# REFLECTION

## COMPUTATIONAL OPTIMIZATION FOR THE FACADE DESIGN OF A NEARLY ZERO-ENERGY HIGH – RISE OFFICE BUILDING IN THE TEMPERATE CLIMATE

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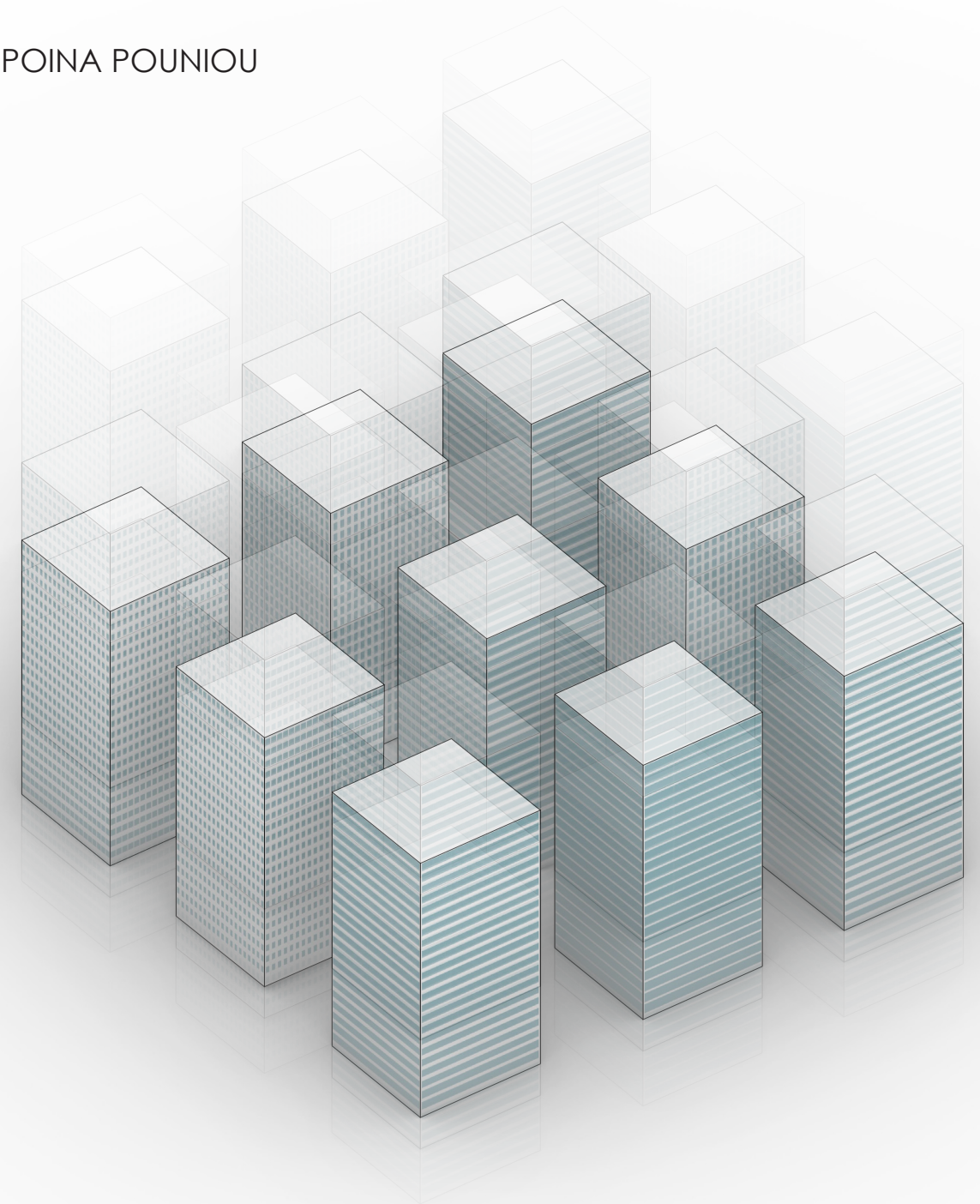

Master Thesis
Delft University of Technology

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## COMPUTATIONAL OPTIMIZATION FOR THE FACADE DESIGN OF A NEARLY ZERO-ENERGY HIGH – RISE OFFICE BUILDING IN THE TEMPERATE CLIMATE

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MSc Building Technology
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27 June 2019

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The objective of the research is to establish guidelines, for early design stages, for the façade design of a nearly Zero – Energy high rise office building in the temperate climate, supported by computational optimization. Based on the results of the optimization, façade design proposals for a reference building are suggested. Within this scope, a methodology is also developed that allows the parametric design and the energy performance evaluation of different façade design alternatives of that type of buildings in the temperate climate.

The research methodology is structured in the following stages:

-Background research
-Determine research question and sub-questions
-Literature review
-Energy Simulation in Grasshopper (Honeybee)
-Design exploration and optimization in ModeFrontier
-Develop façade design proposals for a relevant case study
-Establish guidelines
-Conclusions

**Planning**

The literature review was based on research for four main categories: nearly Zero-Energy buildings (nZEBs), energy-efficient high-rise precedents, façade design considerations and computational optimization. Regulations and initiatives for nZEBs around the world were analyzed. More specifically, regulations for energy-efficient buildings in the Netherlands (BENG and the NVBV Handbook), as well as regulations for the thermal comfort of occupants set the base in order to define the range of the variables of different design façade aspects to be tested in the optimization process.

The review of energy-efficient high-rise office precedents suggested common design strategies to be followed for nearly Zero-Energy high-rises for that climate. The analysis of the examples highlighted the fact that the multi-disciplinary character of nZEBs requires the investigation of many more aspects, for example natural ventilation strategies, such as the use of atria, and efficient HVAC systems. However, due to time restrictions, the research focused on the optimization of façade design parameters.

Additionally, regarding computational optimization, the concepts of optimization and design exploration were analyzed. That analysis gave insight to the post-processing of the results, as the aim of the research is not only to find the best performing designs, but also to understand the effect of the different façade design parameters on the energy performance.

**Process**

The study used the research through design methodology. A reference building was used for the simulation and the optimization process. The set-up of the parametric modeling was done in Rhino, Grasshopper (GH) and for the performance evaluation of the alternatives, the plug-ins Ladybug and Honeybee were used. The latter tools are a part of a constantly developing open source, and their developers have created an online forum, supported by researchers and

designers worldwide. The participation to the forum and the review of similar current researches were helpful for the set-up of the simulation process. However, these tools are still under development, and therefore unforeseen restrictions were encountered during the simulation set-up. For example, the dynamic shading could not be incorporated in the optimization process as planned, since daylight simulations with auto-dimming of the lighting were not fully integrated within the energy simulation, at the time that the research was conducted. Also, Honeybee (HB) has limitations in the way one can define the specifications of an HVAC system. For that reason, the mentors suggested the evaluation of the workflow developed in Honeybee, comparing the results with the results obtained from a well-established programme: DesignBuilder. The two programmes indicate a similar trend regarding the energy performance of the two tested designs. A small difference was found between the numeric values though. However, the difference in the simulation results was thought to be acceptable, considering that the aim of the research is a comparative study between design alternatives, in early design stages. Therefore, in that context, the accuracy of the results obtained from the workflow in HB was considered to be sufficient.

After the optimization run and the results were obtained, the guidelines for the façade design of a nearly zero – energy high rise office building in the temperate climate were defined. A great restriction is that the guidelines correspond to a specific building type: the reference building is a free-standing building, with an open-office layout. The building has also BIPV panels with high efficiency in all orientations and it uses a mixed-mode ventilation system. However, following the methodology of the study, the designer can test different inputs and variables, according to preference, extract information and establish guidelines for other cases.

**Relation with the professional framework**

The workflow that is developed within the scope of that research allows designers/engineers design parametrically, assess the energy and thermal comfort related performance of the alternatives, and optimize different façade design parameters for high-rise nZEBs in the temperate climate. The definition that is developed can be modified and extended, in order to meet the demands for low-rise buildings, other types of buildings (e.g. residential buildings), and even other climates. Furthermore, two suggestions for potential use-cases of the workflow are made, as they are expected to have great applicability to the professional framework these days. First of all, it is recommended to test specific products of the market, including cost, and secondly, to incorporate the urban context in the script.

**Relation with the wider social framework**

The aim for conducting the research for high-rise nZEBs is to contribute to an energy-efficient built environment, in order to offer a livable environment to occupants, and also to minimize the impact of human activity on the planet. More specifically, the background research shows that high-rise buildings are one of the most sustainable solutions to accommodate the expected urban growth in urban areas worldwide in the coming future. In respect to international policies for nZEBs, guidelines for the façade design of high-rises in the temperate climate could be a great shift towards sustainable high-rises, with high levels of energy efficiency and indoor comfort.

Furthermore, the lack of a commonly accepted definition of the concept of nZEBs in the global

community, and the fact that regulations for nZEBs are still changing show the complexity of the subject. Since the research is restricted to the temperate climate, with focus on the Netherlands, research for regulations in the Netherlands, BENG, was conducted. The BENG regulations are still changing, as the aim is to meet the energy requirements set by Europe, and also make a smooth transition towards nZEBs. The last indicates that the determination of regulations for nZEBs is a work in progress, and therefore relevant research would support such efforts.

**Conclusions**

The optimal designs derived from the optimization comply with the BENG requirements, showing that the goal for nearly zero-energy high-rise office buildings is feasible. It should be noted that the nearby buildings are not taken into account in the simulations, which is expected to have a great effect on the energy generated. What is more, the study focuses on the optimization of façade design parameters. Towards the potential for zero-energy or energy-positive high-rise buildings, an holistic approach according to regulations should be followed. Design strategies such as dynamic shading, an improved building management system and natural ventilation strategies could minimize the energy demand of the building. Specifically for offices, more efficient equipment should be applied, in order to minimize the high internal heat gains. Regarding renewable energy, the study highlights the great potential of using the extended facade area of high-rises for the production of energy. However, within a dense urban environment, the energy generated from the PV panels is expected to be insufficient to meet the set goal, and therefore potentials for off-site energy production should be considered.