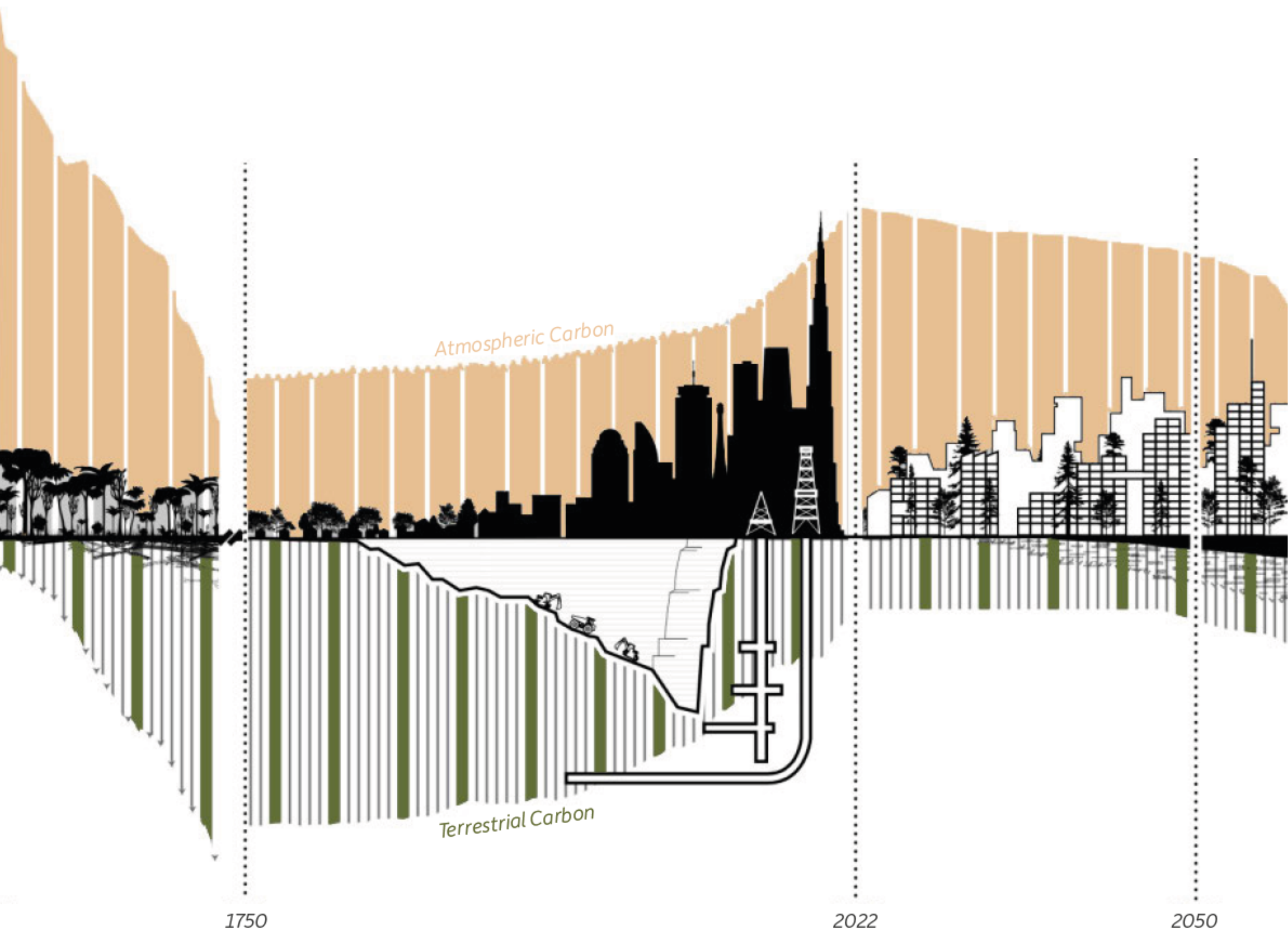
'Embodied Impact'

A framework for sustainable growth

Keywords; *Timber Structures, Sustainability, Embodied Carbon, TU Delft*



Delft University of Technology
Faculty of Architecture
and the Built Environment

Research plan
Architectural Engineering
Graduation studio 2022-23
Mick van de Leur
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General Information

Research plan Q1 2022

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Argumentation of studio choice:
I have chosen the Architectural Engineering graduation studio because it allows me to explore innovative solutions in design whilst at the same time focusing on the practicality and feasibility of these ideas.
The integration of engineering and architecture as supposedly two distinct disciplines ensures that the technical solutions are also grounded in a broader perspective. This way, I am able to explore my role and position as a future architect. The freedom granted in the studio allows me to research topical environmental and societal issues that I think are most relevant. Moreover, it allows me to contribute to the mitigation of these issues through architecture.
I think this studio is a great way to conclude my educational career here in Delft.

Title page figure : *Atmospheric- and Terrestrial Carbon*
Image source: *Churkina et al., 2020. Buildings as a global carbon sink, adapted by author*

Table of contents

General structure

Glossary

Defining keywords, aphabetically

Built environment
The built environment encompasses the human-made surroundings where human activity takes place. It is a material, spatial and cultural product containing forms of living, working, and playing (*Built Environment, n.d.*).

Bill of quantities
Inventory of all the materials involved in the construction.

CO^2-Neutral
CO^2-neutrality means balancing the emission- and absorption of CO^2 in order to achieve net zero emissions (European Parliament, 2022).

Glossary

Defining keywords, aphabetically

CRE

Campus and Real Estate, a department of the TU Delft.

Embodied energy

The amount of energy required to produce a material (*Embodied Energy, n.d.*). In some cases the energy associated with construction, maintenance, and disposal is also considered to be part of the embodied energy.

Embodied impact

Environmental impact of materials that cover all life stages including material extraction, processing, construction, maintenance and, disposal (*Embodied Impact, n.d.*).

GWP Global Warming Potential, caused by greenhouse gases, calculated in CO^2 equivalents (carbon dioxide) (Centre for Industrialised Architecture, 2019).

AP Acidification Potential, the influence of acids on the environment, calculated in SO^2 equivalents (sulphur dioxide) (Centre for Industrialised Architecture, 2019).

EP Eutrophication Potential, the influence of excessive loads of nutrients, calculated in PO^4 equivalents (phosphate) (Centre for Industrialised Architecture, 2019).

ODP Ozone Depletion Potential, the influence of chemical compounds that affect the ozone layer, calculated in R-11 equivalents (freon) (Centre for Industrialised Architecture, 2019).

POCP Photochemical Ozone Creation Potentials, formation of smog, calculated C^2H^4 equivalents (ethylene) (Centre for Industrialised Architecture, 2019).

EPD

Environmental Product Declarations, a report of the environmental impact of different material products (*The International EPD System, n.d.*).

Functional Unit

A functional unit is a quantitative reference unit that allows different systems or options to be compared (Mennenga et al., 2019).

GFA

Gross Floor Area

IPCC

Intergovernmental Panel on Climate Change

LCA

Life Cycle Assessment, a tool where all environmental burdens of a product or service are assessed (Klöpffer, 1997).

LCI

Life Cycle Inventory, where additional information is given to evaluate the magnitude of environmental impacts (*Life Cycle Inventory, n.d.*).

Material efficiency

Material efficiency entails the pursuit of strategies that lead to a substantial reduction in the production of energy-intensive materials (Allwood et al., 2013).

MXI

Mixed-use Index, the ratio of dwellings in relation to the rest of a building. Calculated by dividing the GFA of dwellings with the GFA of the total building (Harbers et al., 2022).

Operational energy

The amount of energy required to operate a building. For example by air-conditioning and lighting (*Operational Energy, n.d.*).

Sustainability

Although the term has been ascribed many meanings, one of the most common is that it is defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs (United Nations, n.d.).

System boundary

The establishment of boundaries for an analysis, refers to which aspects of the product life cycle are included in the LCA (*System Boundary, n.d.*).

Transition

A transition is a radical, structural change of a societal (sub)system (Rotmans & Loorbach, 2012).

Problem statement

Introduction

Currently, our society is facing persistent problems that are complex, uncertain, ill-structured, and hard to grasp. Moreover, the symptoms of these problems are becoming more and more apparent. These persistent problems confront modern societies and express themselves in crises, such as the climate crisis among others. However, crises are also a chance to transition into a more sustainable future. Right now, we are experiencing these transitional times. This goes along with uncertainty, fear, lack of confidence, turmoil, and impotence (Grin et al., 2010), but it should also be approached with great optimism.
A transition is a structural change of societal (sub) systems that resulted from numerous economic, cultural, technological, and institutional developments (Rotmans & Loorbach 2012). One of those transitions is the shift from a fossil-fuel based- to a biobased economy. According to the European Union, this shift reduces the environmental impact without compromising economic growth and job creation (Morone, 2018).

A societal subsystem that has a large share in climate change is also transitioning. The built environment receives much attention in terms of energy efficiency as it is responsible for 36% of global energy use and nearly 40% of energy-related CO2 emissions (UNEP, 2018). However, most policies focus on capping the operational energy of buildings rather than on embodied energy of building materials. But as operational energy decreases, the share of embodied energy in buildings increases and decreasing operational energy usually corresponds with higher material use. The embodied- energy and greenhouse gas emissions linked to manufacturing, transport, construction, and disposal have only recently received global attention (Pomponi et al., 2018).
More energy-efficient buildings will reduce energy use and carbon emissions in the long run. But without a simultaneous focus on embodied energy and carbon, the savings that could be made now are lost, resulting in an increase in short-term impact. The IPCC warns that reductions are needed now and not only in 30 years' time (Pomponi et al., 2018.) Embodied carbon and energy are linked to manufacturing, transport, construction, and disposal. The most effective strategy for mitigating embodied emissions however is to intervene at the material level. Either by using less of the same material or by substituting with alternative materials (Pomponi et al., 2020). Conventional materials, such as concrete and steel, can be substituted by biobased materials that store carbon instead.
Biobased materials are becoming increasingly popular in the construction industry, particularly wood. The properties of wood allow it to compete with concrete and steel. Furthermore, wood is renewable and stores CO^2. It is often argued that wood deserves the grade of 'sustainable' more than others. But, as is argued by Hudert & Pfeiffer (2019), the sustainability of wood is not absolute. 1) All-natural wood is hardly used in modern building construction. Instead, engineered wood and wood-based products are used which usually rely on plastic adhesives or comprehensive manufacturing processes. 2) Although wood is renewable, its availability is not unlimited. Sustainable production of wood requires sustainable forestry. Aggressive adoption of bio-based materials raises practical questions about the capacity of global forests (Pomponi, 2020). Arguably, the most effective strategy to mitigate embodied carbon is to substitute for biobased materials, and simultaneously use them more efficiently and considerate.
Embodied impact of building materials can be quantified by the Global Warming Potential for example. Treating this figure as the one and only indicator of environmental footprint, however, undermines the intention of material efficiency. Besides GWP, there is also the Acidification Potential and Ozone Depletion Potential that are expressed in different equivalents. They should not be ignored.

Although the limits to growth are explored many times, most (in)famously by Meadows et al., (1972), the coming decades will be characterized by demographic and economic growth as well (Churkina et al., 2020). The UN projects 2.3 billion new urban dwellers by 2050 (United Nations Department of Economic and Social Affairs, 2018), which entails huge housing and infrastructure production. And although growth historically does not correspond with sustainability, urban planners propose sustainable schemes for development. The preferred response to sustainable development is compact city planning. The compact city supposedly secures an environmentally sound, economically viable, and socially beneficial development through dense, diverse, and mixed-use urbanism (Bibri, 2020). Compact cities have been attributed to lower energy use per capita (Resch et al., 2016). Thus, energy use relates to urban density.

Despite the difference in scale, the TU Delft is undergoing similar developments. The Executive Board prospected a growth to 40.000 students in the near future while upholding sustainability targets that are even more ambitious than what many nations or institutions pursue. By 2030, the TU Delft wants to be CO2-neutral, circular, and climate adaptive whilst contributing to the quality of life for both people and nature (Blom et al., 2018; Technische Universiteit Delft, 2018). A way to approach this seeming contradiction is by looking through the lens of sustainable development, informed by the compact city concept and embodied carbon to ensure both a short- and long-term mitigation of environmental impact.

Objective

Intentions of the graduation

The objective of this graduation project is to figure out how ongoing transitions within the built environment can inform the way we should build. It seeks to address the most topical issues related to architecture, not in order to 'solve' everything but to contribute to a larger societal transition. Because repeatedly misusing the term 'sustainability' will not ensure our continued existence. It is therefore extremely important to find out what 'sustainability' actually entails.

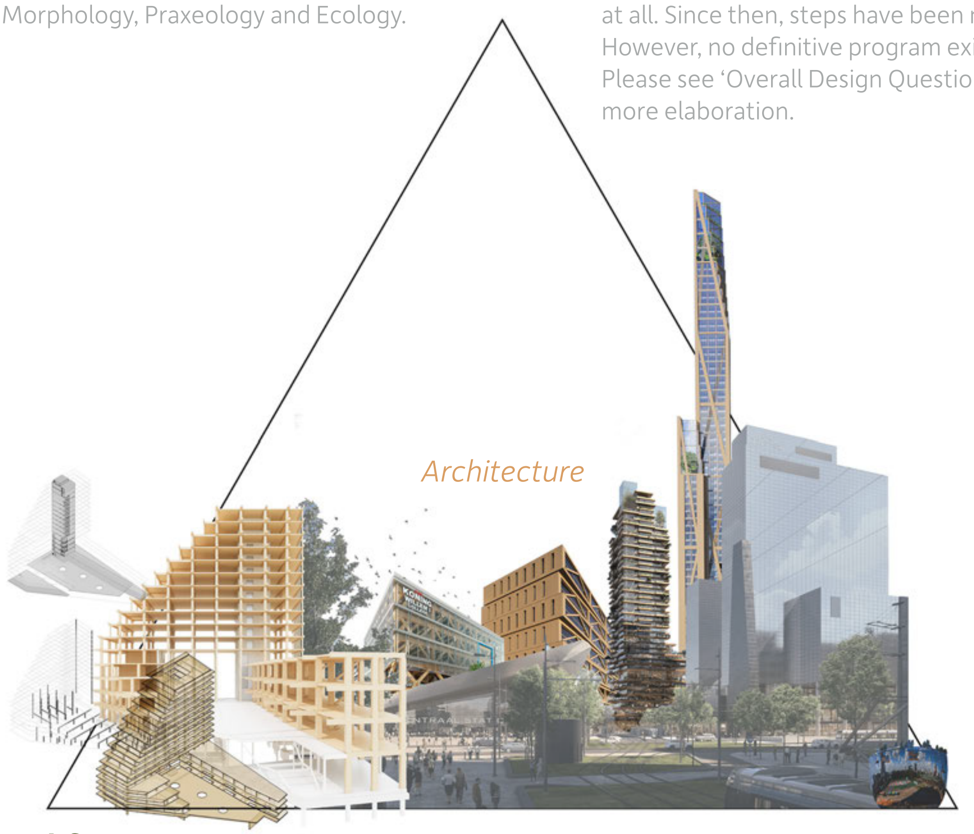
Practically, this graduation should familiarize me with the Life-Cycle-Assessment principles and timber engineering, two topics that will arguably become ever more important within architecture. In that sense, the research part should provide me with the framework that enables me to effectively design for the TU Delft. The research (method) is quite generic and therefore widely applicable whereas the specificity of the design allows for a proof-of-concept.

The design project aims to show how the TU Delft can meet its sustainability ambitions whilst continuing to develop, whereas the research aims to develop a framework that enables architects and planners to design according to material efficiency, particularly with regard to embodied impacts. The research is the foundation on which the design is built initially. Conversely, the design can also be assessed according to the preceding research. The goal of the case study is to find out which structural system is the most efficient in terms of embodied impact.

Themes: Make, Flow
Epistemes: Morphology, Praxeology and Ecology.

Program

In week 1.2, the program was not defined at all. Since then, steps have been made. However, no definitive program exists yet. Please see 'Overall Design Question' for more elaboration.



Technical fascination

The project is the result of a personal fascination about timber engineering, high-rise buildings and sustainability. These initial interests are still evident in the final research plan, now with a better sense of direction and objective.

Context

Inititally, the context was Rotterdam. Mostly because of the city's inclination to build tall. Now, this has changed to the TU Delft Campus. Mainly because their ambitions can be easily aligned with the objective of the research.

Figure 1: *aE framework collage, originally from week 1.2*
Image sources: *See figure references, adapted by author*

Overall design question

Technical interest, context, and program

How can the ***TU Delft*** accommodate the ***growing student population*** whilst ***complying*** with its ***sustainability goals***?

European governments are expecting universities not only to contribute to scientific knowledge but also to the economy and society. Issues like valorization, entrepreneurship, energy efficiency, and sustainability became essential in a changing academic context (van der Hoeven, 2015). And so, the TU Delft sets out to build upon its intellectual power to mitigate- and adapt to climate change. In their own words; "The problem is complex and urgent – but we have no other choice than to be optimistic..." (Technische Universiteit Delft, 2022). This has resulted in sustainability targets that are way more ambitious than what many nations pursue. The TU Delft aims to be CO^2-neutral, circular, and climate adaptive by 2030. In the EU, these goals are set for 2050.

Engineers play a vital role in solving these societal issues and the TU Delft is committed to supplying the increasing demand for engineers. The TU Delft sees it as its responsibility to educate as many engineers as society needs, not as many as the university can handle (TU Delft Executive Board, 2022). Therefore, the university is looking to expand to 40.000 students. This poses a contradiction, however, as growth does not correspond with sustainability historically.

Simultaneously, there is a mismatch between the student- and employee population and the current building stock. From 2016 to 2021, the student population grew by 20,84% whereas the GFA of educational facilities grew by just 1,35%. In that same period, the employee population grew by 28,11% and the GFA of offices grew by 11,4%. The CRE department acknowledges that there is a shortage of educational facilities but argues that there is already a surplus of offices.

So, if you want to be CO^2-neutral in only eight years, and you want to increase the student population by nearly 1/3th, you have no other choice than to change / expand the current building stock in a way that does not compromise your sustainability targets.

As of today, the idea is to densify in the centre of the campus by adding dwellings and other mixed-use functions (such as education). These additions might be combined with renovation of the worst performing buildings (Applied Physics). This would accommodate the growing student population whilst spreading the energetic load over the entire day.

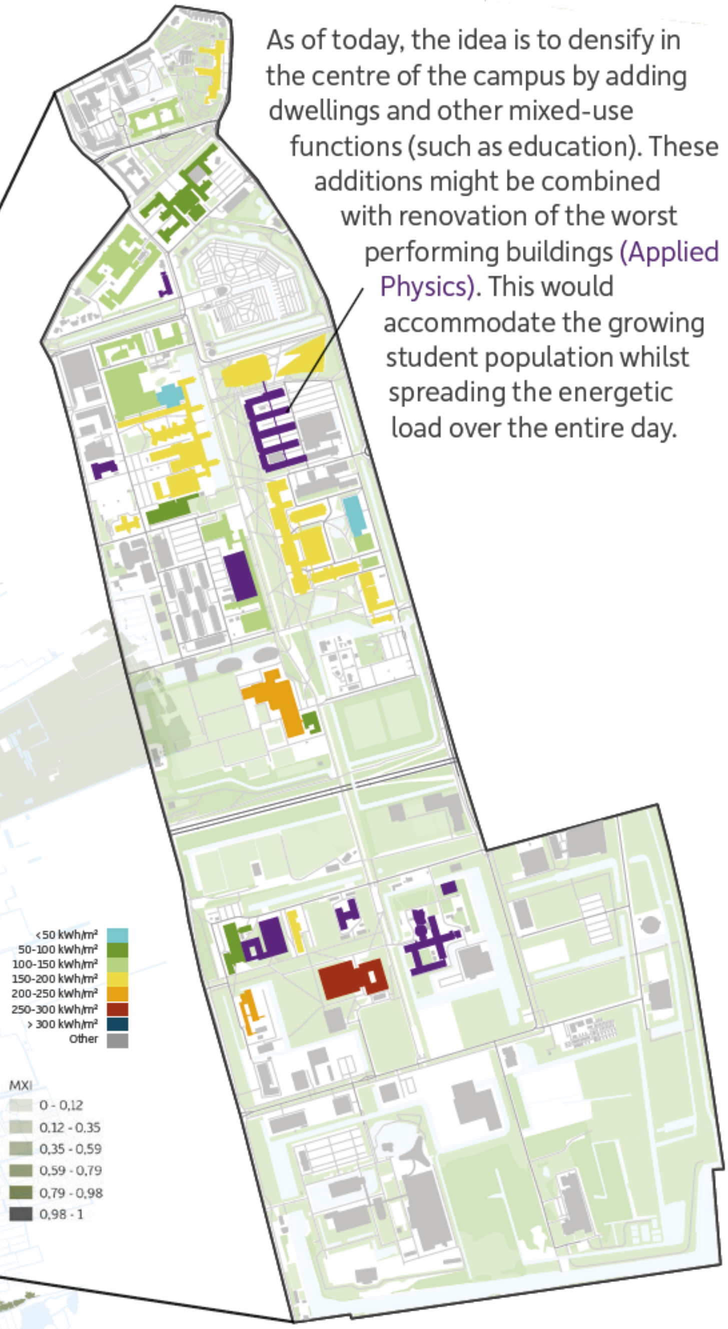


Figure 2: *MXI's of the municipality of Delft showing the monofunctionality of the campus*
Source: *Own work, adapted from Planbureau voor de Leefomgeving (2022)*

Figure 3: *Energetic performance of the TU Delft building stock*
Source: *Own work, adapted from Blom et al. (2018)*

Thematic research question

Main- and subquestions

How can the ***structure*** of ***multistorey timber buildings*** be ***designed*** when taking ***material efficiency*** as a ***guiding principle***?

1. What constitutes a multistorey timber building and why is it significant?

2. Which parameters govern the structural design of multistorey timber buildings?

3. How can material efficiency be quantified and by which criteria is it defined?

4. Which structural design is more efficient in terms of material use?

Literature study (questions 1–3) | Case study (question 4)

The design question is a direct result of the problem statement. How can we design multistorey timber buildings, in accordance with the compact city model, by maximizing material efficiency? This also closely corresponds with the design question, because, the IPCC warns that carbon reductions are needed now (Pomponi et al., 2018). More energy-efficient buildings will reduce energy use and carbon emissions in the long run. But without a simultaneous focus on embodied energy and carbon, the savings that could be made now are lost, resulting in an increase in short-term impact.

So, if you want to be CO2-neutral in only eight years, and you want to increase the student population by nearly 1/3th, you have no other choice than to change/expand the current building stock in a way that does not compromise your sustainability targets. - By designing with material efficiency in mind, particularly embodied carbon, you might be able to achieve these ambitious targets and simultaneously expand your building stock.

Hypotheses

1. Although a multistorey timber building defines a certain typology, it could still mean a lot of things. Particularly the 'multistorey' needs further specification. In urbanism, the compact city is often proposed as the most 'sustainable' paradigm (Bibri, 2020). This is because energy use relates to urban density. Several studies propose an 'ideal' building height of somewhere between 7-27 stories (Resch et al., 2016) and 10-20 stories regardless of construction technologies (Bohne et al., 2017). For timber buildings, this might be higher since the embodied emissions versus building height is lower compared to steel and concrete (Bohne et al., 2017).
2. As with any structure, timber structures have to comply with certain limits, such as the Ultimate Limit State and Serviceability Limit State. Strength, stability, and dynamic behavior usually govern these limits. Furthermore, timber structures have to comply with fire safety and acoustic demands. At times, parameters such as adaptability, demountability, and longevity inform the structural design.
3. Material efficiency, in this case, is formulated twofold; 1) Substitute conventional materials with bio-based materials and 2) use less of the same material. Both are in order to reduce the environmental footprint. In the European building sector, EN 15804 and EN 15978 are used to assess the environmental impact. Together with the Environmental Product Declarations (EPDs) the impact of building materials can be assessed. The impact can be expressed in Global Warming Potential, but also in Acidification Potential and Ozone Depletion Potential for example.
4. The cases will be assessed in two ways; 1) The entire building structure and 2) a representative fragment is analyzed. The first should give a general overview of which cases are most efficient and the second should give a more justified comparison. (See also the methodology). It is very likely that the building with the most timber has the least GWP. For AP and ODP this is less predictable.

Cases:

Figure 4: *Cases; 1. Haut, 2. Brock Commons, 3. Rocket&Tigerli*
Image sources: *See figure references*

Methodologies

Research methods

The research is mainly focused on two research methods that supplement and inform each other. Firstly, the literature study used for the first three sub-questions sets the framework in which the case study can be done constructively. The literature study sets out the parameters that govern material-efficient multistorey timber structures. With those parameters in mind, the case study will be conducted which will make the study in general more explicit and tangible. The cases are used to quantify material efficiency that has been qualitatively described in the foregoing literature study. This way, the research is supposed to give a thorough description of what it entails to build materially efficient in general. The research can then be used as an instrument for the following design assignment.

See the table below for the methods used per sub-question:

Sub-question:	What data is needed?	How can this data be collected?	How will this data be analyzed?	What will be the expected result?
1. What constitutes a multistorey timber building and why is it significant?	Literature regarding sustainable urbanism and studies on the most efficient building height	Literature study	Comparative overview of the results	Conditions that constitute a multistorey timber building and why these are considered sustainable
2. Which parameters govern the structural design of multistorey timber buildings?	Literature regarding the design and construction of said buildings. And also parametric studies regarding this topic	Literature study	Comparative overview of the results	A list of all the parameters and perhaps a scheme or chart that interrelates the different parameters because some are probably interdependent
3. How can material efficiency be quantified and by which criteria is it defined?	The European Standard on LCA (NEN-EN 15978) and the similar international standard (ISO 14044)	Literature study	Comparative overview of the results	A matrix with all the criteria and the 'weights' of these criteria
4. Which structural design is more efficient in terms of material use?	Structural drawings (plans, sections) of cases to be analyzed and the EPDs per building material	Reaching out to the firms involved in the structural design of the cases	By 3D modelling the buildings, the volume per building material can be extracted. This can then be analyzed	A matrix with all the materials and the criteria regarding material efficiency, based on which the cases can be assessed.

Table 1: *Research methods*
Source: *Own work*

The literature study is accompanied by a case study. The case study should make clear which structural system is the most materially efficient in terms of embodied impact. In other words, which structure has the least impact on the environment. The scope of the research is thus mostly concerned with the material performance itself. Calculating embodied impacts does not include the building process or the operational consumption, and only looks closely to the materials of the structure. Furthermore, the study comprises only the structure of the building since this part is based on a rationale / logic. It has to comply with the basic rules of nature. This allows for a fair comparison between building structures.

Methodologies

Case study method

The case study compares three buildings in terms of their material efficiency. The comparison is done in two ways:
1. The entire building structures are assessed and compared
2. Their representative fragments are assessed and compared.

The first gives an overview of the embodied impacts of the buildings as a whole, whereas the second allows for a more accurate comparison of the different structural systems.

Calculating embodied carbon (and impact) is methodologically similar to Life-Cycle Assessments (Pomponi et al., 2018). Therefore, the LCA framework is taken as a starting point for the case study and adapted in accordance with the scope of the case study. (See the scheme below)

See also the glossary for key terms.

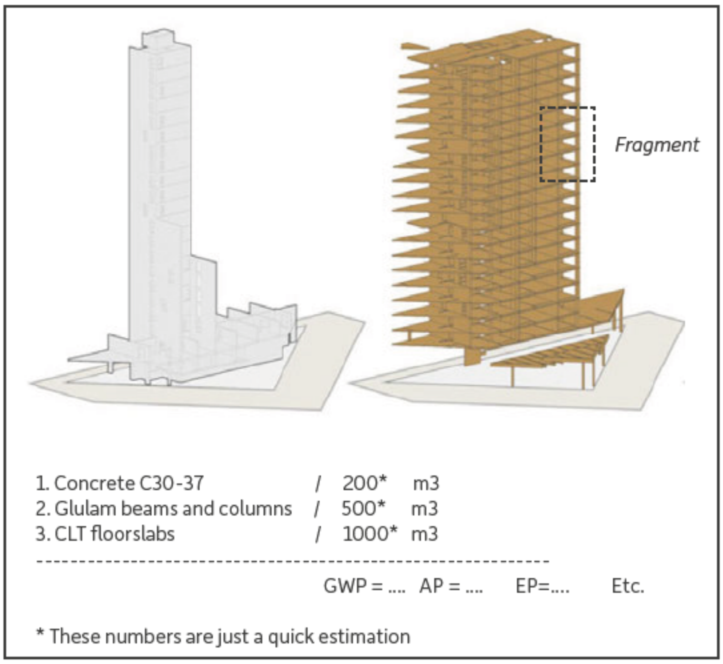
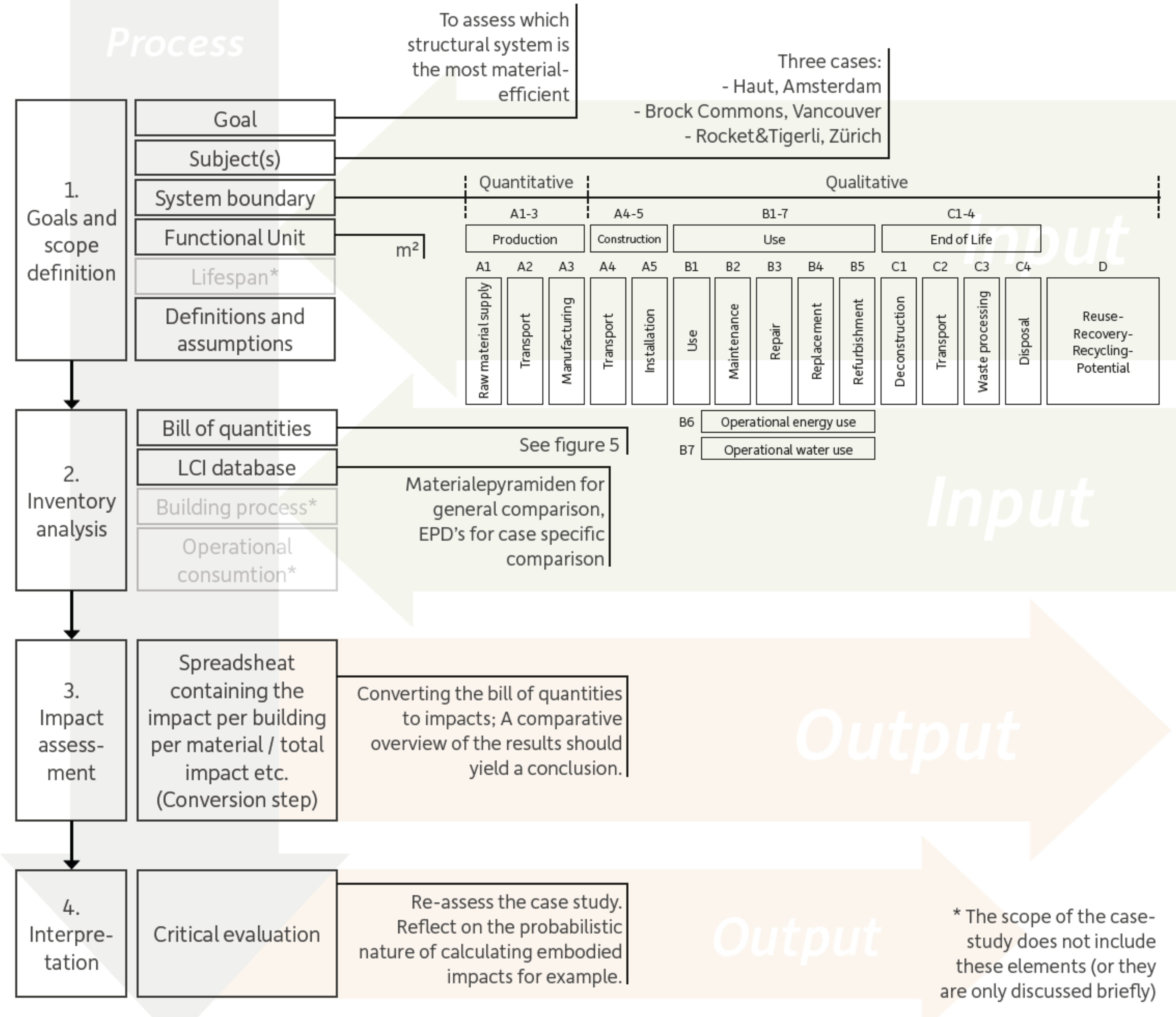


Figure 5: *Example bill of quantities, LCA phase 2*
Image source: *Team V Architectuur, adapted by author*



Scheme 1: *LCA framework, adaopted according to scope*
Source: *Based on (Bahramian & Yetilmezsoy, 2020; Duan et al., 2021; Klöpffer, 1997), adapted by author*

Positioning

Of the research

The research attempts to aid the discussion on building materially efficient. Arguably, the notion of embodied carbon and -energy are the most noteworthy indicators of material efficiency. However, other indicators such as AP, EP, ODP, and POCP should also be taken into account. Quantification of embodied carbon and -energy is methodologically similar to Life-Cycle-Assessment and is thus closely related to studies on LCA's. Specifically, timber structures are elaborated since they very likely mitigate the environmental footprint of the built environment, particularly with regard to embodied carbon. Consequently, this research is positioned in the overlap between LCA and Timber Engineering. Both can be categorized under the catch-all term of 'sustainability'.

Theoretical framework

Academic context

The research touches on a variety of subjects, either located fully within architecture and the built environment or in the larger scope of society as a whole. This way, the societal relevance of the subject is shown as well as its place in current trends and paradigm shifts. The encompassing theme of this research is sustainability. However, this term has been widely misused. Therefore it is imperative to show what this term truly entails. Examples of sources that have helped me to clarify the notion of sustainability are Transitions to Sustainable Development by Grin et al. (2010). This book, as well as the paper Complexity and Transition Management by Rotmans & Loorbach (2012), helped me to understand that transitions towards sustainability have a pace and direction which can be managed. This has widened my perspective and influenced my sense of purpose.

The aforementioned examples have a wider scope than the built environment and are used to construct a context in which this research operates. They have a more socio-technical and management perspective. Nevertheless, I think it is very important for architects to look beyond the boundaries of architecture itself (if these boundaries even exist). Arguably, architecture is not just about architecture itself.

This context widened my scope and at the same time helped me to search more specifically for literature regarding my subject. Looking at the used material thus far, three scales can be distinguished;

1. Urban scale: In terms of urbanism, sustainability has been widely researched. Academics are looking for energetically efficient configurations of the built environment. It is often argued that the compact city is the most favorable paradigm. Bibri's (2020) literature review has shown this. The energetic efficiency of the compact city has been attributed to density and mixed-use.
2. Building scale: The studies by Bohne et al. (2017) and Resch et al. (2016) found an optimal building height within the bandwidth of around 10-25 stories. This bandwidth helped me to define 'multistorey' in the research question. Other building-related parameters are found in publications such as *Buildings as a global carbon sink* by Churkina et al. (2020), *Timber Construction Manual* by Herzog et al. (2004), and T*imber Engineering – Principles for Design* by Blaß & Sandhaas (2017).
3. Material scale: Finally, looking at the materials, a lot can be derived from literature such as C*arbon in Buildings: Measurement, Management and Mitigation* by Pomponi et al. (2018) and *Carbon Based Design* by Sobota et al. (2022).

Relevance

Value of the graduation

The relevance of this graduation project is twofold: On the one hand, it provides an understanding of how to design with material efficiency in mind, ultimately contributing to more sustainable design methods. On the other hand, it provides the TU Delft with a concrete proposal of how to expand the TU Delft building stock whilst complying with their ambitious sustainability goals. It goes to show that the transition toward a bio-based built environment is the most sustainable paradigm.

Considering that historical transitions often have not led to a more sustainable society (Rotmans & Loorbach, 2012). By adopting a bio-based design, based on material efficiency, the TU Delft can accommodate its growing student population and at the same time comply with- and demonstrate its sustainability goals.

Planning

From P1 to P5

The graduation consists of two semesters, MSc3 and MSc 4. In both, the research and design run in parallel. The research is drafted up until week 1.10 and elaborated until week 2.10. The research of the 2nd semester contains mostly reflection and design-research. The design assignment is defined in the first quarter and conceptualized in the second. During MSc4, the design is elaborated further. Deadlines and presentations are marked in dark-grey.

The planning can also be found in the appendix.

Msc 3

Week	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5
Week	1.1	1.2	1 3	1.4	1.5	1.6	1.7	1.8	1.9	1 10	2.1	2.2	2.3	2.4	2.5	2.6	-	-	2.7	2.8	2 9	2 10
Date (from)	5-Sep	12-Sep	19-Sep	26-Sep	3-Oct	10-Oct	17-Oct	24-Oct	31-Oct	7-Nov	14-Nov	21-Nov	28-Nov	5-Dec	12-Dec	19-Dec	26-Dec	2-Jan	9-Jan	16-Jan	23-Jan	30-Jan
Date (to)	9-Sep	16-Sep	23-Sep	30-Sep	7-Oct	14-Oct	21-Oct	28-Oct	4-Nov	11-Nov	18-Nov	25-Nov	2-Dec	9-Dec	16-Dec	23-Dec	30-Dec	6-Jan	13-Jan	20-Jan	27-Jan	3-Feb
Presentations										P1											P2	P2
Education																						
Deliverables			Research plan draft						Research plan										Research paper + Graduation plan			
Research phase	Drafting the research plan										Doing the research and writing of the paper											
Tasks	Orientation			Topic decision						Presenting	Elaborate on method					Drafting conclusion			Formatting		Presenting	
		Researching				Writing						Literature research					Writing			Review		
			Writing					Formatting						Case study modelling				Concluding				
Design phase	Definition phase										Conceptual design											
Tasks	Articulating fascination						Define the assignment			Presenting	Site analysis				Research						Presenting	
			Choosing a context									Conceptualization				Design						
					Researching the context								Sketching					Work on presentation				

Msc 4

Week	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Week	3.1	3.2	3 3	3.4	3.5	3.6	3 7	3 8	3 9	3.10	4.1	4.2	4 3	4.4	4 5	4 6	4.7	4.8	4.9	4 10	4.11	4.12
Date (from)	6-Feb	13-Feb	20-Feb	27-Feb	6-Mar	13-Mar	20-Mar	27-Mar	3-Apr	10-Apr	17-Apr	24-Apr	1-May	8-May	15-May	22-May	29-May	5-Jun	12-Jun	19-Jun	26-Jun	3-Jul
Date (to)	10-Feb	17-Feb	24-Feb	3-Mar	10-Mar	17-Mar	24 Mar	31 Mar	7-Apr	14-Apr	21-Apr	28-Apr	5-May	12-May	19-May	26-May	2-Jun	9-Jun	16-Jun	23- un	30-Jun	7-Jul
Presentations							P3	P3	P3					P4	P4	P4			P5	P5		
Education																						
Deliverables							Concept reflection paper						Research plan / paper / grad. plan / reflection									
Research phase	Drafting the reflection paper									Writing the reflection paper												
Tasks	Reflect on 1st semester						Preliminary conclusion				Continue reflection				Review				Presentation			
			Reflect on the design					Review						Presentation								
					Reflect on the process			Presentation														
Design phase	Design elaboration																Final alterations					
Tasks	Iteration				Work on plans			Presentation		Drafting the presentation				Review			Final review		Presentation			
		Finalize concept				Work on sections					Model			Presentation								
			Define the products				Start detailing					Prepare drawings										

Deliverable / presentation
Regular education
No education
Research
Design

Table 2: *General planning MSc 3 and MSc 4*
Source: *Own work*

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Figure 5:

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Appendix
Planning

Msc 3																						
Week	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**1**	**2**	**3**	**4**	**5**
Week	*1.1*	*1.2*	*1.3*	*1.4*	*1.5*	*1.6*	*1.7*	*1.8*	*1.9*	*1 10*	*2.1*	*2.2*	*2.3*	*2.4*	*2.5*	*2.6*	-	-	*2.7*	*2.8*	*2.9*	*2 10*
Date (from)	5-Sep	12-Sep	19-Sep	26-Sep	3-Oct	10-Oct	17-Oct	24-Oct	31-Oct	7-Nov	14-Nov	21-Nov	28-Nov	5-Dec	12-Dec	19-Dec	26-Dec	2-Jan	9-Jan	16-Jan	23-Jan	30-Jan
Date (to)	9-Sep	16-Sep	23-Sep	30-Sep	7-Oct	14-Oct	21-Oct	28-Oct	4-Nov	11-Nov	18-Nov	25-Nov	2-Dec	9-Dec	16-Dec	23-Dec	30-Dec	6-Jan	13-Jan	20-Jan	27-Jan	3-Feb
Presentations										P1											P2	P2
Education																						
Deliverables				Research plan draft						Research plan											Research paper + Graduation plan	
Research phase					Drafting the research plan											Doing the research and writing of the paper						
Tasks	Orientation				Topic decision							Elaborate on method				Drafting conclusion			Formatting		Presenting	
Tasks		Researching					Writing			Presenting			Literature research				Writing			Review		
Tasks			Writing					Formatting							Case study modelling			Concluding				
Design phase					Definition phase											Conceptual design						
Tasks		Articulating fascination						Define the assignment				Site analysis				Research					Presenting	
Tasks				Choosing a context						Presenting			Conceptualization				Design					
Tasks						Researching the context								Sketching					Work on presentation			

Msc 4																						
Week	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Week	*3.1*	*3.2*	*3.3*	*3.4*	*3.5*	*3.6*	*3.7*	*3 8*	*3 9*	*3.10*	*4.1*	*4.2*	*4.3*	*4.4*	*4 5*	*4 6*	*4.7*	*4.8*	*4 9*	*4 10*	*4.11*	*4.12*
Date (from)	6-Feb	13-Feb	20-Feb	27-Feb	6-Mar	13-Mar	20-Mar	27-Mar	3-Apr	10-Apr	17-Apr	24-Apr	1-May	8-May	15-May	22-May	29-May	5-Jun	12-Jun	19-Jun	26-Jun	3-Jul
Date (to)	10-Feb	17-Feb	24-Feb	3-Mar	10-Mar	17-Mar	24 Mar	31 Mar	7-Apr	14-Apr	21-Apr	28-Apr	5-May	12-May	19-May	26-May	2-Jun	9-Jun	16-Jun	23-Jun	30-Jun	7-Jul
Presentations							P3	P3	P3					P4	P4	P4			P5	P5		
Education																						
Deliverables								Concept reflection paper							Research plan / paper / grad. plan / reflection							
Research phase					Drafting the reflection paper										Writing the reflection paper							
Tasks		Reflect on 1st semester						Preliminary conclusion				Continue reflection			Review				Presentation			
Tasks				Reflect on the design				Review							Presentation							
Tasks						Reflect on the process		Presentation														
Design phase								Design elaboration										Final alterations				
Tasks		Iteration				Work on plans		Presentation			Drafting the presentation			Review			Final review		Presentation			
Tasks			Finalize concept				Work on sections				Model				Presentation							
Tasks				Define the products				Start detailing				Prepare drawings										

Legend
Deliverable / presentation
Regular education
No education
Research
Design

Table 2: *General planning MSc 3 and MSc 4*
Source: *Own work*