

Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences



Graduation Plan: All tracks

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.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Anne Eder
Student number	5846072

Studio		
Name / Theme	Architectural Engineering	
Main mentor	Mo Smit	Architectural Engineering
Second mentor	Luca Iuorio	Urbanism
Third mentor	Engbert van der Zaag	Building Technology
Argumentation of choice of the studio	<p>In my opinion, one of the greatest challenges that (future) architects, designers, and engineers are facing is creating a more sustainable and resilient built environment—one that not only withstands the effects of climate change but also reduces its impact on the environment, potentially even helping to restore ecological balance. We need to relearn how to live in harmony with nature, rather than trying to dominate it. I chose this studio because I see myself as a sustainable designer who is passionate about contributing to a greener, better world. This studio's focus on sustainability across various scales, coupled with the flexibility to explore one's own topics, aligns well with my technical, solution-oriented approach to design. That is why I thought this studio would be the right fit.</p>	

Graduation project	
Title of the graduation project	<p>THE FORT OF THE FUTURE</p> <p>REDEFINING RESILIENCE: DUTCH FORTS AS INSPIRATION FOR SELF-SUFFICIENT BUILDING DESIGN</p>
Goal	
Location:	Utrecht; Merwede
The posed problem,	<p>Water and Energy Deficits and Overloads in The Netherlands</p> <p>Globally, climate change has emerged as a major challenge in recent years, leading to more frequent events like extreme heat, heavy rainfall, floods and droughts, which pose risks to the built environment and public safety. Buildings significantly contribute to climate change, accounting for nearly 40% of global energy consumption and approximately one-third of greenhouse gas emissions, while also driving resource depletion (Okwandu, Akande and Nwokediegwu, 2024). Therefore, the way buildings are designed and constructed greatly affects the environment. Studies</p>

show that the building sector offers considerable potential for mitigating climate change and reducing carbon emissions (Andrić, Koc and Al-Ghamdi, 2019).

In response, both the building- and energy sector have already started shifting towards reducing greenhouse emissions by building more sustainably and implementing more renewable energy sources, such as solar and wind. However, due to dependency on natural circumstances, these energy sources come with the drawback that they deliver a fluctuating energy output (Sandhu and Thakur, 2014). During periods of high solar and wind energy production, combined with a low demand, the grid becomes overloaded, resulting in inefficiencies and wasted energy.

The Netherlands, with its temperate maritime climate, faces challenges due to rising temperatures and changing rainfall patterns, which lead to issues such as water overload during heavy downpours and water scarcity during drier summers (KNMI, 2023). Simultaneously, the Dutch energy grid, originally designed for a one-way flow of electricity, struggles with grid congestion caused by the rise of decentralized renewable energy sources (Netbeheer Nederland, 2019).

Architecture can play a vital role in addressing these stated challenges by meeting resource demands independently and thus off-grid. Self-sufficient buildings could help reduce issues like grid congestion and water deficits or overload. By managing their own demands and flows, these buildings reduce reliance on external systems, offering greater resilience and sustainability.

Definition of self-sufficiency

Self-sufficiency, in this context, will refer to buildings or neighbourhoods capable of meeting their own needs for energy, water, and food. This implies a system that operates off-grid and ideally functions within a closed-loop system that minimizes waste and resource inputs. This approach involves integrating systems for renewable energy generation, energy storage, water collection and recycling, waste management, and food cultivation to enable the building to operate autonomously.

A Brief History of Self-Sufficiency In The Netherlands

Self-sufficient buildings are not a new concept in the Netherlands; in fact, they are rooted in the nation's rich history with water. Water has been both a persistent enemy and a crucial ally to the Dutch. To protect and expand their land, they constructed dikes and drained marshes to create polders. However, with the creation of the Dutch Water Line, the Dutch ingeniously used water as a tool for protection. This 200-kilometer-long defence system used a network of dikes, locks, and canals to flood strategic areas, creating natural barriers against enemies (Hollandse Waterlinies, 2023). Across the country, five such defence lines were established between 1590-1972 (Steenbergen et al., 2009), as illustrated in Figure 1. These defence systems were hidden within open and green landscapes and were carefully designed to remain secret for a long time (Hamberg and Ros, no date). They were fortified with strongholds located on land that could not be flooded but held strategic importance for controlling the waterworks.

	<p>The forts were designed to operate autonomously, anticipating on the possibility of being completely surrounded by water. They incorporated integrated defence mechanisms and self-sustaining systems capable of temporarily supporting life within. By using stored and collected resources such as coal, wood, fossil fuels, food, and water, the forts could sustain themselves for limited periods. However, they still required occasional external supplies to continue operating in the long term. Meaning, they were designed to be “temporary-self-sufficient” or “resource-supported self-sufficient”, highlighting that while their system covered some of its own needs, they did not fully eliminate dependence on external resources. Today, some forts continue to operate with a combination of historic and modern self-sustaining practices, which reflect a deep cultural connection to resilience and independence.</p>
<p>research questions and</p>	<p>As previously mentioned, the Netherlands faces pressing challenges related to both water overload and water scarcity, as well as an overloaded energy network. By studying the forts of the Dutch Water Line, we might be able to uncover valuable lessons from their self-sufficient systems and innovative designs. These historic structures were built to withstand periods of isolation, providing resources and resilience during sieges and enemy intrusions. The principles and strategies behind these forts may hold potential for translation into modern solutions that address today’s challenges. Additionally, advancements in technology and contemporary sustainable projects offer opportunities to enhance these historic ideas with innovative approaches to resource management and climate-resilient design.</p> <p>The objective of this thesis is to identify key design principles and boundary conditions for “the fort of the future”—a climate-resilient, self-sufficient building capable of addressing the pressing challenges of today’s and tomorrow’s world. This leads to the following thematic research question:</p> <p>What design principles and boundary conditions can be derived from the Dutch Water line forts and contemporary projects in the Netherlands to create a self-sufficient, climate-resilient building for the future?</p> <p>This research will explore both the historical and modern dimensions of self-sufficient design by examining the functioning of the forts of the Dutch Water Line alongside innovative contemporary projects in the Netherlands. The goal is to develop a framework for the design of climate-resilient, self-sufficient buildings that can meet their demands for water, energy, and potentially food.</p> <p>The following sub questions will help structure and build up de research to be able to answer the main thematic research question in the end:</p> <p>1. Self-sufficient, climate resilient buildings <i>Which are the characteristics/aspects/principles that makes a building self-sufficient and climate resilient?</i></p>

	<p>2. The Dutch Waterline and their Forts <i>What can be learned from the historical forts of the Dutch Waterline in terms of self-sufficient building systems/ regarding achieving self-sufficiency?</i></p> <p>3. Contemporary projects <i>What innovative strategies and systems in contemporary buildings or neighbourhoods in the Netherlands can enhance self-sufficiency in water, energy, and food?</i></p>
<p>design assignment in which these result.</p>	<p>The framework developed through this research will serve as a foundation for designing a self-sufficient, climate-resilient mixed-use building in the Merwede neighbourhood of Utrecht. By defining key design principles and characteristics of self-sufficient, climate-resilient buildings, the research provides valuable insights and direction for the design process.</p> <p>Why Utrecht and why Merwede?</p> <p>Utrecht is deeply connected to the Dutch Waterlines, as it is surrounded by historic forts, reflecting a deep connection with this heritage. Additionally, today, the region faces challenges such as water overload, water scarcity, and energy grid congestion, making climate-resilient and future-proof solutions essential. Merwede, a former industrial area in Utrecht, is currently being redeveloped into a sustainable urban district, providing a unique opportunity to combine historical insights with innovative approaches to climate adaptation, energy, and circular systems, making it an ideal location for this project.</p>
<p>Process</p>	
<p>Method description</p> <p>As the goal of this thesis is to define design principles and strategies for the "Fort of the Future"—a climate-resilient, self-sufficient building designed to address the pressing challenges of today and the future, it is crucial to first clarify what constitutes a self-sufficient, climate-resilient building. This foundational understanding will be developed through secondary data collection via an extensive literature review.</p> <p>The next step involves exploring how such a building can be realized and assess the potential for buildings in the Netherlands to achieve true self-sufficiency. To do so, an analysis of both historical and contemporary projects will be conducted. To examine these projects, a framework will be developed to systematically evaluate and compare their Level of Self-Sufficiency (LoS).</p> <p>A qualitative analysis of forts from the Dutch Waterline, alongside contemporary building projects, will be executed to understand the technologies and architectural systems employed to achieve grid independence. By grading these projects on their LoS, the analysis aims to identify which approaches are most effective and which are less successful. This grading system will ensure consistent comparisons, determining the strengths and limitations of historic and current self-sufficient designs. The insights gained from this analysis will provide valuable guidance for designing the Fort of the Future and advancing self-sufficient building design in the Netherlands.</p>	

Literature and general practical references

For my research, I consulted various references to address my research question, including books, papers, reports, articles, websites, and more. It is important to mention that not all of these sources are scientific, particularly those related to contemporary projects, which are based on articles or website information from architectural firms.

To answer my first question, "*What constitutes a self-sufficient, climate-resilient building?*" and to develop a foundational understanding, secondary data was gathered through an extensive literature review. Key references include:

- Marquez, T. (2023). *Climate-resilient buildings are the way forward for finance, architects, and engineers*. [World Green Building Council](#).
- McDade, E. et al. (2020). *A decarbonization framework for planning, landscape, and infrastructure*. [Architecture 2030](#).
- UNEP and SEfficiency (2021). *A Practical Guide to Climate-resilient Buildings & Communities*, UNEP. [UNEP](#).

To answer the second question on the Dutch Waterline forts, various sources were consulted:

Books:

- Steenberg et al. (2009). *Atlas Nieuwe Hollandse Waterlinie*. 010 Publishers.
- Claesen, P. and Stichting Forteiland Pampus (2022). *Handboek voor de Pampusgids*. [Pampus Guide Handbook](#).
- Van Der Heijden, P. and Ruissen, E. (2012). *Fort Pannerden*. Matrijs.

Reports and Documentation:

- Zaaijer, L. and Van Der Gun, J. (2019). *Bouwhistorische verkenning met waardestelling, Fort Honswijk*. [Fort Honswijk Report](#).
- De Groot, D. (2013). *Nieuwe Hollandse Waterlinie: Fort Everdingen Naslagwerk*. [Fort Everdingen Reference Work](#).
- Register Vesting Gorinchem (1888). *Genieregister van het Fort Everdingen*. [Fort Everdingen Documentation](#).

Articles and Websites:

- Hamberg, R. and Ros, R. (no date). *Hoe werken de waterlinies?* [Waterlinies Knowledge Center](#).
- Harlaar, T., Kwant, M., and Stichting Liniebreed Ondernemen (2015). *Groene Forten*. [Groene Forten Brochure](#).
- Hollandse Waterlinies (2023). *Zo werken de Hollandse Waterlinies*. [Hollandse Waterlinies](#).
- Vuurtoreneiland (2023). *Het eiland*. [Vuurtoreneiland](#).
- Kustbatterij bij Durgerdam (no date). [Kustbatterij bij Durgerdam](#).
- Kustbatterij bij Durgerdam: *Wie alles wil verdedigen zal alles verliezen* (no date). [Kustbatterij bij Durgerdam - Article](#).
- Pampus (2024). *Forteiland Pampus - waar toekomst en geschiedenis samenkomen*. [Pampus](#).
- Jotem Water solutions (no date). *Drinkwaterinstallatie Pampus*. [Jotem](#).
- Stichting Honswijk - Everdingen (2024). *Fort Honswijk*. [Fort Honswijk](#).
- Batist, J. (2023). *'Bier met water uit druipkokers op fort Everdingen'*, Stichting Honswijk - Everdingen, August. [Fort Honswijk - News](#).
- Fort Pannerden — *Trotseer de elementen!* (no date). [Fort Pannerden](#).

To answer the third question and analyse contemporary projects, the following references were used:

Schoonschip:

- Greenprint Schoonschip (no date). [Greenprint Schoonschip](#).
- Schoonschip (no date). *Schoonschip – Amsterdam*. [Schoonschip](#).

Four Elements Hotel:

- Smith, A. (2019). *Force of nature – naturally ventilating Amsterdam’s Breeze Hotel*. [CIBSE Journal](#).
- Wassink, J. (2013). *‘Veteran engineer develops natural airco’*, Delta, 6 June. [Delta](#).
- Ddonave (2024). *Four Elements Hotel | Amsterdam*. [Oz Architect](#).

Proyecto Roble:

- Équipe (no date). *Proyecto Roble*. [Equipo Amsterdam](#).
- Kantoorpand Helvoirt Groenprojecten (no date). [Helvoirt Groenprojecten](#).

Floating Farm:

- Dogan, R. (2024). *How can floating farms revolutionize urban agriculture in Rotterdam?* [Parametric Architecture](#).
- Goldsmith (2023). *Floating Farm Dairy*. [Goldsmith](#).
- Frearson, A. (2019). *‘Floating Farm in Rotterdam is now home to 32 cows’*, Dezeen, 10 July. [Dezeen](#).

ReGen Village:

- Bosschaert, T. (2022). *ReGen Villages Oosterwold*. [Except](#).
- Effekt (2016). *ReGen villages*. [Effekt](#).

Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?

My graduation project, The Fort of the Future, aligns with my master track in Architecture as it explores sustainable and resilient design solutions. It focuses on how historical Dutch Water Line forts can inspire modern self-sufficient buildings, addressing current challenges like climate change, resource deficits and energy grid congestion. This project aligns with the Master Architecture and the Studio Architectural Engineering, as technology, architecture and urban design are closely connected in this topic. By developing a framework for sustainable, independent buildings capable of adapting to climate challenges and grid constraints, the project supports the study’s broader goal of creating future-proof architecture.

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

The project addresses critical issues like water overload, water scarcity, and energy grid congestion in the Netherlands, all of which are exacerbated by climate change. By studying historical Dutch forts that were designed to be self-sufficient and autonomous, and by incorporating innovative technologies from modern sustainable projects, this research provides strategies for reducing dependency on external resources. It contributes to the field of sustainable architecture by offering design principles that can help guide future building practices, making it valuable for professionals in architecture, urban planning, and climate adaptation, as well as for policy-makers focused on sustainable urban development.