Affordable energy neutral climate systems for a modular strategy

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AR3A010 | Research Plan
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Name of studio Architectural Engineering Graduation Studio
1 Million Homes
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Argumentation of choice of the studio The focus on the technical aspects within architecture and the opportunity to try solve problems within housing

Keywords
Affordable Climate System, Modularity, Flexibility, Housing Shortage, Eco-Materials, Low Emission

Definition Key Terms

Affordable Architecture
The purchase and usage price of the building is affordable for the average Dutch inhabitant

Architectural Elements
Elements that are part of the architecture of a building, think of walls, roofs, shades, etc.

Climate Strategy
A design strategy based on the climate system and the internal climate of a building

Climate System
An ensemble of elements that passively or actively affect the internal climate of a building

Emissions Architecture
The CO2 emissions during the production, transportation and disposal of materials, the construction of buildings and the use of a building

Energy Neutral/Positive
The building tries to keep his energy requirements low and provides its needed energy/more energy than needed in a sustainable way, think of solar energy or wind energy (Milieu Centraal, n.d.)

Flexible Buildings/ Flexibility
Buildings that can be adapted to future trends and that can be personalized to the inhabitants' wishes, think of more/fewer rooms

High Quality Neighbourhood
A neighbourhood with different functions to create vitality, where people feel safe and enjoy their stay

Modular Strategy
A design strategy based on modularity, the idea of having different elements that together can create houses that can be prefabricated and personalized by the inhabitants

Nearly Zero Energy Buildings
The building is nearly able to produce its needed energy, but in some occasions bounded by an external source (Rijksdienst voor Ondernemend Nederland, 2021)

Varied Housing
Different sizes, e.g. 60m^2, 80m^2, 120m^2

Problem Statement

Over the last years, the Netherlands has been struggling with a continuously growing housing shortage, because of the decreasing average household (Obbink, 2020). Even though it is not clearly visible, as most of the Dutch inhabitants do have a roof above their head, there is currently a shortage of 331.000 habitations, which will rise to 419.000 habitations in 2025 (Obbink, 2020). Despite the fact that this problem has been around for a while, the Dutch government did not consider the housing shortage as one of its priorities and nowadays they want 1 million new habitations before 2035 (ABF Research, 2018).
This is an extremely elevated number, which the government has determined based on the population forecast from the Dutch Statistics Office (CBS), but is there really such a necessity? According to Frans Schilder of the “Planbureau voor de Leefomgeving” is the amount of 1 million homes not fixated as there are great uncertainties within the predictions (Bekhuis et al., 2021). The number is supposed to radiate the urgency and to encourage people to start building. Friso de Zeeuw, emeritus professor of area development, thinks it is not realistic to build 1 million homes in the given time, even though he considers it necessary (Bekhuis et al., 2021). The important thing seems to start buildings as soon as possible, but what kind of habitations are needed? As the last few years have been focused on building houses for the more expensive segment, there is a necessity for affordable owner-occupied homes for the low/middle classes, including starters (Bekhuis et al., 2021).

This necessity for affordable housing is accompanied by the fact that the Dutch government decided that all the buildings built after January 1th 2021 need to be nearly zero-energy buildings (NZEB) (Rijksdienst voor Ondernemend Nederland, 2021) to lower the CO2 emissions within the construction environment (Lammerse, 2020). Research states that nearly 40% of total global CO2 emissions derive from the construction industry, which is far from reaching the goals set by the Paris Climate Accords to tackle the rising temperatures worldwide (Lammerse, 2020). Different crises, like the human impact on the nitrogen cycle and the COVID pandemic, did slow down the construction industry, but it is also an opportunity to look at the changes that can be introduced within the industry to become environmentally friendly. These changes do not only affect the environment, but are also interesting investment opportunities to breathe new life into the economy.
It is important to realize that these interventions do affect the construction, purchase and usage price of buildings (Pricewise, 2020), which requires finding solutions to develop affordable environmental friendly habitations for the average Dutch inhabitant (figure 1).

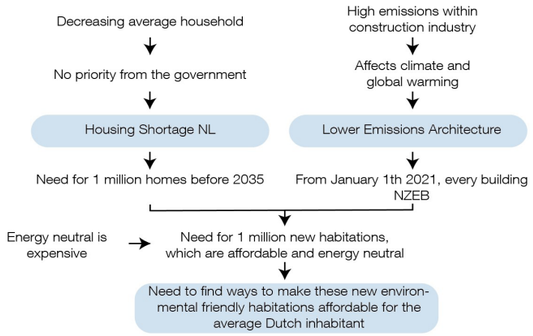


Figure 1 Problem statement (own work, 2021)

Objective

The goal of this project is to find ways to make new environmental friendly habitations affordable for the average Dutch inhabitant. This project should help find possible solutions for two of the bigger problems within architecture in the Netherlands, the housing shortage and rising prices, and the emissions within architecture, but how to address them?

To find ways to lower the emissions within architecture, it is first important to know where these emissions come from. It starts at the preparation of the materials. Not only the material itself, but also the ways it is cured in factories and the transportation to the site can affect the emissions. At the end of the life cycle of a material, it is also important to consider the possible emissions during the disposal of materials. (Benda, 2021) Eco-based, reusable materials do lower the emissions.
Furthermore, there are emissions during the construction on site (van der Molen, 2021). By using prefab elements, the emissions on the field can be lowered.
Lastly, there are also emissions released during the use of a building, through the use of gas and other fossil fuels (Lammerse, 2020). By focusing on the climate strategy of the building, and making them energy neutral, the emissions are significantly lower. It is however important to focus on the affordability of these elements.

To lower the housing shortage, it is important to make high density neighbourhoods with affordable habitations in different sizes. The habitations need to be quick to build and flexible for future trends. By working with a modular strategy, all the elements can be addressed and the habitations can be personalized to the inhabitants’ wishes.

By combining these elements it is possible to design a high quality neighbourhood by using a modular and climate strategy.

The **overall design question** proposed in this research plan is: “How can a modular and climate strategy help develop an affordable, high quality neighbourhood with varied houses for the middle class in the Merwedeterrein, Arnhem?”.

To address this question, the following sub questions have been formulated:
- What climate system elements can be used to design an affordable energy neutral/ positive building for a modular strategy? (Thematic Research)
- What elements are needed to create flexible, modular housing and what kind of habitations are needed?
- What classifies as a high quality neighbourhood and what is needed to make Merwedeterrein high quality?

During this project, the climate design will define the architectural choices, to properly integrate the climate design into the architectural design.

Figure 2 Merwedeterrein, Arnhem (own work, 2021)

Context

The chosen context is the Merwedeterrein in Arnhem, Netherlands. Arnhem is one of the cities that expects a growth in household until 2050 (Bekhuis et al., 2021). The Merwedeterrein is located nearby the center of the city, which makes it an attractive location. During a first site visit, the location showed different challenges (Figure 2).
The site is positioned between two train roads. This affects the accessibility of the site which at the moment is only reachable through a few tunnels under the train roads. Currently, the location houses various functions, from industrial functions to a trailer park to an art workplace. Even though the site is located between different residential areas, the location does not feel pleasant, it is not equipped for pedestrians and it is not an urban habitable area. However, due to its flexibility, this location does lend itself for the design of an experimental neighbourhood, with lots of opportunities.

Frame of Reference

This thematic research will focus on the design of a climate system for a modular strategy. To design a high quality, energy neutral/positive neighbourhood following a modular and climate strategy to create an affordable building, it is important to know the state of the art around energy neutral/positive architecture. To achieve the label “energy neutral” a building tries to keep his energy requirements low and is able to provide for its needed energy in a sustainable way, think of solar energy or wind energy (Milieu Centraal, n.d.). Since January 1th 2021, the Dutch government declared that every new building needs to be a nearly zero-energy building (NZEB), which forced architects to think about the climate design of their buildings. The climate design of buildings is influenced through the climate system, a system with elements which control the climate inside of the building in an active or passive way. The chosen system affects the inside comfort of a house. In case of an active system, your house adapts the climate to your needs, and in case of a passive system, you have to adapt to the climate created by the house. Nowadays, the most used building components within an energy neutral building are very good isolation in roofs, facades and floors, HR++ or triple glass and air tightness. The most used services are a ventilation system with heat recovery, underfloor heating, heat pumps with solar water heater and solar panels (Milieu Centraal, n.d.). With these elements it is possible to create an energy neutral climate system, but the use of these machines can make the buildings in some cases quite expensive in the construction and purchase price. For example, some architects see the requirement of energy neutral as a box they have to check to get their building permit, and just add all the machines that are needed to make a building energy neutral, without integrating the climate system into the architectural design, to create passive solutions and in this way decrease the prices of the buildings. In my opinion it is important to start looking at climate design as a part of the architectural design, and try to make a building as passive as possible and to add machines to solve the problems that were not possible to solve in a passive way. This helps the buyers of these new habitations to get a more affordable purchase and usage price, instead of paying a much more elevated price because of the decisions of the architect.

This thematic research will focus on the ways to create a climate system for a modular design. The **thematic research question** proposed in this research plan is: “How can the design of climate systems for modular strategies decrease the purchase price and the emissions of new energy neutral/positive buildings in the Netherlands?”
To address this question, the following sub questions have been formulated:

- What are the current used climate systems in the Netherlands?
- What architectural elements can passively influence the climate necessities of a building?
- What elements can compose a climate system for a modular design?
- What are the most expensive elements of a climate system and how can we make them more affordable/prevent using them?

The end result will be a catalog with active and passive elements of a climate system, categorized based on purchase and usage price, purpose and effectiveness, which can help architects use climate design within their architectural design.

Hypothesis

Expected is that if most active solutions are replaced by passive solutions, the energy consumption will decrease, which will lower the usage price, which will then lower the amount of needed active services, which will lower the purchase price. There are two relevant arguments regarding the use of passive and active climate system solutions. The first argument is sustained by proponents of the “passive house”. They sustain that a passive strategy is the most reliable and sustainable, as it has the lowest net energy demand and that a building with only an active and without a passive system will have a very high energy bill (Passief bouwen, n.d.). The second argument is sustained by proponents of the “active house”, that sustain that the use of active systems within a passive house makes a building more intelligent (Zeiler, 2006). These theories both identify justified insights, however they both address that each system works best in combination with the other system. Therefore, this research will focus on the potential that the two methods have together. The hypothesis is claimed based on the previously mentioned arguments and case studies (Appendix I) which seem to use a combination of active and passive solutions. However, the hypothesis might not stand after the P2 research, if it results that some solutions are not as effective as one might think. The hypothesis will be tested by comparing elements based on purchase and usage price, purpose and effectiveness (quantitative and qualitative).

Positioning and Methodologies

The overall used research method is qualitative research through case studies. To understand climate systems it is important to realize how different elements work and what kind of cycle they are part of. Through case studies and contacting the architects one can see the realistic costs, what restrains there are within the building industry and what kind of difficult situations buyers have to deal with in the housing market. By only focusing on literature study one would remain on a more superficial level.

This research is divided in five parts. (Appendix II)

1. First, the research will focus on the climate situation in the Netherlands. Through the program Climate Consultant, the climate will be analyzed based on temperature, wind, sun and rain. This study will help define which climate elements are more urgent to address within the climate strategy of a building. (Data collecting, Quantitative study)

2. Next, the current used climate systems will be studied. Through 3 case studies of energy neutral apartment buildings in the Netherlands and by contacting the architectural firms, the current used techniques and elements will be analyzed. The elements will be looked at separately and classified based on the following criteria: purchase and usage price, purpose and effectiveness. These elements will be placed into the catalog. (Case studies/literature study, Qualitative study)

3. Afterward, the research will focus on the architectural elements that can passively influence the climate necessities of a building. These passive systems will also be studied through 3 case studies and by contacting the architectural firms. These elements will also be classified based on purchase and usage price, purpose and effectiveness and will be placed into the catalog. (Case studies/literature study, Qualitative study)

4. Subsequently, the research will focus on the elements that can be used within a modular strategy. The elements within the catalog will be classified based on flexibility. Afterward, there will be a study to find out how a climate system would work within a modular strategy, based on the position of the shafts and the installation rooms. This will help decide if climate elements are more flexible as a single element or as a system. These findings will also be placed into the catalog. (Case studies/research by (climate) design, Qualitative study)

5. Lastly, the most expensive elements of the climate system in the catalog will be studied to see if there are ways to prevent using them or making them more affordable. This will be done based on the density of a neighbourhood: what elements are more expensive in low, middle and high density neighbourhoods. This information will also be added to the catalog. (Literature study, Quantitative/qualitative study)

The catalog will contain the elements to create an affordable and adaptable climate system for a modular design.

Relevance

The housing shortage and the emissions of buildings that affect global warming are very relevant topics. The first one more specific to the Netherlands, but the second one worldwide. A catalog providing an architect with the different options to design affordable, energy neutral habitations should lower the threshold for sustainable, affordable design. Furthermore, a design for an affordable, sustainable, high quality neighbourhood, which is flexible thanks to the modular strategy, could help solve partially the housing shortage, and the need of sustainable habitations within the whole country. This project could be placed in a lot of different locations in the Netherlands. It is a specific project focused on climate systems, but generic in its position.

Research Plan Diagram

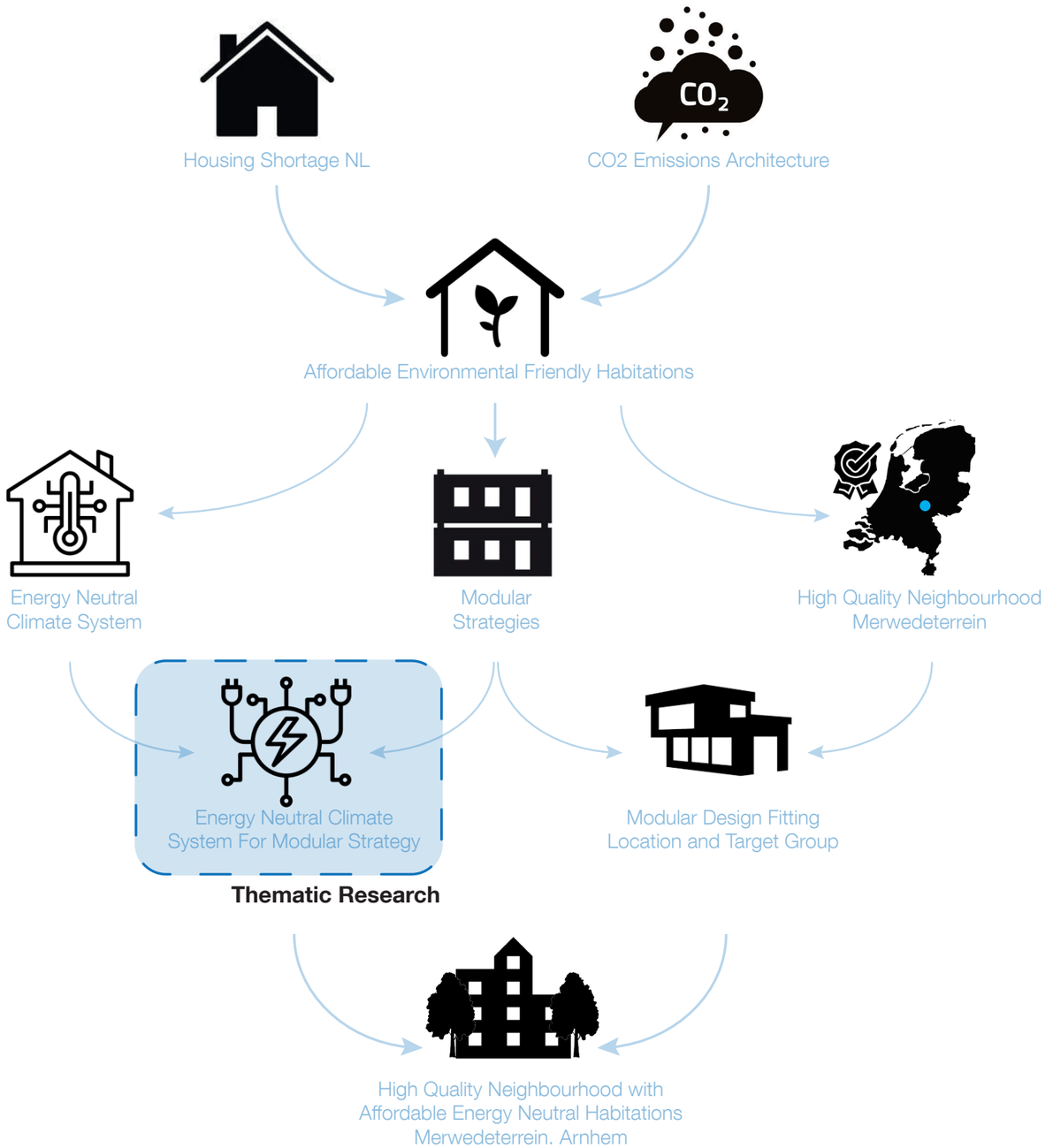
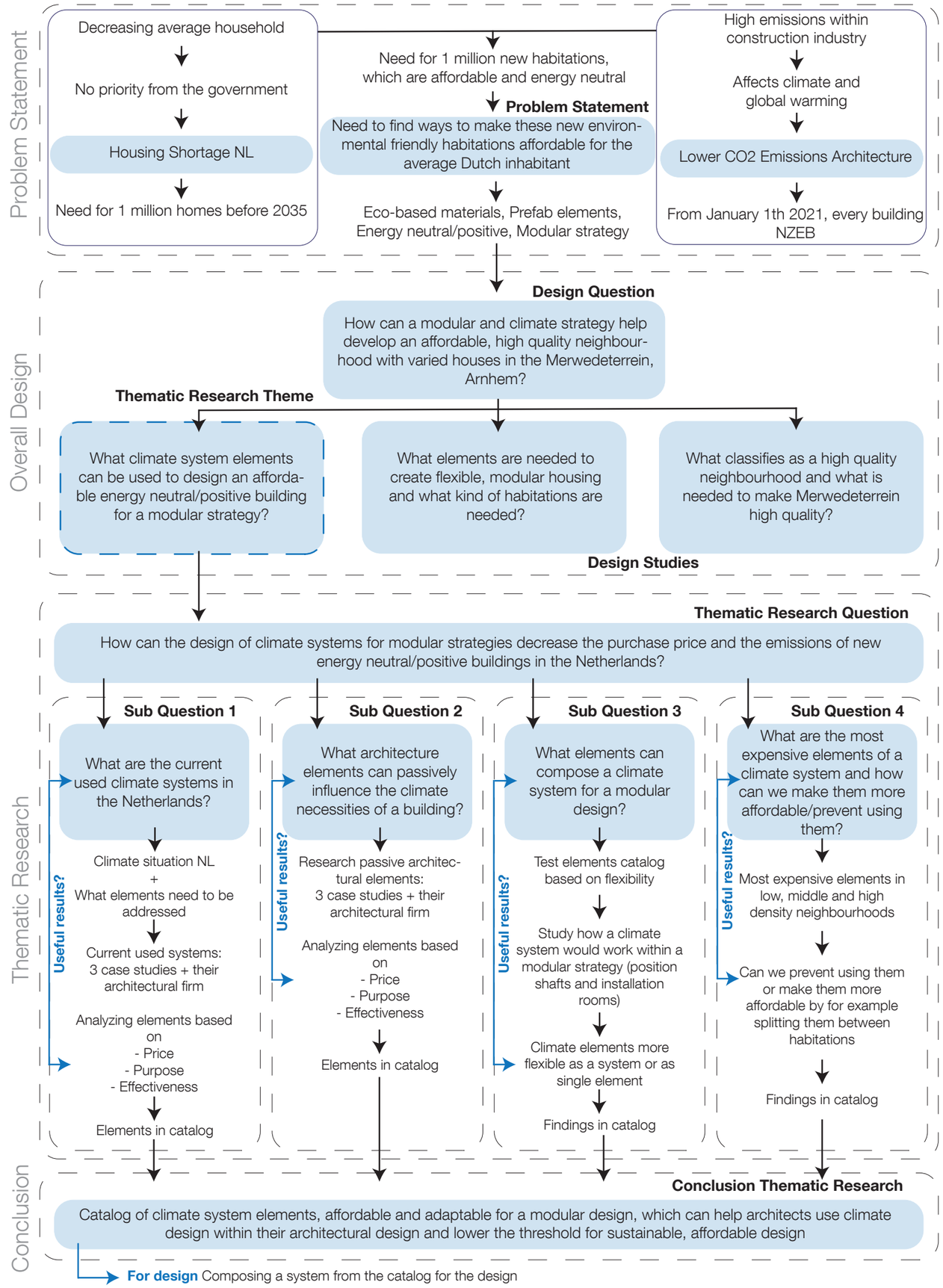
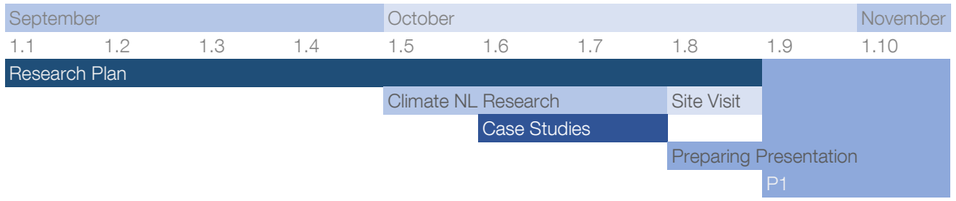
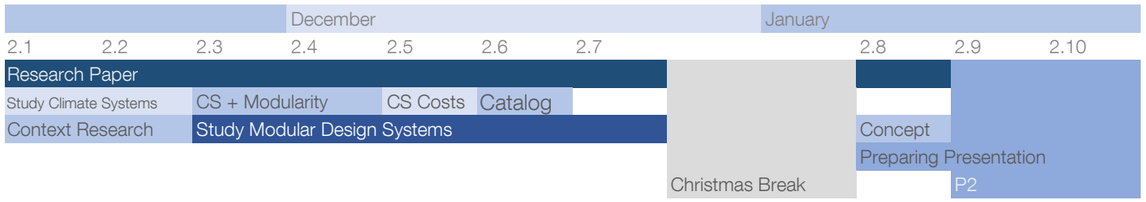


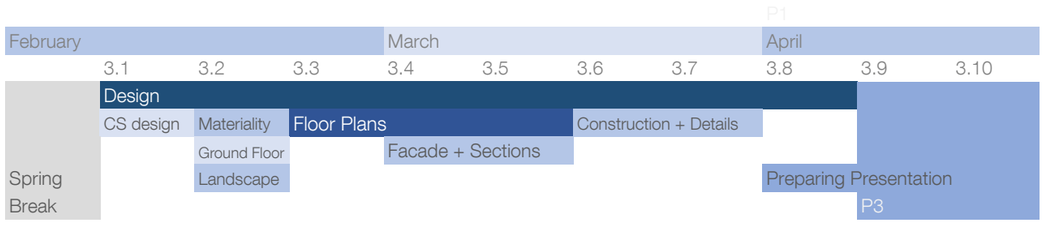
Figure 3 Research Plan Diagram (own work, 2021)

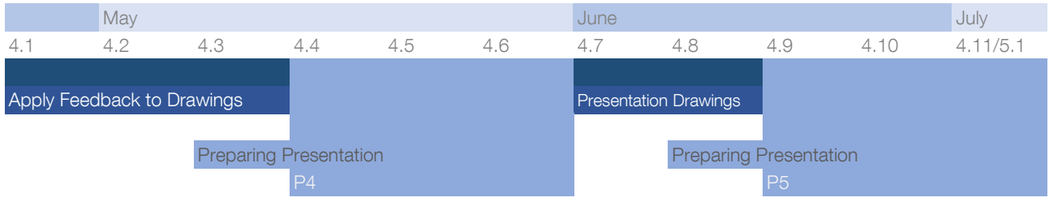


Planning









	Week	Date	Research	Design	Deadlines
P1	1.1	30/8 - 5/9	- Pavilion Pitch		Pavilion Pitch : 2/9
	1.2	6/9 - 12/9	- Pin-Up Poster		Pin-Up Poster: 9/9
	1.3	13/9 - 19/9	- Start working on research plan - Specify research		
	1.4	20/9 - 26/9	- Working on RP - Meeting with Research Tutor		
	1.5	27/9 - 3/10	- Working on RP - Reading literature - Climate research NL		Extra Draft Jorge: 1/10
	1.6	4/10 - 10/10	- Working on RP - Reading literature - Meeting with RT - Climate research NL - Research Case Studies		
	1.7	11/10 - 17/10	- Working on RP - Incorporate feedback Jorge - Climate research NL - Research Case Studies		Draft RP Jorge: 11/10
	1.8	18/10 - 24/10	- Working on RP - Presentation P1	- Visit Arnhem Location	
	1.9	25/10 - 31/10	P1		Presentation RP: 26/10 Deadline RP: 29/10
	1.10	1/11 - 7/11	- Contacting architects		
P2	2.1	8/11 - 14/11	- Study currently used climate systems - Study architectural passive elements	- What classifies as a high quality neighbourhood? - Urban analysis Arnhem	
	2.2	15/11 - 21/11	- Study currently used climate systems - Study architectural passive elements - Writing paper	- What is needed in Merwedeterrein, Arnhem, to make it high quality? - Urban analysis Arnhem	Results useful?
	2.3	22/11 - 28/11	- Study climate systems for modularity	- Start looking into modular design + kinds of housing	
	2.4	29/11 - 5/12	- Study climate systems for modularity - Writing paper	- Study modular design elements	Results useful?
	2.5	6/12 - 12/12	- Study expensive climate systems elements	- Study modular design elements	Results useful?
	2.6	13/12 - 19/12	- Setting up catalog	- Study modular design	
	2.7	20/12 - 26/12	- Writing paper	- Study modular design	
		27/12 - 9/1			Christmas Break
	2.8	10/1 - 16/1	- Writing paper	- Concept	
	2.9	17/1 - 23/1	P2	- Working on Presentation	
	2.10	24/1 - 30/1	P2		
		31/1 - 6/2			Spring Break

	Week	Date	Research	Design	Deadlines
P3	3.1	7/2 - 13/2		- Study climate system based on Thematic Research	
	3.2	14/2 - 20/2		- Study materiality (eco-based materials) - Study ground floor filling - Study landscape/urban	
	3.3	21/2 - 27/2		- Study modular design: floor plans	
	3.4	28/2 - 6/3		- Study modular design: floor plans, facade and sections	
	3.5	7/3 - 13/3		- Study modular design: floor plans, facade and sections	
	3.6	14/3 - 20/3		- Study construction + details	
	3.7	21/3 - 27/3		- Study construction + details	
	3.8	28/3 - 3/4		- Preparing presentation	
	3.9	4/4 - 10/4	P3	- Preparing presentation	
	3.10	11/4 - 17/4	P3		
P4	4.1	18/4 - 24/4		- Working on drawings feedback	
	4.2	25/4 - 1/5		- Working on drawings feedback	
	4.3	2/5 - 8/5		- Working on drawings feedback	
	4.4	9/5 - 15/5	P4	- Preparing presentation	
	4.5	16/5 - 22/5	P4	- Preparing presentation	
	4.6	23/5 - 29/5	P4		
P5	4.7	30/5 - 5/6		- Presentation drawings	
	4.8	6/6 - 12/6		- Presentation drawings	
	4.9	13/6 - 19/6	P5	- Preparing presentation	
	4.10	20/6 - 26/6	P5	- Preparing presentation	
	4.11/5.1	27/6 - 3/7	P5		

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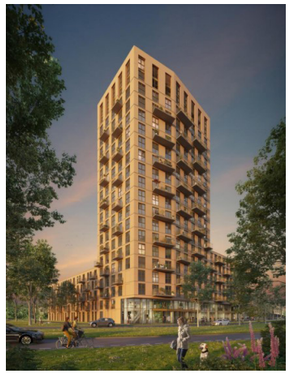
Appendix I

Possible Case Studies

Active Climate Systems



Buitenhof Blok B | Juli Ontwerp
(VORM Bouw B.V., 2019)

M'DAM | Finch Buildings
(Finch Buildings, 2021)

Park Avenue | Klunder Architecten
(Klunder Architecten, 2021)

Passive Climate Systems

Woonzorgcomplex Veldhuis | Rens Architecten
(Troelstra, 2021)

Veldhuizerschool Ede | Jorissen Simonetti Architecten
(Yanovshtchinsky et al., 2012)

Passiefhuis Lent | Jade Architecten
(JADE architecten, 2020)

Appendix II

Research Structure

What are the sub questions?	What data is needed?	How can this data be collected?	How will this data be analyzed?	What will be the expected results?
What are the current used climate systems in the Netherlands?	Climate data about the climate in the Netherlands (temperatures, wind, sun, etc.) and data about currently used active systems	Data bank, case studies, interviews with architects and literature study	Climate Consultant for climate in the Netherlands + analyze elements climate systems based on price, purpose and effectiveness and add them to the catalog	Climate: focus is on heating Used systems: Heat pump, mechanical ventilation, solar panels, etc.
What architectural elements can passively influence the climate necessities of a building?	Data about currently used methods within passive architecture	Case studies, interviews with architects and literature study	Analyze elements climate systems based on price, purpose and effectiveness and add them to the catalog	Used systems: Use of more insulation, sun shades, green, etc.
What elements can compose a climate system for a modular building?	Data about climate systems in modular buildings, data about flexibility of the systems	Case studies, interviews with architects and literature study	Analyze elements climate systems based on flexibility, is flexibility easier achievable as a single element or as a whole system	Flexibility: Easiest to achieve with climate system pods that can be moved
What are the most expensive elements of a climate system and how can we make them more affordable/prevent using them?	Data about the costs, effectiveness and function of the climate elements (retrieved with first two sub-questions)	Sub questions 1 and 2 and literature study	Analyze elements based on ways to prevent using them or making them more affordable	Ideas: Using more passive solutions than active solutions, splitting machines between different habitations, etc.

Research Structure (own work, 2021)