# DESIGN STRATEGIES FOR TIMBER CONSTRUCTION IN THE NETHERLANDS: A 'TRANSPARENT GUIDE' TO MAXIMISE CARBON STORAGE AND MINIMISE EMBODIED ENERGY.

TIMBER - CARBON UPTAKE - EMBODIED ENERGY - GUIDE

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# RESEARCH PLAN

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**Abstract**

This research aims to address the complexities of sustainable timber construction in the Netherlands, focusing on maximizing $CO_2$ uptake and minimizing embodied energy. By streamlining essential sustainability metrics (LCA, MKI, MPG) into a clear, accessible guide, the study will enable architects and contractors to make informed design decisions early in the process. This guide will consolidate best practices, vetted materials, and environmental data, enhancing decision-making for $CO_2$-negative building projects. Ultimately, the guide will support industry professionals in contributing to climate goals, aiding in the shift from conventional to sustainable building practices.

# 1. Introduction

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 $CO_2$ 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). Consequently, wood construction can occupy a crucial position within this sector due to its ability to absorb carbon.

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, 2021). The comprehensive models, including the LCA, PEF, MKI, MPG, when considered alongside databases such as the EPD and ecoinvent, certifications such as BREEAM and BENG, in addition to the NEN standards and selected manuals, do not facilitate the comprehension of design choices, despite their stated intendment to do so.

In response to the growing threat of climate change and the consequent increase in flood risk in the Netherlands, it is imperative to adopt a transparent manual for timber construction that prioritises maximum $CO_2$ uptake and minimum embodied energy. By storing $CO_2$, optimised timber structures can contribute to reducing greenhouse gases and thus mitigate the ultimate impacts of climate change.

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 $CO_2$ uptake while reducing the embodied energy of projects in advance.

## 2. State of the art

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 $CO_2$. 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.

# 3. Research question, aims and objectives

**Problem statement**

In the Netherlands, there is a growing interest in timber construction and $CO_2$–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 $CO_2$ 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 $CO_2$ 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, 2021).

Furthermore, there is a lack of familiarity with the tools and calculation methods involved. Specific calculation tools, such as LCA (Life Cycle Assessment) and MKI (Environmental Cost Indicator), require a certain degree of specialised knowledge. As a result, some architects and contractors struggle to make informed choices to reduce the environmental impact of their projects. In order to attain certification such as BREEAM, it is necessary to have a comprehensive understanding of sustainability and the selection of appropriate materials. For smaller companies, the complexities and costs involved may appear discouraging, particularly regarding integrating timber construction into their projects.

In the course of this transition, certain testing methods and certifications have been the subject of criticism. The models that are made available are frequently incomplete or require modification to provide an accurate assessment of the sustainable nature of wood (Heuvel, 2024). In this way, the lack of clarity and incomplete calculation methodologies do not always facilitate optimal design choices for the construction industry.

The Minervahaven in Amsterdam provides an illustrative example of the aforementioned issues. A considerable number of these building structures have been completed within the last five years. However, many of these structures are composed of concrete and steel. It is plausible that if architects and contractors were better supported in the application of timber construction techniques and the use of clarified sustainability calculations, there would have been a higher proportion of timber buildings than have been constructed to date.

The aim of the research will mainly focus on funnelling and simplifying key metrics (LCA, MKI, MPG) and strategies, to better understand the outcomes of $CO_2$ uptake and minimum embodied energy prior to a construction project. *''Early engagement between the architect and the timber panel fabricator is crucial to streamline and optimise the design process and to secure the fabrication time window to meet the project construction schedule''* (Lehmann, 2023) The systematic collection and examination of hybrid data may serve as an effective approach to the adoption of optimal design strategies, aligned with established norms governing test models, databases, and certifications. This process can facilitate enhanced $CO_2$ capture, ensuring a transparent and structured methodology.

Main question

*"How can design decisions for timber construction in the Netherlands be optimised into a guide for maximum carbon uptake and minimum embodied energy?"*

# 4. Theoretical Content / Methodology

**Sub questions**

**1.** Which existing design strategies, materials and data models for timber construction contribute to $CO_2$ uptake and embodied energy reduction?

**2.** How can these design strategies, materials and data models be filtered and ordered to understandable parameters for a timber project?

**3.** How can these parameters for optimal $CO_2$-uptake and minimum embodied energy in timber construction be integrated into a clear and transparent manual?

** The study takes a quantitative approach and integrates qualitative insights from experts.*

**1. Literature review and Data analysis** (sub-question 1)

A comprehensive literature review and analysis of relevant data sources (e.g. EcoInvent, EPDs) offers insight into existing design strategies, building systems, materials and data models that contribute to $CO_2$ uptake and energy reduction. This provides a foundation for the establishment of an assessment framework for building systems and materials.

**2. Expert interviews** (all sub-questions)

Semi-structured interviews with experts (*see precedents under References*) provide insight into practical applications and challenges, and help identify understandable parameters for $CO_2$ uptake and embodied energy. The outcomes are analysed *thematically* to extract useful design principles and filter them into parameters.

**3. Case Study analysis** (sub-question 2 and 3)

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.

**4. Data analysis and Synthesis** (sub-question 3)

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, assessment guidelines and recommendations, the parameters are prepared for compiling the manual.

**5. Evaluation and Validation with Experts** (sub-question 3)

The initial draft of the manual is submitted to experts for validation and feedback. 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. A trial phase in P3 will facilitate the gathering of data regarding the manual's usability, thereby enabling the identification of potential areas for enhancement.

# 5. Experimental Set-Up

Firstly, the impact of $CO_2$ negative buildings and their relationship with embodied energy will be determined through desk research and refined by experts. Subsequently, the parameters associated with the building type in question will be examined, with a view to identifying those that potentially exert the greatest influence. In accordance with the municipal vision of a high-density housing development, this building type will comprise apartments.

The initial phase of the study will focus on identifying materials, building systems and models with the potential to achieve high $CO_2$ uptake with minimal embodied energy. This inventory will be gathered through a process of desk research and consultation with experts.

Subsequently, these materials, systems and models will be examined for their values ($CO_2$ uptake (kg), embodied energy (MJ), certifications, usability (weight, strength, construction method), assessment from the National Environmental Database). Any criticisms are identified to avoid inaccuracies and maintain transparency. Information on these values can be found from the ECOInvent database, the LETI Embodied Carbon Primer, the Carbon Cost Tracker and other precedents (*see References*).

Subsequently, it is essential to filter and list all of the aforementioned information. This will indicate which information is essential to include in the *materials, building systems and models*. This information will consist of universal parameters (not yet linked to a specific project). A parameter can be seen as a component (*material or building system*) of a building. It can appear in different categories that are yet to be defined (*see figure 2 on page 9 as an example*). It should be noted that *models* will not express a parameter; rather, they will be used solely for the assessment of materials and systems. Once more, the input of experts will be invaluable in the filtering of pertinent information, thus ensuring the manual remains a concise and accessible document.

The final stage of the process is to transform all of the filtered data into a coherent and accessible manual. 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 $CO_2$ 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.

The design of phase P3 will be initiated by utilising the manual developed in P2 as a reference point. Phase P3 will serve as a secondary testing phase, whereby any errors or problematic combinations of materials and systems will be identified and rectified.

** Page 8 shows the schematic representation of the methodology and the experimental setup.*

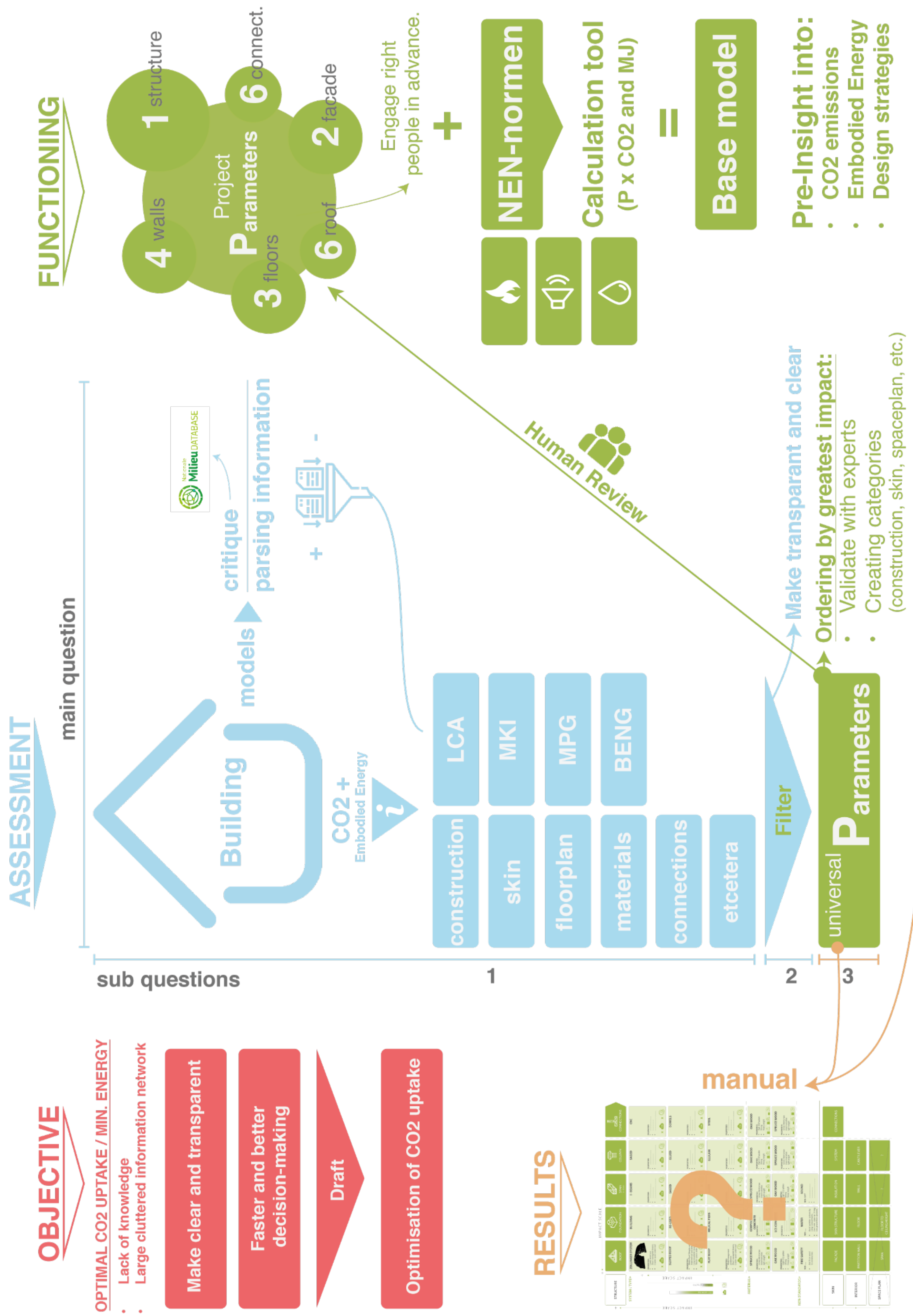



*Figure 1: Visual translation of the research plan.*


*Figure 2:*

* *Visualisation of 'possible' result (manual). Definition of parameters and order is still unknown.* ***Operation****: Structure, skin, interior, etc. are listed in order of most impact to least amount impact (Most $CO_2$ impact with structure). Then it is possible to look at which component (roof, foundation, span, etc.) makes the most impact. Example: Roof indicates that the Zollinger system absorbs the most $CO_2$ with the minimum embodied energy compared to other roofs. This system can be selected together with the best matching wood species and then checked against Nen standards. Thus, the right choice can be made for each component (Parameter) prior to a construction project.*

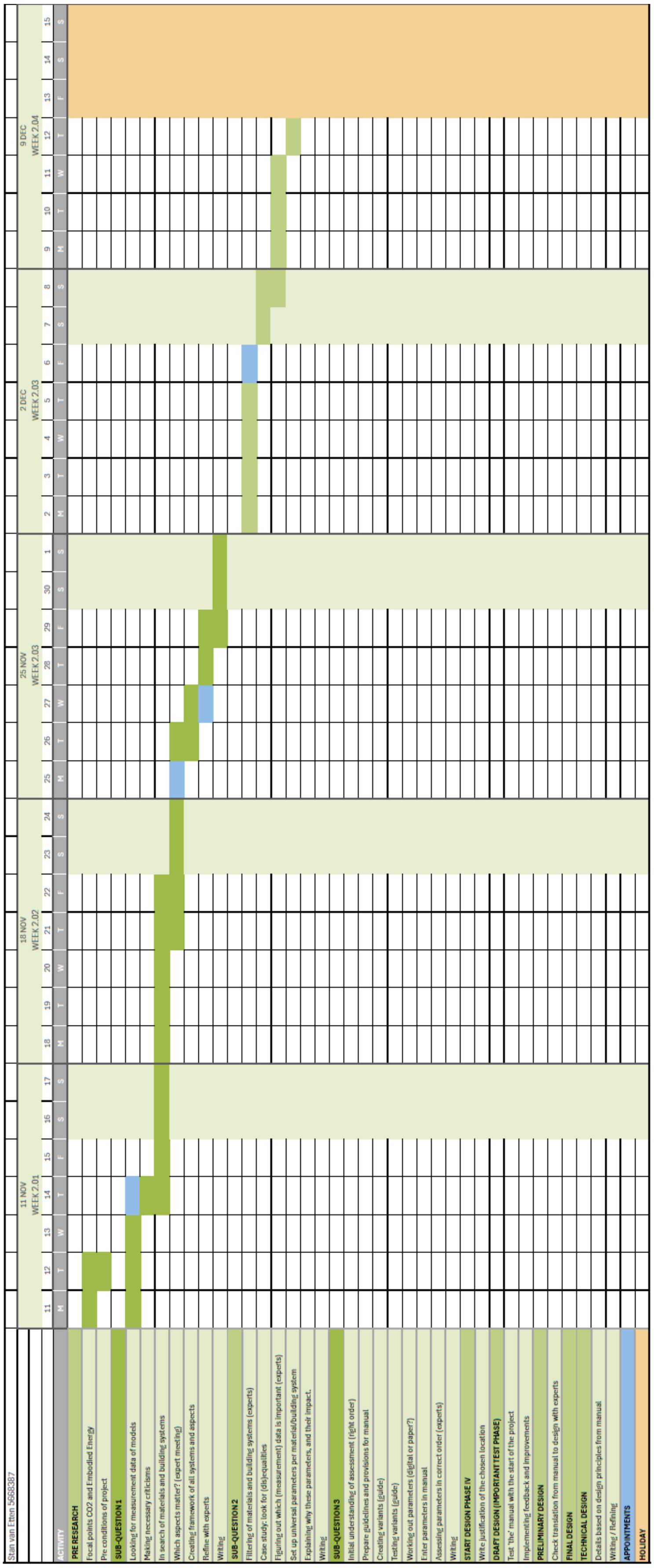
# 6. Results, Outcome and Relevance

The research result will culminate in a validated and transparent guide, using parameters to understand the environmental impacts. To illustrate, the research will primarily focus on the relationship between carbon dioxide (in kilograms) and embodied energy (in megajoules).

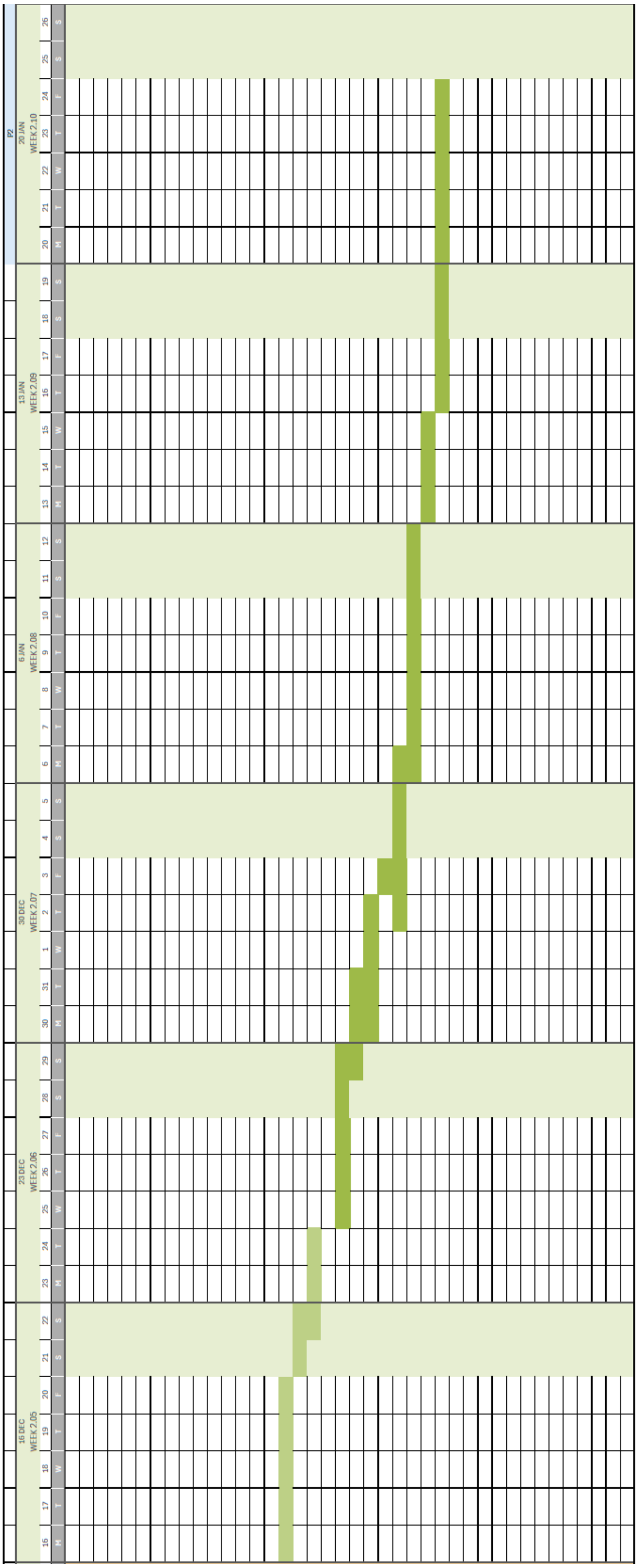
The outcome will be a useful manual with a complete overview of building systems and materials whose data have been assessed by experts for their values ($CO_2$ and Embodied Energy). This manual will allow architects, contractors and other building professionals to apply improvements and improve $CO_2$ uptake prior to a project.

This overview 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 (Ordening, 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.

# 7. Project Planning



| ACTIVITY |
|---|
| **PRE RESEARCH** |
| Focal points CO2 and Embodied Energy |
| Pre conditions of project |
| **SUB-QUESTION 1** |
| Looking for measurement data of models |
| Making necessary criticisms |
| In search of materials and building systems |
| Which aspects matter? (expert meeting) |
| Creating framework of all systems and aspects |
| Refine with experts |
| Writing |
| **SUB-QUESTION 2** |
| Filtering of materials and building systems (experts) |
| Case study: look for (dis)equalities |
| Figuring out which (measurement) data is important (experts) |
| Set up universal parameters per material/building system |
| Explaining why these parameters, and their impact. |
| Writing |
| **SUB-QUESTION 3** |
| Initial understanding of assessment (right order) |
| Prepare guidelines and provisions for manual |
| Creating variants (guide) |
| Testing variants (guide) |
| Working out parameters (digital or paper?) |
| Enter parameters in manual |
| Assessing parameters in correct order (experts) |
| Writing |
| **START DESIGN PHASE IV** |
| Write justification of the chosen location |
| **DRAFT DESIGN (IMPORTANT TEST PHASE)** |
| Test 'the' manual with the start of the project |
| Implementing feedback and improvements |
| **PRELIMINARY DESIGN** |
| Check translation from manual to design with experts |
| **FINAL DESIGN** |
| **TECHNICAL DESIGN** |
| Details based on design principles from manual |
| Writing / Refining |
| **APPOINTMENTS** |
| **HOLIDAY** |


P2
16 DEC
WEEK 2.05
23 DEC
WEEK 2.06
30 DEC
WEEK 2.07
6 JAN
WEEK 2.08
13 JAN
WEEK 2.09
20 JAN
WEEK 2.10

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| | | | | | P3 | | | | | | | P4 | | | | | | P5 | |
| JAN | JAN / FEB | FEB | FEB | FEB | MAR | MAR | MAR | MAR | MAR | APR | APR | APR | APR | MAY | MAY | MAY | MAY | JUN | JUN |
| WEEK 3.1 | WEEK 3.2 | WEEK 3.3 | WEEK 3.4 | WEEK 3.5 | WEEK 3.6 | WEEK 3.7 | WEEK 3.8 | WEEK 3.9 | WEEK 3.10 | WEEK 4.1 | WEEK 4.2 | WEEK 4.3 | WEEK 4.4 | WEEK 4.5 | WEEK 4.6 | WEEK 4.7 | WEEK 4.8 | WEEK 4.9 | WEEK 4.10 |
| 27 UNTIL 2 | 3 UNTIL 9 | 10 UNTIL 16 | 17 UNTIL 23 | 24 UNTIL 2 | 3 UNTIL 9 | 10 UNTIL 16 | 17 UNTIL 23 | 24 UNTIL 30 | 31 UNTIL 6 | 7 UNTIL 13 | 14 UNTIL20 | 21 UNTIL 27 | 28 UNTIL 4 | 5 UNTIL 11 | 12 UNTIL 18 | 19 UNTIL 25 | 26 UNTIL1 | 2 UNTIL 8 | 9 UNTIL 15 |

# 8. Conclusion

The Dutch construction sector is increasingly focused on reducing $CO_2$ emissions and embodied energy, with wood construction seen as a key strategy for carbon uptake. However, despite a growing body of information, architects and contractors face challenges in navigating complex guidelines, certifications, and environmental calculations (such as LCA, MKI, MPG). This can hinder optimal material and design choices for sustainable building. The goal of this research is to simplify these metrics and create a clear guide to support informed decisions in timber construction. Ultimately, this resource aims to boost carbon building practices and contribute to climate goals by enabling better understanding of $CO_2$ uptake and embodied energy impacts in construction projects.

# References


Brugman, S. v. (2021). *Ecologische Waterwoning.* Tilburg: Panvium.

Construction, G. A. (2023). *Beyond Foundations.* UN environment programme.

Haisma, R. (2023). *Impact scan for timber construction in Europe.* UK: Metabolic consulting.

Heuvel, P. v. (2024). *Aanscherping MPG.* Centrum Hout.

Himes, A. (2020). *Wood buildings as a climate solution.* Mississippi State University Department of Forestry: GreenWood Resources.

Lehmann, S. (2023). *Filling the Knowledge Gaps in Mass Timber Construction.* Nevada: The University of Nevada.

Ordening, M. v. (2024). *Het statistisch woningtekort uitgelegd*. Opgehaald van Volkshuisvestingnederland.nl: https://www.volkshuisvestingnederland.nl/onderwerpen/berekening-woningbouwopgave


**Literature / state of the art theories / research data**


Buchanan, A. H. & S. Bry Levine. (1999). Wood-based building materials and atmospheric carbon emissions. In *Environmental Science & Policy* (Vols. 2–2, pp. 427–437). Elsevier Science Ltd. https://www.elsevier.com/locate/envsci

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, Porteron, 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 ¨Ostersund, 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

Haisma, R., Den Boer, E., Rohmer, M., & Schouten, N. (2023). *IMPACT SCAN FOR TIMBER CONSTRUCTION IN EUROPE*.

Himes, A., Mississippi State University Department of Forestry, Busby, G., & GreenWood Resources, Inc. (2020). Wood buildings as a climate solution. In *Developments in The Built Environment* (p. 100030) [Journal-article]. https://doi.org/10.1016/j.dibe.2020.100030

*Lehmann, S., & Kremer, P. (2023). Filling the Knowledge Gaps in Mass Timber Construction. Mass Timber Construction Journal, 6(1), 1-10. Retrieved from https://www.journalmtc.com/index.php/mtcj/article/view/34*

*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).

Mangili, S., Garcia, I., Vangsbo, P., Thomsen, M. E., Frydman, B., Saez, M., Skotte, A., Lockie, S., Doody, L., Walport, E., CNCA knowledge partners, European municipalities, North American municipalities, CNCA, & Arup. (2023). *Dramatically reducing embodied carbon in Europe's built environment*. https://builtbn.org/knowledge/documents/cnca-technical-handbook-for-carbon-neutral-buildings.pdf

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

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