AAR4546 and AAR4817 / 2017

EMISSIONS AS DESIGN DRIVERS

Aoife Houlihan Wiberg

NTNU
Fakultet for arkitektur og design

EMISSIONS AS DESIGN DRIVERS 2017

TRONDHEIM MUNICIPALITY

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Department of Architecture and Technology

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ZERO EMISSION
NEIGHBOURHOODS
IN SMART CITIES

NTNU
Norwegian University of
Science and Technology

TRONDHEIM MUNICIPALITY

INTRODUCTION

The course in Emissions as Design Drivers is the second semester of the MSc in Sustainable Architecture and is a combined theory and design course whose core objective is for the students to learn how to integrate emission calculations in the exploration of holistic, sustainable architectural concepts and strategies, essentially, to 'learn through doing'. In 2016, the MSc students have been asked to develop holistic architectural concepts and strategies to examine how (if) to sustainably transform a derelict building to achieve an energy positive, and potentially, net zero emission building. In addition, the students were expected to maximise the use of ICT to support quantitative and qualitative assessment for decision support and design processes.

FOREWORDS

The book has been organized following the structure of both the theory and design courses “Emissions as Design Drives”. The content of this book reflects the work accomplished though the whole semester, resulting in the final group projects and their display of accumulated learning. The students would like to thank the teachers for their enthusiasm and specialized knowledge within the fields of study.

Authors
Aoife Houlihan Wiberg
Chiara Bertolin
Per Monsen
Håvard Auklend

Layout and graphics
Håvard Auklend

Edit
Håvard Auklend

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NTNU Grafisk senter

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NTNU
Faculty of Architecture and Design

Students

Martin Paul Barrere
Urska Belsak
Martin Charlie Boullay
Hanne Rosa T. Bylemans
Brisa Bøhle
Nikita Chhajer
Juan Manuel Cruz
Margherita D'Alessio
Florent Dulac
Carlos Andres Gomez Galindo
Ida Hallebrand
Florian Härle
Irene Hutami
Christoffer Borge Johansen
Mathilde Marie Axelle Veroniqu Le Levreur-Barton
Nils Manvik Castro
Nejmia Ali Mohammed
Radoslaw Maciej Olejnik
Donald Otterson
Clara María Pérez Pinero
Nikolaj Slumstrup Petersen
Marta Piñeiro Lago
Janja Radivojevic
Azin Rajaei
Kristel Reseke
Sandra Strasek
Kari Tarnstrom
Haakon Tiller Vangsnes
Lisa Windel
Yunyun Zhu

2016 _ teachers:
Course Leader: Aoife Houlihan Wiberg, RIBA
Per Monsen, MNAL
Chiara Bertolin
Zorbey Muharrem Tuncer

Additional Support:
Maria Coral Ness
Eirik Resch

Internal Reviewers:
Aoife Houlihan Wiberg, RIBA
Luca Finocchiaro
Inger Andresen

External Reviewer:
Paul Woodville, MNAL RIBA

TABLE OF CONTENTS

THE COURSE 10

COURSE BACKGROUND 11

- Course Description 11
- ZEN 13
- NTNU Campus 15
- IEA Annex 57 16
- Course Learning Outcome 17
- Course Structure 18

THEORY REPORTS 20

THEMES 21

DIGITAL TOOLS 24

LCA TOOLS 25

DIGITAL WORKSHOP 26

REVIT AND FLUX INTEROPERABILITY 27

VISUALISATION 29

DASHBOARD DESIGN 30

CULTURAL HERITAGE 32

SOCIO-CULTURAL VALUE 35

ECONOMIC VALUE 37

SITE ANALYSIS 40

SITE LEVEL 41

- Urban development 41
- Climate Analysis 42
- Climate Risk Assessment 43

BUILDING LEVEL 45

- Material Analysis 45
- Decay Mapping 45
- NDT Analysis 46
- Material Life Cycle Scenari 46

PROJECTS 48

GROUP X: PROJECT NAME 51

??? 58

NTNU CAMPUS & TRONDHEIM MUNICIPALITY 59

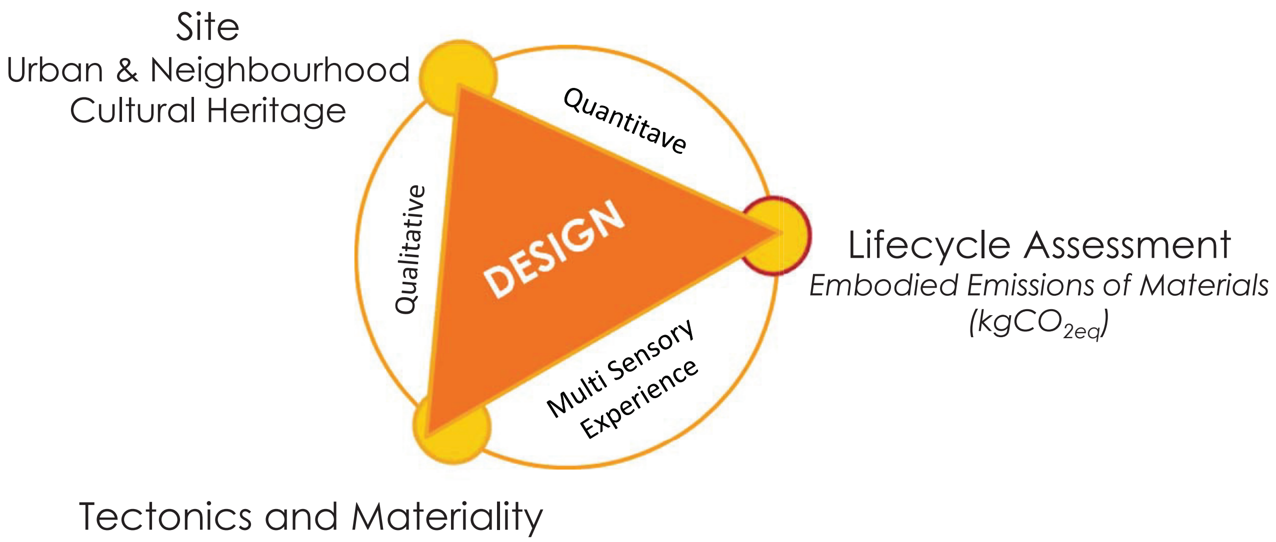
THE COURSE

COURSE BACKGROUND

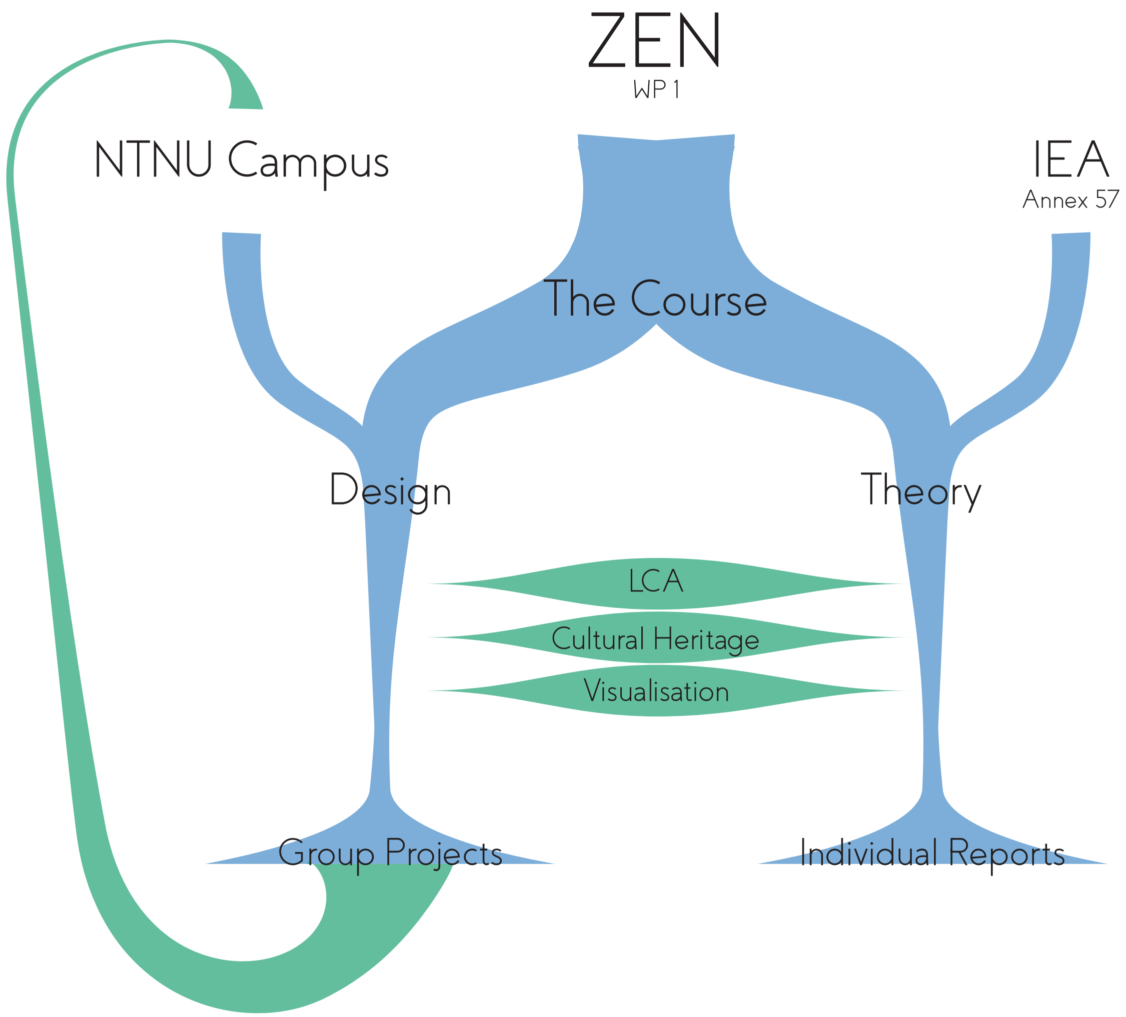
The courses AAR4817 and AAR4545 encompasses the second semester of the master program MSc Sustainable Architecture at NTNU. As a part of the philosophy of the course, the groupwork is fundamentally aimed towards interdiciplinary cooperation with students with different academic and cultural backgrounds.

COURSE DESCRIPTION

The key aspect of both theory and design courses is to understand how emissions act as a driver for design. Conversely, how do the design strategies and the choice of materials act as a driver for CO_2eq emissions but also the tectonics and cultural heritage aspects?
The course gives an overview of architectural concepts and strategies for energy positive (and potentially) nZEB buildings in a renovation context.
The key objective of the parallel courses (AAR4817 + AAR4546) is to link theory and design.
The main design project is a live research project part of the NTNU Campus- and ZEN pilot projects. In addition, the design site, Kalvskinnet will be the location of part of the NTNU campus development in Trondheim. The research questions to be addressed in this project are part of the those being investigated in NTNU Campus and ZEN. The results and outcomes from this course will feed into the ZEN research centre and will be part of a larger publication being planned through the network.



ZERO EMISSION
NEIGHBOURHOODS
IN SMART CITIES



NTNU CAMPUS

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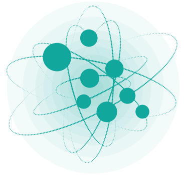

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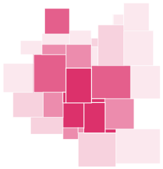

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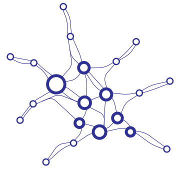

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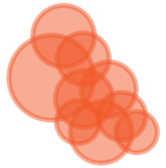
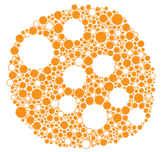


SUSTAINABLE


LIVING LAB


IEA ANNEX 57

The content of the theory lectures following the course AAR4817 is extracted from the results in IEA Annex 57. Through observations from case studies, the research is lectured in ten parts comprising both an overview of the methods and their application to design.

The IEA Annex 57 includes participants from over 20 countries worldwide and aims to provide stakeholders with detailed information, as well as, guidelines on calculation methodologies, databases and methods for design and construction of buildings with low embodied energy (EE) and embodied greenhouse gases emissions (EC). Information and guidelines will be of relevance for different stakeholders, reflecting the current state-of-the art and will have a scientific basis.

The project is dealing with methods for evaluating embodied energy and carbon dioxide (CO_2) emissions of buildings, to develop guidelines that contribute to practitioners' further understanding of the evaluation methods and to helping them to find better design and construction solutions of buildings with less embodied energy and CO_2 emissions.

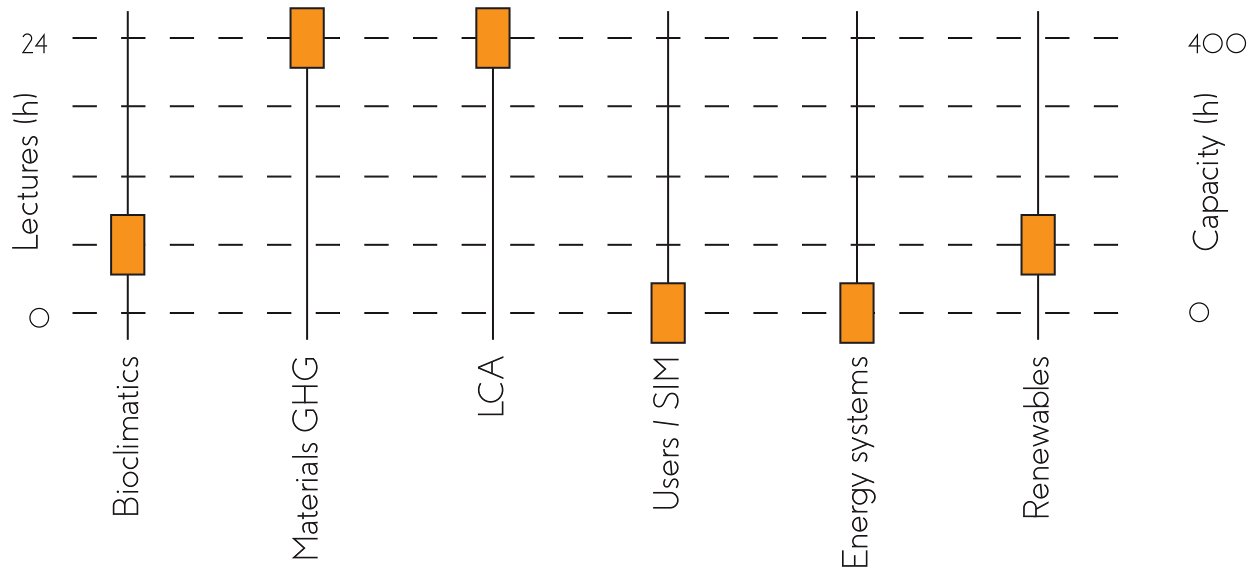
The main objectives of the project are to:

– Collect existing research results concerning embodied energy and CO_2 emissions due to building construction, to analyze them and to summarize into the state of the art
– Develop guidelines of the methods for evaluating the embodied energy and CO_2 emissions due to building construction
– Develop guidelines of the measures to design and construct buildings with less embodied energy and CO_2 emissions

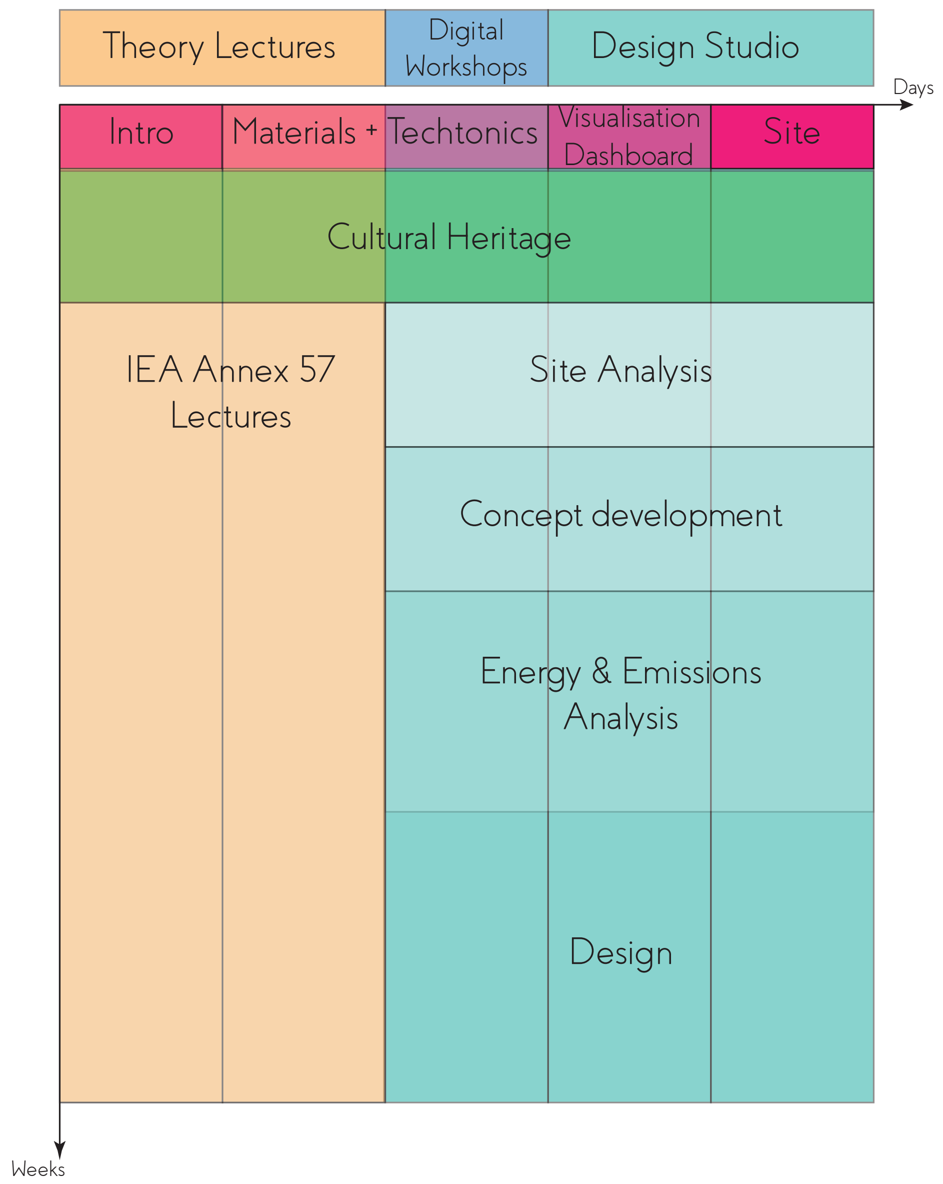
COURSE LEARNING OUTCOME

The aim of the ZEB design course is to enable students to attain knowledge about developing architectural strategies relevant for energy positive (and nZEB) buildings in a renovation context. In ZEN, tvhe key objective of the parallel courses is how to integrate emission calculations in the exploration of architectural strategies in terms of renovation, cultural heritage and tectonics and aesthetic qualities.
The learning is achieved through both quantitave and qualitiative methods using analogous and digital methods to analyse and explore the various elements that contribute to lowering energy and CO_2eq emissions in order to achieve the net zero emission ambition.
Through the semester, students develop deep knowledge on how to create a net ZEB balance (CO_2eq emission) between the embodied emissions from materials and emissions from operation, with the "avoided" emissions from renewable energy systems i.e. PV production.
The design project focuses on developing holistic architectural concepts and strategies to examine how to sustainably transform a derelict building to achieve an energy positive, and potentially, net zero emission building.

FOCUS TUNING



COURSE STRUCTURE



THEORY REPORTS

THEMES

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NATURAL MATERIALS

CONSTRUCTION

LCA

VISUALISATION

ENERGY

CERTIFICATION

DIGITAL TOOLS

DIGITAL WORKSHOP

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EXCEL SCREENSHOT

LCA TOOLS

COMPUTER MODELLING AND EMISSIONS

An integral part of doing life cycle assessments on a design in using Environmental Product Declarations (EPDs) in coordination with a computer model of the building. There is a great potential for a bi-directional link between EPD databases and dynamic computer models to be valuable in an early stage of the design.

MODELLING SOFTWARE ⟷ FLUX CONNECTION ⟷ EPD DATABASE

AUTODESK REVIT

Dynamo

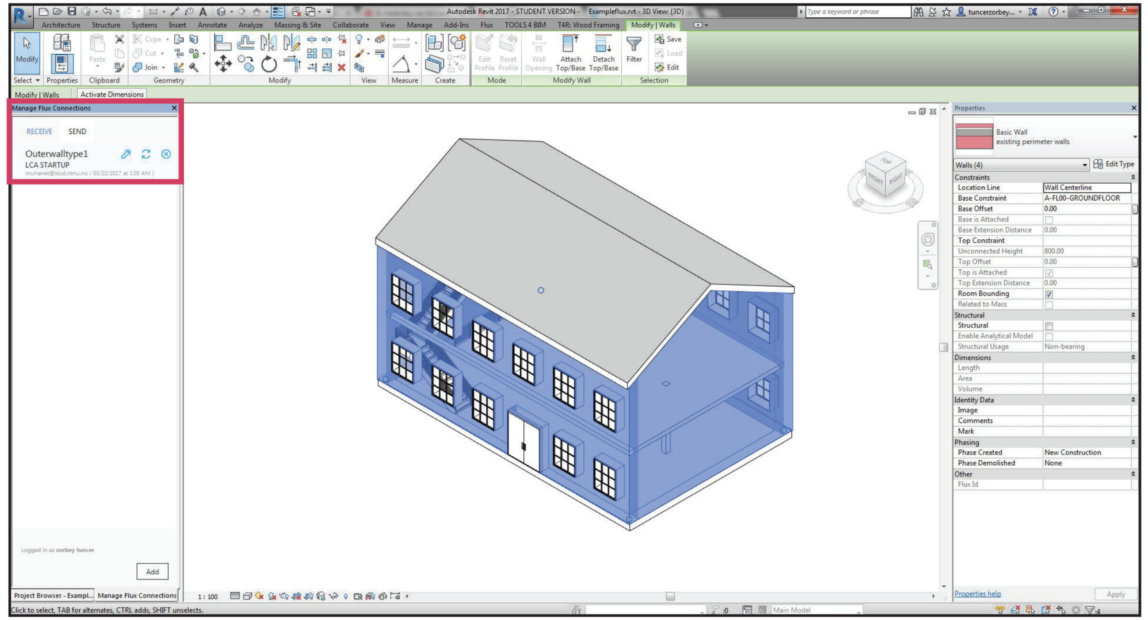
FLUX.IO

REVIT AND FLUX INTEROPERABILITY

DIGITAL WORKSHOP

In the digital workshop, the students learn how to feed building and material data live into the Excel tool for LCA calculations using Flux plugin within Revit. The main idea is to use a tool that is fast and collaborative between team mates for further analysis. The use of dynamo is also recommended for scheduling but it has its limitations when it comes to worksharing and time to time it gets slow when a project that is being developed gets larger in terms of file size and elements.

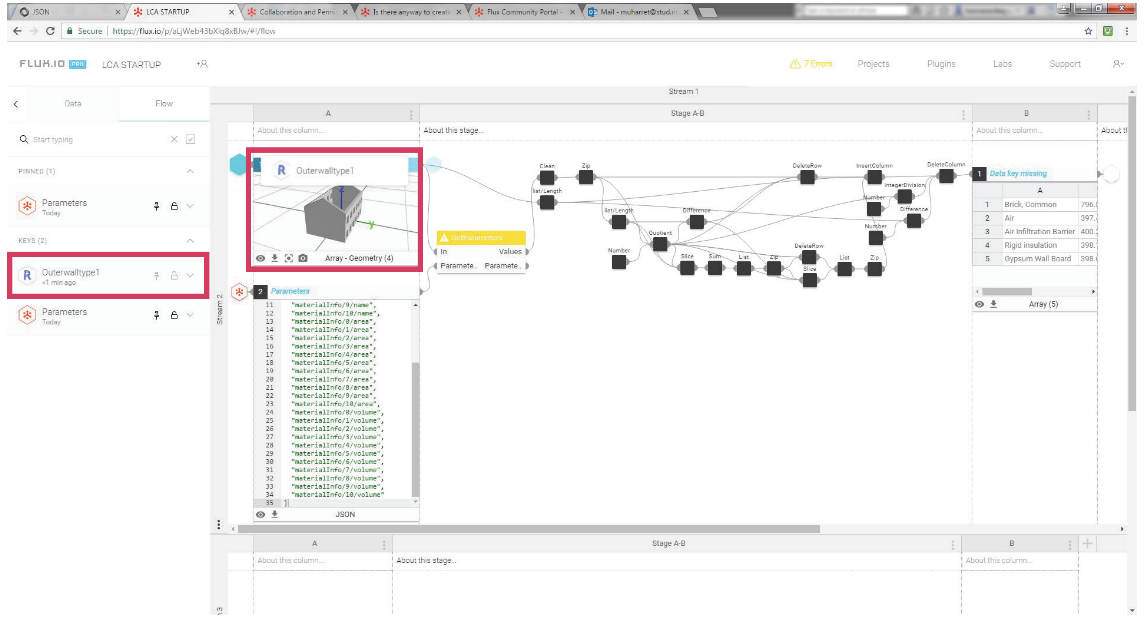
REVIT



Revit screenshot with flux plugin sending data about the outer walls of a building.

WHAT IS FLUX?

It is a web-based service that allows popular design applications such as Revit and Excel to exchange data using native plugins, as well as Dynamo and Excel or Grasshopper and Excel. A useful tool for data exchange and collaboration. Various stakeholders can share, edit and view the data. Each user and application controls when to synchronize data with the project, allowing users to work in isolation until they are ready to share their changes with the team.
For further reading:
https://community.flux.io/content/kbentry/1258/flux-overview.html



Screenshot of the flux web interface showing the outer walls input data.

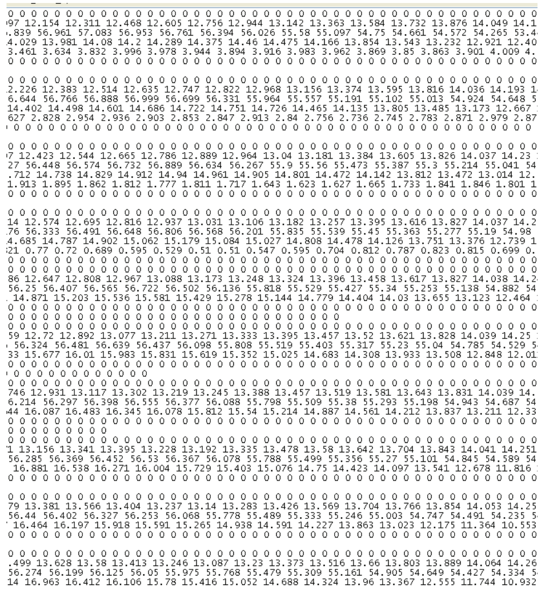
VISUALISATION

“There are right ways and wrong ways to show data; there are displays that reveal the truth and displays that do not.”

- Tuft, E. (1997) Visual Explanations: Images and quantities, evidence and narrative. Cheshire, CN: Graphics Press

“A dashboard is a visual display of the most important information needed to achieve one or more objectives which fits entirely on a single computer screen so it can be monitored at a glance.”

- Stephen Few



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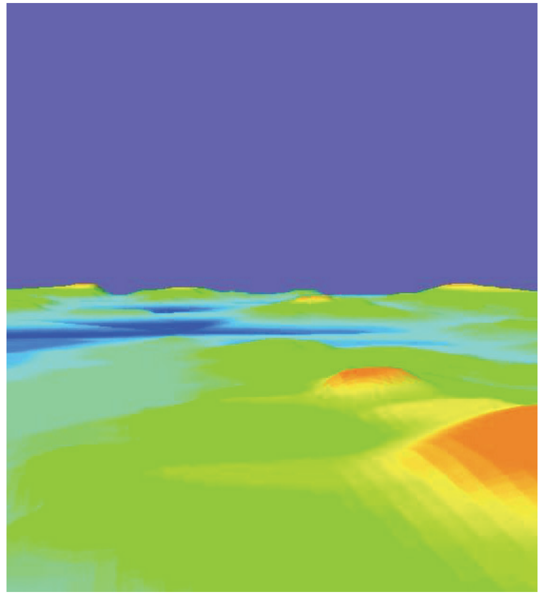

DASHBOARD DESIGN

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CULTURAL HERITAGE

HISTORIC INTRODUCTION

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SOCIO-CULTURAL VALUE

Site Locations

Site A: The Museum's Main Entrance East side of Gunnerushuset

Site B: A Town Park, Located directly north of Gunnerushuset

Site C: Traffic Intersection, Located directly north of the brewery building

Site D: Suhmhuset Museum Entrance / Parking Lot, Located south of Gunnerushuse

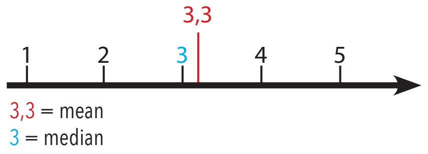
ECONOMIC VALUE

Museums are generally under valued and under funded in urban and regional development scheme of a region. If the potentials are explored adequately museums can play a vital and effective role in urban revitalization initiatives. They can help revive and diversify a local economy and the competitiveness of their environment. The role of museums as both an incubator and source of creativity and innovation is not well recognised.

Museums attract tourists and scholars from across Europe and around the world. Museums nurture creativity and innovation, they act as a space for reflection on the present and a source of inspiration for new creative and innovative concepts. We have witnessed major changes in terms of economic development, tourism, employment of locals in respect to museum management and touristic facilities and above all the preservation of tangible and intangible aspects of cultural heritage which would have been neglected otherwise.
Cultural tourism initiates people from other country to know more about the local history and cultural heritage. Creativity and innovation are fundamental dimensions of human activity and essential to economic prosperity. Museums act as a focus for reflection on the present and as a source of inspiration for creative and innovative concepts.

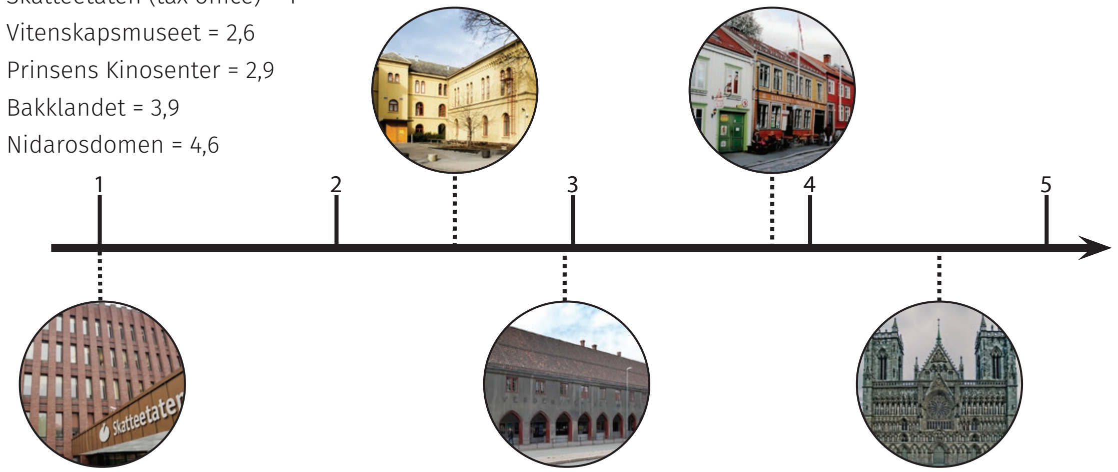
In order to obtain the economical values which are stricly linked to the social perception of the goods (existence value, non-use value, option value and bequest value, a student group decided to organize a field survey in the city centre of Trondheim, with a questionnaire structured as follows:

- Do you know about the existence of the vitenskapsmuseet? (Existence value)
  9: Yes (70% has been there at least once)
  1: No
- How much would you rate it (from 1 to 5) even if you have never been there? (Non-use value)
  1 answer: 5
- Hypothetically considering that you would never go to the vitenskapsmuseet (again), how much money would you be ready to invest in the vitenskapsmuseet in order to keep it as it is? (Option value)



- If we give you a list of buildings in Trondheim, could you rank them regarding how keen would you be to invest in their conservation and preservation? (Bequest value)

Skatteetaten (tax office) = 1
Vitenskapsmuseet = 2,6
Prinsens Kinosenter = 2,9
Bakklandet = 3,9
Nidarosdomen = 4,6



SITE ANALYSIS

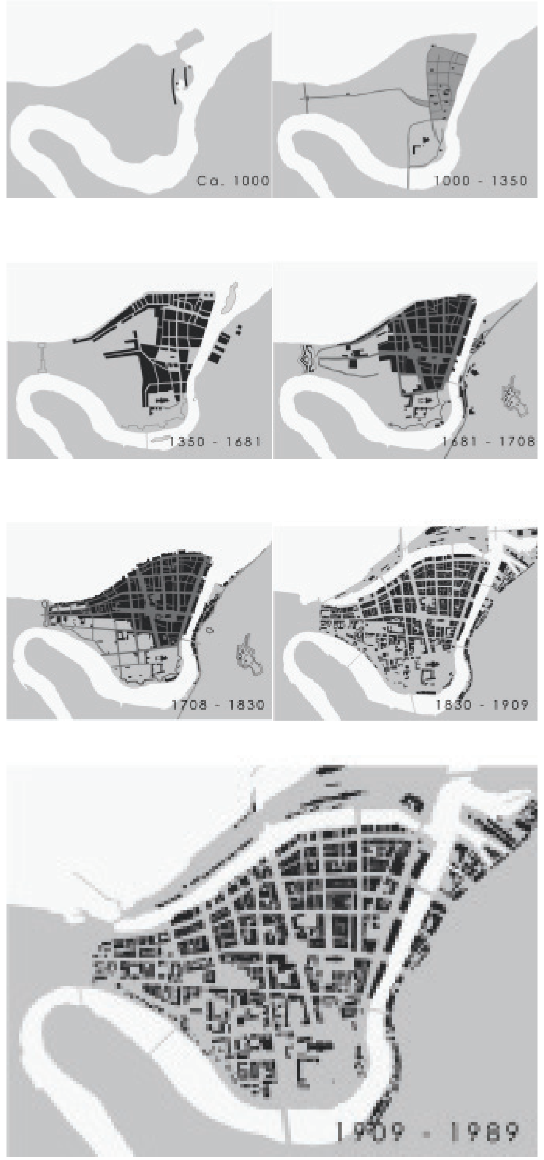
SITE LEVEL

URBAN DEVELOPMENT

Trondheim city center development begins from the Nidelva river mouth, as the city is known as a trade town. After the city was torched, during 1000 – 1350 the city was rebuilt with new main streets in north – south direction. Around 1640 the city continues to grow westward.

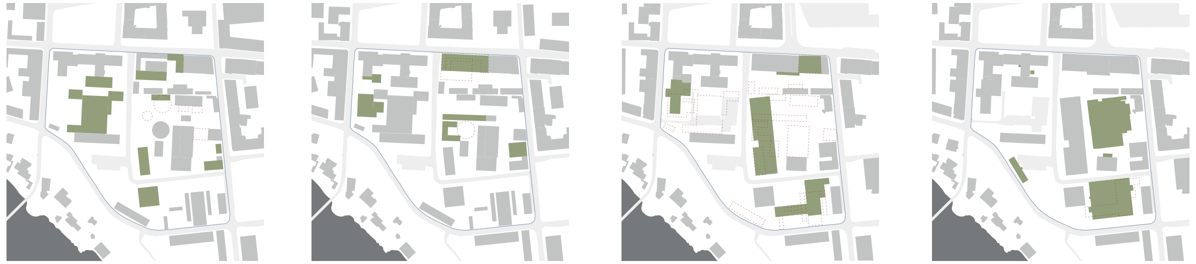
After the great fire in 1681 destroyed most of the houses in the city, the city is re-planned in Baroque style by Jean Caspar de Cicignon. The streets are made wider and deeper so that people could get access from the main streets. However the old narrow streets from the middle age are still retained, giving a contrast to Cicignon's new boulevards.

During 1708 – 1830 Kalvskinnet area started to grow with public institutions started to be built in the western part. The city infrastructure continues to improve with the railways from the south and east connected in 1884 and several new bridges being built. The development of the Kalvskinnet area continues with roads facilitated for cars.



1847 1866 1883 1909

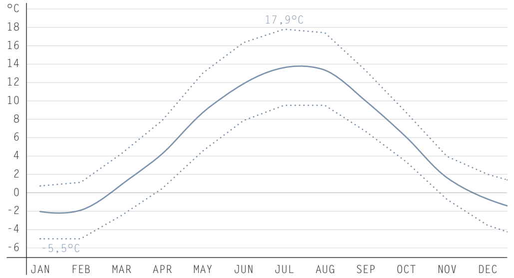
1937 1957 1986 2017



CLIMATE ANALYSIS

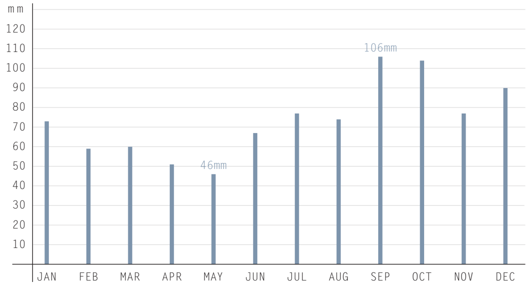
Due to its latitude (63° N), Trondheim enjoys a “subarctic or boreal” climate. Therefore the temperatures are quite low: between 0 and -6°C for the coldest month (January) and between 11 and 20°C for the hottest month (August). One should note that the nearby fjord limits the temperature variations (and prevent them for getting really low as in some other parts of Norway). Extreme temperatures are seldom reached: the temperature get below -10°C only during a couple of days in the winter months and above 25°C only during a couple of days in summer.

Trondheim area is rainy, with nearly 50mm of precipitation each month. The precipitation graph shows that, in average, it is raining nearly every two days. The precipitation reach their maximum during winter and summer. The driest month is April which still get 38mm of water.
The area is quite windy, especially in win-ter time. Indeed, the wind speed can be abo-ve 38 km/h nearly 10 days in January and 3 days can even enjoy wind speed above 61km/h. The prevailing wind direction is from South and South-West while in summer times it can be additionally from North and North-West.

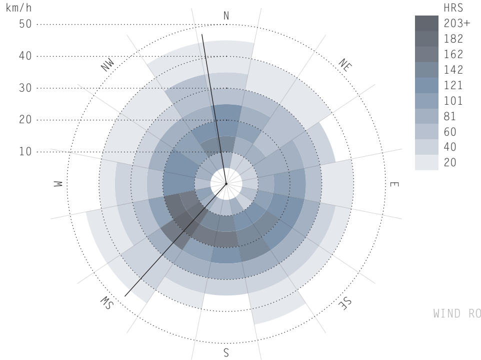


TEMPERATURE GRAPH

HUMIDITY GRAPH

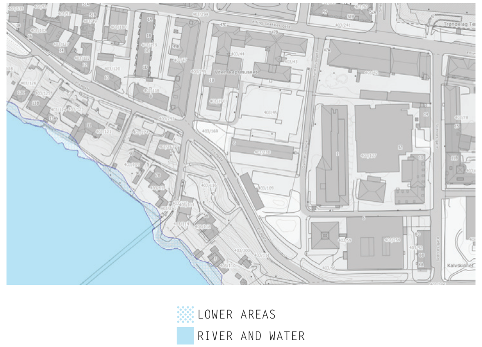


PRECIPITATION GRAPH

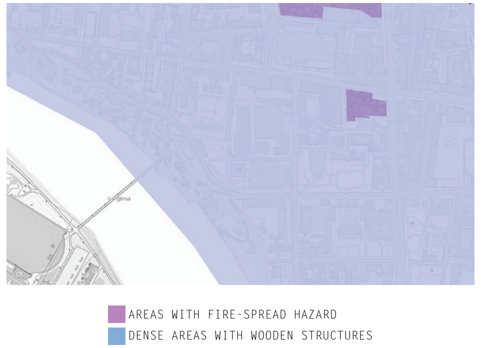


WIND ROSE

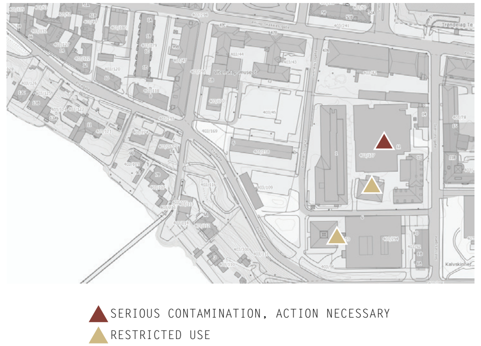
CLIMATE RISK ASSESSMENT



FLOOD HAZARD | 100 YEARS



FIRE HAZARD | 100 YEARS



NEARBY SOIL CONTAMINATION RISK

CLIMATE CHANGE VULNERABILITY

BUILDING LEVEL

MATERIAL ANALYSIS

The gross of materials involved in the construction of the Gunnerushuset building is headed by bricks, within approximately the 60% of the gross building. Timber is the following one (20%) because of the ceiling and floor structure, window frames and of course the furniture. The roof is fully covered by slate tiles. Glass, insulation materials and concrete mortar has also a big presence in this building.

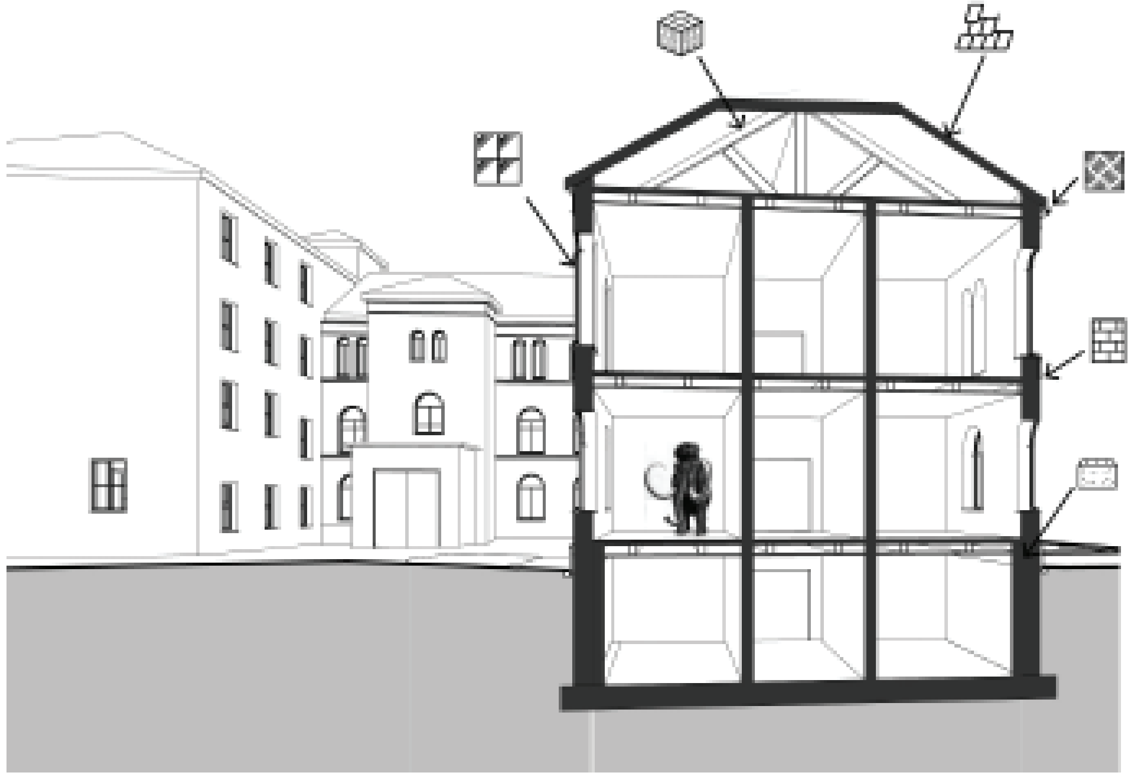
In general, all construction materials based on wood have a lower-impact. The promary energy demand is basically from biomass, representing 69-83% of the total primary energy demand. As the timber used for Gunnerushuset building is most probably extracted from Trondhiem, the transportation Energy demand is very low, even more in 1864, when GunnerusHuset building was build, and the wood was transported by non energy consuming vehicles.
Despite the low impact of these products, there is room fot improvement, in particular related to the replacement of conventional formaldehyde and melanime with natural resins, with an estimated 16% recuction of CO_2 emissions.

Approximately 60% ‘of the gross building material is from bricks. Regarding the environmental impact of bricks, it depends on the use of light clay or silico-calcareous bricks. When the building was built in 1884, a brick factory was working in Trondheim, so the environmental impact of the transportation is very small.

Cement mortar is present all over the structure as a glue for the bricks assembly and also on the bottom part of the building. Cement mortar is made from cement and sand. Therefore, it has lower impact than clinker cement, which is mixed with higher environmental impact materials.

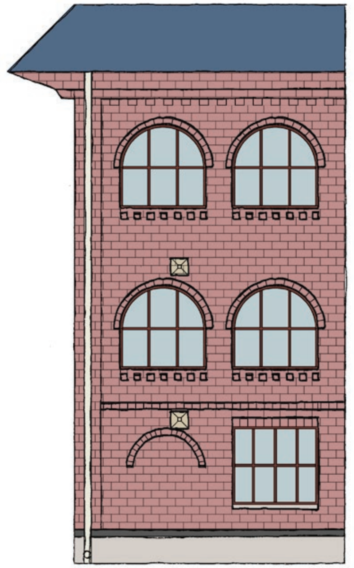
Metals are intrinsically envolved in almost every building built, as a joining mechanism. The environmental impact is much higher than the rest due to their high consumption of energy and raw materials in the numerous production processes that makes up their Life Cycle.
Another importnt factor is that, as they are products made in fully globalised industries, multiplies the impact related to the transport.
The positive point of them is that, properly managed, they can be recicled.

Besides the most used materials in the Gunnerushuset building, we have to be aware of others materials like glass, PVC, or slate tiles, also present intrinsically in the building, and specially dangerouse in terms of environmental impact.

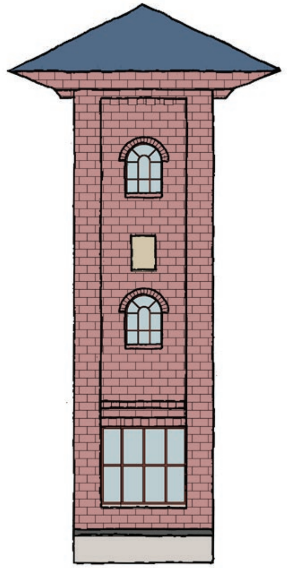


MATERIAL MAPPING

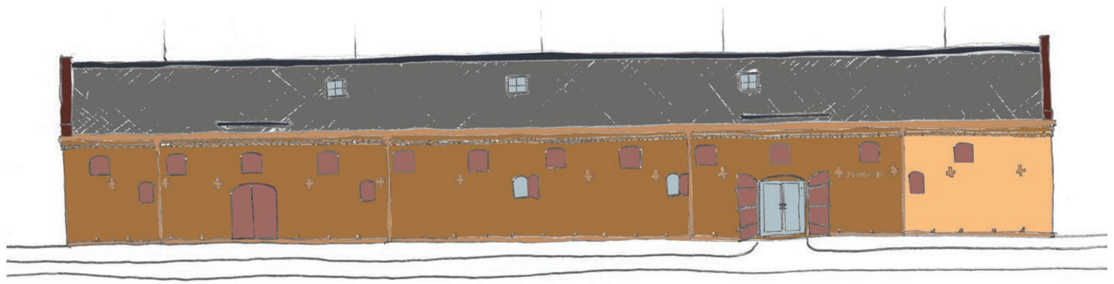
Suhmhuset; East façade



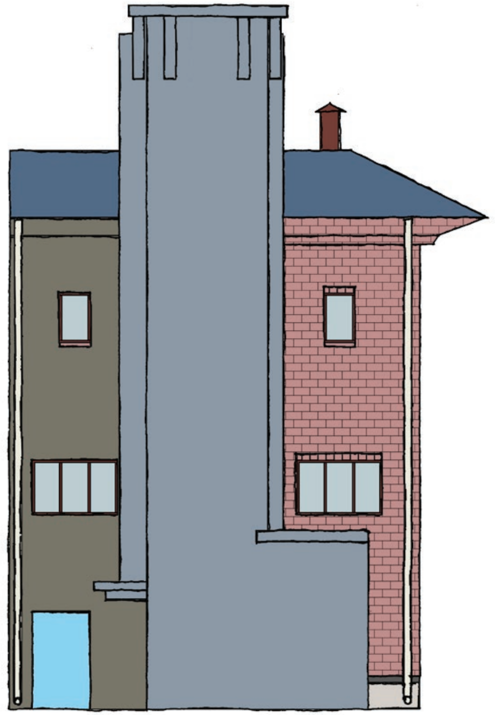
Schøninghuset; North façade



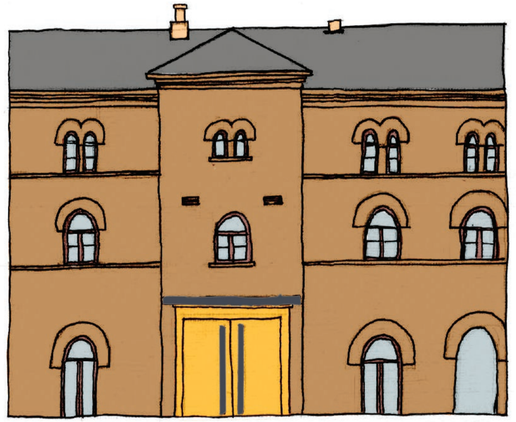
Schøninghuset; North-east façade



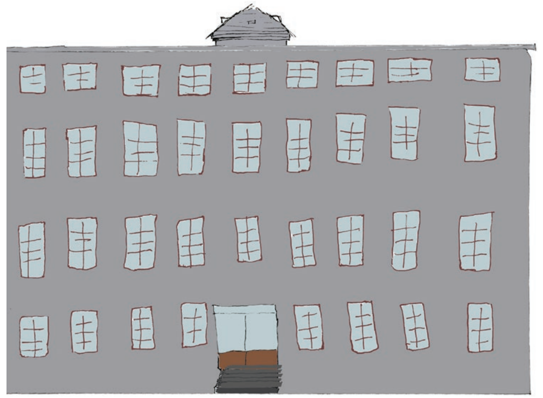
Suhmhuset; North façade



Schøninghuset; South façade



Gunnerushuset; East façade



Gunnerushuset; South façade

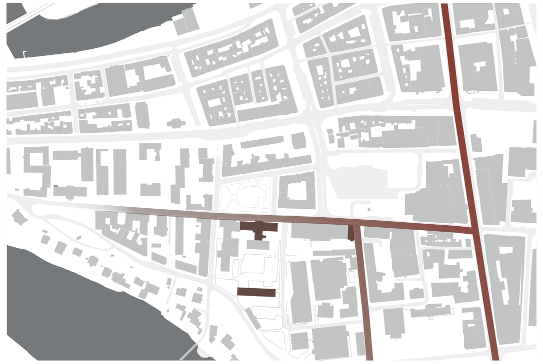
Polished orange plaster	Brown plaster	Orange-painted stone	Metal 3	Wood 2
Light-orange plaster	Brick 1	Stone rooftiles 1	White-painted metal	Red-painted wood
Orange plaster	Brick 2	Stone rooftiles 2	Orange-painted metal	Light-blue painted wood
Grey plaster	Concrete	Metal 1	Red-painted metal	Plastic
Yellow plaster	Stone	Metal 2	Wood 1	Glass

DECAY ANALYSIS

The variation of decay patterns on the three buildings are partly due to the difference in immediate surroundings and partly to the materials at risk.
Most common on the three buildings are the black and white crust due to the chemical agents from the traffic and city's pollution. Its decay is mostly evident in the severe blackening of the plaster surfaces especially on Gunnerushuset and Suhmhuset. The brewery has some blackening as well, but it is more affected by the salt weathering seen on the surface – potentially causing mechanical damage to the brick and mortar.
All the buildings are also affected by mold, moss and algae due to accumulated water on the window sills and minor back-splashing from the side walk. Gunnerushuset and the brewery are more heavily affected compared to Suhmhuset. The location of Suhmhuset surrounded by grass and gravel makes it more susceptible for capillary rise and back-splashing. The brewery and Gunnerushuset are also affected by back-splashing from the sidewalk as well as mold, moss and algae build-up around the drainpipes and metal detailing on the facades.

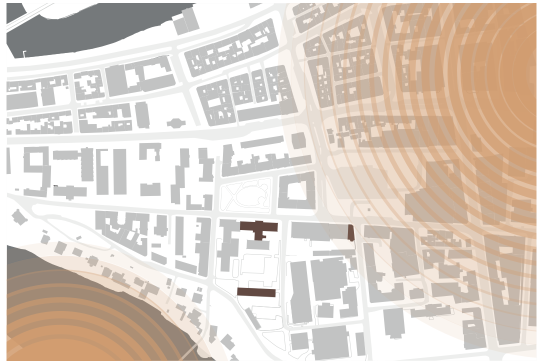
There is mechanical decay in the form of cracks in paint visible on Gunnerushuset and Suhmhuset. This type of decay is significantly more visible on the brick walls of the brewery: cracks in the mortar can be found on several places, mostly around corners, windows and details in the facade. This is typical only for the brewery because this building is exposed to the traffic vibrations the most and also exposed to vibrations caused by constraction work directly nearby.
Although exposed to the same environmental impact, each building shows different dominant decay patterns. Where most of the risks affecting these building are preventable as long as they are kept out of the building structure, the gaps in the brick walls of the brewery may grant access to mold infestation, chemicals and water to erode the building from the inside. For this reasons, the brewery is more susceptible to decay than the other two buildings. The following analyses will therefore explore in depth the current damage and sources of decay of the brewery only.

SALT POLLUTION



TRAFFIC POLLUTION

NEARBY GREENERIES

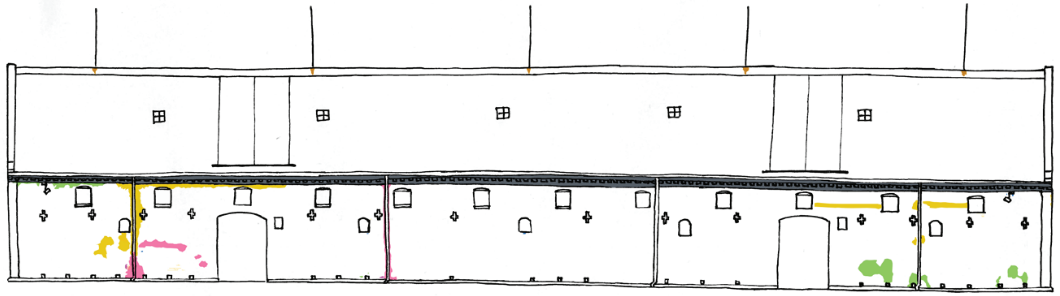


NEARBY SOIL CONTAMINATION

DECAY MAPPING

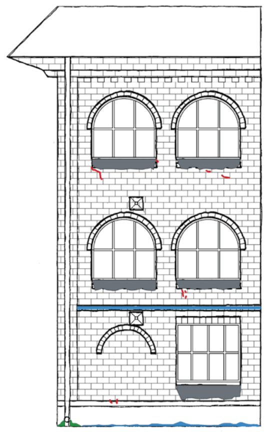
Suhmhuset; East façade

Suhmhuset; West façade

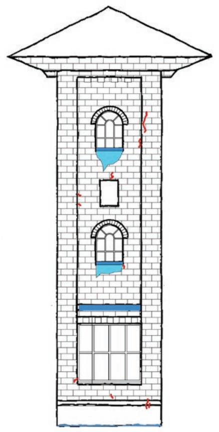


Suhmhuset; South façade

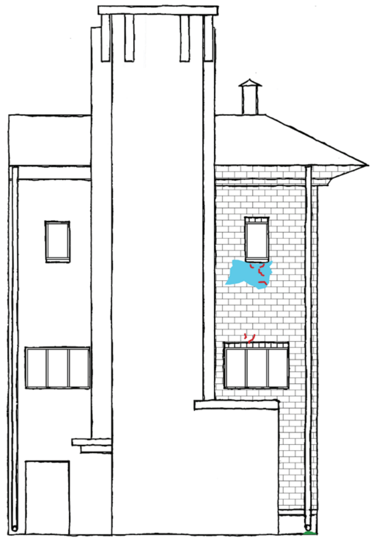
Suhmhuset; North façade



Schøninghuset; North façade



North-east façade



South façade

Schøninghuset; East façade

Biological

- Mould

Mechanical

- Micro-cracks
- Cracks

Chemical

- Detachment
- Pollution
- Corrosion
- Wash-out

- Man-made
- Discolouration
- Humidity spots
- Erosion
- Exfoliation

NDT ANALYSIS

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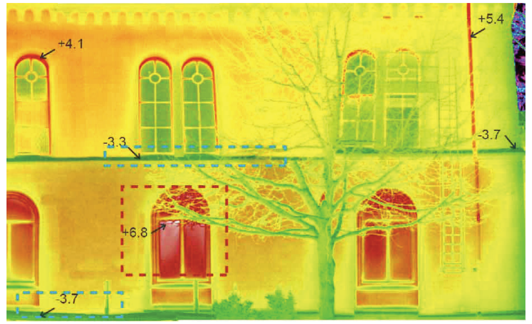
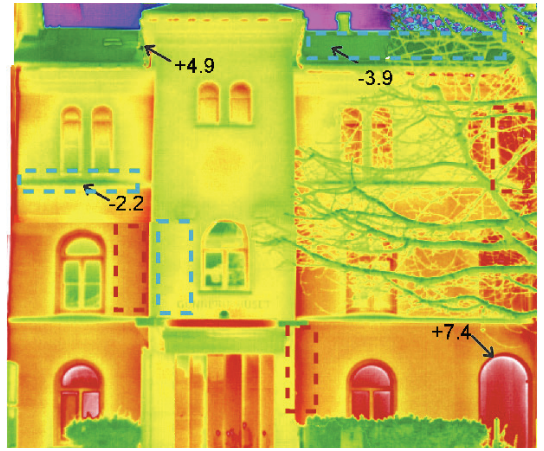
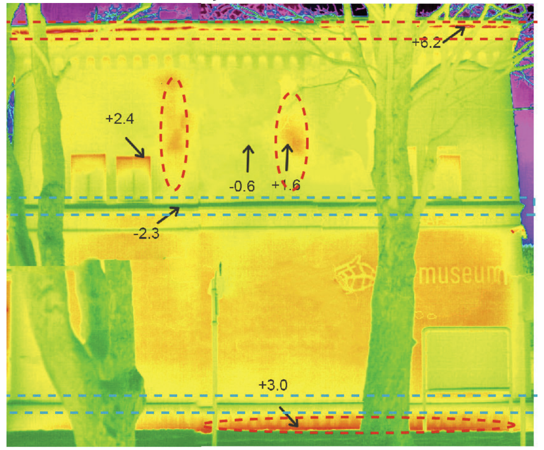


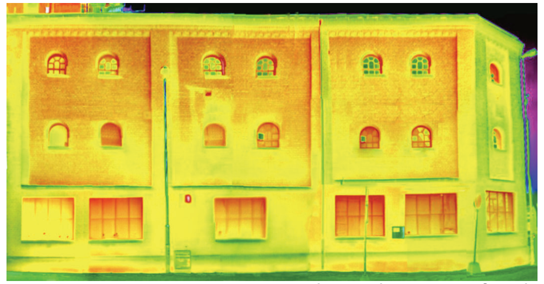
Gunnerushuset; South façade



Gunnerushuset; East façade, main entrance

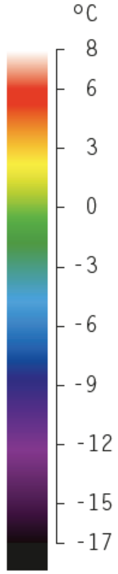


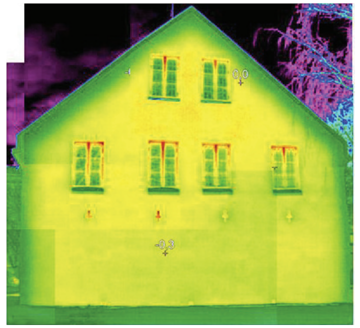
Gunnerushuset; East façade

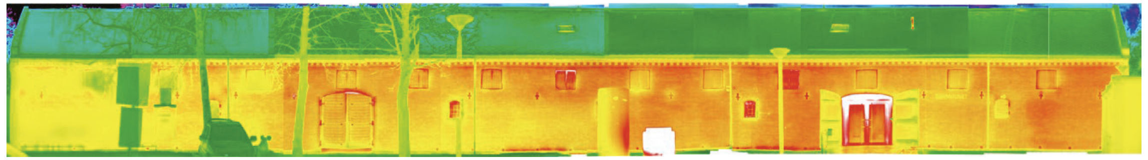

Schøninghuset; East façade


North-east façade


North façade

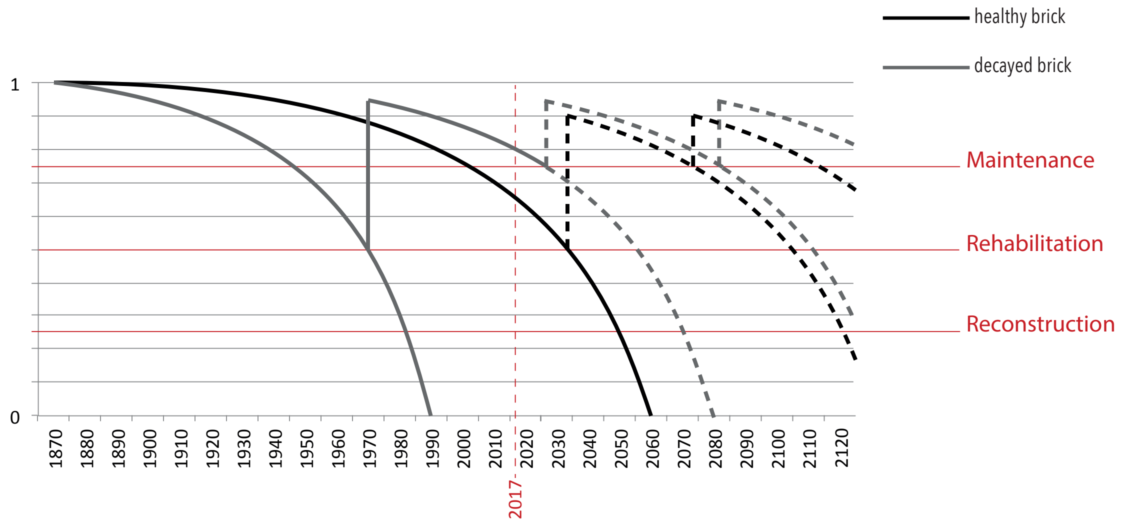


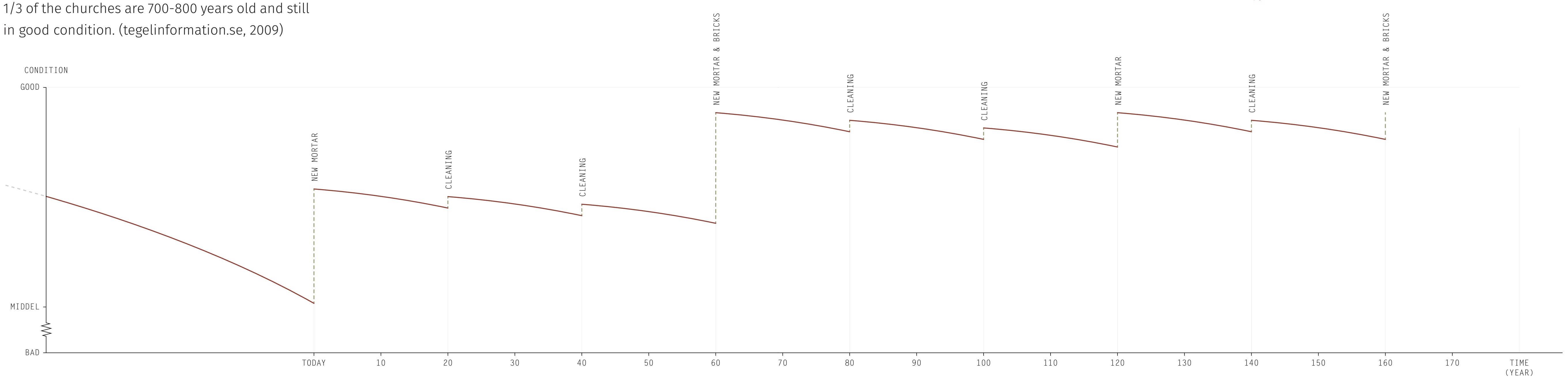

Suhmhuset; west façade


Schøninghuset; North façade

MATERIAL LIFE CYCLE SCENARIO

The estimated lifetime of bricks manufactured today is approximately 100 years, but they can last longer in a good environment. The lifetime for mortar is less. It has an expected lifetime of approximately 60 years, the lifetime is however closely linked to what the mortar contains and can therefore vary. Maintenance is a factor of great significance with respect to the lifetime of a brick wall and proper and regular maintenance can probably make the brick wall last for much more than 100 years. An example of this is the brick churches in Scandinavia, where more than 1/3 of the churches are 700-800 years old and still in good condition. (tegelinformation.se, 2009)





MATERIAL LIFE CYCLE SCENARIO GRAPH

PROJECTS

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GROUP X: PROJECT NAME

Students: Names

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