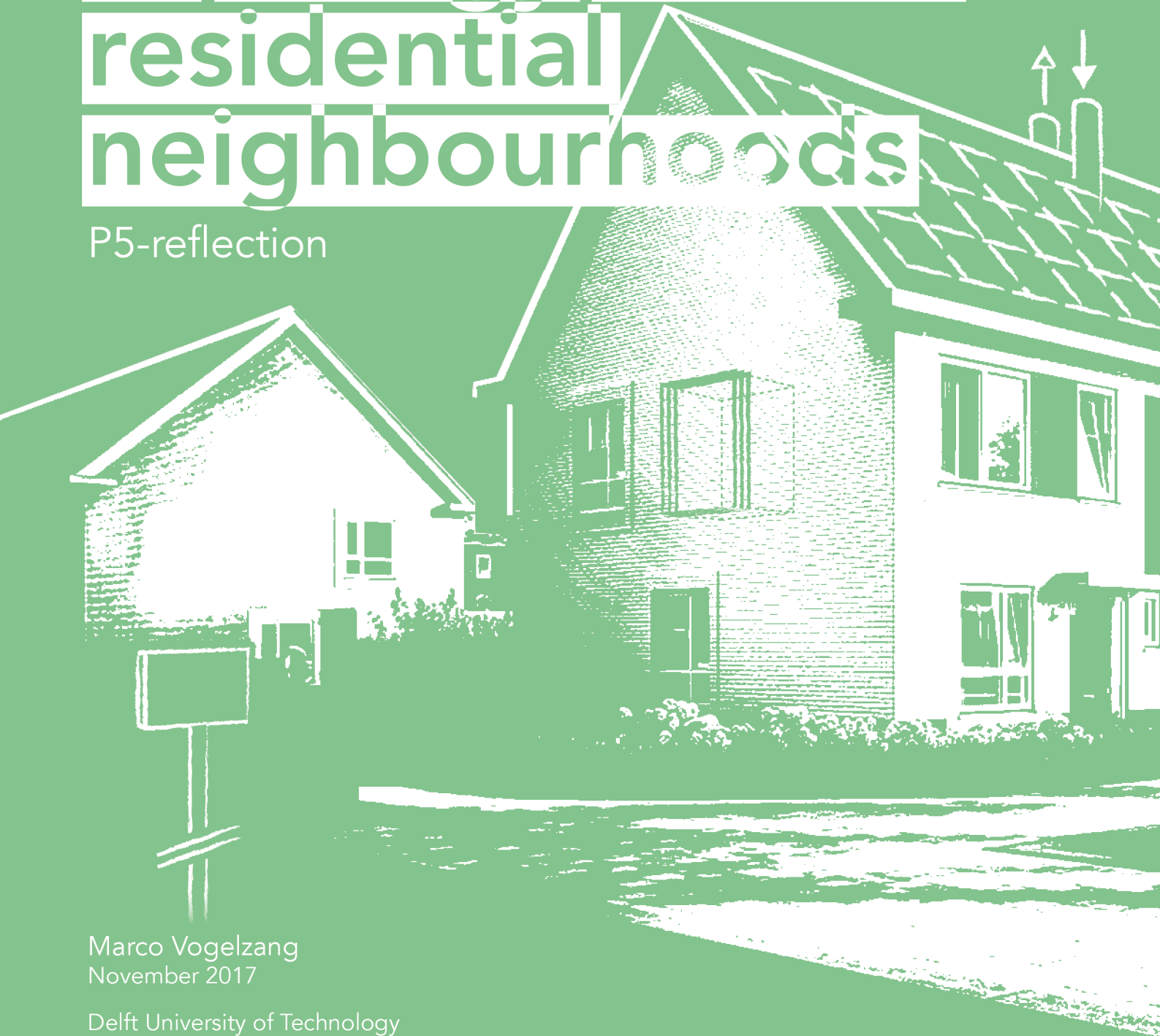# Business case optimisation for the development of energy neutral residential neighbourhoods

P5-reflection

Marco Vogelzang
November 2017

Delft University of Technology
Faculty of Architecture and the Built Environment
MSc Management in the Built Environment

Business case optimisation for the development of energy neutral residential neighbourhoods

Linear programming applied in a decision support tool
for business case optimisation of multi-actor decision-making processes
in the realization of energy neutral residential neighbourhoods
consisting of all-electric, single-family and owner-occupied dwellings
from the viewpoint of the real estate developer

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Introduction

Between February 2015 and November 2017, I have been conducting research for this master thesis. The topic is about optimisation of the business case of energy neutral residential neighbourhood development from the viewpoint of the real estate developer. As researcher, future decision maker in urban development and as engineer I have learned a lot during this research. This document reflects upon the research process and results.

The structure of the review is based upon Appendix 3 of the Graduation Manual 2017-2018 for students from the Faculty of Architecture and the Built Environment. This Appendix describes that the reflection must consists of *"a short substantiated explanation to account for the preliminary results of the research and design in the graduation phase (product, process, planning). […] the reflection must contain an answer to the question of how and why the approach did or did not work, and to what extent. "*

In addition, the proposed discussion points of the Appendix 3 are all included in the reflection and determine the structure of the topics discussed. *First*, the research process is reflected from a personal point of view. *Second*, the research approach is discussed including aspect 1 with the relationship between research and design. Did the approach work and why? An academic approach is taken in this chapter. *Third*, the position of the research within the graduation lab, the master track MBE and the master programme (MSc AUBS) is given (aspect 2). *Fourth*, the research methods are reflected with a focus on the graduation studio methodical line of inquiry and its scientific relevance (aspect 3). The *fifth* aspects reflect upon the position of the research within the wider social, professional and scientific context and the last, *sixth*, aspect focus on ethical dilemmas. The reflection ends with a conclusion.

1   Research process

This part discusses the personal side of how the researcher experienced the graduation process. It first gives the most important decision making moments in a chronological order, followed by the feedback of the mentor team and is concluded by reflecting upon the learning goals and summing up the main lessons learned.

In general, the research process started with sky-high ambitions. The researcher wanted to combine its broad interest in urban development management, influencing decision-making, sustainability and technology. He experiences that a lot of knowledge is required to realize sustainable urban developments and that this knowledge is shattered among different parties and knowledge institutions, which makes it hard to make (the right) decisions. The first idea was to combine this knowledge in a decision support tool. The tool would propose a design optimisation to accelerate decision making in multi-actor decision-making processes of sustainable urban development.

In summary, the research demarcation and focus started at the smart city discourse, which inspired the idea of creating a decision support technology for realizing high sustainability ambitions and ended at a LP-modelling technique which optimises local residential neighbourhood development of all-electric, single-family and owner-occupied dwellings. The steps within this demarcation and change of focus are discussed next.

1.1   Reflection upon approach

At the time of the research proposal, the research plan was too general and the research topic too broad. This led to a performed research that was according to some people too big for a graduation topic. For the researcher it was an exploration of a new interesting world and combined his knowledge and vision about sustainable urban development. In the beginning, he wanted to create a decision support tool (DST) that would design and propose the perfect solution for sustainable urban area development. In his vision the

design results proposed by this DST were checked for costs and profits and therefore ideal to use for real estate developers. This was based on the question that was wandering in the mind of the researcher: "*How to get whole mega cities sustainable?*" But with an approach from the local, financial viewpoint of the real estate developer. These thoughts were not combinable. Sustainable mega cities aren't the problem of this stakeholder, but of society as a whole and therefore linked to government institutions like the municipality. The effect of this missing link between the research problem and the involved problem owner is explained later.

In the end the researcher still has the vision that a sustainable urban area development is a combination of both the product, design side as the process, decision-making side. Complex urban area developments need an integrated vision. The thesis could have gone deeper into the complexities of these decision-making processes. The cases used in this research often contain only one real estate developer and was relatively straight-forward in comparison to the complex, multi-stakeholder urban development projects discussed within the courses of the department of Urban Development Management.

The researcher is satisfied that he continued the combination of the three involved disciplines, namely urban development management, decision science and renewable energy in the built environment. These disciplines are expressed via the scale level of the involved cases and the multi-actor decision making processes in urban area development management, decision science is operationalized by optimisation modelling with the LP-technology and the topic of energy by the technologies applied to realize energy neutral developments. Though, only mentors of the first two disciplines are involved, the third discipline was also important according to the researcher. He wanted to get more knowledge and skills in this field. It is the future in his opinion. And he has the attitude that if you do not know the basics, you do not have the right to criticize the execution.

Demarcation and conceptualization of research topic
At first, I proposed to develop a decision support tool which assists in the complex multi-actor decision making processes for sustainable urban developments. The tool had to optimise energy, water and mobility variables. This was based on the knowledge that dense urban areas consume more energy and have less possibilities for renewable generation, while, they are more efficient due to compactness and reduction for the need for mobility. The model had to propose the perfect situation. This vision was based on the smart city discourse in which the combination of technological enhancement and big data offers new possibilities for urban development. The vision lacked the insight that the real estate developer uses a bottom-up approach based on the location of development. Such a tool would be more appropriate to a municipality. The combination of research problem and problem owner was wrong in the beginning of the research. In addition, this proposed structure was criticized by the size and was founded too broad to be answered within one year at the time of the P2.

The decision was made to narrow the topic down from sustainable urban developments to a focus on the realization of energy neutral neighbourhoods. This decision to focus on energy was based on several reasons. The first one was personal interest and the motivation to create EnergyPlus neighbourhoods (e.g. Monti *et al.* (2017: 64)). In this concept a neighbourhood provide on a yearly basis more energy to the central electricity grid than it consumes. Secondly, energy is a very actual legal theme in real estate development, because the expected new and tighter regulation of energy efficiency in the building standards. These regulations are based on the EU directive that all new buildings from 2020 have to consume nearly zero energy (European Parliament & Council of the European Union, 2010) and Dutch regulations will possibly determine that new buildings have to get an energy performance coefficient (EPC) of around 0 in 2020 (RvO, 2016). However, this would be called 'BENG' at that time, which involve new legislative boundary conditions (Bouwens & Bouwmeester, 2017; Haytink & Valk, 2017). This expected change in legislation creates a sense of urgency at the involved parties, which makes the research relevant for them and a very actual topic. The addition of the legislative component also connects the research problem to the correct research owner, because the real estate developer needs to meet the regulatory requirements. Third, there is a lot of new research in (net/nearly) zero energy building and districts/ neighbourhoods ("*NZEB*" or "*NZED*"). Also this makes it a very actual topic. And fourth, the first energy

neutral development projects are applied in practice in the Netherlands, which makes it possible to do research on those cases.

The demarcation from sustainable urban development to energy neutral developments was later narrowed down to energy neutral residential neighbourhoods and after a period of time, the next demarcation to all-electric, single-family and owner-occupied dwellings was executed. This was the right decision. Although, the decision should have been made earlier. In the end the initial topic was demarcated on function (residential), type of sustainability (energy), ownership status (owner-occupied) and type of dwelling (single-family).

There was no demarcation on research methods, because the researcher wanted to know how to make an optimisation model and to gather insights from current practise. In the end, only one of the approaches was sufficient for graduation in the opinion of the researcher. The usage of both a qualitative and quantitative approach enhanced the research, as will be explained later.

Stuck in the literature review
The literature review was an ongoing process. Even after the P2 the review continued, because of the new demarcation after the P2-report and the lacking in-depth knowledge of the problems and possibilities at stake at that moment. The researcher kept on reading and learning, and all this new knowledge had to be added to the literature review. This new knowledge was added along the way and therefore the coherence within the literature review was fragile and still leaves space for further improvement. After some time, the literature review changed to a theoretical framework as more sources than only literature were added to the review.

In addition, the ongoing process was stimulated by the degree of actuality of the topic. Working on such an actual topic was very interesting, but also had its disadvantages. First, while the research progress was ongoing, it was published that the Dutch EPC-regulations are going to be adjusted to BENG. Second, a new benchmark of the sustainability criterion for buildings was introduced: The Environmental Performance of Buildings (Dutch: '*Milieuprestatie van Gebouwen, MPG*') was going to be limited by 1 in January 2018. The researcher decided to adopt BENG and to reject a focus on the MPG.

The adapted 80%-20% rule
The generalized Pareto-principle by Joseph Juran states that 80% of the outcomes can be explained by 20% of the causes. There is no scientific underpinning of this principle, but in this research it felt like that 80% of the time was in writing and only 20% in doing research. This did not felt right, because the variable that has the greatest impact on the outcome should be addressed effectively. In this case that is the quality of the research, which got relatively little attention, because writing must be finished. Because of the time-consuming aspect of writing, the research process felt to the researcher as lengthy, tough and intensive. The new experience, knowledge and skills gained by this thesis were very pleasant, which kept the motivation high till the end of the process.

1.2 Feedback by mentors
This parts reflects upon the feedback that was given by the graduation mentors and how it was translated into the research process and research results.

Keep focus related to the research objectives and the general research question. The topics were literally on top of the agenda made for every feedback meeting. However, as discussed before, the objectives and the main research question were too broad for a long time. The researcher had too little insight in the current problems at stake to get the arguments ready for a correct demarcation of the research. This leaded to many reviews of literature and practise and the attendance of the congresses and the courses.

Start with the investigation of a single case. This led to an internal dilemma with the researcher, because this was difficult to combine with the research steps. The first step was to explore the cases to get input for the second step, the creation of the LP-model. Thus, on forehand insights and knowledge from existing

cases had to be gathered. This was required for the researchers' know-how about the different possibilities to be included in the model. It took a while before the break-even point was reached with knowledge saturation to get onto the next step of research.

The structure of the model is more important than the key figures added to the model. Key figures can be adapted easily when new knowledge is gathered. The structure of the model is rigid and cannot be adapted easily. The development of a rigid structure of the model determines if the student has sufficient insights in the system operations of the related theory. In the case of this research, the opinion of the researcher is that he has sufficient knowledge of the theory about the LP-modelling technique and that the structure of the model is good. Some key figures can be improved, but this was not relevant to the graduation thesis. In addition to the LP-model, the research mentors have contributed with the development of the LP-model. One transformation of a mathematical relationship into a linear function was not realized without the help of Rein de Graaf.

Start with gathering results. The mentors asked for results and conclusions about the model already when the model was hardly operating. The researcher has invested a lot of time in the optimization of the model. A lot of variables had to be incorporated to answer the general research question. In the beginning the operation of the model had to be analysed and results had to be verified. This consumed a lot of time and therefore the researcher was one step behind where the mentors wanted him to be.

Read and write. The combination of reading and writing is fixed in the memory of the researcher since the first feedback sessions. This was not executed accordingly. The break-even point when readings were relevant to the research and to stop reading and start writing was hard to determine. In addition, also the usage of knowledge questions could have been better. They were gather broad in the beginning, because of the broad demarcation. This is normal when somebody is exploring a subject, but in this case, it took too long.

Structure the research outline. The research outline and structure had to be rewritten and restructured several times. It is known to the researcher that he thinks in schemes, drawings and presentations. His dyslexia caused him problems in getting to the core of the text. It became clear that a new structure of a text does not help him in structuring the research. When the research was summarized in frameworks and schemes, the new structure of the research followed rapidly and was fixed for the rest of the research. This restructuring and focus on writing causes that the feedback sessions with both mentors mostly did not result into in-depth feedback about what was written, but was kept to the structure of the report and the process steps taken. This in-depth feedback was desired more often. For instance, critical questions about the new added theory or other texts added. The researcher did not ask about this feedback, because he had the feeling that he was always one step behind. In his mind, he was many steps ahead of his writing, however, the status quo of writing was judged by the mentors. One time he did asked how to apply best the cross-case analysis method, this was discouraged, because first one case should be completed first. This was a good point of advice, but did miss the opportunity to learn more.

Do not use hypothesis. The researcher was focussed on the hybrid research and wanted to add hypotheses to the first part which used empirical research. Later, literature on research methods explained this argumentation and supported the omitting of the hypotheses.

It is not fair to exclude concepts of the LP-optimisation, because the LP-model determines which factors do not have influence and can be excluded. This was for instance about the decision of the researcher to let the balancing agreement (Dutch: "salderingsregeling") out of scope. This feedback made it even more complex how to deal with the demarcation of the research. On the one hand, the research was too broad and on the other hand, the research could not be demarcated, because it could be that relevant aspects were excluded from the optimisation.

This list can be prolonged with more points of advice given. The mentors of this graduation thesis were dedicated and had a lot of support and brought motivation and inspiration to the research project.

Hindsight shows that the involvement of a third mentor from a discipline related to energy in the built environment would have enhanced the research. In that case, all three knowledge disciplines would have been represented in the mentor time. In the end of this research the idea came up to have a meeting with an expert at the TU Delft to reflect on the research from the viewpoint of this discipline. This is postponed due to time limitations. Finishing the report had priorities.

1.3   Reflecting on personal learning goals

In the P2-report some personal learning objectives of the researcher were stated. This part reflects if the objectives are achieved. The four learning goals were:
- Understanding how to get urban development sustainable;
- Understanding (new technological tools for) real estate developers;
- Understanding of the playing field for the various stakeholders in urban area development;
- Executing individual research.

These research goals are realized successfully. The researcher did not only gained understanding of the three described topics, but he also can apply this knowledge in practise to realize sustainable urban developments in the complex multi-actor playing field of urban area development. As example, during his practical internship at SITE urban development the researcher was involved in various projects for various stakeholders in the field of urban development. One of the projects was to develop a new development strategy of a complex mixed-use, inner-city location with the involvement of the municipality, other governmental institutions, real estate owners, tenants and end-users. The researcher also gained skills to create new technological tools for real estate developers. Examples are the decision support tool made during this research, a GIS-tool to search for new development locations for institutional investors in large cities in the Netherlands, which was used during the internship at SITE and a tool to show the value creation of energy efficient investments for a large municipality in the Netherlands, which the researcher co-developed during his time at Planmaat. The next part also describes additional lessons learned, so that the next research can be executed in an improved way.

1.4   Lessons learned

The research process was a whole journey of exploration into an interesting world and my work taught me a lot. It has changed my way of thinking about complex decision making in urban development, the quantitative aspects behind sustainable development of our cities, realizing complex financial calculations in real estate development, the difficulties of applying open design processes, demarcation of research and writing up research. I hope my thesis challenges the way of thinking of my readers.

The most concrete lessons learned are the importance of a clear, concrete and specific research plan and the documentation throughout the research. The demarcation and conceptualization of the research and the clarity of the research methods are indispensable for a good research plan. A detailed description of the research methods within a structured approach also gives an indication about the feasibility of the research methods within the available time. This demarcation, conceptualization and clarity are required to get a feasible time planning of the research. At the moment of P2, the research methods of this research were too much based on theory instead of how they were applied within this research and they were too vaguely described. At that time this was thought to be the best solution, due to the first qualitative, exploring nature of the research proposal and the associated, in theory described, unstructured nature of this research approach. It appeared that an unstructured research is even harder to get feasible, mostly in sense of available time and planning issues, compared to a fixed and structured approach.

The second lesson learned is about the documentation throughout the research process. As mentioned before, this failed for the literature review. However, during the design and construction of the model every little addition that was created and tested successfully was documented first. In that way, a coherent story line about the development of the LP-model is created. Although this approach took time during the development of the model, it saved time in the end. This incremental approach is now also being used by the researcher in other research projects and it works. For example, during his work at Planmaat the steps

taken in the development of the model for the value creation are documented. This has to reduce the time needed to write the final report for the client.

And thirdly, during the long journey the researcher acquired new knowledge and insights related to the business case of energy neutral residential developments and new skills such as complex financial calculations and optimisation through LP-modelling.

Summarized, biggest lessons learned:
1. Demarcation and conceptualization before research proposal; feasibility within time
2. Clear research methods and plan of approach. It was too general.
3. Test research methods if feasible within time, also with an unstructured approach.
4. Documentation throughout research (e.g. with the literature review and creation of the model)
5. New knowledge and experiences gained
6. Enhanced skilled in real estate finance and LP-modelling

2 Research approach

The coming paragraphs reflect if the approach used worked and arguments why. In addition, a reflection is given on the relationship between the research and design (aspect 1).

The choice of the research methods and its argumentation is already included in the research plan of P2. This part solely reflects if the approach worked and why it worked.

2.1 Reflecting on research approach
The research approach is reflected in the steps of the research design.

Qualitative exploration and quantitative explanation
First the research design itself. It was a very suitable combination of qualitative exploration and quantitative explanation. The exploration of the current practises was required due to the fast developments in practise and literature was lacking behind. The combination with the quantitative aspects of the thesis gives the possibilities to quantify the variations between different solutions to optimise the business case. However, not all solutions could be quantified in terms of money and profit. In that way, a gab would be present if only the quantitative approach was used. A knowledge gab also would be present if only peer-reviewed journals were used in the theoretical exploration. That is why, both approaches strengthen each other and also the research.

Part 1a: From semi-structured expert interviews to courses, congresses, internship and student job
At the P2 semi-structured expert interviews were planned to gather knowledge from the field about how to realize energy neutral residential neighbourhoods. This is executed in a different way. Instead, congresses and presentations about the topic and additional courses were attended. The courses offered the opportunity to learn about energy calculations in the built environment and other possibilities to reduce the energy demand. The lecture series on the energy transition at the Academie van Bouwkunst in Amsterdam present a coherent future vision about the spatial impact of a renewable energy supply and the role of the built environment. The lecture series on '*Meet the energy leaders*' showed how the real experts, the directors of big companies, think about this renewable transition and its effects on our society, but also the effects on the built environment, depending on the company the 'energy leader' was related to. The congresses offered useful insights from practice and had led to interesting conversations with professionals in the field about the topic. In the end, one of the congresses resulted into the two most interesting case studies, of which one is elaborated for the P5. In addition, the researcher has completed an internship during the graduation. This internship was not about the graduation, but to explore the decision-making process in general in complex urban area developments. After that he started a student job related to the

financial aspects of urban area development. This internship and the student job offered insight and many experiences from practise of both involved disciplines of the mentors. The discussions with supervisors at the companies were additional to the feedback of the mentors at the TU Delft and let to an improvement of the research. This adapted approach was thus very successful to succeed the exploration phase.

The only negative aspect was the number of interviews for the case studies in the exploration phase. Semi-structured interviews were executed till data saturation has occurred. All required knowledge was gathered after interviewing the real estate developer and executing desk research. However, a second semi-structured interview with another stakeholder would be better for sake of verification of the findings about the case studies.

Part 1b: Describing one in-depth case
The research investigated multiple cases during the research process. The involvement of multiple cases had to make the research approach a comparative design. This design has the aim to seek explanations for similarities and differences to gain a greater awareness and deeper understanding of a phenomenon (Bryman, 2012). In this case the deeper understanding is about the identification of different solutions for realizing energy neutral residential neighbourhood development-projects. The comparative study is in fact the same as the cross-sectional design, because the design is essentially two or more cross-sectional studies carried out at more or less the same point in time. For that reason, the comparative study also has the same terms of issues of reliability, validity, replicability and generalizability (Bryman, 2012).

When the comparative design is applied in relation to a qualitative research strategy, it takes the form of a multiple-case study (Bryman, 2012). The main advantage of the multiple-case study is that by comparing two or more cases, the researcher is in a better position to establish the circumstances in which a theory will or will not hold and this improves theory building (Bryman, 2012; Eisenhardt, 1989; Yin, 2009). In addition, the comparison may suggest concepts that are relevant to an emerging theory (Bryman, 2012).

The comparative case study design thus has several advantages, however, due to a lack of time and a slow pace of writing only one case is descripted in-depth. In next research the amount of cases and objectives for the cases has to be more clear from the start of the research process.

Research part 2: LP-modelling
One of the attended extra courses taught the researcher about LP-modelling. LP-modelling is relatively easy to learn in comparison to other optimisation programs like MATLAB. The application of the design approach of Dym and Little (2004) was used instead of the empirical research process of Kumar (2005, 2011, 2014). This change of approach was a key decision of the success of this part of the research. This approach was motivated by the course attended. The designed and constructed LP-model reflects valid results. Although not all the possibilities of a real-life case are captured within the model, it is still an extensive model with many possibilities.

The position of the LP-model in the research design was also adapted after the P2-presentation. At the P2 the idea was that the model was the final result of the thesis. In the new research design, the development of the decision support tool has lost this central focus and the model was used as research method. In this case the position of the decision model is to analyse the current situation and proposes ways of improvements by optimisation. The model gives not only insight in how decisions are made, but also proves that new configurations of ingredients lead to a better (group)result. The idea was to create a feedback-loop. In the first part of the research cases are still analysed, in the second part the model is created and in the third stage a selection of the used cases is optimised to propose a new or adapted business case. In case the model proposes a new business case, the last step is to verify why the involved real estate developer did not go for that strategy. This last step is not executed due to time reasons.

Research part 3: Expert session and application of tool
The expert session, or the focus group, was useful to let professionals reflect upon the added value of the model. Valuable results came out of the session. Although, the expert session was limited by time and

diversity of people. Next time, involvement of professionals with different background knowledge would have enhanced the research.

Internship
Lastly, all parts of the results could have been executed with an internship at a company. This would have offered the possibility to gather valid input data instead of the generic key figures used now. It could also have enhanced the speed of the first exploration phase, however, it was also likely that other real estate developers would became reluctant to be investigated. Due to another internship based on general experience in complex decision-making processes in urban area development the time was lacking to do a second internship related to the graduation. The researcher expected that the search for this internship would delay its graduation process.

2.2   Relationship between research and design
The research was executed at the department of Management in the Built Environment. This department does not require a design like the other specializations of the master Architecture, Urbanism and Building Sciences. Though, this research has a connection to design.

During the research the LP-model was designed. The development of the LP-model is more of an engineering approach as the esthetical approach for urbanism, architecture or landscape architecture. Those professions give shape to the design-decision variables by shaping a specific design alternative. The developed LP-model gives shape to the design space by optimising the values of the design-decision variables. That is why the LP-model does effect design decisions.

In addition, the design cycles of Dym and Little (2004) were used in its development (as discussed in the previous part). This led to an iterative process of going back and forth from the conceptual design to theory and to the preliminary design and to the detailed design. This process was finished when the LP-model gives reliable outcomes. This consumed a lot of time and the iterative nature made it hard to create a sufficient research planning.

3   Position of research within graduation laboratory and MBE-departments

This part reflects upon the relationship between the graduation topic, the studio topic, the related research departments, the master track MBE and the master programme of AUBS (aspect 2 of the list). The last two options are jointly discussed.

3.1   Position within the graduation laboratory
The graduation lab is titled Sustainable Private Sector-Led Urban Development (SPSLUD) and is about creating incentives, overcoming barriers and aligning interests with the private organisations to engage them in sustainable urban development (SUD-)projects and about stimulating governance methods or partnership arrangements to stimulate this engagement (Heurkens & Hobma, 2016). This is required, because the existing ways of collaboration seem to be unfit to meet current and future city challenges. In the end the research lab wants to provide insight in how the existing institutions can change to support SUD and make it a common practice. The examples within SPSLUD are mainly highly complex and inner-city area developments (e.g. King Cross London, Buiksloterham, New Songo, etc.) and involve huge institutional developers/investors (e.g. AMVEST, others).

The research contributes to the graduation lab by the creation of a decision-making model for the business case of the real estate developer. The incentives, barriers and interests of the real estate developers are investigated during the case study research. It also concludes that the changing legislation is the most powerful tool for the government to let the real estate developers engage in energy neutral developments, however, the market demand for these types of dwellings also starts to increase.

This research has some differences with the graduation lab. First, in this research the role of the real estate developer is investigated in public realization, the building rights partnership and private realization. In none of the used cases the concession model was applied. In case of the public realization, the viewpoint of the real estate developer was taken and how they made the decisions about the business case to win the tender. Heurkens (2012) sees private sector-led urban development as a part within the concession model. In the researchers' opinion, private sector-led urban development is part of private realization in which a real estate developer or a consortium of private parties buys a plot of land and develops it. The municipality is facilitating this development by changing the land-use plan. Second, this research focus on the sustainability variable of energy. In the graduation lab sustainability is much broader. It is about mixed-use, greenery, water, climate adaptation, social cohesion, food production, etc. Third, the decision-making in the used cases is often less complex as in the presented examples of the graduation lab. Often a single real estate developer is involved to realize the whole project (in 4 out of 6 cases).

In the end, the research focus is on the role of the private sector in the realization of energy neutral residential developments. This is very much the topic within the graduation lab.

3.2 Position within the department of Urban Development Management

The core of Urban Development Management (UDM) is the management of decisions of the many stakeholders involved in urban area development towards a high-quality outcome. The focus of this graduation research is on decision making and managing projects in residential urban area development. Although the focus of this thesis is not on the complex inner-city locations, many theories and concepts are used from this department. The relation is evident.

The position is the same as within the SPSLUD-graduation lab. It contributes to the knowledge about the role of the private sector in the realization of energy neutral residential developments and which incentives, barriers and interests are related to this party.

In addition, the exploration of the research topic started with the determination of the possibilities within the smart city concept, related to the local influences of the real estate developer. This is also one of the new graduation labs. Though, the link is faded during the research process.

3.3 Position within the department of Real Estate Management

The core of Real Estate Management (REM) is about the management issues from the initiative till the operation phase of real estate with a specific focus on (property) management of corporate and public real estate (CREM / PREM). CREM plays a large role in this department. The focus of this graduation research is on the development of housing. This looks like a misfit, however, the research does also not perfectly fit into the other departments within MBE, for instance, the department of design and construction management, because that one is mainly focussed on construction process innovation or the department of housing, because that one is mainly focussed on housing associations, which are excluded in this research. The REM-department also has a lot of knowledge about real estate finance, which is needed in the creation of the optimal business case. Altogether, it looks like the research has hardly a position within the department of REM. However, the former department about design and decision systems is currently part of the REM-department. These systems are the core of the research.

This research can add to the body of knowledge about the application of the decision support systems in complex decision-making process. The incorporation of the energy aspect in these optimisation systems also looks new in the department. At first sight, the research does not look in place at the REM-department, but with a closer look the added value is clearly present.

3.4 Position within the master programme of AUBS

This part tackles the questions why this research is executed at MBE and what can students from other masters of AUBS learn from this graduation research.

The core areas of MBE are real estate management (REM), design & construction management (DCM), housing and urban development management (UDM). All topics are relevant to this research. REM and UDM are already discussed. The research does not only focus on the design and construction of housing, which are topics within the remaining two departments. Besides, the research focuses on the decision-making in the integration of partnership models, finance and design and not solely on architectural design on which scale whatsoever. In addition, MBE is the only master's program in AUBS that incorporates all stages of the building's life cycle: from initiative to use. The focus of this research is on the optimisation of the business case during the feasibility phase (the first step of the initiative), however, it incorporates the total costs of ownership for the end-user in its optimisation. In that way, it incorporates all phases of the life cycle of the dwelling, which is only possible at MBE. The explanation about the departments within MBE is probably too simplistic, but all three arguments together give an indication of the relevance to MBE and why it shouldn't be executed at another department.

The topic of energy in the built environment is big and this graduation contains interesting aspects and reasons for further research for all masters of AUBS. *Architecture* can benefit from this thesis by recognizing the growing importance of design in the realization of the BENG-requirements within a dwelling. For instance, theory of passive solar design and skills in designing of the optimal locations for energy-related installations (for instance to ensure short hot water pipes) can both be applied in the realization of BENG1. Architects with this knowledge and skills can benefit from this. Innovation in the details of this design is required to realize even higher energy ambitions as presented in this research. This research shows that the thermal envelop is of big importance in realizing BENG1. Especially the details for airtightness have a huge influence. Students from *Building Technology* can study these and engineer innovate solutions which are cheaper and better. Another possibility is the connections of PV-panels to the roof. This connection influences the effectiveness of PV-panels. How can it be constructed best? Besides the details on a building scale level are also the larger scale level interesting. *Urbanism* students can learn from this thesis how the effects of passive solar design can be quantified. In much design theory PSD is presented as the holy grail. This is not the case, according to the researcher. Active installations are required to get dwellings energy neutral or even zero on the meter, because electricity is consumed and that cannot be generated by PSD. This graduation gives also insights in how decision support tools can be used in deciding on the optimal value of the design-decision variables. This can affect the approach of an Urbanist. Instead of designing one alternative within the design space the students can learn how to design the optimal alternative. Lastly, students of *Landscape Architecture* can benefit from the concise description of the energy transition and how it is going to affect spatial planning and design in the Netherlands. Energy landscapes is a more often heard term. This thesis explains why.

4   Research methods and scientific relevance

This chapter elaborates on the research method and approach chosen in relation to the graduation studio methodical line of inquiry and reflects upon the scientific relevance of the work (aspect 3).

4.1   Reflection on research methods

This part reflects on the research methods in related to the often-used research methods in the graduation lab. The reflection of the research methods as applied in this research is discussed in chapter 2.

Research methods used in the graduation studio are: Mixed-method approaches, qualitative (inter)national (comparative) case studies, quantitative actor- focused surveys, structured and semi-structured interviews. (Heurkens & Hobma, 2016).

In this research a mixed-method approach was used by combining qualitative national case study method and a quantitative optimisation tool. Data was gathered by desk research, semi-structured interviews and by applying the optimisation tool.

The graduation lab is grounded in empirical research and has the objective to create new knowledge based on observations of the past. The first part of the research about the qualitative exploring case studies fits in this approach. The second part of this research, the development and application of the LP-modelling technique does not fit into this graduation lab. The nature of LP-modelling is in operational research, because the model wants to improve a situation and it is future oriented. Though, this approach fits into one of the objectives of the graduation lab, namely to develop and define new decision-making models, new investment/development strategies and new business models and effective partnerships (Heurkens & Hobma, 2016). In this research a decision support model/tool is created to assists in multi-actor decision making, which hopefully results into a business case for a specific location in which one part is the investment or development strategy and other part is about new effective partnerships. This looks suited to the approach of the graduation lab, however, the researcher expects that Heurkens and Hobma (2016) are more oriented to specific company-oriented business models and investment/development strategies instead of the ones for specific locations.

4.2   Scientific relevance

The scientific relevance is based on the triangulation, validity and reliability of findings and the possibility of generalization of findings. Before these concepts are discussed it is worth stating that it is relevant to scientific research that the first zero-on-the-meter neighbourhoods in the Netherlands are currently under development. This is the introduction of a new area of commercially developed neighbourhoods with the highest possible energy standard at this moment. Some of these neighbourhoods are investigated by this research.

Triangulation
Triangulation is "*a valuable and widely used strategy involving the use of multiple sources to enhance the rigour of the research.*" (Robson, 2011: 158) Triangulation is reached by using multiple methods of data collection (data triangulation), namely the literature review, desk research in policy, municipal or company documents, the semi-structured interviews, case studies, expert gatherings like congresses, expert presentations and LP-modelling. Both the qualitative as the quantitative research part uses at least three methods of research. The usage of both research strategies also ensures methodological triangulation. Theory triangulation is ensured by using multiple references to make a bold statement. Theory triangulation is also applied for the development of the LP-model by checking the method used with multiple references. As stated before, the observer triangulation could be increased by increasing the number of interviews per case study.

The previous text is based on the text within the research methodology chapter of the report. In addition, Yin (1994: 90) describes the three principles of data collection:
1. Use multiple sources of evidence
2. Create a case study database
3. Maintain a chain of evidence

All three principles are included in this research. The first principle is discussed in the previous text. The case study database is available at the computer of the researcher. Each case has its own digital map filled with files and data. The chain of evidence is presented by the in-depth description of the case study.

Validity and reliability
A description how validity and reliability are considered can be found in the research methodology chapter of the research report. Figure 1 shows the reliability of the findings. Two dwelling types are comparable to the reference case study and for both the building-related energy usage are only a bit higher. There is one note to this, the reference dwelling is about 10m2 UFA smaller and the ground source heat pump has a higher COP as the case in the LP-model. These could be the reasons that the reference dwelling has a slightly

lower building-related energy usage. The household-related energy usage cannot be compared, due to a unique promotion action of the involved stakeholders to stimulate a degree of household-related energy usage. That action worked and therefore the household-related energy usage is much lower as in other cases. The calculation of household-related energy usage in the LP-model is based on the official calculation method of NEN 7120+C2 (2012) and can therefore be seen as reliable.
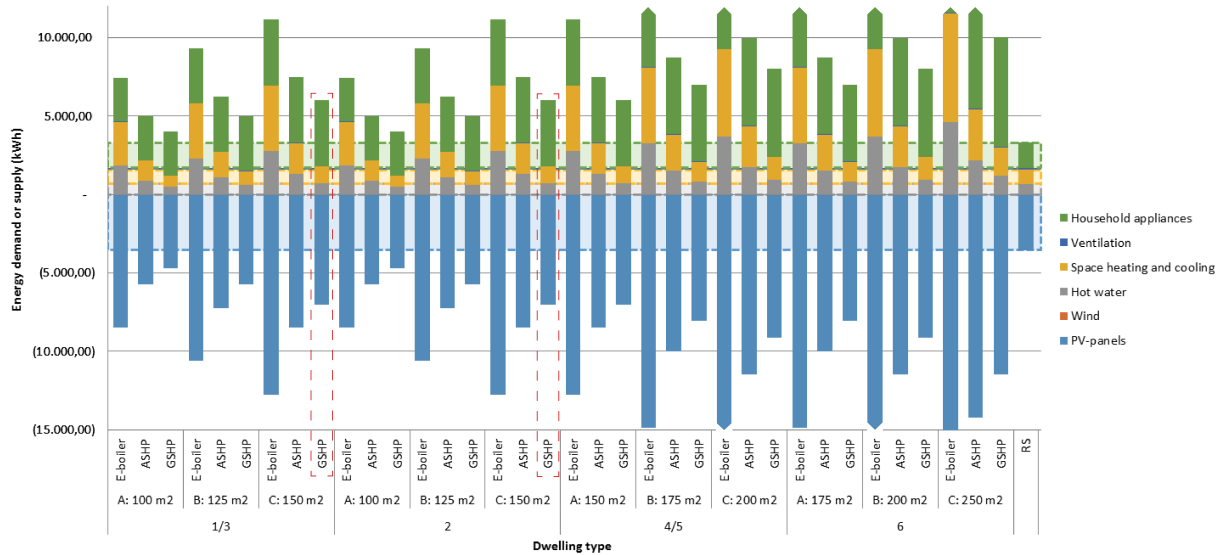

Figure 1: One of the outcomes of the LP-model shows the energy profile of different dwelling types in first year (based on a thermal energy demand of 37 kWh/m2/a). The results are compared to reference studies in RijswijkBuiten of Staats (2016) and Sijpheer *et al.* (2015). This reference study is show at RS (Reference Study) (own illustration).

More information about the verification can be found in the report. This image shows that the LP-model can produce reliable results, if the correct input variables are present.

Generalization
Lastly, the topic of generalizability. In the report two reasons are explained based on theory why the results of the case studies cannot be generalized. First, the objective of a case study is not to confirm or to quantify and second, the applied sampling methodology of purpose sampling cannot be generalized to the whole population (Bryman, 2012; Kumar, 2005, 2014). Applied to this research is the objective of the exploring case studies to gather an in-depth and holistic insight in how different aspects of the business case and the development context have affected the optimisation and realization of the energy ambition. Those aspects can be different in other circumstances and therefor are the solutions used in one case study not generalizable to other contexts. In addition, the sampling approach looked for cases which are best suited to the research questions. In this case residential neighbourhood developments consisting of all-electric, single-family and owner-occupied dwellings and with an increased energy ambition. These are not necessary the cases that best reflect the typical case within the whole population. The locations are also location bound and therefore are the best solutions for one case/location not per definition the best for other cases.

Concluding, the research will not give generalizable results to a whole population of energy neutral residential developments. Though, interesting lessons learned are produced for practise. These lessons learned are based on multiple explorative case studies and quite reliable outcomes of the LP-model.

5   Position of research within wider social context

The next paragraphs elaborate on the relationship between the graduation project and the wider social, professional, scientific and political context. The transferability of the project results is touched.

5.1   Social context

The research has a high societal relevance. The energy usage of dwellings has a huge effect on the total CO_2-emissions (climate change), resource depletion, earthquakes in Groningen and are subjected to fluctuating electricity prices and rising natural gas prices. All-electric energy neutral residential neighbourhoods do emit less CO_2 for energy purposes and therefore its energy usage is less contributing to climate change[1] and the neighbourhoods do not use natural gas and therefore they are causing less resource depletion, less earthquakes in Groningen and are less subjected to rising natural gas prices[2].

When these all-electric, single-family and owner-occupied dwellings will be developed, the owners should get used to the presence of more installation technology in their dwelling. A lot of prejudices must be overcome, like "*I cannot open my window.*" and "*I have too little hot water for a shower.*" Windows can be opened in the new dwellings and the amount of shower water is considered. For all dwellings count that opening the windows during cooling season will lead to an increased energy bill, because the incoming cold air needs to be heated in the dwelling. The energy neutral dwellings are often equipped with CO_2-controlled balance ventilation systems with heat recovery. Opening a window is not needed in this dwelling for fresh air. This does not imply that these comfort related issues should not be considered in the development of these dwellings (see also ethical and scientific parts), they must.

The research touches upon the balancing agreement. The abolishment of this legislation will have huge effect for the home owners on their business cases of PV-panels. It is likely that it would trigger demand side management systems. These are systems within new or added to old installations that control the energy demand to moments when renewables are locally supplied. This ensures less interaction with the grid, which has a positive effect on the business case and it also satisfies the grid operator (see next part).

5.2   Professional context

This research explores the possibilities real estate developers have when the new BENG-legislation will be active. This was the main research motive related to the private sector. This change instigates a sense of urgency for the problem owner to explore the new business models possible. This research explores the financial business models with additional mortgage space (not every professional in the field is aware of this possibility) and by the usage of ESCOs or other third financing options. It also explores the expected possibilities of the high speed of innovation within technological solutions. With this exploration and explanation of the main possibilities the results are very relevant to the real estate developers.

Professional parties and the government collaborate within the ZEN-platform about his topic of new dwellings with a high-energy efficiency. Central thesis in that research is how to combine a feasible business case with an increasing comfort level of the consumer.

The outcomes of the research also effect the grid operator. When all new dwellings will be all-electric, this will have a huge effect on the stability of the electricity grid.

Municipalities can also benefit from the research. As explained in chapter 7 on added value of the LP-model. They can explore the possibilities and define a better price for the land.

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[1] A long discussion can be added about the usage of fossil fuel-based electricity retrieved from the electricity grid during moments when the dwelling does not produce renewable energy (mostly in the evening), because electricity can be freely balanced with the electricity grid and there is currently no incentive to reduce this exchange. This discussion is omitted and therefore it is not suggested that these dwellings cause zero CO_2 emissions based on energy purposes, only less.

[2] The same as the first footnote. A big bulk of electricity in the Netherlands is generated by gas fired power stations. Therefore, also all-electric energy neutral dwellings with electricity exchange to the grid cause resource depletion. These power plants mainly use high caloric natural gas from Norway and Russia and that is why the effect on the reduction of the earthquakes in Groningen is even more (in Groningen low-caloric natural gas is exploited).

5.3 Scientific context

Recommendations for further research are given in the recommendations chapter in the graduation report and the positioning of the research within the scientific domains in chapter 4 of this reflection.

The scientific world is lacking behind on the knowledge present in practise. This was also experienced during an internship interview. The company was not interested in the proposed decision support model. They explicitly stated that they already knew how to optimises those dwellings. According to the company, the problem was not in the technological solutions, but in the legislation. The company truly was a front-runner. The added value of the model is to combine the shattered knowledge of all those parties. This benefits the parties who are not in the frontline of development.

This shattered knowledge is also present in between the different research disciplines. It is hard to combine multiple fields of knowledge. This research is relevant because it combines multiple disciplines. Even more disciplines could be added to the research. Knowledge about comfort, health and other sustainability aspects is welcome. Sustainability is more than just energy.

The research also touches upon the investigation of an actual occurring trend (the shift to private sector-led urban development). This trend, the application of the concession model in urban area development, is hardly seen.

5.4 Political context

The research is also very relevant to politics for several reasons. *First*, a lot of policy research is currently going on about the energy transition. This research proposes a top down governmental approach in chapter 2. *Second*, the BENG-legislation is under construction. It is still under investigation which values are optimal (Valk, 2017). This research shows the effect of reducing the energy demand in kWh/m^2. Larger dwellings stimulated to get the most financial profit out of the most energy efficient installations (ground source heat pumps). This is not the desired effect, because larger dwellings use more energy. *Third*, the research shows that it is possible to develop whole neighbourhoods without a natural gas connection. Government can speed-up the reduction of natural gas connections by forbidding a connection to new dwellings. *Fourth*, the research also indicates that the additional borrowing capacity for energy efficient dwellings is under discussion. It is still unclear what the future will bring. However, clarity is needed to reduce the risks in the business case. A change of the calculation of the total borrowing capacity from dwelling value to total living costs (mortgage costs + energy costs), would give a huge boost to energy efficient dwellings, because people can borrow a lot more for these dwellings.

The research thus indicates several possibilities for politics to speed-up the development of energy neutral dwellings. What is next? Preparation of BENG is already a few years old. What can be expected in 2021-2025? BENG3=100%? Zero-on-the-Meter requirements? Other required levels of sustainability indicators? The adaptation of the balancing agreement? This research shows that all effect the business case of the dwellings investigated in this graduation.

6 Ethical dilemmas

The coming paragraphs discuss the ethical issues and dilemmas the researcher has encountered in the execution of his research and the ethical issues and dilemmas he envisions in the potential applications of the results in practice.

6.1 Ethical dilemmas in research process

Bryman (2012) refers to Diener and Crandall (1978) as useful classification of ethical principles in and for social research. The researchers have identified four main areas of ethical principles (Bryman, 2012: 135)
  1. Whether there is harm to participants;

2. Whether there is a lack of informed consent;
3. Whether there is an *invasion of privacy*;
4. Whether deception is involved.

Harm to participants

In this research, no harm is done to participants. The most relevant ethical dilemma is the issue of identification and confidentiality. In qualitative research and its secondary analysis of the qualitative data specific information is gathered and analysed. This can be related to individual people. In that way they can be identified by the non-involved people of the research. This item of confidentiality is considered and decided not an issue at stake. Instead, one of the interviewees even explicitly stated that he would be prefer his name in the report instead of 'participant 1'. The real estate developers are proud of their projects they have recently realized with an increased energy ambition.

The used data was not protected and open available to everyone by literature and on the internet. One ethical dilemma is that the outcome of the models is not presented to the real estate developers. They did not have the opportunity to verify wrong results such as the percentage of profit. It can be questioned if that can harm them. This verification is considered a point of action for the next steps of this research.

Lack of informed consent

The principle of lack of informed consent means that possible research participants should be given "*as much information as might be needed to make an informed decision about whether or not they wish to participate in a study*" (Bryman, 2012: 138) This issue is tackled in this research by clearly present the research problem, methods and objectives to the possible participants before the appointment was made and before the start of the interview. Participants knew in what kind of research they participated and where fully informed about the research process and methods. At the beginning of the interview the structure and type of questions were introduced. At that moment, it was also asked whether the interviewees agreed if the interview was recorded. A respondent could skip questions if preferred during the interview. This did not happen.

Some references to personal communications were made in the report. Permission has been requested to use these as a reference. Also in that case this dilemma was prevented.

Invasion of privacy

Personal information is not included on exception of the name and publicly accessible data on the job function of people involved.

Deception

"*Deception occurs when researchers represent their work as something other than what it is.*" (Bryman, 2012: 143) Although the exact focus of research was further narrowed down throughout the research, the representation of the research was always about a decision support tool for the real estate developer to create sustainable urban neighbourhoods. The interviews always had a purpose in the research to add new insight for one of the sub research questions (SRQs). So, for the semi-structured interviews within the case studies it was about the current practises. And for the expert session/ focus group it was about the added value of the decision support tool. In all circumstances the overall objective of the research was explained together with the objective for the interview ("to add insights for the SRQ"). In that way, the available options are used to prevent deception.

Deception can also occur with the representation of literature. For instance, if a quote or source is used as secondary literature and it was already misleading represented in the first source. Secondary literature sources are always indicated as such throughout the report. In that way, no misleading representations are given directly related to the first-hand source. The first-hand literature is reviewed when possible and in case relevant, only that reference was added.

Plagiarism

Plagiarism is not part of the main ethical principles. However, the researcher would like to name some own material which was originally created for another purpose. *First*, the basics for the energy demand model were made in the course '*Environmental Sustainability in the Built Environment*'. This model is used to gather input values for the LP-model created within the graduation lab. This is also presented in the intended Appendix. *Second*, some own research is used from other courses (e.g. operational research methods and courses at the WageningenUR about sustainable urban development). Both topics are discussed with my mentors, and when it wasn't published, this is possible. It would not be plagiarism as I created it myself.

Concluding, the researcher has no illegal activities encountered or committed during the execution of this research. All data used was open accessible, including the used key figures as input for the LP-model, or permission was obtained.

6.2   Ethical dilemmas for the application of results in practise

There are some ethical dilemmas for the potential application of the results in practise. The dilemmas related to the limitations of the research are presented in the discussion. These are not considered ethical dilemmas.

There are some moral dilemmas. *First*, the research purely focuses on optimisation of the business case. In that way, it optimised legal, financial, technical and organisational aspects. The optimisation does not consider comfort, heath, aesthetics and design. This can be part of future research, but when the model is applied in practise, these previous topics must be addressed. *Second*, the limitation of the LP-modelling technique is that it can only optimise a single variable. In this case that is profit. Financials, especially in real estate, are often part of an ethical discussion. If one makes more profit, there is somebody else that has to pay. In this optimisation that is often the end-user, by repaying the additional mortgage or ESCo. Hidden in this optimisation are the extra costs for the electricity grid. The all-electric concept gives a huge burden on the electricity grid, because the consumer changes to a consumer/supplier and starts to exchange a lot of electricity with the grid. This is caused by the supply of electricity from PV-panels throughout the day when people are not at home and the demand of energy in the evening, when the PV-panels will not supply renewables and electricity is taken from the grid. This exchange is free of charge, due to the balancing agreement. The electricity grid needs to be extended for this reason. Those costs on the grid operation are charged by an increase of the connection costs. These costs are fixed for all users. In such a way, people without a renewable supply installations do extra pay for the people with a renewable supply by, for instance, PV-panels. These are hidden costs to normal people, unaware of the technocratic reasons behind the increase of prices. This was the *third* dilemma.

In these three dilemmas end-users are relatively disadvantaged by the application of the model in practise. It is relatively, because in the end, the end-users still get an energy neutral dwelling with lower living costs as the in the reference situation. It is also likely that the real estate developer would have found the best possible solution, but by trial-and-error instead of in one click at a button.

7   Conclusion

To conclude the reflection. The researcher has many things during his research and it satisfied with the end-result. The major lesson learned is the need for a proper demarcation of the research topic and methods used within a clear plan of approach on forehand. Lastly, the researcher thanks his supervisors for their help during this process.

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