest to the highway are also close to the more dense part of the municipality. So it is preferred closer to the northern part of the municipality and in close relation to the industrial area of Fredericia. There are two main ring roads within Fredericia from the inner and outer, marked with red on illustration 33. The outer ring road is connecting the larger road 28 with the highways, so the site should be in its immediate distance.


Børkop
Trelle
Bøgeskov
Østerby
Egeskov
Pjedsted
Bredstrup
Herslev
Fredericia
Taulov
Erritsø
Strib
Skærbæk
Middelfart

Ill. 32


28
E45
28
E45
E20
28
E20

Ill. 33

Green & blue elements

Ill. 35:
Illustration showing green and blue elements within the municipality of Fredericia.
(Own illustration)

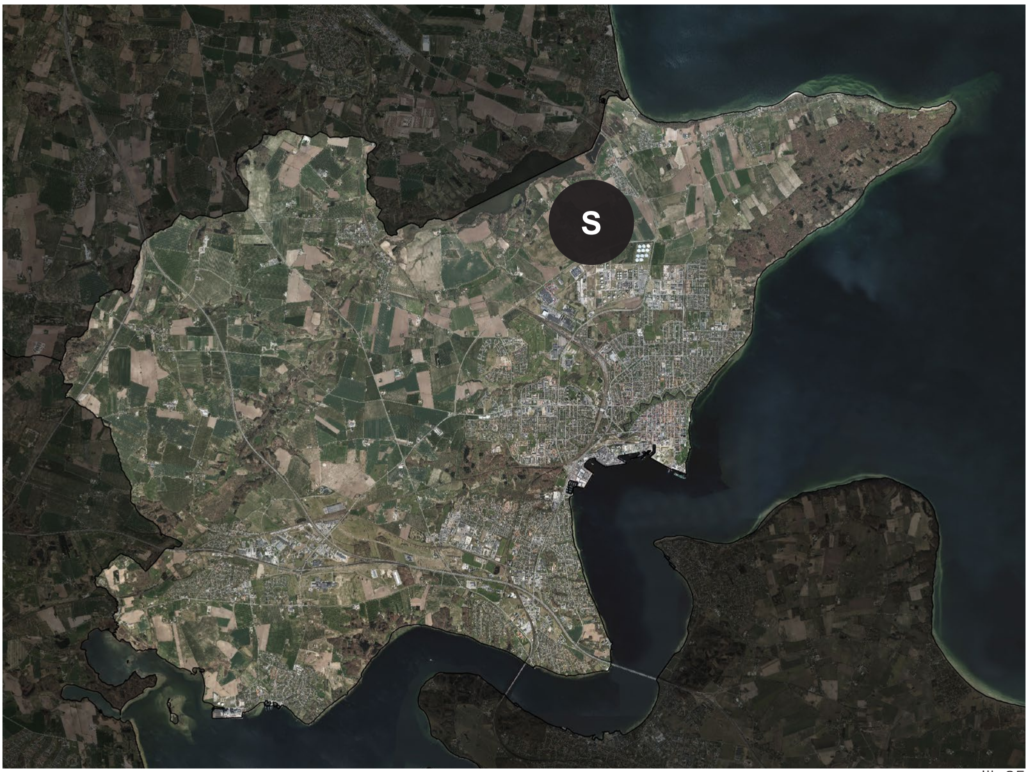
Ill. 36:
Illustration showing the area of interest within the municipality.
(Own illustration)

The green elements within the municipality are primarily in contact with the larger Rands fjord, which creates an edge through the municipality. To the east the large forest Vesterskov enhances the tip of the municipality with nature. The site should be placed away from these locations, however still within viewing distance.

Area of interest

Placing the building in the northern part of the municipality, adjacent to the industrial area of Fredericia. Situated close to other larger industries and within distance to the grid of Fredericia. It is close to the outer ring road and thereby well connected. The infrastructure in this area is suited for larger vehicles and has the needed capacity. The area is within viewing distance of Rands fjord and the nature around it, without ruining parts of it.

Ill. 34



Ill. 35

Ill 36: Aerial view of Fredericia, zoomed on historical ramparts

Ill 37: A view of Rands fjord


Ill 38: Aerial view of Fredericia harbour


Ill 39: A view of the Lillebælt bridge

Context analysis

Ill. 40:
Illustration showing the cadastre of interest norh of Fredericia.
(Own illustration)

Ill. 41:
The built- and industrial areas in proximity to the cadastre.
(Own illustration)

The selection of the land area is decided through different parameters among these are the primary: space for the needed square meters and the location regarding energy net and infrastructure.

These parameters are fulfilled by the cadastres north of the outer ringroad of Fredericia. Placed between Fredericia and Rands fjord. The area must be larger than 20 ha, 200.000 m2 due to the assumed size of the buildings facilities.

The selected site is adjacent to the disposal center of the municipality, so the theme of the area is already that of reusing and disposing. Regarding the infrastructure it's important that the selected area has more connections to different roads, since there will be two main users: the steady flow of trucks supplying the residues to feed the insects and the employes & visitors of the building.

Another important parameter is the room for sustainable energy, this could be in the form of solar energy. However the factory will provide an vital resource to the danish agriculture, so the importance of being well connected to heating possibilities.

South of the ring road is SHELL located. The extra heat are primary from the process of heating the oil, after cooling down the elements the cooling water has an above room temperature. Currently SHELL is forwarding its surplus heat to Fredericia, much like Aalborg portland in Aalborg.


Site

Ill. 40


Bøgeskov
Trelle
Østerby
Egeskov
Vejby
Site
Egum
Shell
Carlsberg
Fredericia

Ill. 41

Ill. 42:
Showing the infrastructure surrounding the site. The earlier mentioned outer ringroad is marked with red.
(Own illustration)

Ill. 43:
Showing the green and blue elements within and around the site.
(Own illustration)

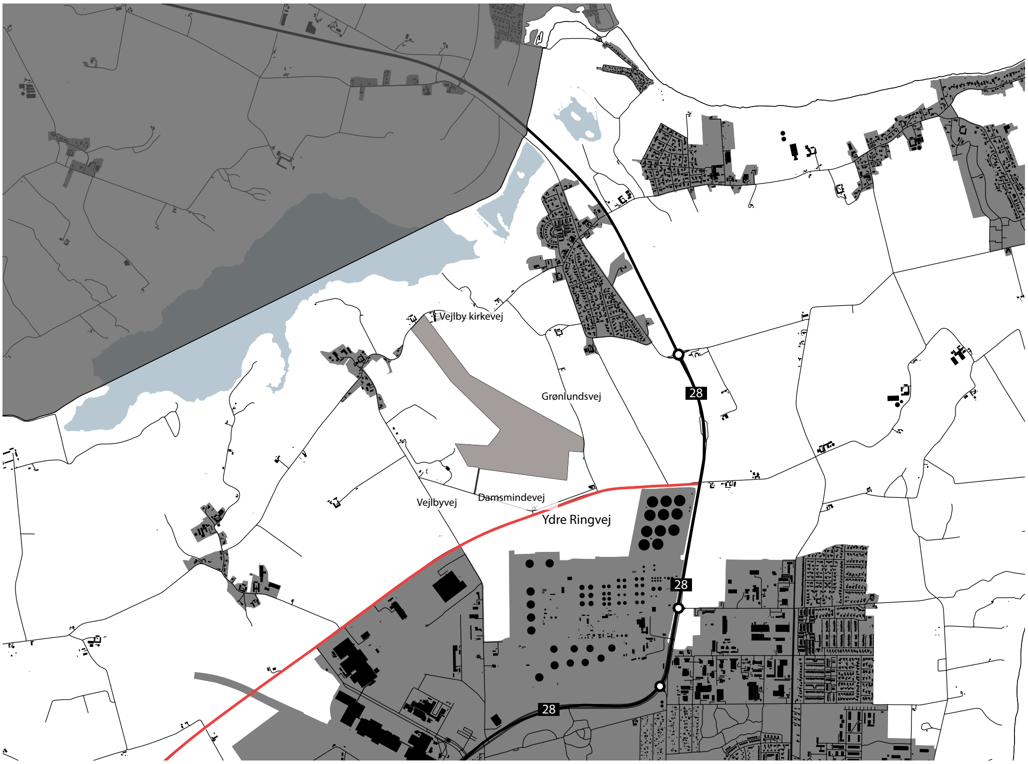
Infrastructure

The site is framed by three roads: Grønlundsvej to the east, Damsminde, to the south and Vejby Kirkevej to north. The connection to the outer ring road, is prefered through Damsmindevej, hence this road connects to the outer ring road, but also to the Vejbyvej. This create a good setting for larger vehicles, because when they are arriving/departing from the factory they have multiple options.

Visitors and employees will arrive at the building by car, mixing these with the larger vehicles should be prevented, due to a different rhythm and scale. Grønlundsvej will serve as main connection for private cars, while still in short distance of the outer ring road. This also divides the site into two main parts. The backstage from Damsmindevej and the frontstage from Grønlundsvej.

Green & blue

The site contains very little green elements. Its surrounded by shelter belts, due to its current function as a field. However the topography in the northern part is assesed as valuable landscape by the municipality. Preventing from building on that specific area is essential. As mentioned earlier the site has a view to Rands fjord.



Vejlby kirkevej
Grønlundsvej
28
Vejlbyvej
Damsmindevej
Ydre Ringvej
28
28

Ill. 42

Vejle fjord
Rands fjord
Vesters
Randal skov
Ny skov

Ill. 43

Ill. 44: View of the narrow part of the cadastres connecting the site with Damsmindevej towards south. (Own photograph)

Ill. 45: The view of the eastern part of the site along Grønlundsvej towards the outer ring road. (Own photograph)

Ill. 46: The silos of shell in the southern direction (Own photograph)

Ill. 47: The view along Damsmindevej, to the left is the disposal center (Own photograph)

The site

Ill. 48:
Marking of the zoomed cadastre 7d.
(Own illustration)

Ill. 49:
Spatial division of the site, and initial ideas for mobility.
(Own illustration)

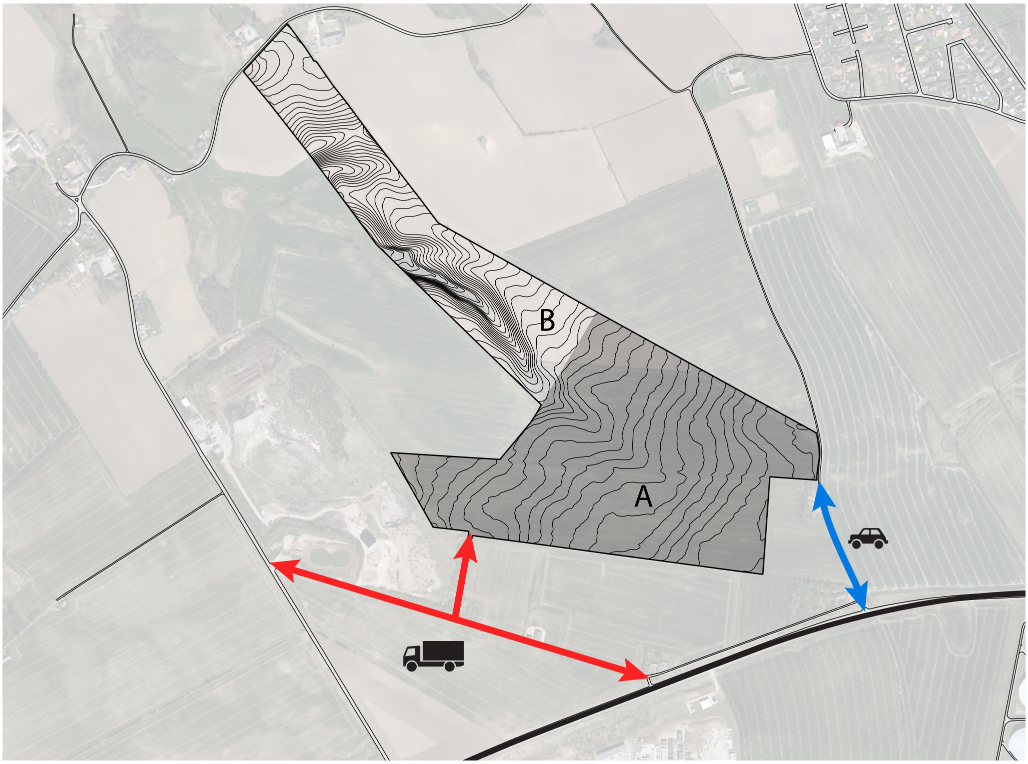
The site is 35.562 ha, located north of Fredericia, it will provide the needed space for a factory of this size. However it's too large, its size is equivalent to 50 traditional football fields. The site will have to be divided into smaller sections. The topography of the site is also very variated, with an internal difference of 22.5 m from the upper part to the lower northern end. The southern part is within proximity to the Damsmindevej and Grønlundsvej.

The site is divided into two parts a southern part (A) and a northern part (B). The A part is well connected and the topography are more planar compared to the more excluded B part of the site.

The A part is a squared shape of 23,4022 ha, which make it easier for the placement of the building. Its connection to Damsmindevej and Grønlundsvej will make it the primary area of the cadastres. The building will be built in this part, due to the better connections.

The B part is left alone, since it is assessed as valuable landscape. Beside the connections and topography makes it less durable to build on.

Ill. 48



Ill. 49

Summary

Located close to the highways, the building is visible to passing people thus becoming a landmark. The existing area will need to develop its infrastructure, which also will generate a new addition to the industrial area of Fredericia, north of the outer ring road.

Placing the building within the selected cadastre requires more analysis and understanding within of the site. Drafting and sketching is necessary reach a design. The initial starting point is the spatial division of the site into a front stage and a back stage. The needs and design of these will be of different character making the building jigsaw pierce connecting them in order to create a holistic area.

The arriving visitors at the front stage should have an experiencing driveway to the building, allowing them to slowly understand its appearance. While the backstage should be focused on a functional focal point, the rapid delivery of organic waste and the departing protein requires well developed infrastructure solutions and exclusion from public traffic, while being within the site.

The calculations of the height of the building suggests it to be above 25 meters, along with being situated on a hillside, the building will unavoidably interfere with the existing vision of a large amount of people. However Egeskov and Vejby are both more than 1 km away from the site and placed further down the hillside. Since the cities are facing Rands fjord, the building will not interfere with the vision towards the fjord.

CHAPTER 5

DESIGN

This chapter identify what a possible solution may look like, through a conceptual design of a factory which handle garbage and produce protein. The different aspects of importance will be illuminated and explained through an pragmatric approach.

"In the big picture, architecture is the art and science of making sure that our cities and buildings fit with the way we want to live our lives"

Bjarke Ingels

Concept

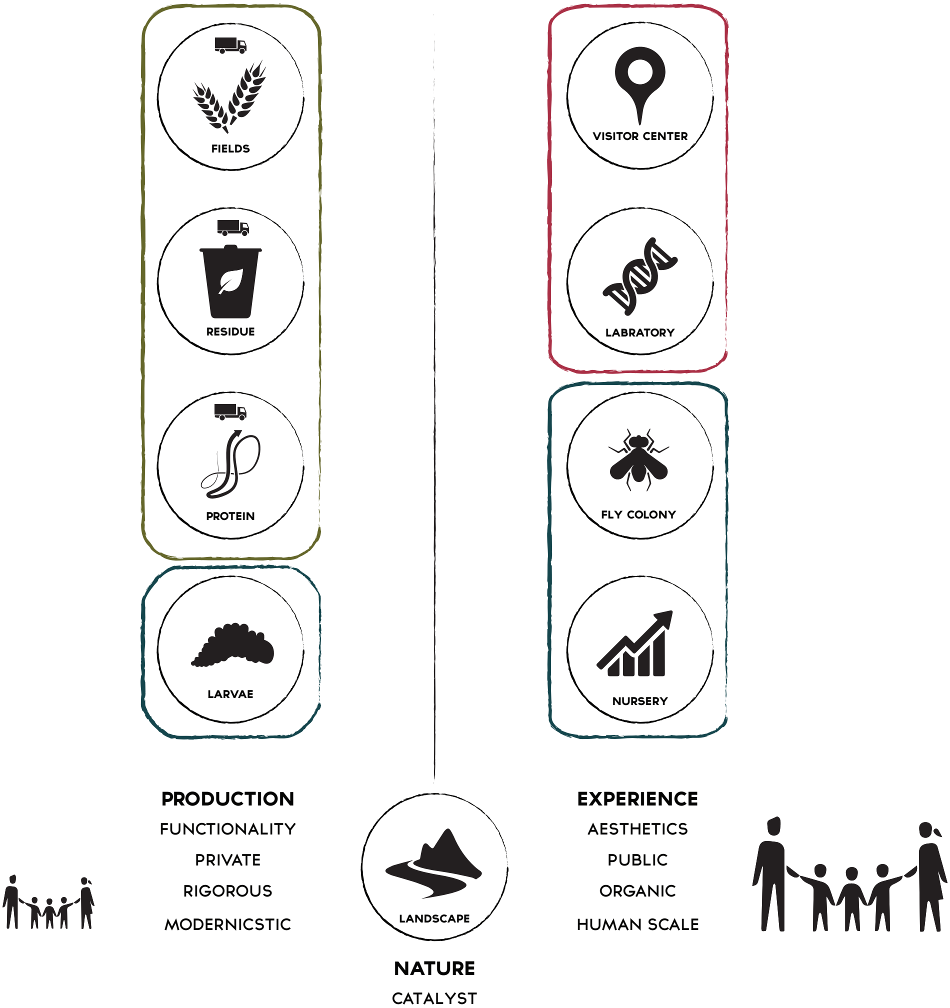
Ill. 50:
The concept of the project showing how the landscape will serve as a catalyst between the huge production facility and the human scaled experimentarium and labaratory.
(Own illustrations)

Before it is possible to create a concept of a building, the different parts have to be understood. On one hand there is the production facility, which requires considerable space and infrastructure, and on the other, the vision of a building that will introduce and enlighten people about the food production. Producing and supplying such huge quantities requires sizes and systems, that are unmanageable for the public. Between the giant trucks, silos and buildings people easily become invisible.

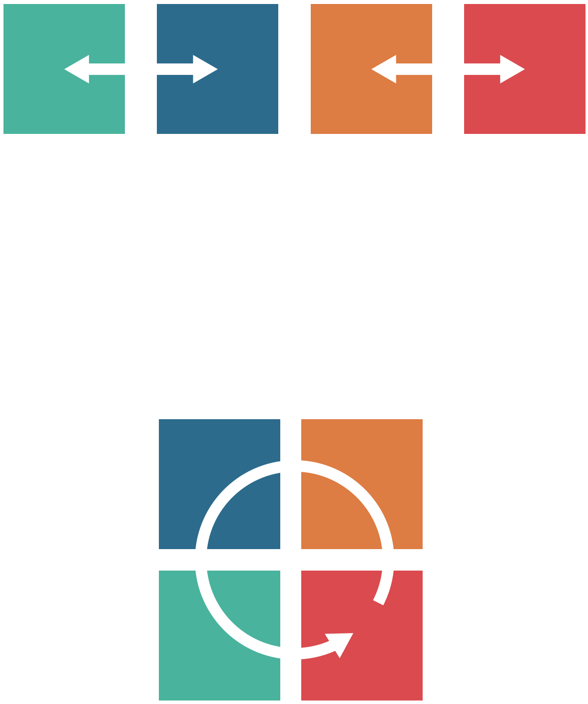
Thus the design parameter is to design a building containing a factory and providing educational purposes for the public. Fulfilling the requirements for professional and clinical necessities as well as providing an interesting and informative environment for visitors.

Is it possible to invite the public in, while you have a functioning factory? As always in design, the scale is the focal point of such a permit. Therefore, it is important to break the large production down and meet people at eye level, whilst segregating the two functions. Transparency and an open minded approach allow the visitor to meet and greet with the scientists in shared function areas such as canteen and recreational regions.

A medium between these extremes could be the landscape. The landscape is perfect for breaking the scales, it will envelope the production while becoming a lovely outdoor area for visitors and workers at the facility. It becomes a neutral borderland between fierce production and knowledge center for visitors.


FIELDS
RESIDUE
PROTEIN
LARVAE
VISITOR CENTER
LABRATORY
FLY COLONY
NURSERY
PRODUCTION
FUNCTIONALITY
PRIVATE
RIGOROUS
MODERNICSTIC
LANDSCAPE
NATURE
CATALYST
EXPERIENCE
AESTHETICS
PUBLIC
ORGANIC
HUMAN SCALE

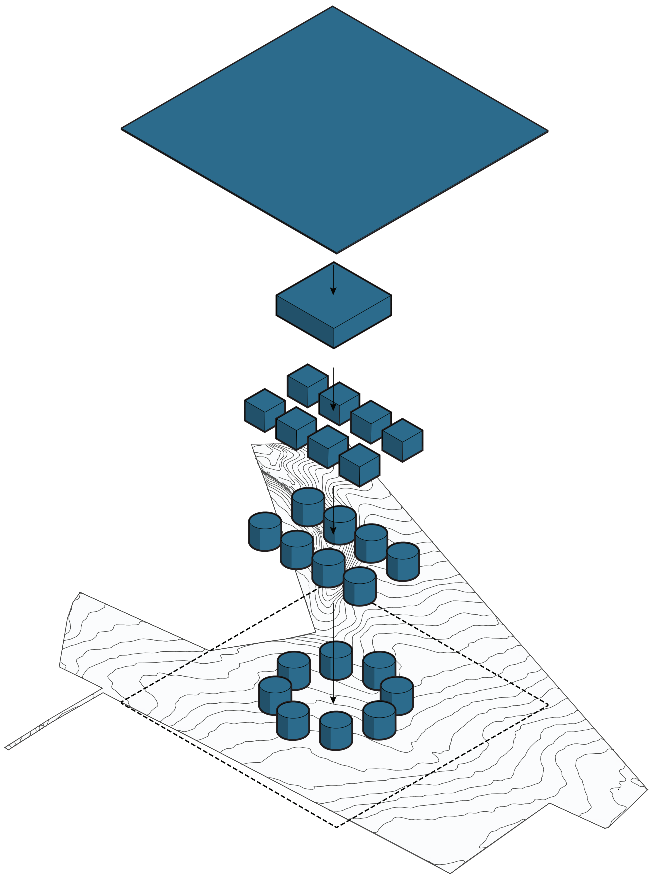
Ill. 50



Ill. 51 (Own illustration)

Holistic functions

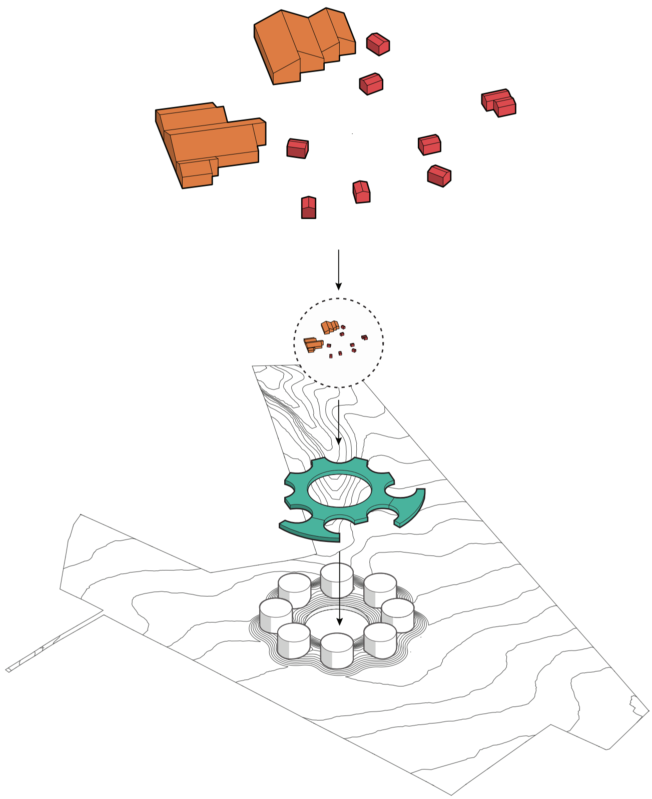
The functions within the building differ in two categories, production and enlightenment. Hard productions, colored in blue and serving production area, colored teal. Experimentarium colored red and remaining elements such as laboratory and fly colony is orange. Each element has its own specific needs, but shares secondary functions with the other parts. Combining the functions in a cyclical shape, will generate a holistic understanding of the building.



Ill. 52 (Own illustration)

Initial spatial division

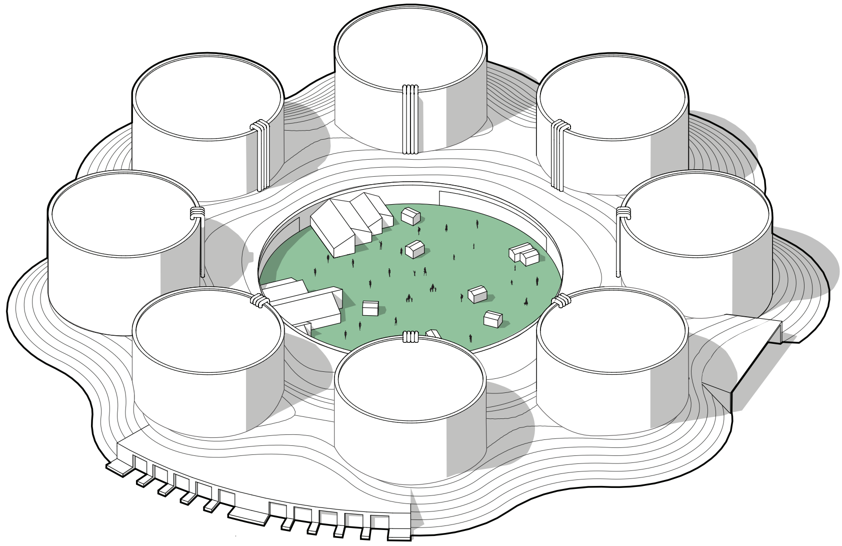
The main function is the production, and the first calculated spatial division of the building. Morphing and dividing the capacity becomes the initial shape for the building. The silos become mountains creating suitable areas for the remaining functions in its voids.



Ill. 53 (Own illustration)

Adding up the volumes

The surrounding landscape gradually slides in over the silos, allowing the building to become quiescent with the landscape. A circle is extruded between the voids of the silos, becoming the connecting production area within the building, taking the iconic shape of a gear. Two "teeth" on the gear are extruded becoming entrance and freight terminal. The center of the building is used for a subdivided hut like experimentarium and the shared functions within the building, colored in orange.



Ill. 54 (Own illustration)

Room for activities

The outdoor area in the middle of the building serve as a public domain in which visitors of the experimentarium are able to interact with workers within the facility. Wide glass facades allow light into the production, while providing vision from one extreme to another. In the north western part of the outdoor area two larger huts contain interesting functions such as fly colony, egg nest, laboratory and cantine

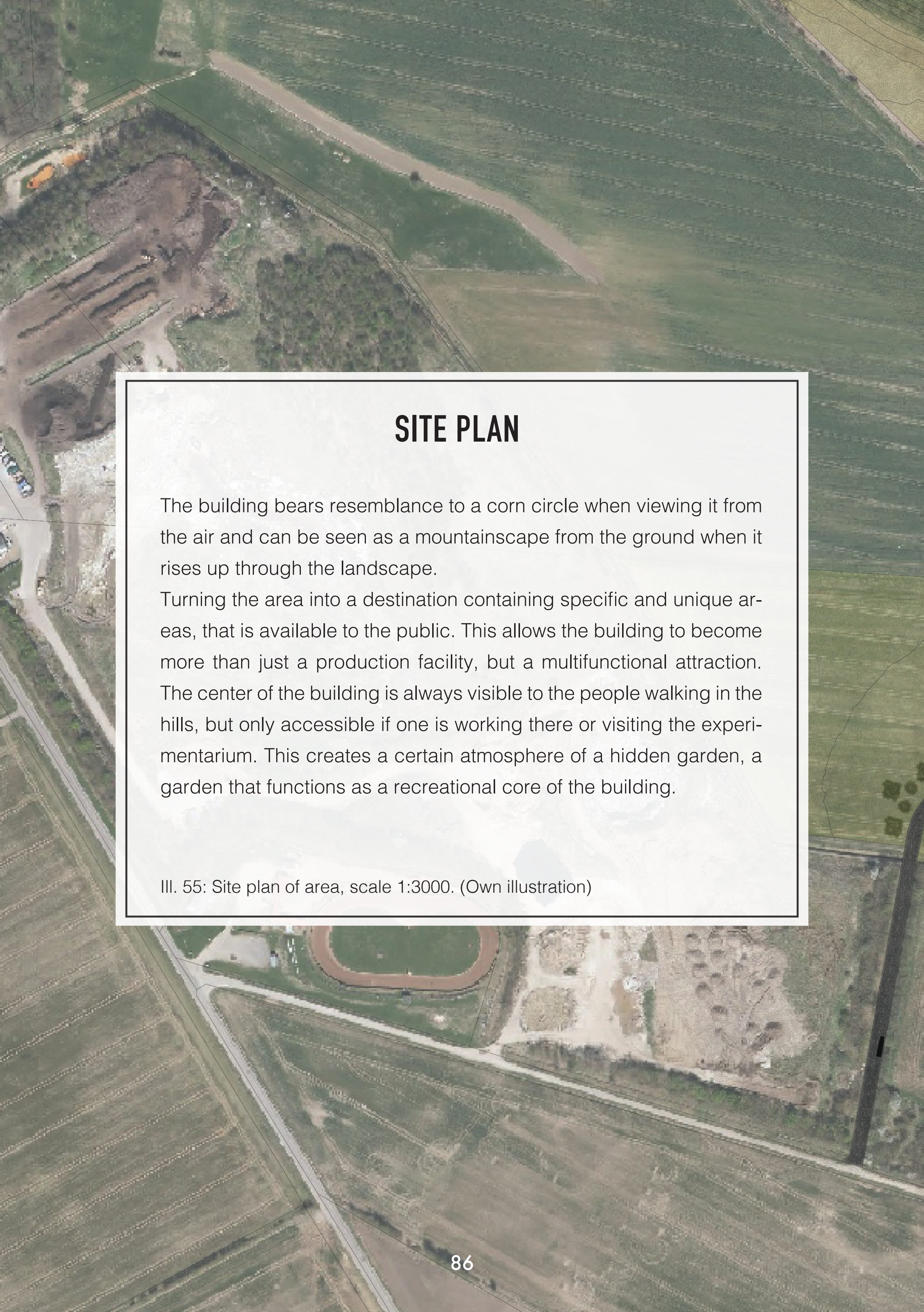
CHAPTER 6

PRESENTATION

The following pages will show illustrations and drawings formed from the design proces. The drawings within the chapter have been scaled to fit the format of the book. Higher resolutions of the drawings are within the supplementing drawing folder.

"A great building must begin with the unmeasurable, must go through measurable means when it is being designed and in the end must be unmeasurable"

Louis Kahn



SITE PLAN

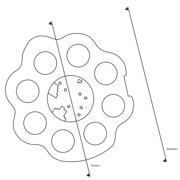
The building bears resemblance to a corn circle when viewing it from the air and can be seen as a mountainscape from the ground when it rises up through the landscape.

Turning the area into a destination containing specific and unique areas, that is available to the public. This allows the building to become more than just a production facility, but a multifunctional attraction. The center of the building is always visible to the people walking in the hills, but only accessible if one is working there or visiting the experimentarium. This creates a certain atmosphere of a hidden garden, a garden that functions as a recreational core of the building.

Ill. 55: Site plan of area, scale 1:3000. (Own illustration)

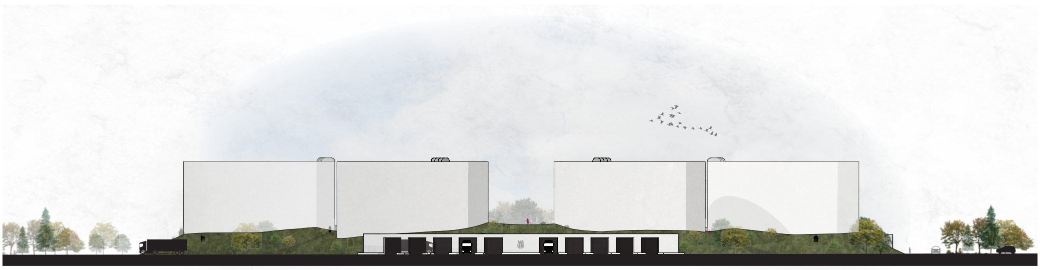
Ill. 56. Elevation 1:2000, (Own illustration)

Ill. 57. Section 1:2000, (Own illustration)

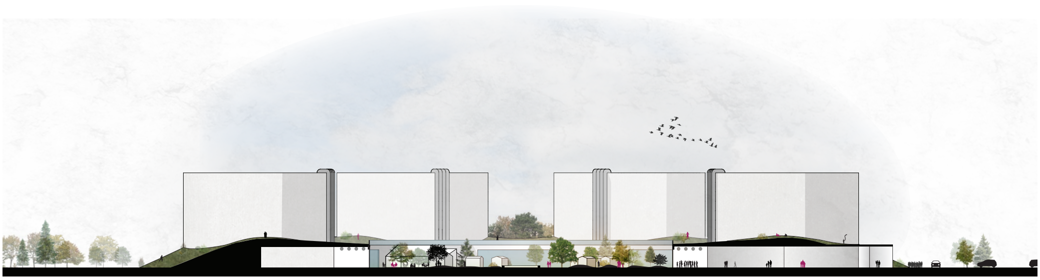


Front stage

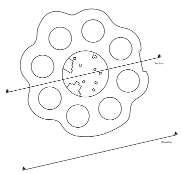
Driving through the densely planted entrance area, the building are slowing introducing itself to the visitor. At first seeming defensive, similar to the ramparts in Fredericia but like the ramparts the hills are public and accessible. During the ongoing seasons of the year different recreational purposes such as sunbathing and sledding are performed here. The center of the building is solely accessible for employees and visitors of the experimentarium through an entrance between the hills. When walking from the outer edge of the building towards the center, the visitors are temporary passing through the production part of the building before ascending in the hidden garden



Ill. 58. Elevation 1:2000, (Own illustration)

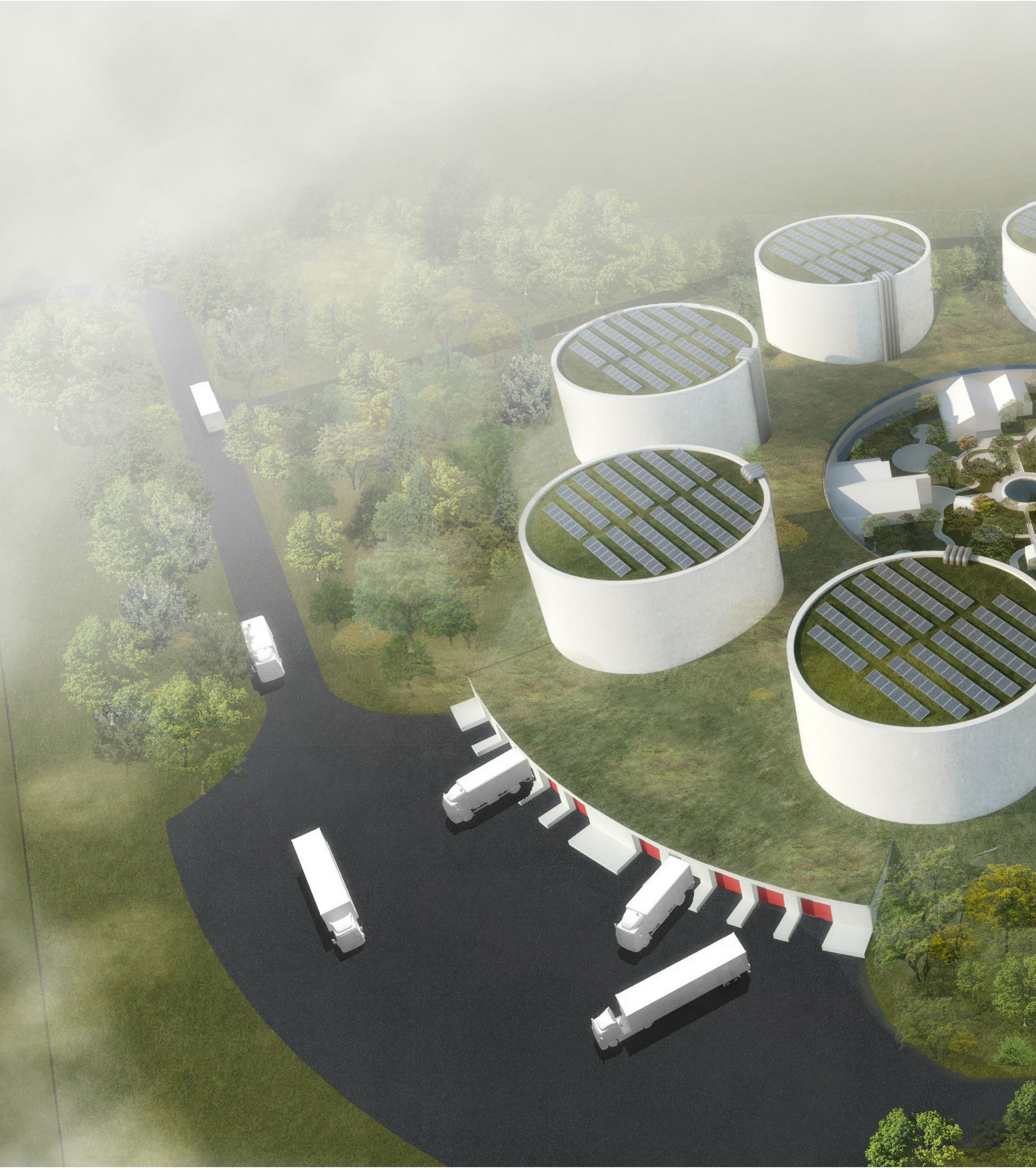


Ill. 59. Section 1:2000, (Own illustration)

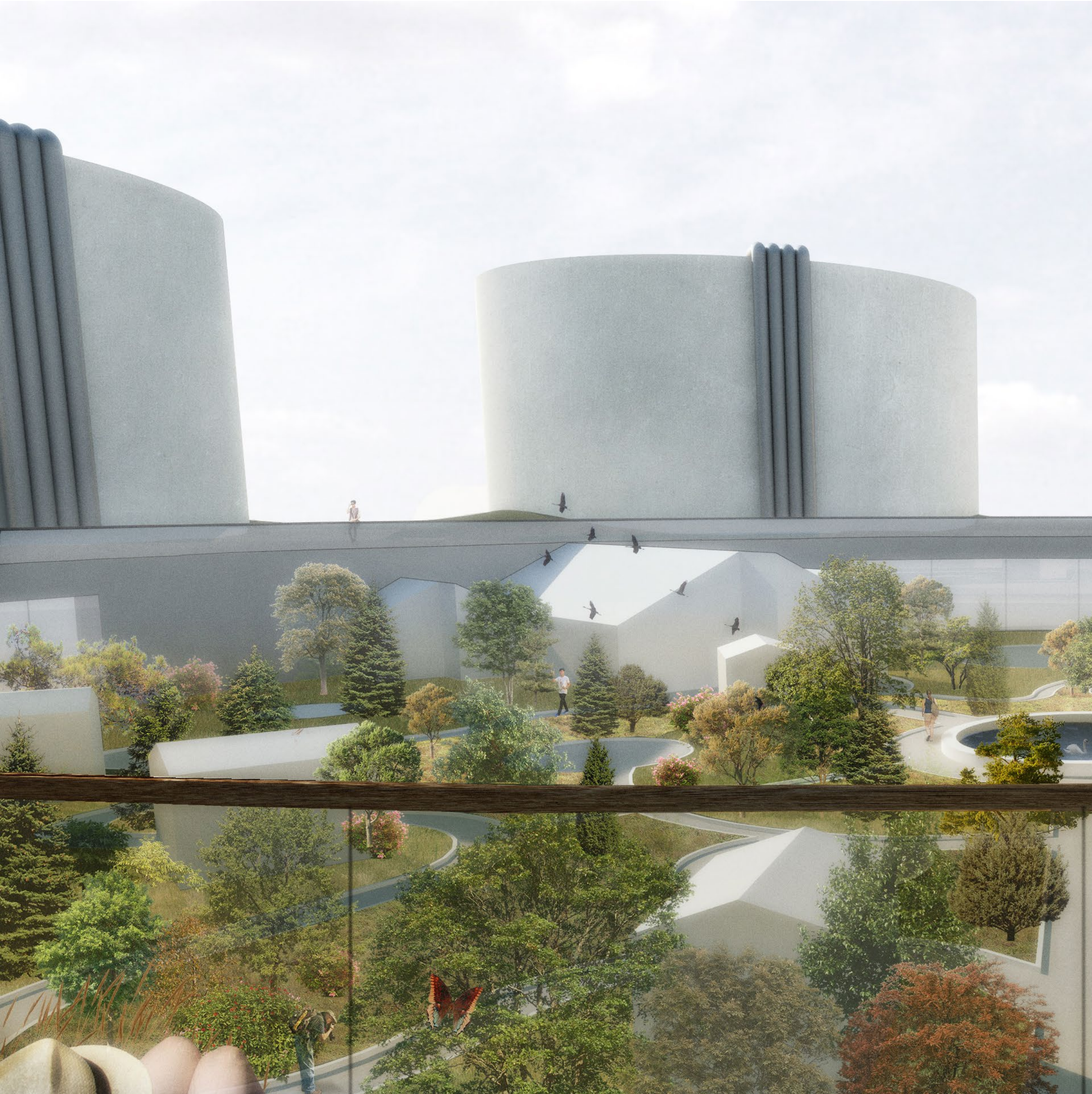


Back stage

The back side of the building are focused on heavy traffic, the freight terminal is constantly manded and large trucks are arriving and departing within all hours of the day. The residue are handled and shredded into a homogeneous consistency, then transferred with cyclical pipes through the facility towards the larvae within the silos. Just a stone throw from the busy freight terminal is the relaxing outdoor area, an area where the hard working employes of the facility are able to enjoy their packed lunches or something from the canteen. The possibility of conversations with visitors will happen, and the workers thus becomes a multitude of experts that can explain parts of the experimentarium



Ill. 60 Aerial view of the building (Own illustration)



Ill. 61 View into the building courtyard (Own illustration)

Ill. 61 Zoomed aerial view of the building (Own illustration)

CHAPTER 7

CONCLUSION & REFLECTION

This chapter will conclude on the given research question and reflection upon the discoveries of the project. Followed by the bibliography and appendix

“I am dying by inches, from not having any body to talk to about insects...”

Charles Darwin, Letters. A Selection, 1825 – 1859

Conclusion

The initial idea of the project was to rethink the linear movement of food and to devise a system in which the waste produced in the cities becomes nutrients in the farming industry. A cyclical system in which residues are utilized and benefit rather than being a hazard, in this case the Danish agriculture, and how this could be beneficial in all three aspects of sustainability.

The theoretical part of the project investigated a wide range of sources, that became gateways to larger and slightly morphed prerequisites of the project. A term like “sustainability” was replaced with “ecological footprint”, which led to a new understanding of the notion of sustainability. If sustainability means to maintain status quo it cannot be considered as a suitable vision for humanity. We have to move past that and become more than sustainable. In order for us to change our ways as a whole society we have to undergo a paradigm shift not in the fields of morality and solemn and noble proclamations to save the world but rather adapt a new agenda within economics, that will make it affordable and favorable to “save the world”. People and societies are rational short term but not long term when it comes to how we perceive the world and everything around us. The future is simply too abstract and intangible for us to make the right decisions here and now, so in order to make up for this human weakness we must direct our attention at what is realistic and viable. With this in mind the initial understanding of reusing residues was now a vision expressed through the final design, in which contributing to nature was given as much priority as anything else.

For humanity to develop a cyclical food system new methods and alternative ways must be explored, we must seek new frontiers within the food production. Systems that work without our interferes are of interest. Humanity has always learned from nature, and our modern ways have their roots in the traditional aspects of nature. The basic idea of the production of food is a concentrated use of nature. Choosing certain species to domesticate allowed for larger and more effective rearing possibilities to become a reality. The focus on cultivating plants and breeding animals were the humble steps that the modern agriculture was founded on.

Today the agriculture has changed rapidly, not in the sense that it has become more environment friendly, but that the sheer scale of production has increased dramatically.. Inhabitants of the western world have become used to the vast varieties of food, which provides a steady demand. This creates a situation where a country such as Denmark can have a large footprint, which is a fact that puts the disproportionality in perspektive, since this should not be possible.

In agriculture, in the world of farming, the general demand is protein, since it is the main component that provides the animals with what is needed in order to have quality meat on the market. Increased demands for meat have created a large demand for proteinaceous animal feed. The current supply of this is not sustainable, economically or environmentally.

Khepri proposes a production facility in which the cycles of nature are mimicked. Parts of the natural cycle is already present within agriculture, only lacking species within the decomposers category to become completely cyclical. Within the category of decomposers, insects provide the largest biological resource. Among these the one of the most effective bio converters are the fly larvae. Domesticating a species, would be the foundation of a new kind of farming. In its natural habitat the fly larvae serves as a scavenger, decomposing waste from other organisms. They are also a part of several animals diet, among these are pigs and poultry.

The waste problem and demand of proteinaceous animal feed have a shared solution, fly larvae. The larvae are able to eat organic waste, degrading it to nutrients. While they themselves are becoming proteinaceous animal feed. Thus supplying the demand within the agricultural sector in an economical sustainable way. A local production within the borders of Denmark of animal high in protein ensures a reduction in the import of foreign animal feed and a more environmentally sustainable relationship to agriculture.

The organic waste fed to the larvae are from people, which puts a small but necessary demand on people. We all have to start dividing our waste into biodegradable and nonbiodegradable segments. The new understanding will create a social sustainable approach towards waste, for future generations. People need to know why they are dividing their waste, the prefered way of introducing them to the concept of Khepri is by inviting them into the building. Within the building a hidden garden overgrown with different plants, have small huts. In these small huts information and games will explain the importance of developments within this topic, the multiple huts functions as a scattered experimentarium.

Designs similar to Khepri are looking at possibilities instead of limitations. The replenishment of nature is either done by waiting or contributing. The cyclical food chain allows better living standards, while having a lesser toll on nature. Instead of not allowing parts of the world to evolve, western countries should suggest sustainable methods in which nature are mimicked and people becomes an active contributing part.

Reflection

After deciding the focal point of the report, it became clear how complicated the assignment turned out to be. Choosing a topic, not explored within urban design before, demanded a comprehensive understanding ranging from suitable area, animal feed import down to which insects capable of eating waste. All these aspects was interfering during the execution of the report, constantly influencing the focus area, as new information was introduced.

Hence the importance of deciding a final product became important, the fact that the analysis should turn out as a building was necessary to gain a guiding point. This created a design based on facts, where the different aspects came together in a holistic system, despite having no references of a similar building or facility.

Discussing the facility, the location of it is explained through mappings all with the understanding that only one building would be built. The transportation between cities and agricultural areas will generate a large carbon footprint, which could have been avoided with several smaller compounds.

It would have been beneficial visiting existing insect farms, in the Netherlands larger productions of mealworms are being conveyed. Since the references for topic of designing artificial habitat for the insects is scarce.

Discussing the subject with experts within the agricultural development, suggesting it as a possible solution would also have been interesting.

Litterature

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Illustrations

Illustrations not mentioned below are own illustrations

Ill.1 (Hansen & Knudstrup, 2005 : 895)

Ill.4 http://vegetable.gardenworld.online/wp-content/uploads/2016/03/gaden-of-eden-vegetables.jpg

Ill.5 http://cdn.nanxiongnandi.com/bing/SoyFarming_JA-JP156628037.jpg

Ill.7 http://speakertv.com/news/easter-holiday-entertainment-for-free/

Ill.8 http://factor-tech.com/connected-world/7789-drones-at-sea-automated-cargo-ships-to-set-sail-by-2035/

Ill.10 (McLellan, 2014 : 37)

Ill.14 http://www.ricesolutionslimited.com/images/foodwaste-slider.jpg

Ill.15 http://www.blr.com/html_email/images/EDA/EDA_042814.jpg

Ill.19 http://www.bloomberg.com/slideshow/2013-08-18/14-smart-inventions-inspired-by-nature-biomimicry.html#slide4

Ill.20 http://www.sla.dk/dk/projects/novo-nordisk

Ill.24 (Arnold van Huis, 2013 : 64)

Ill.25 http://nourishtheplanet.com/2012/03/update-on-the-black-soldier-fly-project/

Ill.28 https://no.wikipedia.org/wiki/Portal:Danmark#/media/File:Denmark_satellit3.jpg

Ill.36 http://www.danmarkc.tv/10854/

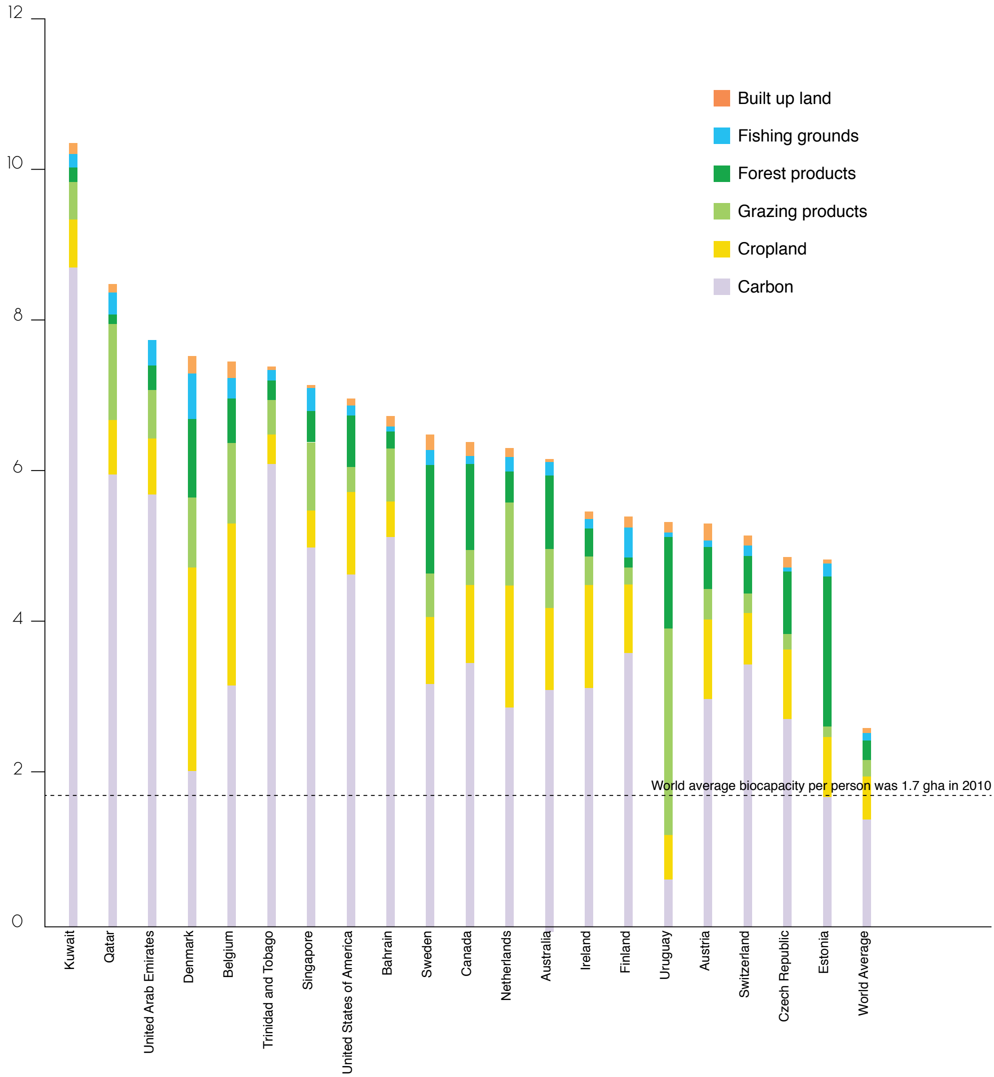
Ill.37 http://www.fredericia.dk/Borger/Natur-miljo/Sider/Natur/Naturen%20i%20Fredericia/Juni.aspx

Ill.38 http://www.adp-as.dk/download/billedarkiv

Ill.39 http://www.vejdirektoratet.dk/DA/om-os/nyheder-og-presse/pressemeddelelser/Sider/Stribearbejde-forbereder-lukning-af-nordsiden-p%C3%A5-Den-nye-Lilleb%C3%A6ltsbro.aspx

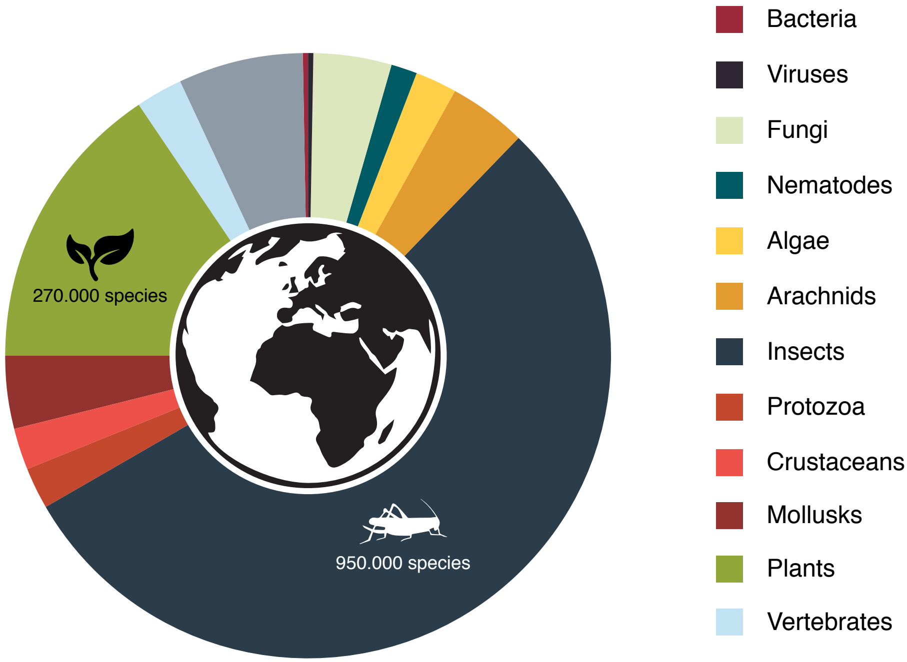
APPENDIX

Appendix A - Ecological footprint per capita



Replica of graph showing the ecological footprint per capita from the WWF Living Planet - Report, 2014. As seen on the graph Denmark is placed as number four. (McLellan, 2014 : 38)

Appendix B - Division of species



Division of kingdoms on earth, counted by different species within each kingdom. As seen on the diagram the largest kingdom is the insects, followed by plants. This makes the insect kingdom to the largest unused biological resource. Diagram created of data from the article Getting the measure of biodiversity (Purvis and Hector, 2000 : 216) Own diagram inspired by diagram from the report.

Appendix C - Area of BSFL needed

Protein need				
Soja import	1.464.000	tonnes		
Monthly	122.000	tonnes		
Black Soldier Fly Larvae				
Bio conversion	15	kg/m2	0,015	tonnes
Protein	45	%		
Protein conversion per day	6,75	kg	0,00675	tonnes
Delivery time	30	days		
Monthly protein conversion	202,5	kg	0,2025	tonnes
Size insect vessels				
Production organ	602.469	m2	60	ha
Percentage solved	25	%		
Realistic production organ	150.617	m2	15	ha
Vertical farming	15	floors		
Footprint production organ	10.041	m2	1	ha
Floor height / Combined height	2	m	30	m
Division of area				
Number of silos	8			
Footprint per silo	1.255	m2		
Silo radius	20	m		

Organic residue				
Yearly	700.000	tonnes		
Monthly	13.462	tonnes		
Black Soldier Fly Larvae feed				
Monthly feed per m2	450	kg		
Needed residue	67.777.778	kg	6.778	tonnes
Ratio between larvae / residue	2	times more residue		
Input and output				
Monthly each silo produces	3.813	tonnes protein		
Monthly each silo consumes	5.909	tonnes residue		
Combined				
Protein	30.500	tonnes protein		
Residue	47.275	tonnes residue		
Transport				
Truck capacity	25	tonnes		
Daily residue transport	63	trucks		
Daily protein transport	41	trucks		
Per hour	4	trucks		
During work hours	9	trucks		

Calculations of the area of BSFL needed to provide the wanted amount of protein used in Danish agriculture. Data used to calculate soybean area, (Aske Skovmand Bosselmann, 2014 : 3-4). Data used for calculation of BSFL area, (BSF Farming, 2016). Data used in calculations of organic waste generated in Denmark, (Miljøstyrelsen, 2014/2015 : 27)

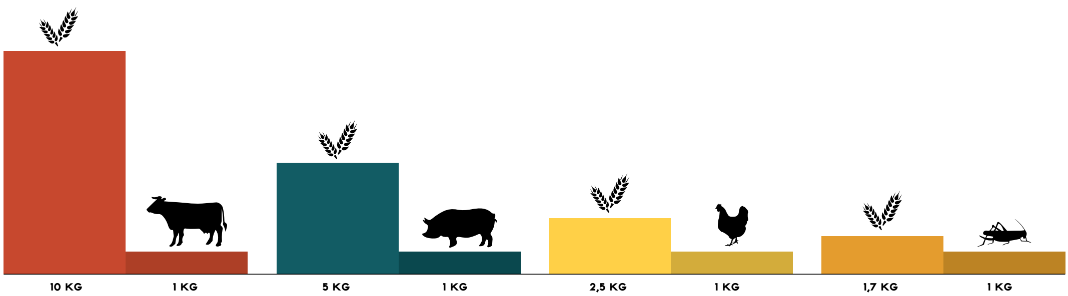
Appendix D - Soybean area outside Denmark

Denmark							
43.094	km2	4.309.400	ha				
Argentina				Amount of times the country is	If the soybeanfield were located in Denmark		
2.780.000	km2	278.000.000	ha	bigger than Denmark	it would consume % of the combined land area		
Soybean area				65 times	7,1 %	307.606	ha
3.076	km2	307.606	ha				
				Amount of times the country is	If the soybeanfield were located in Denmark		
Brazil				bigger than Denmark	it would consume % of the combined land area		
8.516.000	km2	851.600.000	ha	198 times	3,0 %	129.438	ha
Soybean area							
1.294	km2	129.438	ha				
				Amount of times the country is	If the soybeanfield were located in Denmark		
USA				bigger than Denmark	it would consume % of the combined land area		
9.857.000	km2	985.700.000	ha	229 times	2,2 %	95.731	ha
Soybean area							
957	km2	95.731	ha				
Andre lande							
177	km2	17.721	ha				
					If the soybeanfield were located in Denmark		
Combined area used					it would consume % of the combined land area		
5.505	km2	550.496	ha		12,8 %	550.496	ha

Calculations of soybean field areas of the countries, from which Denmark import. Showing the areas size if situated within Denmark. The data used for the calculations are from, (Aske Skovmand Bosselmann, 2014 : 2-4).

Appendix E - Interesting facts

Diagrammatic visualization of data regarding edible per centage of different livestock and a locust. Data provided from, (Arnold van Huis, 2013 : 62) Own diagram inspired from diagram in the report.



Diagrammatic visualization of data regarding the needed amount of raw grain to produce a kg of different types of livestock and a kg locust. Data provided from, (Arnold van Huis, 2013 : 60) Own diagram