# informing sustainable architecture

## the STED project

Polyteknisk Forlag

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# If the key to sustainable transformation is in the design process – what benefits do ICT tools bring?

# INTRODUCTION

This book presents results from a joint project between 4 research institutions and 5 architectural offices; The Sustainable Transformation and Environmental Design (S.T.E.D.) project funded by the Nordic Built Foundation in 2015. It focused on design processes. The design process is where critical decisions are made. It seems evident that when inquiring about the factors that influence sustainable transformation, research on how design decisions are made should be at the fore. However, architectural design processes can vary quite significantly depending on the project and the architect. The design process is informed by many different factors such as the architects' skills, geographical and cultural circumstances, financial aspects, and technical possibilities. Architectural design processes, therefore, often have a high degree of complexity, which in some cases can be difficult to sort out and to communicate. Nevertheless, the use of information and communications technology (ICT) in this phase can have a great impact on the sustainability and on the performance of the building design. It is, therefore, of great importance to investigate the role of ICT tools in the design process.

During the three years of collaboration across universities and architectural companies in the S.T.E.D. project (2015-2018), it has become clear that design processes are based on tacit knowledge and therefore are not very tangible where sustainable transformation in architecture is really taking place. The central questions that emerged during the project were: Should quantitative information of a technical scientific character inform early design decisions? If so, how does it make sense to do so? And, how can this best be organized?

Being explicit and transparent concerning the information on which design decisions are based is not new for architects. History & Theory viewed as an institution in architecture can be seen as a true reservoir of knowledge, sharing design processes and strategies for all architects and related disciplines to learn from. With reference to historical examples, Vitruvius and Palladio's books defined architectural elements and systems of ordering and proportions and made tacit knowledge from centuries of architectural experience explicit and transparent to a broader audience. As manuals for design processes, these books greatly influenced design processes and design decisions of their contemporaries and today they are still points of reference. In other words, architectural design knowledge and methodologies can be transformed into systems of language and categorized in order to be communicated to other disciplines and to be used across the various design phases of the project.

In the same way, engineering knowledge has been made explicit, transparent, and available to the general public for centuries. During the last four decades, this has been done using software with easy-to-use interfaces and colorful graphics. The Swedish historian of building technology, Elias Cornell, has stated that all engineering really came about in an explosion of knowledge during the 19$^{th}$ century. In the 20$^{th}$ century, minor optimizations and adjustments were made. However, in the second half of the 20$^{th}$ century computation took off and discussions are still going on. If computation has improved engineering – or created new ideas – could an experienced structural engineer using graphostatics like Cullmann did around 1900 reach the same results in the same time as a modern finite element modeling expert? Yes, probably. The difference lies in the 'popularization' of engineering knowledge to non-specialists. The accuracy and the complexity that can be handled in a short time period enlarges the space of solution.

To early 20$^{th}$ century architects, producing drawings was an integrated part of the design process and the major part of consultancy service or what architectural offices were selling as products. Computation has changed this. Today, architects design models in software programs. They also define Building Information Models (i.e. use BIM) as part of their central project material. But in present day building projects these digital information models have many stakeholders and BIM is not developed by one group alone or for a single purpose. In recent years, these digital models have created a common ground for architects and engineers to collaborate and exchange specific information about the building design. The S.T.E.D. project enters the arena exactly here.

## Integrated Design

*Integrated design* is a common denominator describing design processes that take advantage of computation. In spite of three decades of research and development in integrated design, the concept and its practice are still vaguely defined. Also, it is only partially implemented in a handful of the largest and most technology appraising architectural offices. In short, integrated design states that design processes should be driven by interdisciplinary teams working closely together from programming and pre-design until the completion of the building. The integrated design processes consist of iterations of analyses performed with fast, accurate engineering software where graphical output from the software facilitates communication within the interdisciplinary design team. After each iteration, the design team evaluates the propositions and works on new design decisions in order to improve the outcome or to strategically direct the architectural design.

The MacLeamy curve is part of the story of integrated design. It was developed in 2004 by Patrick MacLeamy and shows that the time invested in providing and analyzing a high level of information in the early design phases (by an interdisciplinary team of experts) will minimize the problems and extra cost that the project might will have later on. This is important because the costs generated from altering the project or fixing problems in later design phases near completion are much more expensive than correcting or avoiding them in the earlier design phases.

The S.T.E.D. project questionnaires and interviews of the participating architectural offices have revealed that there are great differences in the degree to which integrated design has been implemented in the offices. In some architectural offices, the architects create digital models instead of drawing on paper with a pen, but no further ambitions concerning computation is demonstrated. In other architectural offices, the full scope of digital tools is embraced and the design processes at the architectural office are streamlined to address this. This irregularity in the use of digital tools is also manifest amongst the five participating architectural offices in the S.T.E.D. project and among the three partner universities.

## The transition from energy and indoor climate focus to Life Cycle Assessment (LCA)

During the first decade of BIM and integrated design methods, the focus was mainly on energy and indoor climate simulation. In the early 1990s and 2000s it was demonstrated that the building sector was by far the largest consumer of energy. In Denmark, as in many other countries, it became mandatory to document energy consumption by calculating kWh per $m^2$ in order to obtain a building permit (Energistyrelsen 2007). Research conducted during this period at universities in Denmark and internationally (Brunsgaard et al. 2014) (Koch & Buhl 2013) demonstrated that a large reduction in energy consumption could be obtained by addressing the overall building geometry, building orientation, and window façade proportion during the early design stages using ICT tools. This approach requires the adoption of new design processes and digital tools for optimizing energy use and to improve the indoor climate. This new approach was called Integrated Energy Design (IED) (Nielsen 2012; Strømann-Andersen 2012).

IED is implemented widely in the Danish building industry by means of utilizing the Be10 (Be15) software, which is the official documentation tool for a building's energy balances (kWh per $m^2$). Simultaneously, easy-to-use daylight calculation tools became widely used by architects.

The so-called third generation Sustainability Certification Systems (such as DGNB) use Brundtland's three levels of sustainability (social, economic, and environmental sustainability) as a meta-framework. DGNB proposes methods for systematically working with these three sustainability elements. It also includes easy-to-use software for documenting Global Warming Potential (GWP) and $CO_2$ emission effects, which together are one of the categories measured in Life Cycle Assessment (LCA). Thus, the $CO_2$ emission consequences of a design decision have come within the reach of architects and design engineers and could be used to inform the design process.

In the S.T.E.D. project, the majority of the tools and design processes developed address $CO_2$ emissions and LCA. Energy efficiency and indoor climate are still important parameters in a BIM/integrated design process but knowing the Global Warming Potential of design decisions has moved to the fore. It can influence architectural tectonics in fundamental ways and it gives the architects new arguments for choosing durable and natural materials carrying low embodied $CO_2$.

Life Cycle Cost (LCC) has also been a central part of the S.T.E.D. project. LCC includes considerations from LCA but adds an economical framework to the environmental aspect. By including all costs considered in the widest sense over a long period of time in the calculations, design choices that seemed obsolete a few years ago now can be argued to be economically beneficial and sustainable at the same time.

Both LCA and LCC expand the range of solutions in architecture. The industry partners of the S.T.E.D. project – the architectural offices – have a profound interest in developing design processes that are informed by LCC and LCA. The complexity and large amount of data for LCC and LCA seem to contradict the benefits of informing early design stages with these measures. However, the S.T.E.D. project has worked intensely with this question. It has demonstrated that this is possible and that the tools and procedures can be defined in many ways. Several of the tools developed in the S.T.E.D. project facilitate the integration of LCC and LCA in early design decisions.

## The transition from standalone tools to integrated dynamic tools

One reason that the immense complexity of LCA and LCC can be introduced in the early design phases is due to another major development that is currently taking place in the BIM field. In the hey-days of integrated design and IED, each engineering division developed their own simulation software, incorporating their entire professional knowledge from decades of research and practice. As an example, the Lawrence Berkeley Center created a large indoor climate and energy balance database *EnergyPlus* that runs through most of the software that HVAC engineers use professionally today. Structural engineers drew on finite element work by cohorts of predecessors when developing different types of structural calculation software. The German Ministry of Housing took responsibility for developing large databases of construction materials. This is the foundation of LCA software such as *Quantis Suite*. The Velux window company has developed the *Velux Daylight Visualizer* tool. These are all standalone tools where digital models can, at best, be imported and exported into the applied software with some difficulties.

Integrated dynamic tools work in a different way. Here the designer programs a direct link between the digital model and the engineering databases such as EnergyPlus. The link is structured by means of visual programming, where the coding is performed by manipulating graphics on the screen. The result is that when the architect alters the digital model of a building, he or she can instantly see the consequences given by the energy balance of a particular design decision. The same is true for LCA (e.g. Global Warming Potential), indoor climate, and so on. All the tools and design processes developed in the S.T.E.D. project operate within the paradigm of integrated dynamic tools where the intention is to create direct interfaces between digital models and engineering knowledge, and thus provide new combinations of information.

## Question–answer implementation as an organizational idea in the S.T.E.D. project.

The S.T.E.D. project is a development and innovation project. Therefore, it was essential that the industry partners (the 5 architectural offices) would want to be part of the development processes and to implement the various outcomes related to both general aspects and to the specific challenges in the projects.

Instead of work packages defined from the beginning (as is the norm in research projects), the development/innovation project was organized around the questions that the industry partners stated as areas of interest. The research institutions developed a series of methodologies, prototypes tools, and 'answers' (analyses) to these questions. These outcomes have then been tested and partly implemented in the architectural offices. In this way, series of iterations and tests have been taking place.

*Cases*

In one category, the questions encircled a specific project – a case. One example was with the partner in Sweden – *White Arkitekter*. The office of White Arkitekter is working with refurbishment of the 'Million Housing Programme' (1965-74). This housing scheme was developed during the 1960s and 70s. It set out to build 1 million dwellings in order to address a huge housing shortage in Sweden after the Second World War. Many of these housing estates are in need of refurbishment today. The White Arkitekter case of '*Ekocanopy*' is an alternative solution that addresses indoor climate and energy issues as well as aspects of social sustainability. The major part of the collaboration with White Arkitekter has developed around using ICT tools for quantifying aspects of the Ekocanopy design proposal, which appears to lie outside the scope of traditional perceptions of 'interior/ exterior' and 'building urban landscape' – instead, it is something in between. Based on the series of analyses, White Arkitekter has succeeded in raising interest and funding for a prototype development. *Helen & Hard* Architects also centered their questions around one particular case, the *Union Canning project*, which is an old manufacturing facility/warehouse in Stavanger that was in great need of refurbishment. A special circumstance in this case has been that Helen & Hard were not only the architectural designers of the project, but they also happened to have the role of the client since they bought the building and the surrounding land prior to the S.T.E.D. project. The question in this case concerned which strategy to use. Would it be most sustainable to add insulation and new windows and to plaster the interior walls, as is the most common procedure? Helen & Hard has a preference for using wood and has developed a series of wood-based projects, therefore the alternative would be to build large wooden enclosed spaces (boxes) inside the existing structure with only air cavities between them and the exterior walls. LCA calculations have demonstrated that innovative solutions may also happen to be the most sustainable.

*Tools*

The Danish architectural office *Tegnestuen Vandkunsten* had a more tool-oriented interest. The office has spearheaded the integration of Life Cycle Assessment information in early design decisions. The office has researcher specialists in this area and has worked to streamline the design processes in the office to match new LCA oriented strategies and demands. Tegnestuen Vandkunsten has been a driving force in the development and implementation of new interfaces (tools) between BIM and LCA during the S.T.E.D. project. Due to their expert competencies, they now can work more efficiently and strategically with LCA data, which provides a better overview in terms of particular sustainability measures that might be needed in a project. Also, they can work at a more general (generic) level across projects, which provides a well-defined baseline for sustainable solutions in their project portfolio.

*Design processes*

The third category of questions have addressed the design process at a practical level for the daily business and at a conceptual meta level.

At a practical level, the Finnish architectural office *OOPEAA* has been interested in developing design processes informed by ICT tools while preserving the characteristics and artistic endeavors of the studio. This is because Churches and Art Museums happen to be their main clients. The studio has a preference for using wood – but is wood always the most sustainable solution in these cases? This question has been investigated in collaborative studies and testing of various tools.

On a meta-level, KADK/CINARK has tested the Survey of Architectural Values in the Environment (SAVE) evaluation methodology in projects across the participating offices in order to support strategic decision making in the early design phases by mapping the existing qualitative values of the existing building environment. SAVE has not yet been developed into a digitally-based (ICT) tool. However, it has been applied as a planning and assessment methodology by Danish building authorities for estimating the present values and qualities of historical buildings and urban environments to define when a building is designated as "worthy of preservation".

Similarly, NTNU has proposed design processes where LCA has been applied in ways that help it to become the main 'design-driver'.

As part of the project, Chalmers has conducted a series of interviews to paint a portrait of the design processes taking place in the architectural offices of the S.T.E.D. project and how they developed or were altered during development of the S.T.E.D. project. 'Action research' conducted by DTU and White Arkitekter also belongs to this category of design processes. These research activities have focused on implementation of the new tools developed in the S.T.E.D. project.

## Future work

The overall ambition of the S.T.E.D. project was to target innovation in architectural design solutions and design processes for construction, renovation, and transformation. Furthermore, the intention of the project has been to develop a catalog of best practices that included sustainable architectural solutions and innovative design processes, methods, and services based on the Nordic Built Charter. Finally, the project has strived to develop process tools and concepts to implement the Nordic Built Charter in architectural design practice. All of these aspects have been addressed and worked with in different ways in the pool of projects and activities that have been part of the S.T.E.D. project.

With reference to the overall framework, the central topics of the S.T.E.D. project have been: How to specify the measures by which we define sustainability and to what extend is it possible to quantify the effect of a particular design decision? And to what extend should we inform the early design decisions with technical scientific knowledge and tools that are based on ICT (e.g. its inherent work procedures and logics)?

Certain areas of interest to the architectural offices defined within the framework of the S.T.E.D. project have proven difficult to address. Some of these difficult topics are described below.

*Social Sustainability*

Several of the architectural offices posed the question: How can social sustainability be quantified? How can we document if an architectural project works well socially? During the project, a couple of seminars on this question were held; these exposed the fact that researchers at Chalmers have a tradition for working with social sustainability and here methods for gathering qualitative data have been developed. White Arkitekter has invested seriously in developing and expanding their consultancy in order to deal with social sustainability. As part of this expansion, they have employed specialists outside the discipline of architecture such as anthropologists. Tegnestuen Vandkunsten have a history of working with clients who represent many of the largest social housing companies in Denmark and therefore focus on social sustainability in all projects (particularly their housing projects).

A direct outcome of the work with social sustainability in the S.T.E.D. project has been that Chalmers, Tegnestuen Vandkunsten, and KADK/CINARK have worked together on a Post Occupancy Evaluation (POE) of two housing projects designed by Tegnestuen Vandkunsten.
The first steps for developing an operational design tool have also been taken in a very extensive literature study on (all?) existing tools and methods for assessing and quantifying social sustainability in the built environment (including the ones developed by Chalmers and White).

*Natural and man-made materials*

A large part of the environmental impact of the construction industry lies in the surface treatment of exteriors (facades, roofs, exposed foundations, etc.). Often, facades are refurbished not because they are functionally rundown, but because they aesthetically do not live up to the expectations or present ideals. It is thus very important in a world of material scarcity to find ways to embrace the weathering of exteriors by hindering or prolonging their longevity. A ruin may be considered to be beautiful for centuries. Literal greening of architecture – the merger of Nature, Climate, and Architecture – is thus an important contribution to sustainability. A question posed by Studio Granda and Tegnestuen Vandkunsten was: "Is it possible to enhance the growth of lichen and moss on concrete and predict the growth rate?"

Biology has already proven to be a new partner for building designers and a couple of rounds of experiments with concrete facades and monitoring growth have been made in Iceland as part of the S.T.E.D. project.

*Climate change and early design processes of landscape architects.*

How can landscape architects get access to the engineering tools of urban flood water management without involving the consultancy of expensive environmental engineers?
This question has been addressed by DTU and Tegnestuen Vandkunsten who tried three tools that had not been used previously by landscape architects in a series of design processes taking place at the office. It turned out that one of the GIS-based tools could be used for early design processes in the landscape design discipline. However, testing showed that it needed some improvement. A collaboration with the software developer has since been established.

The three areas described above all concern interesting questions that apparently are of major relevance to the architectural offices. The questions have all been addressed and solutions developed even though they lie on the fringe of the S.T.E.D. project (whose major focus is directed more towards LCA and ICT tools in refurbishment projects). Even though these topics do not completely fit the matrix of the S.T.E.D. project, these sort of design problems are important to include since they point to the very core of the paradox: which topics and measures are suitable to address in the early design phases and what sort of ICT based tools should be developed for these purposes? What are the tools that truly support innovation and efficiency in the decision making and strengthen architectural design processes? Outcomes and questions that have been worked on in this part of the S.T.E.D. project are interesting and point towards future development of research projects within the group.

DTU Technical University of Denmark

CHALMERS

NTNU

NORDIC BUILT

Nordic Innovation

Vandkunsten

white

OOPEAA

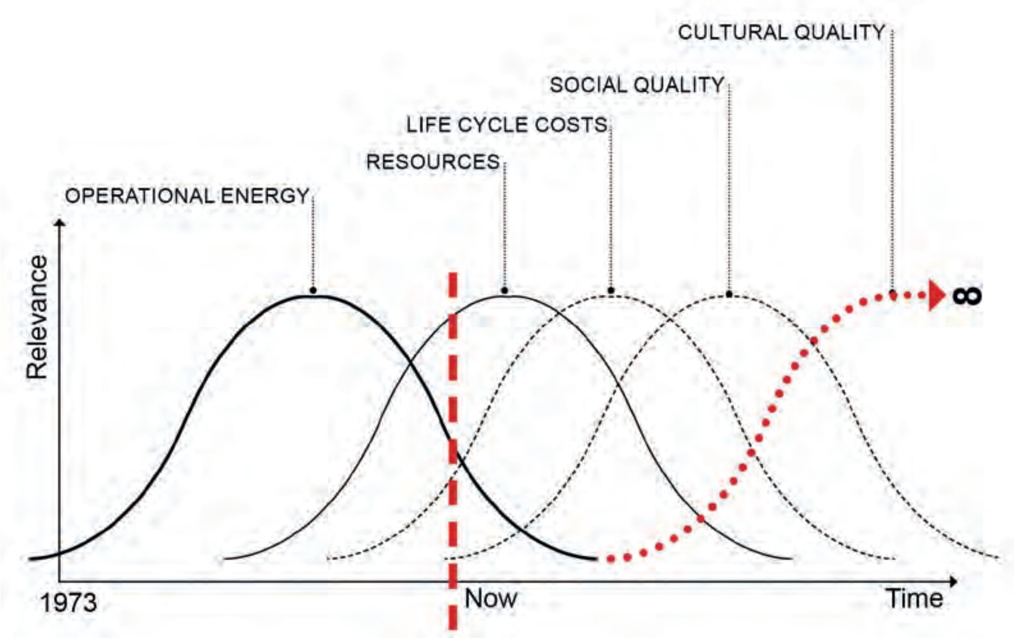
Studio Granda

HELEN & HARD

# without ~~beauty~~ BIM no sustainability

# Vandkunsten

Trends regarding sustainability in the building sector, Søren Nielsen, 2017




# VANDKUNSTEN'S APPROACH TO SUSTAINABILITY

## When we have control over quantifiable parameters, we create the freedom to preserve and maintain a social and cultural focus

Vandkunsten Architects has been associated with sustainability throughout the company's existence. Established as a counter-cultural and counter- technocratic architectural collective in 1970, our strong social commitment has been naturally accompanied by a critical focus on energy consumption, material use, weathering, and technology. At the time sustainability was not necessarily a positive association by our contemporaries, yet our work and ambitions to cut energy consumption in buildings have been incorporated into the legal Building Regulations. Meanwhile, the goals we set for various aspects of sustainability have developed to be more, as well as less, quantifiable.

While energy savings and LCA are considered to be quantifiable sustainability topics, it is on our agenda to further pursue aspects related to LCC. We see and predict how the agenda will change in various circles and create ways to measure and quantify each type of quality – maintenance, resource use, life cycle cost, social quality, and cultural quality – as illustrated.

Technology into design: Vandkunsten has a sustainability agenda of its own: new technical requirements and technologically-based resource saving strategies are approached with the intention of detecting and releasing every possible social and cultural potential. When we nerd out construction details and optimize cost for production or future expenses for maintenance, we aim at releasing economy for the architectural quality – and build buildings that are resilient – in terms of technical, aesthetical, and cultural quality. Modern headlines for sustainability are, in fact, classical Vitruvan virtues that we, as architects, pursue for all projects. It has been our experience over decades of practice that when we have control over quantifiable parameters, we create the economic latitude to preserve and maintain a social and cultural commitment.

Sustainability should never be an excuse for impairing spatial, material, or compositional quality, rather it should become a vehicle for artistic development - as expressed in the slogan: 'No Sustainability without beauty!' This slogan is coupled with another – 'To BIM or not to be' – implying that BIM is a necessity for efficient and resource optimized production and furthermore that the use of BIM affords freedom to pursue beauty.

Social engagement: Vandkunsten has a long history of engagement in the everyday lives of ordinary people. Our houses are designed to support non-conformal ways of living. Housing, workplaces, and cities have to be at eye level and make room for communities. At the risk of sounding extravagant, we reserve the right to think and believe that good architecture has the capacity to make society more livable. Our architecture rarely draws attention to itself but seeks to engage in a dialogue with the people and communities that use it. For nearly 50 years, we have challenged the routine practices of the construction trade and consistently sought to create architecture that embraces social and sustainable goals. The process always begins with history - with what already exists.

BIM: Does a social focus imply less engagement with technology for construction or digital media? On the contrary! At Vandkunsten we welcome BIM tools as potent remedies for efficiency improvement as well as for explorative fact-finding exercises in the design process. Experiences from the deployment of multiple dimensions of BIM (e.g. lifecycle parameters, indoor climate, flooding, costs, construction logistics, and safety) inform the level of consciousness with the designing architects – even when the tools are not applied. The cases displayed in this publication are examples of how a socially engaged office finds it helpful to cultivate BIM tools in order to become less restricted by – and better prepared for – new requirements for saving energy and resources.

Business perspective: The BIM development projects we undertake at Vandkunsten in collaboration with Technical University of Denmark (DTU) are part of an overall business strategy of strengthening the innovative capabilities and knowledge base of our company in order to maintain our position as an independent business. Widespread integration of improved BIM tools in the early phases of project planning affects the general mindset of the designers, in turn leading to competitive and attractive architectural concepts. In the ten-year period from 2007 to 2017 Vandkunsten has increasingly engaged in focused and strategic in-house research, often co-funded 50/50 by grants and always in collaboration with universities and approved research organizations. The balance between the net expenses of these activities and the resulting turnover from commissions won solely due to research implementation has shown a return of investment rate of minimum 1:25 over the period. It is a necessity to undertake research in order to remain at the forefront of the competition.

# THE LCA QUESTION

Related Nordic Built STED Project: Sustainable Design with Respect to LCA using Parametric Design and BIM Tools

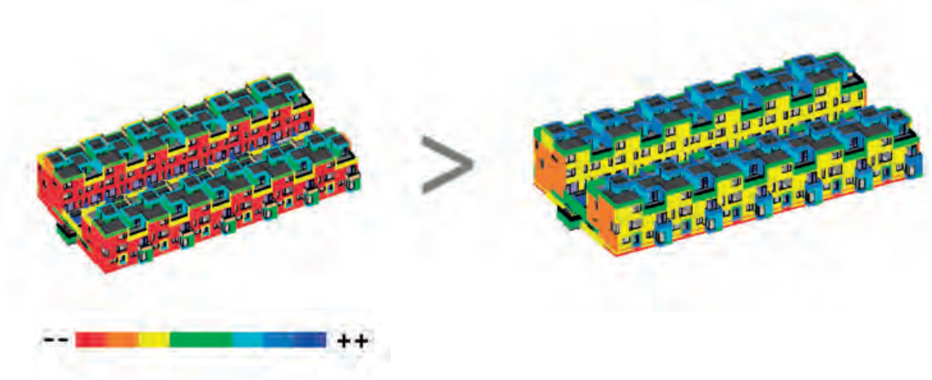



Fig 1: Visualization of impact category "global warming potential" for two options of a building design regarding materiality. Graphics are generated with Aeforos in Revit.

At Vandkunsten we have found through different projects and tasks related to sustainable design that information from LCA is relevant for the design process and actually does support design decisions in the early project stages. At the same time, no tools exist to allow us to use LCA in the early stages when information about the building design still is vague and when many changes are expected that will affect the LCA and make it necessary to redo the analysis. Furthermore, the existing tools do not allow us to perform LCAs quickly enough to actually be able to inform the fast-paced and on-going design process in a sufficient manner.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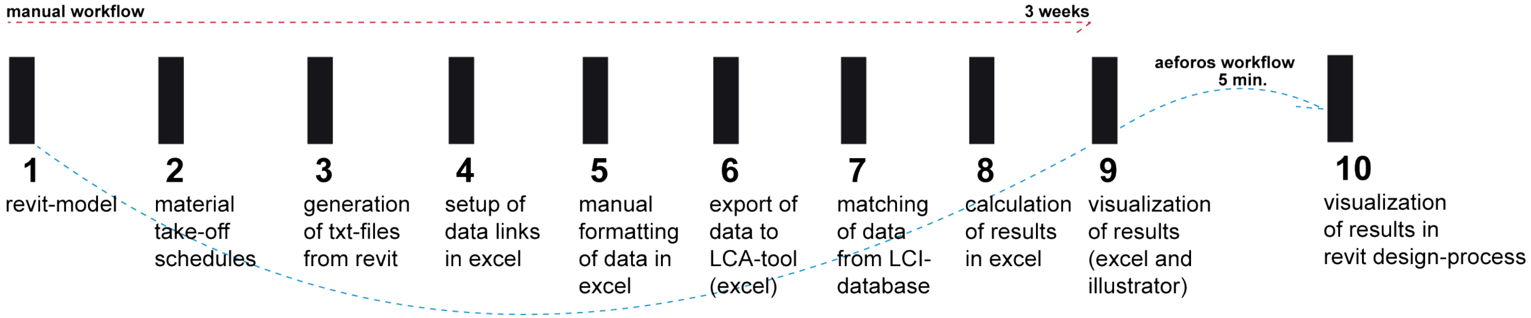
Both problems have led to the idea of creating a tool – on any possible platform – that will enable us to utilize Revit models (1) using various LCI databases (2) to get quick results in a variety of formats (3) and to control data input and user-generated errors (4).



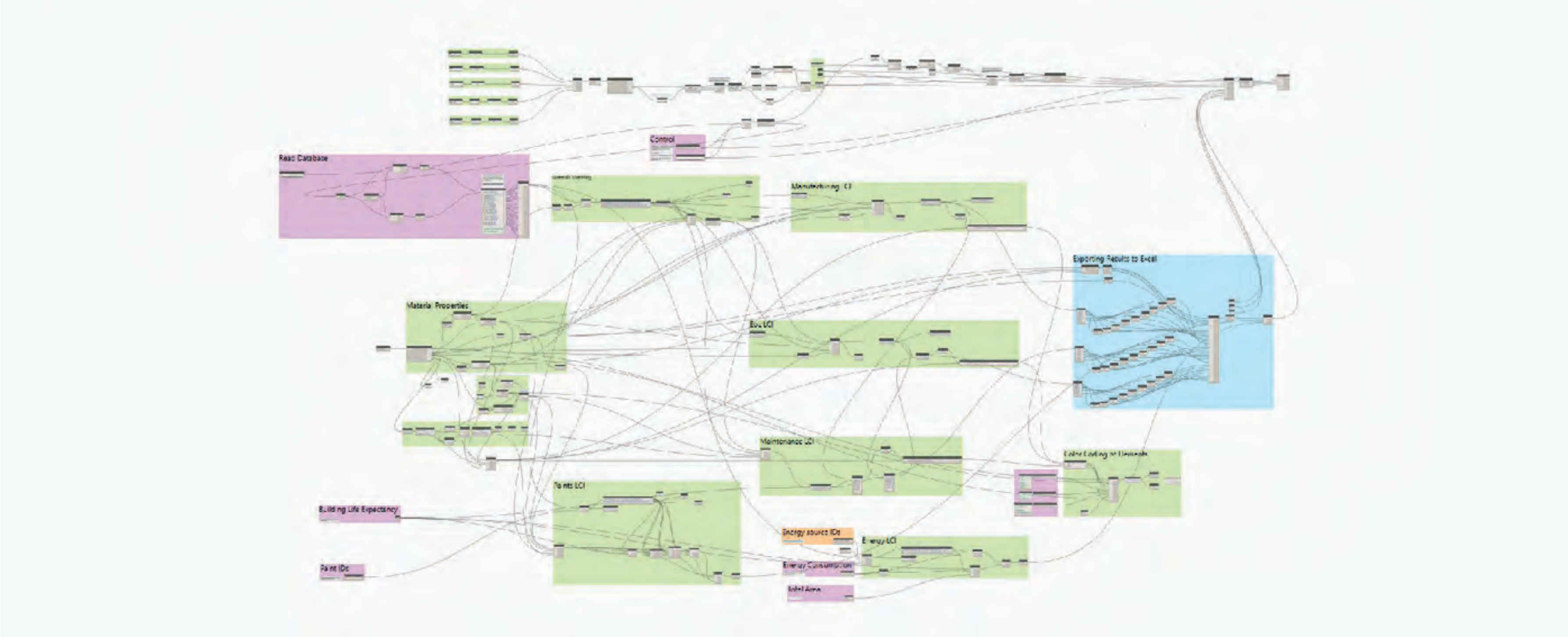

Aeforos performs a workflow in 5 minutes that traditionally takes 3 weeks

1. Revit models: In manual LCA processes, we found, in particular, that the LCI (inventory) is very time consuming; this results in a barrier for calculating and comparing many variants of a design. 3D BIM models provide the data to do quick material takeoffs at nearly any point in the design process that can form the basis for the LCI under certain predefined conditions.
   The main purpose of drawing in Revit still is to generate 2D plan drawings (and not to perform LCAs).

2. LCI databases: For the time being architectural offices are merely bound to the freely available LCI data, e.g. ökobau.dat or producer-issued EPDs. Since LCA has become a vital part of certification systems, e.g. DGNB, an LCA tool should be usable in a variety of contexts and for different purposes (e.g. early design stage, certification, full LCA after design-build phase, etc.). These requirements make it necessary to separate the tool from the database and thus allow the usage of different databases / datasets.

3. Speed and output: Calculation speed is crucial in the early design stages. If results cannot be calculated quickly and often, including after small changes in the design, then LCA cannot efficiently be used as a design-informing tool.
   The output needs to be versatile to allow any possible usage of the data. All different data levels need to be accessible to allow comparisons of materials, building elements, and at the building level over different time periods. Furthermore, a graphical overview is needed to allow, for example, quick hotspot analysis.

4. Data input and errors: In manual LCA processes, we found that manual input of data and parameters leads to “user-generated” errors that are difficult to identify once the data is compiled in the LCA. This is true regardless of the tool used. The automated processes of reading values from the 3D model, reading the LCI database, connecting materials in the 3D model with data sets from the LCI database, and producing the output minimizes the probability of errors in the data input and the later calculations.

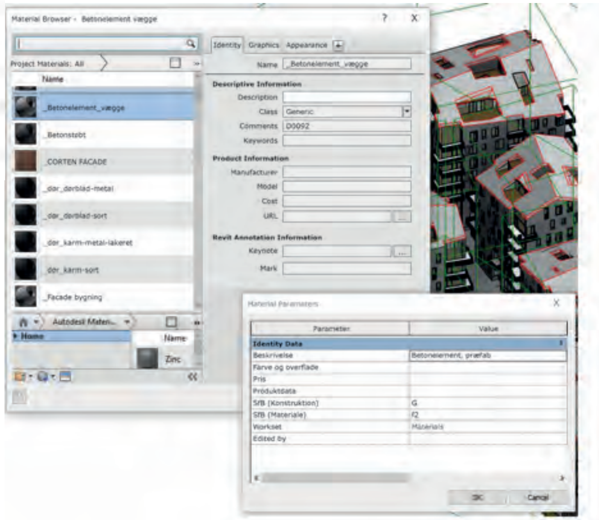


Screenshot from the Aeforos Dynamo script

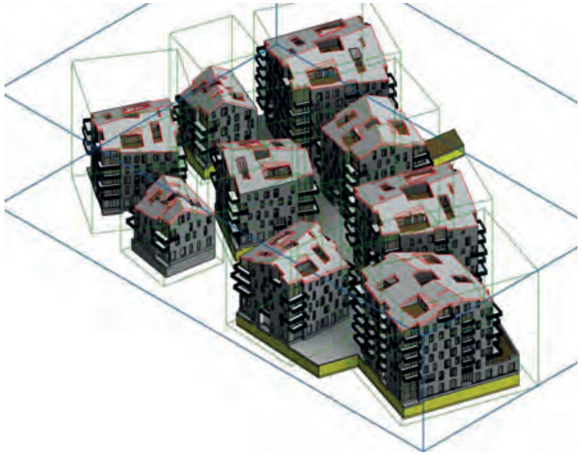
**One solution…**

… to our problem has been found in the development of a Revit/Dynamo-based tool – Aeforos – that was programmed by Marios Tsikos in 2016 while he was a Master's student at DTU. The tool addresses all of the issues discussed above and was specifically developed to address real design processes and the types of drawing that we do at the office. This point is very important and one of the reasons why established tools such as Tally have not been an option for us; we cannot alter the way that Revit is used by the different project teams at the office who are just beginning to utilize existing LCA tools. Thus, our "custom-made" tool started with the office's existing workflow around Revit with a focus on minimizing the changes to the workflow and the office-specific Revit templates. The key was to connect the LCI database (e.g. ökobau.dat) to the material database in Revit by using unique IDs for materials. This allows the data sets in both databases to be matched regardless of naming conventions, changes to the material database in Revit (which usually happen for graphical reasons in the drawing process), and/or changes in the LCI database (which usually happens when the databases are updated). The material databases in Revit can easily be administered and used across different projects without requiring the people who actually work with the projects to have any knowledge about LCA.

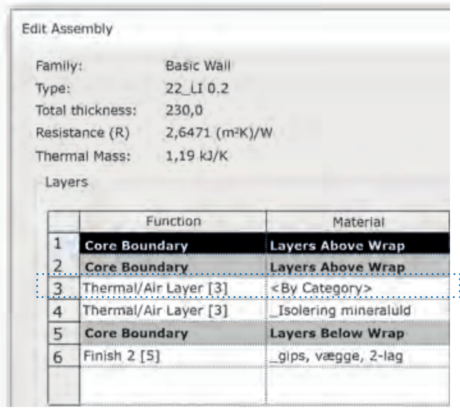
Aeforos also has the ability to output all raw data to Excel and, in connection with predefined graphs, to give a graphical overview of all impacts and resource uses to enable quick analysis by comparing data on materials, building elements, and/or at the building level in Excel directly. LCA data can also be output into the Revit model itself, giving a graphical overview directly in the 3D model (Fig. 01).



Screenshot from Revit, showing the material database and ID link to the data sets in the LCI database



Screenshot from Revit, error checking of the model prior to the LCA calculation process




Screenshot from Revit, typical error that is found in the precheck proces: a layer in the wall assembly has no material assigned to it.

In order to ensure that a Revit model can be used, there are a couple of pre-check modules that can be applied to spot errors in naming, material connections, and the connected database prior to running the LCA. This function has proven to be especially useful when using Aeforos on "older" models that have been drawn without the post-Aeforos "office standard".

## Less human errors

During Aeforos' testing period and the comparison of its results to those from, for example, LCA.Byg it became obvious that a key advantage of the Revit/Dynamo LCA tool was fewer steps necessary for the user. For example, our testing showed that a huge error quotient is added to the calculation (up to 20%) during the processes of material takeoff in a CAD program, subsequent conversion in Excel, matching of building elements and materials to the LCI database, and eventually yet more data conversion.

When using the integrated tool, many of these steps are automatically performed, and errors are thus not possible to the same degree.

On the other hand, having everything programmed means that a thorough check of the input data is necessary as errors in data sets or in the way material takeoff is conducted are much harder to spot.

## Read more about the project in the following publications:


Tsikos, M., Negendahl, K. & Kauschen, J.S. (2017). Sustainable Design with Respect to LCA Using Parametric Design and BIM Tools. Paper presented at World Sustainable Built Environment Conference 2017, Hong Kong, Hong Kong.

Tsikos, M. (2016). Sustainable Design with Respect to LCA Using Parametric Design and BIM Tools. Master's Thesis DTU, Kgs. Lyngby.

# IMPLEMENTATION @VANDKUNSTEN

LCA calculation of global warming potential (GWP, left) and ozone depletion potential (ODP, right) for the project Bispevika, Oslo (2016) as part of a pitch for the client on the sustainability assessment and more specific LCA

Illustration: (Bispevika)

As part of the STED project, the industry partners had agreed to attempt to implement the newly developed tool into their office work and workflows.

Aeforos had such an immediate impact in 2016 that the main office template was adjusted. The material database was also adjusted after undergoing an update process. Furthermore, some code blocks were developed to perform more accurate material take-offs from models for use in conjunction with the production of tender documents for two projects.

Implementing the Aeforos tool has proven to be difficult because the main reason to change the workflows is necessity, e.g. in response to a client request or for a task related to a project. Since the value of LCA in the building sector is still not fully acknowledged, there are very few projects where the clients specifically ask for an LCA. Mostly, we use it on a smaller scale when comparing different material options to each other. Thus, there has not been a strong incentive to use LCA as a standard in our design processes. In addition, the need to have Aeforos used in more projects decreased after the development of Aeforos at Vandkunsten ended.

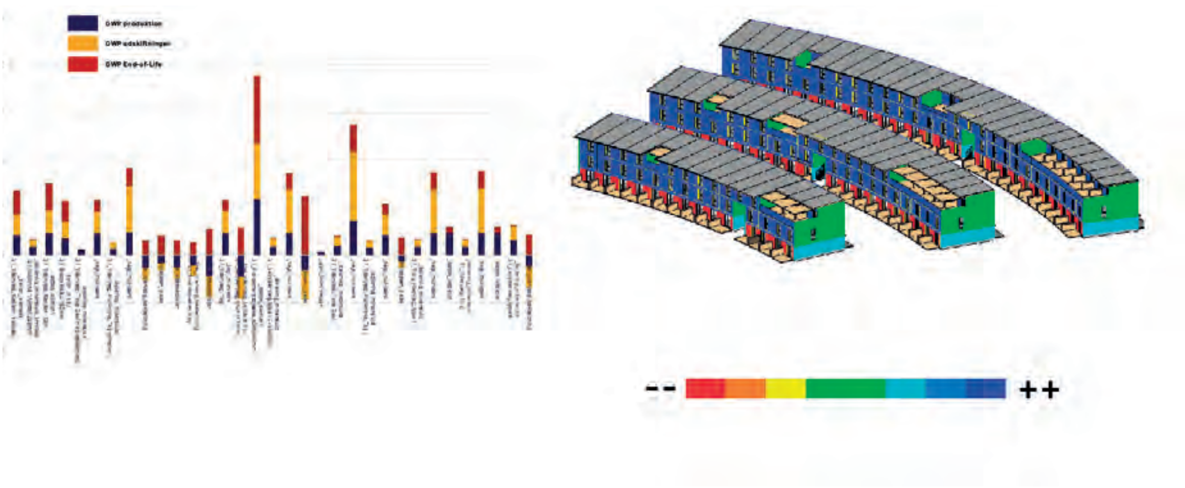
To make Aeforos widely accessible, Marios created a package that can freely be downloaded from the Dynamo repository.

In 2018, we have to say that Aeforos had not been used as much as expected during its development – merely due to the lack of tasks related to LCA, and not because it is a complex piece of software or because its usage is demanding.

# AEFOROS 2.0 + LCC?

Project: Aeforos 2.0

Example of output from Aeforos for an older Revit file - Danmarksgrunden from 2012




Perhaps the biggest issue with developing a script like Aeforos is the task of keeping the software and databases updated. As LCA in the building sector is still in development, the accepted method is due to change. LCI databases such as oekobau.dat are updated once or twice a year and include changes in the internal structure. These issues were, of course, discussed in the course of developing Aeforos, but were not so important during the initial development and the first few times using it. But after a year or more, concern that the software was not sufficiently up-to-date was enough to cause designers to stop using Aeforos and to fall back to alternatives that are serviced externally.

Secondly, we found that life cycle costing (LCC) was becoming increasingly valuable during design processes and that LCC, especially in combination with LCA, made results much stronger and easier to communicate when questions about the sustainability of a material or building component needed to be answered.

The way LCC data is generated from a Revit model is very similar, while the data input and data sources regarding economic data, of course, were different.

Photo: Danmarksgrunden

# LCC.BYG + REVIT DYNAMO PLUGIN

Thesis student Kristian Brink, DTU + Vandkunsten 2017

## Still under the STED umbrella, we decided to start a project where we connected Revit to the established programs by Trafikstyrelsen: LCA.Byg and LCC.Byg.

In 2016, it seemed possible to generate data files directly from within Revit that could be read in LCA.Byg and/or LCC.Byg. The task was then formulated and given to two students from the DTU Department of Civil Engineering (DTU Byg – Institute for Byggeri og Anlaeg). While the project regarding LCA.Byg never really got started within the time frame of STED, in July 2017 Kristian Brink from DTU Byg successfully developed a Dynamo plugin that would read model data from Revit and output a text file that could be opened and further handled in LCC.Byg.

The idea behind both projects was to avoid having to program and maintain the core for the calculations ourselves and to be able to comply 100% with the standards that will be set for LCA and LCC in the Danish building sector in the future.

The approach of generating a readable data file proved possible, yet it was not without problems. Especially for LCA.Byg, it quickly became clear that the construction of the data files was very complex and thus they were difficult to generate without deep insight into the way that LCA.Byg was programmed. For LCC.Byg, the approach seemed to be more straight forward, as the file structure and the complexity of the contents are smaller in LCC.Byg.

**LCC+REVIT**

The LCC+Revit plugin that was programmed in the project started with a wish to be able to conduct LCCs in parallel with the development and design of a project in Revit. The main task was to establish the connection between LCC.Byg and Revit; there was less focus on the LCC method itself or the way it could be integrated into our office workflow (as this was a task for Aeforos). Very unusual for the office, we neither critically questioned the way LCCs are made nor attempted to find a new way of implementing the method.

The setup in Revit is fairly simple – the LCC+Revit script builds upon the Aeforos scripts and conducts the material takeoff in a similar way.

The main functionality of the LCC+Revit tool is to reformat the Revit information to fit the structure of the LCC.Byg data file.

As we do not input economic data into the Revit model yet, we decided to input LCC.Byg itself as this is fairly easy to do. In a next version of the tool, we imagine it will be possible to use data from material or component parameters that reflect cost information since the inclusion of lifetime data is high on the wish list.

After running the script, an .xml file is generated that can be opened again in LCC.Byg. Here, the final input has to be done – the tool itself has created the building elements and typed in amounts and has thus undertaken the most time-consuming tasks.

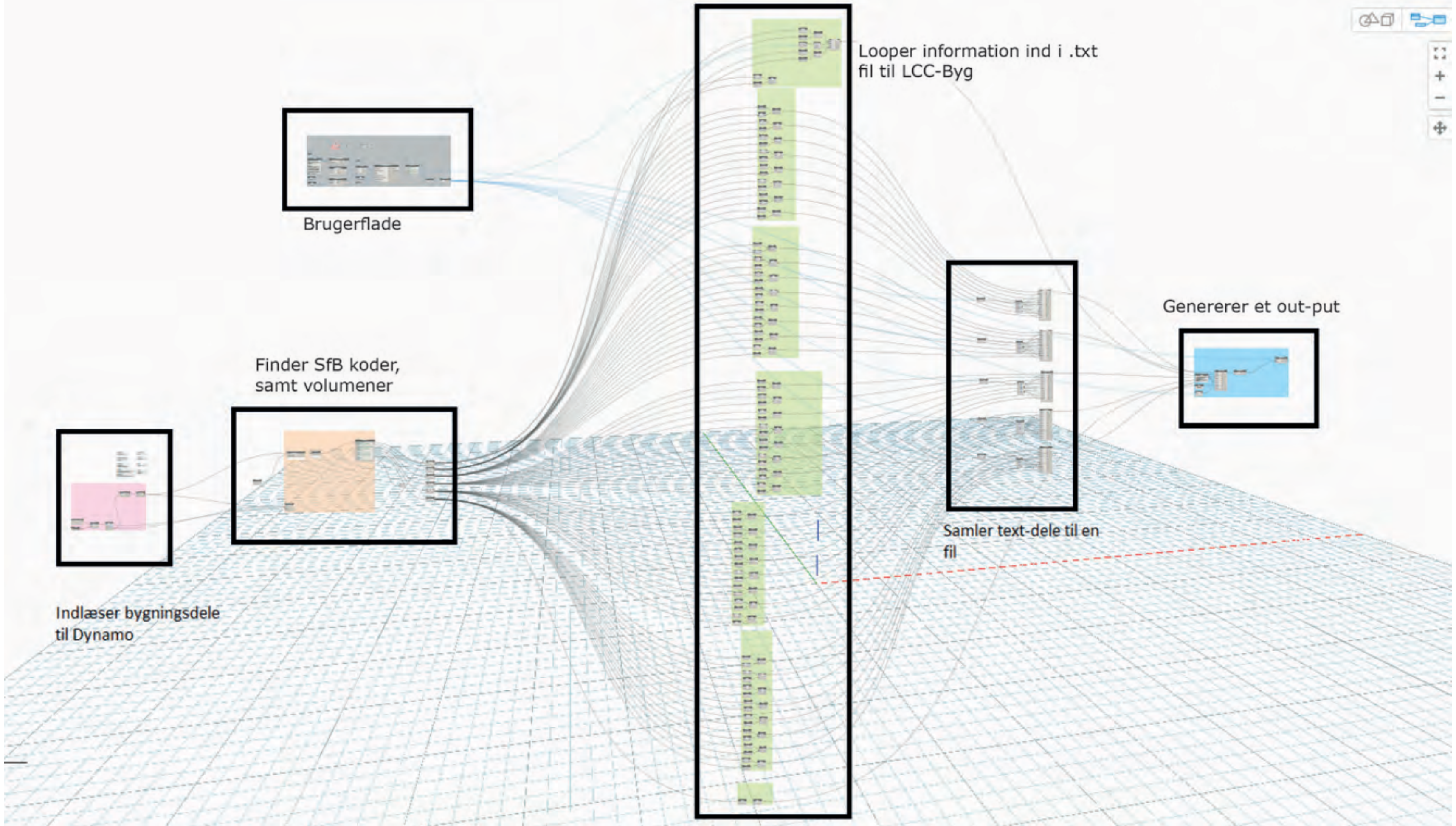
**Bill of quantity as yet another approach?**

After discussing this approach with the people behind LCA.Byg, and especially with those behind LCC.Byg, namely senior researcher Kim Haugbølle and programmer Peter Scheutz from SBi, it seems that our approach is a fine example of functionality but will not succeed in the long-run.

This prediction is based on the strong focus on Revit in the project and the fact that the possibilities that lie within Dynamo cannot easily be transferred to other BIM programs. Furthermore, it would be preferred if the data formats of LCA.Byg and LCC.Byg were altered in a way that allows open access to them. The idea of a bill of quantity ("stykliste") – a common exchange format for both LCA.Byg and LCC.Byg – was suggested by Kim Haugbølle/Peter Scheutz . After all of the learnings from the STED LCA and LCC projects, we conclude that a straight forward approach that can be used for years to come is certainly worth pursuing in the future.

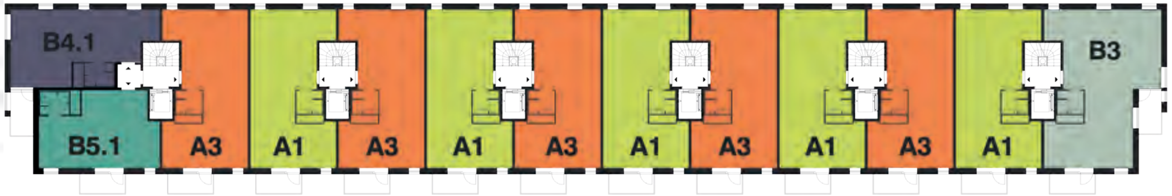
# THINGS TO COME

Screenshot from LCC+REVIT Dynamo script

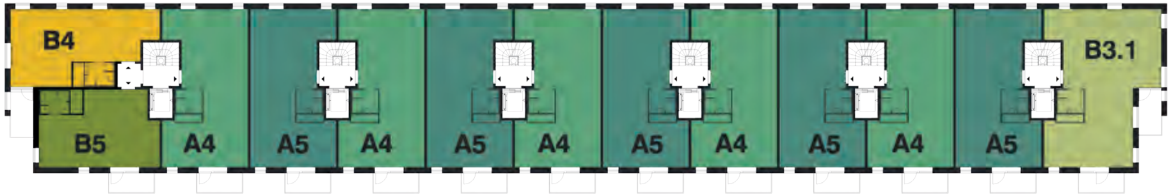



LCA and LCC will increase their relevance for sustainable buildings and the assessment thereof. In Denmark it is likely that a voluntary sustainability class will be adopted in the building code that will request both LCA and LCC information as part of the official building documentation. The sustainability class has been talked about in a long time. Now it should be implemented: the sooner the better!

# LEARNING FROM POST-OCCUPANCY EVALUATION AS A FOUNDATION FOR SOCIAL SUSTAINABILITY ASPECTS




| FLOORS 2,4 and 6 | | | | |
|---|---|---|---|---|
| A1 | A3 | B4.1 | B5.1 | B3 |
| 5 | 5 | 1 | 1 | 1 |




| FLOORS 1,3 and 5 | | | | |
|---|---|---|---|---|
| A4 | A5 | B4 | B5 | B3.1 |
| 5 | 5 | 1 | 1 | 1 |


| GROUND FLOOR | | | | | | |
|---|---|---|---|---|---|---|
| A1 | A2 | A2.1 | A3 | B1 | B2 | B3 |
| 4 | 4 | 1 | 1 | 1 | 1 | 1 |

Results from a recent questionnaire (68% answer rate, n=315) sent out in a Chalmers project to inhabitants in Swedish modern owner-occupied apartments (similar to the Danish andelsbolig) showed that considerable reconstructions were made by the residents themselves shortly after moving in. The reconstructions were driven by a wish to personalize the home, but also by the low quality of materials and equipment at delivery and the layout of the apartment itself. More than 30% of the inhabitants had reconfigured the layout of the apartment by altering openings or internal walls. Alterations have been made to fit the changing needs of the inhabitants (i.e. dividing rooms to fit in more residents) or to increase functionality or possibilities to furnish. Many respondents saw adaptability as a major quality of their apartments and felt very satisfied with their apartment after their own adjustments. The material flows and related climate impact of the owner-occupier reconfigurations were estimated to be large enough that they should not be neglected when considering the sustainability of modern apartments from a life cycle perspective.

These results raised the question of whether apartments could be a more sustainable alternative in terms of generating less material flow and providing a higher user satisfaction if they delivered more as raw space, e.g. without internal walls, flooring, equipment etc.

Æblelunden, designed by Danish architects at Vandkunsten Architects, was built in 2008 as an owner-occupied

# PROJECT: CHALMERS + VANDKUNSTEN

Vandkunsten: Anne-Mette Manelius, Jan S. Kauchen. Chalmers: Ruxandra Bardas-Dunáre, Paula Femenías. KEA: Jan Johansson.

apartment complex for a private developer. Designed at the height of the pre-crisis real estate market, there appeared to be a need to offer a more affordable solution for potential buyers. Apartments were sold and delivered with five levels of outfits. Level 1 had no floor coverings - just raw material, no internal walls, and a small basic kitchen. The concepts for levels 2 to 4 included full kitchens, wood flooring, and an increasing number of internal walls to divide the initial space into up to two bedrooms, a kitchen, and a living room. Level 5 was fully equipped, also with storage and finishes, and had three separate bedrooms. All the apartments had a fully equipped bathroom.

Æblelunden has a total of 91 apartments with 14 different plan types.

The aim of the project became to investigate to which degree the flexible outfit of the apartments was still an asset and whether the inhabitants had altered their apartment layout in the ten-year period since the construction of the building. A questionnaire in Danish was carefully prepared and designed with an attractive layout including individual apartment types and was delivered in all mail boxes in early summer 2017. The questionnaire gave the inhabitants the possibility to show how they (or a former owner or resident) originally fitted out the apartment after delivery, how the apartment looks now, and the plans they have for future alterations. The questionnaire focused on what has been done, the satisfaction of the alterations, the satisfaction with this kind of housing concept, and the skills and resources that are need to engage in this kind of housing.

Despite the high level of preparation, unfortunately, the response rate from the first round of questionnaires was very low . A reminder was sent out along with a link to an online version of the questionnaire. The low response rate persisted and responses offered no academic validity.
The low response rate may be linked to a number of factors: The Æblelunden project was delivered in 2008 during an economic crises that hit the real estate market in Denmark very hard. As a consequence, almost 50% of the initially designated "condominiums" were initially sold to an investor and are now rented. Another group of apartments are sublet by the private owner. The administration of the building is divided between a group of owner-occupiers and a tenant manager responsible for the majority of the rental apartments.

The research group was unsuccessful in making engagements with any of the organizations and contact people – hence, as opposed to a well-known 'ambassador', we had only the mailbox to inform residents about our intentions.

The high number of tenants in sublet or rental apartments seemed to be a major factor in the response rate. Tenants

traditionally have few options or motives to alter the layout of the apartment and little knowledge or relationship with the original story of the building and hence the premise of the investigation.

There is a remarkable difference in the answer rate of 68% in the Swedish study and 7% in the Danish study.

Without comparing results in detail, it appears that the culture of Swedish inhabitants in owner-occupied apartments varies from the Danish model, especially in terms of the mandatory layout of Swedish apartments (e.g. built-in closets and wardrobe) and the general tradition and regulation of how apartments are left when sold.

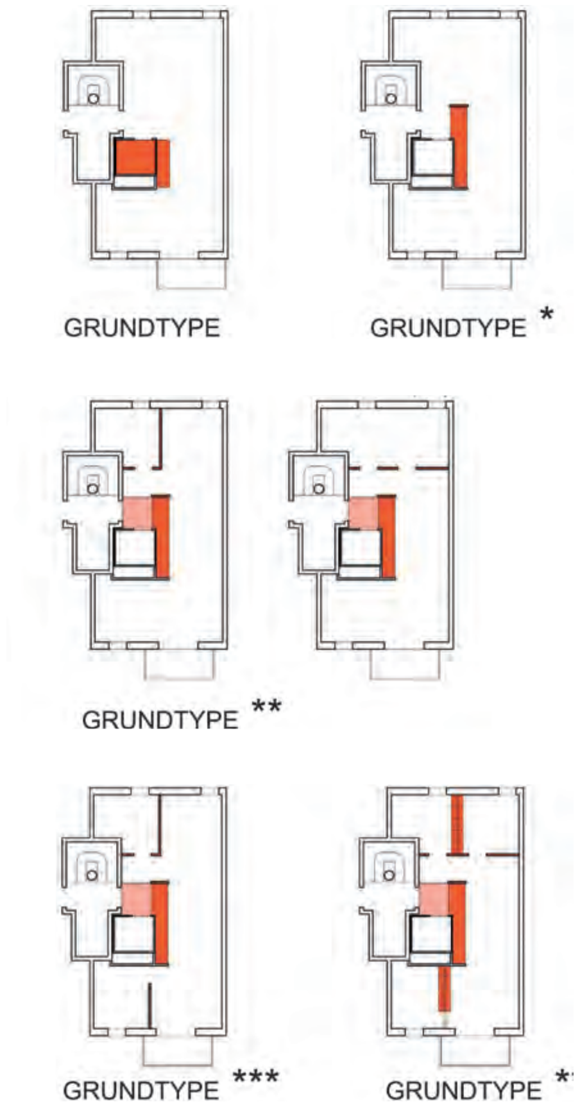
Furthermore, the varying response rates may be based on other factors that are worth investigating. For example, we encountered several inhabitants who did not speak Danish and would not be able to read the questionnaire. Numerous names on mail boxes were international and if this indicates language barriers and cultural differences, this is part of the complexity in performing Post Occupancy Evaluations (POEs).

Crucially, ten years after completion, the inhabitants at Æblelunden are not new neighbors or engaged by contract such as tenants of AlmenBolig+ estates. Instead the questionnaire came 'out of the blue' and remains an academic investigation. There is nothing in it for the inhabitants. This relevance at a personal level is part of the social fabric for such investigations as well as the topic for entire research fields.

The outcome of the project until now shows how difficult it is to perform Post Occupancy Evaluations!

### What's next?

Perhaps future POEs could benefit from a more diverse cross disciplinary research group.To improve the engagement with POEs, at a starting point could be mutual relevance. Future POEs could be undertaken with an engaged tenant organization client behind novel organizational or technical projects. These organizations have clear incentives to evaluate their projects. Specific clients could be KAB who developed the AlmenBolig+ concept or Al2Bolig who is behind the Future Sustainable Non-Profit Housing (Fremtidens Bæredygtige Almene Bolig – FBAB) just finishing in Lisbjerg near Aarhus, Denmark. Here the a solid-wood based construction system is expressed with raw wood facades and exposed wood interiors. The novelty of the project affords obvious relevance for the tenant organization client as well as for the architectural and wood research communities. For both, it is worth designing a way to evaluate several aspects of sustainability such as well-being, resource use, maintenance efforts, and economy and design flexibility.



# Flood risk: How can we enhance the use of nature-based storm water solutions in urban development areas?

# PROJECT: VANDKUNSTEN + DTU

Project: Thesis student Lærke Philipsen Vandkunsten / DTU: October - December 2016
A Case Study of Digital Tools Used for Analyzing and Screening of Climate Adaptation Challenges in Early Design Phases

**Background:**
The research project was a collaboration between DTU Byg and the landscape department at Vandkunsten Architects. It was motivated by a need in the branch for better handling of rain and storm water in the initial planning phase of urban development projects.

The general hypothesis was: "Get an early indication through simulation modeling and make better design choices!"

Often, early design choices are based on simple maps with very limited information about site levels and water runoff. This is contradictory to current demands from municipalities, as it is now a standard requirement to handle, and to a certain degree store, rain and storm water locally.

The aim of the research project was, therefore, to identify digital tools that could give more than just a preliminary indication of waterways and catchment areas. The goal was to find a tool that could give more exact data, allowing the designer to 'sketch' through different solutions and hence to document the chosen solution with both graphical illustrations and numerical data.

The focus was to be on nature-based solutions as design elements and parameters in urban development plans from a city-wide scale to local settlement areas.

**Process:**
The research project was initiated with a quick survey of all employees.

The survey showed a clear demand for an early design phase tool that could provide realistic water volumes from sketch proposals. Other high priorities were flow paths, quick simulations, visual and spatial results instead of numbers and diagrams, and illustrations that can be used directly in deliverables.

Along with developing the project concept and identifying relevant cases, a background survey was performed.

The background survey included an account of existing tools. This revealed that most existing tools for storm water management in the Danish context are developed for engineering practices and are intended for use at much more detailed project levels.

Nevertheless, three potential tools were selected for further testing.

In addition, the "3 Points Approach" was presented to the office. The "3 Points Approach" is a categorization of different precipitation situations, where the correlation between the repetition period and precipitation (in millimeters) is visualized. Precipitation is grouped into 3 categories: everyday rain, dimensioning rain, and extreme rain.

The primary method in the project was to test and observe how the three chosen tools worked in current cases at the office.

A total of eight case studies were conducted using the following tools:

Fig.1: The connection between the return period and the event depth based on calculations obtained from multiple rain events at four different locations in Denmark.

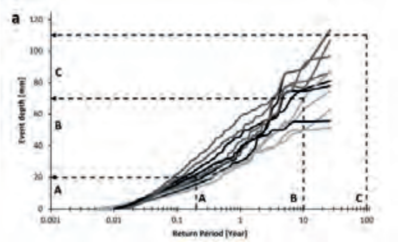
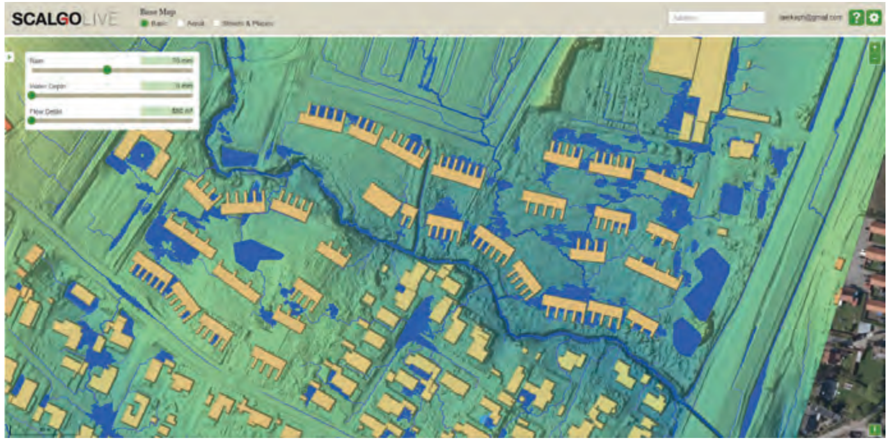



Fig.2: Example from SCALGO Live: competition layout with existing terrain and blue spot identification




SCALGO Live:
This is a fast GIS-based tool where the 2015 height model from Denmark is used as a basis for flow way and blue Spot analyses. The height model is public data and returns data for 0.4x0.4m spot levels with a few centimeters of accuracy. The SCALGO LIVE tool is based on a simple "glass plate model" and returns quick results for the chosen area. It offers a graphical interface that is well suited for documentation and reporting. In SCALGO Live, it is possible to import models into the existing terrain, thus analyzing runoff for different designs, possible building layouts, and potential rainstorm elements.

Waste Water Committee LAR Sizing Sheet:
This is an Excel sheet based on Script 30 where it is possible to dimension storm water elements. The inputs for the calculation are the location, repetition period, safety factor, land area, and earth conductivity. Based on this information, one can choose a rainwater management solution (for example, a rain bed), and then get the required bed / pool volume..

LAR Potential:
DTU Environment is developing a new tool that will calculate storm water solutions in terms of the 3 Points Approach domains. Although not developed yet, the aim is to provide a tool that gives answers about local nature-based solutions and provides the tool with a graphical interface on top of the underlying calculations.

Through the case studies, the advantages, disadvantages, and development potentials of the three different tools became clear. The cases varied in process stage and scale, and therefore provided important insight into the diversity of projects in an architectural company.

Fig.3: Example from the Waste Water Committee spreadsheet with the 4 different storm water elements

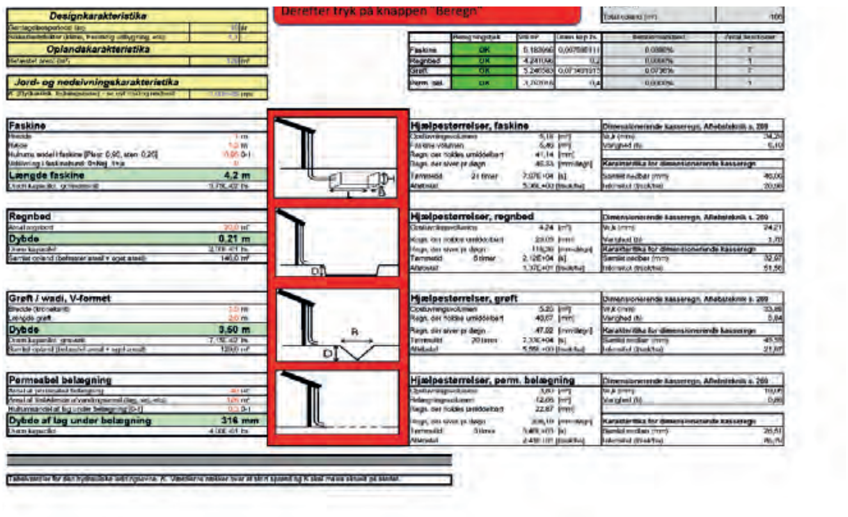
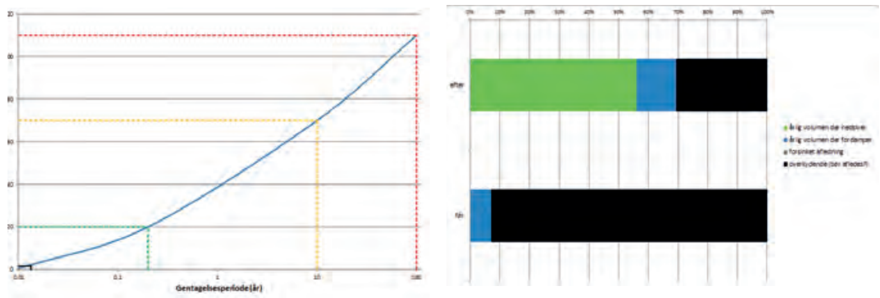



Fig.4: Example from LAR Potential with the figures showing a 'before and after' scenario for a chosen storm water management method. The colored figure shows the relative amounts of evaporation, drainage, and runoff.




## Implementation

Until now, design decisions regarding storm water management have been based on simple maps with very limited information about site levels and water runoff. Only late in the design process are engineers included for precise calculations of volumes and drainage capacity. The research project has, above all, led to the acquisition of SCALGO Live and a general knowledge of the Waste Water Committee's LAR Sizing Sheet in the office.

Several architects and landscape architects have been trained to use the tools. As a result, SCALGO has been used in several competition proposals.

The project has led to a greater awareness and knowledge of the possibilities for calculating and simulating storm water elements in the early design phase.

## Outlook

The project has initiated a process for an even more optimal tool for climate adaptation projects at architectural offices.

Based on the experiences from the previous project, Vandkunsten Architects is currently involved in a new collaboration project with SCALGO Live, DTU Environment, and DTU Byg where the aim is to combine the precise data, fast calculations, and graphical interface from SCALGO Live with the nature-based solutions included in the "LAR-Potential" tool. The goal is to develop a new optimal tool that enables landscape architects to easily investigate different climate adaptation measures and to deliver highly informed design solutions in the early design phases.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# LEARNING FROM STED:

## BIM – A NEW TAKE ON KNOWLEDGE MANAGEMENT IN ARCHITECTURAL OFFICES

Knowledge management is a difficult task in many industries, but especially in architectural offices. Knowledge in architectural offices is built up over time and is heavily linked to the people working at the office. The process of designing a building and later building it are both huge learning processes. Furthermore, architectural projects are multifaceted, with many people involved who all take their share of the total workload. As a consequence, knowledge is not built-up in the office physically - unless the office has developed methods to do so – but only exists through the people working at the office. And once someone chooses to change jobs, the knowledge also wanders and may be totally lost for the office. Other industries, like automotive, have seen the value of keeping the "data" that only exists with their employees: their learning and tacit knowledge. Larger firms are (and have been for some time) undertaking great efforts to bind this data and make it accessible for the firm's employees (e.g. BMW in the late 1990s).

**BIM:**

BIM tools such as Revit are currently used primarily to optimize, streamline, and especially speed up the drawing during the planning processes. File sizes has originally been an issue when working with Revit, but computers have become faster and better hardware more affordable. Bigger model files allow more information to be included even if it is not solely necessary for the architectural project in the end. More information also helps to obtain a more holistic view on specific questions. Especially in the later design stages (e.g. the design-build phase), many conflicts will arise between the architectural concept, the stakeholder needs, the economic framework, various laws and rules, the contractor's processes, standards, and abilities. Eventually, this will dictate the building products that can be used and will result in a one-of-a-kind building each time. However, with BIM it seems possible to actually learn from one project and hand over more tacit information to the next.

**The template:**

In Revit, a project template is used when starting up a new project. The template is user specific (or office specific) – it can contain a significant amount of basic data or be totally empty all depending on the office's take on ICT. While previously it was an advantage to have "empty" templates where only a few drawing standards were predefined, an "information loaded" template could ultimately be the way to transfer learning and thus knowledge from an earlier project to new ones. An information loaded template will also contain information about materials, predefined objects such as windows and doors ("family"), predefined building elements such as walls and roofs ("system family"), and many more specific parameters and information that has proven necessary or helpful in earlier projects.

**Feedback loops:**
Usually the information transfer from the later phases such as design-build and especially from the building phase is nonexistent in architectural offices. Since the project teams normally change when going from the early design stages to the building phase due to the different demand in man-power on the architect's side at the end of a project, there is no natural connection that will allow transfer of knowledge to the sketching architects unless serious issues arise with the project that are taken up on a more general level in the office. Specific knowledge transfer from the late stages will, therefore, demand a specific culture or workflow at the offices. Actually, there is also a lot to learn from what went well (e.g. what was easy, risk-free, and produced good results). These learnings could tell us how problematic issues can be addressed in the early stages, how to make the design robust to late changes, and how to actually describe the results that are advised.

**"Tacit digital data":**
BIM can grow to help close this gap. Because the BIM model is constantly worked with during the building process (e.g. in many cases, as-built information is integrated after the actual construction work is done), it is possible to adjust the relevant information in BIM at a late stage and thus to save this valuable information. This data could be called "digital-tacit", as it is not clear at this time if the information will be relevant again, but it can still be considered a learning process. To make the data accessible and to transfer the "tacit digital" information to future projects, families and eventually also material data should be revised and then transferred to the office template. This will allow the next planning team to reuse the information gathered earlier without having to redo research for many aspects of the building and to relate to past internal learnings. Families (e.g. roof windows and distance to walls) should thus be drawn, coded, and parametrized to ensure that errors that happened earlier cannot recur.

**The user does not need to know.:**
Interestingly, based on learnings from the LCA Aeforos project, it can be said that users do not need to know about all levels of data that are integrated in a BIM model; they only need the parts that are relevant for the respective user and for the field of work being conducted. For example, the office's template was changed during the development of Aeforos without comprising the workflow that the architects and construction architects used at the office. The necessary parameters and material information were supplemented in a way that merely made it "bullet-proof" for changes. This was aided by explicitly asking the users to take a stance when using the respective elements.

This strategy can be seen as having been successful at the office because the recent template contains significant LCA-related information and enables all new models to deliver the necessary data to conduct an LCA – including in early model stages, even though this service is rarely requested by clients. As a result, integrating the LCA information in all new models has not created any extra work for those who draw the actual BIM models but will allow us to save many time consuming steps in case an LCA needs to be calculated.

The same applies for LCC. In the case of LCC, the data collection is much less complex than it is for LCA but still much of the work that is necessary to conduct an LCC could be done inside the BIM software. For example, price information could be added, as could maintenance ratios that are specific for building elements or components. This information could easily be updated in projects in later design stages and when prices have been provided by the construction firms or suppliers.

## The Standard?

(and why some are afraid of it)

Many contemporary architects see standardization as a threat to high quality architecture. "Contemporary" must be emphasized here as architects early in the last century (e.g. Bauhaus) took the lead in installing industry standards in order to heighten the quality of buildings, reduce costs, make good products accessible to a broader range of people, and ultimately to have a greater impact on what was actually being built at that point in time.

Standardization also goes hand-in-hand with resource issues. Every time there is lack of resources, standards are developed and applied to address these shortages. For example, after WW2 the building industries in nearly all European countries were focused on using the available technology and available resources for building. While standards can create demand and push markets, and thus have been an engine for innovation and development, in recent times the picture has changed and standards ("lobbyism") have overly regulated the branch. Secondly, especially during the years from 1950-1970, the ubiquitous shortage of flats has driven a building standard that seems to be restrictive and has prohibited creativity in architecture in many countries. As a reaction, standards have gotten a reputation for being limiting and preventing high quality architecture. Working according to these "older" standards was later been dropped and they are now ignored.

Today, standards could easily be expressed in a more dynamic way. Interaction of the site, economy, local availability of resources, and modern production methods could, with the help of ICT tools, be documented and eventually show compliance.

Regarding BIM alone, smart objects could actually help planners tackle the issue of many unaligned standards that can be time consuming to manage. By issuing objects that inform the planers of changes that have been made that deviate from the standards, it might be possible to address the issues that will eventually arise early in the process.

## Will ICT replace the pen?

No they won't – no worries – but the pen alone is also not an option in the future. Complexity in the building industry is growing extremely fast; architects today have to handle a multitude of that data that an architect only 10 years ago didn't have to deal with. At the same time, speed is increasing. This is resulting in a major change of the phasing models that have been developed over decades. It probably also requires us to break down the planning process into chunks that can be handled.

In the last few years, the phases have overlapped more and more. Some phases are being dropped totally. But don't we need the same information anymore? Yes, we do, but the planning process is becoming more and more streamlined to production or delivery dates (e.g. using prefab concrete elements), economic flows (no investor likes unused money), or market developments (is there a lack of dwellings right now?). The planners have to take into account the situation that has been created for them. Schedules are dictated and might not make lots of sense if the goal is to build to with high quality, high precision, and low risk; to yield a good investment; and, at the same time, to develop great architecture and leave "loveable" buildings for the next generation. So, there is a bias today – while the pen fits the "old process", it will not suffice in the present, and it will not do at all in the future if the race continues.

Today ICT helps when complexity grows. ICT facilitates investigation of many preconditions and related risks, thereby allowing more precise and faster decisions to be made earlier. It does not prevent errors, but by simulating and testing in a digital environment, the number of errors certainly can be reduced and risks can be found and visualized for the clients at an early stage.

Some might say that the use of ICT makes us poorer architects as it limits our ways of expression – but maybe we just need to learn how to express the architecture that we want to make and at the same time develop the tools we want to have at hand – exactly as any other craftsman who needs to use tools for their work.

# FURTHER TOOLS WE WOULD LIKE TO SEE:

…we need to learn how to express the architecture that we want to make and …develop the tools we want to have at hand – exactly as any other craftsman who needs to use tools for their work

The STED project has provided us with unique opportunities to use great resources from DTU students and have fruitful discussions with Nordic project partners. Both have led to think out and actually develop tools that are specifically related to LCA, the STED key issue. There were also a couple of "spinoffs" in the development process. One was the "Early bird LCA-tool" where you don't need to know the actual building design yet; another was a small Revit-tool that allows the user to make more precise bills of materials than in Revit's own schedules.

Many additional ideas were developed that could not be developed within the STED framework or within the remaining timeframe. In the hope that ideas will be picked up, realized and shared in the future, we would like to share what we find are some of the most interesting ideas for further tools:

**Graphical representation of LCA-results in Revit**
How can results from an LCA calculation be shown in Revit in a way that allows designing with this information? How can LCA results be communicated to project stakeholders that are not experts in LCA?

**LCC on the fly**
How can LCC be made yet more usable within the design process. Can a database with economical data be connected that allows realtime evaluation of economical consequences including life cycle costing, supplying information on lifetimes, maintenance, replacements and other materialspecific information relevant to the economy of a project.

**The "design-for-disassembly decoder"**
– Can we create a tool that checks 3D models for interconnections that will hinder design for disassembly and that will visualize dependencies and interconnections in a graphical way in BIM?

**The "life-time-predictor"**
Related to the software tool above, but intended to calculate lifetimes of building components and materials at a given place, point in time, and building context.

How are lifetimes affected by the building principles and methods of construction used? What effect does the purpose of the building and location have on the lifetimes? Here, knowledge from additional projects on building life prediction and the use of "big data" at DTU could become very relevant.

Working at the office

climate
action now!

# white

# Climate action now!

One of our business goals for 2019 is to create 30 projects with zero carbon footprint. This will challenge not only ourselves, but also our clients. The aim is to strengthen the focus on, and our understanding of, the climate impact from building materials and to introduce a more holistic approach.

During 2016 we increased our focus on climate friendly materials such as wood, and we de-signed over 2,000 apartments making substantial use of this renewable material. The STED project allowed us to develop new tools and processes for the very early stages of a project to enable a zero carbon footprint We also developed a more resilient urban typology: eco-canopy. We can now inform our design processes with Life Cycle Assessment (LCA) tools in the early stages and validate material choices. These kinds of informed decisions are necessary to inte-grate climate-friendly materials and constructions in industrial building processes.

“The advantage of being a large collective is the sheer amount of knowledge we amass as a whole. The key to using this knowledge is to share it, build upon it, and continually develop it.”

ANNA-JOHANNA KLASANDER
DIRECTOR OF RESEARCH AND DEVELOPMENT

**WHITE ARKITEKTER** is an interdisciplinary practice for architecture, urban design, landscape architecture, and interior design. Embedded in our work is a commitment to sustainability in all its forms, underpinned by practice-based research. As a collective of 900 employees organized in networks across 15 offices in Sweden, Denmark, Norway, and the United Kingdom, we work with clients, communities, and consultants to create inclusive, resilient architecture that inspires sustainable ways of life. To achieve an ongoing high level of sustainability, we invest in practice-based research - White Research Lab (WRL). Currently we have 4 centers of excellence, 10 White Research Lab-networks, and 7 Ph.D. scholars. We also participate in national and international research projects.

@whitearkitekter
www.whitearkitekter.com


# White & the Global Goals

At White Arkitekter, we work directly and indirectly with global goals every day. A few of these goals are more relevant to our business than the others; those are highlighted in the figure above.

The key target is Goal 11: Sustainable cities and communities. As an architectural firm that designs for sustainable buildings and cities, we use the sustainable development goals to underline and clarify for our customers and for the people who live in and use the spaces that we create what we are trying to achieve together. To achieve these goals, we work together in multi-disciplinary teams and in early project phases to have the biggest impact on the design process.

“

If we change the way we do things, we will get a different result. We now experience a shift in focus from product to process, from object to system, from I-think to We-think. With a combi-nation of social processes and digitalization, we can accelerate the uptake of sustainable ideals in society.”

ELISE GROSSE, HEAD OF SUSTAINABILITY @WHITE

Our goal is social well-being. We can reach that goal through the means of a sustainable economy. The basis for our existence is an ecology in balance.

To deal with the challenges of complexity, we develop processes to improve our ability to think in groups from different perspectives. Every project’s vision is created from a sustainability analysis that establishes the added values in that specific context. With the support of digital techniques, we inform our decisions with calculations and simulations. We engage the whole spectra of our collective intelligence: an applied intelligence of computation, rational thinking, our senses, and embodied knowledge. By engaging in a social process supported by technique, we engage in man-machine thinking on a group level to inform our design. The basis for our existence is an ecology in balance, and through the means of a sustainable economy we strive for social well-being.

# White & Nordic Build Collaboration & cases

2015 •••••• 2016 •••••• 2017 •••••• 2018

CONCEPT DEVELOPMENT
PROJECT: ECO-CANOPY

RESULT: New resilient urban typology for the city transformation project in Ebbe park, Linköping.

TOOLS & PROCESSES FOR LCA INFORMED DESIGN IN EARLY PROCESSES AND
PROJECTS: THE LOOP, CITU, AND SKELLEFTEÅ

RESULT: New LCA tools and processes are being integrated in the White Digital Sustainable Design methodology.

The Nordic Build STED collaboration allowed us to develop tools and processes for zero carbon footprint, as well as a novel concept with a holistic approach to sustainability; eco-canopy. In the case of eco-canopy, the various topics researched by the scholars, contributed to get a stakeholder group interested in the concept, which is now being developed as an urban resilience response to climate change in the city of Linköping. Through the STED project we can now inform our design process in early stages with Life Cycle Assessment (LCA) data. The tools and processes developed in the STED-collaboration, allows us to integrate climate friendly materials and constructions in industrial building processes.

DTU Technical University of Denmark

CHALMERS

NTNU

white

# PROJECT:
# CASE ECO-CANOPY


## How do we develop novel ideas? If we use the same rational thinking we used when we first created the problem, we will continue to produce solutions of the same problematic character.

“This solution came to me in a dream: I was flying over my old hometown, following the river. I had that great freedom sensation of flying in dreams. The scenery was beautiful; my hometown had changed. Where there used to be old rugged industrial structures, there was lush greenery and the glittering waters of the river. Over the old structures I saw a transparent membrane with large openings moving as if it was breathing. Inside were large green trees. As I woke up the first thing to come to mind was: Miljonprogrammet!“

“Eco-canopy is the story of a dream on the verge of materializing in the real world. Hopefully it will inspire the young and old, people of different disciplines and perspectives, to come together and dream their way into the sustainable future. It all started with waking up from a dream...”

ELISE GROSSE, HEAD OF ENVIRONMENT

# BACKGROUND MILJONPROGRAM

“The old native to the young apprentice: If you see a great chasm flying by, jump! It’s not as far as you think.”

OLD NATIVE AMERICAN PROVERB

Eco-canopy is an attempt to holistically address all the challenges of the Miljonprogram within one concept for refurbishment. It offers a regenerative solution for ‘slab block’ houses, which is exemplified with the property Fyrklövern, at Dragonvägen in Upplands Väsby, a northern suburb of Stockholm.

**The Swedish Miljonprogram**

During the period from 1965-1975 the Swedish Government implemented an ambitious building project known as Miljonprogrammet: one million homes being built in 10 years. This fast paced building had a great effect on the development of industrialized building in Sweden. It consists mainly of 5 different typologies. Proper documentation on structures and technical systems is rare to find as it was commonly produced and documented only for individual buildings, and not for the whole area. Another effect of the Miljonprogram was on the organization of the building sector in Sweden. It introduced a clear division between the planning and construction phases, where architects were mainly involved in the planning phase and less involved in the building phase, which was run by national building corporations. Some of these corporations were also affiliated with the production of cement. This is part of the reason why concrete building materials have dominated industrial building in Sweden and have been only somewhat challenged by steel construction.

The Miljonprogram is of rational, functional quality with little focus on esthetics. The simple and straightforward material choices have suffered from neglected maintenance. This is not only the case in Sweden but is common all over Europe for these types of concrete suburban areas. The rugged look of many Miljonprogram areas is also due to the non-design of the spaces in between buildings, with unclear definitions of the private, semi-private, and public realms. The built fabric that could, and should, support social sustainability is, in most cases, non-existent. Such built (or non-built) structures have materialized in the socio-economic stigma of generations of people growing up in these areas around Sweden and Europe. The challenge is of environmental, economic, and social character.

# BACKGROUND MILJONPROGRAM

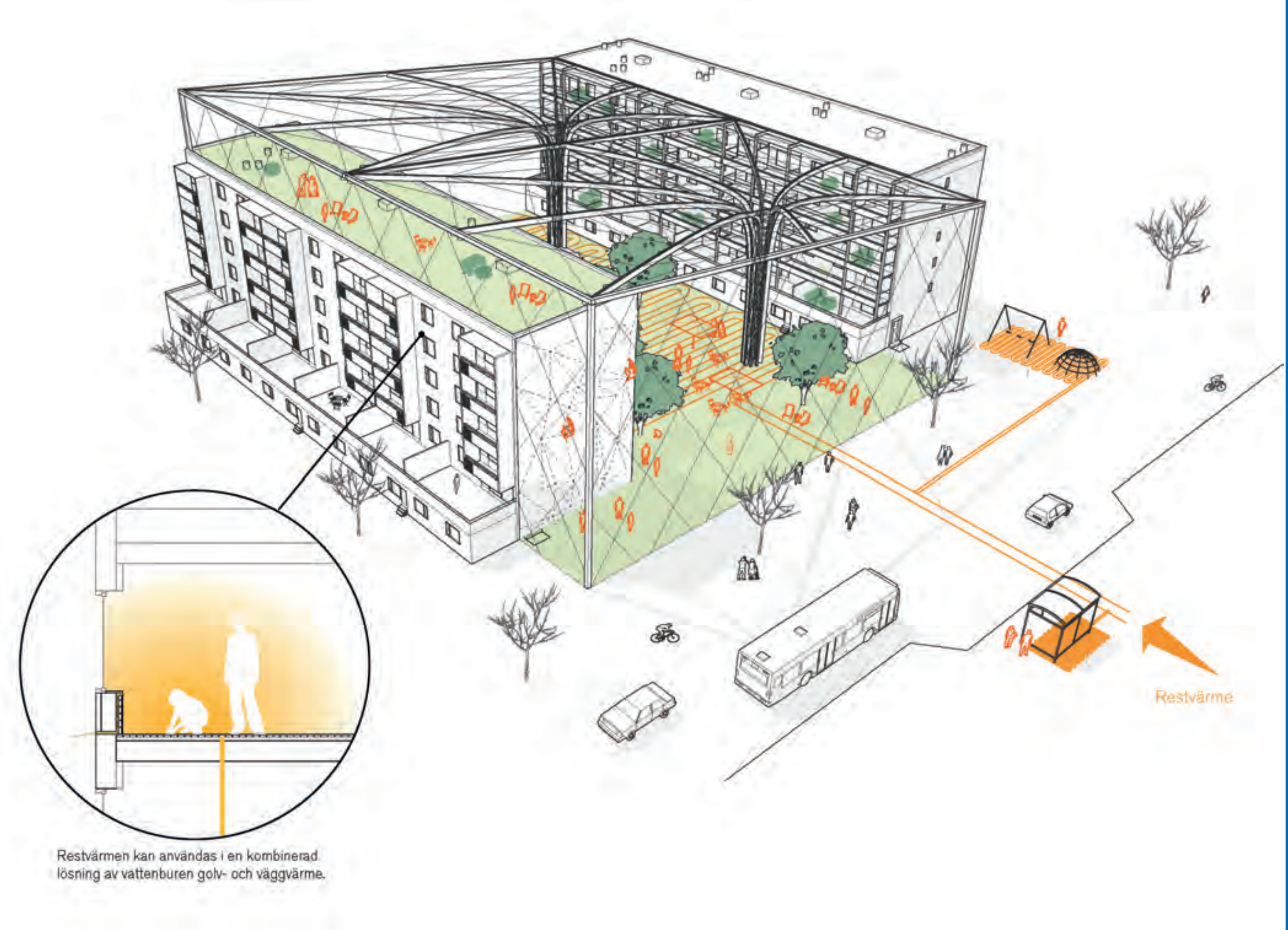
"The building sector is responsible for approximately 1/3 of global greenhouse gases with projections of raising to 50% with growing urbanization (IPCC 2010).
Innovation in refurbishment is a key interest as 99% of the buildings we will have in 2030 already exists today. Politically we don't have so called social housing in Sweden, but the so called 'Miljonprogrammet' is in great need of energy refurbishment and part of the socio-economic stigma of suburbia. To address this, we need both ecological and socio-economic innovation."

# PROJECT ECO-CANOPY

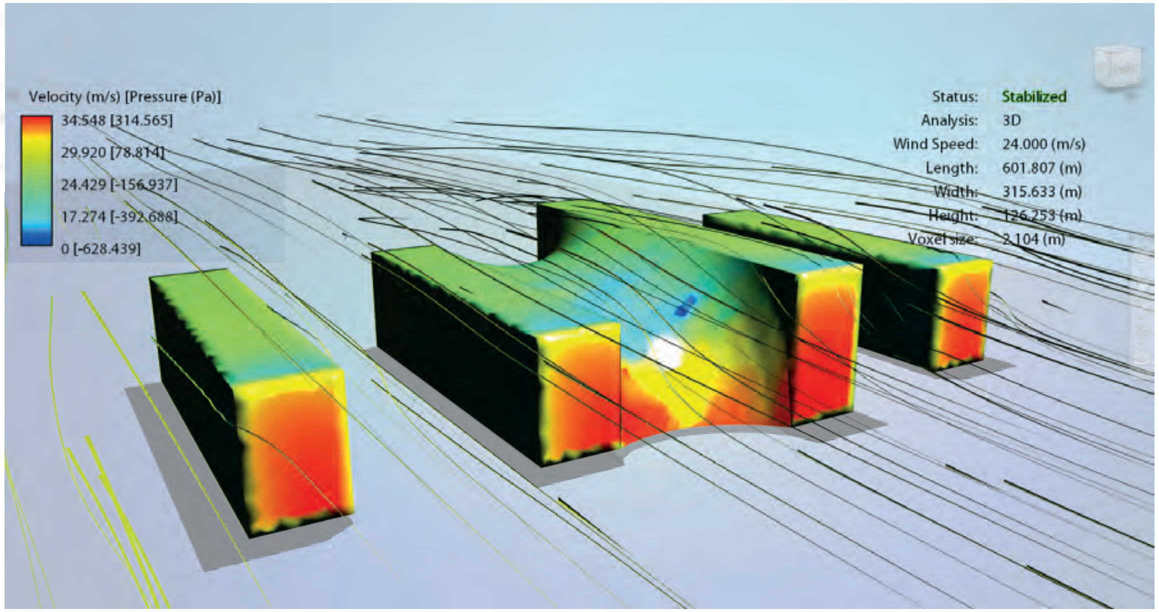
## If you can see it, you can believe it.

The concept of Eco-canopy, is not in the common experience of built structures. After presenting the concept to many property owners, municipality and private real estate organizations, we understood that we need to create a demonstration – one need to see in order to believe. Therefore, with the aid of Whites own research fund White Research Lab, we developed the concept, produced visualizations and researched reference projects in Europe and did a rough energy simulation. This got the project an honoree price in a competition. The winner was of a more standardized solution. Soon after we submitted to the Nordic Built program STED.

Nobel prize winner in psychology Daniel Kahneman showed that investment decisions are not always rational and logic. In situations of uncertainties, investment decisions were mostly shaped by former experiences. In short: if a person lacks an experience of a certain solution, that person is most likely to feel negative about it. This is a dilemma for sustainability in construction, as most sustainable transformation requires investment in something new.



# CASE ECO-CANOPY
# A HOLISTIC APPROACH




This solution would challenge the Swedish building ventilation industry and make the Eco Canopy concept a realistic sustainable solution.

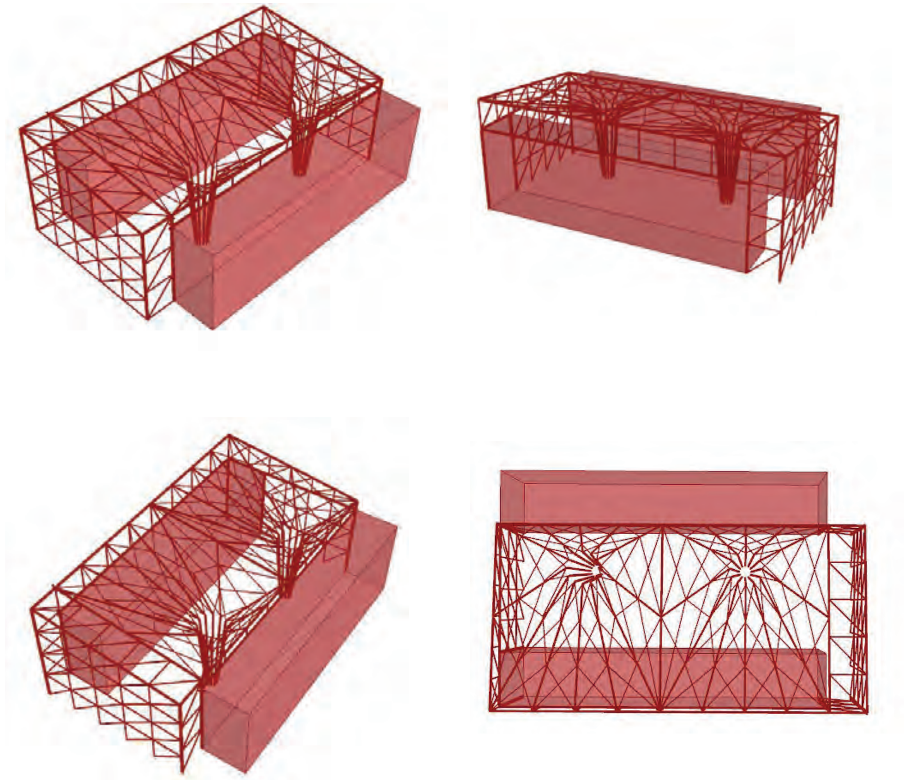
The eco-canopy concept was presented to the thesis students within the STED collaboration. It was selected by Mikkel, an architectural engineer at DTU, who was intrigued by the holistic approach of the concept. Soon after, a lot of new questions emerged related to energy consumption, wind loads, daylight, and the problem of handling snow loads. Mikkel used a form finding method to develop a lightweight construction that was made possible by a novel material choice (ETFE) to minimize energy losses. Together we drafted a regenerative ventilation concept where the canopy functions as a buffer zone for heating, cooling, and ventilation through adiabatic passive systems and automated openings.

Thesis by Mikkel Kirkeskov Knudsen
Investigation of EKO-Canopy energy renovation concept for Swedish Million Program apartment buildings.

# CASE ECO-CANOPY
# LCA-SCRIPT 4 EARLY DESIGN STRUCTURE

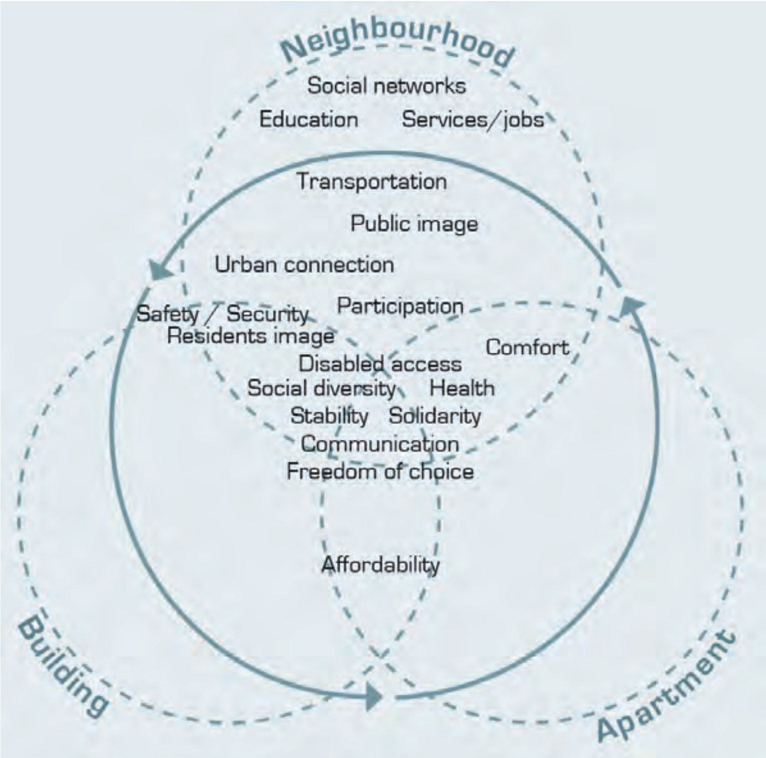
## "Digital sustainable design and the quest for scripts and computations ... ... whatever it is good for?"

To compare different structural alternatives in very early stages are essential to project climate impact (LCA). How can we do that in very early stages, when we only have sketchy drafts of 3D-models? Laura developed a script for telling climate impact between different materials in structural compositions. By introducing structural verifications in the models since the beginning, with the script, it is now possible to compare different structural concepts and make informed decisions on the choices of materials, without spending too much time building different models.



Thesis by Laura Fernandez Vila
Parametric Structural Design Integration of structural verifications in the early design phases.

# CASE ECO-CANOPY
# TO MEASURE SOCIAL SUSTAINABILITY




“...if it doesn’t have a number,
it is not in the budget.”

The study offers a comprehensive overview of relevant research on social sustainability as well as a matrix tool of indicators that can support the design process. The interest and demand for social sustainability is increasing. However, it is not something that is easy to measure or calculate. The literature study investigates the fundamental theory of social sustainability. Social sustainability could best be described through a range of defining themes and characteristics, which include, for example, equity, social mixing, cohesion, empowerment, participation, well-being, and quality of life. The basic report suggests an approach for systematic enquiry into social sustainability, and covers the key topics using a compilation of themes with associated sub-criteria and indicators. Based on the conditions surrounding the individual project, these indicators can be weighted to direct focus towards the most relevant issues, to support the design process, and to secure more socially sustainable solutions in the transformation.

Thesis by Aleksander Probst Otovic
Designing Social Sustainability
Towards an operationalization of social sustainability concepts in integrated design processes.

# CASE ECO-CANOPY
# DYNAMIC MICRO-CLIMATES IN 3RD SPACES

## “Get out and into your comfort zone”

How is comfort evaluated in 3rd spaces – spaces neither inside or fully outside – such as the Eco-Canopy? The question imposed some engineering challenges to simulating dynamic environments.

The first challenge is that most existing comfort evaluation frameworks is concerned with the rather uniform conditions found in an indoor environment. Rather than working with one fixed range of comfort, 3rd spaces offers the possibility to work with a distribution of different comfort zones. When evaluating 3rd spaces further adaptive factors have to be taken into account - just like tectonic and architectural impressions might play a role in occupants perception of comfort.

This opens for research questions with a lot of architectural implications: Does the visual reading of a space affect the experienced comfort? When the design of the environment signals to the visitor if the ‘spot is more cool or warm’, the visitor can read the environment and might adjust their expectations about the climate accordingly. This is crucial information when designing any “open system, dynamic environment”. For example, if you suspect that you will have a hot corner on one side of a space and a cold corner on the other, designing the right ‘look’ of the environment, for example a “dry dessert look” for the hot spot, might affect the user towards a comfortable experience since they have different expectations about the environment and choose their spot accordingly.

Thesis by Peter Jantzen
Comfort in 3rd Space Canopies


The plots of different comforts inform the design process. Here, spring and autumn offer the most comforting conditions.

# CASE ECO-CANOPY
# COMPARATIVE LCA EVALUATION

In short: it is very helpful to obtain numbers so we can show in black and white the positive effects of regenerative solutions like eco-canopy. Less is more.

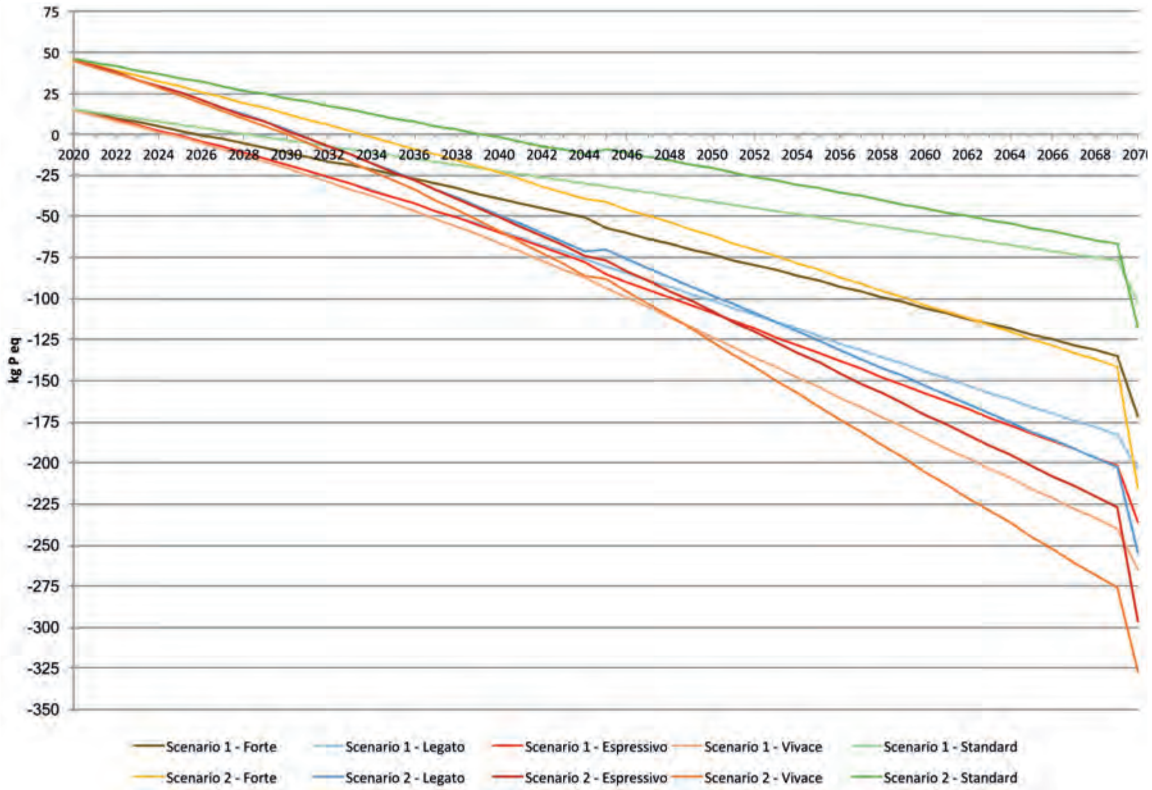



Figure 4.2.18 Annual ozone depletion impact over 50 years. The energy scenarios have a high potential to help avoid impact from ozone depletion.

Rune´s work was a major success in the eco-canopy story. He provided great accuracy in calculating climate impact (LCA) thanks to his thorough data gathering. The results are impressive! The LCA illustrates how the eco-canopy reaches break-even for climate impact even before conventional renovation (changing to a heat-pump and adding insulation) in all 5 energy scenarios. Eco-canopy is a reinvention of our vernacular architecture, free from heavy techniques in constant need of maintenance and modernized to use intelligent systems only where needed. In conclusion, Rune´s work contributed to convincing a project owner to 'bet on the concept'; an eco-canopy is currently being developed in Linköping in Sweden.

See Figure 4.2.18 All dynamic energy scenarios will reach the break-even point within the first year for canopy scenario 1. The standard energy scenario will reach the break-even point in the second year. The impacts from the canopy are twice as great as the impacts from the renovation materials that were avoided in the first year.

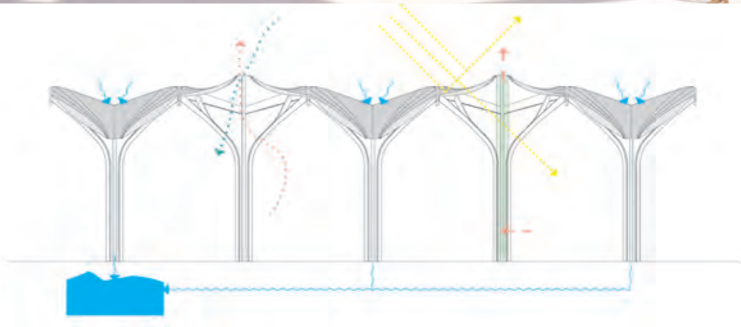
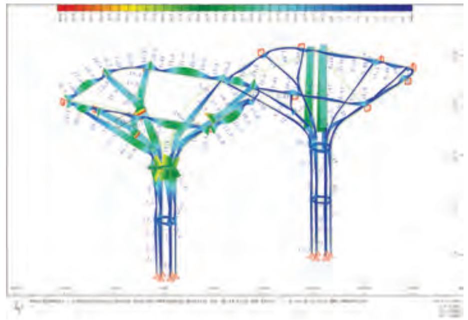
It is encouraging to see how passive solutions have a lower climate impact, not to mention the added value of a healthy environment and spaces provided for social sustainability.

# ECO-CANOPY IN LINKÖPING

## The Nordic Built has supported a dream to come true. Currently, eco-canopy is being devel oped as a new urban resilient typology in Linköping, Sweden.

Eco-canopy: a dynamic micro-climate integrating ecosystem services with the regenerative architecture of the eco-canopy. The canopy, supported by an intelligent AI-control system, will create a learning environment for both humans and buildings. The eco-canopy can offer resilience in terms of a self-supporting local system in the urban environment.



The material on this page presents three parallel studies for the architectural and structural design of the EcoCanopy concept, as applied to Ebbepark, Linköping. EcoCanopy is proposed as a new urban resilient typology, where a dynamic micro-climate is integrating eco-system services and a regenerative approach to architecture. The three concepts all follow this objective, and the underlying the technical requirements that follows, but also provide additional opportunities in terms of spatial design, material savings, modularity and re-use. The concepts were developed to be used as an input for further development and decision making and have all been assessed in terms of design sensibility, structural optimum and minimum material use.

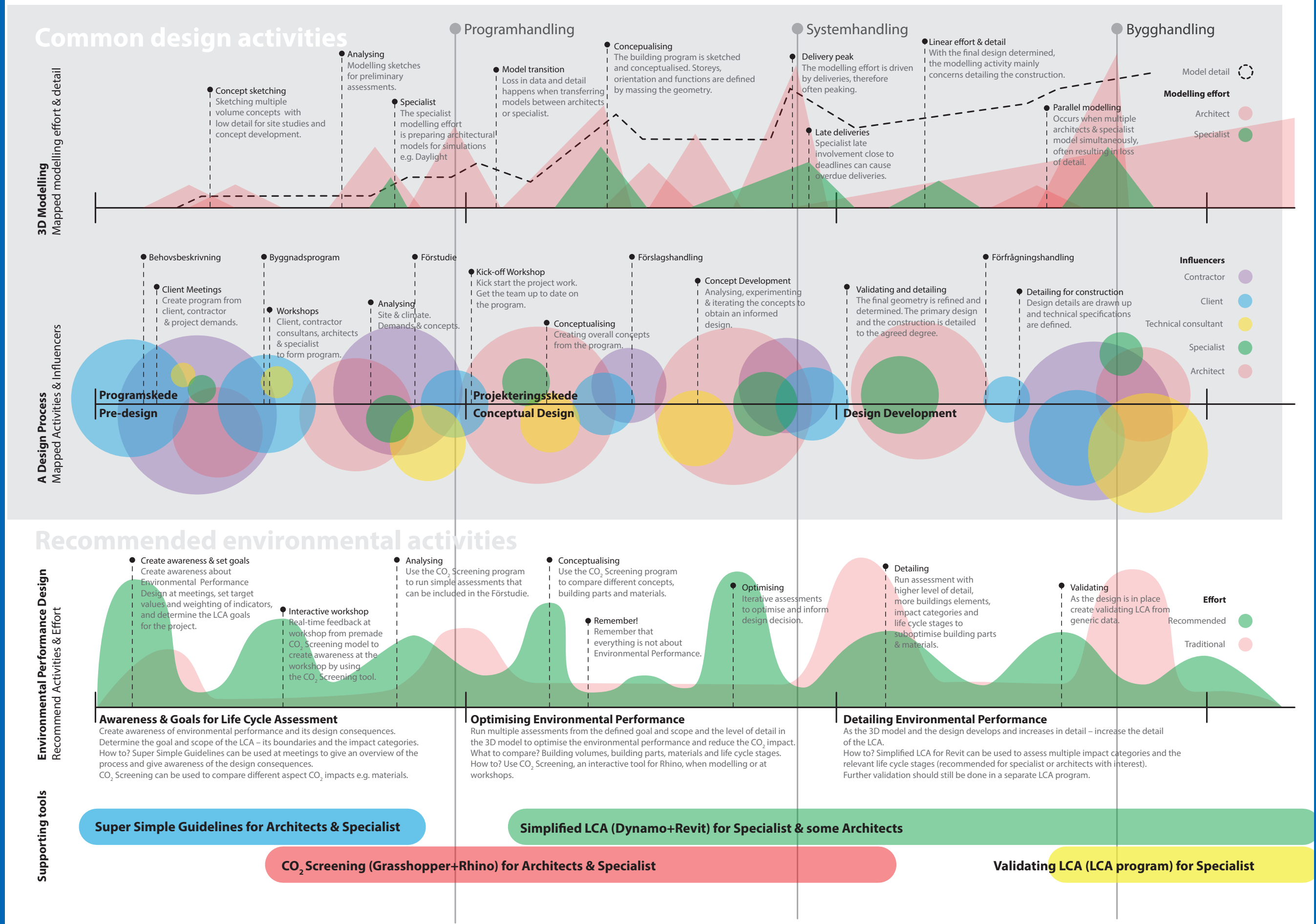
All concepts use a double layer transparent ETFE membranes as roofs, providing insulation and daylight. Concept A is based on a modular approach where the structure is divided into "tree-like" modules with a central column and a cantilevered canopy. A differentiation between high- and low-points between the modules provides good rain water and snow fall-off and collection and good ventilation where active climate control could be placed. Concept B is constructed from wooden modules that together form a space-frame like truss system. This main system is fitted on horizontal beams that are either flat (for a uniform height) or curved (for either dome-shaped form), in turn carried by wooden columns. Concept C uses a grid shell logic and provides a very light weight structure that gains its strength from the global overall curvature of its form. It is a very adaptive system that can be designed to fit many different configurations of the site.

The concepts were developed as a fast track workshop, facilitated by the digital design specialist team Dsearch within White arkitekter AB, in close collaboration with light-weight structures specialist engineers Str.ucture GmbH, based in Stuttgart. The purpose of this workshop was to develop alternative design concepts directly informed by structural constraints, all fulfilling the environmental needs of the EcoCanopy project.

# PROCESS TOOLS LCA

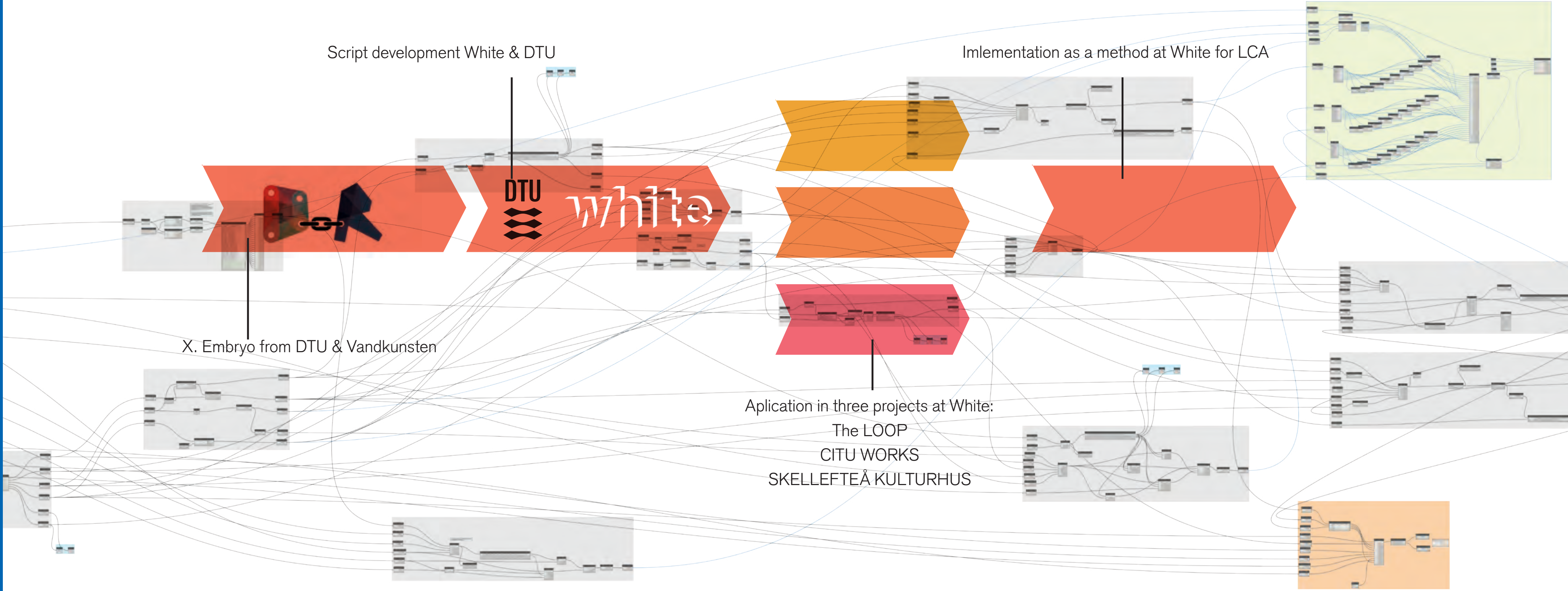
WORK FLOW – MAPING OF THE PROCESS

Through STED, White had the opportunity to receive students from DTU for internships. The scholars had specialized in life cycle assessment and wanted to investigate how this could be implemented in the daily work of an architectural office. This is the result of their research where they mapped and examined the work process at an architectural office and had the possibility to implement digital LCA tools and methods in that process.



# PROCESS TOOLS LCA

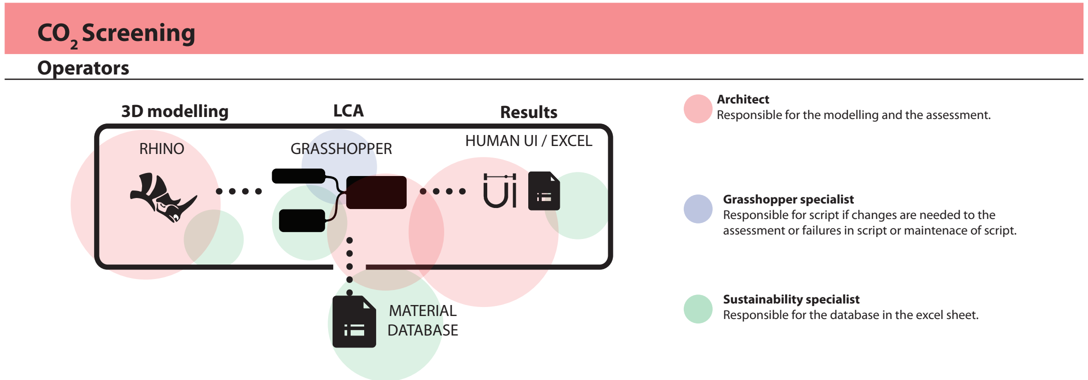
AN ACTION RESEARCH APPROACH TO LCA TOOL DEVELOPMENT IN 3 PROJECTS



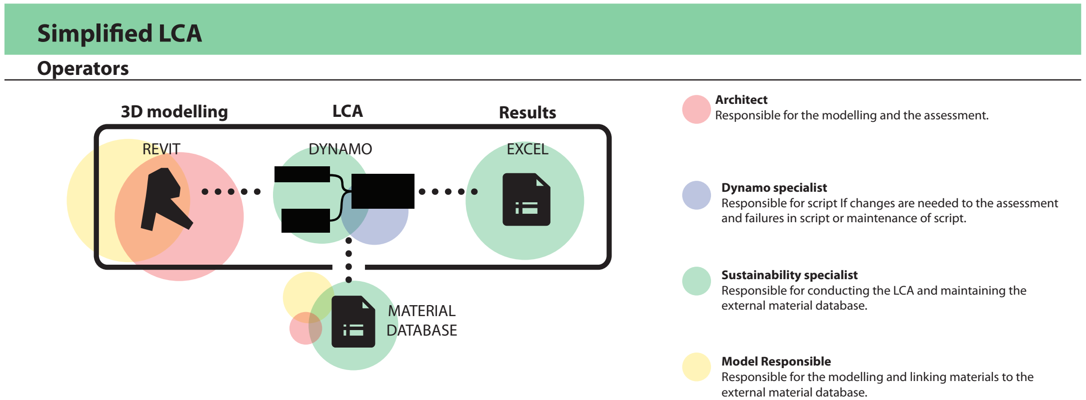

The DTU collaboration further included the continued development of a script for LCA estima-tion in early design processes. The scrip was originally developed by another DTU student during his internship at Vankunsten Arkitekter, another STED collaboration partner. White inherited the script and adapted it to the White work processes. The work between DTU & WHITE resulted in two different scripts being used in three projects to obtain an LCA result. One reason why this was so successful was that the thesis students, Mads and Anders, could take part in the projects and get instant information about the changes that affected their work. The result of the collaboration between DTU and White has resulted in a further development of these scripts and methods to inform other projects at White with LCA in the early design stages.

# PROCESS TOOLS LCA
# THE LOOP AND CITU PROJECT

THE LOOP – LCA SCREENING IN VERY EARLY DESIGN, VOLUME STUDY



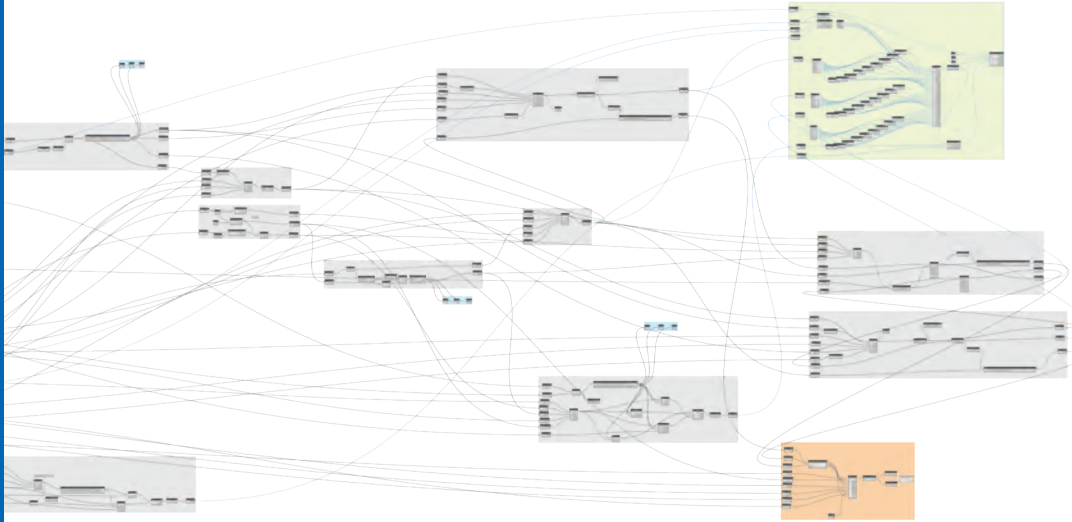

CITU – LCA ANALYSIS, CHOICE OF MATERIALS

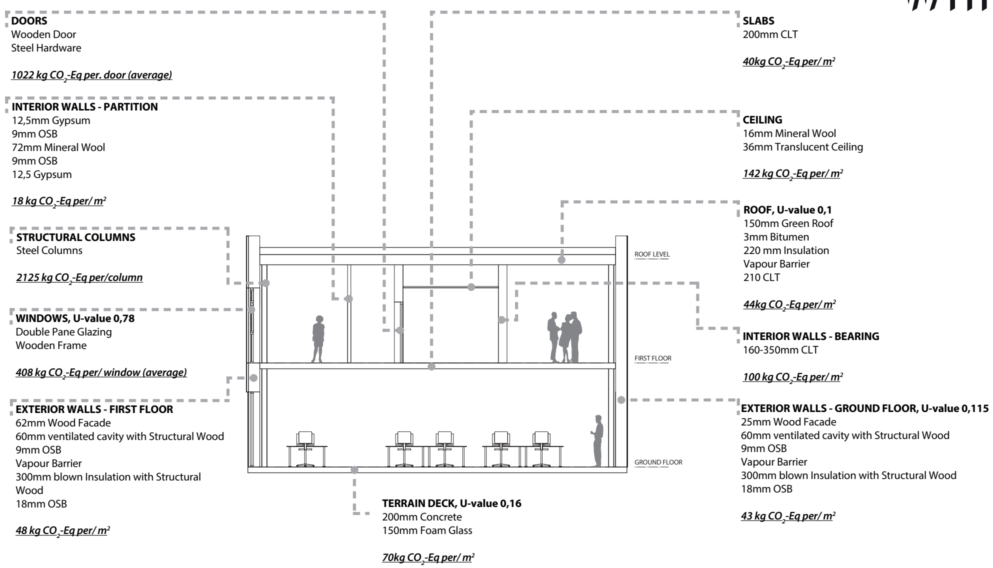



**RESULT**

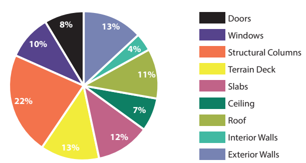
LCA Grasshopper scripts were developed within The Loop and CITU as bespoke tools specific to the projects, and hence have different aims. The first tool/script, LCA Screening, is suitable for very early stage design, when designing volumes and forms. The script assesses the embodied carbon of different materials and building elements. It's a good guide for very early material and design strategies. The second script, LCA Calculation, is Revit-based for detailed design stage. Every modelled Revit element is included in the assessment. Material lifespan can be additionally specified according to the design needs of specific elements. This script can be used to demonstrate the building's environmental impact, measured in global warming potential (GWP).

# LCA RESULT
# CITU






**Component Impact in CITU Works**




**Total Impact of CITU Works** - *50 years Life Expectancy*

| | | |
|---|---|---|
| Roof | 1033 $m^2$ | ***45506 $CO_2$-Eq*** |
| Exterior Walls - Ground Floor | 694 $m^2$ | ***29625 $CO_2$-Eq*** |
| Exterior Walls - First Floor | 515 $m^2$ | ***24722 $CO_2$-Eq*** |
| Windows | 139 pieces | ***56849 $CO_2$-Eq*** |
| Terrain Deck | 1119 $m^2$ | ***78170 $CO_2$-Eq*** |
| Interior Walls - Partition | 725 $m^2$ | ***12829 $CO_2$-Eq*** |
| Interior Walls - Bearing | 110 $m^2$ | ***11028 $CO_2$-Eq*** |
| Ceilings | 266 $m^2$ | ***38021 $CO_2$-Eq*** |
| Doors | 49 pieces | ***50075 $CO_2$-Eq*** |
| Structural Column | 62 pieces | ***131764 $CO_2$-Eq*** |
| Slabs | 1747 $m^2$ | ***69554 $CO_2$-Eq*** |
| **Total GWP** | | ***548144 $CO_2$-Eq*** |

## WORK FLOW, METHOD, AND RESULT

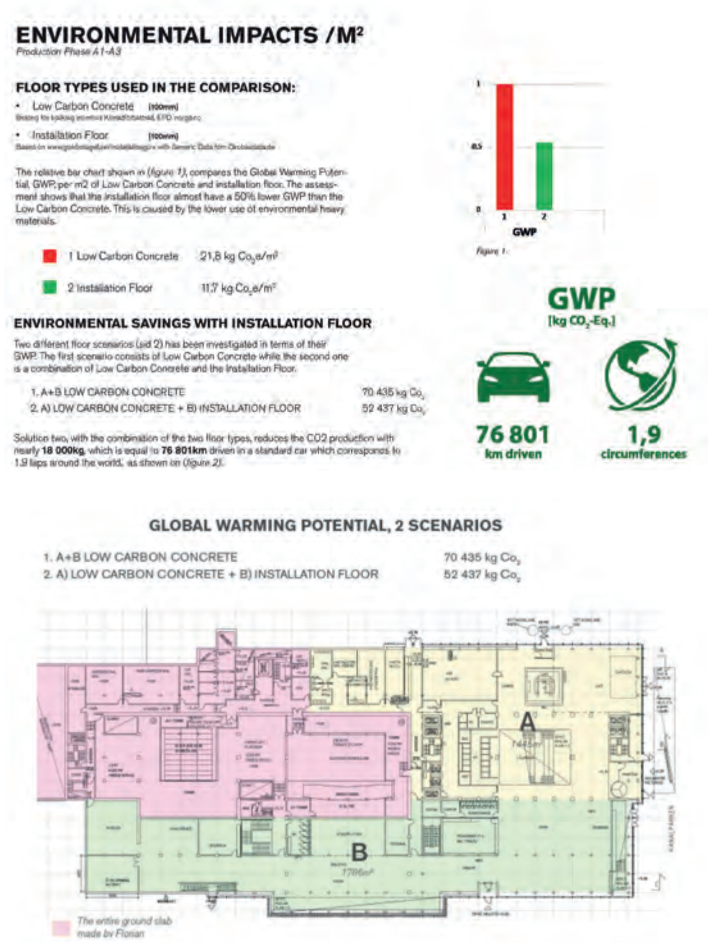
LCA Calculation has been applied within the design of CITU Work, an office building with low-carbon targets. The aim of this was to provide the design team with relevant embodied carbon information at crucial points in the program to drive design decisions. Within CITU Work, we weren't able to achieve this fully. We believe a better result can arise with early consensus on the approach, and a clear perspective across the design team. This would enable a collective view of designing for low lifecycle carbon.

# LCA IMPLIMENTATION SKELLEFTEÅ KULTURHUS

BACKGROUND

A numerical comparison was made to assess two different ground-floor finishes. The first scenario had low-carbon concrete in all areas of the ground floor. The second scenario had a combination of low-carbon concrete and installation floor. Environmental product declarations (EPDs) are internationally recommended within LCA, however here they were not available. The Ökobaudat material database was used instead. The assessment strengthened the client's final floor type design decision.

# LCA RESULT
# SKELLEFTEÅ KULTURHUS




**RESULT**

The results were visualized in a diagram that illustrated the relative impact in GWP and PERNT for the two floor types. The assessment showed the advantage of using the installation floor in relation to the GWP, as the low carbon concrete had nearly twice the impact as the installation floor. For primary non-renewable energy, PERNT, the installation floor had four times the impact as the low carbon concrete. The savings from using the installation floor, in terms of GWP, was presented in a small diagram showing how the savings corresponded to kilometers driven in a standard car.

# FINAL REFLECTIONS
# WHITE AND STED


The STED project produced a significant quantity of knowledge relevant to both practice and academia. Many of the contributions were made possible through the collaborative culture within the project group. The White experience of the STED-project was a fun and creative process of co-creation, where the actions were based in the individual initiatives, interest, and values of the participants. The STED-project illustrated the importance of cultivating a collaborative culture to obtain a relevant result. Such collaborative culture is now included in a new project stakeholder-group in Linköping, where the eco-canopy is being further developed through a participatory process with multi-disciplinary stakeholders and end-users: from the Starchitect to the collective, from product to process, from I-think to We-think. Further, the LCA tools and processes developed in the STED project are now being implemented as part of White´s Digital Design Strategy to sup-port projects in early design stages to obtain climate neutrality. We can only recommend that architectural practice continues to participate in transdisciplinary research, fusing the abilities of practice and academia when co-creating new urban environments that matter: healthy, resilient and naturally beautiful.

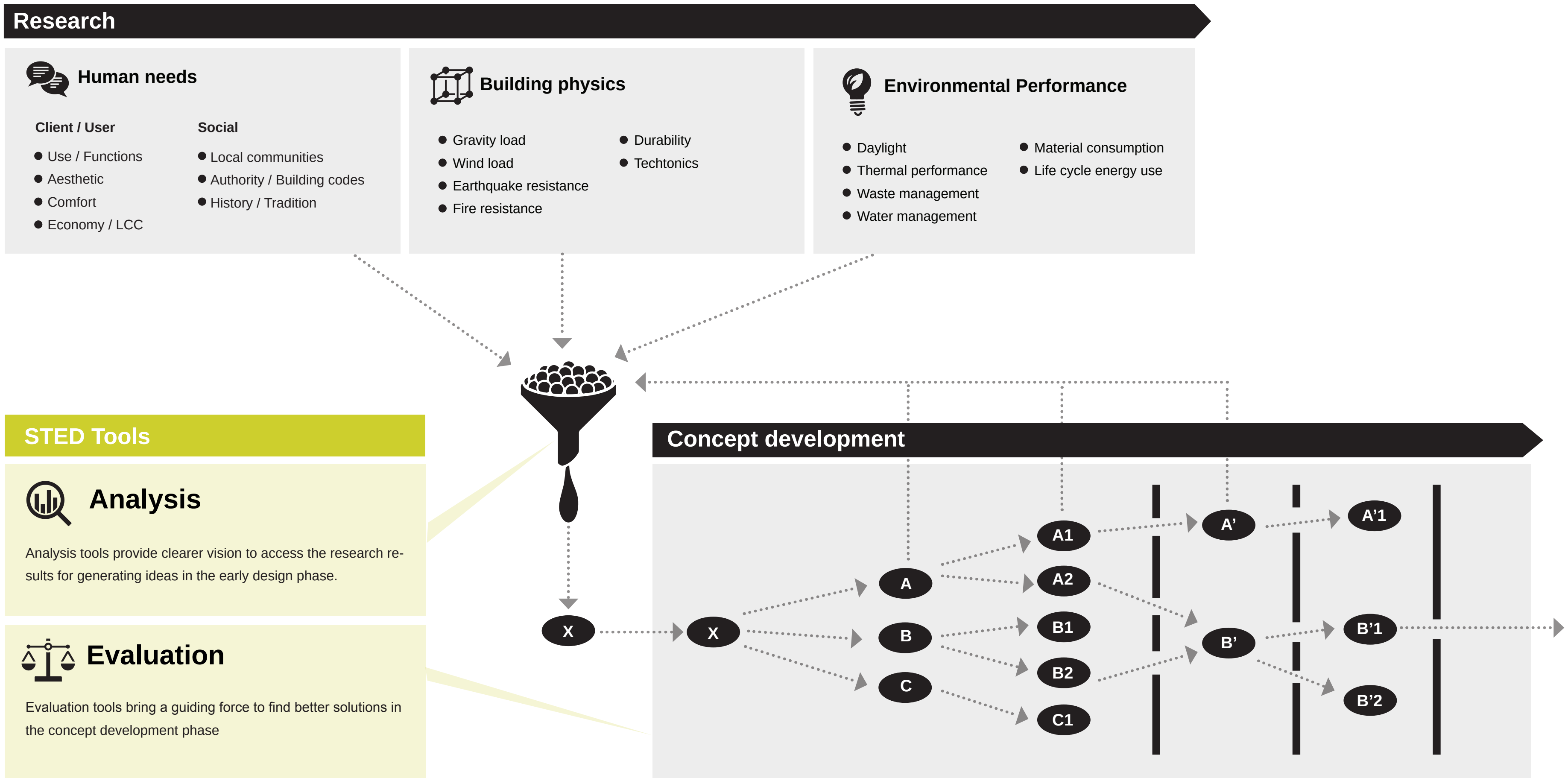
# architects should compute


OOPEAA

## OOPEAA OFFICE FOR PERIPHERAL ARCHITECTURE

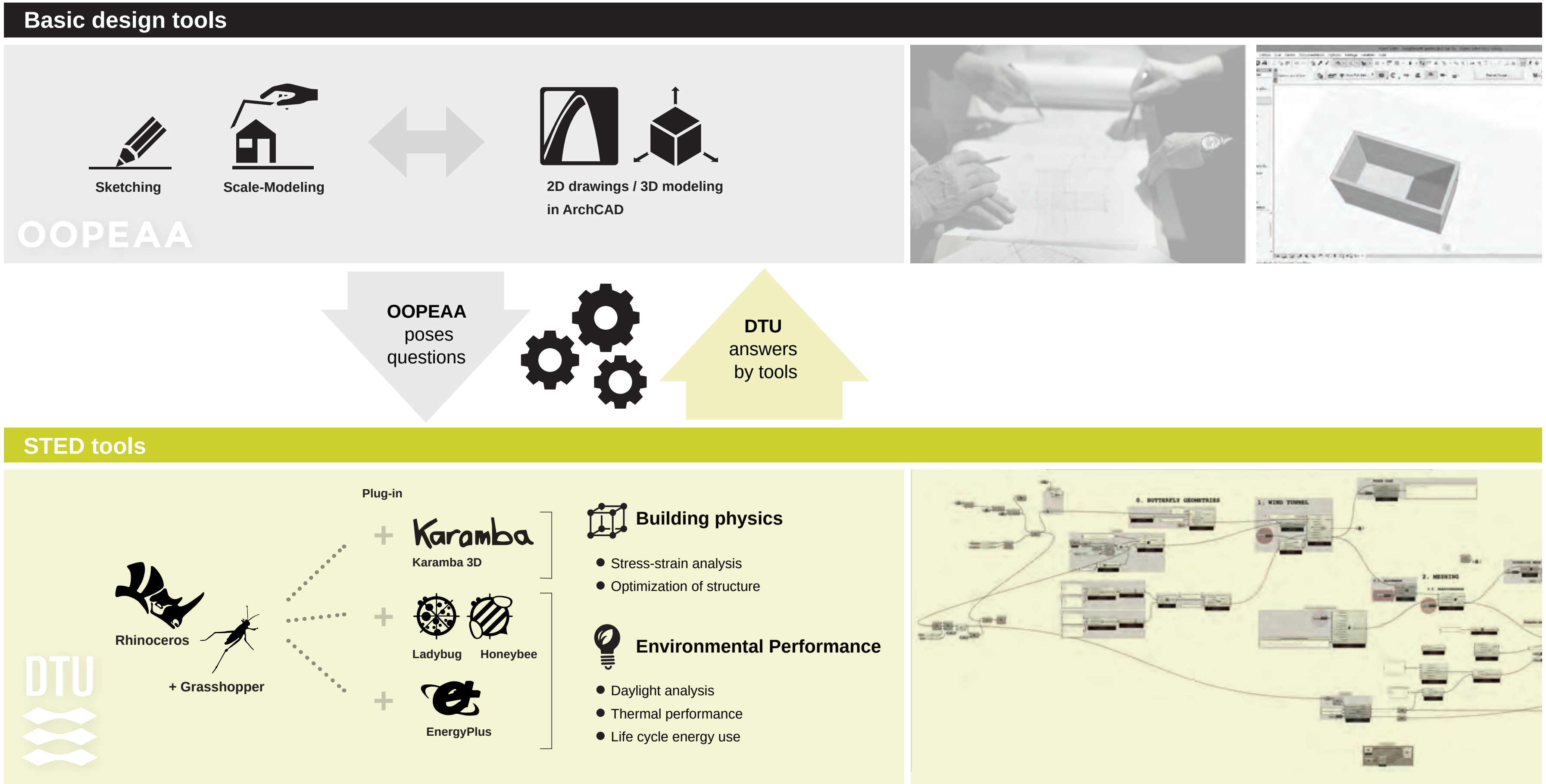
**OOPEAA joined the STED network with a singular focus: developing a deeper understanding of the relationship between environment and architecture for a transformation of the early design process.**
**As sustainability issues in the built environment are becoming increasingly complex and sophisticated, the best solutions are rarely achieved by a single discipline. The challenge for architects now is to transform the conventional exclusive design process to a more inclusive, comprehensive approach.**
**The collaborative partnership between academia and architects enables us to take advantage of tools to inform design decisions. A lack of tools can no longer be an excuse. As the lead designers of the built environment, which is the biggest consumer of the world's resources and energy, now architects should compute.**

# DESIGN PROCESS



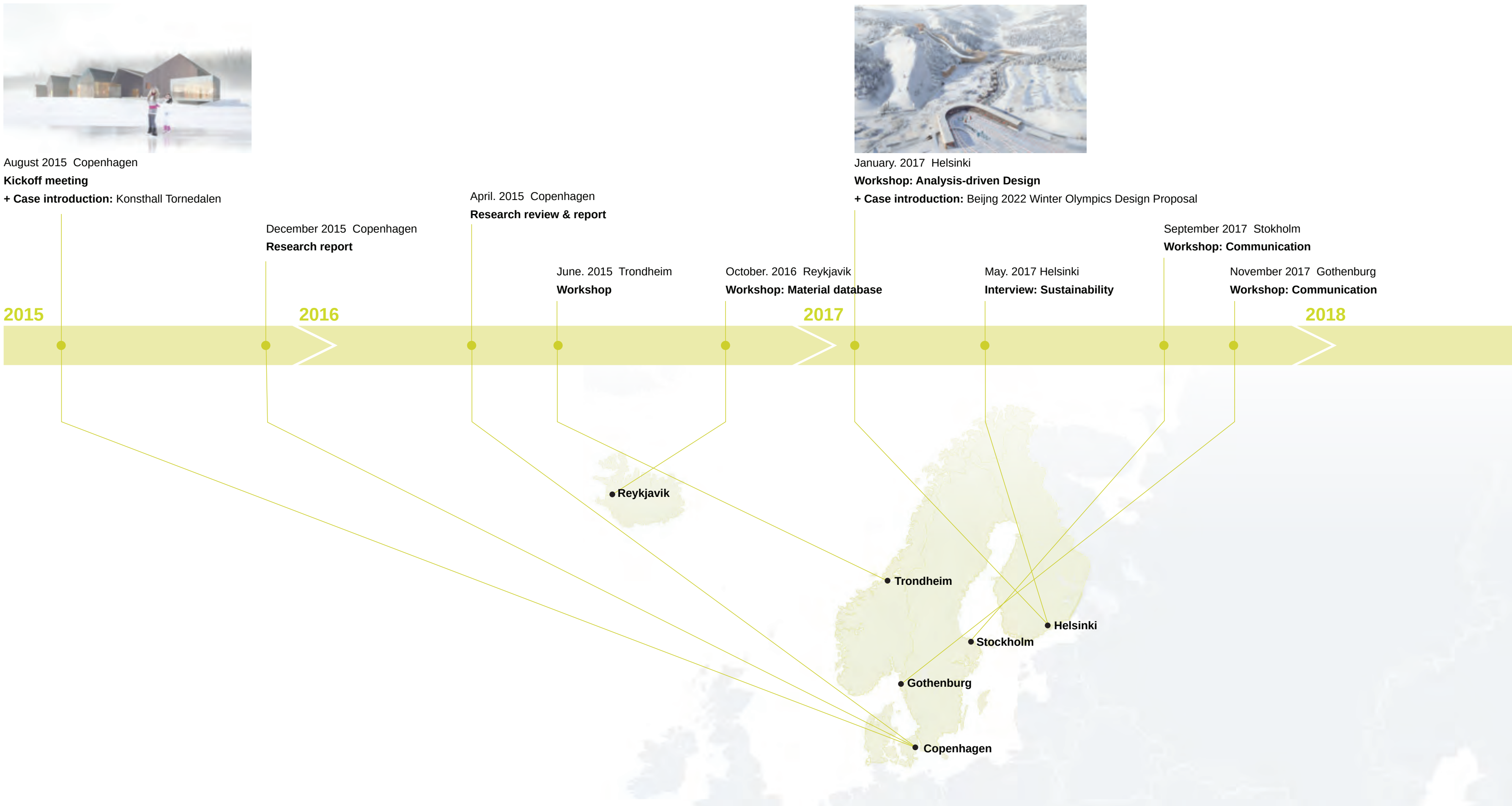

Research is intellectual fuel to generate innovative ideas in the beginning of the design process. It encompasses a range of aspects from understanding the needs of clients and local communities and evaluating the technical requirements of building physics to assessing the environmental performance of materials and building components. The STED network enabled us to strengthen our sustainable design strategies by providing analysis tools for research and evaluation during concept development.

# DESIGN TOOLS




The STED network provided a platform for a seamless collaboration between OOPEAA and DTU. In the early design phase, OOPEAA posed questions regarding building physics or environmental performance. In response, DTU worked in parallel with OOPEAA to develop analysis tools in Grasshopper plug-ins.

# PROJECT TIMELINE




In 2015, the project started with the case study of "Konsthall Tornedalen", an art museum in Sweden. After several sessions involving discussions and workshops to recalibrate the research strategy, OOPEAA and DTU joined hands in 2017 for a "Beijing 2022 Winter Olympics Design Proposal". In this project, comprehensive studies were undertaken to demonstrate the possibilities of mass timber building systems.

“Sustainability” is a perspective in which we see economy, ecology, and quality of life as a whole. It is one of our main concerns in architectural design. For us, “sustainability” is not only about the choice of materials that are ecologically sustainable, recyclable, renewable, and energy efficient, it is also very much about social and cultural sustainability - about a sense of rootedness and connectedness with one’s environment and the community around us, whether on a small or a large scale. Our approach to architecture is about combining innovation and the exploration of the potential of new ideas with a sense of respect for “locality” and “tradition”. This approach has led us to “sustainable” solutions, as illustrated in our work from the earliest project “Kärsämäki Shingle Church” to the latest competition entry “Beijing 2022 Winter Olympic Design Proposal”.

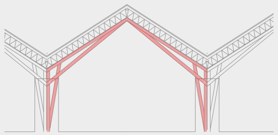
# CASE:
# KONSTHALL TORNEDALEN

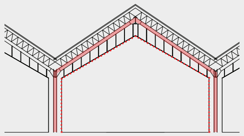
## Research Topic

### LCA COMPARATIVE ANALYSIS: WOOD VS STEEL

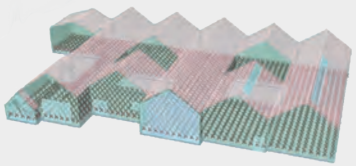
**Wood structure exposed**

**Steel structure with interior cladding**

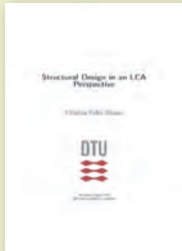




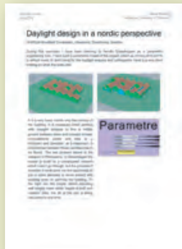
### PARAMETRIC DAYLIGHT ANALYSIS



## STED Report




**Research Report**
Structural Design in an LCA Perspective / Christine Collin




**Research Report:**
Daylight design in a Nordic perspective / Mads Mårbjerg

**Project:**
Konsthall Tornedalen

**Site:**
Vitsaniemi, Övertorneå / Sweden

**Program:**
Art Museum

**Design team:**
OOPEAA Office for Peripheral Architecture
Architect in charge: Anssi Lassila
Design team: Teemu Hirvilammi, Mia Salonen, Hanna Heikkilä, Kazunori Yamaguchi

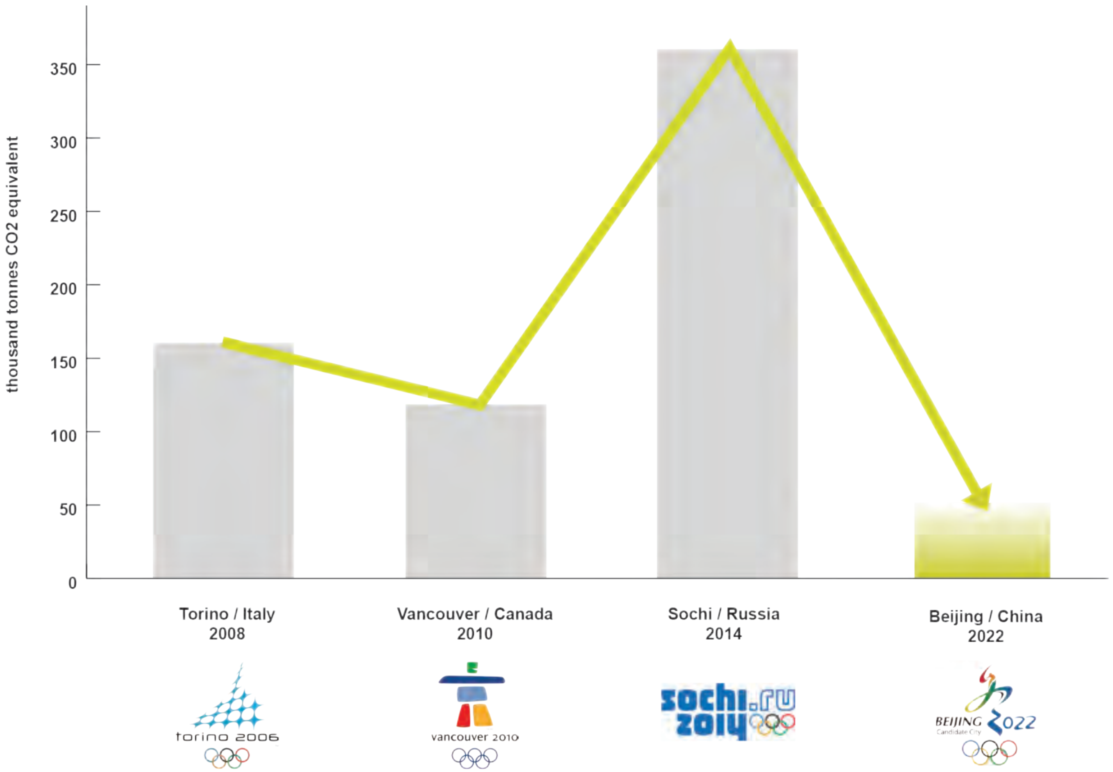
**STED Network research team:**
Technical University of Denmark
Lotte Bjerregaard Jensen, Kristoffer Negendahl, Christine Collin, Mads Mårbjerg, Tina Mizal, Alberte Munk Hansen

Located on the beautiful banks of the Torne river that marks the border between Finland and Sweden, Konsthall Tornedalen - a space for making and exhibiting art, and a place for people to gather and come together - will soon be built. This project initiated a number of research projects at DTU, including Christine Collin's study on LCA to compare structural systems parametrically and the indoor environment research by Mads Mårbjerg that focused mainly on daylight in the Nordic context.

# CASE:
# BEIJING 2022 WINTER OLYMPIC DESIGN PROPOSAL

## CHALLENGE: REDUCE THE ENVIRONMENTAL COST OF OLYMPICS

**Environmental impact of winter Olympics**




**Project:**
Beijing 2022 Winter Olympic Design Proposal

**Site:**
Chongli, Hebei / China

**Program:**
Venue design for Beijing 2022 Winter Olympic (Nordic Center Venue for Ski Jumping, Cross Country, and Biathlon)

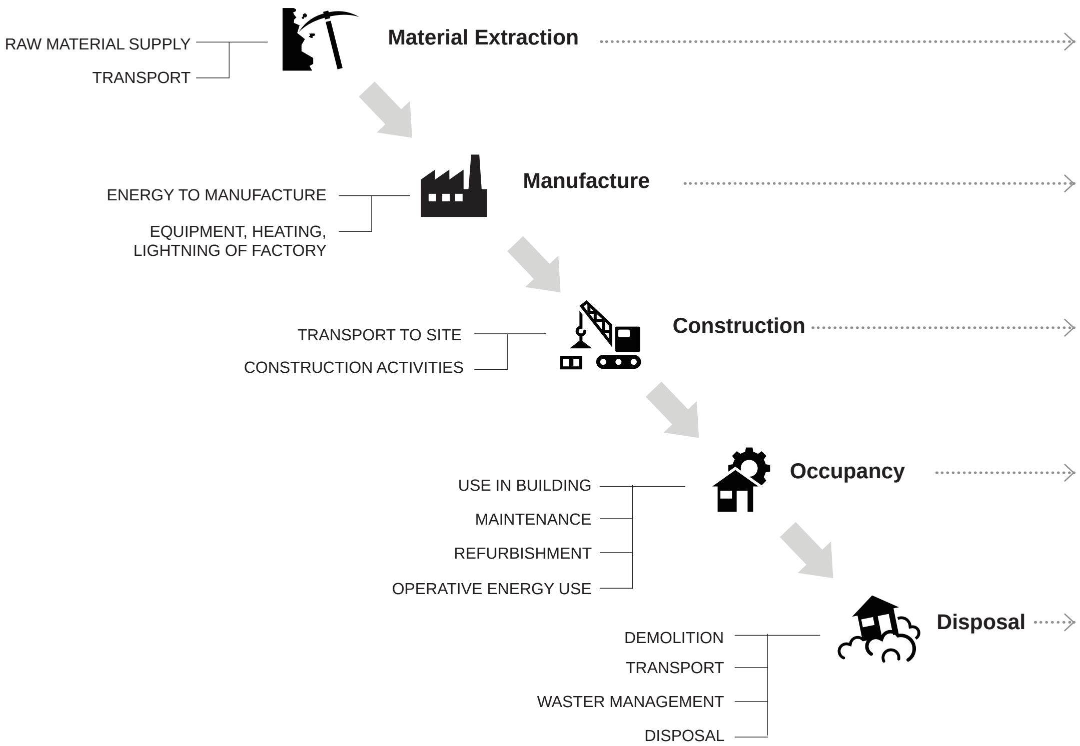
**Design team:**
OOPEAA Office for Peripheral Architecture
Architect in charge: Anssi Lassila
Design team: Kazunori Yamaguchi, Marko Simsiö, Katharina Heidkamp
In collaboration with
PES Architects Ltd., FCG Finnish Consulting Group Ltd., VSU Landscape Architects Ltd.

**STED Network research team:**
Technical University of Denmark
Lotte Bjerregaard Jensen, Kristoffer Negendahl, Lucas Philip Rinne Toh

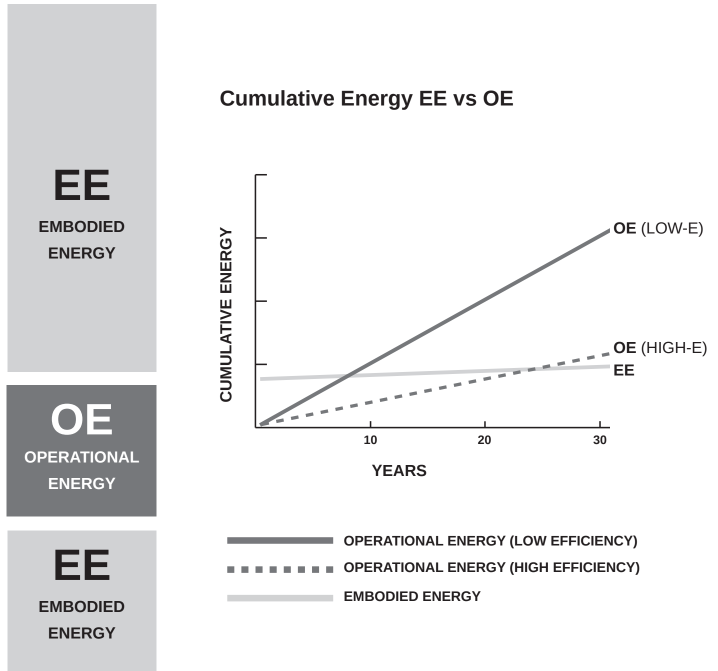
In 2017, OOPEAA was invited to participate in the competition for the Beijing 2022 Winter Olympics Design Proposal. As the Olympics Committee increasingly emphasizes sustainability, the challenge was to minimize the environmental impact of the Olympic games as a whole.

# BUILDING LIFE CYCLE PERSPECTIVE

## Building Life Cycle

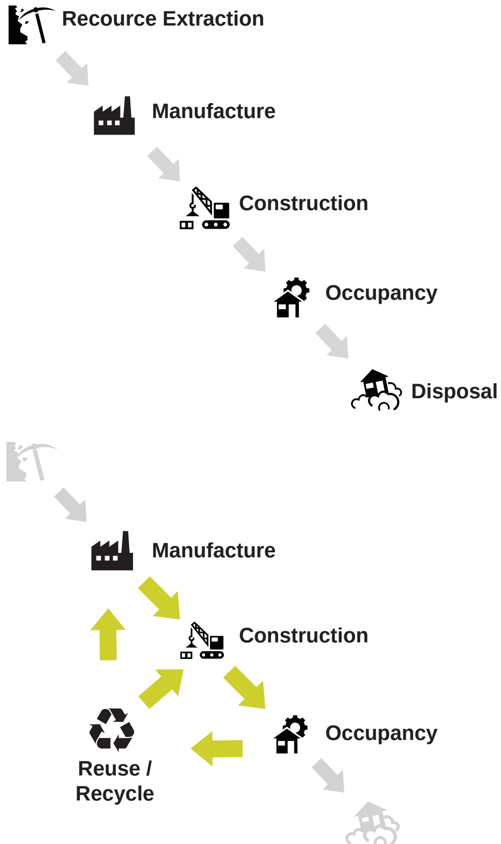



## Embodied Energy vs Operational Energy



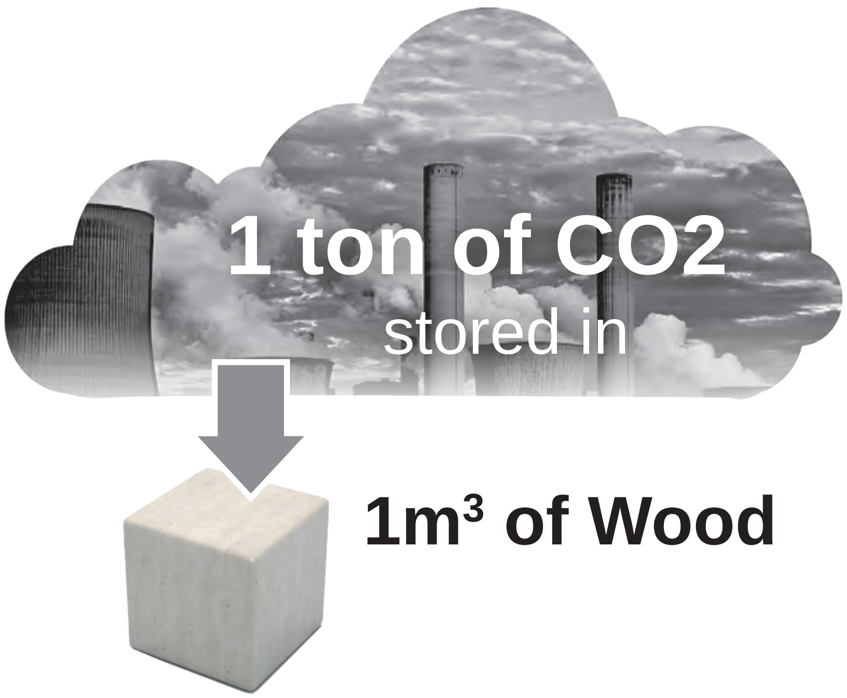

While most sustainable design strategies have been focusing on operational energy (the energy used for occupancy and maintenance), the embodied energy (the energy embodied in the material extraction, manufacture, and transport of building components, and the construction and demolition) has been largely ignored. However, embodied energy can be an important contributor to cumulative energy in total when buildings have a short lifespan like facilities for the Olympics.

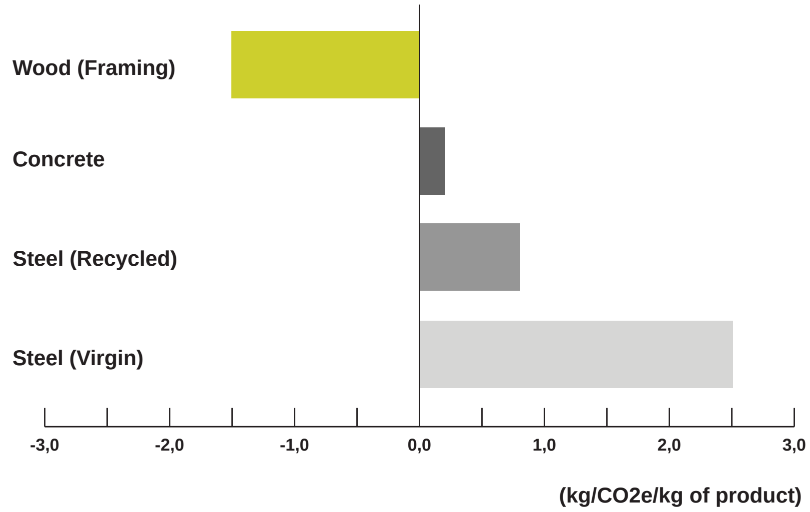
# SUSTAINABLE MATERIAL SELECTION




When considering the environmental impact of the whole building life cycle, wood is the most sustainable choice. It is the only major building material that is created by nature - both renewable and sustainable when harvested responsibly.

## WOOD: CARBON NEGATIVE MATERIAL




**Process Emission Including Carbon Storage within Material**

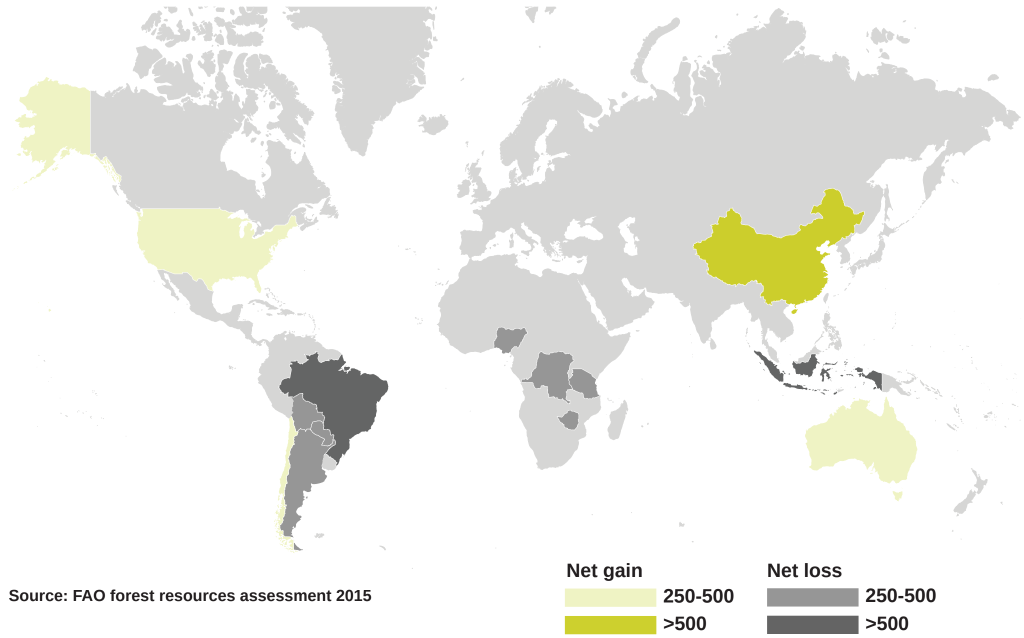
Source: 2006 US EPA Database

In addition, wood stores the equivalent of 1 ton of carbon dioxide for every cubic meter. Wood is a sustainable building material, as it is derived from a renewable source and has low embodied energy when compared to most other structural materials. The literature study showed that the use of wood was the most favorable option in terms of minimizing carbon footprint.

# RESOURCE

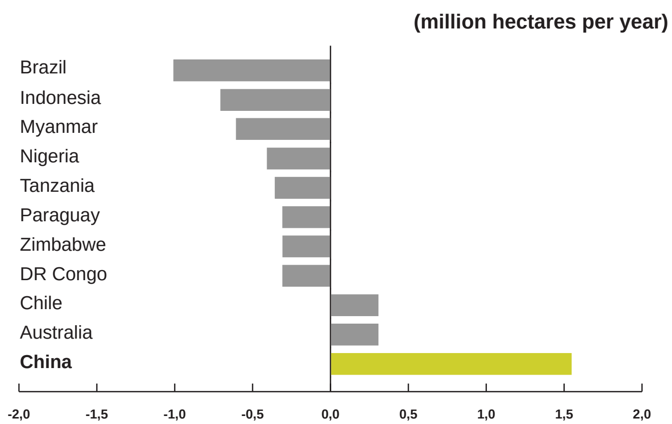
**RESOURCE EXTRACTION** MANUFACTURE CONSTRCUTION OCCUPANCY DISPOSAL

### ANNUAL CHANGE IN FOREST AREA




Source: FAO forest resources assessment 2015

### ANNUAL CHANGE

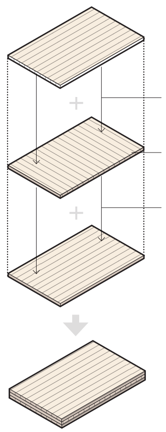



When using wood as a building material, the first and most important thing is to make sure that the forest resource is managed sustainably. According to research in 2015 by FAO – the Food and Agriculture Organization of the United Nations – the forests in China have been growing remarkably.

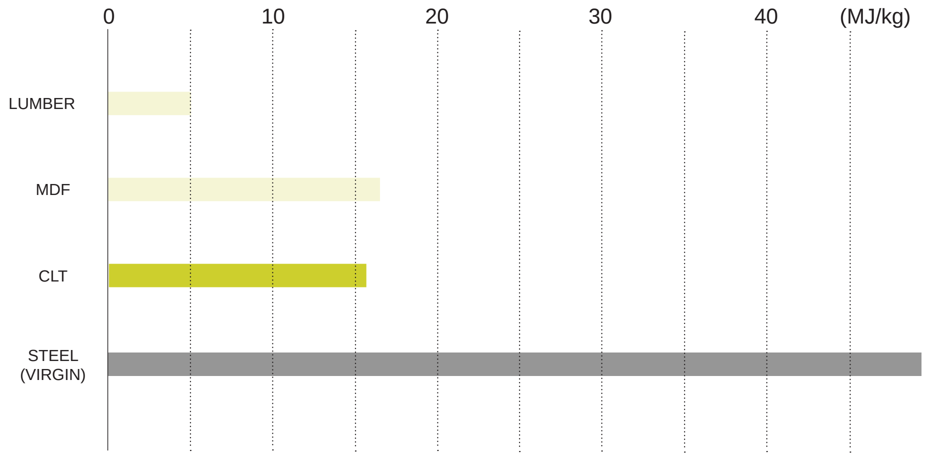
# MANUFACTURE

RESOURCE EXTRACTION | **MANUFACTURE** | CONSTRCUTION | OCCUPANCY | DISPOSAL

### CLT: CROSS LAMINATED TIMBER




### ENERGY TO MANUFACTURE BUILDING MATERIAL



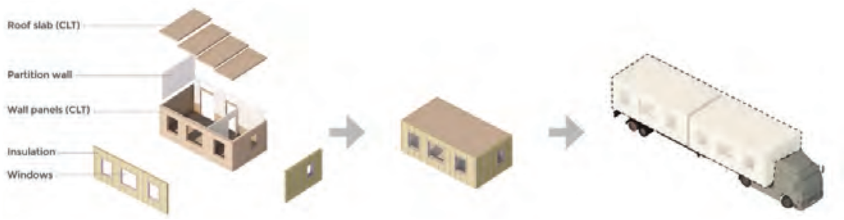

Cross Laminated Timber (CLT) is an engineered wood product made from layers of solid-sawn lumber glued together. Each layer of board, known as a lamella, is orientated perpendicular to the adjacent layers and glued on the wide faces of each board to provide optimum strength.

CLT was selected as a building material for the project, after considering its advantages over steel, concrete, and masonry construction in terms of environmental impact.

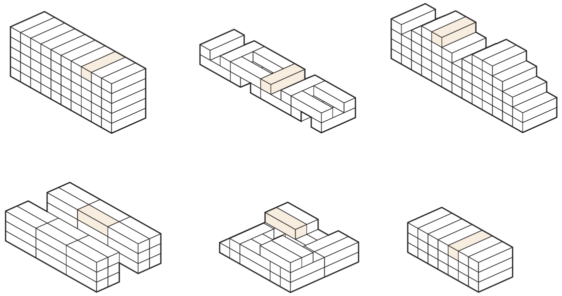
# CONSTRUCTION

RESOURCE EXTRACTION MANUFACTURING **CONSTRCUTION** OCCUPANCY DISPOSAL

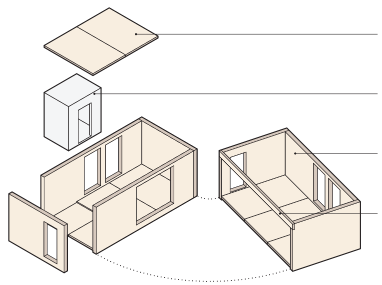
## PROPOSAL CONCEPT: MASS TIMBER BUILDING SYSTEM

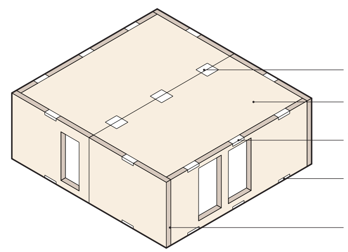



### VARIATIONS



### PREFABRICATION



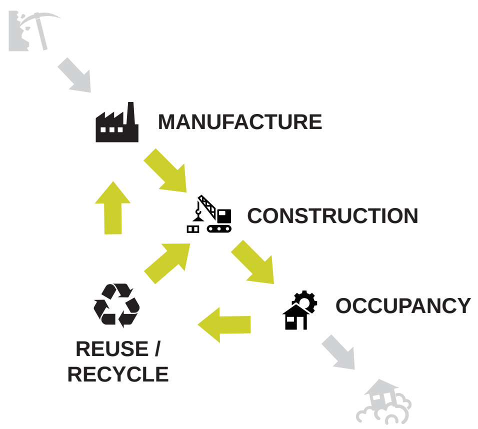



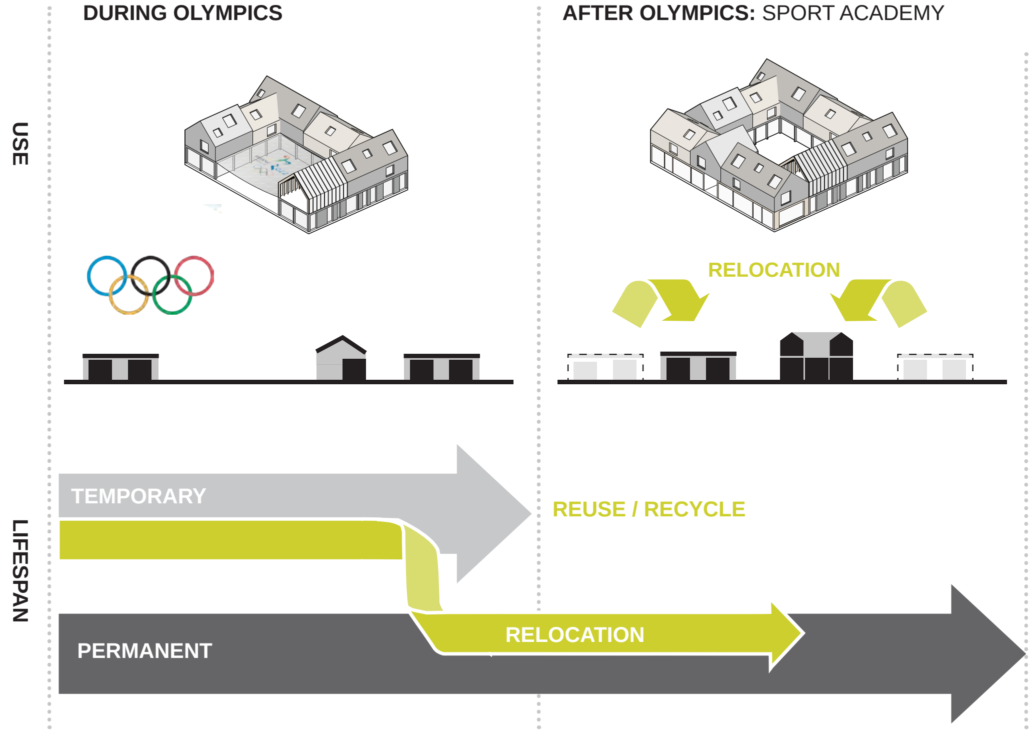

The use of Cross Laminated Timber in the form of prefabricated volumetric modules and panels makes it possible to keep the construction time short and efficient. In addition, it also enables the full reuse of the building parts and their components.


RAMIRENT

# DEMOLITION


## REUSE, RECYCLE, RELOCATE



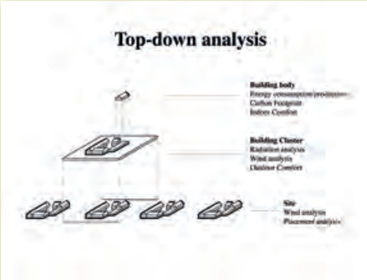




With the possibilities of reuse, recycling, and relocation, a mass timber building system enables a variety of scenarios at the end of the life cycle. During the Olympic games, the CLT buildings will house services for the visitors. There will be shops, restaurants, and information services on the ground level, and offices on the upper floor. After the Olympics, the structures will be recycled to serve the needs of the post-Olympic use as a sports academy.

## STED Report

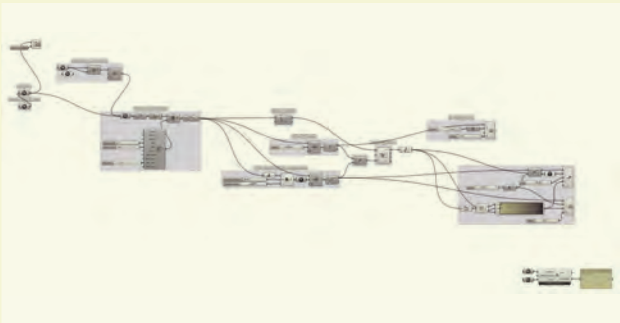
### Research Report: “Top-down analysis“

Lucas Philip Rinne Toh

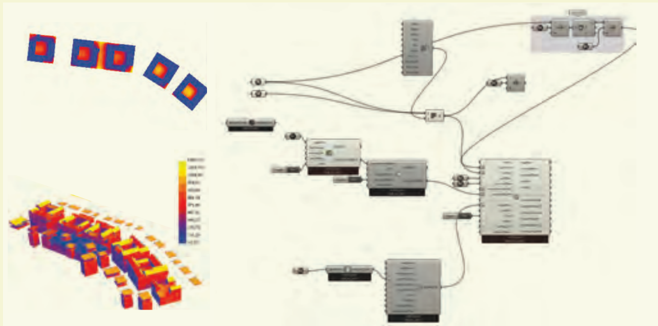



**Wind analysis tool**

**Site planning evaluation tool**



**Radiation analysis tool**



As the research was an intrinsic part of the proposal, DTU joined the design team from the very beginning of the project. Lucas Phillp Rinne Toh from DTU worked closely with OOPEAA to conduct a comprehensive research study including energy, wind, material, radiation, and resource analysis based on literature studies. This seamless collaboration between OOPEAA and DTU enabled a totally new approach in sustainable design in the early design phase.

# no humor
# no hope

small practice – big issues

**some of the best ideas start as mistakes or misunderstandings**

contemporary Reykjavík

Studio Granda was established in Reykjavík, Iceland in 1987. The office has always been small with between two – nine staff. Right now, it has three. Design, production and supervision is undertaken collectively so there is no long chain of command and all three of us do everything from concept to making coffee. Projects range from major public projects, educational buildings, private residences, infrastructure, planning, and installations with artists. Presently the office is designing the new offices for the Icelandic parliament.

Iceland, with a population of about 340,000 is a very special environment in which to practice and this has certainly had an effect on our position within the STED collaboration. The work of the office is not specialised, no two projects are alike and very few are of similar building type or size. There are very few indigenous building materials, so the selection of building elements is often governed more by prices on the international market and shipping options than appropriateness. The climate is extreme but there is an abundance of cheap geothermal and hydro power and this, so-called, renewable energy skews all calculations. Even though half the population live in the capital area one is always aware that nature is more prevalent than man; as surmised by Adamus of Bremen “The mountains are their castles”. To cut a long story short, the normal way of practice doesn’t seem to equate with the way things are done in Iceland.

**to be useful creatively digital tools must be equally abstract**

Good architecture has always been sustainable. It maximises site and climatic conditions, is efficient in structure, manageable in construction, looks great and people love to use it. Usually, the best buildings last a long time, have many uses, and become an essential part of our built environment and cultural identity. However, although this may be true it's not a reason to believe that buildings can't be made even better.

In practice one accumulates knowledge and experience and uses it in the design of successive projects. When a task is new outside help and opinion may be sought and very often this takes the job to a new level.

In a perfect world, each project would be designed by a carefully selected team with the necessary skills and time to design, develop and prepare documentation for its construction. The process would investigate and evaluate various design approaches to achieve a perfect synthesis of technical prowess, sophisticated materiality, spatial precision and timeless looks. The building would be carbon neutral, totally recyclable and economic. In this scenario, advanced digital design tools could be an ideal partner, providing accurate feedback on design decisions and creating a living database for the development of the design from concept to completion and beyond.

The reality of practice, as we have experienced it, is a parallel universe. Competition briefs and project proposals typically state an overwhelming desire for greenness, cutting edge design and quality finishes but these desires are seldom matched by the budget nor time schedule to realistically achieve them.

Competitions offer an opportunity for experimentation, but they are by nature either worked for free or a token fee in exchange for the chance to win. The time investment in design has to be balanced with the chance of success, in the uncomfortable knowledge that the decision of the jury will often be swayed as much by clever presentation as design quality. Furthermore, it's no secret that ecological performance is rarely the main issue in the juries' comments. Once won the opportunity for design development is often limited by time schedule, financial constraints or the simple fact that the client has chosen a particular design and just wants to build it. The fact that it was done, essentially for free, in a rush, in evenings and weekends doesn't seem to register.

Direct commissions are an even faster process as many clients expect the architect to have a solution for their project up their sleeve: surely any professional worth their salt is well aware of all the requirements and has the experience of previous projects to draw upon – so what's the problem?

The upshot of this reality is that much design is done on the run with major decisions taken on a hunch or a whim. That's not to say that the first sketch always makes it to the building site, rather one would expect dozens of different approaches to be tested in a very short timescale through crude sketches, models and discussion. With an experienced team it's possible to check the key issues quickly while still allowing for changes of mind and personal preoccupations. Not surprisingly, most detail design and resolution is founded on these rule-of-thumb decisions and it usually works rather well.

In our practice, the involvement of digital tools has proved to be too slow. We need an immediate response, not one that takes a few hours, let alone days. Furthermore, it's very rare that sufficient information is available in the early design stages to make a realistic digital assessment. The fluidity of the creative process means that no sooner has a form started to develop than a conversation turns the design on its head. Structure, lighting, circulation routes, insulation, materiality, views, sound and so on are all part of the debate and all have a part to play in making the entity work. Everything has to be considered simultaneously and once it's all in place there's rarely any time left to check if the decisions were right. It just gets built.

That's not to say that technology isn't used on a continuous basis in the design of our buildings, we use, in collaboration with consultants, an assortment of tools and techniques to inform and check decisions. However, when told that a comment can't be made on, say, a sprinkler system until the 3D model is finalised we momentarily lose faith in everything digital.

Maybe, the promised age of augmented intelligence will collapse the time frame to a usable level but while digital tools are still in their infancy we envisage that the best use of the technology is in advance of the design process - to increase our knowledge base and awareness of possibilities and as a post evaluation check on the effectiveness of what has been done.

There are endless generic challenges that need addressing. For example, new regulations require better soundproofing between floors. Research, with the assistance of digital tools, could try to optimise structural floors and their inherent acoustic characteristics to speed construction, maximise ceiling height and eradicate the need for additional layers of sound proofing. They would ideally be made of a high proportion of recycled material and be, in turn, easily recycled.

But not all solutions need to be digitally driven. Tried and tested analogue techniques, or just straight trial and error, are often just as effective either alone or in tandem with digital tools. Whatever issues are addressed the results and new solutions can be used to inform design debates. It's an educational tool to ensure that the discussion in the construction environment is concurrent with the latest thinking and knowledge.

At the tail end of the design process it would be enlightening to see if the decisions made in the heat of the moment were really as appropriate as they seemed at the time. By retracing the constrains of a project through its design development


Staedtler MARS-TEHNICO 782 probably the most advanced augmented intelligence yet made by man

weaknesses and errors may be discovered that assist both the maintenance of the building and future projects of a similar genre.

From the viewpoint of our small practice, it's clear that digital tools are not yet in the room, they are too cumbersome, resource intensive and limited in application. But in the same way that CAD has become the de facto means for producing project information it's clear that as they mature integrated digital tools will permeate every level of the profession. This development is wonderful, exciting and new but what is important to remember is that it is we, humans, that need to make the final decisions. The machines are there to assist us, not tell us, how to make our environment.

Three projects have been undertaken under the umbrella of the STED project to try and bridge the gap between theory and reality. The Lichen project is an attempt to make an organic surface finish product: a green wall in a tin. Skipholt looks at the issues surrounding the reuse of 50-year-old buildings that are past their sell-by date but are still structurally sound and represent a moment in our cities history. Breiðholtsbraut is a both a challenge to the accepted norms of bridge construction and a test of the limits of digital tools in assisting the preliminary design phase.

# THE LICHEN PROJECT

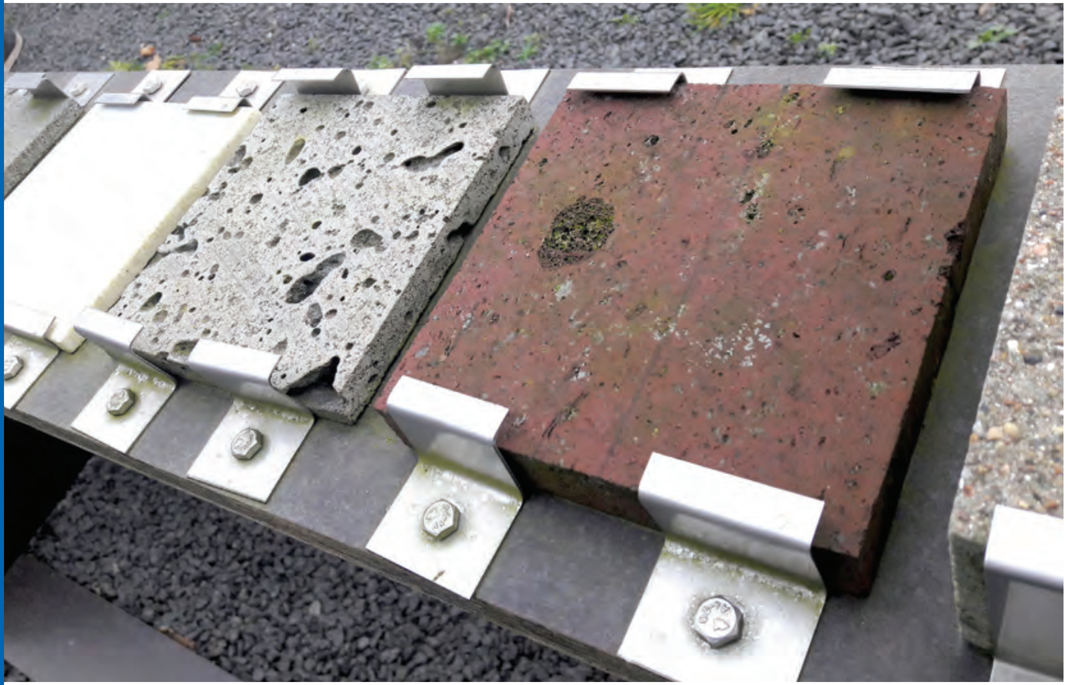
moss wall Reykjavík City Hall 1992

Lichen grows on stone, concrete, trees and many other surfaces. There are various varieties with colours principally in the yellow, green and white spectra. Most commonly the growth is limited to a small area but occasionally one sees an entire surface covered with exquisitely delicate growth. Encouraged by the success of the moss wall on the Reykjavík City Hall (1992) we envisioned an organic, lichen-based, self-healing surface finish. The ultimate green wall in a tin that requires no mechanical lifeline nor maintenance.

Michele Bradanini undertook extensive research on the nature of Lichen, its preferred habitat and what external factors might be adjusted in order to encourage its growth. Substrate and lichen samples were sourced in Iceland and Denmark and a testing rig constructed at DTU in Lyngby. Not surprisingly, considering the slow growing nature of lichen, the results have been indicative of a path to a solution but are far from conclusive. The research will be continued by Wolfgang Kunther and Jean D'ursel.

Michele Bradanini
Jean D'ursel
Wolfgang Kunther

substrate samples to test for lichen growth at DTU



In the recent years there has been an increasing focus on contrasting deficiency of green areas in cities. This comes with the urbanization as there is a desire to introduce green areas in the cities to improve the living conditions. The greening of cities involves also the concept of greening the building envelopes. Green façades and green walls exploit the ability of green to occupy the vertical surfaces, integrating green in cities, without the need of ground space.

The existent systems for vertical green present several limits and disadvantages, encouraging researchers to develop new solutions, with a higher level of integration with the building structures. Conversely, undesired biological colonization is common on building materials and many studies have been done regarding the bio deterioration effects that pioneer organisms have on the building structures.

The aim of this thesis is to investigate the possibilities of using lichens as colonizing organisms on contemporary façade design. An experiment was carried out in order to assess the suitability of several natural and artificial common cladding materials as substrate for lichen colonization. Lichens were collected in Iceland and Denmark and inoculated into specimens of several materials. Then the specimens were exposed to environmental conditions, placed on different supporting structures in order to evaluate also the effects of inclination and of other architectural parameters inducing different micro-climate conditions.

lichens on white marble gravestone, in Hólavallagarður cemetery, Reykjavík

Basalt and lava stones specimens appeared to have a higher bio receptivity compared to the other materials, since a higher quantity of lichens was observed to adhere to the substrates. However, the experiment will be continued for two more years to observe lichens growth.
Also, significant differences were observed in the specimens with changing inclination, and whether or not it was sheltered to protect the lichens from hydrodynamic. Higher presence of lichens presence was observed on the specimens placed horizontally and covered with the shelter. However, the results obtained for the specimens oriented vertically were more significant, considering the intended application is on vertical building surfaces.

A second experiment was carried out in a climate room, in order to assess the correlation between pore size and lichen adhesion to the substrate. The presence of other pioneer organisms, such as bacteria's and moulds, influenced the results of the test. However, from the results obtained it was observed that specimens with larger pores showed a higher degree of bio receptivity.

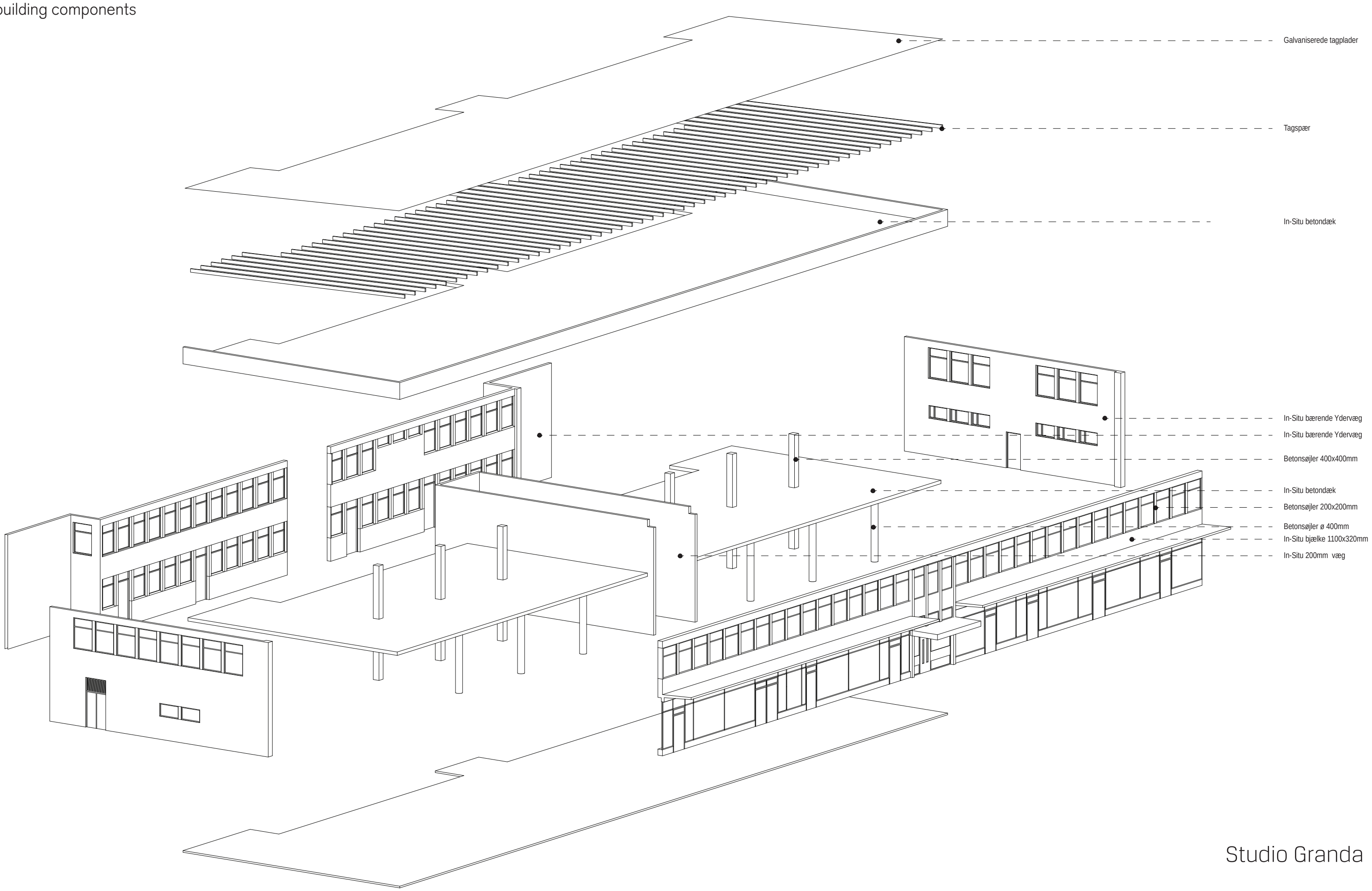
Michele Bradanini

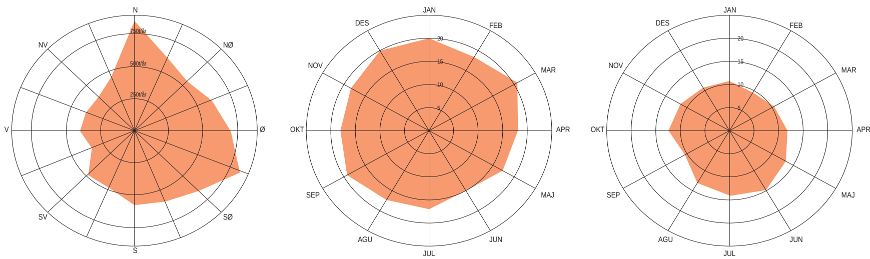

## **SKIPHOLT** URBAN RENEWAL

Jens Arnason
Jonas Nyholm
Kenneth Hannibal
Nicolaj Skovsø

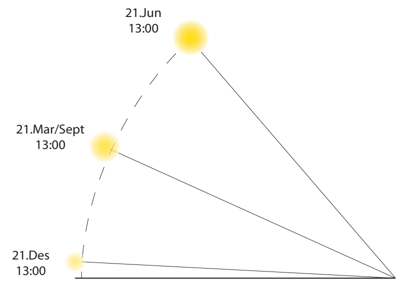
Skipholt 70 is an existing two storey neighbourhood retail and commercial building built in the 60's. Planning permission on the property allowed up to 26 affordable flats on the second floor and in a new attic storey. The existing building presented many constraints including structural limitations, services, access and the active businesses on the ground floor. It's a toxic cocktail typical of urban redevelopment projects resulting in a design that only managed to squeeze 19 apartments into the planning limitations.

exploded axonometric of existing building components



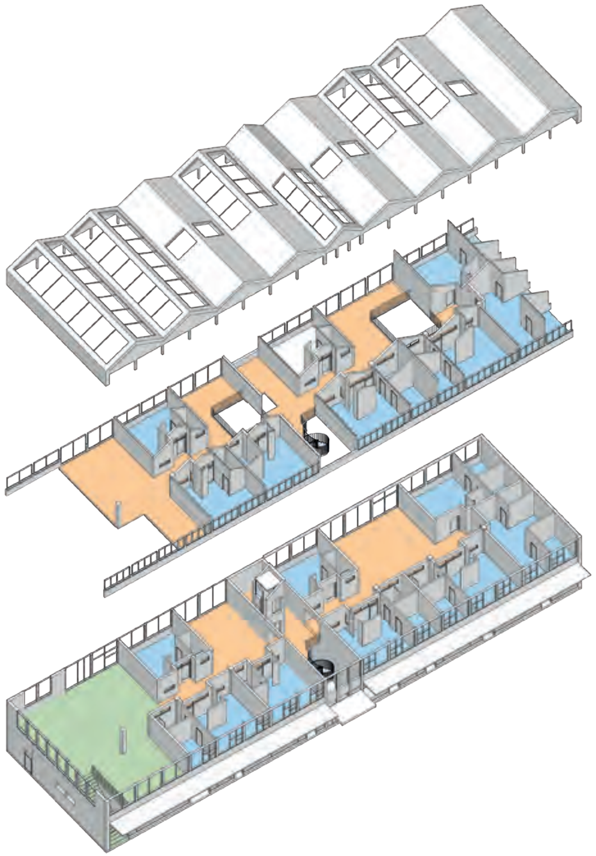



strong, omnipresent winds are a determining factor in shelter provision and ventilation strategies




fenestration design and glare avoidance is challenged by the low sun angle

zoning

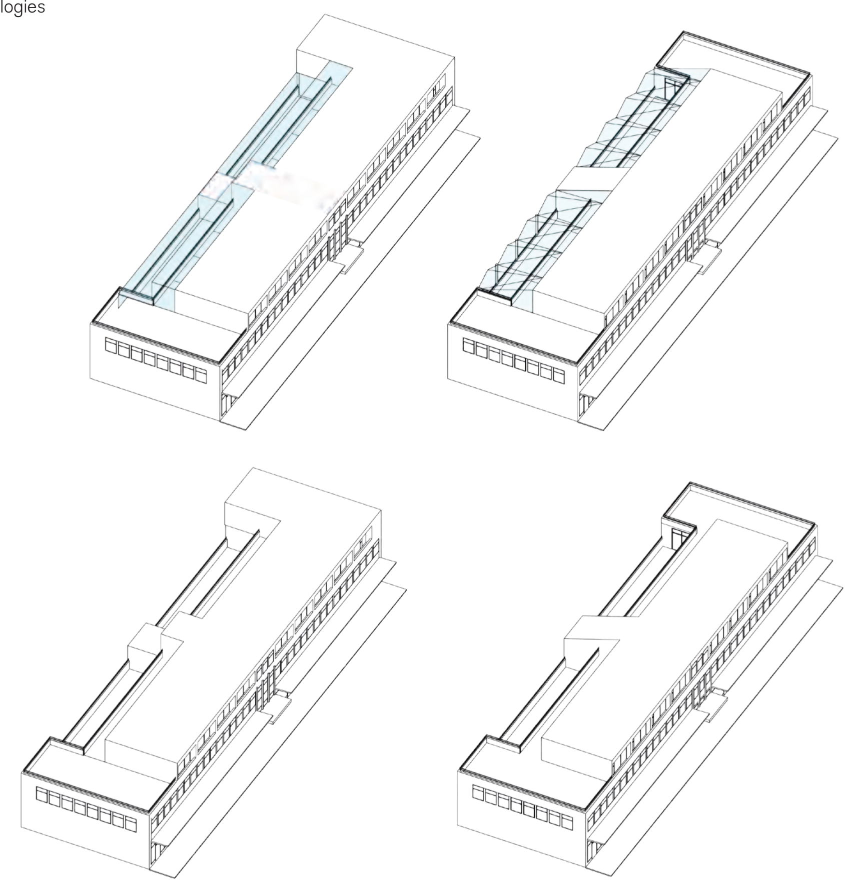


residential

common residential areas

public areas / café

typologies

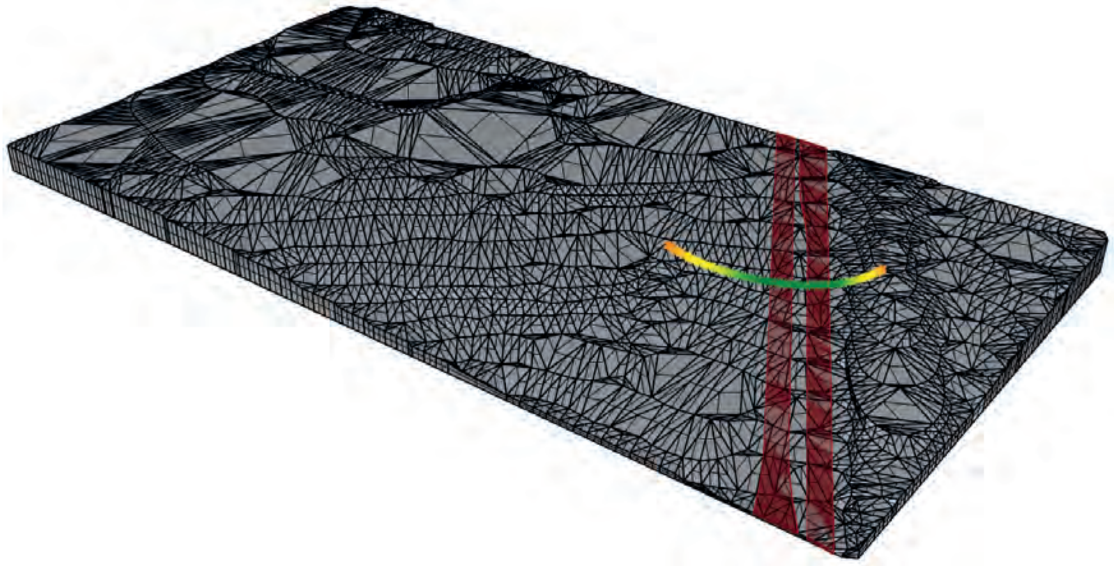


Jens Arnar Árnason, Jonas Nyholm, Kenneth Hannibal & Nicolaj Skovsø reran the program of the project, stripping the building back to the original structure and looking at different means to re-inhabit it, while minimising new material and transport. The investigation was not limited to the Skipholt building rather it was seen as a means of developing a redevelopment strategy for the re-use and renewal of the extensive modernist building stock that has exceeded its best-before date.

contractors instinctively appropriate and re-use insulation, roofing timbers, ducts and metal cladding during construction

communal space

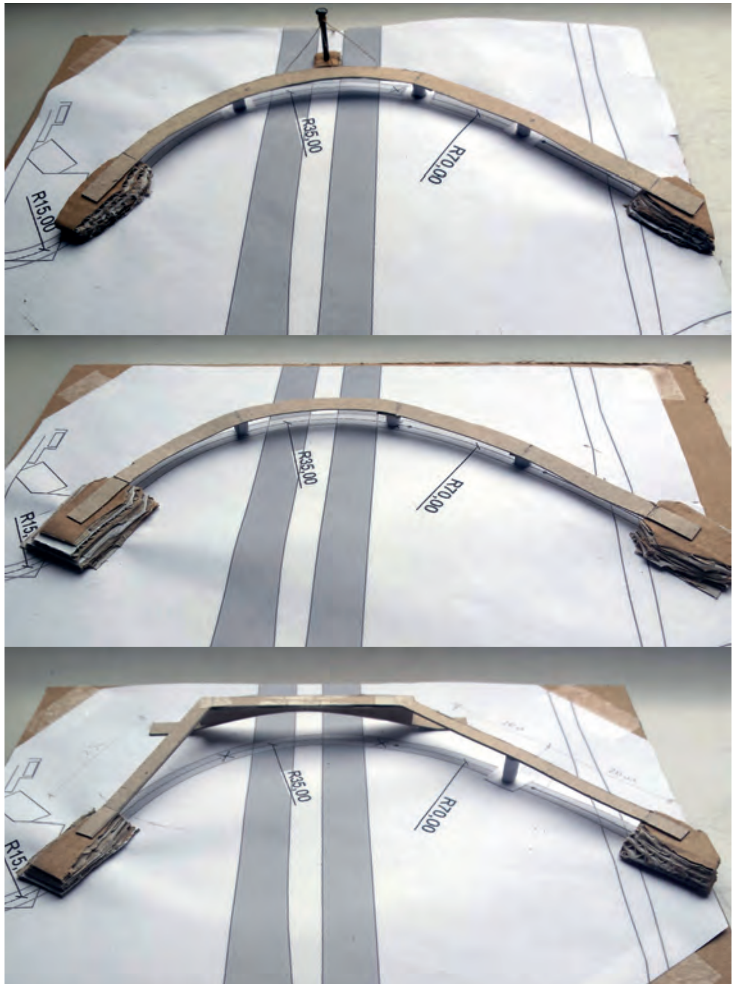
topographic model with bridge geometry



## **BREIÐHOLTSBRAUT** STRUCTURAL TIMBER FOOT & CYCLE BRIDGE

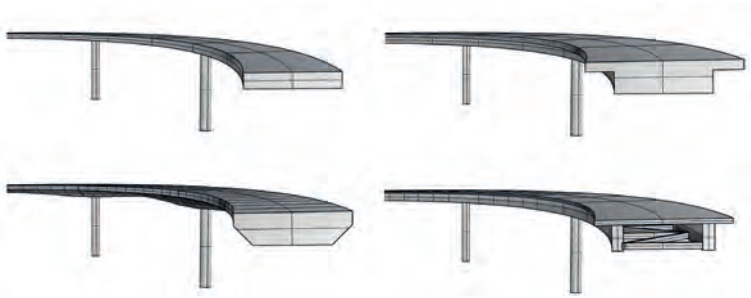
Matej Opacic


sketch models

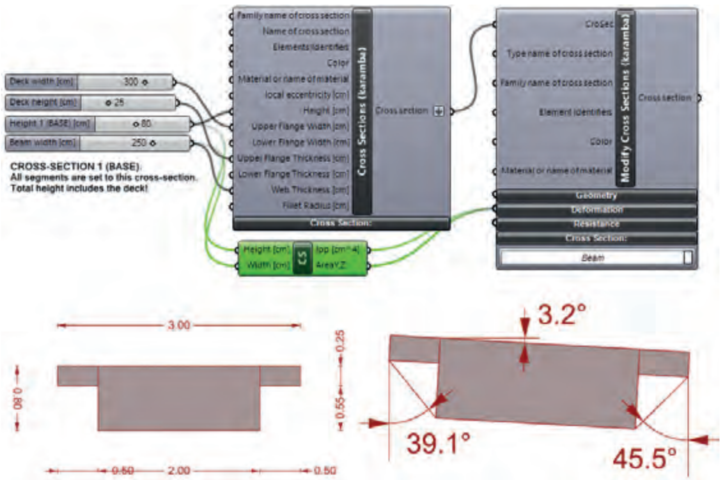



The proposed foot and cycle bridge over the a four-lane highway Breiðholtsbraut is 100m long and 3m wide, with a maximum clear spans of 27m. The architect's role in infrastructure structures is to coordinate the geometry, primary structural system and material finishes with the engineers and obtain the building permit. In addition, the design and preparation of working drawings for more delicate visual design elements, in this case the balustrades, are often part of the remit. The time budget for this project was 80 hours. Not surprisingly, after a cursory discussion of the relative merits of steel, precast, or in-situ construction vis-à-vis carbon fibre, a known solution, post tensioned in-situ concrete, was chosen. There wasn't any time to even open the debate on structural timber.

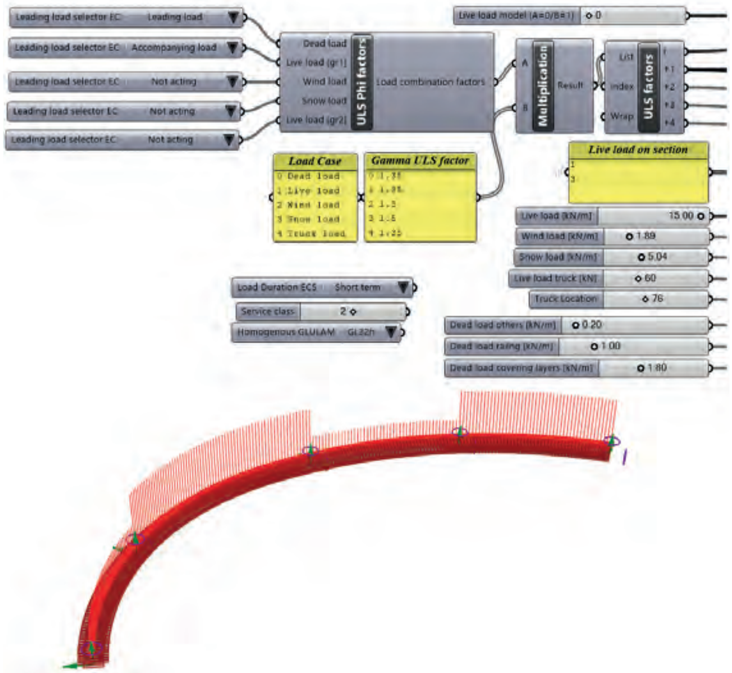
Matej Opacic set out to try and disprove the often-held belief that wood is an unsuitable material for highway bridge structures. He began by tracing the history and development of wooden bridge structures and timber technology to find possible solutions for the Breiðholtsbraut bridge. However, the scale and geometry of the bridge demanded a new approach that mixed known technologies with his own innovations. His methodology used traditional techniques in parallel with a swathe of digital tools including Grasshopper, Karamba, REFM, Anemone & Galapagos. With ingenuity, diligence and skill he managed to prove that a wooden solution could work while in the process discovering the strengths and limitations of new design technology.



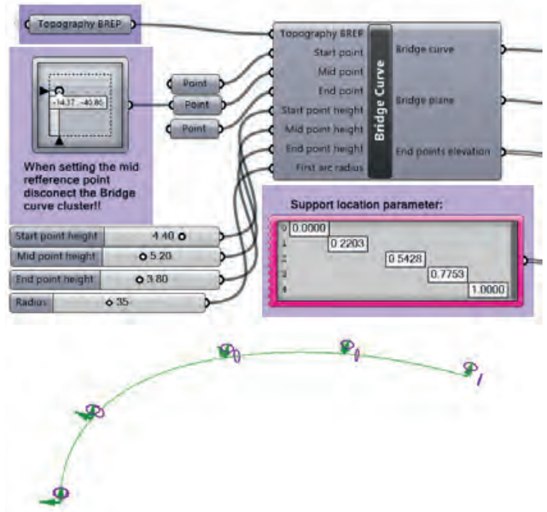
cross section options




cross-section input controls

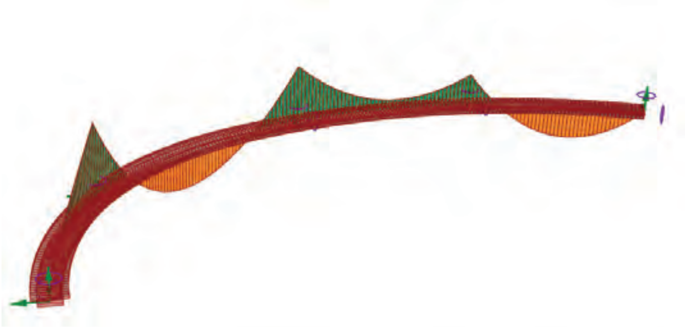



load input controls

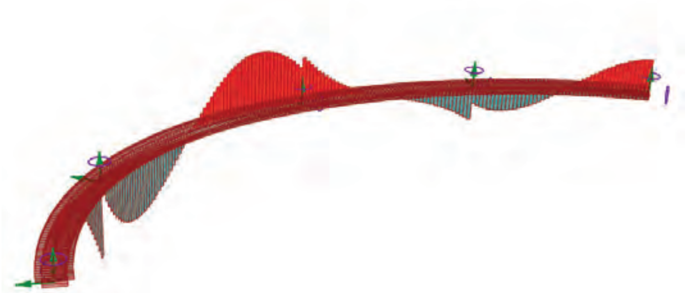



geometry input controls

bending moment diagram



twisting moment diagram

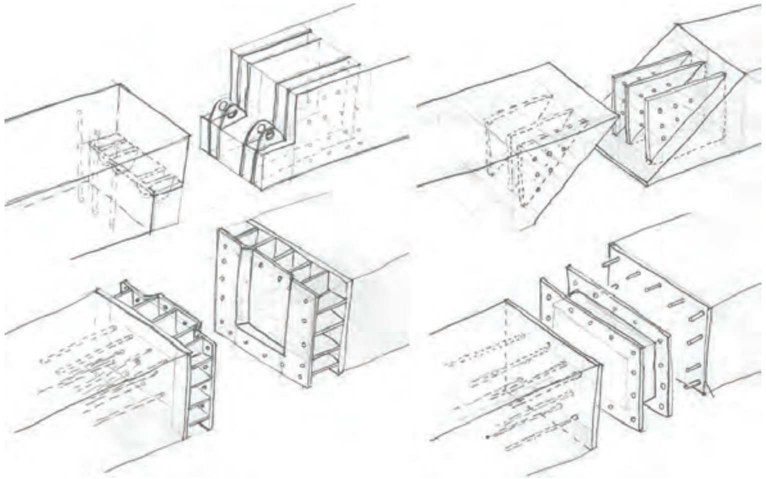


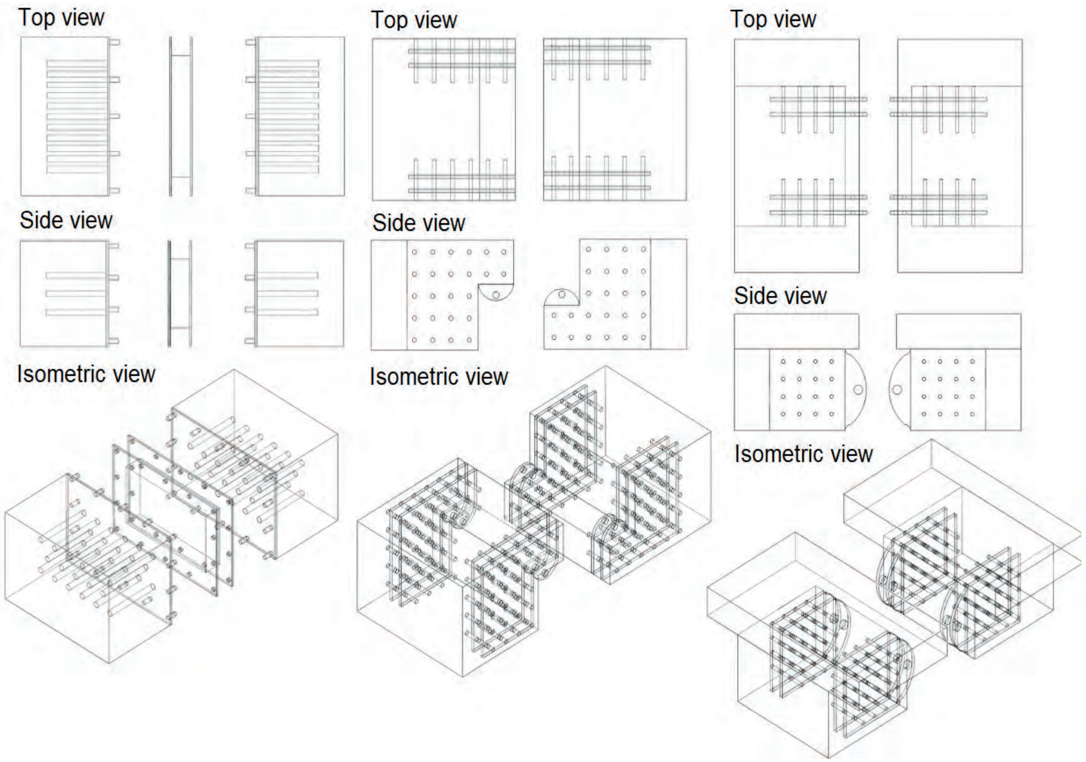
2nd vibration mode

During the project, a study has been made into the methods and principles applied in the earliest design stages of conventional design. The importance of individual parameters and distinct stages in the decision-making process have been outlined in a study of a timber footbridge. It has been concluded that the nature of the curved bridge severely limits the possible applications of timber structural systems, demanding that unconventional structural components, methods, and considerations be used in its design. Nevertheless, a viable timber solution has been found for the alternative superstructure design of the concrete Breiðholtsbraut highway footbridge.

It has been proven through the use of Eurocode standards that with implementing the correct structural and preventative measures, the durability of the superstructure is competitive with that of exposed concrete and steel bridges. Furthermore, the initial misconception that the static height of the bridge profile would need to be significantly higher to account for the decrease in the rigidity of the system has been proven incorrect. In fact, the proposed solution shows that the structure functions well within the limits of serviceability and ultimate limit states according to provisions of the Eurocode standards. Although the lowest natural vibration frequencies were identified as a potential issue in the subsequent stages of the design, these are believed to be manageable through the use of well-established engineering approaches. In retrospect, it has been shown that a timber design of the footbridge is a viable and arguably a preferable solution for not only the structural, but also logistical and environmental reasons.

Matej Opacic





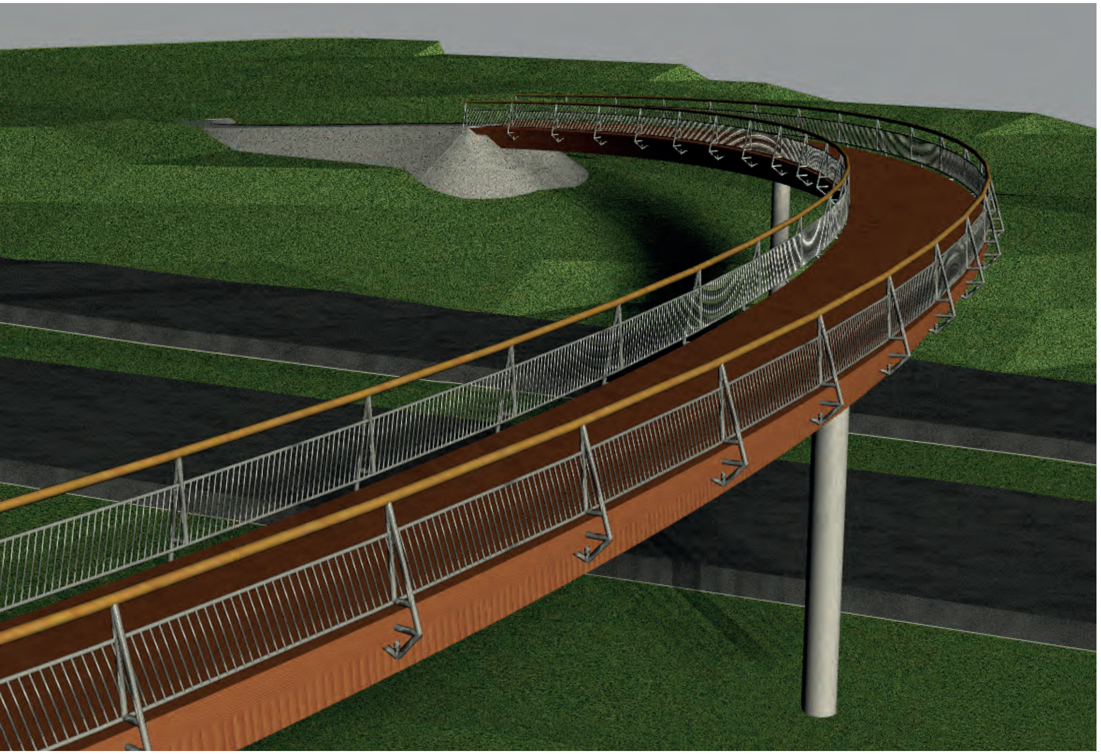

connection details

The most important aspect of computational design tools created for the early design, apart from a comprehensive output of results, is a user- friendly graphical interface. The script created for the purposes of this thesis is in no way a simple and user-friendly way of operating the algorithms. Therefore, for this script to be useful for anyone else but the author, it would need to be thoroughly restructured, and transformed so that the only instance of the script the user would be exposed to would be the input parameter panel, a visual viewport of the resulting model, and the numerical result panel. In this way, even individuals with limited or no knowledge of visual programming in parametric environments would be able to benefit from the use of the program.

post-tensioned concrete proposal Efla Consulting Engineers / Studio Granda architects

Along with this, the obvious topic for further research is the implementation of other structural systems in order to construct a framework for the design freedom beyond just a single type of structural form. But such research will not be economically profitable until the tools for analysis within the parametric environments reach a level of complexity and accuracy where the designer can use them with the same degree of certainty as a commercial software, the likes of RFEM.

Matej Opacic



structural timber concrete proposal Matej Opacic

## CONCLUSION

With a location in Iceland and the majority of our projects within the same postal district we are well aware of the dangers of isolation. It is all-too-easy to fall into a comfort-zone where routine and familiarity supersedes curiosity. Studio Granda joined the STED project with the intention to broaden the office's vision and working methods by learning new techniques and practices from the Nordic region and beyond.

What we discovered is that although we all share many of the same problems, the way of tackling them varied immensely depending on the location, personality and structure of the office involved. As a general rule the larger the office and/or project the greater the appropriateness for digital tools. It also helps if the operator of the tool in question is in regular contact, an issue that, in our case, the much-lauded internet, failed to reconcile. Our remoteness would appear to be as much a mental as a geographical barrier.

At the end of the day we learnt that there is some new, interesting stuff on offer that we will use when the need arrives. But most importantly we have made relationships with gifted people who share our passion to make a better architecture.

# recycling matters

HELEN & HARD

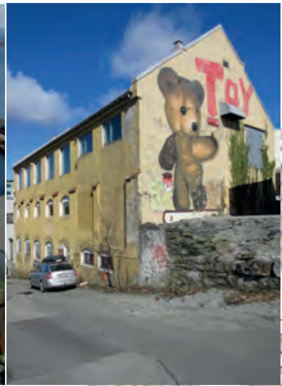
## REFURBISHING AS RECYCLING

**Confronted with a large number of buildings that need refurbishment, we see the necessity to widen the discourse and strategies around how to find the most appropriate solutions. What we have learned from the real case is that**

**a building's potential reuse and the relevant refurbishment solutions are interdependent. Decisions are helped by gaining input from different analytical tools, simulations, and evaluations on different design levels from the contextual**

**urban development level to moisture simulations in the walls. We also learned that if we can let go of habitual preferences of the value of a building, often linked to preserving it as a whole, new possibilities emerge. We can work with the historical value as a narrative which can be told in different ways, while seeing the building as a material resource archive which can be recycled in a creative manner.**

# CASE:
# UNION CANNING





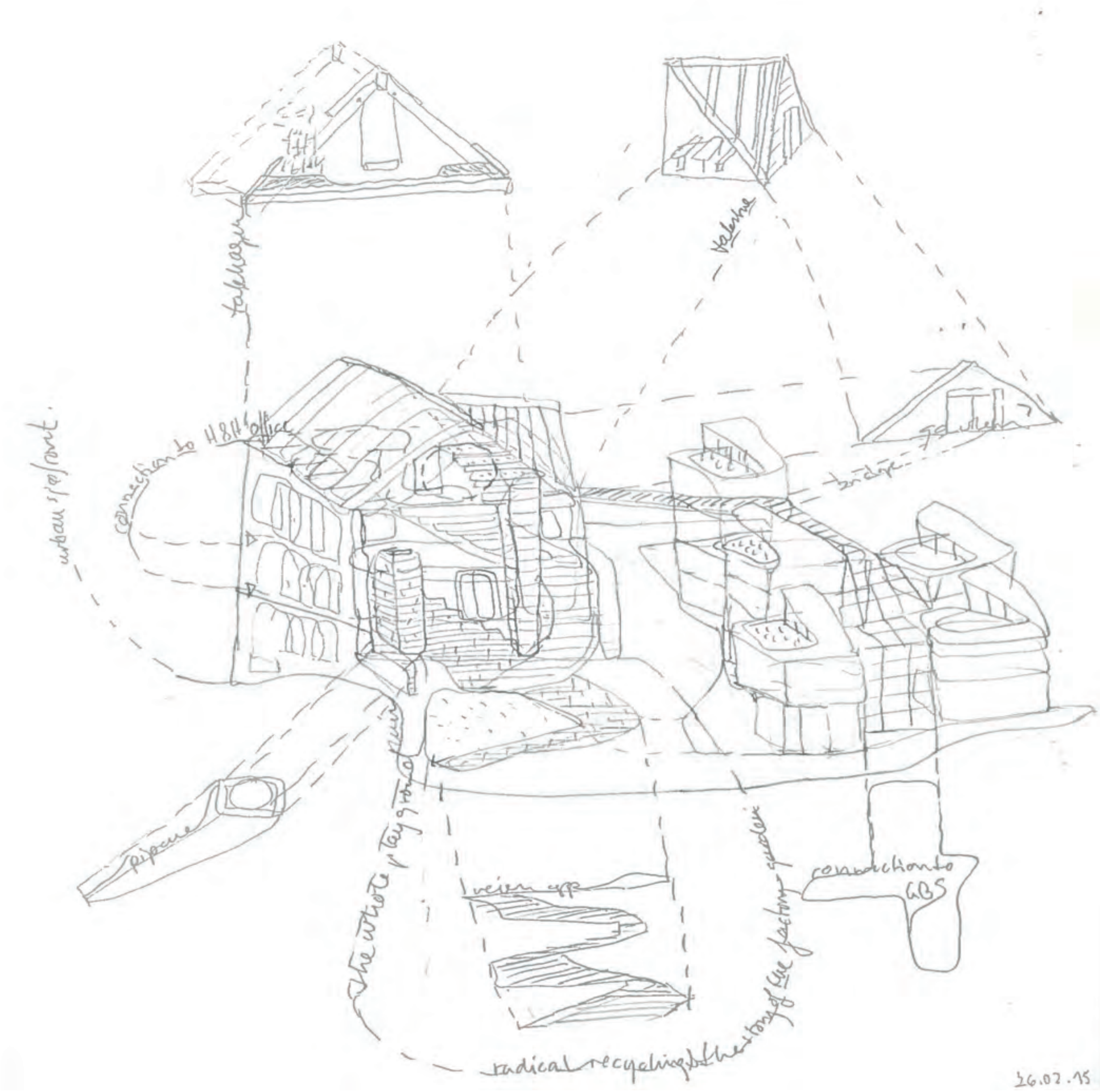
**UNION CANNING**

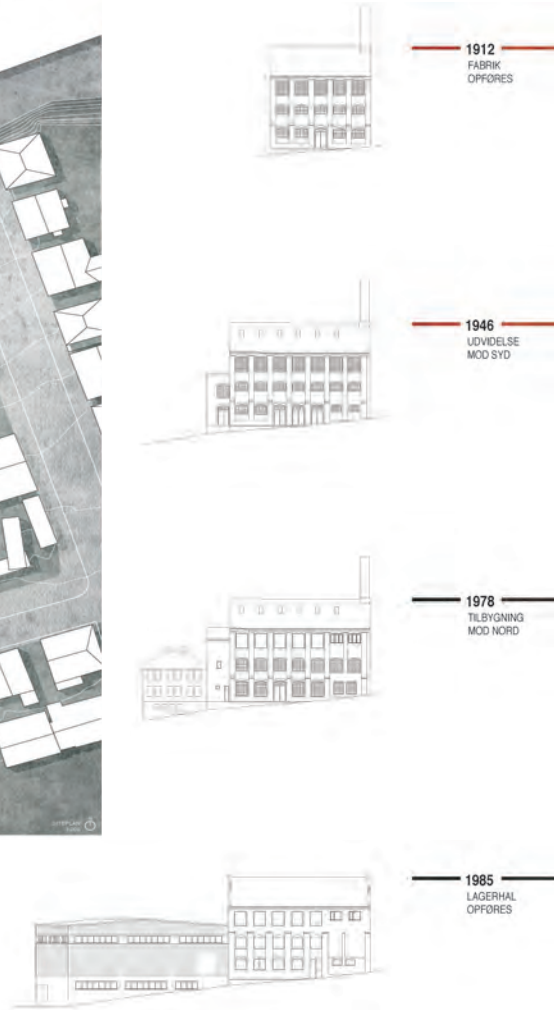
The Union Canning building in Stavanger is one of the few remaining buildings from a prosperous industrial era of the city. The canning industry bloomed in the early 20th century. A group of developers own a large site surrounding Union Canning, bordered by Støperigate and Vindmøllebakken. The plan is to develop the site with new dwellings and also to integrate the Union Canning building as part of the new scheme.

In the STED project, the case of the Union Canning building served as a testbed where new techniques for informing decisions could be tried. This was performed both by inquiring about technical scientific aspects via questions posed by Helen & Hard, and by developing parallel design processes using new ICT tools. The left sides of the pages in this chapter represent the STED development and the right sides represent the Helen & Hard process.

## REFLECTIONS ON RELEVANCE

This complete study of one building and its potential for reuse running in parallel to a real time development shows how complex the task is and how many design and decision levels it requires. For example will different usage of the factory set different technical parameters. Many of the STED students projects have analyzed the neighborhood and suggested programs that are missing in the area, i.e. a community center, hotel, urban gardening, etc., or they have let the spatial potential of the factory be an inspiration for new use like artist ateliers. The final programming seems to be dependent on the stakeholder's own interests and resources as much as on the needs in the area. She wants to start a restaurant and her partner will be running the place. When it comes to the more specific ICT analysis and especially the mold simulations, the information has been useful to create a dialogue with the stakeholders about alternative solutions for insulating the building.






**WHAT IS THE VALUE OF CULTURAL HERITAGE?**

SAVE is the name of a method for mapping and assessing the cultural heritage of a district or a building in a systematic way. Researchers and Master level students at The Royal Academy of Fine Arts School of Architecture in Copenhagen investigated Union Canning and its surroundings. Based on the SAVE analysis, proposals were made focusing on cultural heritage. Design processes in the STED projects that are informed by the ICT tool must incorporate features manifest in the SAVE tool.

Diagram showing the interdependencies of different building elements and the economy.

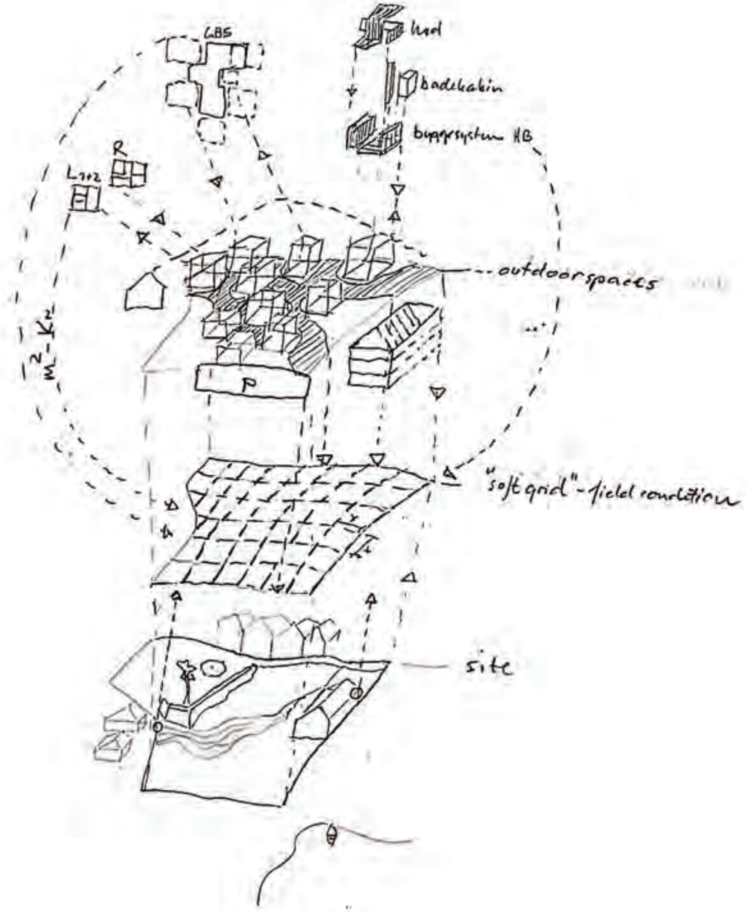
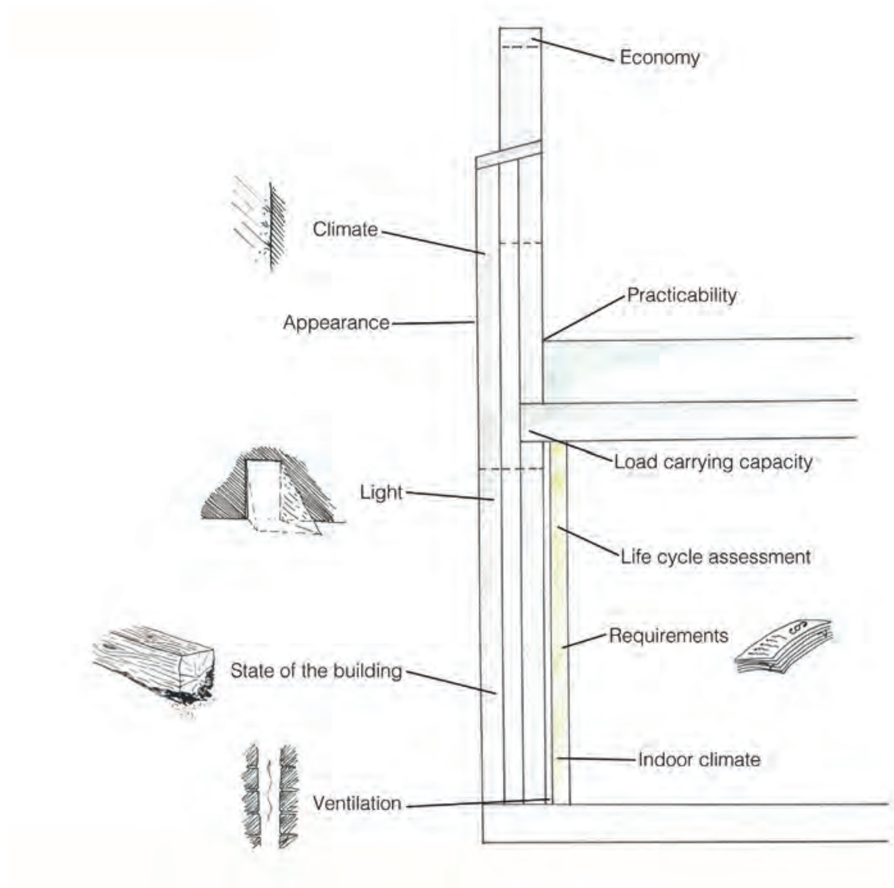



Diagram of different aspects that influence the final solution of the refurbishment of an outer wall of the factory.

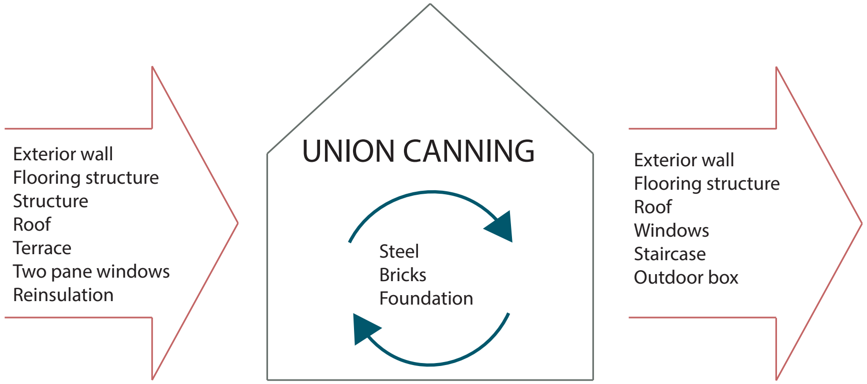



## INFORMATION INPUT, TIMING, AND INTERDEPENDENCIES

The whole project is planned as a low density structure built in timber as a reinterpretation of the vernacular timber houses in the neighborhood. It comprises 4 row houses, 10 normal multistory housing units, and 40 units belonging to a co-living project in addition to Union Canning. The regulation and planning process has taken a long time due to many considerations, among them how to deal with the Union Canning factory. The masterplan process was initiated in 2012. Now, the current plan is to finalize construction of the first building step, including the factory, by the end of 2018. The STED project has run in parallel to the real development and the findings and suggestions from the program have created a fruitful dialogue and helped keep focus on the many considerations that refurbishment demands. It has also been evident that timing and economy - two factors which are closely linked to the very specific local conditions and to the stakeholders in the development - are paramount to how final decisions are made

Trying to keep the construction and appearance as original as possible stood in conflict with many of the other factors. For example to provide sufficient daylight in the rooms for future working spaces, the windows need to be replaced with floor-to ceiling ones, or to avoide thermal bridges the new windows cannot be placed in their original position in the wall, or because the state the building structure was not exactly known, extra supports were installed just to guarantee the stability.

Diagram of which materials are reused and upcycled in the design proposal.




## DEMOLISH, REFURBISH, RECYCLE, OR UPCYCLE?

Projects at NTNU and DTU by researchers and students mapped the materials at the site and in the Union Canning building. This information was used to suggest renovation proposals with almost 100% recycling and upcycling of the available materials at the site. Digital LCA tools were used to compare these proposals with refurbishment schemes without reuse of materials, and finally also to compare to a demolition + build-new strategy.

From these 3 renovation strategy analyses, a number of design proposals based on both LCA and energy balance/ indoor climate simulations came about. The research question focused on if LCA and indoor climate/energy tools could be used in the early design phases of refurbishment projects.

A LCA has been made to evaluate the environmental benefits and impacts resulting from a design strategy relying on the existing materials to set the restrictions. The LCA of our alternative design proposal is subsequently compared to more conventional design approaches relying on more or less complete replacement of the existing structures. This inquiry had the flaw of an overly simple energy balance and indoor climate calculation.

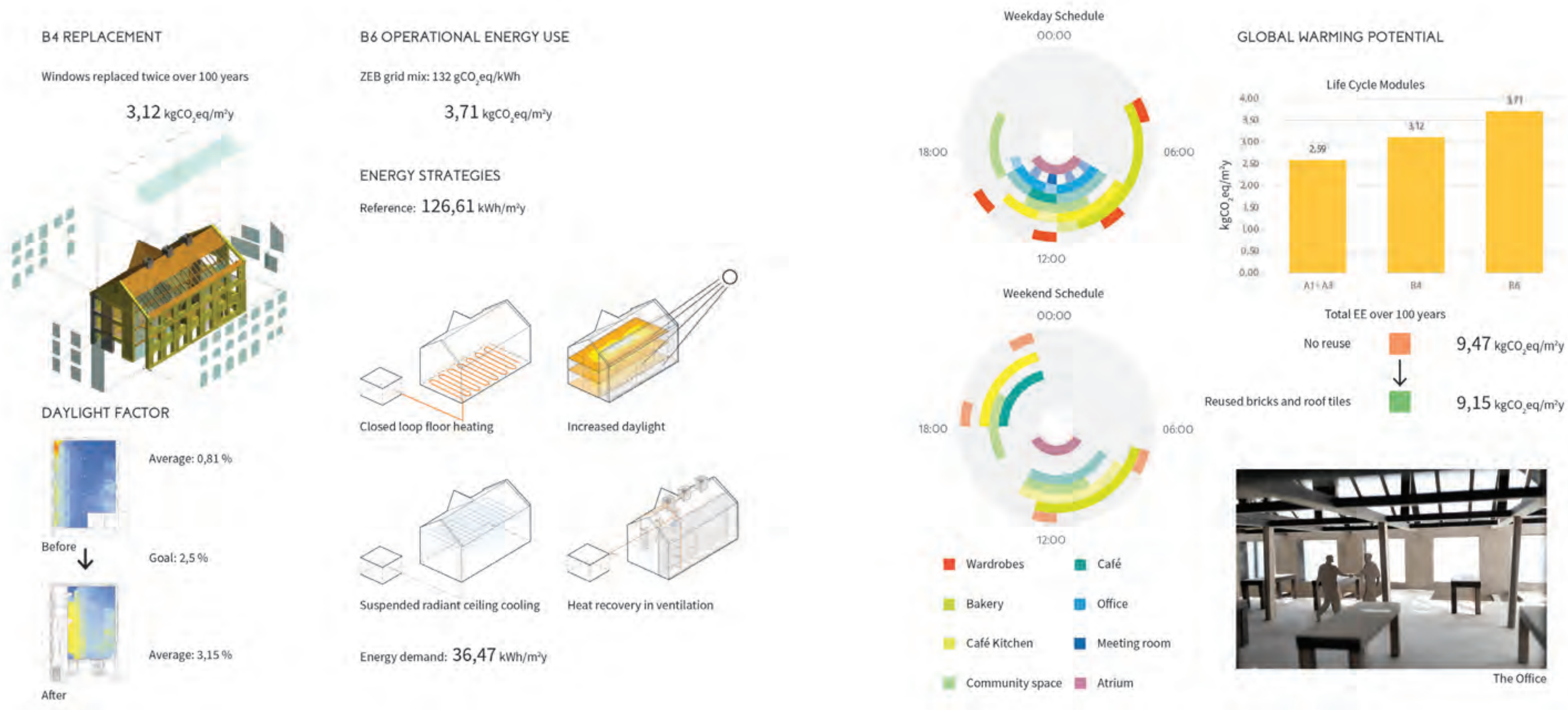


Illustration of factory partly taken down and playground of recycled elements

## A HYBRID SOLUTION

One way to avoid obstructing the daylight for the new dwellings and still keep some of the embodied energy and cultural heritage manifest in the Union Canning building could be to tear down part of the building and give the new roof to the public. This solution provides a generous space on the ground floor for a cafe and a roof terrace as a playground and meeting area for the whole neighborhood. By keeping the façade on the second floor as a balustrade around the playground, more of the factory volume is kept. Building materials like bricks and timber beams and installations from the factory are recycled and used to form the playground and the outdoor furniture.

An interesting proposal also shows that the Union Canning factory can regain a more prominent position in the context by taking away one floor of the warehouse.




## MORE LCA SCENARIOS OF DIFFERENT ALTERNATIVES

NTNU researchers and Master of Sustainable Architecture students developed a line of Union Canning proposals using ICT tools for answering these research questions:

How to sustainably transform a derelict building to achieve an energy positive result and a potentially net zero emission building?

How can the use of ICT be used to support quantitative and qualitative assessment for decision support and design processes?

How can we document what we gain (or lose) by keeping/restoring an existing building, compared to demolition and new-build in terms of cultural values, experienced qualities, etc.?

a) Adaptive Reuse of the building with minimal insertion of new materials (maximize use of wood/bio-based/materials)

b) Demolition of existing building plus maximized reuse of existing materials, i.e. brick, wood, industrial machinery, etc.

c) Demolition of existing building plus construction of a new building using new materials

More LCA scenarios of different restoration alternatives include:

a) How to restore the building to manage new energy demands while keeping the old outer facade?

b) How must the insulation be designed with regard to moisture?

c) How can wood/bio-based/other materials help to achieve better insulation values, indoor climate, ventilation, etc.

B-camp being moved to its new location as a surf-camp.

Warehouse transformed into compact parking house.

## HYBRID SOLUTIONS

In addition to Union Canning, two of the other existing structures on the site will be partly transformed or reused in different ways: the ground floor of the warehouse in the picture at the top will become a compact parking house while the second floor is taken down.
All the modules around H&H's office building will be moved to the beach on Jæren and transformed into a surf camp. They are now being recycled for the third time; starting as a flotell for workers in the oil industry they then served as affordable, small living studios for H&H interns for over 10 years, now two surfers want to create a surf community with them.. Moving the 14 timberframe modules to a new place and refurbishing them proved to be a cheaper solution than to pay for demolition and recycling of materials.

## BUILDING MATERIALS CONSIDERED FOR REUSE

Material analysis of samples of the brick wall made in a laboratory tested negative for paint containing lead. The age of the wall led to the conclusion that lime mortar was used and not cement. This information proved very helpful for the project at the time when recycling was discussed.

"We received the results from the material analysis this week. We got the opportunity to test the paint for lead. The Danish limit value for lead in building materials is a maximum of 2500 mg/kg. Our results show we have significantly lower concentrations in the three samples we tested. The sample with the highest concentration was only 75 mg/kg. Unfortunately, we did not get the chance to test for cadmium, PCBs, or chlorinated paraffins which also have been known to be used in paint."

**VINDMØLLEBAKKEN - Gjenbruk**

20.10.2017

**LAGERBYGG**

Ønskes gjenbrukt:
**STÅLPLATER I FASADE**
Forslag til ny bruk:
- vegger mellom sportsboder
- tak over utendørs sykkelparkering

Mengde / info :
ca 110 lm vegg til boder, ca 25 m2 til små tak

Ønskes gjenbrukt:
**BRUKBARE DØRER**
Forslag til ny bruk:
- f.eks dører til sportsboder

Mengde / info :
- flest mulig
- fri bredde må være min.80 cm, (fri høyde min. 200 cm)

Ønskes gjenbrukt:
**STÅLDRAGERE OG STÅLSØYLER**
Forslag til ny bruk:
- konstruktivt f.eks i kontor eller leilighetsbygg

Mengde / info :
- må avklares med RiB

Ønskes gjenbrukt:
**BETONGDRAGERE I TAK**
Forslag til ny bruk:
- støttemur, trapper og amfi ute

Mengde / info :
- må prosjekteres, info kommer

Ønskes gjenbrukt:
**MURSTEIN I FASADE**
Forslag til ny bruk:
- fasade parkeringsnalegg
- amfi i veksthus

Mengde / info :
- flest mulig hele stein

Ønskes gjenbrukt:
**INTAKT TREVERK; BJELKER OG SØYLER**
Forslag til ny bruk:
- trinn i amfi i veksthus
- benker
- fasade foran parkeringskjeller

Mengde / info :
- flest mulig av god kvalitet

**VINDMØLLEBAKKEN - Gjenbruk**

20.10.2017

**UNION CANNING**

Ønskes gjenbrukt:
**DEL AV STÅLKANAL**
Forslag til ny bruk:
- plantekasser

Mengde / info :
- hvis en hel del enkelt lar seg demontere

Ønskes gjenbrukt:
**TO ARBEIDSBENKER**
Forslag til ny bruk:
- arbeidsbenker i bofellesskapets verksted

Mengde / info :
- begge ønskes tatt vare på

Ønskes gjenbrukt:
**STÅLTRAKTER I TAK**
Forslag til ny bruk:
- lampeskjerm i allrom

Mengde / info :
- 2 stk

Ønskes gjenbrukt:
**GAMMELT TRE-BRETT**
Forslag til ny bruk:
- ikke avklart

Mengde / info :
- Generelt: gamle intakte remedier som en kommer over ønskes vurdert, ta kontakt med arkitekt.

Ønskes gjenbrukt:
**OPPKVERNET BETONG**
Forslag til ny bruk:
- i stier ute
- som drenerende masse

Mengde / info :
- avklares med Kruse. Må være giftfri

Ønskes gjenbrukt:
**OPPKVERNET MUR**
Forslag til ny bruk:
- i stier ute
- som drenerende masse

Mengde / info :
- avklares med Kruse. Må være giftfri

Ønskes gjenbrukt:
**FASADEFELT**
Forslag til ny bruk:
- fasade i veksthus

Mengde / info :
- dør og vindu

Ønskes gjenbrukt:
**VINDUER**
Forslag til ny bruk:
- uavklart

Mengde / info :
- alle ønskes tatt vare på (innvendige vindusfelt)

Ønskes gjenbrukt:
**DIVERSE PLATEMATERIALE**
Forslag til ny bruk:
- uavklart

Mengde / info :
- hele plater av god kvalitet bør vurderes

Ønskes gjenbrukt:
**STORE STEINER**
Forslag til ny bruk:
- i uteareal

Mengde / info :
- flest mulig

Ønskes gjenbrukt:
**STEIN FRA TØRRLØDDE MURER**
Forslag til ny bruk:
- nye murer i uteareal

Mengde / info :
- flest mulig

Ønskes gjenbrukt:
**"PLANTEKASSE"**
Forslag til ny bruk:
- i uteareal

Mengde / info :
- Generelt: gamle intakte remedier som en kommer over ønskes vurdert, ta kontakt med arkitekt.

## FINAL SOLUTION

A considerable amount of the building materials from the partly demolished Union Canning warehouse and factory are being reused in different ways: concrete beams will serve as outdoor stairs, bricks will be used for facade cladding and for building a smaller Amphitheatre inside the co-living project, timber beams are used for outdoor furniture, working tables will be used in the new workshop, corrugated steel plates will serve as partition walls for storage spaces, steel ducts will be transformed into flower boxes, and so on.

"There has been significant change in the way buildings are constructed and in the way that building energy performance is evaluated. Focusing solely on the use phase of a building is beginning to be replaced by a lifecycle-based performance assessment. This study assesses the environmental impact trade-offs between the heat produced to meet a building's space heating load and the insulation produced to reduce its space heating load throughout the whole life-cycle of a building. To obtain a more realistic valuation of this tradeoff, a dynamic heat production model, which accounts for political projections regarding changes in the Danish energy supply, was used in the analysis. This novel approach for generating inventory for Life Cycle Assessment (LCA) helped to refine an understanding of optimal insulation levels. The findings of this study discourage the over-insulation of houses connected to the district heating grid, which is potentially promoted by Danish regulations at present. It is further concluded that improvement of the mineral wool insulation production process could allow for greater levels of environmentally beneficial insulation and would also help in reducing the overall environmental burden from insulating buildings."

Fig. 1. Total life cycle impact curve relating building insulation and lifetime heat requirement (adapted form Richman et al., 2009).

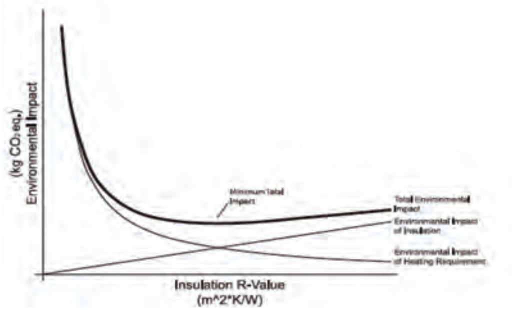
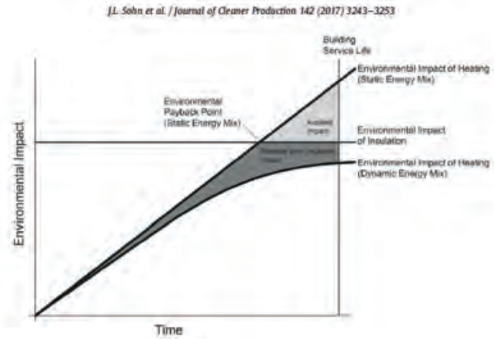


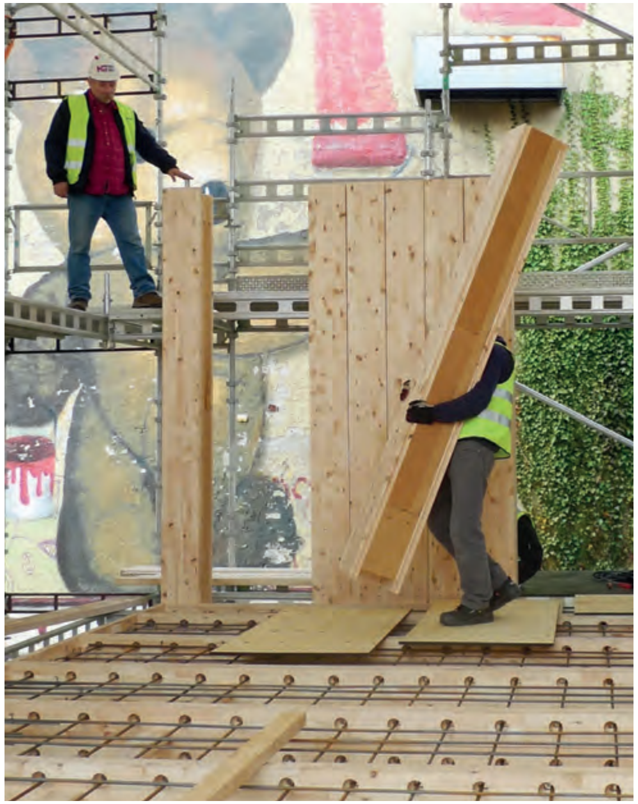

Fig. 2. Potential environmental impact of over insulation based on optimization for static energy mix versus optimization for dynamic energy mix projection




## 1ST ROUND OF "THE-WOODEN-BOX-INSIDE-UNION-CANNING" IDEA

Making old buildings perform well in terms of energy balance and indoor climate mostly involves adding new materials: mineral wool, plasterboard, new windows, new systems (for heat recovery), etc. For decades, the industry has focused on the energy consumption for operating buildings. This focus is changing. The Greening of the energy system with more and more renewable sources - and the actual overall implemented reduction in energy consumption in buildings - has resulted in a shift of concern towards materials and especially the $CO_2$ emissions (Global Warming Potential) of specific materials and technical solutions.

The main questions are: Will there be a breakeven point in the near future where the $CO_2$ used for new windows and mineral wool will not balance out the reduction in energy consumption for operating the building? And, will more and more solutions in the built environment be based on wood? The STED projects have analyzed a solution for Union Canning with interior insulation made of a 'wooden box' (and nothing else) inside the old building. But even just exchanging the plasterboard with a wooden board in a conventional mineral wool solution had a very large impact in terms of $CO_2$.

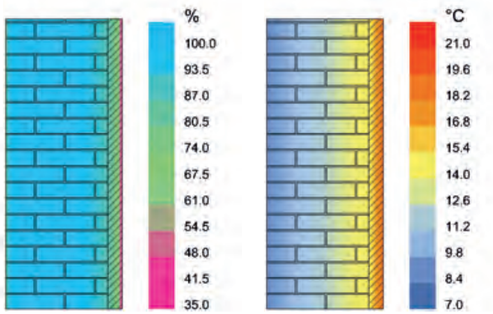


## INFORMATION INPUT – TECHNICAL SOLUTIONS

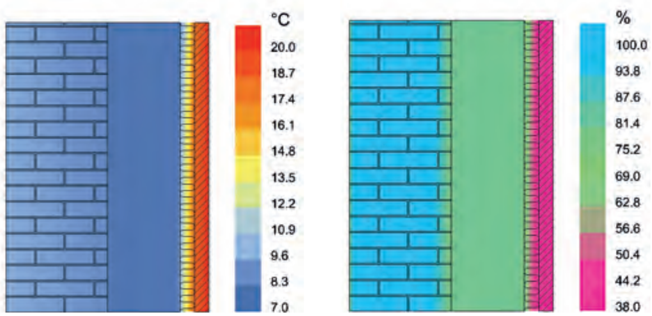
For buildings that have cultural heritage value, inside insulation can be the best possibility to lower the energy loss. It is a solution that makes it possible to keep the façade details and expression very close to the original. However, there are many disadvantages or challenges with this solution. For example, it is difficult to avoid cold bridges which can result in frost and humidity problems when the existing structure becomes colder.

Trying to keep the construction and appearance as original as possible stood in conflict with many of the other factors such as environment (mineral wool and plasterboard), daylight, indoor climate, and economy.

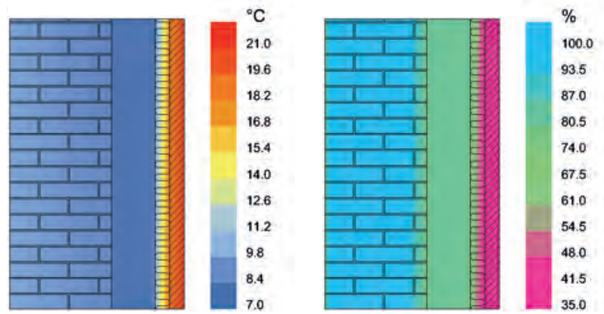
The requirements for the indoor climate to avoid thermal bridges stood in conflict with aligning the windows with their original positions. The STED work has given input on the more detailed technical refurbishment solutions.



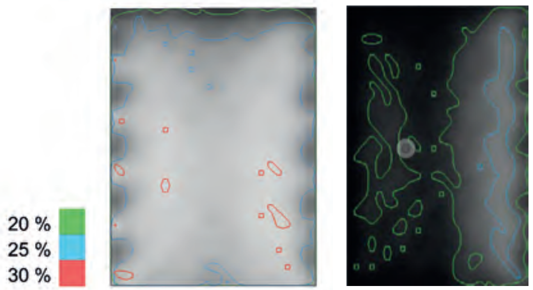

Results from Delphin analysis: scenario: Original wall and wood plate. Left: moisture build up. Right: temperature/heat loss (average over 5 years).




Results from Delphin analysis: scenario: Original wall, air cavity, and wood plate. Left: moisture build up. Right: temperature/heat loss (average over 5 years).




Results from Delphin analysis: scenario: Original wall, air cavity, insulation, and wood plate. Left: moisture build up. Right: temperature/heat loss (average over 5 years).




Left: Solutions with air cavity, insulation, and wooden board.

Right: Solutions with just a wooden board added.

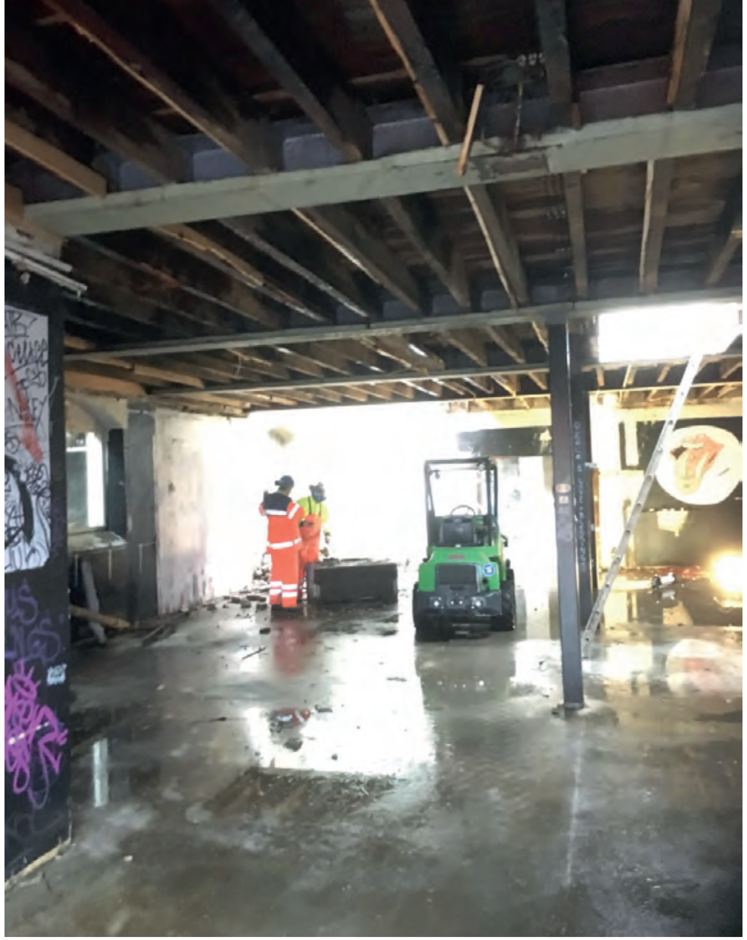
Plans of the first floor of Union Canning mapped according to the predicted thermal comfort. Within the redline, users have thermal comfort a minimum of 30% of the time. The solution without insulation and air cavity (to the right) results in very poor comfort.


Mold index calculated with the input of moisture and temperature from the Delphin simulation targeting the surface of the wooden board facing the interior. It clearly shows less mold risk when the wooden board is isolated and has an air cavity.

## 2ND ROUND OF "THE-WOODEN-BOX-INSIDE-UNION-CANNING" IDEA

Taking up the Helen & Hard idea of an alternative wooden interior insulation, a line of wall build up variations were analyzed in detail using new software such as Delphin. The Delphin software can simulate moisture and temperature effects from a specific climate - here, the rainy and cold Stavanger. This STED project investigated moisture, mold, daylight, thermal comfort, and energy in an internal insulated wall and introduced a ventilated cavity to see if that would solve some of the primary moisture and mold issues that an internal insulated wall has. A solution without insulation and a solution with just a wooden plate were also analyzed.

After performing an analysis of the 5 different parameters, the walls were compared according to weighted criteria. It was found that solution number 2 with an added air cavity was the best solution. The Delphin calculation also showed that the air change rate should be 1 m3/s and, surprisingly, that the air intake to the ventilated cavity should be from the interior (and not the exterior) and the exhaust from the cavity should be placed at the top. However, this work also showed that in some periods of the season this solution would still be at risk of creating conditions for mold growth.



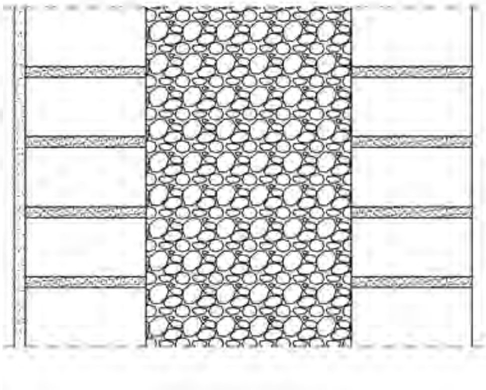

## INFORMATION INPUT – LCA

Refurbishment can easily be more expensive than demolishing and building new. However, old structures hold embodied $CO_2$. When the $CO_2$ consequences of a decision are displayed, refurbishment gains ground.

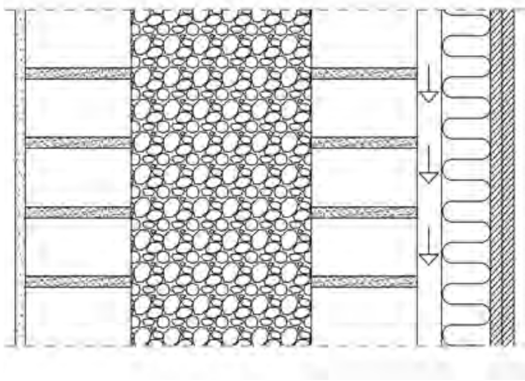
LCA gives an opportunity to discuss and evaluate the level of sustainability in a project proposal. The Union Canning refurbishment idea of creating a wooden box inside the old warehouse can thus be compared to a standard refurbishment. The outcome is displayed in avoided $CO_2$ emissions.

However, when the refurbishment solutions were considered in total, it became clear that nearly 85 - 90% of the surfaces are being insulated and upgraded; walls against the terrain are insulated outside, the roof is insulated on top, the floor gets new insulation, and all windows and doors are changed to energy class A. Evaluated against considerable loss of daylight, the wooden box solution may be left behind and the main façade of the factory will only be given a new layer of plaster.

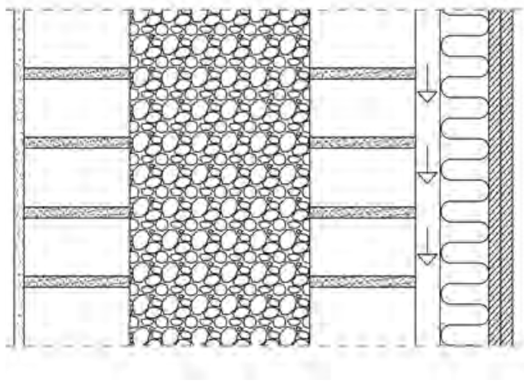
The three examined renovations scenarios of the outer walls: Scenario 1: Reference scenario - no refurbishment; Scenario 2: Internal insulation with mineral-wood, Scenario 3: Internal insulation with wood fiber



Scenarie 1:
108*54*228 teglsten
184mm stenskæver
108*54*228 teglsten



Scenarie 2:
12mm krydsfinersplade
0,2mm dampspærre
12mm krydsfinersplade
50mm mineralsuldsisolering
25mm ventileret hulrum
 - RetroWall systemet
Eksisterende ydervægsopbygning



Scenarie 3:
12mm krydsfinersplade
0,2mm dampspærre
12mm krydsfinersplade
50mm træfiberisolering
25mm ventileret hulrum
 - RetroWall systemet
Eksisterende ydervægsopbygning

## 3RD ROUND OF ‘‘THE-WOODEN-BOX-INSIDE-UNION-CANNING” IDEA

Building on the results of the previous Delphin analysis, another layer of information was investigated: LCA. This last and final very thorough LCA of ‘‘the wooden-box-inside-Union-Canning” idea was made according to the midpoint and endpoint categories of the IMPACT 2002+ vQ2.2 method: Human Health, Ecosystem Quality, Climate Change, and Resources. The collected data has then been processed by converting the product systems into environmental impacts by using the program Quantis SUITE 2.0.

The best solution from round 2 was the one with insulation and a cavity between the wooden board and the original wall. The goal of the LCA was to document the holistic sustainability profile of this solution. Two other questions were answered in the same LCA setup: Which insulation material is the most sustainable - wood fiber or mineral wool? And, when is there a breakeven point for insulation because of the increase in renewable energy - would it be more sustainable to just not insulate the building and live with the discomfort and heat loss? The results show that even in an energy landscape such as in Norway with a lot of renewable hydro energy, it is the energy in the use phase that has the greatest contribution to the overall environmental impact. The discomfort of draught and the effect on human health also gives a large disadvantage to the scenario where the old building is not insulated. Overall, the wood fiber insulation has better LCA results than the mineral wool.

2014

2015

2016

## THE COME BACK OF UNION CANNING

In the very first proposal for the master plan, the factory was torn down completely. Based on previous experience with refurbishments, the high cost of the land, and the fact that the project already included a pilot for co-living, the entrepreneur thought that keeping UC would mean too much risk for the project economy.

Then, the preservation authorities started to show a new interest in the canning factories and H&H decided to take part in STED and to investigate different potentials for keeping the factory.

In the second proposal, we showed that by keeping the factory but tearing parts down and providing public access to the roof, we would not lose the m2 ratio of new housing.

Still, the main challenge was that the factory's position in the master plan cast shadows on the outdoor spaces and dwellings behind it and reduced some of the qualities of the housing project. The whole project now showed an excessively low return and the developers wanted to stop the project.

A compromise was found that united both the wish to preserve parts of the building and to provide the necessary conditions for the transformation of the whole area. The loft and top story of UC were to be taken down to allow for more light and sunlight on site.

The destiny of the wooden interior insulation is still unclear: will it be used or not on the western facade of the ground floor? The wooden element will anyway be an essential part of the structure of the new dwellings.

# LCA in the early design phases

## INTRODUCTION

Making LCA relevant for the building industry was a challenge just a decade ago. Today, it still requires some improvement to be a productive analysis tool. LCA was originally developed for mass produced industrial products where there was time and money for a design process involving a large number of iterations and extensive analysis and documentation. It began in the early 1960s as a lifecycle inventory analysis tool when attention towards limited raw materials and energy resources led to a need to find ways to cumulatively account for energy use and to project future resource supplies and use (SAIC 2006). With the fading influence of the oil crisis, the interest in these sorts of comprehensive analyses decreased from the mid 1970s to the early 1980s. But in the late 80s, solid waste became a growing problem worldwide and environmental concerns moved to issues of hazardous and household waste management. At this time, LCA reemerged as a tool for analyzing environmental problems. As general interest in all areas that affect resources and the environment increased, the methodology for LCA needed to move beyond the inventory to impact assessment. This circumstance brought the LCA methodology to the evolutionary stage that we know today (SAIC 2006; SETAC 1991; SETAC 1993; SETAC 1997). However, it is important to note that LCA is also being used for marketing and branding purposes, and therefore it is necessary to maintain a critical approach to how the methodology is applied. Finally, we must acknowledge the mere fact that LCA was designed to analyze serial industrial products and not one-off building projects.

In the building industry, every project is different and there is usually only one 'product' resulting from each design process. Similar building materials and components may be used across projects, but the volumes are not comparable to the consumer industry. The work load required to perform a life cycle assessment and the lack of available (applicable) data have also been obstacles to easily using the methodology and valuably informing the process of building design.

Nevertheless, LCA has become an institutional part of the building industry. The aim is to include the methodology as part of the building regulations. It is now being used in certain projects during the very last design phases, including the documentation processes, in order to achieve a sustainability certification. Hundreds of pages of Environmental Product Declarations (EPDs) for each individual material used in the building are compiled, and laborious processes involving the calculation of volumes for those materials have to be performed manually. LCA (read: methods for balanced analyses of environmental impact) is far more complicated to work with for architects than for energy performance and indoor climate. Daylight and energy balance calculations are, by now, a natural part of architectural design. Energy balance calculations are included in an LCA because the energy consumption for regulating the indoor climate has a large impact on the environmental performance of a building. Due to the time-consuming complexity of LCA, this kind of work will usually be performed when all design decisions have been made and everything is fixed, i.e. during the very last design phases.

Making LCA operational in the early design phases may seem to be an impossible task. However, because the potential is so significant, it has been one of the core work packages of the STED project. Imagine the architect being able to understand the $CO_2$ emission impact of specific design decisions. In order to address this challenge, several tools have been developed and tested in real life design processes at architectural offices. In addition, we have explored if LCA could be directly connected in an operational way to other methods and tools such as SAVE, indoor climate, and energy calculations.

## BIM AND LCA IN THE EARLY DESIGN PHASES

### STAND-ALONE TOOLS

There are several digital tools that have been developed specifically to address LCA in the early design phases. In the Nordic Countries, LCA-BYG in particular is gaining ground due to the close connection to the increasing use of the DGNB sustainability certification system. In Norway, most practitioners previously used an online GHG calculation tool called *Klimagassregnskap.no*. However, just recently the Norwegian government authority *Statsbygg* has entered into an agreement with the Finnish company Bionova to deliver a new solution for greenhouse gas calculations that is based on Bionova's *One Click LCA* software. This software replaces today's calculation model *klimagassregnskap.no*. In addition, the Research Centre for Zero Emission Buildings (ZEB) at NTNU, which was founded in 2010, has studied the interoperability of modeling, simulation, and calculation tools. The *ZEB Excel tool* is based in a MS Excel environment.

We could call this group of tools 'stand-alone tools'. They are not directly connected to a digital model of the building or to a commercial software tool. This means that the architect has to find the information required and to input it manually. During the course of the STED project, several stand-alone LCA tools have been further developed to integrate LCA information into new design processes. The challenge of the stand-alone LCA tools is that they are perceived as being too complicated and too slow to accommodate the rapid speed at which design decisions are made.

### INTEGRATED DYNAMIC MODELS

An integral part of doing life cycle assessment of a design involves the use of embodied carbon data from specific manufacturers, such as EPDs, in coordination with material quantities from a computer model of the building. There is a great potential for an integrated and dynamic link between EPD databases and the computer/BIM models to enable the early integration of quantitative issues involving LCA into the design process. This is one of the key challenges that has been addressed in the STED project.

In order to follow the pace of the early design processes, the tools have to be fast and integrated but also general enough to be used at a stage when a detailed materials inventory is not available. If the tools are too complex and time consuming to use, it will not be possible to integrate them early enough to inform the design decisions.

To overcome this obstacle, the STED project has focused on a new concept for digital tools: *Integrated Dynamic Tools*. The digital model of the building (the BIM model – a Rhino model or a Revit model) is directly connected to large materials databases containing all of the information needed to perform the LCA. This means that when a window is made larger or the material of the façade is changed, the change in the LCA results is visualized immediately. This allows the designer to be informed of the consequences (e.g. the changes in $CO_2$ emissions) of a specific design decision.

With the stand-alone tools, an energy calculation has to made in a separate tool and the results must be placed in the LCA software manually. With the new *integrated dynamic tools,* the model can be connected to both the LCA databases and to energy and indoor climate calculations tools at the same time. This doubles the speed and makes a large amount of information available and usable to the architect.

First, a Rhino grasshopper version was developed at DTU. The Rhino model was connected to both EnergyPlus to show the indoor climate and energy consequences of a design decision and to extracts from the materials databases to inform the LCA category for Global Warming Potential ($CO_2$). This tool was implemented at White Arkitekter.

Then, a Dynamo script for Revit was developed to extract materials volumes quickly and accurately into both an LCA and an LCC framework following the same set up. This was developed in close collaboration with Tegnestuen Vandkunsten. (See the Tegnestuen Vandkunsten chapter for more information.)In addition, at NTNU the ZEB Excel tool was further developed to become an integrated design tool using two approaches: Dynamo for

Revit and Grasshopper for Rhino. It was tested in design processes during a MSc course in collaboration with Helen & Hard.

This integrated and dynamic tool was investigated for use with Rhino as part of the main design project in the Spring 2016 second semester M.Sc. Sustainable Architecture course 'Emissions as Design Drivers'. While performing an LCA on the design to use a derelict building owned by Helen & Hard, a streamlined method was developed in order to achieve instant feedback on environmental impact from design decisions.

The new integrated dynamic BIM tools developed in the STED project share the general obstacle of the BIM world: if the digital models are not made according to international standards, then the tools have difficulty functioning. Today, many architectural offices work with BIM, but inside the office the architects may use many different ways to construct their models. This problem has also been addressed in the STED project. For more information please see the 'tools' chapter.

## LCA TOOL QUESTIONS

### Which building should be demolished and which should be refurbished?

Since some of the building projects included in the STED project were existing buildings ready for renovation or transformation, methodologies for evaluating their architectural quality and cultural heritage have been considered. One existing and already widely used assessment tool in Denmark was considered: the Survey of Architectural Values in the Environment (SAVE). SAVE is a method for mapping, recording, and evaluating conservation values in urban environments and buildings.

SAVE is a qualitative method that results in a ranking. Thus, in theory, it is possible for SAVE to communicate with the world of engineering tools, such as LCA tools. During the STED project, this interface between SAVE and LCA was explored in a case study on design processes that addressed a large derelict hospital area in Odense. The hospital buildings were assessed in regards to LCA, energy-balance/consumption, indoor climate, cultural heritage value, and estimated remaining years of usability. This would create a classic dilemma of comparing apples and oranges, however it was possible to organize the weighing of the different parameters by means of a multi criteria model (TOPSIS). In this project, LCA informed the designer about the embodied $CO_2$ in the remaining hospital buildings. In some ways, the hospital project described above built on a previous project that was developed as part of a cross disciplinary course between DTU and KADK before the initiation of the STED project. As part of this collaborative project with KADK, the students used simple LCA tools to inform their design solutions for the derelict Carlsberg breweries.

### HOW SHOULD THE BUILDING BE REFURBISHED?

Along the same line of thought, an old derelict warehouse, the Union Canning building owned by Helen & Hard (one of the project partners), was used as case study for several iterations of LCA analysis of three different design scenarios:

1 demolish and build new according to modern standards
2 refurbish in a traditional way
3 refurbish with as many upcycled solutions as possible

Reuse and upcycling strategies proved to perform best from an LCA perspective, especially in the impact category for Global Warming Potential ($CO_2$). Even schemes with a high heat loss (less or no insulation added) pointed to this result. The picture is more complex if other impact categories are considered, e.g. where the effect of draught on human health is quantified. (See the Helen+ Hard chapter for more information.)

### WHICH MATERIAL IS THE MOST SUSTAINABLE?

LCA has proven to be very useful for choosing between different materials and components. In the early design phases, the typical questions and issues being addressed are: demolish or refurbish, geometry, orientation, window/façade ratio, etc. The specific choice of material is not necessarily addressed initially. However, the 'Vitruvian zooming in on the project' - an approach that considers the larger scale before the individual components and finishes with the choice of material and detailing - might be challenged by LCA. In the LCA approach, the choice of materials moves to the fore and the detailing moves with this; both affect the 'end-of-life-scenario' of an LCA (what will happen when the building no longer fulfils the requirements after a number of years in use). During the STED project, a number of stand-alone and integrated dynamic LCA tools were investigated in real-life design processes at architectural offices in an 'action research' set-up. The results were clear: the design teams considered the LCA tools useful when having to choose between different materials, particularly at an early design phase. Choosing the most sustainable material and the detailing very early in a design process is a new standard that affects the tectonic qualities of a building. Whether this is good or bad is still difficult to determine. (See the White Chapter for more information.)How do we define how sustainable a material is? How do we measure the $CO_2$ impact of natural material alternatives such as rammed earth, hemp, and natural stone slates if they are not included in the standard materials databases typically used in LCA? In order to address this limitation, a number of these natural, sustainable materials profiles were registered and prepared for LCA in the STED project.

## WHICH STRUCTURAL SYSTEM IS THE MOST SUSTAINABLE?

Should all primary structures be made of wood? Optimizing the structural system in order to minimize the material consumption was a general trend in the structural design of the 20$^{th}$ century. Sustainability takes on a new meaning when minimizing the $CO_2$ emissions becomes the standard. An optimized structural system is a kind of 'low hanging fruit' that has a great impact on the LCA outcome. A minimal structure might, however, present a problem when materials saved in one part of the building might increase the dimensions of structural elements in other parts or affect the cladding. In the STED project, it was demonstrated that LCA in the early design phases focuses more attention on the structural design than usual during this design phase, and that wood is NOT always the most sustainable solution.

## LCC AND THE EARLY DESIGN PHASES

Just as LCA includes indoor climate and energy, LCC includes a simple LCA. LCC's are thus highly complicated tasks to perform. However, it proved to be more desired by architects because it gives quantitative evidence for classic architectural arguments: long lasting, well-crafted solutions made of quality materials pay off in the long run. In an LCC, the entire economic aspect of a building - its operation and maintenance until demolishment or reuse/upcycling - is documented. By working with the interface between the Revit model and LCC tools, the tiresome and complex process can be automated, giving the architects arguments for better and more sustainable solutions. However, this stresses the fact that the data has to be extensive and cover all material scenarios, and that deep knowledge by the user/architect has to be at hand if the LCC shall give a full (true) picture.

## HOW CAN THE COMPLEXITY OF LCA BE VISUALIZED AND MADE OPERATIONAL IN A DESIGN PROCESS?

The visual communication of the quantitative data from LCAs and LCCs in the form of Excel sheets and diagrams is critical for the early integration of these considerations into the design process. If the architect cannot intuitively match the results with architectural design then there is a tendency that the analyses performed will have no effect on the actual design decisions. This is an area that is rapidly developing and will change the way we inform architectural design decisions. Furthermore, visualization is an essential tool to communicate complex data in an interactive way that makes it easier for all stakeholders to understand.

The main approach of the STED work with LCA has been to leverage architectural visualizations of the results from analyses performed with integrated dynamic tools based on Revit and Rhino models.

# Tools are toys for ...?

Five studios across the Nordic region have come together to improve the way we use tools in architectural transformation. This marks a change in what Nordic Architecture is. While we cannot come with a definitive answer about the role of the architect in the Nordic region and what methods the Nordic architect applies to go from idea to building, we can say one thing; it involves tools.

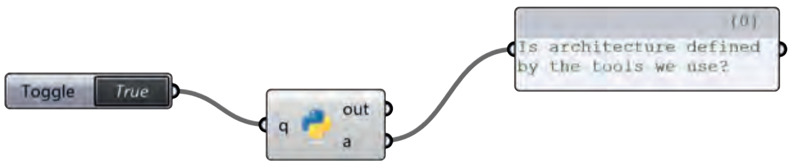
Architecture involves countless tools. This chapter explains how five studios aided by four universities have explored tools, applied tools, developed tools, hacked, and broken tools to create informed sustainable architecture in what we classify as Nordic architecture.

## TOOLS FOR DESIGNERS

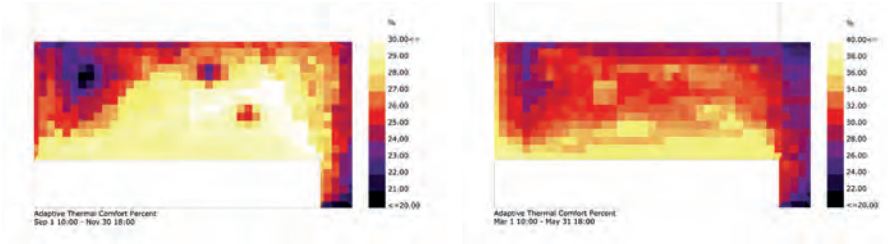
Current architectural practices require more than guidelines and rules of thumb to transform ideas into buildings. Projects are increasingly pushing targets for sustainable development and decreasing the impact of emissions on the environment while setting demands for better efficiency of materials and products. At the same time, the development of buildings is increasingly being met with requirements for more detailed documentation and proof of having met building performance requirements. Architects work continuously to meet their own ideals while trying to meet the client's expectations to reduce time and cost, and to satisfy local and national regulations in ever more performance-based codes. One may think that architectural studios are in a state of crisis and that the architect as a role has never been under threat as it is today. The reality is that the studios are in different states of transformation - a transformation that defines how the tools of tomorrow are developed and consumed in architectural developments.

## TOOL REQUIREMENTS

Most tools today are built by engineers for engineers. To distance the tools even further from the actual building designer, the tools are built to assess, rather than to explore, design. In short, the tools we have available today are almost entirely unqualified for design exploration for architectural practices. It is thought provoking that the idealism and willpower of architects are challenged daily by digits, bits, and bytes pouring out of all kinds of tools that architects have never used or even seen. The lack of control over the evaluation part of a building design performance may be the main reason for the current lack of control over the design process and the actual final outcome. What is needed to take back control over tools? We asked this question and we have tried to solve it by asking how the tool should work if it was up to the architect to decide.




The parametric graph-based programming languages Grasshopper (above) and Dynamo (right) combined with the scripting language Python are the short cut to performance-based analysis with almost any building simulation tool.



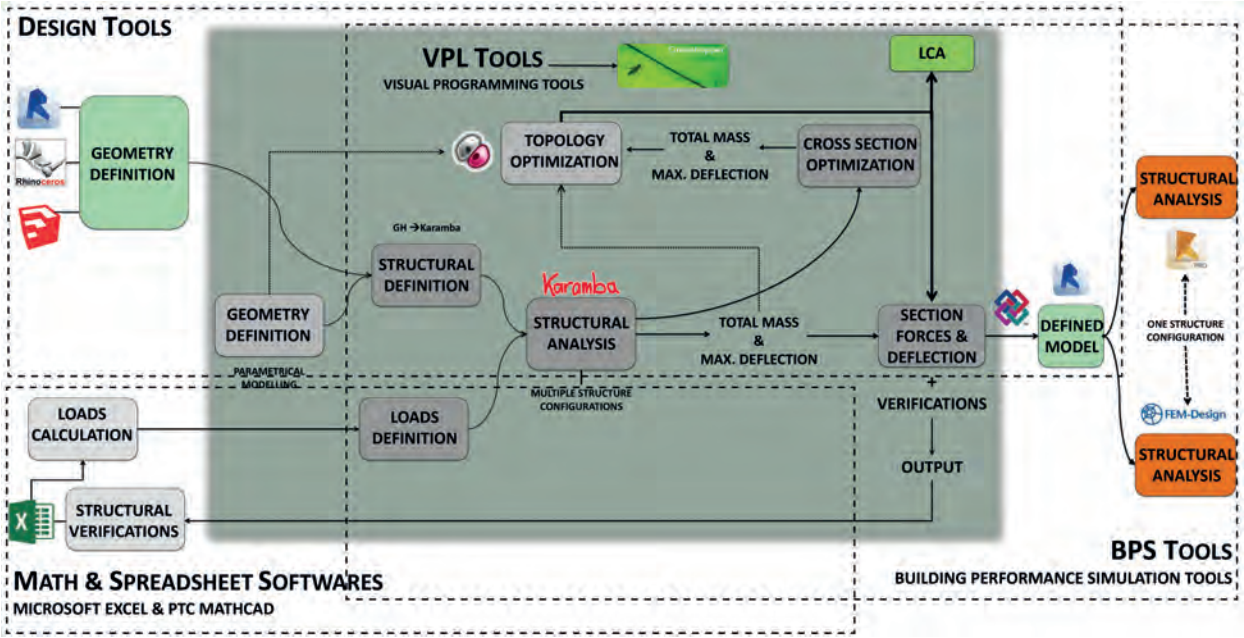

Some tools are built to communicate complex physical behavior or system-wide output. Few tools can communicate the dialogue and the very subjective understanding of human comfort. Above, we see two ways to map out the adaptive thermal comfort in a third space environment such as in the Eco-canopy from WHITE (left September 1st, right March 1st).

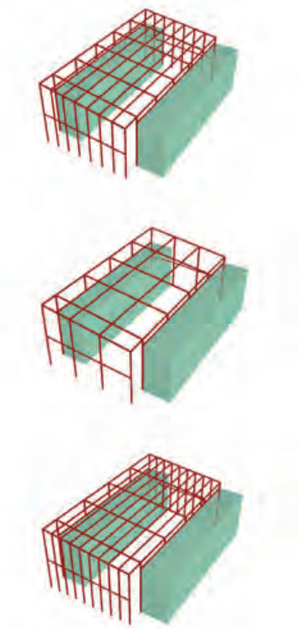
The mapping tool itself is meant to create dialogue, to help experimentation, and to hypothesize and simulate how humans feel temperature inside spaces that are neither entirely inside nor in an outside environment. The tool was built after extensive literature studies of the state-of-art and was built on top of multiple simulation tools; it is considered a breakthrough in the research field.

# Tools – What is required to take control?

## SPEED AND FLEXIBILITY

One essential requirement is speed - the feedback of input to output. Getting the knowledge and the right information fast is central to clear out bad choices and focus on the right ones. The mapping tool described above is built to accommodate fast and flexible structural simulations and embedded analysis. The tool couples multiple simulation tools to a predefined load case generator and to a parametric setup. The idea is “fast setup + fast analysis = more time to explore the design space”. The idea came from our first LCA tool development. (A later generation of the tool is seen on the right side of the page). This worked on an almost abstract level where the designer can input geometry, assign any type of data, and calculate the consequences of $CO_2$ impact spanning over the building’s entire lifetime. The flexibility is built-in as the tool itself is built on the parametric framework of Grasshopper. This tool combined speed with endless flexibility in terms of material inputs and geometry. Combining everything in one platform was a concept that worked on paper – but reality was much more complicated. Speed and flexibility come with great responsibility and technical domain-specific requirements for the designers themselves. The studios responded with huge interest but asked for reliability, validity, and most of all more user-friendliness.

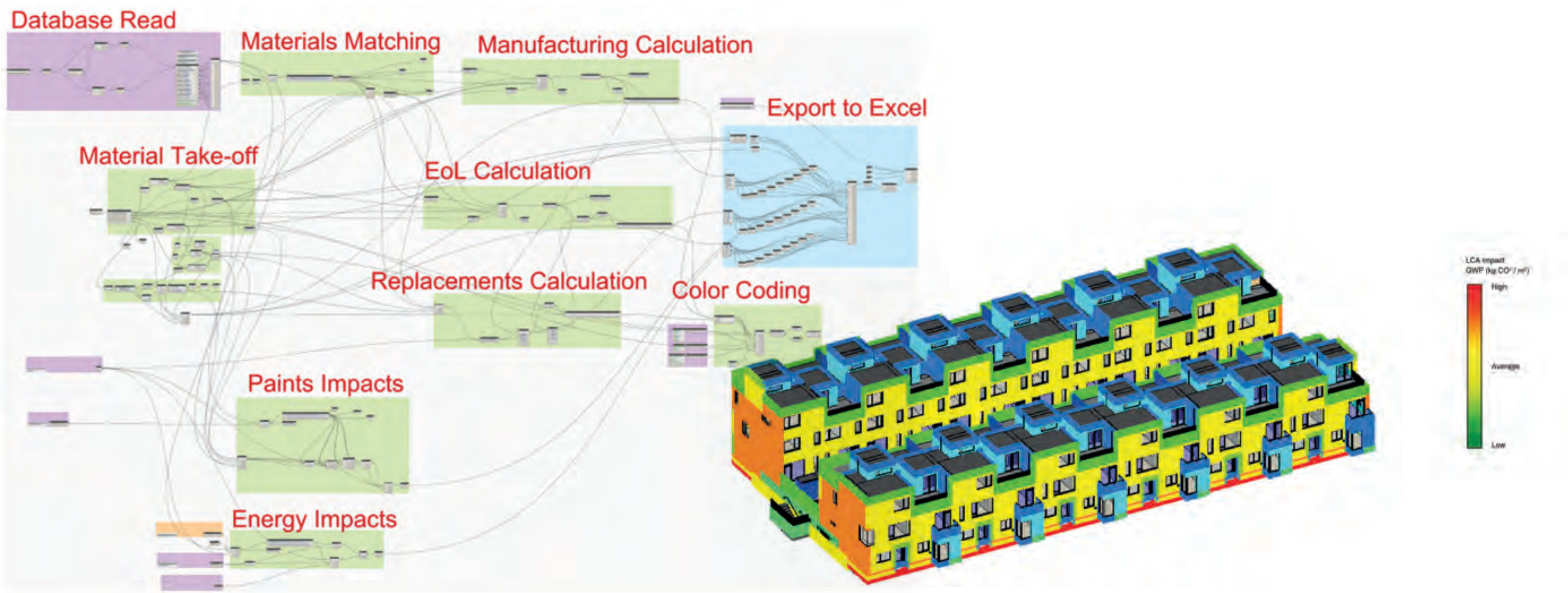


The tools we build take the best of the existing simulation tools we have at hand and combine them as we see fit. Here, we see a tool for structural analysis of the Eco-canopy by WHITE.

## RELIABILITY, VALIDITY, AND USER-FRIENDLINESS

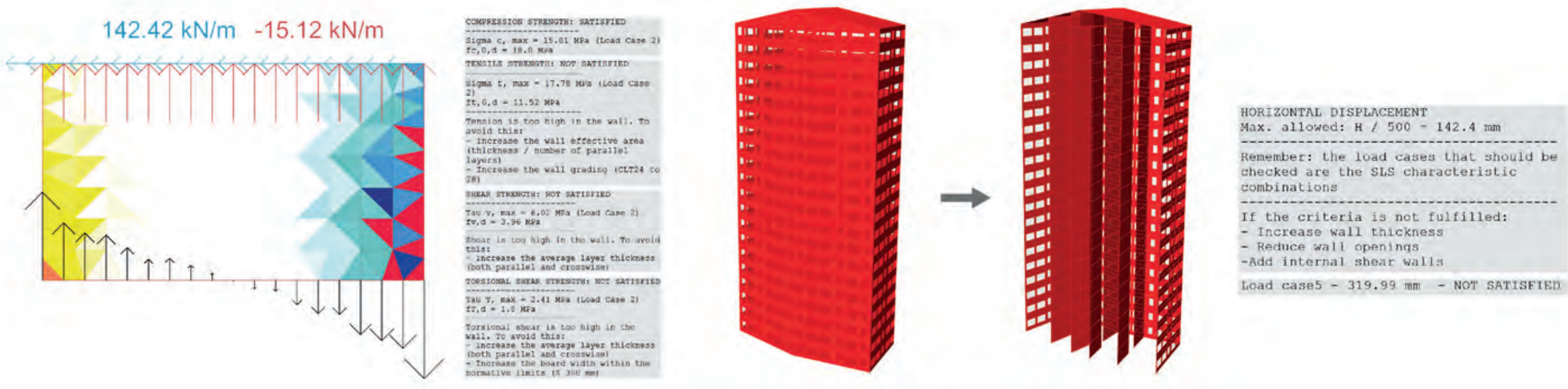
The second iteration of the tool was written using a similar platform (Dynamo) coupled to Revit (shown above). For many studios, Revit is required in the later design stages because it is associated with the BIM-methodology, which is a tool (framework) for delivering deeper information about buildings. The second iteration gave up its primary features, speed and flexibility, as Revit is a slower modeling tool and more restrictive than Rhino. However, by exchanging Rhino for Revit, the LCA analysis tool could deliver analysis outputs that were much more streamlined and with a controlled linked database setup that includes materials as well as quantity takeouts. Great effort was taken to embed internal error handling and to anticipate possible erroneous user inputs to eliminate “human error”. The tool became more locked in, but in the way that the architects defined themselves. Today both Vandkunsten and WHITE are actively using the tool to design and analyze buildings with LCA as a key output. The latest iteration of the tool considers LCC simultaneously with the emission impacts.




In this work, tools are built to couple logical processes and routines, and to bridge the existing simulation and calculation tools that are necessary to generate relevant feedback for the designers. Vandkunsten’s project Havnevigen is analyzed with an LCA tool that utilizes the BIM7AA encoding system as well as the Ökobau LCA database.

## RELIABILITY, VALIDITY, AND USER-FRIENDLINESS

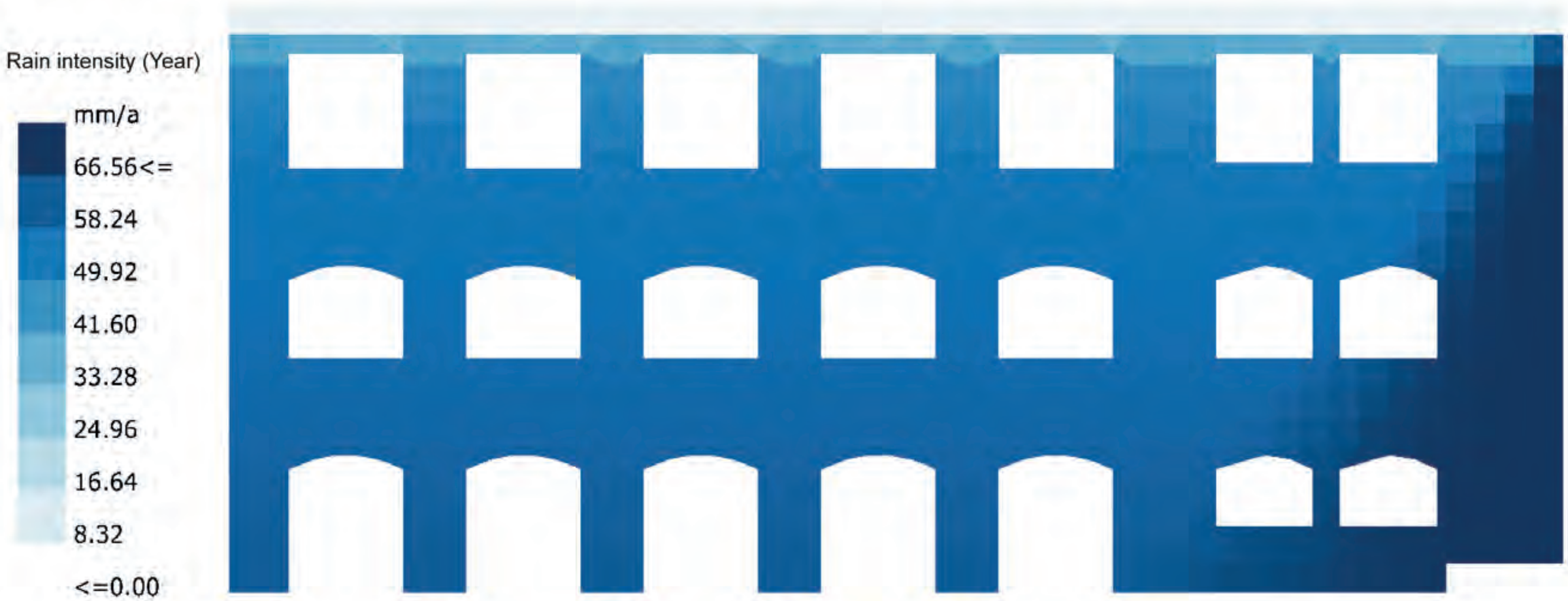
An example where “validity” is an important requirement of the tool is found in the development of a tool to design with cross laminated timber (CLT) to analyze the structural properties of both the building stability and the individual CLT elements in the building. The tool (shown above) is methodically tested and verified against two different finite element analysis tools (Karamba and Robot). The bridge of having a markup of each CLT element means the designer can take direct control over each laminated layer within the walls, decks, and facades, as well as instantaneous feedback of the entire stability of the structure. Simultaneous and scale-less graphical output was essential to understand the complexity and behavior of wooden CLT structures. The tool was developed to give control to the designer. The ability to take responsibility at all scales, from the properties of the glue to the complete structural system in a wooden midrise building, is quite a game changer. We have yet to see the full implications of the various structural-focused tools that have been developed.




Embedded knowledge is a term that we use when we bake in contextual and semantic analysis as feedback to the designer. It is one thing to use very graphical output to translate metrics to colors - the hard part is to facilitate quality assurance with the modeler (grey text fields).

## STATE OF ART, CLOSED SOURCE, AND OPEN SOURCE

Some tools are only available to researchers and consultants with enormous budgets for software licenses. The studios we work with have between 2 and 2000 architects in their studios. However, budgets for software is always limited because tools are never used as to as means to generate scopes, and therefore analysis tools must be either free or inexpensive. We prefer to couple the design tool to existing open source analysis tools that have been tested and validated – and in most cases, this is possible. We have seen this in daylight analysis (with Radiance and Daysim), with energy and thermal indoor environment analysis (EnergyPlus), and with water flow analyses (CMF). We have sometimes transitioned into closed source tools when open source tools were not an option, for instance in structural analyses (Karamba, Robot) or for energy analyses (Be15, BSim, IDA ICE). Other times, we need to develop our own tools as the options we had were limited (Life Cycle Assessment, potential for natural ventilation, fire analyses based on codes, evaluation of comfort in third spaces, and more).

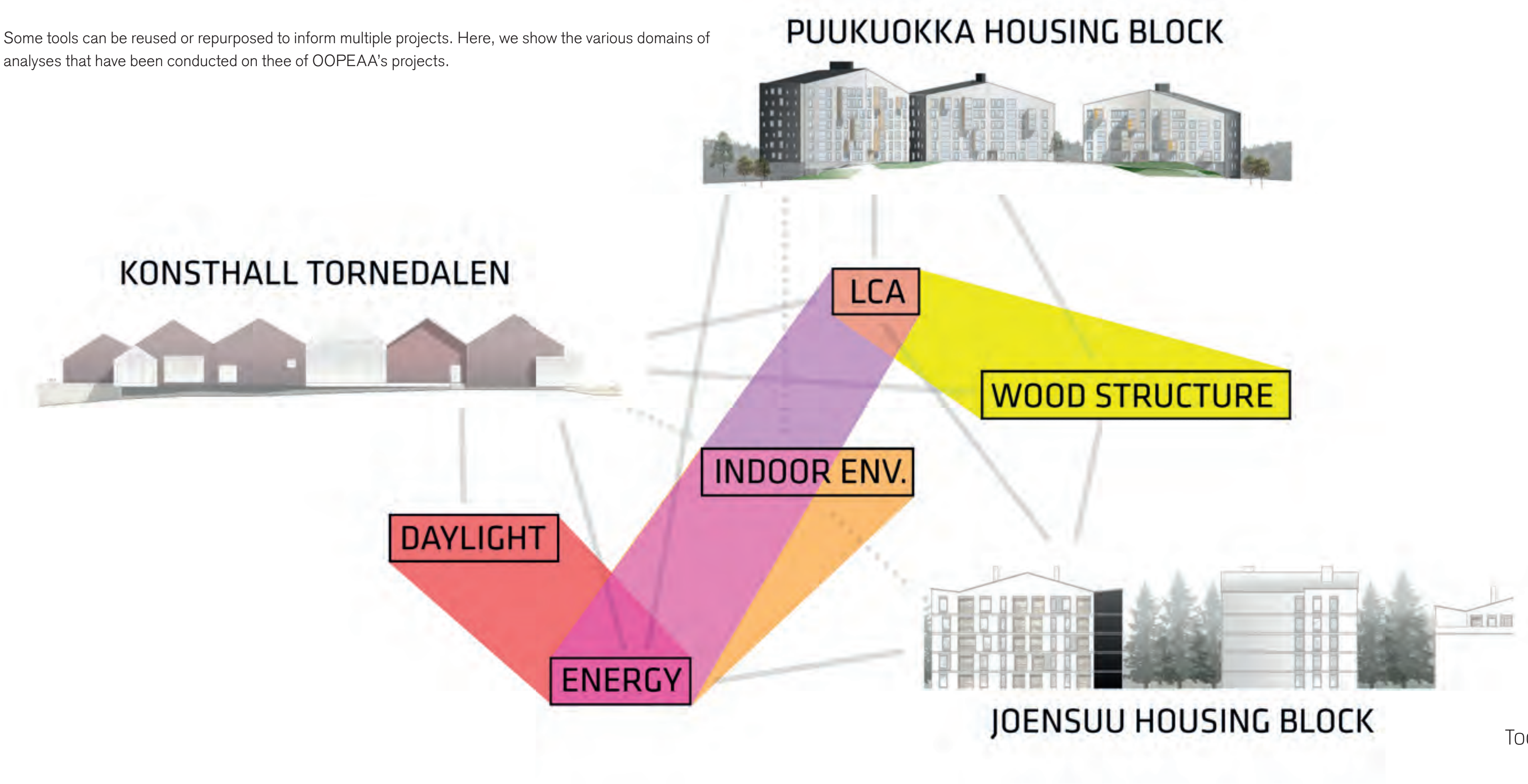



Some tools are built from scratch. When tools are not available elsewhere, we use existing research papers from various narrow fields and implement methods, algorithms, and procedures as code. Above is a tool that simulates annual driving rain on walls.

## STATE OF ART, CLOSED SOURCE, AND OPEN SOURCE

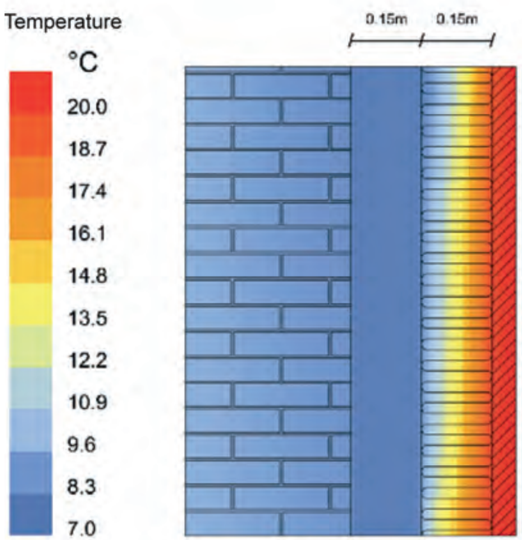
After a few iterations of tool development, we began to see that different studios had vastly different ways of approaching the tools. OOPEAA was using all of the tools that they could manage to fit in to their design process as they aimed for higher information levels for all aspects of sustainable thinking. Above, we see some of the common analysis areas of their projects that required distinct simulation tools. The inclusion of tools can be seen as a completely new way of working with building design. Helen & Hard and WHITE were already familiar with the parametric framework of Grasshopper and saw the tools provided by the universities as a natural extension of an existing design process. WHITE had very clear ambitions to integrate LCA as a design element into their projects and asked for specific material inputs and special features for the tools. This drove the universities to seek out faster and more reliable ways to verify the emissions and climatic impacts from very specific materials.

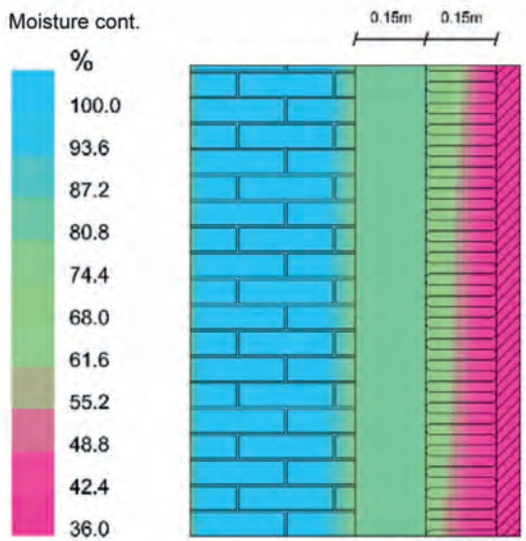
Some tools can be reused or repurposed to inform multiple projects. Here, we show the various domains of analyses that have been conducted on thee of OOPEAA's projects.



## STATE OF ART, CLOSED SOURCE, AND OPEN SOURCE

Helen & Hard had a more direct approach. They asked for tools that could answer specific questions such as "is it possible to clad a masonry wall on the inside with only wood without risking mold growth?". To answer such questions, we needed to take advantage of a state of the art simulation software (Delfin) to simulate the heat and mass transfer inside the structure while testing various airflows in a gap between the masonry wall and the wooden cladding. In the process, we developed a bridge (parser) to/from Grasshopper and setup the (very academic and cumbersome) simulation tool Delfin to be used as an exploration tool instead of as a research and validation tool. The same method has been used in other simulation environments (i.e. IDA ICE, BSim, and Be15) with great success. In all instances of the many tool development cycles that have been conducted, the goal was always to create "a tool for the early design stage". The aim was to create a tool that is used to explore, rather than to validate, a conclusion. Based on our observations of when the studios began to use our tools in practice, we concluded that the "early design stage" was the wrong term, and that "exploring" and "drawing conclusions" are two sides of the same coin.

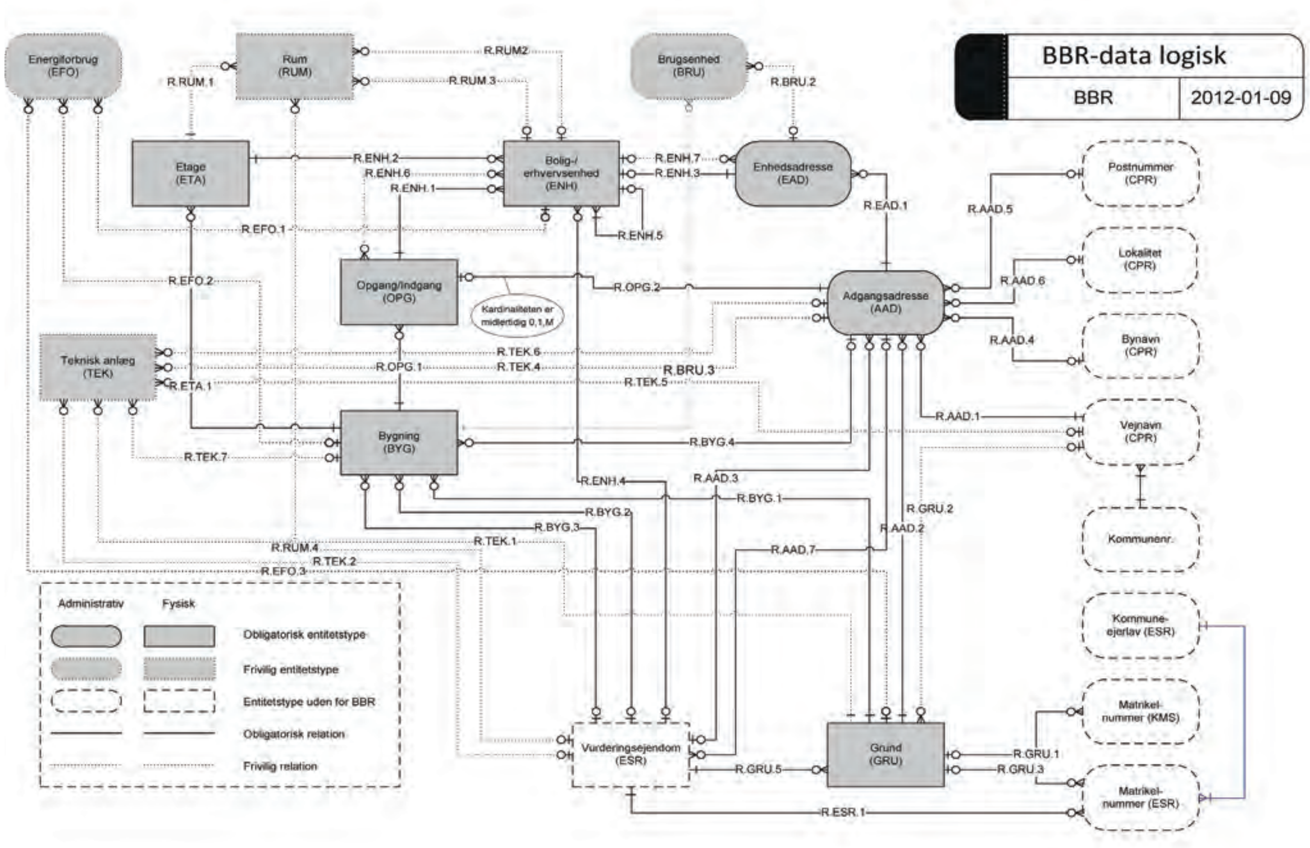



Mass transfer simulations have always been seen as one of the more difficult engineering disciplines to master. With custom tools, there is little difference between one analysis and the next. The working code in the background rarely matters for the user. We go to great lengths to make the tools easy to use, even if they are built on external closed sourced software.

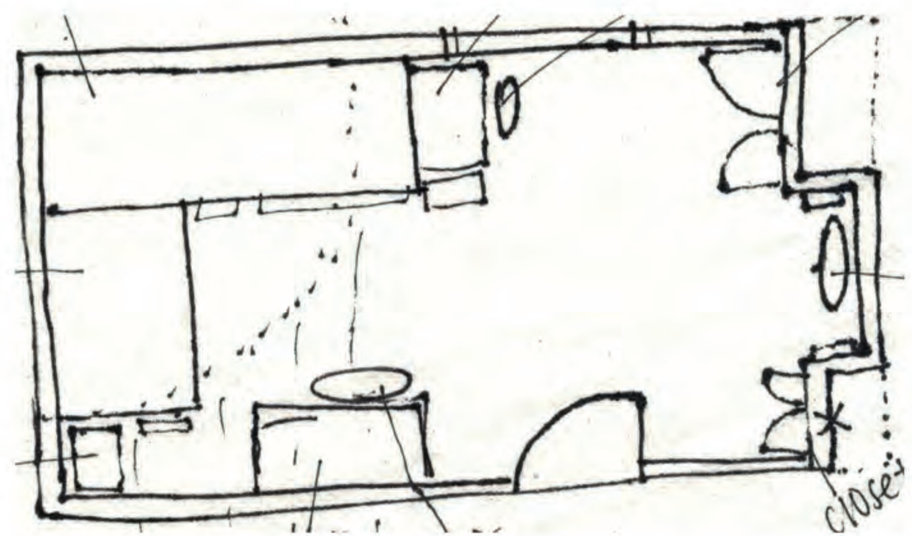
## TOOLS FOR DESIGN VS TOOLS FOR ASSESSMENT

The tools we developed for early exploration were also used as post analyses tools for assessing previous projects (seen very clearly in the LCA/LCC tools used and developed with Vandkunsten), and even for double checking documentation for DGNB-specific LCA assessments. The tools could do this, not because we had intended them to do so during the development phase, but because we built them in a highly flexible way using 100% open source code. There are no use restrictions or limitations to alter the way our tools work. Also, because the studios could participate in the development of the tools, they could change inputs, outputs, and graphical user interfaces (GUIs) as needed. We learned that a good GUI was not essential, but reliability was. Fortunately, our development is a product based on years and millions of working hours in solid coding practice and standardization of protocols and formats (e.g. as seen above: BBR-data protocol for the Danish building register). This means our tools are basically built on a solid foundation of good software engineering practice; we can only be grateful that this exists today.




A diagram of the BBR data structure implemented in one of our tools. Some data structures are well documented and existing simulation software programs have APIs and even generous support from the developers. This has been extremely valuable and saved much time in trial-and-error loops when creating our own tools.

To begin, our collaboration in developing these tools was to point towards a future where we could see how tools should look and work when developed by architects to be used by architects. What we learned was both enormously valuable and highly challenging. Tomorrow's tools are not built for validation purposes alone - they are used to validate, not as a final assessment, but as a validation for the exploration we call the design process. Tomorrow's tools are not built to communicate to architects. They are used by architects to communicate with the client, the consultant, the manufacturer, and the lawmakers of the future. These tools are highly adaptable, allow just the right amount of flexibility to enable outcomes that are trustworthy, and are at low risk of being used incorrectly in all stages of design. The tools can output graphical and detailed information to easily communicate answers to a client while they are producing the exact numbers the consultant, manufacturer, and lawmakers need to make their decisions.





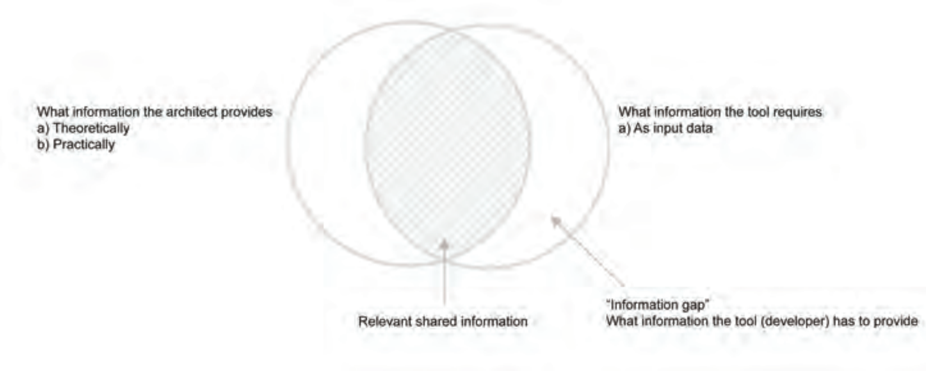
A hand sketch (left) and a fully functional multi-zone thermal simulation model (right). When precision is not the most essential part of the feedback, but fast and flexible feedback is, then there is really nothing stopping us from taking a napkin sketch for the basis of an hourly energy simulation.

The tools we need, we just have to create for ourselves. This is the reality that we have today. The tool developed here can basically take napkin sketches as inputs and then provides the energy consumption and thermal indoor environment of a multi-zone model as outputs.

# Tools – closing the “information gap”

## ANALYSIS AS A NATURAL PART OF THE DESIGN PROCESS

Being able to perform continuous analyses directly on the design intention is not only coupled to the technical difficulties related to the implementation of performance feedback but also very much coupled to the way we design – the design culture or design process. No continuous feedback can be required if there is no interaction with the tools or with the integrated dynamic models. We saw that the design culture did change among the practitioners after using the tools and we saw that change as a sign that industry was seeing the benefits of using the scientific tools to create better and longer lasting architecture. Design tools should not be separated from the analysis domain. In this research project, we are most proud that we broke down the barrier of performance feedback and the process of creating architecture. From the feedback to the university partners regarding the learning experience, we learned to remind ourselves as researchers to question what has been established and what we may change when we have direct access to the industry.




## TOOLS FOR THE FUTURE

We have been questioning traditional building practices in terms of which materials are most relevant to use in Nordic countries, why do we insulate as much as we do, down to the level of how is a U-value actually calculated, and does it really capture the thermal performance of a structure!? If these questions had been posed in a closed academic loop, we may have dismissed them purely based on references to established knowledge written in archival publications. Now, when industry partners question established theories, we have an obligation to look deeper and re-evaluate the established “reality”. Something that may come as a surprise to some is that “reality” is based on assumptions and that science is only as good as its assumptions. Together, we have been on a journey of scientific discovery that is coupled directly to design practice. Our focus has been changing to support and help understand the performance of older and current building design ideas; we have strived to give generic feedback rather than singular assessments. The tools and analyses can be seen as our final outcome, but we certainly see the changed design process within the industry and academia as the most valuable result of the STED project concerning the ICT development.

# If it doesn’t have a number it doesn’t exist

**Social sustainability is about building long-term stable and dynamic societies where basic human needs are met. It's also about creating equal opportunities and environments that allow people to meet and grow.**
**Architecture as a physical form of social interaction and behavior. Buildings as social constructs.**
**Can we measure the social impact? How?**
**Sustainable development was defined as the meeting between social anthropocentric development and environmental protection. While environmental sustainability for the built environment has been fitted with measurable indicators, the definition of what social sustainability is, or could be, is blurry. Some guidelines delimit social criteria to building-related factors such as indoor environment and comfort. Others encompass more complex aspects such as well-being, sense of belonging, human interaction, safety, and social inclusion.**
**Sustainable indicators are often check boxes in the design phase. However, many of the anticipated social effects of the built environment will manifest only after some years in use. Still, there are systematic methods for working with social sustainability in the built environment.**

# What is the real evidence of connections between the built environment & social sustainability?

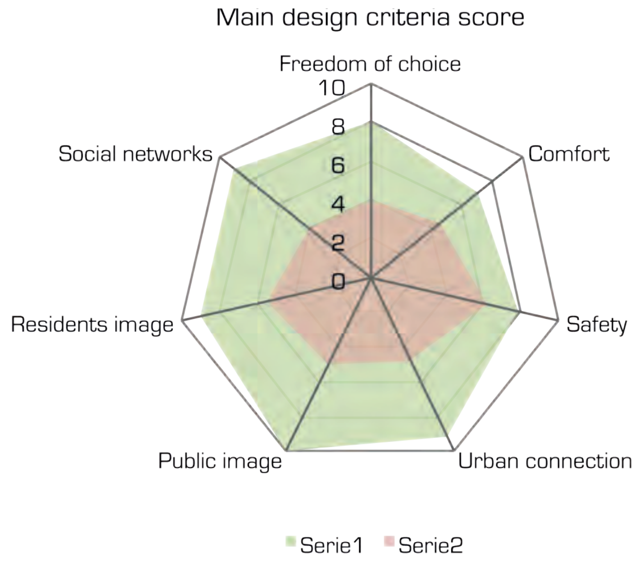
While the concept of social sustainability is gaining relevance, the field is still underdeveloped and lacks a solid framework to operationalize it in a design process. How can a design process be supported to secure more socially sustainable solutions? The table below captures the essence of a large literature study of previous definitions of social sustainability. Based on this, a hierarchy of themes, criteria, indicators, and methods/tools for evaluating them have been established. There is, to some extent, a consensus concerning themes, criteria, and indicators. When it comes to methods and tools for assessing and analyzing, the map looks more blank. However, CPTED, SAVE, and POE offer operational ways forward. In relation to the built environment, the suggestion is that it speeds things up to match criteria and indicators with sets of solutions/attractors for which there is evidence that they have an effect on social sustainability. At the same time, it is suggested to organize the criteria and indicators according to physical scale and time scale for effect.

Proposed model of social sustainability including a condensation of the case study results.

| | Themes | Criteria | Weight | Indicators | Weight | Score | Method / Unit of analysis | Qualitative | Quantitative | Tools | Attractors/Solutions | Scale: Apart. | Scale: Build. | Scale: Neigh. | Time scale |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social Sustainability | Equity / Quality of Life | Affordability | | Rent level | | | | | | | | | | | |
| | | | | Heating cost | | | | | | | | | | | |
| | | | | Individual metering | | | | | | | | | | | |
| | | | | Possibilities for food production | | | | | | | | | | | |
| | | | | Good quality apartments | | | | | | | | | | | |
| | | Freedom of choice | | Variation in apartment sizes | | | | | | | | | | | |
| | | | | Variation in tenure | | | | | | | | | | | |
| | | | | Apartments for residents with special needs | | | | | | | | | | | |
| | | | | Access to balcony | | | | | | | | | | | |
| | | | | Access to green/recreational areas | | | | | | | | | | | |
| | | | | Access to storage | | | | | | | | | | | |
| | | | | Ability to shape own space | | | Variety of available options | X | | | Flexible design, private outdoor spaces, user influence | X | X | X | |
| | | | | Ability to cultivate/grow | | | | | | | | | | | |
| | | Comfort | | Daylight | | | Daylight factor | | X | Velux Daylight Visualizer | Increased glazing area, new facade | X | X | | Medium |
| | | | | Heating | | | | | | | | | | | |
| | | | | Indoor climate | | | | | | | | | | | |
| | | | | Noise | | | | | | | | | | | |
| | | | | Wind | | | | | | | | | | | |
| | | | | Human scale | | | Range of scales that relate to human body | X | | CPTED | New, smaller buildings, varied facade | | X | X | Medium to long |
| | | Health | | Ability to exercise | | | | | | | | | | | |
| | | | | Access to health facilities | | | | | | | | | | | |
| | | | | Awareness of own health | | | | | | | | | | | |
| | | Education | | Access to elementary schools | | | | | | | | | | | |
| | | | | Access to secondary education schools | | | | | | | | | | | |
| | | Safety / Security | | Vandalism removal | | | | | | | | | | | |
| | | | | Road safety | | | | | | | | | | | |
| | | | | Lighting | | | Percentage area properly lit | X | | CPTED | New/improved lighting | X | X | X | Short |
| | | | | Natural surveillance | | | Percentage area with natural surveillance / no. enclosed spaces | X | | CPTED | Active ground floor | X | X | X | Medium |
| | | | | Visibility | | | Percentage area with good visibility | X | | CPTED | Reduce corners | X | X | X | Medium to long |
| | Connection / Accessibility | Transportation | | Public transport | | | | | | | | | | | |
| | | | | Carpool | | | | | | | | | | | |
| | | | | Balance of modes of movement | | | | | | | | | | | |
| | | Urban connection | | Garbage collection | | | | | | | | | | | |
| | | | | Entrances | | | Distinctiveness, openness, brightness, facing direction, privacy | X | | CPTED | Increase glazing, create semi-private zone | | X | | Medium |
| | | | | Parking facilities | | | | | | | | | | | |
| | | | | Car access to area | | | | | | | | | | | |
| | | | | Pedestrian access | | | | | | | | | | | |
| | | | | Bike access | | | | | | | | | | | |
| | | | | Area used by non-residents | | | Volume (no. people), attraction, facilitation | X | X | | Increase number of amenities | | | X | Long |
| | | | | Public meeting places | | | Number (per building), variation | X | X | | Playgrounds, benches, shops, cafés, playing fields | | | X | Medium |
| | | | | Private meeting places | | | Number (per building), ease of access, variation of use | X | X | | Common rooms, laundry rooms, roomy staircases | | X | X | Medium to long |
| | | Disabled access | | Possibility to stay in your own home | | | | | | | | | | | |
| | | | | Accessibility indoors/outdoors | | | | | | | | | | | |
| | | Services/jobs | | Presence of local amenities | | | | | | | | | | | |
| | | | | Range of service | | | | | | | | | | | |
| | | | | Local job opportunities | | | | | | | | | | | |
| | | | | Support system for entrepreneurs | | | | | | | | | | | |
| | Identity of place | Public image | | Name of streets | | | | | | | | | | | |
| | | | | Public stigma (media reports) | | | | | | | | | | | |
| | | | | Public landmarks | | | | | | | | | | | |
| | | | | Heritage value | | | | | | | | | | | |
| | | | | Differentiation of private and public | | | Level of graduation, use of semi-private spaces | X | | CPTED | Semi-private areas, level differences | | X | X | Medium to long |
| | | | | Definition of uses (programming) | | | | | | | | | | | |
| | | Residents image of area | | Maintenance and care | | | Expected quality/ease | X | | CPTED | Easily cleaned/replaceable materials | | X | X | Medium |
| | | | | Resident's opinions | | | | | | | | | | | |
| | | | | Local landmarks | | | Number, variation | X | X | | Artwork, architecture, a special tree, a special shop | | | X | Short to long |
| | Social cohesion | Social diversity | | Social mix | | | | | | | | | | | |
| | | | | Social inclusiveness | | | | | | | | | | | |
| | | Social networks | | Volunteers | | | | | | | | | | | |
| | | | | Local societies/communities | | | Capacity/facilities to support groups/activities | X | | | Common facilities, playing fields, green areas | | X | X | Medium to long |
| | | | | Residents' association | | | | | | | | | | | |
| | Democracy | Participation | | Residents included in decision processes | | | | | | | | | | | |
| | | Communication | | Access to information/internet | | | | | | | | | | | |

[Table of indicators]: The suggested model covers the key topics using themes with sub-criteria and indicators. Based on the conditions surrounding the individual project, these indicators can be weighted to direct focus towards the most relevant issues. By analyzing the indicators and converting qualitative and quantitative results to a common scale (e.g. from 1 to 10), the social sustainability performance of design proposals can be visualized to direct the design process in a more socially sustainable direction.

Taking the Million Program and a specific case suggested by White Architects as a starting point, DTU and KADK tried out the system of criteria and indicators in a design process. Together, DTU and KADK agreed on a weighting of the criteria and indicators. Then, they performed an analysis of the existing conditions and the design proposal. The design process operated both at the large scale and at the smaller spatial and tectonic scale. The design team chose to focus on equity, social mixing, cohesion, empowerment, participation, well-being, and quality of life. Design process integration depended on a breakdown of these characteristics into more tangible indicators; how these indicators were weighted, selected, and analyzed; as well as on their scale, visualization, comparison of results, and inclusion of residents in design processes.




Case study design process using the results from the literature review – spider diagram of social sustainability score for the existing Fyrklövern (red) and the KADK design proposal (green).

| Themes | Criteria | Ex. | Prop. | Indicators | Ex. | Prop. |
|---|---|---|---|---|---|---|
| Equity / Quality of Life | Freedom of choice | 4,00 | 8,00 | Ability to shape own space | 4 | 8 |
| | Comfort | 4,56 | 7,11 | Daylight | 4 | 6 |
| | | | | Human scale | 5 | 8 |
| | Safety / Security | 6,16 | 7,88 | Feeling of security | 7 | 7 |
| | | | | Natural surveillance | 4 | 9 |
| | | | | Visibility | 7 | 8 |
| Connection / Accessibility | Urban connection | 4,73 | 9,08 | Connection to city | 4 | 9 |
| | | | | Entrances | 5 | 10 |
| | | | | Meeting places | 4 | 8 |
| | | | | Foot traffic to and through area | 7 | 9 |
| | | | | Area used by non-residents | 5 | 8 |
| | | | | Common facilities | 4 | 10 |
| Pride and sense of place | Public image | 5,00 | 10,00 | Differentiation of private and public | 5 | 10 |
| | Residents image of area | 5,50 | 9,00 | Maintenance and care | 5 | 8 |
| | | | | Local landmarks | 6 | 10 |
| Social cohesion | Social networks | 4,00 | 9,00 | Local societies/communities | 4 | 9 |

The scores are indicated above. The weighing of the criteria and indicators was established between KADK and DTU. It can, in due time, be fixed if a consensus can be reached and if there is enough evidence (for instance, created through POEs).

[Visualisations] Case study: Architects' rendering of the final design proposal for the transformation of the blue houses in Fyrklövern, Upplands Väsby, Sweden

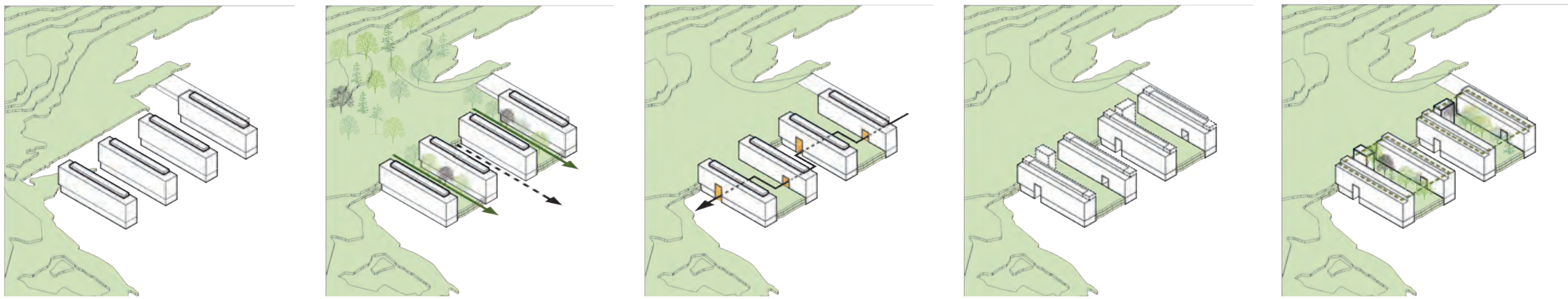


Diagram of architectural concept

# White Architects:

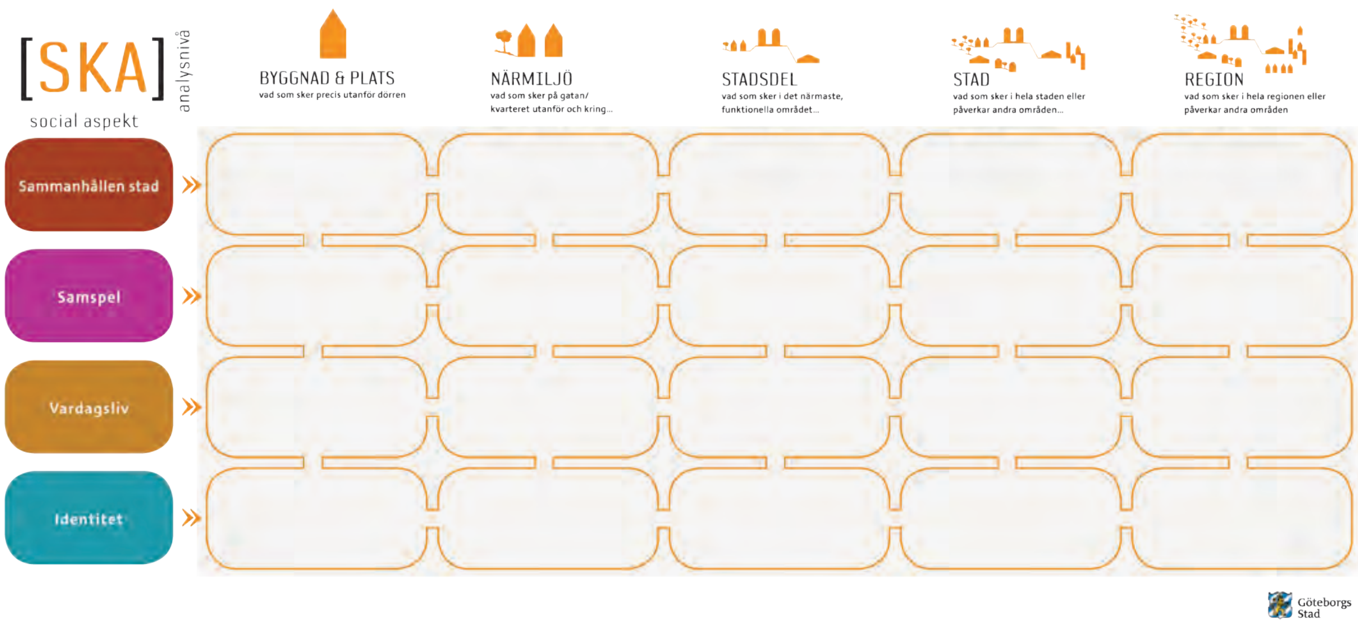
## Screening levels of social sustainability before, during, and after designing

> "Cities have the capability to provide something for everybody only because – and only when – they are created by everybody"
>
> (JANE JACOBS, 1961)

### PEOPLE IN FOCUS

White Architects have a long tradition of and experience working with social sustainability in architecture and urban planning projects. The physical surroundings have great importance for people's lives and wellbeing. Depending on how they are designed, they can either support or hinder sustainable social systems and habits. Creating a socially sustainable city is ultimately about putting people in focus. The specialists at White who work with social sustainability all have different educational backgrounds, ranging from social anthropologists to behavioral scientists and cultural geographers. Together with architects and other professions, we work in an interdisciplinary manner to create sustainable buildings and cities.

In recent years, social impact assessments (SIAs) have become a commonly used method to analyze and evaluate social aspects in architecture and urban planning. Based on the concept of SIA, the municipality of Gothenburg has brought forward its own method of working with social impacts called Social konsekvensanalys (SKA). The Gothenburg method provides a framework and guidelines for analyzing social processes and impacts. A key idea is that social impacts need to be analyzed and addressed on different geographical scales. Another key idea is the importance of doing a proper inventory - in other words, understanding the setting. How does the place in question function today? How do people use and perceive the specific environment? What are the values and challenges that we need to address? Preferably, the inventory should contain some sort of community participation. The next step is to assess the potential effects or consequences of the project, both positive and negative. The last and final step of the process is to provide recommendations that can improve the result and minimize or compensate for negative effects.




## WORKING AT DIFFERENT SCALES

Safety, accessibility, segregation, gentrification, health, and public space are examples of social aspects. Working with social sustainability is about being able to understand what social aspects are relevant at different geographical scales. At White, we work with sustainability both on a smaller scale, for example when building a hospital or designing a playground, as well as on large scale urban planning projects. The relevance of different aspects also depends on the phase of the project - whether it's in the early stages of development or in the building phase. Whatever the project, we at White generally try to address the social issues as early as possible in order to maximize the possibility of influencing the outcome.


One of the main ideas in White's sustainability philosophy is that dialogue and participation are key factors in creating sustainable cities. We have a strong conviction that the people who live in and use a city on a daily basis are the best sources of knowledge. Other sources of information can give important indications, but the user perspective is crucial to gaining a deeper understanding of a place, beyond statistics and reputation.

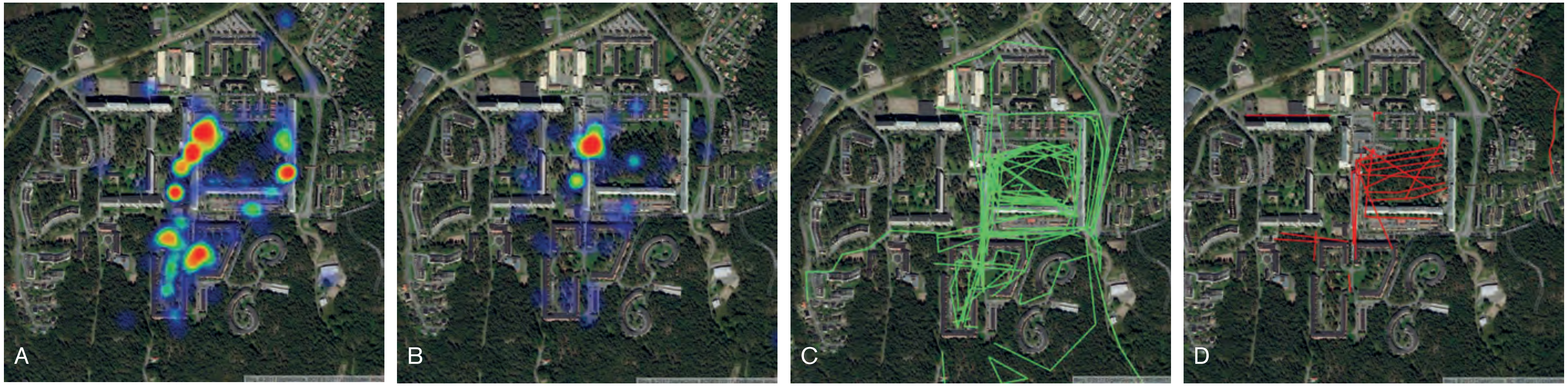
In working with social sustainability, White uses a combination of methods, processes, and sources of knowledge. It is a field that is relatively new and we still have a lot to learn; therefore, transparency, knowledge sharing, and research are very important to us. Examples of methods used at White include:

- Social impact assessments/Children impact assessments
- Workshops
- Social mapping
- Observations
- Interviews, surveys, focus groups, walk and talks
- Geographical information systems (GIS)

# Mapping perceptions and the potential of GIS

## MAPPING PERCEPTION OF PLACES

Placing people and the social perspective in focus is extremely important in the transformation of existing buildings and neighborhoods. Since interventions affect the people who live and work in the building or area, a design proposal that includes the social dimension should not only be based on the perceptions of the design team but should also be deeply rooted in an understanding of how the building or area is perceived from an insider perspective – by the users. But how can different qualities and values in a housing environment or a neighborhood be mapped? How do residents experience different places and how can such information be communicated to different stakeholders such as the property owner or the design team? Maptionnaire (www.maptionnaire.com), which is software as a service (SaaS) for creating map-based questionnaires and civic participation platforms, is an example of a tool for value mapping. It can also be used as a dialogue tool for giving citizens a voice.




Value mapping with the tool Maptionnaire - perception of places and routes in the Hammarkullen suburb in Gothenburg as experienced by the residents.

(a) Places I like

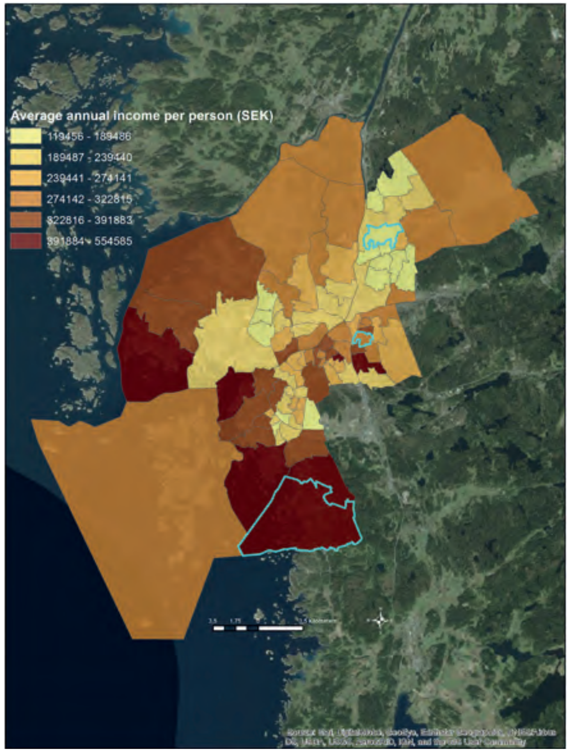
(b) Places I don't like

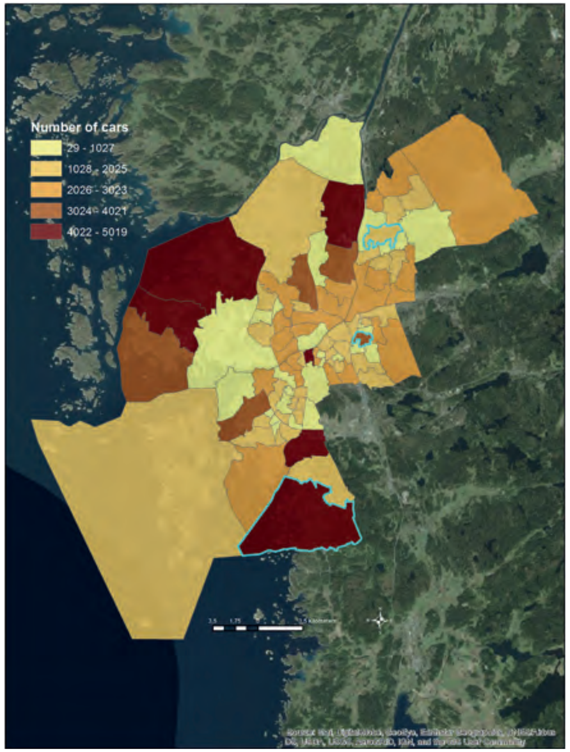
(c) My favorite routes

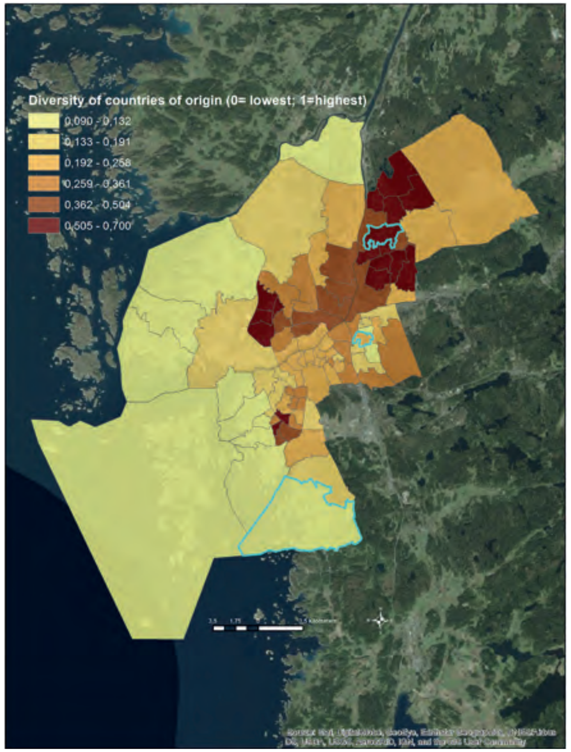
(d) Routes I don't like

Map images from the research project "How do residents in Hammarkullen perceive their neighborhood? – Visual mapping of different values before refurbishment." Ongoing data collection. Project participants: Jenny Stenberg & Liane Thuvander, Chalmers University of Technology. Alfredo Torrez, Ola Terlegård, Kim Weinehammar, and others from the Tenant association.

We often discuss how difficult it is to quantify social sustainability. However, in the Nordic Countries there is actually a large amount of information available concerning socio-economic issues that is stored in GIS format and linked to specific buildings and urban areas. In the recent years, more and more data is getting open access. It would thus be possible to develop a design process that registers levels of education, health, crime, employment, income, etc. before and after an architectural invention in an area.
The interface between data stored in GIS format and the software used by most architects needs to be developed to work more smoothly.




GIS - understanding the locality in a city context: Three georeferenced maps as a starting point for a dialogue with the residents to discuss specific aspects of sustainability in relation to other districts. Examples of indicators: average annual income per person in SEK, number of cars, and diversity of countries of origin.

# CPTED

## Crime Prevention Through Environmental Design

### CTED CRIME PREVENTION THROUGH ENVIRONMENTAL DESIGN (CPTED)

CPTED originates from 1971 and is a part of the CIAM modernistic criticism that began in the 60s. It is rooted in a criticism of post-war modernistic housing projects and borrows from Jane Jacobs' theories, but it also has a close relation to criminology and crime prevention. Because of this, there is a long tradition of measuring the cause and effect of designing and planning with CPTED strategies.

CPTED is a work in progress - a collection of contributions from several scholars worldwide adjusted to different cultures and societies. Therefore, the method, when used in the US, often focuses on access control and electronic surveillance, while Scandinavian countries focus on natural surveillance and territoriality through design and community engagement.

An S-train station close to public housing: Low territoriality (no ownership) , low natural surveillance (no one can see you), Many hiding places (shrubbery) and low visibility, low activity support and the  elements in the geographical juxtaposition has a strong influence on the station area.

## CPTED Wheel:

Territoriality is the primary concept in CPTED from which the other concepts derive. It is a complex human inclination to acquire, define, own, manage, or control space based on perceptions, emotions, motivations, goals, and resources. It can operate at various scales, including for the individual (e.g. a room), a group (e.g. a family house), or a community (e.g. a neighborhood).

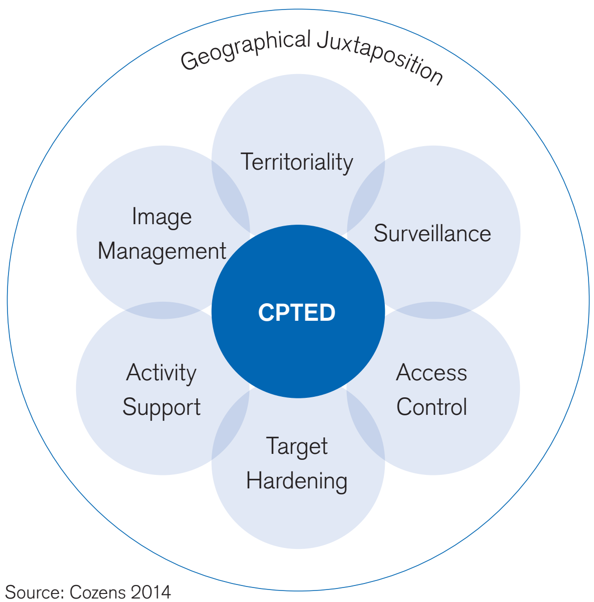
Image management: The design, management, and use of a built form can exhibit positive or negative signals or indicators about it. These can influence the perception of space to have positive emotionally-driven behavioral effects.

Activity support is placing human activity where it can create a lively and safe urban space that suits the purpose in terms of function or definition. It derives from the notion that lively areas create informal surveillance and thereby a perception of safety. This – along with the CPTED term surveillance – is also referred to as 'eyes in the street' (Jacobs, 1961).

Geographical juxtaposition is the understanding of the wider environment's influence on a local situation. This involves land-use, socioeconomic structures, and/or crime generating functions in the geographical juxtaposition.

Natural surveillance involves using windows, balconies, and doors to create visual contact with the street and designing buildings and the street so they create inter-visibility between the buildings. It can also be a street design to increase pedestrian and bicycle traffic or a landscape design that does not provide opportunities for concealment.

Natural access control is possible by defining space and patterns of circulation. This involves clearly defining entrance and exit points, signing, fences, landscaping, and light. (Access control can also be organized (security personnel) or mechanical (bolts, locks, gates, etc.)). Target hardening means using bolts, locks, fences, electronic alarm systems, etc. in order to keep offenders out.




Source: Cozens 2014

Post-Occupancy Evaluation

# Asking people what they think in a systematic way

## POST OCCUPANCY EVALUATION (POE)

What happens after residences are built? In most cases, architects and other building professionals receive little feedback about a building in use and few studies are made of the user satisfaction of housing. A post-occupancy evaluation (POE) defines a systematic process of obtaining feedback about a building's performance after it has been in use for some time. The data collection methods differ depending on the aim of the POE and the type of building in question; they can include measurements and audits.

Vandkunsten developed 5 apartment types: each apartment had a footprint of about 85 $m^2$ with five different standard levels of interior finishing and corresponding prices. Today, the housing area offers both resident-owned apartments and rental units for tenancy.

Æblelunden, constructed in 2007, was designed by the architecture firm Vandkunsten with open, adaptable floorplan layouts and robust architecture.

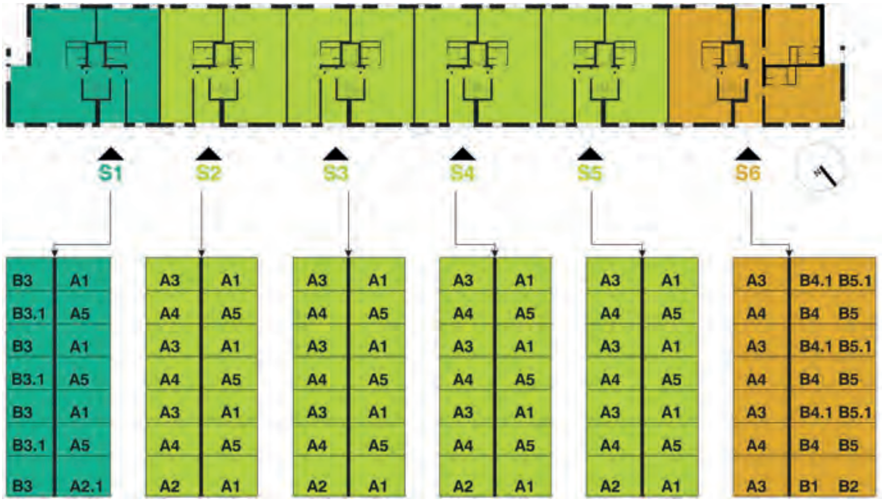
Can adaptable space and raw space deliver more sustainable housing?

POEs were initiated in a collaboration between Vandkunsten, the Department of Architecture and Civil Engineering at Chalmers University of Technology, and DTU. The aim was to provide insights on social sustainability and the design of more raw and adaptable housing spaces that can be sold or let at lower prices and that can be fitted by the users themselves according to their needs and wishes. The concept of adaptable housing was developed by Vandkunsten in the commercial project Æblelunden and in the social housing concept called AlmenBolig+.

## A QUESTIONNAIRE SURVEY

For the POE of Æblelunden, a questionnaire was sent out to all 90 residents. The questionnaire was personalized to fit ten different apartment sizes and types in the building. Efforts were also made to create an appealing design and layout of the questionnaire. The residents were asked about themselves, the initial standard and fit-out of their apartment, changes that they or previous owners/tenants had made in the apartment, and their satisfaction with the adaptable apartment design. The residents were also asked to draw their changes in

> "I could influence the quality of the work being done in the apartment – Respondent to questionnaire in Æblelunden"




Example of occupiers' alterations of an apartment layout. The original single space has been divided into a 4 room apartment.

# Post-Occupancy

# Evaluation of AlmenBolig+

## ALMENBOLIG+ AS DESCRIBED BY VANDKUNSTEN

Challenge no. 1: Affordable homes

The average rent in AlmenBolig+ developments is about 23% less than in other comparable non-profit housing. This is made possible in part by means of energy optimization and by replacing traditional but also costly craft methods with pre-fab units. The sustainable construction system is not only cheaper than conventional concrete structures, it has also cut resource use in half.

Challenge no. 2: Exiting modular architecture

AlmenBolig+ equals modular construction. We, as architects, are really are not trying to make it appear as anything other than what it is, although, naturally, we strive to bring out the best in every project. «The Denmark plot» is characterized by its sloping wedge shape. The box modules are slightly wedge shaped as well. Placed in rows, the wedges create soft crescents.

## INTERVIEWS WITH RESIDENTS

AlmenBolig+ is a concept developed by social housing adminstrator KAB. The aim is to create high-quality but still affordable housing. This is achieved through a combination of new ways to build, finance, and maintain the homes. The concept includes apartments without internal separating walls and finishes and with a higher degree of self-maintenance by the tenants. Six interviews and on-site visits were carried out with five families and one single household. The areas are appreciated and there is a good community although democratic processes for maintenance of the area can be problematic at times. There are no community rooms. Instead, communication is upheld through social media and through outdoor activities. The architecture has had a mixed reception among the tenants: some like it, others don't, and some don't even notice it. The concept of the un-finished dwellings is appreciated as a means to cut costs for the tenants. However, the fit-out is often done without professional help. New tenants will have to make alterations at their own expense.

Above, "The Denmark plot", "Sundbygaard" and "Syndbyvang"

# How to compare apples, pears, and bananas.

Multi Criteria Decision Making (MCDM) is a family of methods for weighing specific criteria or parameters. MCDMs can be very advanced and take months of work to perform an analysis. At the other extreme, they can take 10 minutes. MCDMs exists as freeware that can help outline a solution space at the first meeting. For example, they can help to determine what is most important in the project: architectural expression, indoor climate, economy, etc.? This would be in the category of an analysis that takes 10 minutes.
TOPSIS is at the other extreme where very detailed weighing of criteria and analysis results can be organized.


DTU performed a case study on a design process using TOPSIS as an ‘umbrella’ for weighing different investigations: SAVE (cultural heritage), LCA software (embodied energy and C02), IESVE (energy balance and indoor climate), etc. The case was the former University Hospital of Odense, which is now empty because a new ‘super hospital’ has been built nearby. The question is: which buildings to demolish and which to refurbish? And, if a building should be refurbished, how should it be refurbished? TOPSIS works by setting up a model of an ideal situation. The results are then outlined by the ‘distance’ from the ideal situation.
During the STED project, the interface between SAVE and LCA was also explored in a case study on design processes addressing a large derelict hospital area in Odense. The hospital buildings were assessed in regards to LCA, energy-balance/consumption, indoor climate, cultural heritage value, and estimated remaining years of usability. This would ordinarily create a classic dilemma of comparing apples to oranges, however it was possible to organize the weighing of the different parameters by means of a multi criteria decision making model (TOPSIS). Illustration LCA in this project informed the designer of the embodied $CO_2$ in the remaining hospital buildings. In some ways, the hospital project described above built on a previous project developed as part of a cross disciplinary course between DTU and KADK before the initiation of the STED project. As part of this earlier collaborative project, the KADK students used simple LCA tools to inform their design solutions for the derelict Carlsberg breweries.

| MAPPING (J) | WEIGHT | EXPLANATION |
|---|---|---|
| ARCHITECTURAL QUALITY | 5 | As a part of the SAVE method, 'Architectural quality' often weighs high compared to most of the **others**. Further it is assumed of great importance that the area and houses are of great architectural and aesthetic quality to ease the appreciation of the area and buildings. |
| CULTURAL-HISTORICAL QUALITY | 5 | As a part of the SAVE method, 'cultural quality' often weighs high compared to most of the others. It is further assumed that the cultural quality and history of the buildings and area, are of importance to maintain some cultural heritages. |
| ENVIRONMENTAL QUALITY | 3 | As a part of the SAVE method, 'Environmental quality' is often weighted high along with the two above. However, it is found that the area of the hospital in general can seem messy without a smooth integration, hence the weighting was set down. |
| ORIGINALITY | 2 | As a part of the SAVE method, 'Originality' is often set lower than the above. As most of the buildings today need ongoing renovations, maintenance and 'improvement' to be able to 'live' longer, the originality might always be tampered a bit. |
| CONDITION | 3 | As a part of the SAVE method, 'Condition' is often set lower than the top ones. As most buildings which are on the edge of collapsing or are damaged in other crucial ways are changed immediately, the category is not assumed of great importance, however the appearance and condition have an influence on the further life time of the building, hence the middle weighting. |
| AREA | 1 | The area is weighted relatively low, as it is not seen as a decisive factor. Further the normalization/span of size is sizable in a way that they dominate the entire MCDM-analysis, without taking the others into consideration. The issue is also discussed further down in the discussion section. |
| EMBODIED ENERGY | 4 | As LCA's and impacts potentials are gaining a greater interest and scarce resources are a focus of various stakeholders, it is seen of importance to evaluate the existing building's primer impacts. |
| GLOBAL WARMING | 4 | As LCA's and impacts potentials are gaining a greater interest it is seen of importance to evaluate the existing building's primer impacts. |
| YEARS LEFT | 5 | The buildings in the area are all of different materials and build in different decades. It is assumed of importance when the buildings 'natural' end of lifetime is reached. |

# The Value of Architecture – SAVE or Science?

Evaluation systems designed to estimate the quality of architecture or urban areas are not yet fully developed across the Nordic countries, though they have been of growing interest for a number of years. From a historical perspective, this interest is a reaction to the radical changes that urban and rural landscapes have undergone since the post war era. Unsentimental demolition and redevelopment schemes took place without any particular veneration for the values of the existing building culture.

In the late 1980s, Denmark joined the European Council Granada Convention of 1985 on the preservation of Europe's architectural heritage. This resulted in a greater emphasis on building conservation and led to the development of the Survey of Architectural Values in the Environment (SAVE) by the Danish heritage authorities. The value assessment was initially meant for evaluating building heritage and cultural values of cities, but today it also includes contemporary buildings and urban environments (Kulturarvsstyrelsen, 2011, p. 8). In Sweden, no specific methodology or widespread analytic tool like SAVE has been developed yet, however the association Bygningskulturvårdsföreningen supports citizens and authorities in efforts to evaluate the cultural value of the built environment. The National Trust of Norway is a voluntary association, a trust, and a property owner. Since 1845, it has developed expertise in restoration and maintenance of historical monuments. It is based on personal memberships, but municipalities, institutions, and organizations can also hold memberships.

Today's wider demand for qualitative evaluation systems is partly due to the great number of existing buildings and urban areas that are in need of being renovated either for reduction of energy consumption or transformation for new use. Such interventions need to be led by adequate analysis of cultural aspects in correlation to social, economic, and environmental values. But, as mentioned, these systems do not exist as generalized international standards or digital programs and therefore are not as easily implemented as quantitative evaluation systems such as LCA, LCC, or DGNB.

# SAVE as a Value System

As a companion to SAVE, the KIP methodology (Culture History in Planning) was developed in the late 1990s. This helped conservation of the cultural environments in the open country and strengthened regional planning. While the SAVE assessment is an architectural method developed for the registration and mapping of buildings and cities, KIP is a cultural historical method for the designation of cultural rural environments. The methods have many elements in common, but there are also some differences because they were developed for different purposes. To specify how SAVE differs from KIP, both methodologies are presented below.

A SAVE assessment can provide a basic knowledge about architectural, cultural, and landscape qualities in a built environment so the embedded values can become part of future planning and urban development.
In principle, a SAVE assessment covers two independent parts:
A. Mapping and assessment of one or more built environments
B. Registration and conservation assessment of individual buildings

The assessment of urban areas and buildings consists of two coherent processes that support each other, however the two parts can also be executed independently (Kulturarvsstyrelsen, 2011, p. 11).
Only the exteriors of buildings and outdoor surroundings are included in SAVE assessments. They are evaluated according to five different parameters:
• Architectural value • Cultural historical value • Contextual value • Originality • Physical condition

| Method | SAVE | KIP |
|---|---|---|
| Purpose | Buildings and urban areas worthy of conservation | Cultural environment |
| Analytic focus | Topography<br>History<br>Architecture | Landscape<br>Cultural history |
| Urban environment | X | (X) |
| Rural environment | (X) | X |
| Planning | Local plans<br>Buildings worthy of conservation | City plans<br>Cultural history |

The SAVE evaluation form and the value ranking with 9 levels (1 being the best value)

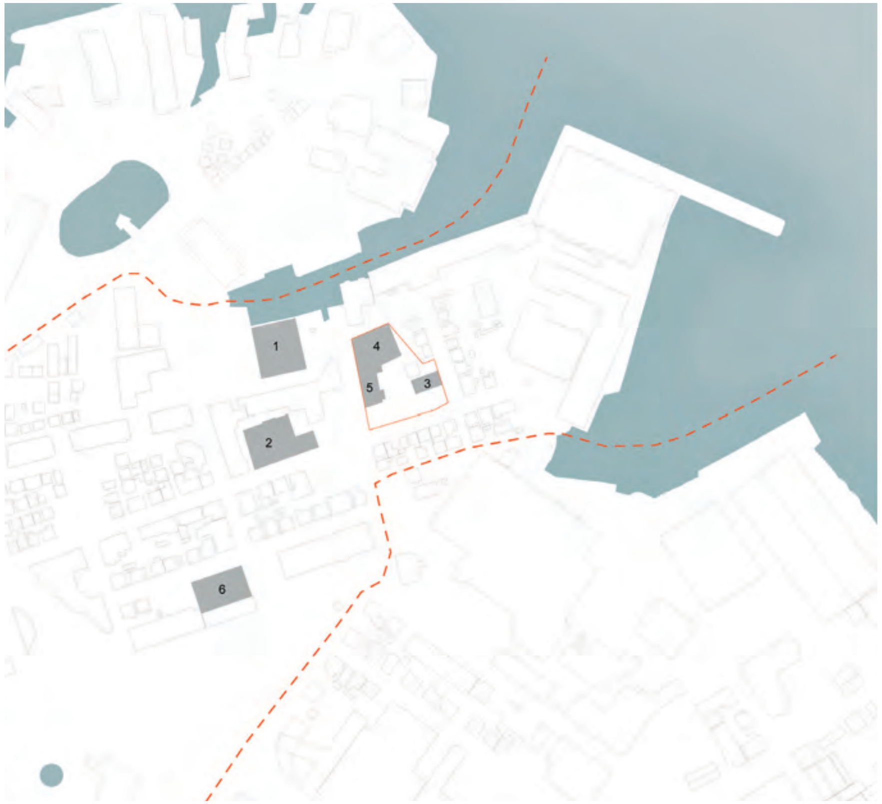

SAVE assessments must use an authorized form that links to a central database named FBB (Database for Listed and Preserved Buildings). The five parameters are summarized in a singular 'preservation value'. The values is on a scale from 1 to 9, where 1 is the highest. Along with the ranking, there is an opportunity to justify the assessments in short accompanying text that describes the qualitative aspects of the building or area, e.g. its uniqueness, architect, regional attributes, etc. Pictures and drawings are also to be included and form part of the total data to be considered. The values are to be substantiated in a positive and professional language, focusing on qualities that can be protected or strengthened, or particular circumstances that may weaken them. The reviews are publicly available through the FBB database, which is meant for planners, owners, local communities, and neighbors (Kulturarvsstyrelsen, 2011, p. 38-39).

As such, the SAVE system is a tool to be used to direct future planning decisions (transformation, demolition, and restructuring) with the main emphasis on supplying a perspective on preservation. Therefore, it is the architectural, cultural, historical, and environmental contextual values that weigh the most and that are judged in relation to the overall authenticity of the built environment. Among the public authorities, it is thus central for managing city development; but as a practical design tool for estimating architectural quality / value, it is not generally applied among practicing architects. How then to use SAVE as an analytic tool to enrich the early design processes or building programs? We decided to test this as part of the STED project.

## TESTING SAVE IN THE EARLY DESIGN PROCESS – DEFINING THE PROGRAM

The contribution of the CINARK research center (KADK) to the STED project has been to introduce knowledge and qualitative analyses to support innovative sustainable solutions for renovation in collaboration with the partners of the project. The aim was to distill the resulting knowledge into design methods in a broader sense than only 'tools'. As part of this endeavor, a group of fourth year architectural students from the Master's program Settlements, Ecology & Tectonics joined forces with the research center and some of the architectural offices, including Helen & Hard (NO), Studio Granda (IC), White Architects (SE), and Vandkunsten Architects (DK). All of the students were asked to test the SAVE assessment methodology as part of the early design process and their programming. First, they tried the tool in a pilot assessment at both an urban scale and at a building scale while looking at an old military building situated in Christiania (Copenhagen) as part of an introduction course.

In collaboration with the offices, the students chose which projects to work with. They could choose the Union Canning transformation (Helen & Hard), a housing block from the Million Programme in Stockholm (White Architects), the Skipholt 70 housing & store (Studio Granda), and the housing project the 'Green Triangle' (Vandkunsten Architects). During the semester, the students worked with the project responsibles in the offices and participated in the research seminars of the STED project. The projects have been presented both individually in the various offices and also at a couple of STED meetings. Two projects have been selected to show different approaches and outcomes by use of the SAVE analysis tool.




1 

2 

3 

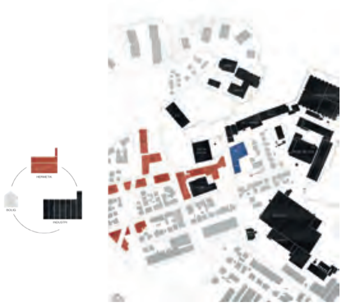
4 

5 

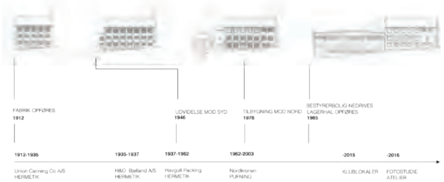
6 

## TRANSFORMATION OF THE UNION CANNING

One project was the Transformation of the Union Canning project by Cathrine Björk Vindheim & Pil Whitta Andersen. To qualify the transformation of the canning factory, the SAVE analysis looked at the site and the sur¬rounding context of East Stavanger. The composite character of the areas became very clear. Then the building and its historical development, character, form, and functional changes over time were analyzed.



Analysis of the site – the Stavanger harbor area – existing qualities and dominating features

ORIGINALITET
- Fuldmurede vægge
- Fag
- Pilastre (delvist sårede)

AUTENCITET
- Forfalden fremfor patineret
- Flere spor fjernet (pilastre, støbejernsvinduer, skorstene, indgangsdør, nypudset)
- Resulterer i at bygningen ikke fremstår tro mod sin oprindelighed.

7 enkel og rytmisk vestfacade

9 hermetikfabrik, dog 1 ud af 44 (26 fredet)

5 del af tidlig industri, repræsentere en skala

8 markante tilføjelser og ændringer

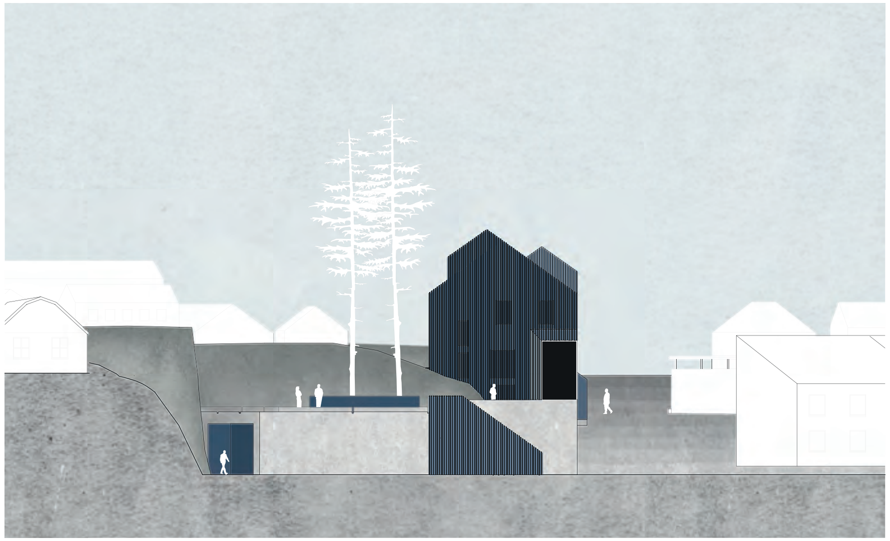
8 lettere til groft forfald

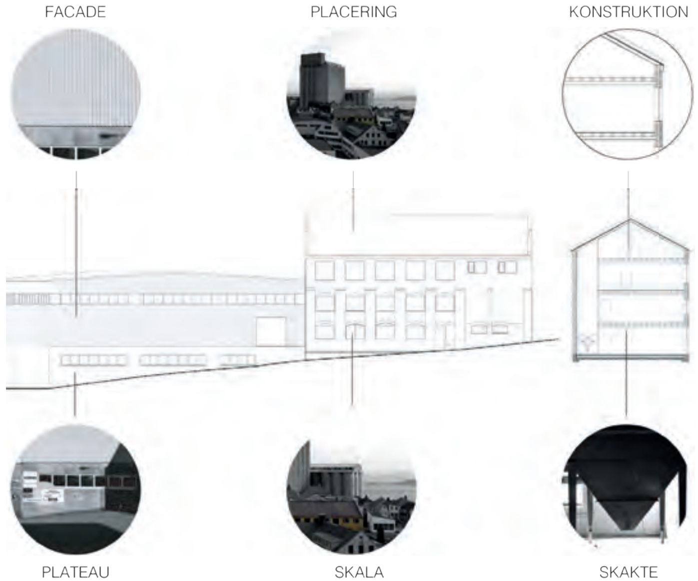
7

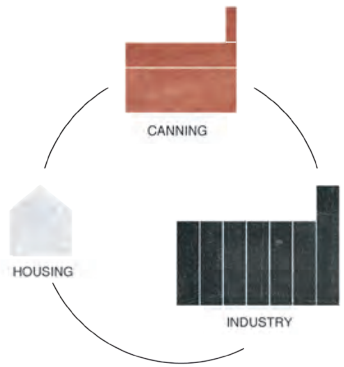
Analysis of the building – existing qualities, historical events, and dominating features - total SAVE score: 7

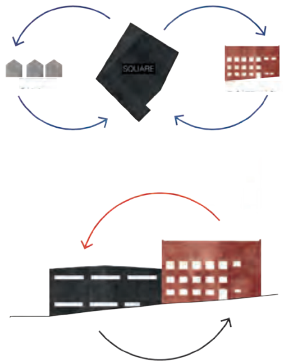
The SAVE analysis made it possible to identify design parameters that addressed both rational aspects and aesthetic potentials. Rational can be understood as including missing insulation, poor lighting, and access. Aesthetic is defined as form of expression, narrative, and tactility, and also includes the desire to link to the composite character of the area in the form of public functions. The Union Canning building had a total score of 7 in the SAVE analysis.

According to the students; “The project defines transformation as a means to point to the future instead of looking back. The primary task is to continue to develop the architectural heritage - in this case, the old canning factories - rather than preserve their original condition or tear them down.”





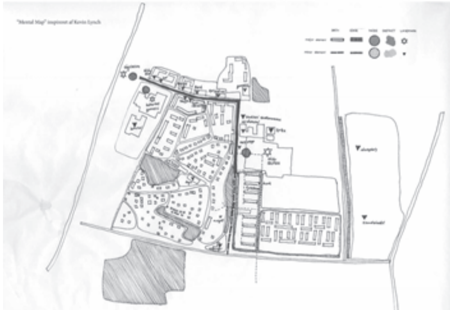



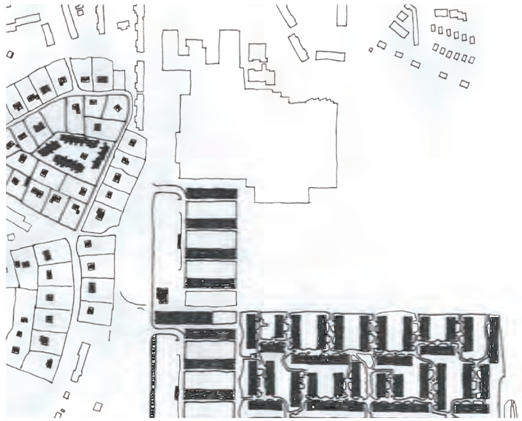
## ONE CHANGE IN A MILLION

The second project was titled One Change in A Million by Amanda Dahl & Märta Helander. They looked at how socially sustainable transformation could be addressed in 'the million programme' in Upplands Väsby.

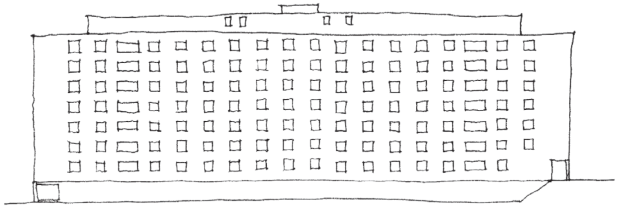
The primary focus was on the outdoor environment and the areas around the buildings, the ground floor, and the facade. In order to develop an architectural design strategy for social sustainability, they made an analysis of the area finding five indicators particularly important - comfort, safety, urban connection, public image, and social networks. This analysis was made in collaboration with DTU

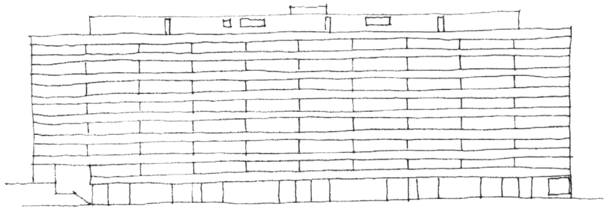


Above: Analysis of the site – the Upplands Väsby housing area – 'A mental map' and outdoor areas and accessibility



Below: Analysis of the building – ex. the architectural value and the physical condition - total SAVE score: 6





The outcome of the SAVE analysis made it possible to program the space between the buildings and give them more character and spatial identity. It helped to differentiate between private and public areas. For example, private gardens were added along the façade by reference to the found qualities. The analyses also informed the design considerations that led to activating the ground floors, making the entrances bigger and brighter, increasing the visibility, and working with a more transparent and variated facade.

## QUALITATIVE VALUE SYSTEMS IN ARCHITECTURE AND THE LCA FEVER

In conclusion, use of the SAVE methodology in order to inform the early design process seems helpful in qualifying the projects. The direct procedure where the location and the building are visited and registered gives a good overall framework for the subsequent analyses, how to approach the project, and what qualities and solutions to prioritize. The simplicity of the tool makes it handy and agile in comparison to heavy BIM modeling software and LCA analysis systems. However, the qualitative value system of SAVE is not comparable to the quantitative digitized measures of, for example, LCA and LCC. Therefore, a full digital model that encompasses both dimensions seems unrealistic. However, an interface (digital) between SAVE and LCA could be interesting to test in order to see the limitations and potentials of both methodologies.

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Graphic Design: Hedda Bank
Copy editing: Mary Kathryn Thompson
Print: Rosendahls a/s

Isbn: 9788750211402

Published by: Polyteknisk Forlag, www.polyteknisk.dk

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