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	Stephanie Moumdjian
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Studio		
Name / Theme	Building Technology: Optimization of High-Rise Design	
Main mentor	Michela Turin	Computational Design
Second mentor	Regina Bokel	Climate Design
Argumentation of choice of the studio	The motive of this studio is related to the author's interest in the computational field of the architectural design and the investigation of the optimization advantages to solve a multi-objective problem, with the outcome of learning new methods and tools to improve my skills in this field of study. Facing the relevance and urgency of climate matters related to architecture and specifically, under the on-going discussion and complaints towards the new BENG regulations starting in 2020, the subject chosen investigates the constraints that are faced in the built environment from a technological aspects, and how can simulation and optimization validate and justify the requirements.	

Graduation project	
Title of the graduation project	Computational design analysis of height scenarios in residential high-rise under BENG 2020.
Goal	
Location:	The Netherlands
The posed problem,	The high-rise typology is a potential solution that can respond to the insufficient supply of the housing market in the Netherlands due to horizontal land conservation and management. For sustainability initiatives, and, under the urge to control the lifecycle of the building sector, the BENG regulations have been

	implemented, and will be applied to all new constructions as of 1st July 2020. Achieving high-rise of significant height is linked to high-energy consumption. As a result, BENG regulations seem to be a constraint in the construction of a residential high-rise in the Netherlands. Thus, this problem requires the investigation on the performance of a residential high-rise in the Netherlands under BENG 2020 regulations.
research questions and	Based on computational optimization, to which extent are BENG regulations a constraint to the construction of a residential high-rise in the Netherlands, and eventually what amendments can be proposed to adapt the desired height to the performance? Sub-questions will help answer this question and reach the goal: Where does the limit in height increment of a residential high-rise stand until the BENG regulations are no longer satisfied? Then, which of the 3 BENG regulations is responsible for this limitation in the height increment? How does the energy performance of the residential high-rise vary in relation to addition of floors, and how does it affect the BENG indicators? What amendments can be proposed to improve the BENG regulations to achieve the desired high-rise height?
design assignment in which these result.	By the end of this study, the following objectives will be achieved: 1. Design guidelines of the early design geometry and façade parameters derived from the optimization results of a conceptual study of a residential high-rise in the Netherlands, under the BENG 2020 regulations. 2. Integrated workflow of the parametric design variables, the height increment and the energy performance (demand and generation) for a nearly Zero Energy (nZEB) residential high-rise in the Netherlands. 3. Assessment of the maximum height of a residential high-rise, in the temperate climate of the Netherlands that can satisfy the BENG 2020. 4. Establish the relation between the 3 BENG indicators and the energy performance in parallel to the variation of residential high-rise's height increment and the design parameters.

Process

Method description

Aiming for a nearly zero energy, with high efficiency performance, of a residential high-rise requires numerous design decisions. Those factors are partly related to the early design stage, while the other are specific to the external envelope of the building. Altogether, these parameters provide passive design solutions, as well as active, where the change in one's variable affects the other's performance. To conduct this study, the methodology applied is based on several steps.

First, the context of the research is analyzed to define the problem statement and the main research question with its sub-questions. Part of the literature review extracted from governmental data and official letter, and conference paper, highlights the nZEB and BENG 2020 regulations to be applied in the Netherlands. To a larger extent, those principles are investigated in regard to tall buildings that demand high energy consumption. With additional background information, the current situation of the housing sector demand and supply led to deepen the focus on the residential sector, specifically to high-rise apartments.

Following, from the Dutch building decree RVO, and from international conference, journal papers and regulations, the referential apartment plan layout used in the Netherlands is selected, as well as the target height and floor numbers of the high-rise are defined according to its skyline to conduct the application phase of this research.

Prior to selecting parameters, climatic factors are analyzed from peer reviewed journal papers and academic research projects in order to establish a relationship between the design parameters that should be evaluated and their impact on the performance of a high-rise. In relevance to this study, part of the parameters selected are related to the early design stage and some others to the building facade. To define the parameters bounds to assess, the range of each variable, benchmarks and limits are derived according to background information, the Dutch building regulations Bouwbesluit as well as the user's comfort.

In order to proceed with the application phase, the software and plug-ins are selected according to the need of this research regarding the integration of the building geometry, multiple parameters variables and simulation data, as well as the optimization process. Following, the computational phase is conducted by setting up the integrated workflow that consists of several parts from which the parametric modeling, the energy simulation, the design exploration and the optimization. The parametric modeling of the high-rise provides a control of the number of floors to consider for different heights of the building providing instant results when evaluating the variation of parameters in parallel to the energy performance, user's comfort and BENG regulations.

In the first part of the optimization research, the early design stage parameters are evaluated according to the outputs of energy performance, BENG regulations and comfort level, on the total high-rise height. The inputs involve the geometry of the building regarding the compactness (shape factor) and the orientation from the North axis. The results are analyzed to assess the impact of the geometry and orientation in relation to the 3 BENG indicators. The conclusion will serve as guidance information in the analysis of the following phase of this study with the façade optimization.

In the second phase, the envelope parameters are assessed from which the window to wall ratio, glazing types, shading systems and energy generating system. The parameters variables are tested according to the target height of the residential high-rise in regard of the BENG requirements and the user's comfort. For the parametric modeling of this phase, the total high-rise geometry is divided into several zones, regrouping categories of lower, middle and upper floors together. Each façade is modeled independently regarding its orientation, for additional control by floor level, to reach optimal results per facade at the given floor level. This strategy allows the adaptation of the height to the changing micro-climate conditions regarding temperature, daylight and wind speed, as well as reaching solutions within the time frame of the study.

The provided results are interpreted according to the regulations. The outcome will define whether the 3 BENG requirements can be satisfied or not. If the goal is achieved, a conclusion will be drawn accordingly. Otherwise, in the case of non-compliance, the regulations that are not met will be identified to the height level of the high-rise depicting the limit that can be reached up to which the BENG regulations are satisfied. Above those limits, amendments are proposed in areas where the current regulations, as formulated, could be revised to not become a constraint in the design of a residential high-rise.

The computational design is based on the use of Grasshopper in Rhino v6, with the additional energy simulating plug-ins of Honey-bee and Ladybug. Other integrated platforms are employed to extract energy data such as Energyplus for energy consumption in heating, cooling and ventilation. Daysim is a Radiance-based platform that is used for annual daylight illuminance analysis and electric lighting energy use. The use of OpenStudio will allow a total integration of the building energy from Energyplus and Radiance.
As for the exploration and optimization of results, modeFRONTIERv2019 extracts data from the Grasshopper workflow and internalizes the inputs, outputs and other boundaries of the parameters. All the resulting data are collected under this single platform required for the complexity of multi-objective optimization. The results are then evaluated and analyzed to reach an optimal spot area of the entire design space.

The outcome of the optimization is to develop the guidelines based on the relationship between the early design stage, the façade parameters and the height increment according to the BENG 2020 regulations in the temperate climate of the Netherlands.

Literature and general practical preference

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Reflection

The multi-objective optimization of a residential high-rise under many constraints from the regulations, the user's comfort and the environmental factors requires the implementation and application of the new information acquired during this master study.

First, the computational design phase requires further more complexity of the integrated workflow for the simulation and the optimization, as well as the use of the parametric modeling for the control of design parameters.

In addition, the climatic design knowledge is applied from the beginning of this research in the literature review, until the reach of the optimal design solution where all the results will be evaluated. Data relevant to the user's comfort, the energy performance as well as the passive and active design are supported by the climate course knowledge.
As for the selection of the parameters, some of the façade design information are implemented in the optimization with an integration of climatic weather data.

Altogether, many aspects of the building technology are interrelated to each other's in this research, allowing a deeper understanding of the influence of a building's parameters on the energy performance and the user's requirements.

Societal Relevance

The building sector is responsible for 40% of the global energy consumption. An exponential increase of the demand and supply of the housing market will lead to a growth in number which underlines a greater impact on the environment.

Many countries around the world are reconsidering the laws and regulations to minimize the impact of the building sector. In the Netherlands, starting from 2020, new regulations known as BENG are implemented to control the energy performance and consumption of buildings.
Currently, aiming for tall structure in the Netherlands should be reconsidered. Building vertically can provide a larger amount of accommodation for similar land area compared to a horizontal skyline.

This study investigates the possibility to reach a residential high-rise with significant height in respect to the energy saving that leads to minimizing environmental impact, while satisfying the user's comfort.

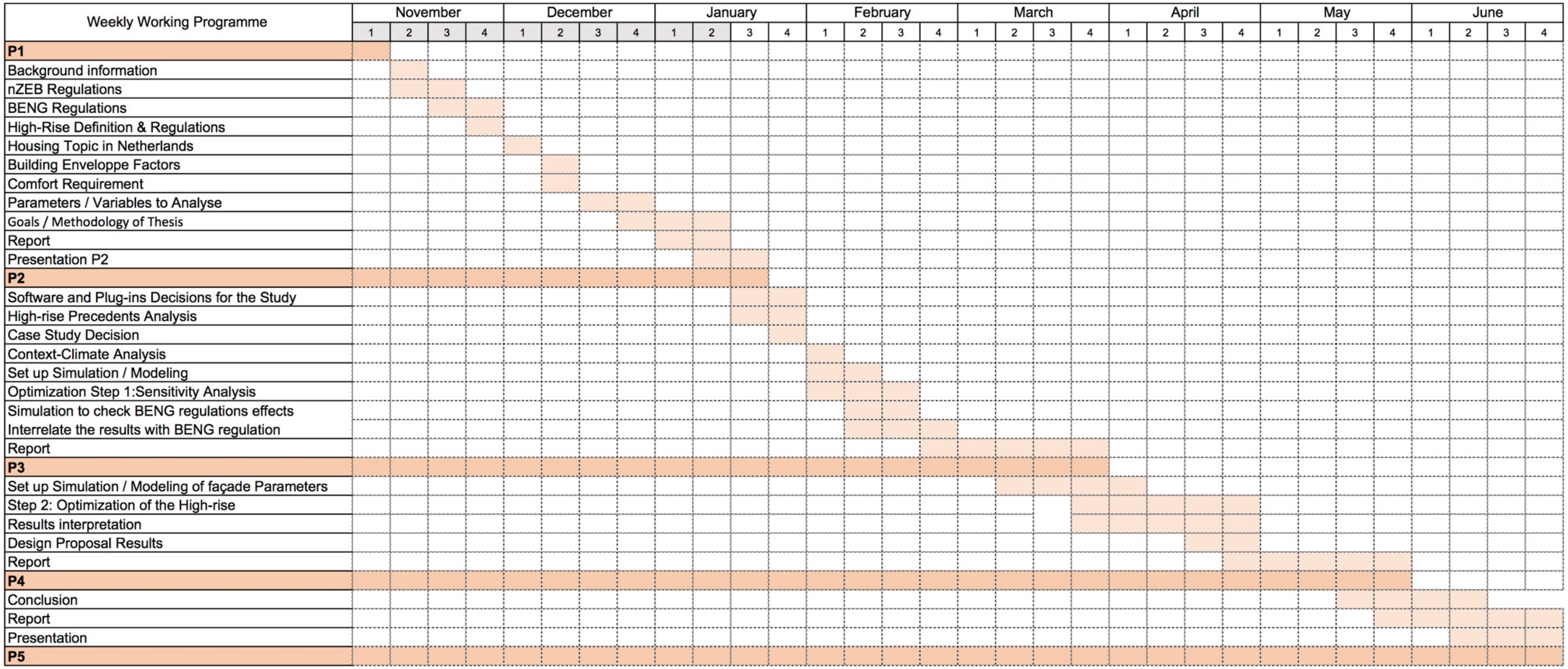
Scientific Relevance

Facing the new BENG 2020 regulations, many constraints occur to the control of the energy consumption and its limitation on achieving a residential high-rise design of significant height. In fact, the higher the structure, the greater its energy expanse and its impact on the environment.

The planning of a building requires specific design decision taking. Some of the parameters involve early design stage factors, while the other part tackles the external enclosure; from which the geometry, compactness ratio, orientation, glazing ratio and glazing type, material properties, shading system and energy generating system.
Facing the numerous variables each of these parameters can translate into, the complexity turns into an obstacle to balance between the target height, the passive and active solution, the indoor comfort and the life cycle energy of the building.

The integrated workflow relates the effect of addition of floors in tall buildings and their performance to reduce the energy demand while maximizing the energy production.
Aiming for nearly-zero energy high-rise, the outcome of the optimization will provide architects, designers, consultants and clients a gap filling knowledge of the relationship between the building's parameters, their impacts on one another, as well as their effect on the energy performance.

Computational tools in this case give access to simulate, visualize, analyze and compare the multi-objective design goals under a single design space in less time. Therefore, for a numerous variables of the inputs, all different combinations can be assessed to reach near-optimal solutions, according to a given objective.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