Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences
Graduation Plan: All tracks

The graduation plan consists of at least the following data/segments:

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In 2012, commercial and residential sectors represented 19.9% and 16.9% of total final consumption (TFC), respectively. Natural gas is the main source of energy in both sectors combined (63.7%), as almost all households and commercial buildings use gas for heating, followed by electricity (26.8%) and heat (4.8%) (IEA, 2014).
Resulting in heavy fossil fuel consumption and CO\textsubscript{2} release in built environment to generate living conditions for the people. However, 90\% of the building stock existing today (2016) will still exist by 2050. The European government leaders in the European Council set a target of greenhouse gas emissions in the EU by 2050, 80 to 95\% lower than in 1990 (Klimaatbrief 2050, 2011). In order to comply with the European ambitions, transition to renewable energy generation or preservation of the generated energy must be prioritized and energy refurbishment of 150,000 buildings a year has to be completed.

In order to reduce energy consumption in the first place it is necessary to renovate dwellings energy efficiently or in energy neutral ways while increasing the renewable energy shares. There are certain pathways for renovation based on shallow and deep approaches. However reduction of energy is never enough and buildings must generate their own renewable energy to compensate for the remaining energy consumption, while increasing their share in total renewable energy percentage.

Refurbishment is a necessity for poorly performing buildings but not only for energy consumption reduction purposes. By greening existing buildings there can be savings in energy, water and waste expenses, but also in “soft” benefits like health, comfort, productivity of occupants, enhances marketing and public relations, risk mitigation, improved recruitment and retention and greater employee morale (Yudelson, 2009). Eventually refurbishment can equally focus on comfort and energy. Resulting in multiple improvements by single intervention. Helping with physical and physiological condition of people and the buildings.

While most of the efforts are focusing on only retrofitting the building typologies and generating electricity on the rooftops or on the footprint of the building, energy generation potentials of the surroundings of the buildings are neglected for achieving actual Energy Neutral buildings as a cluster. Considering that the Netherlands has to reach 14\% renewable energy sources in 2020 and 23\% in 2023 from 6\% in 2012, it is important to consider energy neutral urban clusters to reach expectations consistently. Therefore ‘on-site’ must be redefined in order to compensate for a total solution on energy neutrality of buildings in a cluster where all of the buildings are offered optimal chances of energy.
generation and energy storage regardless of their geo-location, sun exposure of their roofs or their limited spaces in privately defined borders. Eventually reducing unchangeable parameters in refurbishment designs for renewable energy sources to minimum, as well as reducing the inevitable extra electricity load on national grids caused by privately owned photovoltaic panels.

**Main Research Question**

What are possible refurbishment solutions for a cluster of Dutch row houses in Haarlem, Ramplaankwartier built before 1945 to achieve annual energy neutrality including energy generation and energy exchange within the selected cluster?

**Sub- Research Questions**

How to refurbish a Dutch terraced house into energy neutral building, focusing on optimal indoor environmental comfort with passive and active refurbishment measures, following the new stepped strategy?

How to apply the refurbishment strategy to a cluster of terraced houses to achieve annual energy neutrality in buildings based on on-site renewable energy potentials in Haarlem?

The design objective and the outcome of the thesis will be to successfully refurbish a dwelling cluster based on the same typology. Not only to refurbish and reduce energy consumption but also to make them energy neutral focusing on their daily and yearly energy balance and increase indoors environmental comfort. Energy neutrality of buildings will be achieved by near-by renewable energy potentials by generation, storage and exchange following the New Stepped Strategy for clusters. Therefore creating smart urban clusters with minimized energy dependency on national grid.

**Process**

**Method description**

Research methodology, defines the process of how research questions will be answered and how design will reach intended goals in given time period. There are three sequential research phases following the introduction of the thesis. Introduction of the paper describes intentions, problem statement, research questions and research goals to be reached. These sequential research phases are:
- Literature Research
- Case Study Design
- Conclusion & Elaboration

The process in general resembles the design approach of the research. Considering that design decisions rely upon technical input gathered from extensive research on certain variables. Research is in with requirements, goals, design and simulations in a consistent relation of defined design steps further on in this chapter.

**Literature Research**

Literature study is split into three different main research topics. Theoretical background of these research topics forms the requirements and constraints regarding comfort and energy performance, possible refurbishment methods and design variables in a row house for optimizing energy performance and indoor comfort levels.

First topic of the literature study is zero energy building design definitions available globally and the ones mostly used in the Netherlands. Necessary parameters of defining zero energy design are discussed along with types of metric; periods of balance and energy efficiency measures for different types of approaches are evaluated. Hereafter, a conclusion is settled on the zero energy design definition of the thesis with necessary framework steps. Additional site studies will be conducted during case study design on on-site renewable energy potentials to balance energy consumption with generation and storage.

Second topic is about refurbishment of row houses, possibilities, strategies and design variables in refurbishments & examples in the Netherlands. Different levels of refurbishments will be discussed depending on their scale of intervention on the building. Possible refurbishment strategies for the buildings’ envelope will be researched and defined regarding applicability, intervention scale and the outcome of first phase of literature study. Several existing refurbishment projects in the Netherlands will be assessed for passive and active measure applications, refurbishment scales, strategies, energy efficiencies and design variables. These design variables are further defined in case study design and how they will be used as design parameters.

Third topic of literature study is focusing on the necessary indoor environmental comfort levels in a dwelling. Levels of comfort enforced by national standards are researched for setting requirements in a dwelling as design parameters. Thermal, acoustic, daylight comfort and indoor air quality of the dwellings are assessed regarding required values set by Dutch government for refurbishment projects. These values will be used for balancing energy consumption and assessing envelope strategy. More specifically the New Stepped Strategy is going to be followed. The conclusions from the New Stepped Strategy for refurbishment projects will be applied to the case study design phase.

Literature study is to use conclusions from each research topic to form the design
goals, requirements in dwellings and certain strategies that will be followed in order to reach specific sub goals and the main goal of annual and daily energy balance in a row house cluster.

**Case Study Design**

Case study design can be accepted as the design approach of this research paper. First step of the design approach will be based on case study analysis. This will be conducted in several steps. First, the context of the building regarding location, orientation and amount of similar buildings will be defined. Secondly, passive components defining thermal performance of the building will be listed such as: walls, roofs, windows and ground floor. Thirdly, heating and domestics heating water, cooling and ventilation systems will be assessed over type and efficiency. Fourth step will be the assessment of the building detailing and indoor environmental comfort of the users as well as to define possible measures for partial refurbishment. Last step is the validation of 3D model in Design Builder regarding consumption values previously provided. Minimum 90% accuracy of 3D model is required to proceed to the design step.

Second step of design approach is focusing on the refurbishment measures. Two different refurbishment strategies will be followed. These strategies are partial and total refurbishment. Partial refurbishment will be focusing on limited intervention on the building envelope as well as interior, regarding building services, in order to define the most realistic refurbishment approach for the dwelling. The energy outcome is directly affected by the existing situation, because the intervention will be limited to certain building components such as openings on the building skin and building services’ replacement. This approach will aim to reach 60%\(^1\) primary energy reduction in the building as minimum. Total refurbishment will target 75%\(^2\) total primary energy consumption reduction as minimum by allowing total replacement of passive and active measures in the dwelling. One façade strategy, from the conclusion of literature study on possible façade strategies, will be followed for total refurbishment.

Third step of the design approach includes, passive measures and their variables. Specifically, focusing on \(R_c\) values of Wall, Roof and Floor components, Thermal mass, Glazing type, Glazing to wall ratio of primary spaces, Shading, Air tightness, Infiltration, Natural ventilation in design builder simulations. These variables will be assessed for their energy efficiency, thickness of the total structure, feasibility and thermal, visual, acoustical comfort. Technical requirements for Wall, Roof, Floor, Glazing, Air tightness and infiltration variables will be selected from a range of minimum and maximum values defined by EPC 2015 (minimum) and Passive House standards (maximum) derived from literature study.

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1. 60% is based on energy savings offered by the Dutch Government to Row Houses built before 1945 as a nationwide savings option. [http://www.rvo.nl/sites/default/files/bijlagen/4.%20Brochure%20Voorbeeldwoningen%202011%20bestaande%20bouw.pdf page 37](http://www.rvo.nl/sites/default/files/bijlagen/4.%20Brochure%20Voorbeeldwoningen%202011%20bestaande%20bouw.pdf)

2. 75% is following the total primary energy reduction of De Kroeven refurbishment project for single dwelling.
Fourth step is focusing on active measures in the building in forms of Heating, Cooling and Mechanical Ventilation, Domestic Heated water and Artificial Lighting. However, artificial lighting will be included as average consumption in the Netherlands per person and will not be changed in simulations. Assessment of active measures will be added over to the conclusion from passive measures for reaching previously defined energy reduction targets in order to select the best option possible for each service. Certain assessment of active systems will be based on type of energy use, efficiency regarding energy type, overheating problems and feasibility in building footprint and space availability. Even though renewable energy generation is on the next step of design approach, active measures will be designed and considered in relation with possible energy options on-site. If energy reduction targets are not reached with concluded variables for passive and active measures, processes are going to be repeated and concluded with the best outcome in a week for proceeding to annual energy balance.

Fifth step of design approach is the annual balance of the buildings. To get valid total primary consumption value for all the houses, dwellings will be simulated in design builder regarding their orientation. If there is significant energy change, variables such as glazing type, glazing to wall ratio and shading will be optimized accordingly. However, if the research has to back track for meeting the target energy reductions; optimization of the cluster measurements will be neglected to compensate for the time. Annual energy in cluster of dwellings will be balanced by using on-site renewable energy potentials regarding energy generation and energy storage. The balance will be calculated in Excel considering conversional ratios of energy types, efficiencies of machinery and distributional losses. If the application is not feasible, design process will backtrack to passive and active measures step and execute further optimizations considering the outcome from renewable options.

The Final step is daily balance in buildings. This balance will be conducted for only total refurbishment strategies. For daily energy balancing it is more important to reduce indoor temperature fluctuations. The target is to restrict the values of temperatures between comfort zone without using active systems during extreme days of summer and winter. If this is not possible, the energy needed for keeping the temperature in between comfort levels should be provided by renewable energy sources or energy storage systems. The process will check if certain energy storage applications are possible to install in the building for achieving daily balance.

Conclusions & Elaboration

Conclusion and elaboration is the final phase of the methodology. Outcome from daily balance based on most promising results will be elaborated. During this phase conclusions on the whole design step outcomes will be made and graduation products will be fine-tuned.

Literature and general practical preference

Literature study will be based on gathering necessary information on ZEBs, energy
On Zero Energy Building:
- What is a ZEB building and how is it defined?
- What possible energy demand reduction definitions are available?
- Which calculable on-site solutions are considered for energy generation?

On Refurbishment:
- Why Refurbishment is required and how is it defined?
- What are the envelope refurbishment strategies for energy reduction?
- Which refurbishment measures can be adopted in order to reduce energy consumption in a building?
- What are the existing retrofit measures for Dutch Terraced Houses and what are their shortcomings and advantages?

On Energy and Comfort:
- What are the necessary Indoor Environmental Comfort (IEQ) requirements in a Dutch Dwelling based on the type of living spaces?
- What are the energy performance requirements of building services and building envelope in the Netherlands for building refurbishment?
- How to calculate optimum levels for comfort requirements?

On ZEB Calculation:
- How to calculate ZEB?
- Which options are available to tinker energy performance of buildings as software?

Reflection
Relevance
The aim of the research is to successfully refurbish a building cluster and make them Zero energy buildings, focusing on passive and active systems. However, the research wants to highlight the possibilities for energy neutrality for annual and daily balance in dwellings with what is available in close vicinity to utilize. In other words to generate energy efficient and interconnected building clusters for energy neutrality with reduced or eliminated dependency to the energy grid.