

Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences



Graduation Plan: Architecture

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

Personal information	
Name	Stan van Etten
Student number	5668387

Studio		
Name / Theme	Architectural Wood Studio	
Main mentor	Ir. Gilbert Koskamp	Architectural Engineering and Technology
Second mentor	Ir. Olindo Caso	Architecture and the Built Environment, History, Form & Aesthetics
Argumentation of choice of the studio	<p>My interest in sustainable building practices was sparked during my undergraduate studies, where I developed a deep fascination with materials, particularly natural ones. Their texture and tactile qualities captivated me, conveying a sense of time and experience that a plain white wall could never match. This early curiosity led me to explore the potential of designing with ecologically responsible materials. However, I quickly realised that knowledge and data regarding such materials were often fragmented and lacked coherence.</p> <p>To address this, I undertook extensive research in collaboration with Wouter Brugman to establish a more accurate assessment of ecological materials. We compiled and analysed all available environmentally responsible materials, treating them as puzzle pieces in the design of an ecological floating home. This research was recognised with the Jury Prize at the 2021 Bouw&Infra Awards, affirming its significance.</p> <p>This experience led me to question the transparency and accuracy of existing assessment methodologies. I became increasingly aware of the inconsistencies, particularly when near-perfect environmental scores were given to projects where substantial improvements were still possible. A separate study on climate challenges, particularly in relation to flooding, deepened my understanding of the pressing need for adaptive and sustainable design in light of planetary boundaries.</p> <p>With this background, the Architectural Wood studio presented itself as a compelling opportunity. The studio aligns perfectly with my desire to refine my expertise in ecological materials while addressing critical climate challenges. By joining this studio, I aim to contribute meaningfully to advancing architectural knowledge on environmental impact, focusing on the sustainable and transparent use of materials in design. My ultimate goal is to leverage this experience to bridge the gap between research and practical implementation, driving innovation in sustainable construction.</p>	

Graduation project	
Title of the graduation project	Design Strategies for Timber Construction in the Netherlands: A 'Transparent Guide' to Maximise Carbon Storage and Minimise Embodied Energy.
Goal	
Location:	Danzigerkade 15, Minervahaven, Amsterdam. Warehouse
The posed problem,	The lack of knowledge and experience, and the lack of familiarity with the tools and calculation methods which frequently results in the suboptimal capture of CO ₂ and the insufficient minimisation of embodied energy.
research questions and	How can design decisions for timber construction in the Netherlands be optimised into a guide for maximum carbon uptake and minimum embodied energy?
design assignment in which these result.	See text below
<p>Location</p> <p>A thorough site analysis of the Minervahaven in Amsterdam has revealed several key motives underpinning the design location of the Warehouse, supported by both research and the vision of the Municipality of Amsterdam. The site analysis indicates that this location has the lowest risk of flooding and minimal exposure to harmful substances from the northwest industrial zone. Additionally, the research highlights that a long building lifespan provides an efficient means of storing carbon for extended periods. This necessitates a robust and durable structure, as exemplified by the Warehouse.</p> <p>The Municipality of Amsterdam has also identified the need to enhance the office designation of this area with a significant addition of residential units and sports facilities. This requires a strategic approach to creating new habitable spaces. The Architectural Wood Studio proposes a method of vertically extending existing office buildings, which includes addressing the challenge of vertical transport within these structures.</p> <p>The Warehouse capitalises on the potential of the site by allowing for expansion from its plot, offering an innovative solution for vertical transport. This approach not only aligns with the goals of the Municipality but also provides a sustainable and efficient response to the unique challenges and opportunities presented by the Minervahaven location.</p> <p>Posed-Problem</p> <p>In the contemporary era, there seems to be a growing awareness of the importance of treating nature and energy in an appropriate manner. This line of thinking also extends to the Dutch construction sector, where the primary focus is on carbon uptake and embodied energy. A report by the 'Global Alliance for Buildings and Construction' indicates that the construction sector is responsible for approximately 37% of global emissions, with 11% of this figure attributable to material use (Construction, 2023). Of the 9.020 million tonnes of building materials required in Europe, 3.4% are supplied to the Dutch market (Haisma, 2023).</p> <p>Nevertheless, as a consequence of this awareness, an increasing number of newly developed construction methodologies, models and measurement data are becoming available, which should facilitate the industry's ability to make informed decisions regarding the selection of materials and designs. In practice, the vast quantity of new information, among other factors, frequently demonstrates that the construction industry is not being guided in the optimal direction (Brugman and Van Etten, 2021). The comprehensive models, including the EPD, LCA, MKI, MPG when considered alongside databases such as the NMD and Ecoinvent, certifications such as BREEAM and BENG, in addition to the NEN standards and selected manuals, do not facilitate the understanding of design choices, despite their stated intendment to do so.</p>	

In the Netherlands, there is a growing interest in timber construction and CO₂-negative building. However, architects, contractors and other building professionals are experiencing difficulties in comprehending and implementing the numerous and complex rules and systems, which frequently results in the suboptimal capture of CO₂ and the insufficient minimisation of embodied energy. This is, at least in part, attributable to a lack of knowledge and experience. Despite the growing availability of information on sustainable timber construction, many architects and contractors lack the practical experience necessary to fully utilise the specific techniques and design strategies that can minimise CO₂ emissions and embodied energy. Conventional construction techniques, such as those involving concrete and steel, are frequently deeply rooted in the industry, and therefore the transition to building with wood requires a reassessment of familiar design processes and techniques (Brugman and Van Etten, 2021).

This issue is also relevant to the design in phase P3. Due to a lack of practical knowledge regarding construction with carbon storage and embodied energy, creating an optimally environmentally responsible design is challenging. This underscores the need for research to address this gap in practical knowledge and to provide designers with clear guidance on optimising carbon sequestration and minimising embodied energy.

Thesis research questions

The research significantly influences both the design process and the final design. The central question, "How can design decisions for timber construction in the Netherlands be optimised into a guide for maximum carbon uptake and minimum embodied energy?", drives the creation of a guide aimed at designing with maximum CO₂ sequestration and minimal embodied energy while maintaining a balance to avoid excessive material use.

Other sub-questions from the research are::

1. Which existing data models and design strategies for timber construction contribute to CO₂ uptake and embodied energy reduction?
2. How can these data models and design strategies be filtered and ordered to understandable parameters for a timber project?
3. How can these parameters for optimal CO₂-uptake and minimum embodied energy in timber construction be integrated into a clear and transparent manual?

This study will focus on filtering appropriate construction strategies and measurement methods to clarify design strategies for timber construction in the Netherlands. The aim is to produce a transparent and understandable guide using specific parameters, which will enable professionals to understand how to optimise CO₂ uptake while reducing the embodied energy of projects in advance.

Design research questions

It is essential to examine how this research can influence the design. The guide, developed through the research based on various environmentally conscious parameters, is intended to provide direction to the design process. Questions arising from the research to the design include:

How can a design be defined to achieve maximum carbon uptake and minimal life cycle energy?

The research has developed a model that provides guidance in addressing this design question. The aim is for design decisions to be made in accordance with this model (or guide) to balance carbon uptake and life cycle energy. The resulting design will serve as a response to this methodology. Considerations can be made regarding materials, construction systems, cantilevers, foundations, façades, roofs, and more.

How can the lifespan of a design be extended to a target of 500 years?

A significant finding from the research emphasizes extending the lifespan of buildings. Environmental performance estimates for project examples often assume a 'minimum' building lifespan of 75 years. This timeframe is insufficient for trees to reach maturity, suggesting that such designs may not adequately support long-term CO₂ storage. By extending carbon uptake, the planting of biomass can help achieve a better CO₂ balance in the atmosphere. This finding may influence strategies to protect the building against moisture, fire, and UV radiation. For instance, the use of overhangs or over-dimensioning are potential strategies to achieve this goal.

How can the aesthetic value of both an existing building and its vertical extension be mutually enhanced?

A vertical extension almost always results in an aesthetic transformation of the existing building. Such an

extension can either contrast with or harmonize with the original structure. Additionally, a vertical extension can introduce new dynamics, such as shadow casting, altered circulation patterns, new column structures, sound impacts, and more. In essence, the influence of a vertical extension is significant, presenting new design challenges. To maximize the potential of the existing building in relation to its extension, it is crucial to establish aesthetic and functional connections between the two structures.

Design assignment

The design assignment will focus heavily on creating a project where every decision is guided by its environmental impact. Each choice must align with the guidelines established by the developed model, which will direct whether specific design decisions meet the necessary criteria. A key finding indicates that the longer the lifespan of a timber building, the better the carbon balance in the atmosphere becomes. This extended lifespan results in an unconventional approach to form and decision-making. It also influences the program requirements, such as the inclusion of a document room (to store building drawings and strategies for replacing elements) and a workspace dedicated to repairs and maintenance of the structure.

Additionally, calculations can be conducted to quantify the carbon or energy impact of certain choices. Meticulously studying these trade-offs ultimately leads to an optimized design. The task is to translate these well-founded design choices into an aesthetic rationale that supports the environmental objectives.

Process

Method description

This research will mainly focus on literature review, expert interviews, case studies and comparisons.
** The study takes a quantitative approach and integrates qualitative insights from experts.*

1. Literature review and Data analysis

A comprehensive literature review and analysis of relevant data sources (e.g. EcoInvent, EPDs) offers insight into existing building systems, materials and data models that contribute to CO₂ uptake and energy reduction. This provides a foundation for the establishment of an assessment framework for building systems and materials.

The data, together with the developed model, can provide an assessment of design choices. For example, if the embodied energy is too high, a design choice may be rejected.

2. Expert interviews

Semi-structured interviews with experts (*see precedents under References*) provide insight into practical applications and challenges, and help identify design errors in the model or design itself. The outcomes are analysed *thematically* to extract the best design decision.

3. Case Study analysis

Some wood building designs that are already far optimised are studied to evaluate selected design strategies and materials. *Quantitative* data are collected through project data. The case studies can provide new insights and steer the design process in a different direction.

4. Data analysis and Synthesis

After collecting the data from the literature, interviews and case study, the results are synthesised. The data are *quantified* and compared, focusing on the measurable effects of building materials and systems. Based on these analyses, recommendations can be made towards the design in terms of material choice or buildings system.

5. Evaluation and Validation with Experts

The initial draft of the manual is submitted to experts for validation and feedback directly after P2. This round of feedback helps optimise the manual to meet the practical requirements of professionals. The final version of the manual will present a synthesis of empirically validated strategies and recommendations for the selection of materials and construction systems that optimise carbon uptake and minimise embodied

energy. The trial phase in P3 will facilitate the gathering of data regarding the manual's usability, thereby enabling the identification of potential areas for enhancement.

During the design phase, the manual will be subjected to a case study analysis. Ultimately, it is essential that architects, contractors and other professionals involved in the construction industry are able to gain an overview of the impact of specific choices made for a given project in terms of CO₂ uptake and embodied energy. Through a process of human review, these choices are converted into project-specific parameters. To illustrate, by making design choices at an early stage as an architect, the stakeholders involved can be engaged in advance to facilitate the transfer of information or design options within a project and optimise them.

Literature and general practical references

Literature yet to be used

The main literature that will be used is on the design implications of buildings. So the focus is on building systems, materials and practical examples of timber buildings or elevations. Much of the literature used has been incorporated into the research and is not listed here.

De Beus, N., Stratmann, M., Carus, M., Institute for Ecology and Innovation, & nova-Institut für politische und ökologische Innovation GmbH. (2023). Carbon Storage in Hemp and Wood raw materials for Construction Materials. In *Final Report* [Report]. https://builtbn.org/knowledge/documents/23-06-14_carbon_storage_in_hemp_and_wood-x4njho.pdf

Dutch scientists and climate ambassadors. (2022). *Dutch scientists respond to concrete and cement industry report acknowledging role of biobased materials, questioning numerous assumptions and findings*. <https://builtbn.org/knowledge/documents/response-ca4bm-report.pdf>

ECOS - Environmental Coalition on Standards, Porterson, S., & Hart, J. (2024). *ECOS recommendations for progress in assessing the greenhouse gas dynamics of forests and wood products: Review of draft ISO 13391 standard series*. <https://builtbn.org/knowledge/documents/ecos-2024-ghg-dynamics-of-forests-and-wood-products.pdf>

GUSTAVSSON, L., PINGOUD, K., SATHRE, R., Ecotechnology, Mid Sweden University, SE-831 25 Östersund, Sweden, & Finnish Forest Research Institute, Unioninkatu 40 A, FIN-00170 Helsinki, Finland, and VTT Processes, Espoo, Finland. (2005). CARBON DIOXIDE BALANCE OF WOOD SUBSTITUTION: COMPARING CONCRETE- AND WOOD-FRAMED BUILDINGS. *Mitigation And Adaptation Strategies For Global Change*, 11, 667–691. <https://doi.org/10.1007/s11027-006-7207-1>

LETI Embodied Carbon primer. (2020). https://www.leti.uk/_files/ugd/252d09_8ceffcbcafdb43cf8a19ab9af5073b92.pdf

Lifecycle Impacts of Structural Frame Materials for Multi-Storey Building Systems. (z.d.). In *Journal Of Sustainable Architecture And Civil Engineering* (Vol. 1, Nummer 24, pp. 17–28).

Stora Enso Wood Products. (z.d.). *Fire protection of CLT* (pp. 1–50). <https://www.cltsk.info/wp-content/uploads/2019/10/CLT-Documentation-on-fire-protection-EN.pdf>

Vos, M., Yildiz, B., Jackson, G., Van Den Berg, J., & Eugenie Dijkstra. (2021). *Cross Timber Laminated Handleiding voor Architecten en Bouwkundigen*. INBO. <https://inbo.com/wp-content/uploads/2022/12/CLT-Handleiding-voor-architecten-en-bouwkundigen.pdf>

Waugh Thistleton Architects. (2023a). *New model building guide*. https://builtbn.org/knowledge/documents/nmb-guide-book-1.1_1.pdf

Waugh Thistleton Architects. (2023b). *The new model building details*. https://builtbn.org/knowledge/documents/nmb-details-book-1.0_2.pdf

Datasets

- EcoInvent – reachable through Granta EDUpack
- Nationale Milieu Database
- Revalu platform

Precedents

Some experts have already been contacted during the P2 research period. These experts are aware of the research and strategies. These experts will be contacted again to work with the model created and their expertise to steer the design towards one that incorporates as much carbon as possible with the lowest embodied energy. New experts with practical knowledge, such as Tim Vermeend, will also be brought in.

1. Jeroen Verberne (Volantis) - Circular Economy
2. Willem van Genugten (GROUP A/Carbon lab) - Accelerating the reduction of CO2 emissions
3. Ralf van Tongeren (Orga Architect) - Ecological Architect
4. Prof.dr.ir. Arjan van Timmeren (TU Delft) - Environmental Technology & Design
5. Dr.ir. Fred Veer (TU Delft) - Structures & Engineering (Ecological Materials)
6. Prof. Gert-Jan Nabuurs (WUR) - Sustainable Forest Ecosystems
7. Elizabeth Migoni Alexandre (WUR) - Life Cycle Assessment Researcher
8. Sacha Brons (Building Balance) - Carbon certificates
9. Dr. Pablo van der Lugt (AMS Institute – TU Delft) - Environmental Technology & Design
10. Tim Vermeend (Urban Climate Architects) – Climate architect

Reflection

1. What is the relation between your graduation (project) topic, the studio topic (architectural wood), your master track (architecture), and your master programme (MSc AUBS)?

My graduation project and topic focuses on designing an optimal building regarding maximum CO₂ uptake and minimum embodied energy. This coincides closely with the Architectural Wood studio where wood construction is the starting point for possible optopping in Amsterdam. Consequently, wood construction can occupy a crucial position within this sector due to its ability to absorb carbon and its lightweight properties. By translating this knowledge into a design guide for optimizing carbon uptake in building design, the project aligns seamlessly with the Master's track in Architecture. Given that this research holds significant relevance for the current construction sector—exploring and developing innovations in tandem with the novel approach of extending existing buildings—it fits well within the MSc Architecture, Urbanism, and Building Sciences program.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

The relevance of this graduation work in the larger social, professional, and scientific framework is significant. In the year 2024, a wide range of studies have been conducted on the environmental impact of timber construction in comparison to traditional building materials such as concrete and steel. The majority of these studies indicate that the construction of buildings with wood has a significant positive impact on the uptake of CO₂. Indeed, research conducted in 2020 estimated that substituting conventional construction materials with wood in half of new urban construction could achieve 9% of the global emissions reduction necessary to meet the 2030 targets to limit global warming to below 1.5 degrees Celsius (Himes, 2020). However, the majority of these studies focus on merely naming comparative results, showcasing life-cycle assessment calculations. Consequently, these studies do not provide adequate guidance to designers, thereby lacking a solution for how to achieve optimal results. Nevertheless, a synthesis formed by combining these studies may serve as the basis for a comprehensive sustainable design manual that can be used to put studies and numbers into practice. This model also allows for quicker and better decision-making, allowing professionals to be engaged at an early stage to comprehend, in advance, factors such as construction costs and construction methods. In light of the current housing deficit in the Netherlands, estimated at 401,000 homes, and the planned construction of additional housing units, the optimisation, widening of knowledge and clarification of systems and materials will facilitate the attainment of the Paris climate targets (Ordering, 2024). An optimisation of timber housing, as an alternative to traditional building materials such as concrete and steel used at the Minervahaven buildings in Amsterdam, would facilitate the Netherlands' progress towards achieving the global warming limit to a maximum of 1.5 degrees Celsius.

References

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- Construction, G. A. (2023). *Beyond Foundations*. UN environment programme.
- Haisma, R. (2023). *Impact scan for timber construction in Europe*. UK: Metabolic consulting.
- Himes, A. (2020). *Wood buildings as a climate solution*. Mississippi State University Department of Forestry: GreenWood Resources.
- Ordering, M. v. (2024). *Het statistisch woningtekort uitgelegd*. Opgehaald van Volkshuisvestingnederland.nl: <https://www.volkshuisvestingnederland.nl/onderwerpen/berekening-woningbouwopgave>