Reflection
zero energy potential of a high-rise office building
in a hot-dry mediterranean climate

Evangelia-Despoina Giouri-4513207

Mentors:
dr. ir. arch. Martin Tenpierik
dr. Msc arch. Michela Turrin

Aim of this research is to define the extent to which a high-rise office building in the hot-dry climate of Athens, Greece can be a zero energy building (ZEB). Within this scope, the most effective combination of parameters and the most influential design and construction parameters need to be established for the design of a high-rise office building in Athens, Greece.

The realized research within this thesis was divided into the following steps:

1. Background research
2. Shape optimization within Design Builder
3. Orientation optimization within Design Builder
4. Envelope, HVAC and energy generation optimization in Grasshopper coupled with modeFRONTIER
5. Comparison of results
6. Establishing guidelines for the design of a reduced energy-consuming high-rise office building.
7. Conclusions and discussion.

Planning
The background research is based on literature review. The review on environmental problems related to buildings and precedent analysis of low-energy consuming high-rise office buildings built in temperate climates helped to define the strategies towards optimizing elements of the building that can potentially have high influence in energy consumption. The review showed the limitations of passive and active strategies towards creating a nearly zero-energy building. These limitations are reflected also in the built precedents and indicate the difficulties of designing a zero-energy high-rise building.

Through the literature review, it is evident that legislation and regulations towards zero-energy buildings do not yet guarantee the design of nearly-zero energy buildings, especially referring to the national standards of Greece.

The review on previous optimization studies of energy performance optimization of buildings served as a reference for the settings and limits of the optimization processes that can be realized within a restricted time span and within the scope of a master thesis in an academic environment.
**Process**
The transition from the literature research to the experimental phase of the thesis was marked with unforeseen restrictions.

For the shape and orientation optimization in Design Builder 4 different shapes were evaluated with a transition from a more elongated shape, to a more compact one. The transition between shapes was not realized with more steps, since realistic floor plan depths and core sizes served as a limitation.

The envelope and HVAC optimization was implemented in Grasshopper with energy simulations run by EnergyPlus. This software restricts the optimization on HVAC systems and due to long calculation times, simplifications needed to be made in the building model and in the number of design and construction variables.

Moreover, due to time restrictions, the accuracy of the simulations was compromised, although within the scale of this research the final outcome might not have been altered.

Additionally, more in depth knowledge on setting the appropriate optimization algorithms in modeFRONTIER could potentially lead to reduced time spent on the optimization procedure.

The number of different designs generated from the coupling of Grasshopper and modeFRONTIER was restricted by limitations in the connection between the 2 software.

Discrepancies between the results of Grasshopper and Design Builder are mainly attributed to the limited possibilities in the setting of the former aforementioned software.

Establishing guidelines for the design of a high-rise office building derive from the results of the optimization process. Nevertheless, due to simplifications made in order to drastically reduce the energy and daylight simulation time, more time and computing power would be needed in order to achieve more accurate results for high-rise buildings, including the surroundings of the building.

**Relevance to the wider social context**
The increasing urbanization and the need for more sustainable urban systems are issues that are of the utmost importance for future strategic plans and policies. Strategies for a zero-energy building in a hot-dry climate like in Athens, could pave the way for policy improvement on ZEBs in similar climates not only in Greece, but also in other countries where similar climatic conditions are applicable.

Furthermore, literature review shows that multi-objective optimizations of energy-consumption and thermal comfort that could lead to potentially more energy efficient buildings and especially high-rise buildings are currently not widely implemented. This methodology of defining, optimizing and evaluating the various parameters of designing and constructing a high-rise office building, could also be a reference for further applications in similar climates in different countries of Europe.

**Conclusions**
From the literature stage of this thesis it became apparent that building energy performance optimization is not enough to achieve a nearly zero energy high-rise office building according to the European standards. Apart from optimizing certain design and construction parameters of a building, reducing the energy consumption in a building while maintaining a high comfort level in this climate,
would mean better exploitation of natural ventilation, more energy generation from on and off-site generation systems, further optimization of the facade elements according to their direction and position on the building and use of adaptive systems for shading or cooling that could be sensitive to the environmental change. Nevertheless, through the optimization it became apparent which building elements have the highest influence in the building energy consumption and this could serve as information for further research on improving these aspects.