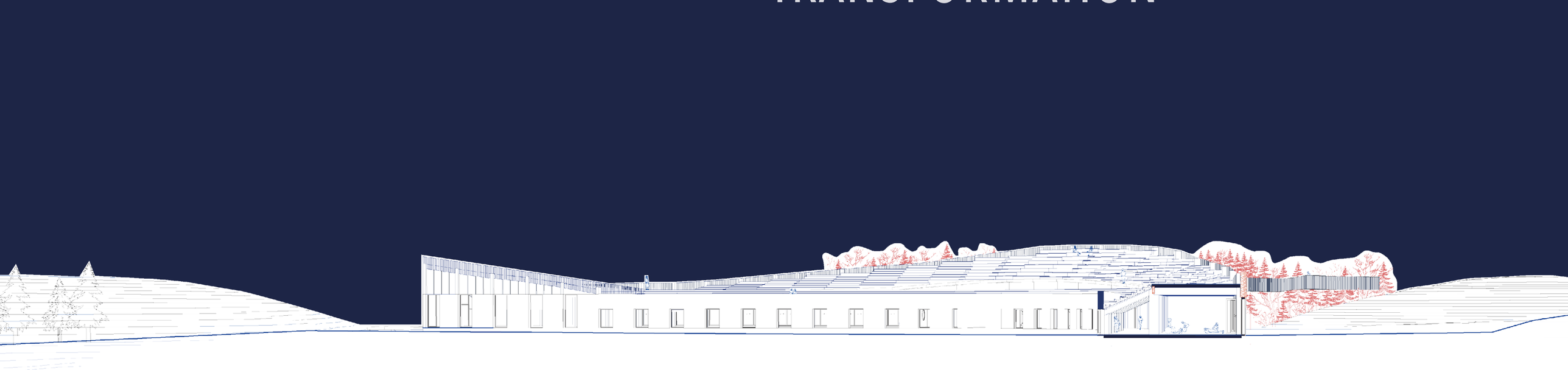
SUSTAINABILITY IN OUTDOORS SPORT ARCHITECTURE

Granåsen ski center, a cultivating TRANSFORMATION



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ABSTRACT

In today's world where the construction sector represents the major part of the greenhouse-effect gas on our planet, it is more than urgent to accelerate the movement towards a better sustainable transition. Progress having already been made in the architectural field, they remind a minority compared to the extent of the task to be solved. It is true that, 40% of the CO^2 emissions released in the world come from the building sector, while many of the materials used are not renewable or even sold out.
Changes have started in the field of construction since few years now, but some types of architecture are more neglected than others in this development, in particular outdoor sports architecture. Indeed, sports complexes have not yet rethought from a more sustainable angle, although they are often imposing buildings and the challenge is only the more interesting to take up.
Today, challenges are not only in the process for constructing buildings but also in the way in which they are used. It is even more positive to take up new environmental issues when user demand is strong and the project is in total connection with the natural environment.
In this project is developed a reorganization of the sports site of Granåsen, in Trondheim, in the most suitable way for the environment. A large-scale assembly reconfigures the means of transport of users and their use of the site. Attraction, access and an enriched experience of the place are the sought key to a successful environmental transition, in a reputed outside sport center.

To our beloved teacher, Per Monsen left too early, whose teamwork with Tommy Kleiven was a pleasure and a great help in the development of my project.

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INTRODUCTION

Winter sport and outdoor activities are deeply linked with the norwegian culture. Nature is never far from home and the wildlife is easily accessible. Most of the nature is untouched but humans always model the landscape at their convenience; ski tracks are groomed, hiking path are marking the ground, and surroundings of lakes are structured. In an outside sport arena, it is as common to have inside sport infrastructure as outside arrangement, because the outdoor attraction is relevant all year long. Granåsen ski center, in Trondheim, is a perfect repesentation of popular outside facilities for inhabitants. It is a common meeting point for families, groups of friends and ponctuals athletes.
Covering an area of around forty hectares, the site is the center of winter sports development for the city. It is also representative of the city size in sport levels, while big equipment are located where the need is. Furthermore, It has a really symbolic visual aspect to have a ski jump that sit on the hill of a land. It shows the serious engagment in sports that have the place and its fame in the field.

A sports architectural approach is developed in this work, with the lowest possible environmental impact. Sustainability in a sport area is not only about having a smart architecture, it is also about how user live the site and their fluctuation there. Users are the main factor in site changes, which greatly affects the needs on transportation. As demand is still growing for the development of such a large place, new activities structure are implanted there with a flexible consciousness. Maximizing adaptability and respect to close environment, allows to prepare amenities that will probably be affected in the future by global warming. A long life cycle of the building on site is one of the environmental objectives to be achieved.

THE SCOPE

The scope of this thesis is to rehabilitate and create a social sports space, where the user is the focus. The visitors being the main consumption source of the place, an approach of changes in consumption patterns is visited through the transportation. In order to considerably reduce carbon emissions and to propose new architectural contributions, a balance of zero positive emissions is defined as an objective. A motivating argument is developed, for users to see a real result of their change in transport choice : «consuming less energy to improve the quality of architectural infrastructure».
This new architectural contribution aims to revitalize the site and serve as a visual example and experience, that claim the importance of changing our way of consuming and the concrete impact that this provides.
Reducing gas emission, changing habits and providing better architectural means is an ecosystem for successfully developing the sustainable sporting infrastructure of Granåsen.

PROCESS AND EXPECTATIONS IN THE PROJECT DEVELOPMENT

The option of a project development at this location is from a personnal choice inspired by experiences. As a user myself of Granåsen, I noticed some differents elements that tcould be improved. This guided me throughout my research. I greatly appreciate to be a sport user myself and to be able to experiment with the various need that other migh benefit frm as well. I started my work without knowing exactly what will be the guideline of the project, but based on previous work and personal experience, I had ideas with regards to what might be improved.

In order to get to know the site well, different analyzes were made on its functioning, its frequentation and its flux. As a work at different scales, a first analysis has been made on the climatic conditions and its close natural environment.
Then a sensible focus has been made in the sensitive areas for bogs and fragile grounds. Certain less common elements relating to outdoor sports had to be taken into account in order not to disrupt the sport disciplines, including in particular the wind direction, which are very important for ski jumping.

After reviewing the traffic and bringing in new modes of transport, a focus has been made on the entry point. It is important to clearly define the entrance and the pedestrian circulation of visitors between the facilities. Moreover, it has been sought through the architecture to recreate the totally open stadium which had occasionally existed as for the 1997 World Championships, where the points of view for the public were maximized. This research leads to give as much visibility as possible to visitors, since this matter is sorely lacking. At a smaller scale, is done a more precise development of the interior construction for a new indoor shooting center, in order to complete the activities needs and users comfort.

At the same time, new circulation development of the area was carried out as well as the search for the location of the new structure. It is primary to use on a first stage qualitative ressources available on site. A sustainable work in a place of such a magnitude is to reuse the existing buildings and the material as much as possible. The Toppidrettsenter and the new cross-country building are both qualitative constructions which can be improved by making their functions more complementary. Adding more space by linking the existing buildings allow to take profit of them, to extend the usable area, and to connect the element together.

After having clearly determined the stakes of the construction, its program and its location, the materials used have been carefully thought out in order to make the most of what the site gives.
The research on the tribunes orientation and a maximized viewing angle are being considered. As well as a potential for PV has not been excluded on the tribunes and the roof of the Toppridrettsenter, because they benefit on a well exposed south orientation and a large area of potential implantation.

The Life Cycle Assessment of yearly transportation from the site is calculated while the analysis of transportation leed to determine the new transport strategy. Secondly, is calculated LCA from the materials of the new construction to determine the best options and to compare the proportion of both of the gaz emission domain. Part of the sources from the site analysis and the number of energy consumption on site for the LCA are taken from recent report. Indeed, an actual project ongoing in Granåsen is developed by Trondheim Kommune. Other project stakeholders such as Rambøll and PIR2 architects provide a lot of information in their report: « *Granåsen som nullutslippsområde* » and « *Grønne-ambisjoner-Granåsen*».

It is expected that an important save of CO2 emissions is made with a new transportation strategy and a carfully use of the site architecture. Yearly average consumption gives an overview of this change and a longer time period is developed in two phases in order to estimate over a period of 60 years the consumption gap, as it is the estimated time of life-cycle for materials. To be closer to reality in relation to changes in demand and techniques, the two different phases have been splitted in two intervals of twenty years each.

The long time period overview of the site emissions is supposed to highlight the changes. It is hoped that the site's total gas emissions is decreasing by a change of transportation by users. Furthermore, it is expected that CO^2 emissions from new construction are only minor compared to total emissions of the site over a long period, including the new transportation system.

DEVELOPMENT OF SUSTAINABILITY IN SPORT ARCHITECTURE

As of today there are almost no sport arenas, especially about outside sport, that are taking into account sustainability in the construction process. Most of the time if it is, the focus is on the emissions of the constructions itself and not on the site organisation functioning.
Even though it is becoming over common to have sustainability in sport complex, the cases remain rare and is often about small scales project. Whereas, conversely, more and more large-scale events are being developed and do not follow any model in terms of environmental construction solutions.
In our imaginery, the ultimate example in sports architecture are Olympic Games, whether winter or summer, their moral and environmental construction process is almost always catastrophic in terms of gas emissions and respect for the environment and local materials. All recent and ongoing examples are in that case (Sotchi, Rio de Janeiro, etc) . However, as consciousness evolves on environmental matters, some host cities are starting to take on new environmental challenges, as for example Paris 2024. It will be interesting to see the outcome of the Paris 2024 Olympic Games from an environmental point of view.

However good examples have existed in the past, as in norway for the olympic games in Lillehammer in 1994. They were indeed renowned for their respect of the environment and their durability, since the installations still have a very good use today. This model, however, was probably not reproduced in terms of costs in other host countries.

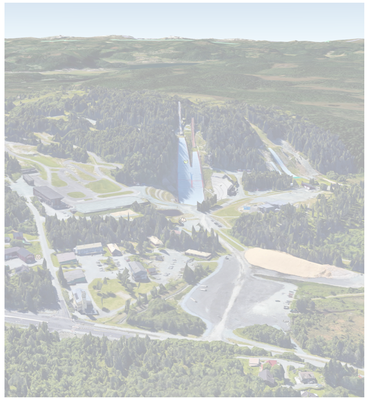
The aspects put forward here are only general to what we know of important events of this type. The scale of Granåsen ambitions is actually smaller, even if there is a development potential. It is reminiscent that the venues of olympic games are often split at several location.
 There is therefore a potential for Granåsen and the region of Trøndelag to be a host site in the future, which could also be a fine international example of sustainable development in the field of sport.

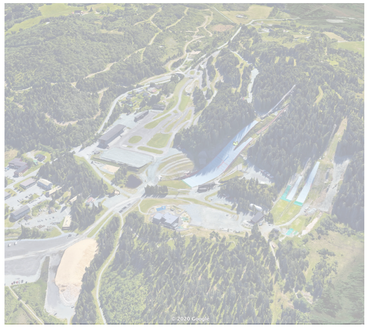
GRANÅSEN TODAY

Located at 7km from Trondheim's city center, Granåsen ski center is the main outside sports structure of the region. At the edge of Bymarka and the Byasen district, the site is an ideal gateway to nature and for the practice of outdoor sports. Cross-country skiing is the most popular activity here but the arena has several facilities an it is well attended in summer too. The most imposing structure are the ski jumps, which are among the best facilities in Norway.
Surrounded by a hill, the site has natural barriers. The ski jumps take advantage of this slope, and the drop in altitude is a good challenge for the difficulty level of the ski tracks.
However, the place is connected with its surrounding. Many hiking paths in the forest give access to the close lakes, and to other often frequented places. The Lian tram stop is close, 3km away, and the Mitbyen ski stadium 500 meters away.
observing the site in close proximity, provide the feeling of being in the middle of nature itself. However, looking a little more broadly, Granåsen is close to schools and neighborhoods, in an area where sport is indeed present.

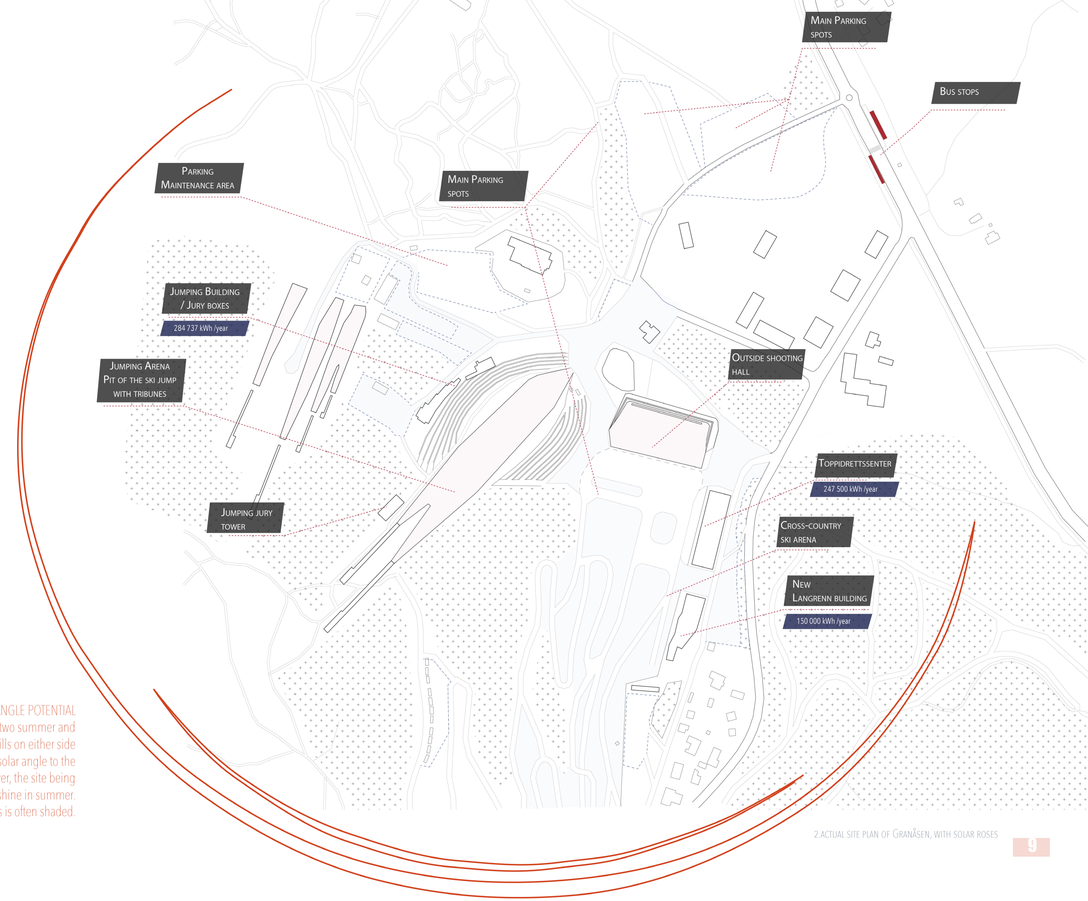
Access to the site is mainly by road, via the use of the car. Some people get around the site by bus, by bike or on foot, while others get there by ski or hiking trails. Yet, it is obvious by visiting the site now, that cars are omnipresent. Moreover, there is a clear difference in priority order between the means of transport. Motorists have access everywhere and it is very easy to get around by car at the foot of the tracks.

Different type of buildings are present at the site. Their disparity due to different arrangements and period of time, prevents uniformity on site. The few buildings are arranged like singular blocks and do not have any external connections for the public between them. Not to mention that many of their functions are duplicated. In addition, few outdoor spaces are arranged to be used by everyone. As a user other than athletes and people working in buildings, there are very few spaces and activities for simple visitors, families, and school groups. However, the space is free to be used for any type of activity without special arrangements. Its large space is advantageous for the city, due to the site ability to accomodate the public in complete safety, as well as being closeto the centrum of Trondheim. There is also a symbolic dimension here, as it represents one of the best sporting levels in Norway and the locals are very proud of it.





1 AERIAL PHOTOS OF GRANÅSEN FROM GOOGLE EARTH



SOLAR ANGLE POTENTIAL
The red axes represent the two summer and winter solstices. The two hills on either side of the ski arena reduce the solar angle to the ground in winter. However, the site being open, it enjoys good sunshine in summer. Only the hill of the ski jumps is often shaded.

2 ACTUAL SITE PLAN OF GRANÅSEN, WITH SOLAR ROSES

HISTORY OF GRANÅSEN

The Granåse arena has existed for over a century and it reflects the popularity for sports gatherings during winter manifested in Norwegians culture well. It has evolved to became bigger and bigger with time as well as more technical, while the sport technique is evolving.
Starting with a simple ski jump following the hill of Granåsen, the area is now occupied by a biathlon shooting range, ski tracks and five ski jumps.
The enthusiasm for sport here gained in popularit. By its conditions, Trondheim became one of the most important location for nordic skiing activities.

For several years and continuing the tradition, Granåsen ski center is annualy hosting one of the many international races in the winters worldcups. The arena thus serves as the location of famously awaited event for athletes, sport spectateur and viewer.

3. Granåsen during the Nordic skiing WorldCup in 1997

Built in 1940, it has seen its sport infrastructure evolving. Indeed differents ski jumps have been changed and transformed over time, following the evolution of the sport. Few years after its conception, cross country tracks were officially part of the site and we can say that Granåsen then definitly became a winter sport centere.

Since the place got developed, the area became a very popular sport location of winter competitions and outdoor shared moments. Nowadays, there are events happening every weeks : ski competitions, ski club manifestation, rock concerts and large WorldCup-events to mention a few. All types of visitors are represented there and their flow is very variable.
However the site reached a peak in the 1990s when work was carried out to host the 1997 World Cup. These many new developments made the arena state-of-the-art for its time and pushed its fame to the international scale. As seen in pictures, the 1997 WorldCup was incredibly popular and it was the first time that such a large number of spectators gathered on the site. All the landscape has been used as tribunes, to the point that we can no longer guess the setted tribunes and the hill. At that time there were no facilities built around the tracks and we can see that this made the site naturally free of its development, as its layout during the World Cup is reminiscent of the imposing and efficient Roman amphitheater.

4. Success of the WorldCup in 1997

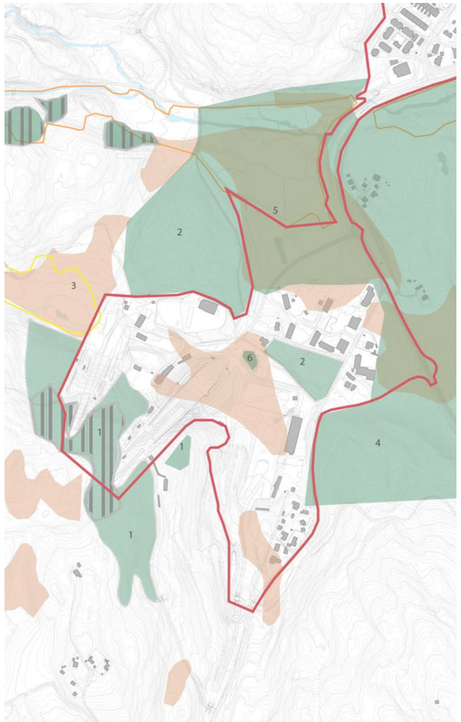
However sports have evolved and so have their facilities. New structures and buildings have been deployed around 2010 to develop more of biathlon and the sport research. Offices, research lab and athletes center complete the program and make the site a winter sports headquarters in central Norway.
Nowadays, even if major events such as the Worldcup are occasionally very successful, the site has no particular appeal apart from its events. In fact, in days of weeks, visitors are mainly passing skiers, athletes in training, people working in the maintenance of the site or even schools groups. There is no demand from tourists for example to come and visit this place. It is therefore necessary to make the arena an attractive place whose image reflects international fame, as Oslo has done with Holmenkollen. The case of the most important nordic center in Norway is a really relevant example for Granåsen, since its image equals its fame, and its transformation is quite innovative in terms of outdoor sport. Indeed, the specific architecture of the ski jump as well as the numerous installations created in Holmenkollen made it famous and developed its fame in a considerable way.
Today, it is no longer just a sports arena but it is a place that we visit, winter sports enthusiast or not.

5. *Hoppbakken*, 1953, crowd of people following a ski jump competition in Granåsen

THE SITE

A.CLIMATE AND BIODIVERSITY

On a plateau in between two hills the site is provided by slopes and flat terrain, the valley is oriented on the North-south axes and is relatively well oriented with regards to solar exposure.
Most of the area is protected from the wind due to the hill, although the cross-country stadium is to some extend more exposed with a north-south wind tunnel orientation. Nevertheless, even if the sun is low in winter, most of the arena is enjoying sun exposure everyday of the year, while the ski jumps facing north received the least amount of sun exposuret. This combination of an open view and a valuable sun orientation makes the ski arena pleasant.
As of now, nature is still dominant in Granåsen, and the terrain need to be flexible to some constraint, like humidity and bog. Granåsen is in fact surrounded by wetland and bog with a fragile environment. The abundant rain in Trondheim as well as the humid environment have an impact on the distribution and regulation of water on the ground and around the buildings. As well as most of the summer tracks and roads are permeable due to the use of tar. Ground impact is a main concern about this site, as well as the preservation of its existing flora and fauna. The developed wild environment around the sport stadium should stay preserved in the future.



6.NATURE AND ENVIRONMENT , SITE ANALYSIS FROM PIR2

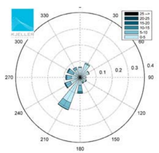
B.CONTRADICTORY SYSTEM

While it may seem like outside winter sport are an activity respectful for the environment, human impact and actions often tend to modify the natural environmental cycle. Indeed artificial lighting is nee-ding in order to light the tracks and ski jump, so that tracks can be used during winter time. Also, machines are preparing the site and transforming the snow, and the most contradictory one is the snow that is removed and stocked outside under 1m of wood chips. A lot of energy is spent for snow production and conservation. The wild and natural part of the sport tend to be more controlled by humans hand, while climate change evolved.

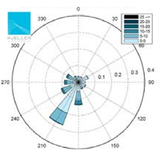
C HOW TO RESPECT THE SITE

It is important for a wild site like Granåsen, that constructions are not polluting flora and fauna. The site remain calm and without traffic most of the time during the year. Nevertheless the decrease of transportation by cars, and the new roads access pollutes less directly in carbon emissions and noises its area. Even though ponctual events are terrible in terms of sounds pollutions, however they remain rare.

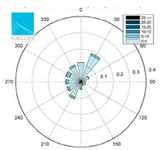
With high humidity rates, water evacuation from should stay as permeable as possible, to avoid overwater effect and to not disturb the bog cycle on the site.
Solutions like new grounds amenagement can be changed for permeable coating and tar roads can be avoided.



Long term wind rose at 10m height



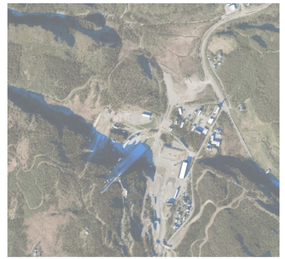
Long term wind rose for winter (dec-feb) at 10m height



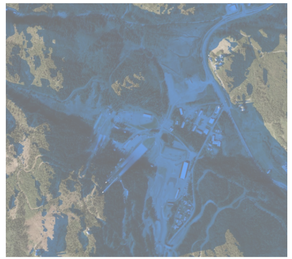
Long term wind rose for summer (june-aug) at 10m height

7.WIND LOCAL ANYLISIS OF THE SITE

Granåsen, 23th March



At 12:00



At 15:00

At 15:00

At 18:00

Granåsen, 23th June

8.SHADOWS INCIDENCE ACCORDING TO THE SEASONS

CIRCULATIONS

A. TODAY

Granåsen is accessed by a main road (Kongsvegen) that pass by near the site. A little behind from it, are the actual sport structure. To connect the site from the road, to parallel roads are emerging from Kongsvegen and give a direct access to the ski jump and the Topidrettssenter. Everything is accessible by car and all the empty spaces near buildings and tracks are used as parking. Pedestrians and bikers do not have advantageous access, as well as the bus stop is by the main road and at 300m of the heart of the arena. However a large parking lot is taking space on the bog and is located near by the ski track. During important events including big crowds, the situation is not preferable due to this prioritization, where the cars are occupying a significant part and are contraining all the area due to their redundant number.
More than improving considerably its use, transportation are by far the main emissions on the site. Gradually approaching a future where cars are not as extensively used, it is of great importance to change the use of area alongside with the change of habits.

B. TOMORROW

As cars are to be decreasing in proportion of use, roads are not accurate anymore and circulation can be completely revised. The heart of the site becomes occupied by pedestrians, while the cars are placed in the periphery by the road reported to the extremity of the area, by the road. Areas of parking and circulations dedicated to cars are considerably reduced and more flexible so they can be reused for other purposes when cars will be called to disappear. Public transportation will then become the most appropriate type of transportation and tramway the main solution. It is indeed consuming twenty times less CO^2 emissions compared to cars. As Trondheim was grided by a tramway network in the past, the line from Lian will be prolongated to continue the experience by Granåsen and distribute a direct access from the city center. By order of priority, access that can't be made by bike or walk will be given by a large tramway mobility. Likewise, pedestrian and biking path would be improved and more connected to the heart of the arena. Further, the bus stop will be localized closer to the main site and a drop-off will take place not far from it. Finally, away from the heart of the site, will be located a smaller parking by the road.

ACTUAL
SITE OCCUPATION

FUTURE
SITE OCCUPATION

CAR TRAFFIC AND OCCUPATION

BUS AXES AND BUS STOP

PEDESTRIAN / BIKERS' TRACK AND OCCUPATION

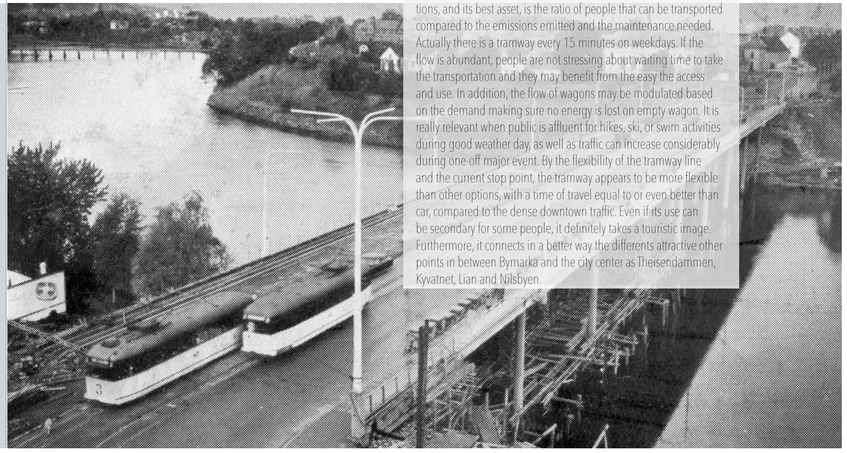
9. Circulations schemes

New tramway line

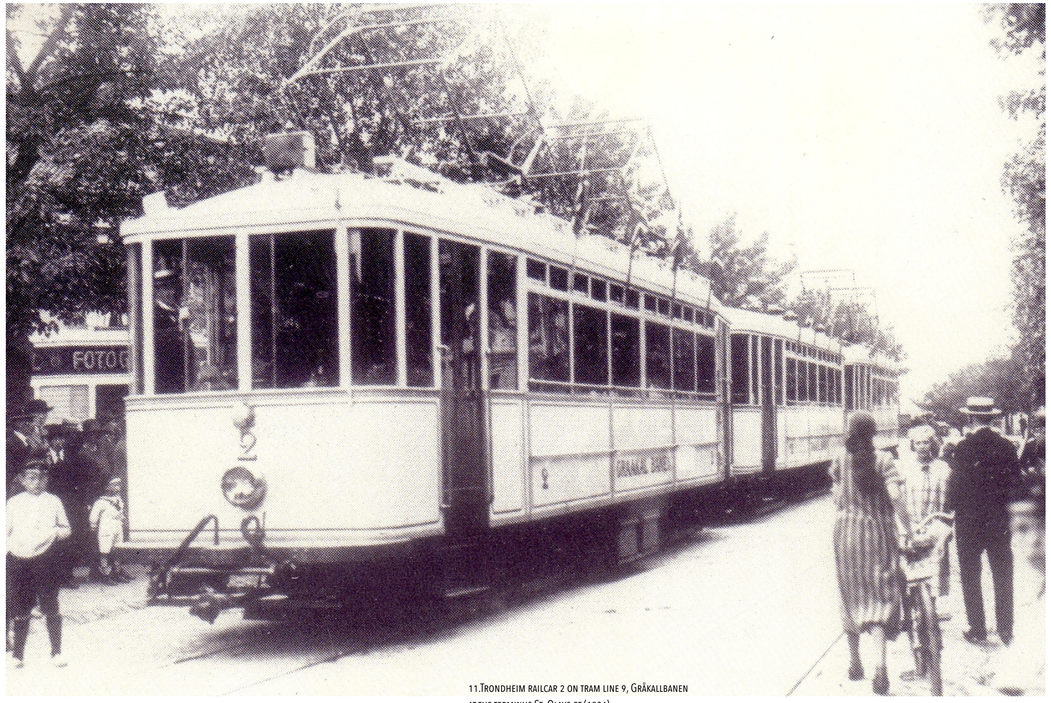
TRAMWAY HISTORY IN TRONDHEIM

C.TRAMWAY

Trondheim's history is linked with the tramway for more than a century now. While the actual Lian line is the most septentrional tram line in the world, we can see that there is a proof of robustness in this installation. Back in the time the tramway was the most common way of transportation in town before buses took the advantage. Many of the bus lines in use are placed along the main axes of the previous tramway circuits. Indeed, the city center was connected to the south of the town, to Bymarka, to Estenstadmarka, and to Lade coast. But for diverse reason in the time (political change, new technologies of transport, demand from users, accidents, etc.) the tramway progressively desppeared for the benefit of cars and buses. Individual transport became increasingly more popular from the 1960's, and buses were more flexible in the road with cars than the tramway line was. Although, as user habits change, the car is pushed to desappear progressively. Buses are well used now by inhabitants, however by looking at Lian line's, it is a line successfully used. Furthermore, some people use the tramway as another experience of traveling. Especially when you get the opportunity to have viewpoints over the city and the fjord. It is a safe and silent transport even in hard climate conditions, and its best asset, is the ratio of people that can be transported compared to the emissions emitted and the maintenance needed. Actually there is a tramway every 15 minutes on weekdays. If the flow is abundant, people are not stressing about waiting time to take the transportation and they may benefit from the easy the access and use. In addition, the flow of wagons may be modulated based on the demand making sure no energy is lost on empty wagon. It is really relevant when public is affluent for hikes, ski, or swim activities during good weather day, as well as traffic can increase considerably during one-off major event. By the flexibility of the tramway line and the current stop point, the tramway appears to be more flexible than other options, with a time of travel equal to or even better than car, compared to the dense downtown traffic. Even if its use can be secondary for some people, it definitely takes a touristic image. Furthermore, it connects in a better way the differents attractive other points in between Bymarka and the city center as Theisendammen, Kyvatnet, Lian and Nilsbyen.



10. Tramways in 1951, Elgeseter bridge



11.Trondheim railcar 2 on tram line 9, Gråkallbanen at the terminus St. Olavs gt (1924)

AN UTOPIST IDEA

TRANSPORTS CHANGE

The idea of transport change is to loose some daily individual habits of today, to gain in mutual sport and life quality through architecture solution. One of the goals of this project is to help people understand what they may profit from changing patterns of action for better solutions. Creating a new experience of transportation and showing how better services could be implemented, can make people forsake cars use and change their individual consumption.

Switching the user habits might seem ambitious, but most of people are open and conscious of the necissity to diminue their personal consumption. Often, changes are roughly accepted at first, but it is necessary to push inhabitants into transition to make changes appear. Although most of the time a lot of criticism follows in the early stages of transformations, they decrease and are very well accepted over time when the change is successful.
Imposin a new system to people is often hard to implement at its beginning. Therefore changing habits on an even larger scale, gives the hope of seeing over satisfactory results on the reduction of carbon emissions, as well as a collective satisfaction and enthusiasm.
Here the transition is driven by the attraction of new means of transport. Indeed, we can see several advantages to these new developments of which the tram is at the heart.
At first, the tramway line is showing other landscapes very close to Bymarka, and the city is well showcased as well. In addition, the vintage and retro aspect is not to be neglected given that the tramway is considered a real tourist attraction in itself. Finally, its layout allows to connect Granåsen to the other attractive strong points of skiing and outdoor activities of the city, as Lian, Mitbyen or Kyvatnet and Teisendammen. It is important to consider the site through its connections to the surrounding environment, and not as an outdoor and enclosed amusement park.

However, the end point of this project is mainly to improve the site in its architectural layout. This is why there must be a coherent link between the efforts made by users to reduce their emissions, and what is given to them in return.

To make this transition successful and possible, it is established accessible stages of change, which is why this transition will be completed over a period of forty years.

12. Extended tramways line of Trondheim

development of traffic and of the site, as well as an immediate reduction of the space set aside for the car. The tram is now becoming the site's main transport, although its use will gradually gain in popularity since intensive use of the car cannot be replaced overnight.

The second phase is gradually established from 2040 when it is conceived that the use of the car is only a distant memory and an old obsolete habit. Public transport has once again become THE usual means of transport. It promises a fast and efficient way of transport in a city that is much more populated than before. In addition, the development of the city on the surrounding land and climate change, promotes soft mobility, as pedestrians and cyclists flows.
It is afforded to have a view extended to 2080 with this system but there will be a time when it will itself become obsolete and new technologies and user demands will have implanted a new system.

LINE *SENTRUM - GRANASEN*

The extension of the line from Lian extends by 3.4 km in the forest roads the rack. It passes near Haukvatnet, joins a direct access from the start of the mitbyen tracks and continues to Granåsen while respecting not to cross peat bogs and protected areas. Its line can be extended to form a loop along the Nidelva river, before reaching the city center. Other future lines (yellow) are to be redeveloped and revive the Trondheim tram network as an alternative to the car.

THE GOAL OF THE PROJECT

Indeed, Granåsen needs a new architecture for users up to the scale of his fame. Nevertheless as a sustainable program, it is needed to reuse as much as possible from the existing and to be smart on the way of adding new programs. By looking at the main CO^2 emission on the existing site life, transport appears to be from far the main polluter of the site. In the long term, obviously reducing general CO^2 emission from the site is a main goal. The new architecture that make the site completely relevant for its users is almost considered as free of CO^2 emission, and contribute to reduction on the long term environmental impact.
As an experimental approach of sustainability in sport, this project wants to take profit of the large pubic to instruct visitor at different scale about sustainability.

A. The experience

Most of all the project exist because user needs has to be improved and expended. However, this playground can became an environmental respectful example and an harmonious public space. Vernacular architecture, local materials and good use of the construction give a better understanding of the solutions.

B. A referense

If public see in terms of size the amount of CO^2 emission they spend every year in transportation, a relevant understanding of their own consumption help them to understanding the CO^2 emission challenges. If for example, it could be allowed to declare that new builded part on the site are free of gas emission, it can be explain because it correspond to what can be save by using the tramway and change transports habits. A concrete reference of this quantity makes the experience even more realistic.

C. Deep Education

By informing the public, people understand that everything is linked in terms of gas emission and that thoughtful actions are the key to reduce emissions. Including new habits in the daily life and a better understanding of the different type of transport, make it possible to reduce CO^2 emissions not only on the site, but also in your daily life at a larger scale.

CROWD OF SPECTATORS

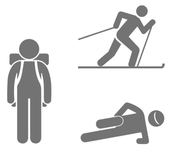
Occasional high crowds during events. The Gateways fluctuate this flow of people. Abondant travel, make dominant car transportation not possible in this case and a solution of public transport is necessary to ensure the movements.

FAMILIES

As a big playground the place is perfect for family's outing, in nature and security. Families are more abondant during weekends and holidays for sport activities and. Teaching ski moment for children often happened in the stadium.

SPORTMAN AND ATHLETES

Granåsen is the entrance to nature and the perfect place for practicing. Athletes and visitors for sport are the more regular type of visitor along the year. The affluence is mostly depending on the seasons and climate conditions.



SPORTS CLUB AND GROUPS

The site is all the year a base and a training camp, well equipped, and available for school groups or ski clubs. It leaves free the regrouping of the teams and their activities. Their attendance is regular during the week, at the rate of training and varying according to the seasons.

REGIONAL, NATIONAL AND INTERNATIONAL COMPETITORS

As the main spot of the region the site is the training place for high level athletes from town but it is also use for training camp by the national team. Sometimes in the year the place became the spot for all international winter competitors.

TOURISTS

Not popular on site actually, a better attractivity of the site should lead them naturality there. Visual attraction and activities discovery are expected.

EMPLOYEES IN GRANÅSEN

Workers in the Olympiatoppen offices, sport coach, sports researcher, doctors, maintenance agent, mechanics.

TIMELINE GOALS

ACTUAL STATEMENT

As of now, the actual context of the site need to be changed. The huge amount of cars and the non adapted circulations systems need to be deeply rethinked. Sport structures require improved changes to correspond to the actual sport criteria for international competitions levels. Since transformation are neccessary in Granåsen, it is a perfect occasion for a deep durable transformation.

2020-2040

The first phase start by the transition of new changes, a time where changes works are applied and evolved before to finally be on point after the new shooting hall is built and the new tram line are operationnal. It is imagined a progressiv habits change of user to adapt to the new transportation system and to make them diminue by themself the use of cars. If the transportation system is efficient, the diminution of gas emissions should be significant in the first years of the transition.

2040 -2060

The second phase is a timeline etsimation of new refurbishment and improving of the actual project after twenty years of use. It is a visual date to marks new evolution in term of transport techniques and habits, as well as maybe a new occupation of the sports program. It is obvious that those changes will apply in the time and not at a precise time date. That is why this last timescale is a representation of an average evolution of the new transportation system as well as the use demand in Granåsen.

LCA
Life Cycle Assessment

The Life Cycle Assessment constitutes the share of gas emissions emitted by the operation of the site and its construction compared to the lifespan of the elements.

In a large and popular site as Granåsen, it is interesting to see the part of visitors in the total CO2 expenditure, compared to the consumption of buildings and the maintenance of the arena. Indeed, today, the operation of the ski center create a significant flow of transport, made almost obligatory since the users need to go to the site. Most of them go on their own transport solution and this mainly by car.

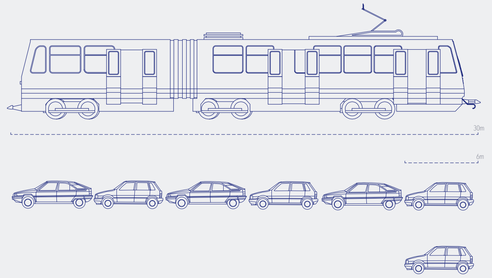
After having identified the main sources of emissions, it has been trying to reduce the environmental impact by focusing mainly on the LCA of the external transportation and the influx of visitors. The calculations were divided into different parts: the actual current traffic in winter and summer, the consumption of buildings on the site, and the emissions due to outdoor activities and their maintenance. Secondly, simulations in two different future periods were made in order to assume the potential of CO^2 reduction from a traffic change patterns in the region. With a phase for the first twenty years as well as a phase for the next twenty following years, we can rationally estimate a gradual, but important, change in transport counsumption.

CAR VS TRAMWAY

The car and the tramway represent to different way of transportation. The main comparaison is their counsumption by passenger, that make the tramway obviously more adapted. Yet, cars traffic is mostly plug in town while the tramway allows a regular and reliable flow. It also saves a lot of floor space and avoid the construction of large parking spot area. Both of transport can be compared for differents relevant reason as the ratio of occupancy and the occupation of road space.

One tramway train like the one used today in Trondheim represents the equivalent of 6 cars in length. Its maximum capacity is 180 people standing against a maximum of 30 people for the same equivalent in a car. The tram journey is then 6 times more efficient than by car transportation. Not to mention that the average car load is 2 people, which makes the car / vs tram ratio even more relevant.

1 Tramway = 6 Cars

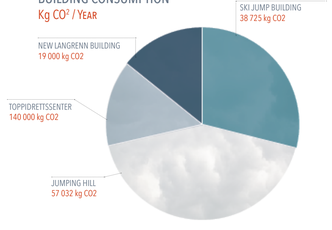


13. Comparaison schemes of transportation

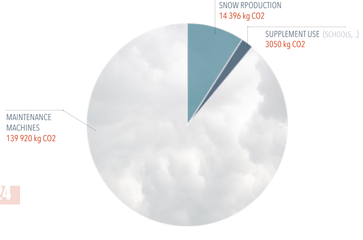
ACTUAL EMISSIONS ON SITE

The building consumption correspond to the quantity of energy (kWh) a building has consumed during the year 2017. This electric consumption is translated here in kgCO2. It is assumed that the electricity used is from the european mixt. However, this impact can decrease if PV panel are implanted on site.
The external use category concern all the outside activities on site that has consumed kWh during the year as : snow production, machines use for maintenance and ski tracks maintenance and lighting of the outside arena.

BUILDING CONSUMPTION
Kg CO^2 / YEAR

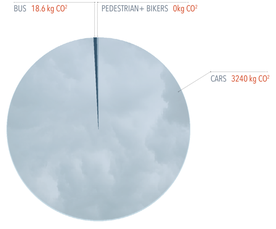


EXTERNAL USE CONSUMPTION
Kg CO^2 / YEAR

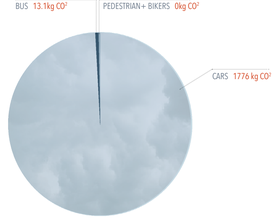


EXTERNAL TRANSPORT

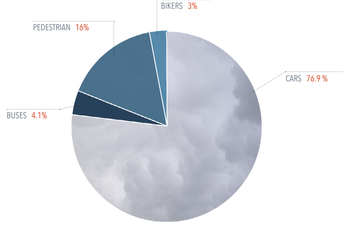
WINTER TRANSPORT
Kg CO^2 / DAY



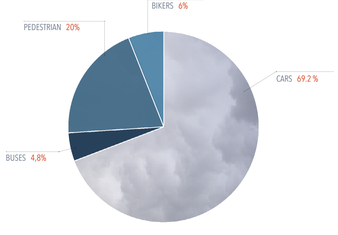
SUMMER TRANSPORT
Kg CO^2 / DAY



WINTER TYPE OF TRANSPORT USE
% / DAY



SUMMER TYPE OF TRANSPORT USE
% / DAY



TOTAL
= 3259 kgCO2 / DAY
= 593 138 kgCO2 / HALF YEAR

TOTAL
= 1790 kgCO2 / DAY
= 325 780 kgCO2 / HALF YEAR

TOTAL
= 918 918 kgCO2 /YEAR

CAR
13.1 kWh/ Passenger / Km
150.0 gCO²

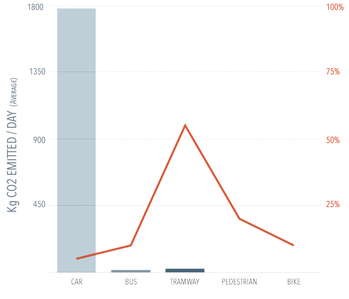
BUS
1.35 kWh/ Passenger / Km
0.016 gCO²

TRAMWAY
0.044 kWh/ Passenger / Km
0.002 gCO²

BIKE (PHYSICAL ENERGY)
0.36 kWh/ User / Km
0 gCO²

PEDESTRIAN (PHYSICAL ENERGY)
0.015 kWh/ Walker / Km
0 gCO²

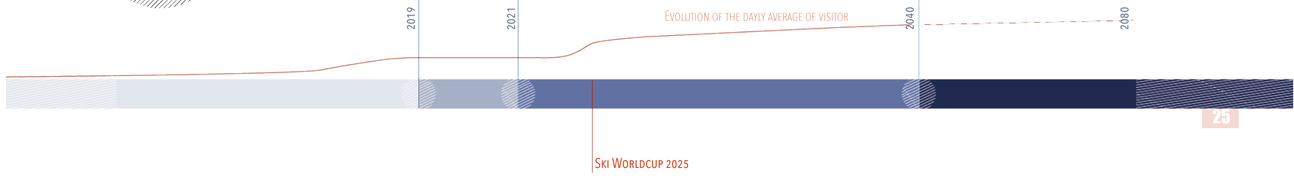
TRANSPORTS goals 2022- 2040



TOTAL
= 1812 kgCO2 / DAY
= 652 320 kgCO2 / YEAR

TRANSPORTS goals 2040 - 2080

TOTAL
= 40 kgCO2 / DAY
= 14 600 kgCO2 / YEAR



PONCTUAL EMISSION PEAKS

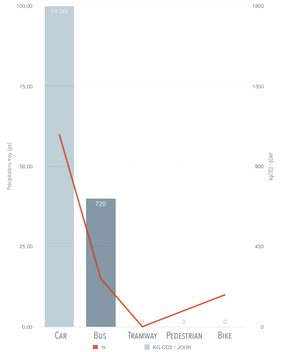
Since the daily gas emissions depend mainly on the influx of visitors, important events make clearly visible peaks in CO2 emissions when a large crowd moves. It was noted that on average, ten days in the year have a peak visit of 40,000 visitors or more, and that about forty days per year have an influx of more than 5,000 visitors. These very significant fluctuations obviously affect the quantity of gas emissions over the year. Occasionnal crowds days obviously show clearly the possibility of CO2 gain from transport and how much we can gain in traffic comfort.

One case is looked at more closely (+ 40,000 daily visitors), by comparing the consumption of CO2 in our three different time periods. Numbers details are described here in the case of +40,000 daily visitors but the readings in the case of an abundance of more than 5,000 people in one day remain proportional to those curves and numbers.

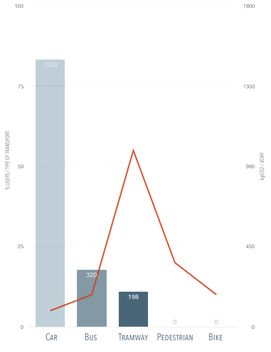
TRAMWAY CONSTRUCTION

To develop the tramway line, the existing line from lian has to be expended to 3.5km of new rails to reach Gran äsen. However , the estimated gas emissions from the new ramline is estimated to 1.7t of CO^2.
The material use are mainly not environmental friendly, but the rails installation benefit of a simple construction. The construction is also durable over time and has a little impact on the environment soil.

+ 40 000 VISITORS

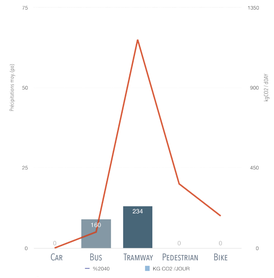


CURRENT TRANSPORT DISTRIBUTION PATTERN



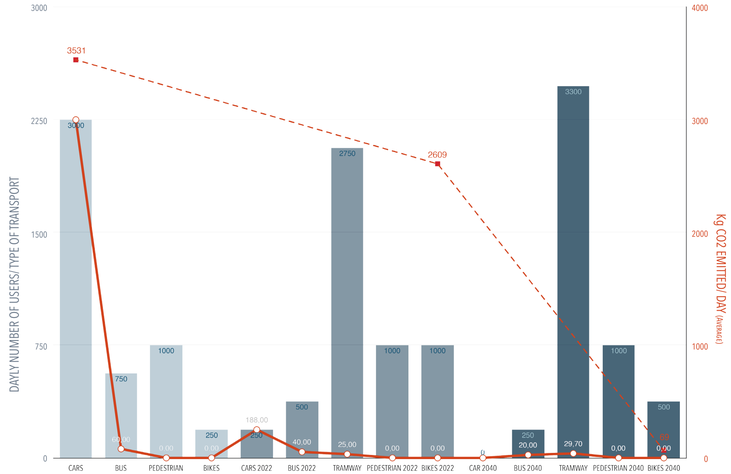
FIRST PHASE TRANSPORT DISTRIBUTION PATTERN

The daily impact of emissions during occasional heavy crowds is considerably reduced between current emissions and their future model.
It is obvious as the tramway transportation become more and more popular, that the total emissions of CO^2 are decreasing.



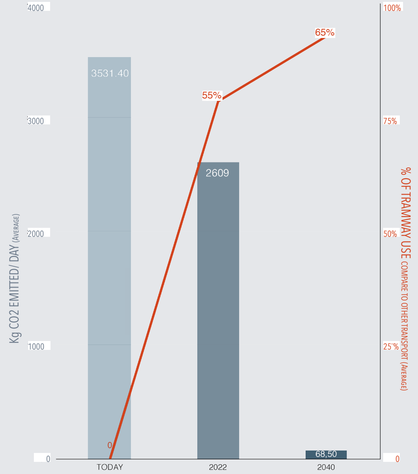
SECOND PHASE TRANSPORT DISTRIBUTION PATTERN

TOTAL EMISSIONS



DISTRIBUTION OF PEOPLE BY TYPES OF TRANSPORT DURING THE 3 DIFFERENTS PHASES
With their CO2 emissions / day / type of transportation

1 692T /YEAR	953T /YEAR	416,6T /YEAR	CO2 EMISSIONS (AVERAGE)



DAYLY CONSUMPTION OF CO^2 BY PHASES
Rise in tramway use / time period

The transportation change show clearly in graph how the use of the tramway cross curve of the dayly CO^2 consumption on site. The total consumption in that case is including the average electricity use of other building on the arena.
Seemingly, the transformation of transport use diminue from fifty times the dayly gas emissions on site, between the actual stage and the second phase.
However the tramway rail construction and its maintenance have to be added in the calculations results, but it remains low since the main traway lines already exist

ARCHITECTURE

PROJECT CONCEPT

HOW TO MAKE THE ARENA GREAT AGAIN?

By implementing new ways of circulating, a new scale of priority is made and the pedestrian became the main actor of the site. In fact, two vertical levels of circulation allow the place to be very fluid during crowds, and the clearly visible gateway are showing the space mainly dedicated to pedestrian visitors. Access to transport is degraded in order of priority, of which the tramway represents the very heart of the site. The surrounding outdoor spaces are fitted out, but remain in a semi-natural state and free for different occupations.
Shortly before the 2010s, a fifty metter shooting range was added to the arena, in order to host official biathlon competitions. However, its orientation in the arena, makes it not very visible for spectators, and deprives the space of very qualitative points of view on the stadium. By moving it against the butt, in front of the existing buildings, it opens the arena and fit naturally between the ski tracks.
A new building is added to the site over the old outside shooting hall, and a connection is made by the continuity of the tribunes from the natural slopes of the site to the new building.
In addition, the location of the new builded tribunes is enhanced by its very beneficial orientation mainly to the west and south, covered by solar exposure.
Then the architectural form is considered with two equally important spaces to be created such as the exterior space and the interior space. They must also be connected to each other, but a natural connection has been made with the nearby environment whose materials, terrain, views on the stadium and the ski jumps have guided the form.

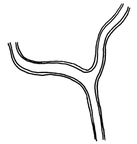
CONCEPT KEY POINTS

The twist

It is referent on the two different sides of the project that are both occupied by people. Indeed, the outside face is used for sitting and enjoying the overview on the arena, and the inner face is where inside sport activities are organised. We can see that the shape of the tribunes is slightly twisting on its extremity, so it let emerge the inner building side. The different hight of the tribunes created by this wawing flow, open the view from the ground on the tram stop to the hill and the ski jump. It also represent how the the site is easily transformable and flexible, to adapt to the various needs and demand of events.

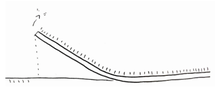
Circulations snake

As circulation are the heart of the project, pedestrian became its motor. It is essential that fluidity of visitor keep the xperience on site always comfortable. The natural shape of the gateway is following without rigidity the architectural form of the tribunes, and is clearly visually distinguishable to facilitate flow and access. An horizontal and vertical connection is created, in order to give access to the tribunes, to the view point but also to the main street on the ground which give access to transport.



Raise the ground

A new hill make the transition between the natural tribunes hill and the constructed and existing tribunes. It allow to get functions under the slope for a new inner shooting hall.



Viewpoint

Optimising the view at the different spot on site has been essential to determine the orientation and the shape of the building. Tribunes procure the main qualitativ spot that overlook the stadium and face the hill. It also create a visual connection up to the ski jump. The inclination of the stands let the gaze always open. Different types of viewpoints impart various experiences as the sitting tribunes, a tilted roof top terrasse, inside openings and variations of hight from the gateways.

14. Project concept schemes

ARCHITECTURAL RESEARCH

EXISTING OUTSIDE SHOOTING HALL

TOPPIDRETTSENTER

The building is a 10 years old sport dedicated place, headquarter of the Olympics Mid-Norway (Olympiatoppen Midt-Norge), as well as the Center For Top Sports Research by NTNU. Medical instute are occuppying a part of the space and the rest of the building is public on the lower floor. A large training hall and a gymnastique hall are used by Trondheims gymnastic club and sport groups.

NEW LANGRENNBYGG

Newly added , it replaces the old building and is very energy efficient. Its occupation is mainly dedicated to competition. Boxes for the jury as well as their work rooms are oriented facing the arena. It is also equiped for groups and has clubs equipments storage spaces. Building is the office for those who work on the site and maintain it, changing rooms and a cafeteria are at their disposal, as well as technical rooms for the machines.

TAKING ADVANTAGE OF THE EXISTING

The mission is to complete what already exist to make it greater. Buildings and structures from different times and uses are occupying the site, while sport techniques are evolving and need adaptable structure. It is necessary that added architecture to the existing is flexible and respect the close environment, so buildings adapts to time and uses.
The visitor are the main life on site and they define the activities and the need. Buildings are mostly dedicated on sport use as well as technical workshop and storage. But there is no architectural space for visitors and common users. Architecture of buildings are really variable and are shaped by the need of each sport. It make the connection in between them really complex.

15. Actual building on site

REFERENCE TO A GREC AMPHITEATER

A REFERENCE TO THE PAST

Back in the day, roman had invented the most efficient and comfortable tribunes stadium that can welcome outside activities. They have a really sensed and practical organization, from vertical to horizontal, where horizontal tribunes make the show visible from every angles. The disposition connect the public by facing each other side. Vertical organization set space for athletes from the ground to the most important visitor on the top of the tribunes.
Nowadays, the Granåsen hill is used in the same way as a natural tribunes, following the shape of the landscape. People were using the slope as view point and sport installation at the very beginning. When the place became attractive, ephemeral structure tribunes where concentrate naturally all along the tracks as the way of an olympic stadium, while people where also taking profit of the hill as tribunes over the stadium.

IMAGE, ATTRACTION, TOURISM

Granåsen is known from inhabitant of Trondheim as well as athletes or interested people in winter sport in Norway. More than that, this little sport valley in between to hills of Bymarka, is known internationally. Indeed, since the arena is welcoming international events, fame and recognition grew to make it famous from international winter sport lovers. Moreover, as football stadium are the recognition of their club and an image for the city that everybody pictures in its head, the winter sport structure are a visual reference point for visitor, athletes and viewer. Many similar references have been done before, and architecture can be the reason of popularity of some area, in a lot of different context (city football stadium, idyllic nature training spot, historical sport spot.. etc).
One of the best example in that case is Hollmenkollen in Oslo. Really notative in sport architecture, the ski jump is the main architectural elements on site while the rest is pretty common to every winter stadium. However, its location on a hill make it really visible from the city center. The beautiful view mixed with its function of ski jump make the site visually attractive for everybody (viewer of winter sports, athletes practicing there, visitor in Oslo, local sport practician). The success is such that the majority of people who comes to the site are visitors, coming to see the ski jump as a curiosity out of any sport event. This symbolic architecture highlights the reputation of the site, and it increases its fame tenfold.

Finally, the public crowd in tribunes is maybe the best facade of Granåsen.

PICTURING THE PLACE DEVELOP ATRACTIVENESS

16. Maximus Circus in Roma, 599 bc.

17. Oslo Holmenkollen, JDS Architects.

18. Granåsen cross-country World Cup, in 2020.

19. Granåsen, Metallica show, in 2019.

20. Granåsen, new site map

21. Ground floor plan

Ground Floor level

Connecting with the existing building, the new tribunes extend the original structure of the Topidrettsenter. The existing training hall, and the changing rooms of the groundfloor level are now connected with the groundfloor amenities of the tribunes building. This part directly linked with the stadium is mainly dedicated to people that are training. The large circulations corridor under the tribunes distribute well the other room boxes. Unheated, it however benefit from a natural heat gain from its south orientation and the storage of the adobe walls. On the other side a coffee above the shooting hall, benefit of an provilegied overview. The double hight of the hall with an apparent structure express a qualitativ architectural feeling. The coffee is ending the twist of the building and has on the highest point under the structure an total overview on the whole stadium and the ski jumps. Above it, a large terrasse complete the tribunes and open a panoramic viewpoint for visitor.
Adobe walls are covering all the south side of the building and have the advantages to insulate and diffuse heat storage in the rooms. More than the esthetical qualities, it also reduce the noise reasoning in the spaces.
On the north side, the main gateway gives a direct acces from the tramway stop to the upper floor where are the tribunes. Gateways are exented to the bus stop and the Spar 1 hytta, through the forest. It dilute the traffic.

Open bathroom for visitors

An easy access to the bathroom for visitors and athletes, is open all the day and free of use. This side give access also to the shop upstair .

Crossing Passage

At the groundfloor level, the tunnel give access from the tramway stop to the center of the stadium. It benefit of daylight from the skylight in the center of the building.

Recovery bath

In the space dedicated to atheltes, a sport recovery spa is used for recovery after training. It contains a sauna, a jacuzzi, and a cold bath.

Changing rooms

To permanent changing room for women and men are available before and after training.

Technical workshop

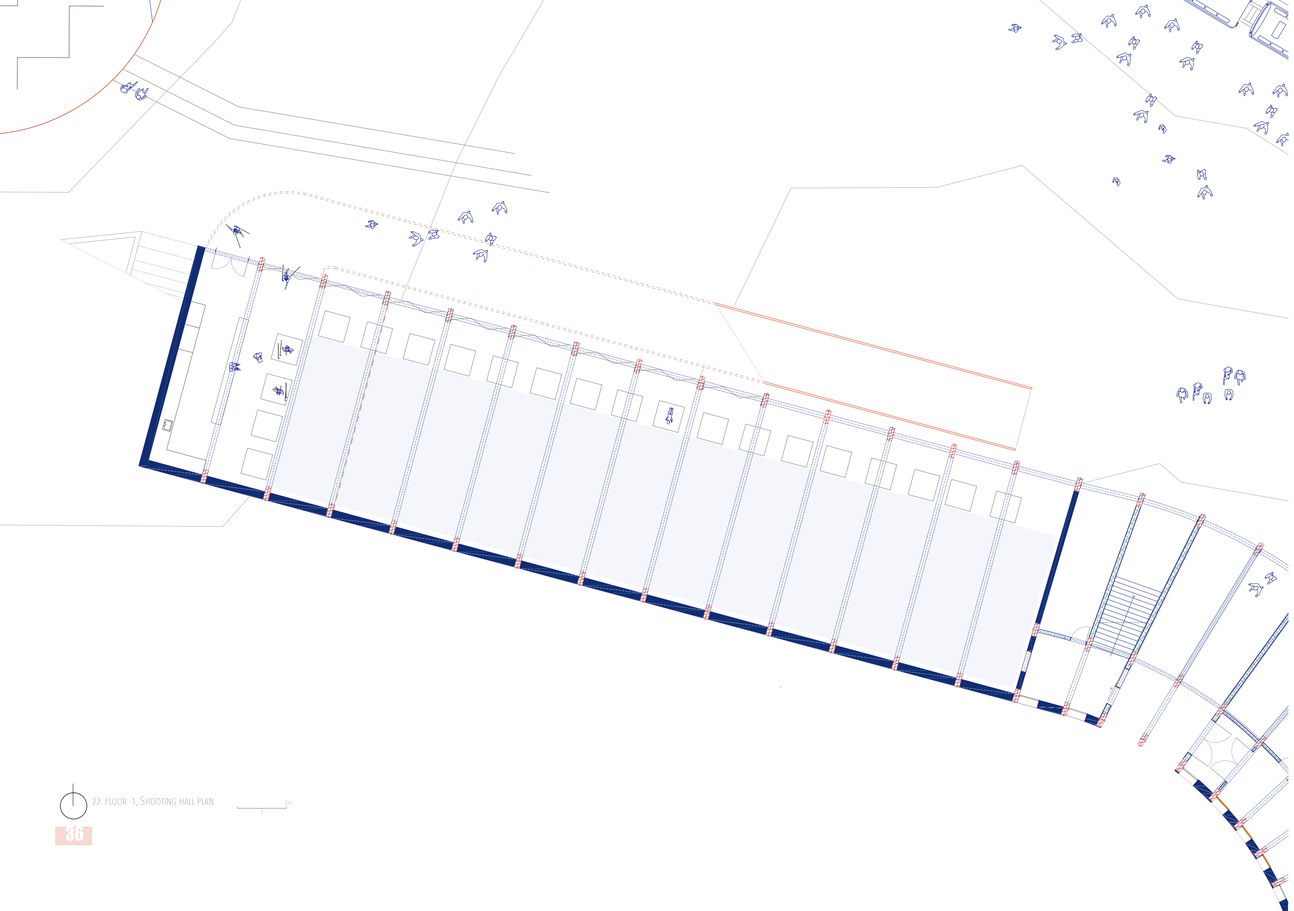
A workshop dedicated to ski and gun maintenance can be use to prepare the equipment.

Cafeteria

Accessible for dayly users, it services can be used during ceremony buffet in the open hall.

Flexible open space

The open hall is free of amenagement because of its open structure. Sliding windows on both side are openable so that it is possible to go accross the space all along the hall.



22. FLOOR -1, SHOOTING HALL PLAN

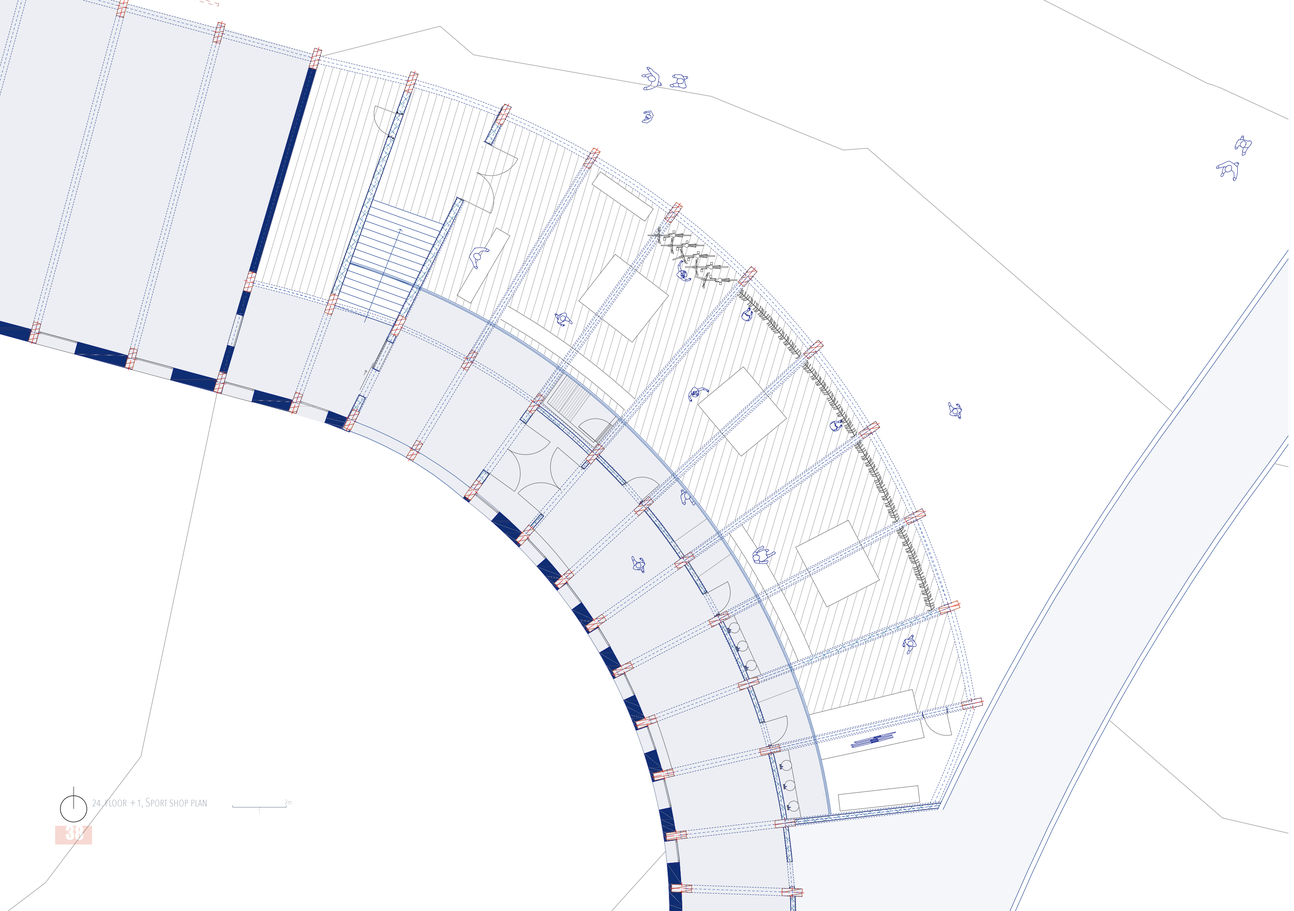
SHOOTING HALL LEVEL

The shooting hall is sixty meters long by fifteen meters large. Half buried, it has direct access on its north side while the south side has windows on the upper part. The double hight of this part make visible the whole twisting structure of the building. Daylight distribution is ensure by the openings on the upper parts, while most of the opening are on the north side. It benefit on a diffuse light and the glare is avoided by a thin texture layer inside, that diffuse uniformly the daylight but allow to see through it the structure of the building. The 50m shooting location is protected of glare and provides perfect shooting conditons because it is located right under the coffee. Ten meters shooters also benefit of qualitativ conditions, because they have the light in their back while shooting. Moreover, the high opening in the room and the lower north facade sliding doors allows natural air crossing ventilation in the room. The airflow getting done on the floor is a good air cleaner to evacuate plumb dust and ventilate the space.

The large openable windows on the north side leave a free way to the hall during summer condition. It connect the space with its outside and allows the biathletes to access inside with rollerski if needed.

However, the inner shooting hall is dedicated to occasional practice in protected shooting conditions, while most of the usual trainig is done outside in the outdoor 50mshooting hall in the stadium. Here the space can be use on both way, long and large, to give the possibility to shoot on to different lengh : 50meters and 10 meters. Experienced biathletes can prac: tice on the longest side while young practician can evolve in groups on the 10meters shooting side. The use of the shooting range obviously cannot be used by both sides at the same time.

Furthermore, the materiality of the adobe walls reduce noise dispersion and diffuse some heat from the exposed walls. The materiality of earth and the wood structure gives the whole room a warm materiality despite the large space.



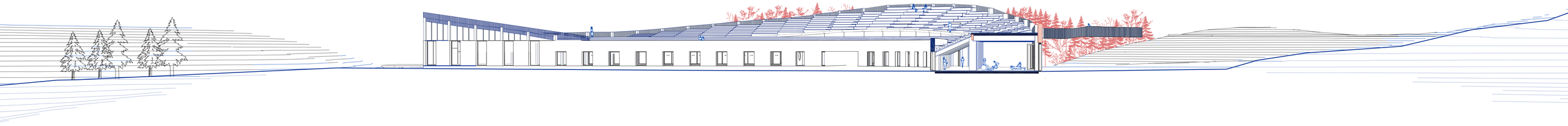
24. FLOOR +1, SPORT SHOP PLAN

SPORT SHOP/RENTAL
SECOND FLOOR

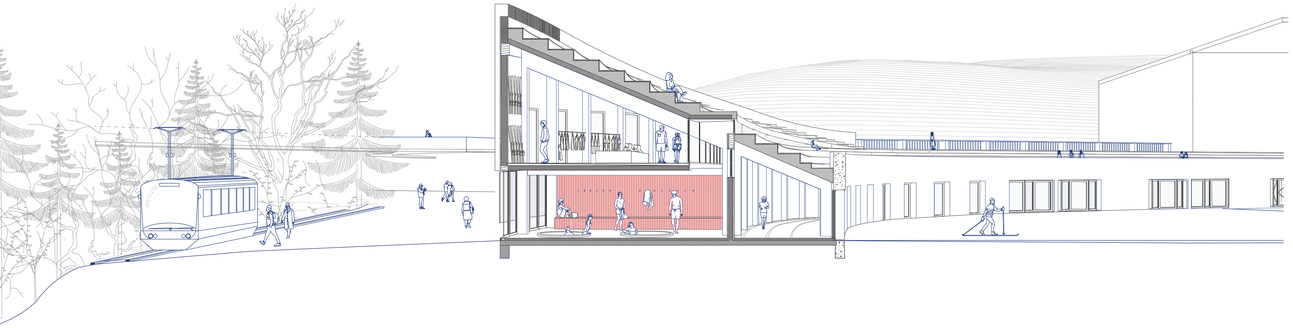
An upper floor is ocated at the turn of the building, under the highest point of the structure carrying the tribunes.

It is accessible by anybody from the lower floor, by the tribunes tunnel.
Today, no materials for sport and rental ski are proposed on the site, while it is not easy to rent ski arround. A practical and a more attractiv solution are proposed to the public here, in a context that fit perfectly a sport store.

Exposed to the north, it benefit of diffuse light by the opening in the wood wall pannel in between the structure. Neverthe-less, the inner opening of the building, let the visitor see at the human hight, a south view towards the stadium. It also let see the circulations corridors on the lower floor, while their is no direct visibility of the rooms under. The vision angle is low and a layer inbetween diffuses the light, and prevents the gaze. Openable north windows and the south inner opening allows cross ventilation over the floor.



25. East - West Section



26.North - South Section

North - South section, showing the tramways stop and the pedestrian area on one side while the other way of the building is facing the center of the arena.Furthermore, the building is passable on both sides, on the first floor level.

PASSIVES STRATEGIES

The architectural willingness is to make the building comfortable to live, along with reaching for low energy consumption. Different approaches have made it possible to make the building architecturally thinked and efficient, through the choice of materials, their uses and the location of the openings and light sources.

The selection of materials according to their contribution to the project, established a range of mainly local materials and on-site ressources. As rammed earth is aboundant and free to use on site, it is use as much as possible in the project. Make the most of the material, ultimately translates to south exposing the adobe walls to benefit from heat storage. Oppositely, it gradually has the opposite effect during the hot summer months. Advantages of adobe construction are that it can be built mostly with the soil of the site. A wooden structure to carry the loads from heavy crowd of spectator gives rythmes to the building. Other constructions elements of the building favor the use of wood as much as possible.

Different strategies have a wise application such as the openings for ventilation in the center of the space. Daylight conditions is maximized and an view relation between the different levels, and the outside and inside space is done. The natural light input in the most used spaces allows to need less electricity in the daylighted season and it give better light conditions inside the shooting range. Furthermore, a south orientation provide good natural heating qualities. The slopes of the tribunes hold also rainwater harvesting along the building. Reused water can serve for the toilet, the workshops and maintenance need .
Moreover, the geology of the land has been preserved as much as possible to avoid major digging work. Indeed, the former location of the shooting range leaves a solid and usable base at the building level. In addition, the new part built is only half-buried at its end since the tribunes are raising on an adobe base, taht makes the view is improved for spectators.

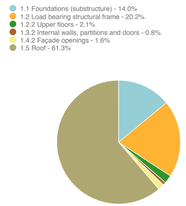
Life Cycle Assesment of the new building

To compare the CO2 emissions impact of the new construction building, an LCA analysis of the materials used makes it possible to situate the impact of emissions on the site, compared to those from transport. The choice of materials for construction is also helped by different combinations of materials, of which LCA gives the environmental impact.
It is interesting to note that the technical and climatic solutions are sometimes prioritized than the gas emissions produced, in the choice of constructions. In this project, is researched a minimum consumption of CO^2 for the materials. Thereby, some options studied can be equal in the final choices even if their environmental impact is very different.

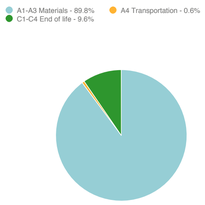
Since the use of materials in construction represent the highest part of CO^2 emissions from the whole constrcution process, the LCA was only calculated for stages A1 to A3 with the EPD sources of the One Click LCA software. This gives an overall idea of the building's environmental impact.

In the selection of materials, preference is given to local materials, and obviously to on site ressources.
Indeed, bog gorund are abundant on site and represents a free and clean resource for construction. Secondly, the significant amount of forest around Trondheim as well as an developed industrialization of wood in the Norwegian culture make its sourcing and its manufacture native. Other sources of elements such as concrete, windows and coverings are preferred near the site.

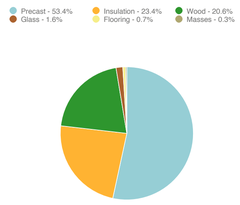
CO^2 EMISSIONS FROM BUILDING MATERIALS



GLOBAL WARMING KG CO2
LIFE-CYCLE STAGES



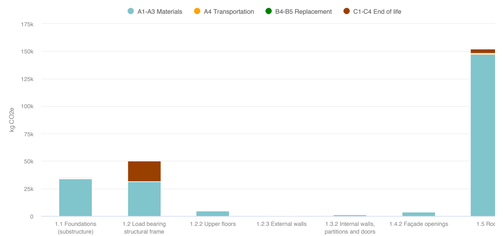
CLASSIFICATIONS
Kg CO^2



RESSOURCES TYPES

The choice establish for the construction of the tribune's building is a balance between greenhouse gas emissions of the materials and their adaptability in that context. The main consern is based on the choice of the floor slab materials and the tribune's slab construction technique. In that case, the choice of a limeconcrete slab floor and a bubble deck concrete slab for the tribunes is made. Indeed, the concrete use for the slab give flexibility and resistance to the project, however its environmental impact is bad and its load result on the structure bearing.

GLOBAL WARMING GROUPED BY LCA STAGES
Kg CO^2



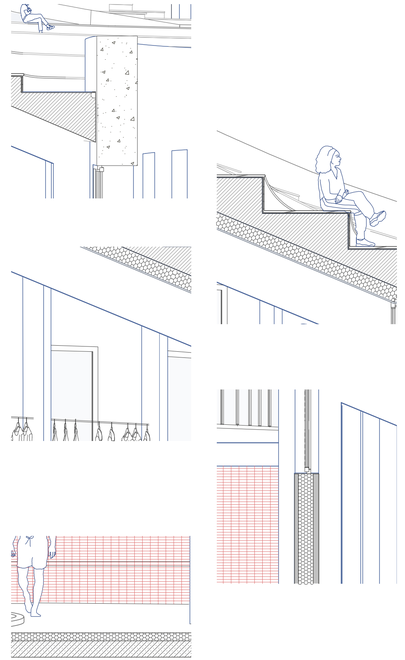
TOTAL 248 329 kgCO2

MATERIALS

ADOBE
The choice to use the clay of the site becomes obvious when the resource is abundant. In fact, the site's terrain is clay and partly exploitable for building in earth. Since the resource is free and very local, the earth used for the walls does not need to be imported and comes from the embankment of the stadium which is dug in order to create the new outdoor shooting range.

CLT STRUCTURE
The post-beam structure allows to give more flexibility to the interior layout as well as to the shape of the building. In addition, the sloping roof of the stands and its twist shape allowed to play with the visual aspect of the wooden structure, which created an interesting dynamic inside. The dimensioning of the CLT elements is evaluated for high loads in order to be sufficient to carry the weight of the slab, the interior elements, a large audience in the stands, as well as the weight of the snow. However, a change of slab for the stands could significantly reduce the dimensioning of the structure, and therefore create a completely different architectural atmosphere inside.

LIME CONCRETE SLABS
The semi-grained slab surrounded by the shooting range as well as the foundation slab of the rest of the building is made of lime concrete. In order to respect the humidity of the rammed earth and the humidity of the site, it is necessary to have a breathable soil.
The slab of the sooting hall is a lime concrete with the insulation included which allows to leave the ground raw. The rest of the building has a traditional lime concrete slab on the ground with wood wool insulation on top, and a natural plaster as a final layer.



27. Building materials details

BUBBLE DECK CONCRETE SLAB
Used for its resistance and similicity of implementation, the construction of a concrete bubble deck slab seems the most suitable for constituting the tribunes steps. The implementation of concrete is one of the most practical options for inclined stands of different heights. The elements also have the advantage of being able to be prefabricated and assembled on site, with an advantageous durability of resistance over time. The heavy weight supported by the tribunes and the hard climatic conditions in winter make the concrete slab an attractive option. However, its weight being very important, this implies a greater dimensioning of the wooden structure. Its relation to the environment is also very poor in terms of gas emissions.

A softer approach can be considered with a timber-frame assembly to create a lighter layer on the CLT load-bearing structure, as well as to use timber as a much more neutral material. Its elements can also be prefabricated and assembled on site. However, the wood must be covered on its outside in order to be protected from the outside climate and to prevent leaks inside. Especially for the safety of the stands in winter, the wood is often slippery or frozen and makes travel more dangerous. Its lifespan is surely to be replaced more frequently than other more resistant materials.

PREFAB CLT PANELS
Between the structure, the exterior and interior walls are prefabricated wooden walls with wood wool insulation between the exposed wooden panels. The insulation of the interior walls is reduced since they are not exposed to the exterior. It is the same for the interior slab between the first and the second floor.

MATERIALS RESEARCH

Different approaches have made it possible to compare combinations of materials and their total emissions. The concrete being the highest carbon emissions index, 3 different variations were made with a more or less important contribution of concrete in the building.
A comparaison is made between a bubble deck concrete slab and a lime concrete slab. A focus is also developed for the tribune's slab, where a wooden structure is considered. Finally, are two very different comparison criteria, including a proposal mainly made up of concrete and a possibility of construction without concrete.

Foundations : Slabs

Load bearing structural frame :
CLT colums and beams structure

Upper floors :
Prefab wood insulated (rock wool) floor panel

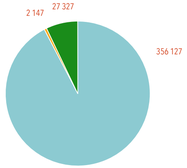
Internal walls, partitions :
Prefab wood insulated walls panel

Facade openings :
Windows and sliding doors

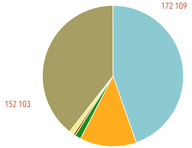
Roof : Tribunes slab

CONCRETE SLABS

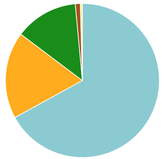
One of the proposals highlighted here corresponds to the most common way of building, with concrete. This scenario echoes a CLT post-beam structure, and a concrete bubble deck foundation and tribunes slabs. It is interesting to compare the environmental impact of concrete itself in a building of this size.
The use of bubble deck concrete is nevertheless a little more qualitative, since it uses less material and the total weight of the slabs is also reduced.



GLOBAL WARMING KG CO2
LIFE-CYCLE STAGES



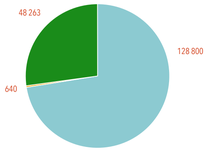
CLASSIFICATIONS
Kg CO^2

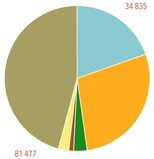


RESSOURCES TYPES

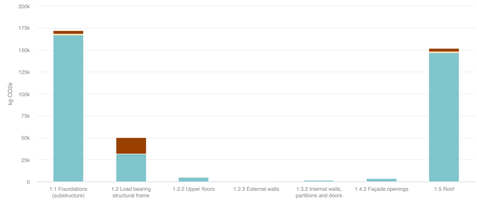
NO CONCRETE

As concrete represent the biggest part of emissions, and as the slab area is pretty large, a logical solution to significantly reduce emissions is to completely remove concrete from the project, through other alternatives.
By combining the two solutions studied previously, such as lime concrete on the ground and the wooden structure for the tribunes, the environmental footprint is significantly reduced. The architectural aspect is different but still very qualitative. The only negative point of a wooden structure for the stands can be its implementation, which is more complex.



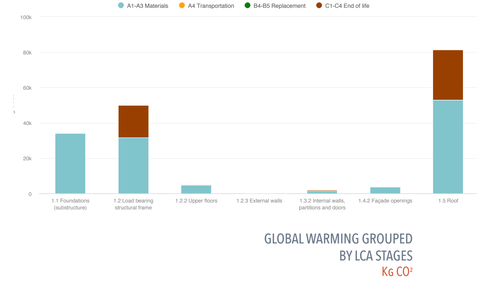


TOTAL 177 703 kgCO2



GLOBAL WARMING GROUPED
BY LCA STAGES
Kg CO^2

TOTAL 385 601 kgCO2



GLOBAL WARMING GROUPED
BY LCA STAGES
Kg CO^2

The study cases are showing large different results about the environmental impact of the materials.
In all the cases the tribunes floor remain one of the main source of emissions.
However the choices of construction technique and material use double the gaz emissions result. Indeed, it is estimated an emission of 150 000kgCO^2 for the construction of the tribunes with a bubble deck concrete, in prefab slab technique, while a wood structure of the tribunes would emit arround 80 000 kgCO^2.
Nevertheless the number are not representative of the maintenance needed and the construction process. The site has an important exposition to hard climate and a concrete exterior coating make its maintenance and its resistance better. However, the load carried by the tribunes floor is really heavy and a lighter solution has to be envisaged so that the wood structure carrying the load can be underdimensionned. Indeed, the bubble deck wait is estimated arround 15 times heavier than a wood structure. It would reduce as well the wood quantity used for the CLT structural frame in the building.

Changes in the foundations materials choices, can reduce by 5 the enrionmental impact if a lime concrete is choosen. However, many negative sides of the concrete bubble deck slab makes the choice for the limeconcrete slab determining.
Indeed the difference on the environmental impact results is so important that we can hardly justified the choice for the bubble deck slab. Also, the adobe walls need a breathable environment to evacuate the humidity they absorb. The limeconcrete has this capacity and is using more reusable materials than a concrete decking.

As of now, an inbetween solution favored limeconcrete foundation of the building with bubble deck construction for the tribunes. Indeed, prefabricated elements in concrete can be built to fit the tribunes shape, and its maintenance in that context seem to be the most adapted.
Although the design and the materiality construction can be improved even more, to make the building lower on its materials consumption.

LCA TOTAL - OVER THE NEXT 40 YEARS

RECAP OF THE TRANSPORT MODEL

ACTUAL MODEL CONSUMPTION

1 692 T of CO^2 / year — 67 680 T of CO^2 over 40 years

OVER 40 YEARS = **40 288 T** CO2 SAVED

2022 MODEL CONSUMPTION

953 T of CO^2 / year — 19 060 T of CO^2 over 20 years

27 392 T of CO^2 over 40 years

2040 MODEL CONSUMPTION

417 T of CO^2 / year — 8 332 T of CO^2 over 20 years

MATERIALS FROM BUILDING CONSTRUCTION

MODEL CONSUMPTION

249 T of CO^2 / year

TOTAL = **27 642 T** CO2 over 40 years

Finally, the total results for this project show an emissions of almost 28 T of CO^2 over the 40 years timeline goal. The result include the energy consumption of the existing buildings, the new transportation system and the impact of the new building materials construction. It is a save of 40T of CO^2 over 40 years compares as if the energy emissions model stayed the same as today. However, the reduced number are also providing a qualitative environment , thanks to a new architectural answer on site. Amount of visitor average is also extended of 10% in the futur simulations. Nevertheless, the emissions from the new shooting hall have to be overestimated since this is not including the yearly energy consumption from the building and its construction process. Yet, it is estimated that the building can have a really low operation consumption, and that a more environmental friendly solution can be found for its materials choices.

Although, even if the final gap number is lower than this results, the benefit is still profitable. Indeed the balance between the new plan for Granåsen against today's system, let see a significant drop of gas emission on site and a real benefit from the new structure and the transportation changes.

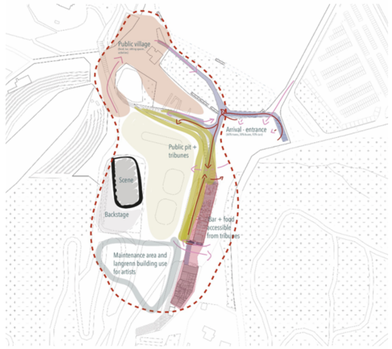
FLEXIBILITY OF SPACE EVENTS

Space being occupied in different ways throughout the year and in different climates conditions, it must be very flexible in its uses. Function defenetly follows the demand from users. A minimum daily occupancy of every spaces is considered, so that the area are not waisted empty.
A maximum of adaptability ensure a good occupation of the space, depending on the type of activity, the type of user, the climatic conditions and the flow of users.
Inside functions and management are easily transformable, and give the site a lot of flexibility, mainly thanks to the big opening in between the wood structure grid. Yet, even if the functions can be transformed, the circulations always remain very fluid and cleared.

LARGE SCALE

One of the sustainable aspects dear to the project is that it can adapt to its evolution and always shape its new uses. This is why on a large scale space, must be left enough freedom for modeling the site to all convenience. Indeed, in the majority of the time the site is left free to its users and half wild, but during a few peaks per year it becomes the major event venue of Trondelag. During these moments, quick transformation and easy modulable elements are necessary to host the best possible organization.
The orientation of its stands and the large number of seats make the arena an ideal place for major sports competitions as well as for an open-air concert hall. Indeed, already today events bring together more than 40,000 people during the Ski World Cup or major concert in summer. In both cases, the site takes the form of a closed place like a mini festival, the layout of which gives the visitor several spaces (stage, village, activity space). It is therefore imagined that most of the area is dedicated to pedestrian. The space outside the stage is adaptable to accommodate the large streams of visitors, spaces for meals, rest and activities, all always connected to the event ongoing.

CONCERT FESTIVAL



SKI EVENTS

28. Map, potential development of the site according to different events

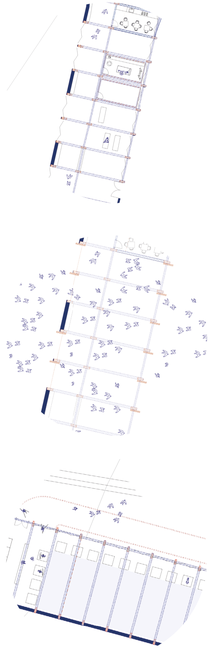
LOCAL SCALE

A BIG OPENING

If the site in general is large and easily transposable, the new shooting hall building is also flexible. It is composed of a wooden post-beam structure that free up the floor space. The side of the stadium arranges traffic and the side of the transport system flexibly accommodates the various programs. This EAST-WEST crossing space under the tribunes can turn into a wide entrance to the stadium when the two sides are fully open. In fact, the rest of the time, isolated removable boxes, in a wooden structure, can be moved to be used elsewhere on the site or in rows. Dedicated athlete's boxes, create partitioned compartments for the daily uses of the building, such as massage rooms, additional changing rooms, and an equipment preparation workshops. However, the angle rooms arrangement of the building is a not removable part.

TRANSFORMATION OF THE SHOOTING HALL

The indoor shooting range hall can also be used for other circumstances. Indeed, the space being high under the ceiling and completely open due to its configuration, can serve as a covered hall for the public during outdoor events. The north facade in front of the tramway can open along its length and creates an interior - exterior space. A large cafeteria, a refreshment bar or even a space for meals or activities offered to young people can be installed there, noting that a cafe is located just above, at the first floor level.



29. Different layouts for various occasions

AN UTOPIAN FUTUR

As the adaptability in time of the stadium is one of the major points of this project, it is important to imagine how it can become anchored in its environment in a more or less near future.
Indeed, the rise in temperatures having an increasingly impact on our daily lives, it is important to consider a future without snow, or almost, in the region. Especially when the main layout is dedicated to winter sports competitions, it must be ensured that the space can be used in various contexts.
In the case of winter without snow, the stadium may continue to be used for roller ski competitions as in summer. Warm season sports can be played throughout the year and more entertainment events, such as concerts, can be offered along the differents seasons.

In addition, passives strategies can be adapted to meet new needs. The openings for cooling and ventilating the air can have a more recurring opening, so that the heating is considerably reduced. Adobe walls have an efficient effect if the climate heats up since they can store heat and redistribute it, or at the opposite, walls are a cooling interiors solution when the climates are hot. Few part of the building are insulated, but as temperature average increases, It is also becoming less and less necessary to have isolated interior spaces.

CONCLUSION

The fame of Granåsen ski center is still relevant and the demand from users keep feeding it. However sports techniques and humans habits are evolving. Structure for ski jumping and skiing demand are then transformed, so the site can continue to welocme international events in the coming years.
However, constructions which are useful to the visitors must also follow the evolution to fit into new needs. Today, the car is less important than in the past in users habits, and the number of visits to the site is increasing. It therefore seems normal to change the order of priorities on the arena, and to give more space for visitors. Even if it means transforming and improving the premises, it would be a shame not to seize the opportunity to reduce the site's GHG emissions. In that context, this thesis had explored strategies to reduce the total emissions of the site, while providing architectural qualities that meet the demands of occupants.

Emissions on site appears to come mainly from transportation, while building consumption and activities are minor in the total environmental impact of Granåsen. The new order of transport types and the new tramway's implantation generates a significant decrease of CO^2 emissions due to transport on site.
At the smallest scale, the choice of materials for the construction of the new tribunes building was also a determining factor in the environmental impact. However, the estimates of this project remain global when it comes to the energy efficiency of the building. Another more advanced architectural proposal could result to a similar building with better properties for materials, sizing of structures, and the internal consumption of the building. The daylight apport in the shooting hall could be seen more deeply by experimenting the different opening possibilities. Furthermore, textures to diffuse interior light and reduce noise echo could potentially be valued.
The site's energy autonomy can also be further developed, especially for its potential in solar production. Indeed, the advantageous south orientation of the site and the large square meters area available on the roofs and tribunes of the arena, are an exploitable asset to be explored further.

Finally, the development of this project has shown that the constructions themselves on a site of this size are not the major sources of CO^2 emissions. It is much more efficient to think of the ski center as an ecosystem, rather than just focusing on the buildings frame.
In Granåsen, this project makes it possible to considerably reduce GHG emissions over time, while providing visitors a much more enriching experience, in a valued architectural context.

REFERENCES

Grønne ambisjoner for Granåsen hverdagsanlegg - Trondheim 2030 : TRONDHEIM2030.NO

Granåsen idrettspark : TRONDHEIM.KOMMUNE.NO/GRANASENIDRETTSPARK

Granåsen som nullutslippsområde - Miljødirektoratet : WWW.MILJO-DIREKTORATET.NO

Arenabygg Granåsen : Bygg.no - Byggeindustrien : WWW.BYGG.NO

Endelig åpner toppidrettssenteret – NRK Trøndelag – Lokale nyheter, TV og radio : WWW.NRK.NO/TRONDELAG/

Kulm Eispavilion / Foster + Partners : ARCHDAILY.COM

Granåsen arenabygg - Betonmast : WWW.BETONMAST.NO

13.-trafikkrapport.pdf : TRONDHEIM.KOMMUNE.NO

190520-grønne-ambisjoner-granåsen.pdf : BADPARKIDRETT.NO

ETABLERING AV TOPPIDRETTSSENTER/NÆRINGSBYGG I GRANÅSEN FILE:///USERS/LEAPIARD/DOWNLOADS/11092875.PDF

Ricola Kräuterzentrum / Herzog & de Meuron : ARCHDAILY.COM

GRANÅSEN SOM HVERDAGSANLEGG KLIMAGASSUTSLIPP - Rambøll rapport : TRONDHEIM2030.NO

Holmenkollen nasjonalanlegg – Fabel Arkitekter :FABELARK.NO

Toppidrettsenteret i Trondheim, from Olympiatoppen : OLYMPIATOPPEN.NO

Upper Skeena Recreation Center / Hemsworth Architecture : ARCHDAILY.COM

Architecture Classic: The Zarzuela Hippodrome / Carlos Arniches, Martín Domínguez and Eduardo Torroja : ARCHDAILY.COM

Trondheims Tramway, Wikipedia WIKIPEDIA.ORG/WIKI/TRONDHEIM_TRAMWAY

Comparative energy consumption of trams and buses : BATHTRAMS.UK Bath & Bristol Area Trams Association

Framtidsbilder Trondheim sentrum 2050 med sentrumsstrategi: TRONDHEIM.KOMMUNE.NO

Granåsen arenabygg – agraff arkitektur: AGRAFF.NO

Émissions de CO2 des transports ferroviaires en France : FR.WIKIPEDIA.ORG

Tribunes, GUIDE Union Sport et Cycle 2017.pdf : WWW.HUSSON.EU

Nomad Office Architects - Dalseong Citizen's Gymnasium : DIVISARE.COM

Petit guide du constructeur en pisé by Gurvan Arnaud - issuu ISSUU.COM/GURVANARNAUD

Indoor Shooting Range Lighting Guidelines WWW.ACCESSFIXTURES.COM

RANGE DESIGN CRITERIA, U.S. DEPARTMENT OF ENERGY Office of Health, Safety and Security : WWW.ENERGY.GOV

The Couch / MVRDV : WWW.ARCHDAILY.COM

-Emilie Zakariassen Hansen - «How to develop a strategy for sustainability for sport events?- A case study of Holmenkollen Skifestival», NTNU Master's thesis in Project Management, 2019

-Le Monde, «Electricity and CO2: the european table», 2019 WWW.LEMONDE.FR

FIGURES

PERSONNAL RESSOURCES / DESIGNING

google earth
www.aftenbladet.no
Rune Petter Ness, NTB Scanpix
Digitalmuseum.no

From PIR2, in *Grønne-ambisjoner-Granåsen* report
Trondheim Kommune, KU hovedrapport Granåsen
Trondheim Kommune, KU hovedrapport Granåsen

Tram Travels
en.sporvognsrejser.dk

www.visiterlecolisee.com
JDS Architects
Adressa.no

ACRONYMES

CO^2	Carbon Dioxide
LCA	Lifecycle Assessment
GHG	Greenhouse gas
EPD	Environmental Product Declaration
$kgCO_2$	Kilogram of Carbon Dioxide
kWh	Kilowatt-Hour

ANNEX

LCA MATERIALITY SHOOTING HALL

RESULTS FROM ONECLICK LCA

MATERIALS LISTING FOR THE SOLUTION WITH A BUBBLE DECK SLAB AND BUBBLE DECK CONCRETE FOR THE TRIBUNES

Granasen: Granasen

Level(s) life-cycle carbon: Construction Materials

Construction	Resource	User input	Global warming kg CO_2e	Biogenic carbon storage kg CO_2e bio	Comments
Building materials > Foundations and substructure > Foundation, sub-surface, basement and retaining walls					
	Bubbledeck concrete slab, B35 MF45 35 mm (Systembolag)?	800 m2	**27,78 %**		SLAB SHOOTING HALL
	Bubbledeck concrete slab, B35 MF45 35 mm (Systembolag)?	1 300 m2	**44,91 %**		FLOOR SLAB
	Rock wool insulation, L = 0.033 W/mK, 80 kg/m3, 33 mm for R=...?	800 m2	**10,44 %**		INSULATION SLAB SHOOTING HALL
	Rock wool insulation, L = 0.033 W/mK, 80 kg/m3, 33 mm for R=...?	1 300 m2	**16,88 %**		INSULATION FLOOR SLAB 1ST FLOOR
		Section share	**46,93 %**		
Building materials > Vertical structures and facade > External walls and facade					
	Light expanded clay aggregate, 8-20 mm, 245 kg/m3 loose bulk...?	0 m3			ADOBE WALLS
		Section share			
Building materials > Vertical structures and facade > Columns and load-bearing vertical structures					
	Cross-laminated timber (CLT), 420 kg/m3 (Splitkorn)?	120 m3	**48,82 %**	**48,82 %**	CLT BEAMS
	Cross-laminated timber (CLT), 420 kg/m3 (Splitkorn)?	130 m3	**51,18 %**	**51,18 %**	CLT COLUMNS
		Section share	6,33 %	**69,28 %**	
Building materials > Vertical structures and facade > Internal walls and non-bearing structures					

MATERIALS LISTING FOR THE SOLUTION WITHOUT BUBBLE DECK CONCRETE LIMECONCRETE SLAB AND TRIBUNE IN WOOD STRUCTURE

Granasen: Granasen

Level(s) life-cycle carbon: Construction Materials

Construction	Resource	User input	Global warming kg CO_2e	Biogenic carbon storage kg CO_2e bio	Comments
Building materials > Foundations and substructure > Foundation, sub-surface, basement and retaining walls					
	Sand, compacted wet density, 2082 kg/m3?	260 m2	0,74 %		SLAB TRIM CONCRETE SHOOTING HALL
	Limestone aggregates (Franzefoss Minerals AS)?	36 000 kg	0,23 %		SLAB TRIM CONCRETE SHOOTING HALL
	Limestone aggregates (Franzefoss Minerals AS)?	60 000 kg	0,39 %		SLAB TRIM CONCRETE BUILDING
	Rock wool insulation, 30-125 mm, 90 kg/m3, Lambda=0.035 W/(m...?	260 m2	**15,93 %**		SLAB TRIM CONCRETE SHOOTING HALL
	Rock wool insulation, L = 0.033 W/mK, 80 kg/m3, 33 mm for R=...?	1 300 m2	**82,71 %**		INSOLATION FLOOR SLAB 1ST FLOOR
	Recycled gravel (waste status), dry bulk density, 1680 kg/m3?	170 m3			SLAB TRIM CONCRETE BUILDING
		Section share	**26,48 %**		
Building materials > Vertical structures and facade > External walls and facade					
	Light expanded clay aggregate, 8-20 mm, 245 kg/m3 loose bulk...?	0 m3			ADOBE WALLS
		Section share			
Building materials > Vertical structures and facade > Columns and load-bearing vertical structures					
	Cross-laminated timber (CLT), 420 kg/m3 (Splitkorn)?	120 m3	**48,82 %**	**48,82 %**	CLT BEAMS
	Cross-laminated timber (CLT), 420 kg/m3 (Splitkorn)?	130 m3	**51,18 %**	**51,18 %**	CLT COLUMNS

INVIRONMENTAL IMPACT (A1-A3) THE SOLUTION WITHOUT BUBBLE DECK CONCRETE : LIMECONCRETE SLAB AND TRIBUNE IN WOOD STRUCTURE

No.	Resource	Cradle to gate impacts (A1-A3)	Of cradle to gate (A1-A3)
1.	Rock wool insulation ?	48 tons CO_2e	37.5 %
2.	Planed wood from pine or spruce ?	34 tons CO_2e	26.2 %
3.	Cross-laminated timber (CLT) ?	32 tons CO_2e	24.5 %
4.	Rock wool insulation ?	9,1 tons CO_2e	7.1 %
5.	Float glass, single pane, generic ?	3,9 tons CO_2e	3.0 %
6.	High pressure laminate floor covering ?	1,2 tons CO_2e	1.0 %
7.	Glued laminated timber (Glulam) ?	0,58 tons CO_2e	0.4 %
8.	Sand, compacted wet density ?	0,25 tons CO_2e	0.2 %
9.	Limestone aggregates ?	0,21 tons CO_2e	0.2 %
10.	Recycled gravel (waste status), dry bulk density ?	tons CO_2e	0.0 %
11.	Light expanded clay aggregate ?	tons CO_2e	0.0 %

INVIRONMENTAL IMPACT (A1-A3) THE SOLUTION WITH A BUBBLE DECK SLAB AND TRIBUNE IN WOOD STRUCTURE

No.	Resource	Cradle to gate impacts (A1-A3)	Of cradle to gate (A1-A3)
1.	Bubbledeck concrete slab ?	128 tons CO_2e	57.4 %
2.	Rock wool insulation ?	48 tons CO_2e	21.7 %
3.	Cross-laminated timber (CLT) ?	32 tons CO_2e	14.1 %
4.	Rock wool insulation ?	9,1 tons CO_2e	4.1 %
5.	Float glass, single pane, generic ?	3,9 tons CO_2e	1.7 %
6.	High pressure laminate floor covering ?	1,2 tons CO_2e	0.5 %
7.	Glued laminated timber (Glulam) ?	0,58 tons CO_2e	0.3 %
8.	Sand, compacted wet density ?	0,25 tons CO_2e	0.1 %
9.	Limestone aggregates ?	0,21 tons CO_2e	0.1 %
10.	Recycled gravel (waste status), dry bulk density ?	tons CO_2e	0.0 %
11.	Light expanded clay aggregate ?	tons CO_2e	0.0 %

INVIRONMENTAL IMPACT (A1-A3) THE SOLUTION WITH A BUBBLE DECK SLAB AND A TRIBUNE SLAB IN BUBBLE DECK CONCRETE

No.	Resource	Cradle to gate impacts (A1-A3)	Of cradle to gate (A1-A3)
1.	Bubbledeck concrete slab ?	249 tons CO_2e	70.1 %
2.	Rock wool insulation ?	66 tons CO_2e	18.5 %
3.	Cross-laminated timber (CLT) ?	32 tons CO_2e	8.9 %
4.	Float glass, single pane, generic ?	3,9 tons CO_2e	1.1 %
5.	Rock wool insulation ?	3,7 tons CO_2e	1.0 %
6.	High pressure laminate floor covering ?	1,2 tons CO_2e	0.3 %
7.	Glued laminated timber (Glulam) ?	0,58 tons CO_2e	0.2 %
8.	Light expanded clay aggregate ?	tons CO_2e	0.0 %