Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences
Graduation Plan: All tracks
The graduation plan consists of at least the following data/segments:

### Personal information

<table>
<thead>
<tr>
<th>Name</th>
<th>Anne Leeuw</th>
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<tbody>
<tr>
<td>Student number</td>
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### Studio

<table>
<thead>
<tr>
<th>Name / Theme</th>
<th>Building Technology / Energy producing facades for high rise</th>
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<tbody>
<tr>
<td>Teachers / tutors</td>
<td>Prof. Dr. Ir. Andy van den Dobbelsteen</td>
</tr>
<tr>
<td></td>
<td>Ir. Arie Bergsma</td>
</tr>
<tr>
<td>Argumentation of choice of the studio</td>
<td>I followed the Building Technology master track focusing mostly on sustainable climate concepts and façade technology. During the SWAT-project I got interested in effects on an urban scale, so that further motivated the choice for this track and a focus on climate and façade design.</td>
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### Graduation project

<table>
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<tr>
<th>Title of the graduation project</th>
<th>Energy envelopes for high rise.</th>
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### Goal

<table>
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<tr>
<th>Location:</th>
<th>Rotterdam &amp; Temperate climate zone</th>
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<tr>
<td>The posed problem,</td>
<td>Energy consumption is on the rise and cities are growing. Energy consumption is correlated with economic activity, transport costs, geographic factors and urban form. Cities provide a dense living environment that offers certain advantages over wide spread town structures. 40% of energy consumption is used within buildings and construction. So this part is less directly influenced by the above mentioned factors. The Kyoto protocol, drafted in 1997, requires all participants to reduce their greenhouse gas emissions to 20% below the emission of greenhouse gasses in 1990. Reducing energy consumption is a large part of that. Policymakers of participating countries set new regulations for all energy consuming sectors, also for the built environment. The European Union has anticipated by requiring all new buildings to be nearly zero energy by December 31st of 2020. New building methods and effective renovation strategies have already proven to work, but they remain limited to reducing energy consumption. The nearly zero energy building stock needs to keep increasing, so it cannot only be about new buildings. Zero energy buildings and positive energy buildings will be the standard requirement in a few decades. This means that the buildings need to produce energy to compensate for their consumption. Buildings provide surface area usable for renewables-based energy production. In the year 2015 we still rely mostly on fossil fuels for heat and electricity generation. That needs to change, sooner rather than later, because the earth is running out of fossil fuels. Solar powered electricity has the fastest growing share in the</td>
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total energy production, although it only accounts for 2% of the total energy production right now, it has the most potential of all types of energy production. We see solar energy (electricity and thermal) used more and more on low rise buildings. In cities however, especially in historic city centres in Europe, applying solar energy systems is not always an option. This is where the potential of high rise comes forward. High rise is a building typology strongly related to urbanity. In European cities where low rise is the main building typology, the verticality of singular high rise can be utilised to generate energy in a number of ways. It could become a farm for bio-gas and oils with an algae-plant, solar thermal collectors might be integrated to provide heat and warm tap water to the buildings itself and the surrounding buildings. Photovoltaic cells can provide electricity, especially further away from the equator where the sun’s angle is closer to vertical than horizontal.

High-rise buildings tend to consume more energy than low rise buildings. It needs pumps and vents to distribute air and water around the building. High-rise has a relatively small roof area compared to low rise buildings. Where low-rise buildings (of up to 6 stories) can cover the roof with photovoltaic panels and thermal collectors to compensate its energy usage, high-rise cannot. According to a study conducted by Engineering firm Arup(2012) a 12 story office building, built with passive strategies cannot become zero net energy. What the study doesn’t take into account is that high-rise buildings have large facade areas which are underutilized.

Research questions and

Research question
The vertical surfaces of high rise are underutilized. Many articles about energy consumption of high rise can be found and about low energy building strategies, but research seems to focus less on energy production on facades. The research question for this thesis is:

“How can high rise envelopes be used for energy production within urban areas?”

Sub research questions
The research focusses on three main topics: High rise, façade systems and (urban) energy-cycles, from production to distribution and storage.

High Rise
1. What is the role of high rise in urban areas now and in the future?
2. What height classifies as high rise?
3. How much energy does a high rise building consume and for what uses?
4. What are design strategies for low energy high rise?
5. How is the indoor climate controlled in low energy high rise?
6. Besides design, what other factors influence energy consumption in high rise?
<table>
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<th>Design assignment in which these results</th>
<th>Literature review Test models for different energy production methods and a final redesign of the envelope of the Rotterdam tower.</th>
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<tbody>
<tr>
<td>Literature review to answer the first questions and to formulate criteria for models that test the potential of differ energy systems. Test models for different energy production methods and a final redesign of the envelope of the Rotterdam tower.</td>
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**Method description**

The general approach to reach the objective is by starting with a literature review to answer the research questions. Than models are built to test propositions that form from the literature and new assumptions. Through an iterative design process the energy envelopes are optimized. The models will provide input for a redesign proposition for the façade of the Rotterdam, located in Rotterdam, the Netherlands. A building within a mostly low rise city with a relatively high density.

1. **Literature review**
   - The literature review is phase 1 of the research project and answers most of the sub-research questions first. The literature review provides a diving board for the model building phase.
   - The literature review furthermore contains a summary of case studies into low energy building strategies for high rise in order to formulate criteria for the low energy building model. This means the model criteria do not follow building decrees, but look to meet the best achievable values to minimize the energy use intensity.
   - Another look into case studies involves a summary of the renewables-based systems that are already implemented in high rise or have working principles similar to which they may have when implemented into high rise envelopes.

2. **Low Energy Building model (LEB) using DesignBuilder**
The low energy building model is used to project the envelope onto. The aim for the LEB is to have the lowest possible energy use intensity (EUI). The EUI is expressed in kWh/m², as is the production potential of different renewables-based production systems. This model will be built in DesignBuilder. This software lets users build a model that contains information about building physics, building installations, occupancy and more. The input-criteria for the HVAC-systems, occupancy and activities will be based on the studied buildings from the literature review. Input for DesignBuilder aims at high indoor climate comfort, which should at least meet current NEN-standards.

3. **Envelope model building using Rhinoceros, Grasshopper, Ladybug & Honeybee, ClimateConsultant.**

The energy envelopes (models E1 – E5) will be modelled within Rhinoceros and the plugins Grasshopper, Ladybug and Honeybee and Kangaroo. This plugins allow the input of climate files from EnergyPlus. All envelopes will be designed using the Amsterdam climate data, because there is no specific file for Rotterdam, but both lay within the temperate climate zone. Using the weather data as input for Ladybug and Honeybee, irradiation hemispheres are projected onto the model. Kangaroo provides wind-data and modelling, used for the wind powered envelope.

4. **Redesign for the envelope of the Rotterdam**

Assumptions will be made on the energy use based on the LEB and case study review from phase 1. The Envelope will be remade in Rhinoceros of drawings (sections and floor plans) of the Rotterdam. The envelope design will be created with Rhinoceros and grasshopper and tested in the same way as E1-E5.
Literature and general practical preference
This list provides the main literature to be studied, or already read for this thesis. The full list is already a lot longer, but these are the main articles and center of focus articles.
High Rise


Facade systems

- ...

Urban energy production

- ...

Urban energy distribution & storage

- ...

Software input help/validation:


Reflection

Relevance

Scientific Relevance

By researching the ways in which tall structures can contribute to the urban energy system, designers and policymakers are given an incentive to incorporate energy production in their designs. Developing
energy facades is only useful when the high rise is energy efficient by itself. Otherwise, the impact could never be compensated. It is thus important to also show the current state of low energy building for high rise. When the European Union and the Kyoto protocol ask for a zero energy built environment, it must be feasible to build zero-energy high rise. Otherwise, high rise cannot be a part of the future built environment, although it offers advantages over solely low-rise urban areas.

**Social relevance**
Fossil fuels are running out fast. Without the discovery of new oil and gas bubbles these resources will run out in between one to two human lifetimes. That means we need to transpose our energy resources to renewables. We cannot depend on the fossil fuels in the future so energy technology needs fields for testing and research. Since most people will live in urban areas in the future, the implementation of renewable energy generation in these areas makes sense. With development of smart grids, which look to share and transport energy more efficiently (and thus over shorter distances) it makes even more sense to generate energy on the sites where we live or work.

**Ecological relevance**
High rise puts pressure on the environment in a number of ways. It affects the climate conditions around the building. Its shape affects wind flows and creates shadows. All construction materials have a specific embodied energy. The production and transportation to the building site add to the environmental impact of the building. During construction, waste is produced. Waste materials, but also waste energy. When a construction is finished, it keeps using energy. It is already proven that low rise buildings can be energy positive, so they can compensate for the energy used in construction and use phase. While high rise office towers have been found impossible to become zero-net energy, that doesn’t mean its surfaces shouldn’t be designed to mitigate its energy use. Especially when the building is not in use 24/7. The energy generated when the building is not in use, can benefit the surrounding area. With local production of clean energy, air pollution from fuel combustion will decrease.

When the temperature rises by 2 degrees Celsius compared to that of the pre-industrial era climate change will have strong consequences. By providing clean renewable energy, greenhouse gas emissions can be reduced.

**Time planning**
I have all finished all prior courses to the graduation preparation. The planning contains the phases mentioned in the approach and methodology scheme. P3 and P4 are indicated by the vertical black lines with P3 and P4 at the bottom. All elements show some overlap to incorporate delays or iterations.