Development of an Assessment Tool for Energy Neutrality at a District Level

Evaluation of master plans on sustainable energies applied to Stadshavens, Rotterdam
Development of an Assessment Tool for Energy Neutrality at a District Level

Evaluation of master plans on sustainable energies applied to Merwe-Vierhavens, Stadshavens in Rotterdam

Author

Ismini Stroumpou
istroumpou@tudelft.nl, istroumpou@gmail.com
MSc Industrial Ecology
Technical University of Delft and University of Leiden.

Graduation Committee

1st supervisor
Dr. Ellen van Bueren,
E.M.vanBueren@tudelft.nl
Delft University of Technology,
department of Policy, Organization law and Gaming,
faculty of Technology, Policy and Management (TBM)

2nd supervisor
Prof. Arjan van Timmeren,
A.vanTimmeren@tudelft.nl
Delft University of Technology,
department of Environmental Technology and Design,
faculty of Architecture (BK).

1st external supervisor
Dr. Oubbol Oung,
o.oung@Rotterdam.nl
Stadsontwikkeling,
Ingenieursbureau Gemeente Rotterdam

2nd external supervisor
Ir. F. M. Freyre Hechavarria
fm.freyrehechavarria@rotterdam.nl
Stadsontwikkeling,
Ingenieursbureau Gemeente Rotterdam
Preface
This thesis research was conducted to complete the MSc of Industrial Ecology. Technical University of Delft and the Engineering office of the Municipality of Rotterdam (public works of Rotterdam) (Ingenieurs bureau Gemeente Rotterdam) cooperative program ensured and provided guidance, information and tools to achieve this thesis.
The subject of this master thesis report is the development a concept assessment tool to assist public authorities in choosing an energy neutrality master plan for district development.
The port of Rotterdam is at the phase of relocation causing a redistribution of space and authority. The “abandoned” areas need to be redeveloped and change function usage. Municipality of Rotterdam sees the current situation of Stadshavens as an opportunity window for sustainable development. Energy neutrality at a district level is one potential proposal for sustainable district development. This development implementation will be held by a private consortium chosen by the Municipality of Rotterdam with a concession type of project. The pre-mentioned circumstances made a development of an assessment tool to assist the choice of energy master plans at district level a necessity.
Acknowledgements

“Ithaka gave you the marvelous journey. Without her you would not have set out. She has nothing left to give you now. And if you find her poor, Ithaka won’t have fooled you. Wise as you will have become, so full of experience, you will have understood by then what these Ithakas mean.”
Kavafis, Ithaca

There are a number of people who helped and supported me in their own unique way to my journey to this “Ithaka”, conducting this thesis. Therefore I am in greatly indebted to them. I take this opportunity firstly to thank my external supervisor Dr. Oubbol Oung for giving me the chance to conduct my thesis with co-operation with the Municipality of Rotterdam and proposing this interesting topic to work on. We both knew from the start that it was a difficult project but with her management skills she helped me prove that I can accomplish it. Hence, I would like to express my deepest appreciation for her guidance and her patience with me. She taught me how to focus my research work without losing my ambitions and that time management is super important. I cannot express enough thanks neither in English nor in Spanish to Ir. F. M. Freyre Hechavarria for his continued support, valuable help and guidance from the start till the end of this thesis, for his free psychological sessions and his tolerance and imagination towards my lack of vocabulary in Spanish. I am happy that these two persons encouraged and helped me to reveal my skills and enrich my knowledge in a competitive purely Dutch environment.

I would like to express my very great appreciation to my two university supervisors Dr. Ellen van Bueren and Prof. Arjan van Timmeren for consenting to be my thesis guides though their busy schedules. Their ideas and comments were always assisting solving problems that occurred and make me think in a more constructive way.

My grateful thanks are also extended to my colleagues Roland van Rooyen, Sebastian van der Ven and Maarten Nijpels for their help testing and evaluating the concept tool with their useful comments. As it always happens in the end of journeys, I realize how grateful I am to all these precious “creatures” that accompanied me on the way. To my housemates and friends that live in the Netherlands which I consider them as my family here. I appreciate that they were there for me listening to my grumble and relieving my stress with long coffees and alcoholic beverages. I do not forget my friends that live in Greece. I miss you guys a lot but your good vibes are received. I envy you for the times that I was seeing a grey sky and you could see the bright sun and blue sea. My envy was diminished when I received messages like “we wish you were here” or “when are you coming?”.

To my beloved parents and grandmother I would like to express my deepest gratitude for their love and support in any way that they could. They are far away but I know and I feel that they are always next to me, to every step and decision that I make. Without them I wouldn’t be the person I am and thereby I wish they are proud of me not only for the achievement of this Masters’ degree but also for the person I became due to their influence. Closing my thanks I would like to let them know that the greatest comfort and relief was that they were there for me always willing to provide me help in any problem that I had to face.
Summary
This thesis examines the reasons and the way of development of a concept assessment tool for energy neutrality at a district level.

Merwe-Vierhavens district of Stadshavens, Rotterdam is reforming, as the port activities are immigrating towards the seafront, creating space for new urban developments. The Municipality of Rotterdam wants to see energy neutrality concept applied on this area embedded with its aspiration for sustainable development. Additionally, this area is going to be developed and maintained for 30 years by a chosen private consortium under a concession type of contract. Therefore, the Municipality of Rotterdam wants an appropriate assessment tool to assess energy neutral plans generated by private consortia for Merwe-Vierhavens.

Firstly, it was necessary to examine if an existing assessment tool could assess energy neutral plans for district development. A selection method, focused on the Municipality of Rotterdam’s requirements (10 criteria) was developed to assist on finding the most relevant existing assessment tools. The selection method was based on the existing tools’ anatomy. Applying this selection method, six existing assessment tools appeared to cover in a great extent but not 100% the requirements posed. These six existing assessment tools (BREEAM-NL new buildings, BREEAM-NL area, GPR-urbanism, LEED for neighbourhood development, CASBEE for urban development and CASBEE for cities) were thoroughly analysed and used as foundations for a new concept tool development.

The concept tool development method followed. The development method was based on the tools’ anatomy eight steps (goal and scope, system boundaries, evaluation criteria and indicators, fulfilment of data requirement, aggregation and weighing, validating results and analysing, presenting results and designing an effective interface). For each of these eight steps, choices were made towards energy neutrality at a district level. This thesis’ part is focused on defining the methods and technologies that could assist the posed requirements of the Municipality of Rotterdam. Briefly some of the examined methods that were presented and/or used are: Goal Tree Success Tree (GTST), Multi-Criteria Decision Analysis (MCDA) methods (AHP, MAUT, SMART, PROMETHEE and ELECTRE) and excel.

Afterwards the developed method was applied to Merwe-Vierhavens and created a concept assessment tool. The concept tool is developed in excel environment to be accessible and relatively easy to use by the public authorities servants. The concept tool is composed by three parts. The first part is the aggregation and weighing of energy neutrality objectives using AHP matrixes. Experts from different fields suppose to fill in these matrixes. The results of the matrixes are preferences weights to each objective of energy neutrality. The results of every expert that filled in the spreadsheet of matrixes are the input of the next part. The second part of the concept tool is a spreadsheet that calculates the averages of the weights preferences of the experts and statistics analysis of their weighs of preferences. The average of their preferences is input for the third part of the concept tool. The third part of the concept tool is calculating the score of energy neutrality alternatives. The alternatives are plans generated by private consortia and decomposed in order to be rated. The concept tool is a trial to fulfill in a great extended the aforementioned desired characteristics for an assessment tool.
Finally, the concept assessment tool needed to be tested and evaluated to identify its advantages and lacks. The first part of the concept tool was tested by six experts of the Municipality of Rotterdam who gave their opinion concerning their experience using this part of the tool and reading the operation manual of the concept tool in questionnaire forms. Their results were used as an input to the second and the third part of the concept tool. For the third part seven ideal alternatives plans were developed and scored.

The strengths of the concept tool and its procedure is that it provides a more organised, transparent, and flexible assessment. It is also promoting dialogue between assessors and could facilitate decision making process in a better way. The adding value of the concept tool is that it is adjustable to the assessment area. Nevertheless, is a concept tool so recommendations for further improvements to its specific to its parts and its way of development are proposed.
# Table of Contents

**Preface** ................................................................................................................................. IV

**Acknowledgements** ............................................................................................................... V

**Summary** ................................................................................................................................. VII

**List of Figures** ......................................................................................................................... 12

**List of Tables** ............................................................................................................................ 14

**Acronyms** ............................................................................................................................... 16

**Introduction and Methodology** ............................................................................................... 17

- **Background** .......................................................................................................................... 17
- **Problem definition** ............................................................................................................... 18
- **Problem statement** ............................................................................................................. 18
- **Sub-questions** ..................................................................................................................... 19
- **Research objectives** ............................................................................................................ 19
- **General Research framework** ............................................................................................. 19
- **Thesis plan** .......................................................................................................................... 21

**Value of this research** ............................................................................................................. 22

- **Societal relevance** ................................................................................................................ 22
- **Scientific relevance** ............................................................................................................. 24

**Part A: Selection of an assessment tool** ................................................................................ 26

- **Existing assessment tools** ................................................................................................... 26
  - **A tools’ anatomy (in steps)** ............................................................................................... 28
- **Selection method** ................................................................................................................ 33
  - **Process steps** ................................................................................................................... 33
  - **Application of the selection method** .............................................................................. 34
  - **Process steps** ................................................................................................................... 34
  - **Selection and results** ........................................................................................................ 39
  - **Selected tools** .................................................................................................................. 41
  - **Organization aspects** ........................................................................................................ 46
  - **Assessment scheme aspects** ............................................................................................ 46
- **Conclusions Part A** ............................................................................................................... 51

**Existing assessment tools** ...................................................................................................... 51

**Selection method** ................................................................................................................... 51
Selection and results........................................................................................................51

**Part B: Development method of a concept assessment tool**..............54

1. Goal and Scope of the concept assessment tool ..................................................54
   End users of the concept assessment tool ..............................................................54
   Scope of the concept assessment tool .................................................................55
   Goal and Scope of the concept assessment tool ..................................................56

2. System Boundaries of the concept tool .................................................................56
   Definition of district systems and boundaries ......................................................56
   Concept tool’s system boundaries ......................................................................61

3. Evaluation criteria and indicators .......................................................................61
   Goal Tree Success Tree (GTST) .........................................................................61
   GTST applied on energy neutrality ......................................................................62
   Function trees .....................................................................................................63

4. Fulfillment of data requirements .........................................................................69

5. Aggregation and weighing ....................................................................................69
   Comparison of Multi-criteria decision analysis (MCDA) methods .....................69

6. Validating results and analyzing ..........................................................................73

7. Presenting results ..................................................................................................73

8. Designing an effective interface ...........................................................................73

Conclusions on Part B ...............................................................................................74

**Part C: Concept assessment tool** .................................................................77

   Concept assessment scheme ...............................................................................77
   Concept tool’s anatomy .......................................................................................78
   Concept tool’s description ...................................................................................80
   Concept tool’s parts .............................................................................................70

Conclusions on Part C ...............................................................................................81

**Part D: Concept tool applied to MVH** .........................................................83

1. MVH district .........................................................................................................83
   Brief introduction of Merwe-Vierhavens ............................................................83
   System boundaries of MVH ...............................................................................85

2. Application and evaluation (Test and response) ................................................88
Application.................................................................................................................. 88
Evaluation.................................................................................................................... 89
Conclusions on Part D ............................................................................................... 93

Reflections ................................................................................................................... 94

Final Conclusions and Recommendations ............................................................... 97
  Existing assessment tools (Part A) .......................................................................... 97
  Developed method (Part B) .................................................................................... 97
  Concept assessment tool (Part C+ Part D) ............................................................. 98
  Specific Recommendations ................................................................................... 99
  General Recommendations .................................................................................... 99
  Epilogue .................................................................................................................... 100

References ................................................................................................................. 101

Bibliography .............................................................................................................. 107
List of Figures

Figure 1: Checkland’s seven stages overview, known as the SSM framework (Rodríguez-Ulloa and Paucar-Caceres, 2005) ................................................................. 20
Figure 2: Thesis plan ........................................................................................................ 21
Figure 3: International Rating Tools in 2003 (Reed et al., 2009; Reed and Krajnovic-Bilos, 2013) ........................................................................................................ 27
Figure 4: International Rating Tools in 2013 (Reed and Krajnovic-Bilos, 2013) .... 27
Figure 5: Anatomy of tools (IEA Annex 31, 2001). ............................................................. 28
Figure 6: LEED (dark orange) and BREEAM (light orange) based rating tools (Reed and Krajnovic-Bilos, 2013) ........................................................................ 41
Figure 7: Comparison of the number of environmental sustainability criteria aspects addressed to the frameworks of assessment tools studied ........................................... 48
Figure 8: Comparison of the number of economic sustainability criteria aspects addressed to the frameworks of assessment studied ................................................. 48
Figure 9: Comparison of the number of social sustainability criteria aspects addressed to the frameworks of assessment tools studied .............................................. 49
Figure 10: Comparison of the number of institutional sustainability criteria aspects addressed to the frameworks of assessment tools studied .................................. 49
Figure 11: Comparison numbers of aspects taken into account per sector of sustainability of assessment tools studied ........................................................... 50
Figure 12: The two main sub-systems of an urban district and their main interaction processes (Klaasen, 2004). ........................................................................... 57
Figure 13: Correlation between data generated from the real district and policy, planning and implementation adapted scheme (Johnson, 2012) ............................................. 60
Figure 14: Conceptual GTST framework (Modarres et al., 1999) ........................................ 62
Figure 15: Concept assessment scheme of energy neutrality at a district level ....... 78
Figure 16: Anatomy of the concept tool ........................................................................... 79
Figure 17: Concept of energy neutrality assessment tool................................................. 81
Figure 18: Example of 3x3 AHP matrix pair comparison of objectives A and B ...... 71
Figure 19: Example of 3x3 AHP matrix pair comparison of objectives A and C ...... 71
Figure 20: Example of 3x3 AHP matrix pair comparison of objectives B and C ...... 71
Figure 21: AHP example 3x3 pairwise sample matrix ....................................................... 72
Figure 22: Screenshot of an AHP matrix page ................................................................. 74
Figure 23: Types of normal distribution bell curve (a) Normal, (b) Negatively skewed and (c) Positively skewed ................................................................. 75
Figure 24: Screenshot of assessors’ preference weights .................................................... 77
Figure 25: Screenshot of the page of Ideal alternative score ........................................... 80
Figure 26: City-ports areas in Rotterdam (Daamen et al., 2013) .........................83
Figure 27: Port regionalization phases (Notteboom and Rodrigue, 2005) ..........84
Figure 28: Urban system boundaries interaction scheme ................................86
Figure 29: Merwe-Vierhavens geographical boundaries ...............................86
List of Tables
Table 1: Synopsis of the 10 criteria, their maximum points their weigh factors and the introduction of the score of the ideal tool ................................................................. 38
Table 2: The top ten existing assessment tools against the 10 criteria, and the outcome of their evaluation (the green light indicates that the criterion is fulfilled more than 67%, the yellow light indicates that the criterion is fulfilled more than 33.3% and the red light indicates that the criterion is fulfilled less than 33.3% ........................................ 39
Table 3: Summary of the analyzed tools .................................................................. 45
Table 4: Criteria derived from the function tree with main objective “to transit from fossil fuels to renewable energy systems” ........................................................................ 65
Table 5: Criteria derived from the function tree with main objective “To design an area that will be energy neutral” ................................................................................. 67
Table 6: Criteria derived from the function tree with main objective “To maintain energy balance”. .............................................................................................................. 67
Table 7: Criteria derived from the function tree with main objective “To generate energy equal or more than the energy consumed” .................................................. 68
Table 8: Comparison of MCDA against the element of objectives, three scales are used with three levels each Low (Low -, Low 0, Low +), Moderate (Moderate -, Moderate 0, Moderate +) and High (High -, High 0, High +) (adopted table from Papadopoulos and Konidiari, 2011) ................................................................................ 69
Table 9: Comparison of MCDA methods against the elements of assumptions, three scales are used with three levels each Low (Low -, Low 0, Low +), Moderate (Moderate -, Moderate 0, Moderate +) and High (High -, High 0, High +) (adopted table from Papadopoulos and Konidiari, 2011) ................................................................................ 69
Table 10: Comparison of MCDA methods against the elements of methodology, three scales are used with three levels each Low (Low -, Low 0, Low +), Moderate (Moderate -, Moderate 0, Moderate +) and High (High -, High 0, High +) (adopted table from Papadopoulos and Konidiari, 2011) ................................................................................ 70
Table 11: Comparison of MCDA methods against the elements of advantages and disadvantages, three scales are used with three levels each Low (Low -, Low 0, Low +), Moderate (Moderate -, Moderate 0, Moderate +) and High (High -, High 0, High +) (adopted table from Papadopoulos and Konidiari, 2011) ................................................................................ 70
Table 12: Example calculation AHP 3x3 sample matrix ................................................. 72
Table 13: Example of composing overall objective score ................................................ 79
Table 14: Different stages in the traditional port-city interface (Hoyle, 1998) .............. 84
Table 15: Score of Alternatives of energy neutrality development of Merwe-Vierhavens ...................................................................................................................... 92
## Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHP</td>
<td>Analytic Hierarchy Process</td>
</tr>
<tr>
<td>BREEAM-NL</td>
<td>Building Research Establishment Environmental Assessment Method - Netherlands</td>
</tr>
<tr>
<td>CASBEE</td>
<td>Comprehensive Assessment System for Building Environmental Efficiency</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographical Information System</td>
</tr>
<tr>
<td>GPR</td>
<td>Green Performance of Real estate</td>
</tr>
<tr>
<td>GTST</td>
<td>Goal Tree Success Tree</td>
</tr>
<tr>
<td>ELECTRE</td>
<td>ELimination Et Choix Traduisant la REalité (ELimination and Choice Expressing REALity)</td>
</tr>
<tr>
<td>LEED</td>
<td>Leadership in Environmental and Energy Design</td>
</tr>
<tr>
<td>MAUT</td>
<td>Multi-Attribute Utility Theory</td>
</tr>
<tr>
<td>MCDA</td>
<td>Multi-Criteria Decision Analysis</td>
</tr>
<tr>
<td>MVH</td>
<td>Merwe-Vierhavens</td>
</tr>
<tr>
<td>OM</td>
<td>Outranking Methods</td>
</tr>
<tr>
<td>PPP</td>
<td>Public-Private Partnerships</td>
</tr>
<tr>
<td>PROMETHEE</td>
<td>Preference Ranking Organization METHod for Enrichment of Evaluations</td>
</tr>
<tr>
<td>SMART</td>
<td>Simple Multi-Attribute Rating Technique</td>
</tr>
<tr>
<td>SSM</td>
<td>Soft System Methodology</td>
</tr>
</tbody>
</table>
Introduction and Methodology
This chapter outlines the context and content of this research thesis.

Background
Anno 2008, Municipality of Rotterdam started using concession type projects for urban development and regeneration.

Projects that called concession type of projects follow concession scheme. Under a concession scheme a private company or consortium designs and builds specific investments/infrastructures on the basis of finance provided by it, and recoups the money by a contract to provide services for a period of years, (usually decades), while the asset itself remains owned by the public sector (Hall et al., 2003; Akintoye et al., 2003; Grimsey and Lewis, 2004). In order to execute a concession type of project, concession arrangement /agreement is signed by public and private sector, usually named in literature as Public-Private Partnerships (PPP). Three are the main needs that motivate governments to enter into PPPs for urban development (European Commission, 2003; Felsinger, 2008; 2011 Witters et al., 2011).

1) Limitations in public funds to cover investments needs
2) To increase efficiency and use available resources more effectively.
3) To reform sectors through a reallocation of roles, incentives, and accountability

More specifically, the Municipality of Rotterdam wants to develop Merwe-Vierhavens in Stadshavens, for 30 years with this type of contract scheme.

The area of Stadshavens lies along the bank of river Maas. These areas contain harbors and industries related to harbor activities. Because of the newly reclaimed Maasvlakte 2 project, the scenery of the area is changing. Harbor activities are moving away from that area towards the seafront. The result of this relocation is a change in functions, areas that used to be “city harbors” and related industries and creation of space. This makes room for implementing new concepts of urban development and redevelopments (Rijnmond D, 2013). The situation at Merwe-Vierhavens (MVH) in Stadshavens provides an opportunity to rethink infrastructures and gives a chance to include sustainability in the principles of city development. The development of the area of Stadshavens is used as a “playground” for innovation and sustainable solutions (Stadshavens Rotterdam.nl, 2013). In the framework of the project Stadshavens, the private sector is invited by the Municipality of Rotterdam to propose reconstruction plans of the various districts of Stadshavens (Stadshavens Rotterdam.nl, 2013). One of the concepts that are favorable to be implemented in Merwe-Vierhavens is energy neutrality.

Energy neutrality is a successful sustainability concept applied widely in buildings. Energy neutrality concept is a result of implemented technologies and it is used to state the ambition of energy performance of a system. A system is defined as energy neutral when for a given amount of time (usually annually) and the energy consumption is equal to the energy generation. To a higher level of system complexity, to the level of a district, few examples of energy neutrality concepts are encountered worldwide but scaling up the concept and take advantages of the benefits of energy neutrality is gaining more and more fans (Opstelten, 2007; Voss and Musall, 2013, Jablonska et al., 2012).

If consortia generate plans of energy neutral Merwe-Vierhavens then the Municipality of Rotterdam will be at the position of choosing. Often, assessment methods and tools are used to assist decision making process against alternatives selection. Existing assessment methods and tools have limitations concerning their usefulness and effectiveness in relation to environmental performance, due to change of future requirements (Chun, 2008). They vary in great extent (like in scale of assessment, type of projects, use, etc) because they have been designed for different purposes and needs. They can be used as design tools, for assisting selection processes and for labeling purposes (Chun, 2008; Reed et al., 2009). Their “design” differences can be caused by regional variations (individual characteristics of the country where they have been developed or addressed to), addressed complexity of environmental, social and financial aspects,
evaluation of qualitative and qualitative data, weighing criteria and finally the measurement scales (benchmark) (Chun, 2007; Sauders, 2008; Reed et al., 2009). Therefore, the choice of the assessment tool one should use strongly depends on the projects’ needs and purpose definition by the user (Haapio and Vitioniemi, 2008). The majority of the existing assessment tools developed are scoping the assessment at a building level.

**Problem definition**

The Municipality of Rotterdam aims to develop MVH energy neutral under a concession scheme. Merwe-Vierhavens (MVH) is part of Stadshavens. Stadshavens area faces spatial and functional changes under concession type of projects. The main spatial and functional changes are that from an industrial port area and polder area is transforming to vacant area and eventually to a residential area. Another big change is that with the concession type of agreement of PPP, responsibilities of urban development from public sector are passing to private sector. The Municipality of Rotterdam in order to control that change of power towards the private sector will provide the guidelines for the development of MVH. By these guidelines and its decision Municipality of Rotterdam is aiming to promote and pose its ambitions and requirements to private consortia. The main requirement will be the implementation of energy neutrality concept at Merwe-Vierhavens.

Energy neutrality is a trend in urban development and it is proposed as development option for Merwe-Vierhavens district. Proposed urban development plans will present the way the current district system of Merwe-Vierhavens can be transformed to an energy neutral district system. These plans are named energy master plans from now and on. Energy master plans could vary in great extent. Their variation results of different choices of alternatives of technology and of the consistency of the consortium. Private consortium can consist of many different companies. Since energy neutrality is a concept that is not yet scaled up at a district level, seem to be necessary to examine at what extent existing tools can be used. Summarizing, the Municipality of Rotterdam will be soon called to assess which urban development plan generated by private consortia will be the best fitting plan for MVH to be developed as energy neutral. Municipality of Rotterdam wishes to have a substance assessment tool to facilitate its decision.

**Problem statement**

The Municipality of Rotterdam wishes to have a tool to assess energy master plans to facilitate decision making.

**What is the lack of insight?**

The main objective of the Municipality of Rotterdam is to assess energy master plans developed by private consortia for MVH scoping energy neutrality development. In order to fulfill this main objective searches for an appropriate assessment tool that could assess energy master plans for a district development on energy neutrality performance. This assessment tool could be a fitting existing one or a new developed tool that could cover prerequisites of the Municipality of Rotterdam. The prerequisites posed by the Municipality of Rotterdam are objectiveness, flexibility, robustness, transparency and equality. The aforementioned prerequisites are placed in order to assist decision making process by reassuring in great extent that the choice will be according Rotterdam’s vision and ambitions for sustainable development.

Private consortia, citizens of MVH and of Rotterdam in general are the main stakeholders that are affected of the choice use the assessment tool. Private consortia want to be chosen to develop Merwe-Vierhavens and make profit out of this contract. Citizens of MVH and of Rotterdam in general want the best possible plan to be chosen that will reassure and promote a sustainable development.
Main Research question
How to assess energy master plans proposed by private consortia for developing and maintaining Merwe-Vierhavens as an energy neutral district?

Sub-questions
A. How to discover tool for energy neutrality assessment at a district level and at what extent existing assessment tool cover energy neutrality at a district level?
B. How to develop a tool for energy neutrality assessment at a district level?
C. How to assess energy master plans proposed by private consortia for developing and maintaining an energy neutral district?
D. How to apply this assessment tool to energy neutrality in MVH?

Research objectives
The objectives of this thesis are twofold.
A. A method to select or/and develop a suitable assessment tool for energy neutrality at a district level.
B. Based on this method, a substantive assessment tool for energy neutrality at a district level that could be tested on Merwe-Vierhavens.

General Research framework
Soft System engineering Methodology (SSM) framework (Figure 1) by Checkland (Rodriguez-Ulloa and Paucar-Caceres, 2005) was used in order to solve this complex problem presented by the problem description. Soft System Methodology (SSM) helps formulate and structure thinking in complex problems. SSM main core is construction of conceptual models and comparing them with a real world situation. The rational processes of creating with conceptual models are based on perceiving, predicting, comparing and determining the changes and actions (Kristy, 1995). Conceptual models are representations of an ideal constructed system that follows the main principals and functions of the system that we want to achieve. In our case the ideal system is an assessment tool for energy neutrality at a district level. The SSM has seven stages (Figure 1) according to Checkland (Rodriguez-Ulloa and Paucar-Caceres, 2005; Kristy, 1995)

I. Situation that is considered to be problematic  
II. Problem situation expressed  
III. Root definition of relevant systems  
IV. Conceptual models of systems described in root definitions  
V. Comparison of models and real world  
VI. Changes: systemically desirable, culturally feasible  
VII. Action to improve the problem situation
Figure 1: Checkland’s seven stages overview, known as the SSM framework (Rodríguez-Ulloa and Paucar-Caceres, 2005)
Thesis plan
Thesis plan scopes to present the thesis structure, its connection with the SSM framework that was previously introduced. Each of the four parts of this thesis (A, B, C and D) answers a sub-question. The main research question is answer in the conclusions of this thesis. Figure 2 is schematic representation of the thesis plan. Each part that is presented at Figure 2 is briefly analyzed afterwards for proving a general view to the reader.

Part A Selection of an assessment tool
Part A presents how the existing assessment tools developed and a method of how to select an assessment tool according to its characteristics.

All the assessment tools developed following the same structure/anatomy. Based on their anatomy and the scope of this thesis a selection method was developed. This method was applied on energy neutrality at a district level. The results of this application are the selection of six existing assessment tools to be analyzed and compared in order to show why they do not fulfill the prerequisites to assess energy neutrality at a district level.

Part B Development method for a concept assessment tool
Part B is dedicated to develop a method to generate an assessment tool that could cover the assessment of plans for energy neutral districts with a concession type of contracts by the Municipality of Rotterdam. In order to describe the full picture of a problematic situation the first step was to determine the scope and system boundaries of the concept tool. The scope and the system boundaries of the tool derived from the analysis of district systems and their notions, and the current assessment process of concession projects. Then the objectives of energy neutrality needed to be defined. The energy neutrality objectives were defined and generated by the facilitation of Goal Tree Success Tree (GTST) methodology in combination with the objectives of the existing assessment tools previously analysed. The next step was to aggregate these
objectives. The main Multi-Criteria Decision Analysis (MCDA) methods were analysed and compared to identify which is the most appropriate method to facilitate the development of a concept tool for energy neutrality at a district level. The method chosen and therefore presented is Analytic Hierarchy Process (AHP) for the part of aggregating and weighing the objectives of energy neutrality.

Part C Concept assessment tool
Part C is dedicated to the concept tool. It is divided in three main procedures, aggregation of energy neutrality objectives into a hierarchy, weigh the objectives and decomposition of alternatives and scoring. The procedures of weighing and decomposing and scoring were facilitated by excel to be relatively easy environment of use. The weighing of energy neutrality objectives is using a series AHP matrix. Experts from different fields suppose to fill in these matrixes. The results of the matrixes are preferences weights to each objective of energy neutrality. The results of every expert that filled in the spreadsheet of matrices are the input of the next spreadsheet which calculates the averages of the weights preferences of the experts and statistics analysis of their weights of preferences. The average of their preferences is input for the third part of the concept tool. The third part of the concept tool is calculating the score of energy neutrality alternatives. The alternatives are plans generated by private consortia and decomposed in order to be rated.

Part D Application to MVH
Part D is dedicated to the application and evaluation of the concept assessment tool. After the development of the concept tool application and evaluation was done for indicating its strengths and its lacks. For that reason six experts for the Municipality gave their input to generate the objectives weights for energy neutrality development at Merwe-Vierhavens district. Also seven ideal alternatives for Merwe-Vierhavens were developed in order to proceed to a complete test of the concept tool.

The results of this thesis and of the application and evaluation are reflected at the conclusions and recommendations.

Value of this research
The aim of this thesis is on developing a tool for assessing energy neutrality plans at a district level. The fact that energy neutrality could have many different positive effects (explanation at the societal relevance section) makes the assessment of the implementation plans towards neutral energy district development important. Society benefits indirectly from the assessment tool development but it benefits directly and in many ways if the energy neutrality is applied at a district level. Hence, the reason that energy neutrality was chosen to be assessed and not another concept will be presented toughly at the section societal relevance concluding why the assessment of energy neutrality plans is also important. The scientific relevance will be focus more on the assessment tool.

Societal relevance
The “axes” of sustainability are: “Profit”, “People and “Planet”. For “Profit”, prosperity stands for the economic quality, profit, affordability. For “People” stands for honesty/reliability and transparency, the social quality included health, livability, freedom and freedom of choice, (among other aspects, whereas. For “Planet”, prosperity stands for the environmental quality and focuses on the purity and availability of energy, water, materials, waste and mobility (van Timmeren, 2013). All the goods and services that characterize modern western societies’ prosperity depend on the provision of energy. (Haas and Nakicenovic et al., 2008). At a district level system prosperity aspect liveability is important. Liveability to this document means suitable to live in, comfort. More and more cities and districts turn to eco-friendly solutions (Joss and Tomozeiu et al., 2013). Improving the livability of the built environment at a district level requires a new approach of development. The new approach is the concept of energy neutral
district (Willems and Jablonska, et al., 2011). The drivers to embrace and promote energy neutrality at a district level will be classified to environmental, social and economical drivers.

Environmental drivers
One environmental driver is the willing of decrease the CO2 emissions by take into account also the trend of energy consumption growing (European Commission's targets). According to Meijer et al. (2011) it is better to focus on the development of an energy neutral city and not to focus on the emission of less CO2. Targeting the source and not the effects with an integrating manner like energy neutrality better results can be achieved. Another really important environmental issue is the depletion of the fossil fuels’ proven reserves and the shift towards renewable energies (REN21, 2011 Rotterdam’s approach towards renewable energies implementation). Energy neutrality at a district level is driven towards renewable energies uses and independence from fossil fuels by the local generation of energy.

Social drivers
A district could not be ‘alive’ without its citizens. Nowadays, people demands towards a more livable and cleaner environment are rising. Social awareness is rising towards sustainability matters and that is a development of a niche. Finding smart solutions that work across different scales and steer local and regional developments to make them ‘future-proof,’ ecological and attractive – and thus meet the needs of society (Meijer and Adriaens et al., 2011). The balance between the generation and the demands could lead to a shift of the users’ mentality, to more ecological and more sustainable practices. The intensive search for suitable technologies can lead to innovations. The design process can involve the users that could lead to a bottom-up design approach (Voss and Musall, 2013). People want to be generators of their own energy and gain the feeling of independency, self-sufficiency and mostly the power of choice. An indicator could be the district of Wetering in Amsterdam that a collective community organization of citizens asked for plan proposals to develop energy neutrality at the Wetering district (Wetering sustainable2013).

A governmental driver is that after 2020, all the new building will have to be nearly zero energy consumption buildings (Ec.europa.eu1, 2013) adding to the targets posed by the European Union of 2020. Energy neutrality is also targeting to lower energy consumption. New technologies and practices, research for technical solution can lead to generation of jobs, new professions and new ways of working (Ec.europa.eu1, 2013). But also the part of energy generation can generate a great number of jobs as the market will demand experts in new fields having the relevant knowledge (Wei and Patadia et al., 2010).

Economic drivers
Economy is always a big driver to change current situations. Energy prices will always be a catalytic driver to market changes. Financial incentives are more important for the adoption of renewable energy technologies and overcoming certain market barriers (Bertoldi and Rezessy et al., 2009). Such incentives are broadly used in various environmental and energy fields provided for governmental authorities or electricity companies. The incentives are usually associated with specific technology support, rather than a general sustainable behavioral change. European commission provided incentives, co-funded many projects for smart cities. Another common practice used in Europe, for example in UK, is the “feed in tariff” scheme. The feed in scheme means that if someone generates energy and feed it in the grid, the owner of the grid (the electricity company) is paying for the amount of energy that was feed in to the grid. As the economic crisis is an issue, European commission is giving less and less subsidies or co-funds projects (Concerto conference, 2013). Hence, new business models and approaches must be developed.
Without reducing our well being, the balance between generation and production offers cuttings to the monthly energy bill by optimum use of energy (Ec.europa.eu1, 2013). The benefit of a reduced electricity bill and long-term when the balance between generation and consumption is achieved, no cost for electricity, (only the system maintenance costs) is the stronger driver for every governmental organization, consortia, industry and company or household embrace the concept of energy neutrality (Voss and Musall, 2013). Hence, the combination of reducing the energy consumption, increase the energy efficiency and generate renewable energy seems the three main pillars energy neutrality is based on, seems like a rational choice to generate cutting on the energy bills.

Scientific relevance

The development of such a tool is not only serving the ambitions of Rotterdam Municipality (as mentioned at the previous paragraphs) but also the Master program of Industrial Ecology. The scientific relevance of the development of the assessment tool is that the development will be based on system engineering approach. System engineering is widely in use but as a scholarly and formal discipline just start to exist (Shenar and Sauser, 2009). The process of developing the tool will provide a better understanding of what are the function requirements for achieving energy neutrality at a district level. The review of the existing assessment tool performance on energy neutrality at a district level will give an insight of what are the lacks and the strengths of these tools. The case study of Merwe-Vierhavens will also provide to real data for energy potential and relevant information for energy neutrality development. The complete occupation layers for developing energy plans for the area of Merwe-Vierhavens will be available for future use. The criteria posed will be based on the pillars gained by Industrial Ecology. Hence, the “lessons learned” could be a gained from the pathway from theory to application using the existing methods (multi-criteria analysis), assessment tools (Breeam-nl etc) and technologies like ArcGIS in an optimal way for energy neutrality assessment at a district level.
PART A
Assessment tool selection
Part A: Selection of an assessment tool

Numerous assessment tools exist, many of which assess energy performance of buildings of areas. The majority of the existing assessment tool focuses in assessing energy performance in various types of buildings. Since 2007, assessment tools started to scale up with BREEAM scheme leading the way. Hence, the selection of appropriate assessment tool that serves better a certain assessment could be a difficult process. The purpose of this part is

- to provide a method that can be used to select an existing energy and building related assessment tool
- to apply the selection method to narrow down the existing assessment tools in order to see if existing tool could assess energy neutrality at a district level
- to analyze the most promising for energy neutrality assessment tools in order to identify their strong and weak aspects of their schemes

The scope of this part is to identify if the existing assessment tools can assess energy neutrality at a district level and at what extent.

The selection of an assessment tool starts with the presentation of the existing assessment tool, proceeds with the method developed to choose an assessment tool and ends with the application of the developed selected method to energy neutrality at a district level. This part’s conclusions scopes to provide the whys the existing assessment tools are not suitable to assess energy neutrality at a district level.

The existing assessment tools are presented in order to show how they were developed. All existing assessment tools have a certain similar structure in order to be developed, which is called anatomy of the tools in the text. Anatomy is a set of elements, backbones that provides guidelines for developing an assessment tool. They differ at the elements of their anatomy. Based on their anatomy a method of selection was developed.

The selection method is an accredit method (credits appointed method) that is based on the choices of desirable characteristics (of the assessment tool) by the end user(s).

The developed selection method was applied to energy neutrality at a district level. A number existing assessment tools were examined with that method. The most promising ones were analyzed and compared to show why they are not 100% suitable to assess energy neutrality at a district level.

Existing assessment tools

Energy related environmental assessment tools are an interface between environmental objectives and decision taking and policy making (IEA Annex 31, 2001; Happio and Viitamiemi, 2008). Their utility is to inform the decision maker to understand the consequences of different choices but also they can provide guidelines to improve environmental performance of buildings. This interface aims solutions for implementing evaluation methods and calculations at a building environment (Haapio and Viitamiemi, 2008). Their solution driven nature, makes them to vary in great extent. The existing energy-related environmental assessment tools are numerous, approximately 600 (Haapio and Viitamiemi, 2008; Reed et al., 2009).

Figure 3 presents the assessment tools that are used globally in 2003 (Reed et al., 2009; Reed and Krajnovic-Bilos, 2013) and

Figure 4 presents the assessment tools used globally in 2013. By comparing Figure 3 and Figure 4 we can see that more and more countries are interested in assessing their building environment and that the number of tools increases.

The number of tools is huge and is increasing (Reed and Krajnovic-Bilos, 2013) which makes their classification a difficult process (Annex31, 2001; Happio and Viitamiemi, 2008; Haapio, 2008; Chun, 2007; Saunders, 2008; Reed and Bilos et al., 2009). Their classification would be a helpful sorting procedure that could permit us an easier identification of which class could be more suitable for assessing energy neutrality at a district level.
At an attempt to classify the assessment tool we discover that all assessment tools have two things in common that their purpose of development is solution driven and they prescribe similar steps of structure (anatomy).
Their anatomy is the same (*IEA Annex 31, 2001*) however the aspects that are included in each and every step can differ. In other words every assessment tool follows the same basic structure (anatomy) but the specific elements of its structure (*Annex31, 2001; Happio and Viitamiemi, 2008; Haapio, 2008; Chun, 2007; Sauders, 2008; Reed and Bilos et al., 2009*).

The differences can be identified to combination of the different elements to justify its existence.
The anatomy of an assessment tool is presented at Figure 5 (IEA Annex 31, 2001). The steps (anatomy's elements) that are used for a tool development are the following eight (Figure 5):

1. the goal and scope,
2. the system boundaries,
3. the evaluation criteria,
4. the data requirements,
5. aggregating and weighing,
6. validating results and analysis,
7. presenting results and
8. designing an effective user interface.

It is important to notice that the development of an assessment tool starts and ends at the same point which is the goal and the scope (Figure 5). That point is a meeting point of the developers and the users and it explains why the tools are solution driven developed. The steps 1, 2, 7 and 8 are in relation to the decision making framework. The decision making framework is mainly affected by actors, the actors involved and their roles towards the creation and use of the tool (IEA Annex 31, 2001). The steps 3, 4, 5 and 6 are in relation with the environmental framework. The environmental framework is mainly affected by the building and technological system context and improvement (IEA Annex 31, 2001).

Each anatomy element (1, 2, 3, 4, 5, 6, 7 and 8) presented in Figure 5 could be analyzed to specific aspects that it could be composed of. Each aspect offers a series of choices. The combination of these choices might differ in each tool (Annex31, 2001; Happio and Viitamiemi, 2008; Haapio, 2008; Chun, 2007; Sauders, 2008; Reed and Bilos et al., 2009).

These aspects will help us to understand why they differ in great extent and what we need from an assessment tool. These aspects are choices made by tools developers to serve a specific goal and scope of an assessment tool. The following paragraphs present in an analytical way the steps and the different aspects that could lead to an assessment tools' development.

A tools' anatomy (in steps)

The following lists are created by the literature review conducted using Annex31, 2001; Happio and Viitamiemi, 2008; Haapio, 2008; Chun, 2007; Sauders, 2008; Reed and Bilos et al., 2009. It is an attempt to provide an insight of how a tool's anatomy can look like and how a tool can be developed follow the
steps and making choices in every aspect highlighted with red color. It is essential for a complete assessment tool to make choice in each aspect presented on the following list.

1. **Goal and Scope**: to determine who is going to use the assessment tool (to whom it is address to) (1.1) and for what reason of assessment (1.2).
   1.1. **Users** *(the users might differ in background but also mainly in interest)*
   - 1.1.1. Architects, engineers, contractors
   - 1.1.2. Producers of building products
   - 1.1.3. Consultants
   - 1.1.4. Residents
   - 1.1.5. Facilities managers
   - 1.1.6. Researchers
   - 1.1.7. Authorities
   - 1.1.8. Investors and building owners
   - 1.1.9. A combination of the above

1.2. **Users’ objective** *(the objective of assessment might differ because of the user choices, in any case it should be highlight and be clear for a more effective use of the tool)*
   - 1.2.1. Choice of product or technical solution
   - 1.2.2. Improvement of overall environmental building performance
   - 1.2.3. Living environmental information to customer or authorities
   - 1.2.4. Marketing/product comparison
   - 1.2.5. Project comparison
   - 1.2.6. Labeling/certification
   - 1.2.7. Meeting standards

2. **System boundaries**: to determine the system boundaries of the tool. The system boundaries of the tool determine it use and usefulness to the user.
   2.1. **Geographical** *(in different geographical scales we should expect different standards)*
   - 2.1.1. Global
   - 2.1.2. National
   - 2.1.3. Regional
   - 2.1.4. Local

2.2. **Scale of the assessment area** *(the different scale of assessment areas has to do with a different focus and also system complexity. In general the larger scale the complexity is rising)*
   - 2.2.1. Country (assessment only for CO2 emissions)
   - 2.2.2. City
   - 2.2.3. District
   - 2.2.4. Building

2.3. **Type of buildings** *(different types of building serve different functions therefore they are adopted in such a way to serve these functions)*
   - 2.3.1. Single dwelling
   - 2.3.2. Multiple dwellings
   - 2.3.3. Offices
   - 2.3.4. Hospital
   - 2.3.5. Schools
   - 2.3.6. Combination of the above

2.4. **Time horizon of assessment** *(in the construction environment the time horizon is really important because it affects the material and the cost)*
   - 2.4.1. Short term
   - 2.4.2. Mid term
   - 2.4.3. Long term
2.5. **Phase of life cycle of building** (the phase of the life cycle can affect the criteria posed for the assessment, a potential assessor looks for different things in the different phases of life cycle of a building)

- 2.5.1. Design
- 2.5.2. Production
- 2.5.3. Construction
- 2.5.4. Use/operation
- 2.5.5. Maintenance
- 2.5.6. Demolition
- 2.5.7. Disposal

2.6. **System level of buildings** (is related with the function that the offer)

- 2.6.1. Building services
- 2.6.2. Building stock
- 2.6.3. Building component
- 2.6.4. Building material
- 2.6.5. Other product

2.7. **Adaptability** (is related with time and assessment object. It determines how much flexible is the assessment tool in time passing (if it is revised every year, every couple of years or never) and if the scheme takes into account specifications of the assessment object with result being different in every assessment)

- 2.7.1. Entirely
- 2.7.2. Partially
- 2.7.3. None

3. **Evaluation criteria and indicators**: are the cores of the assessment and it is to identify the evaluation criteria and indicators of the assessment.

3.1. **Character** (determines the nature of the criteria used and the means that need to be used to gather these criteria)

- 3.1.1. Qualitative
- 3.1.2. Quantitative
- 3.1.3. Number of criteria
- 3.1.4. Number of indicators for each criterion
- 3.1.5. Number of criteria
- 3.1.6. Number of indicators for each criterion
- 3.1.7. Units
- 3.1.8. Measurements
- 3.1.9. Combination of the above

3.2. **Content** (determines the focus of the assessment scope)

- 3.2.1. Social
- 3.2.2. Environmental
- 3.2.3. Economical
- 3.2.4. Institutional
- 3.2.5. Combination of the above
4. **Fulfillment of data requirements** (refers of how the previous criteria and indicators are going to be fulfilled by whom and which means)
   
   4.1. **Standards** *(depend on the scale and the validity of the assessment that is necessary or wanted)*
   - 4.1.1. Regional
   - 4.1.2. National
   - 4.1.3. International

   4.2. **Certifications** *(depend on the validity that the assessor wants to promote and the use of the assessment)*
   - 4.2.1. ISO
   - 4.2.2. EPA
   - 4.2.3. Others

   4.3. **Organizations** *(certified organization or authorized organization that can provide data or certification for the assessment’s requirements)*
   - 4.3.1. National
   - 4.3.2. International

   4.4. **Sources and methods** *(refer to the type of sources that will be used to validate the criteria and indicators of the assessment)*
   - 4.4.1. Quality
   - 4.4.2. Format
   - 4.4.3. Databases in calculations
   - 4.4.4. Guidelines and questionnaires

5. **Aggregating and weighing** (how the posed criteria and indicators can be aggregated and weighed in order to offer to the user a complete effective scheme of assessment)
   
   5.1. **Method** *(is the framework of the assessment tool)*
   - 5.1.1. Credits
   - 5.1.2. Calculations
   - 5.1.3. Checklists

   5.2. **Weigh** *(shows how important is the criterion or indicator for the assessor and subsequently for the user)*
   - 5.2.1. Different
   - 5.2.2. Equal

6. **Validating results and analysis** (determine who and how validates and analyses the results and it is important to provide a sense of security and transparency to the user. It provides the context of assessment scheme used)
   
   6.1. **Validation results and analysis** *(determines the validity of the assessment scheme, data that were used)*
   - 6.1.1. Method
   - 6.1.2. Standards

   6.2. **Assessors** *(adds to the credibility of the assessment scheme)*
   - 6.2.1. Experts different than the users
   - 6.2.2. Same as the users
   - 6.2.3. A mix of the above
   - 6.2.4. Public
   - 6.2.5. Private
7. **Presenting results** (The presentation of results affects usefulness and the marketing of the assessment tool)
   7.1. **Grades** (provide a visualization of the result especially if it want to be compared with another assessment)
      7.1.1. Scale (ex. 1-5, 1-10, 1-100, A-F etc.)
      7.1.2. Pace (1, 0.5 etc.)
      7.1.3. Type (number, symbol, percentage)
   7.2. **Labels** (provide another type of visualization of the result used mainly for assessments aiming labeling and positive public opinion)
      7.2.1. Pass, Good, Very Good, Excellent
      7.2.2. Gold, Silver, Platinum
   7.3. **Certificates** (aim mostly to prove the quality of the assessment object for financing reasons)
   7.4. **Graphs** (aim to visualize the results compared them with a benchmark situation or for comparison reasons)
      7.4.1. Pies
      7.4.2. Histograms
      7.4.3. Bars
      7.4.4. Heat-maps

8. **Design an effective user interface** (The assessment should be designed effectively for relative ease of use for the user and be explained in such a way to promote it to facilitate the assessment process)
   8.1. **Interface** (plays important role to the usefulness of the assessment scheme and it has an effect on the users' behavior and choice. In general more user friendly or familiar environments are chosen for an assessment tool's scheme. The interface might have a result on complexity, time and price of the assessment tool)
      8.1.1. Spreadsheet
      8.1.2. Checklist
      8.1.3. Calculator tool
   8.2. **Information providence** (For a useful and effective assessment tool the type of information provided for its use and scope is quite crucial as it could assist the user)
      8.2.1. Technical manual
      8.2.2. Organizational manual
      8.2.3. The tool itself
      8.2.4. Interactive
      8.2.5. Non-interactive
   8.3. **Revision of the tool** (Depended on the assessment scheme the revision is an important aspect, in some cases costly but the updates are always contributing to the progress of the assessment)
      8.3.1. Annual
      8.3.2. Every n-years
      8.3.3. When it is required
      8.3.4. From the users
      8.3.5. From experts
   8.4. **Fees** (can be asked in many phases or stages of the assessment and are depended on who is assessing and for what scope)
      8.4.1. Certification fee
      8.4.2. Fee to become an assessor
      8.4.3. Fee for registering a project
      8.4.4. Fee for specific credits to be assessed
      8.4.5. Fee for complaints
      8.4.6. No fees
How the previous list of steps, elements and choices can be used?

This list can be used for a selection or a development of an assessment tool that will follow wanted characteristics. Each step must be followed. At each element there must be choices made that will reflect the wanted characteristics of the user.

The anatomy presented is important because it explains the variety of the existing assessment tool and it gives us an insight view of the specific characteristics (choices) that every tool could have. The presented anatomy will be used to develop a selection method that will assist our sub-questions

A. How to discover tool for energy neutrality assessment at a district level and at what extent existing assessment tool cover energy neutrality at a district level?

B. How to develop a tool for energy neutrality assessment at a district level?

The analysis of the anatomy of the assessment tool is a useful method not only to identify the differences of existing assessment tool but also to understand the essential elements of an assessment tool that could fulfill energy neutrality at a district level by the public works authorities of Rotterdam which is presented at the following paragraphs.

Selection method

Since the tools could differ in a great range at aforementioned characteristics, proper choice of tool is a challenging process, depended on the user’s purpose and objective of the assessment (Haapio, 2008). The choice should be based on desired results (Haapio, 2008). In literature (Happio and Viitamiemi, 2008; Haapio, 2008; Chun, 2007; Sauders, 2008; Reed and Bilos et al., 2009) usually the most popular assessment tools are compared. The idea of the development selection method is based on the anatomy of the tools and it scopes to facilitate the identification of the tools that will fit most the needs and wants of the end user.

Process steps

The process steps of the selection method are presented to organize the procedure of the existing tools selection that was followed. These steps were followed by the other on November of 2014, and assisted by six experts of the Municipality of Rotterdam. The reason of the assistance by those six experts was because they are the potential users/ assessor of an assessment tool selected.

1) Formation of the selection criteria.

The criteria are derived by making “choices” to the elements of tools' anatomy by the end users of the tool. The scope of the criteria formation is the identification of the necessary and wanted characteristics of an assessment tool for energy neutrality assessment at a district level by public authorities.

2) Rating scales and points to each of the criteria.

The criteria of selection of an assessment tool differ in nature and importance. In order to be able to compare them in a visible way rating scales and points were introduced.

a. Points

The existing assessment tools differ in great extent. In order to rate the chosen criteria a point system was to be developed by the author and revised by six experts of the Municipality of Rotterdam. Each criterion has been awarded with certain points. Allocation of points scopes a more visible way of rating the existing tools. The allocated points are described at the application of the method. The scope of the points is the facilitation of selection and not objectivity or sensitivity of the method.

b. Normalization scale

Then the points of each criterion are normalized in order to be comparable.

c. Pair-wise comparisons matrices
The criteria chosen by the user are not equally important that is the reason that a pairwise comparison matrix is introduced. The matrix should be filled in by all the potential users that of the assessment process.

The selection aims to be objective as much as possible and to help the end user decide which will be the most fitting assessment tool to assess energy neutrality plans developed for MVH. If the examined tools do not covers 100% or at a satisfactory percent the end user/s’ needs and wants then a development of a new assessment tool is necessary.

Application of the selection method
The presented method was applied to energy neutrality at a district level facilitated by the end users of the tool. The end users are experts/public servants of the Municipality of Rotterdam that will probably be assessors for MVH’s project. The steps of the method were followed to select the most relevant tools. Then the most fitting tools were analyzed and compared. It is needed to be highlighted that the choices made are case study driven are to assist the Municipality of Rotterdam and are made from the Municipality of Rotterdam’s experts.

Process steps
1) Formation of choice criteria
The Municipality of Rotterdam as the future user of assessment tool posed a logical set of requirements. The assessment tool should provide an answer to the following question: “How to assess energy master plans proposed by private consortia for developing and maintaining energy neutral district?

The criteria are derived by making “choices” from the elements of tools’ anatomy. The choices have been taken by the author with the consultancy of its supervisors and six experts of the Municipality of Rotterdam. (The choices taken are presented with *italics*. Some of the elements are stripped out, that means that they consider being less significant at the selection process of an assessment tool in this specific case accordingly to the needs and wishes of the Municipality of Rotterdam.)

1. Scope and goal
   1.1. Users: *Public authorities and architects, engineers and contractors*
   1.2. Users’ objectives: *Project comparison and more specifically assessment of energy neutrality plans for district development*

2. System boundaries
   2.1. Geographical:
   2.2. Scale: *District*
   2.3. Type of buildings: *All*
   2.4. Time horizon: *Long term*
   2.5. Phase of life cycle: *Design*
   2.6. System level: *District development alternative plans*
   2.7. Adaptability: *Entirely*

3. Evaluation criteria and indicators
   3.1. Character:
   3.2. Content: *energy indicators in building environment*

4. Fulfillment of data requirements
   4.1. Standards: *National, Dutch government’s standards*
   4.2. Certifications:
   4.3. Organizations:
   4.4. Sources and methods:

5. Aggregating and weighing
   5.1. Method:
6. **Validating results and analyzing**
   6.1. Validation of results
   6.2. Assessors
7. **Presenting results**
   7.1. Grades
   7.2. Labels
   7.3. Certificates
   7.4. Graphs
8. **Designing an effective user interface**
   8.1. Method:
   8.2. Information providence: Technical manual, organizational manual, the tool itself
   8.3. Revision of the tool:
   8.4. Fees

In order to rate the choices they needed to be translated into criteria for the selection method. These criteria are formed in a way that could provide a more clear idea of what the end user of the tool wants and named by the Latin alphabet just to separate them from the tools’ anatomy choices.

1. → A. The scope of assessment energy neutrality
   B. Destine for use by public authorities
   C. Destine for use by architects, contractors, engineers and scientists
2. → D. The ideal scale focus is on district level because this is the required scale of the development.
   E. Used for assessing plans.
   F. The time validity of assessment is at least for 30 years.
3. → G. Include energy performance criteria (generation and consumption) qualitative and quantitative to their framework for assessing energy neutrality
4. → H. To be used preferably in the Netherlands
5. 
6. 
7. 
8. → I. To have a high level of transparency
   J. A good penetration of use

The above criteria (A, B, C, D, E, F, G, H, I and J) are the results of the choices made by the Municipality of Rotterdam on what requirements should an assessment tool have in order to be able to assess energy neutrality at a district level.

2) **Rating scales and points of choice criteria**
The existing assessment tools differ in great extent because of the nature of the criteria. Therefore in order to rate the aforementioned criterion a point system was developed. Each criterion is awarded with certain points. Allocation of points was developed as a more visible (communicative way) of rating the existing tools and to be able to assign them a numerical value. These points are explicitly described and represent the wanted results of the selection of the assessment tool. Then the points of each criterion are normalized in order to be comparable. Further each criterion is weighed. The weigh presents the importance of the criterion placed by pairwise matrices filled in by experts of Municipality of Rotterdam.
The purpose of scoring is to select the high scored existing tools as most promising to assess energy neutrality at a district level. Hence, the ideal assessment tool to assess energy neutrality at a district level would be the tool that scores 100% on the aforementioned criteria. Each criterion is awarded points to the examined assessment tool. The scope of the selection process is to select the tools that are more fitting to assess energy neutrality at a district level and not to develop an objective method to assess existing environmental assessment tools.
In the following paragraphs the explicit way of rating is presented, the allocation of points, the normalization scale and pair-wise matrices results. Finally, the points’ system to screen the existing assessment tools is summarized in Table 1.

a. Points

A. The scope of assessment. The scope of assessment would be ideal if it was energy neutrality, hence it will be awarded with the highest score. Unfortunately, not there despite the statements of the tool in many cases the scope of assessment is different. Hence, the researcher has to be careful with the claims of the each tool and assign the following points accordingly. The existing tools will be rated with points from 1 to 5 according to their scope description:

- 1 point will be awarded if the assessment tool declares that the scope is to evaluate energy consumption.
- 2 points will be awarded if the assessment tool declares that the scope is to energy consumption in different phases or lifecycle analysis.
- 3 points will be awarded if the assessment tool declares that the scope is sustainability.
- 4 points will be awarded if the assessment tool declares that the scope is energy performance and environmental load.
- 5 points will be awarded if the assessment tool declares that the scope is energy neutrality, zero net energy or CO2 neutrality.

The users B, C are rated in different categories because in most of the cases the end user of an assessment tool is either public authorities or professionals of the building sector.

B. Destined for use by public authorities because public authorities, the Municipality of Rotterdam is the potential user.

- 1 point will be awarded if the assessment tool is used by authorities.

C. Destined for use by architects, contractors, engineers and scientists because the development of energy neutrality plans will be done by private consortia. To promote transparency and to have better results on the assessment process access to a tool as end user is wanted by architects, contractors, engineers and scientists. There will be two groups distinguished: the architects, contractors and engineers and the second group the scientists because of the division of most of the assessment tools to commercial and scientific. The maximum points awarded will be 2 points.

- 1 point if the assessment tool is used by architects, contractors and engineers.
- 1 point if the assessment tool is used by scientists.

D. The ideal scale focuses on district level because this is the required scale of the development. The range of the score is 1 to 5 according to the possible options of building scale.

- 1 point is given to a tool that is developed to assess single buildings
- 2 points are for assessment tool that can assess more than one building
- 3 points are for assessment tools that can assess more than one building and different types of buildings
- 4 points are for assessment tools that can assess neighborhoods
- 5 points to assessment tools that can assess districts and cities.

E. Used for assessing plans is a criterion and it derives from the use of the wanted assessment tool. Not all assessment tools are aiming to assess plans there are many tool that are assessing operation phase of a project or a building when it is fully implemented/ build.

- 1 point is awarded to the assessment tool if it is used for assessing plans.
F. The time validity or time horizon of assessment is at least for 30 years taking into account the long term project phases and ask for re-assessment of the scheme, their time horizon of development is set for 30 years. The maximum points that a tested existing assessment tool can gain from this criterion is 3 point according to the period that its assessment is valid
- 1 point for short-term
- 2 points for mid-term
- 3 points for long-term

G. Include energy performance criteria (generation and consumption) qualitative and quantitative to their framework for assessing energy neutrality. The energy criteria are derived from the scope of the wanted tool to be able to assess energy neutrality, hence consumption and energy generation at all kinds of forms and phases. The maximum points awarded for this criterion are 8. The following:
- 1 point if only energy consumption is taken into account.
- 1 point if the energy consumption is measured in different phases of the project
- 2 points if there are energy generation measurements and the promotion of renewable energies generation.
- 1 point if energy consumption from the grid is taken into account
- 3 points if energetically independency from the grid is promoted

H. To be used preferably in the Netherlands. The reason that this criterion is posed is because the existing assessment tools that are used in the Netherlands are already adopted to the context including the legislation parameters of the country. It does not exclude assessment tools developed or used in other countries, just provided a preference to tools that are already embedded to the Dutch context.
- 1 point will be awarded if the assessment tool is used in the Netherlands

I. To have a high level of accessibility this leads to transparency. Enough available shared information for analysis provides highest possible standards of performance (Reed and Krajnovic-Bilos, 2013). The maximum gained points are 5 and are the following:
- 1 point if in order to get access to the tool you need to register a project.
- 2 points if you have to the trial version for a small amount of money.
- 3 points if the trial version is free but the assessment scheme is a black box
- 4 points if you can have access to the assessment tool but not to the specific criteria requirements.
- 5 points if the access to the assessment tool and the criteria is free and open

J. A good penetration of use is a criterion that provides the benefit of the assessment scheme being revised from many stakeholders and provide to projects value. The maximum credits that an assessment tool can be awarded are 5 points the following:
- 1 point if it is used not only in one country but internationally.
- 1 point if the number of the users/projects assessed is below 10 or unknown, because the assessment tool is in the process of development.
- 2 points if the number of the users/projects assessed is greater than 10.
- 3 points if the number of the users/projects assessed is greater than 100.
- 4 points if the number of users/projects assessed is greater than 200.

b. Normalization scale
Normalization means adjusting values measured on different scales to a notionally common scale, often prior to averaging. Criteria's points will be normalized to the scale of 10 in order to have the same scale of comparison. The normalization rates are presented at Table 1 third column.
c. Pair-wise matrix

The 10 posed criteria (A-J) are not equally important to the Municipality of Rotterdam. Their difference of importance is caused by their heterogeneity and the assumptions of what is more important by the experts of the Municipality of Rotterdam, potential assessors. In order to weigh the criteria a pairwise comparison matrix is created and completed by six experts of the Municipality of Rotterdam. A pairwise matrix is a simple raking method that prioritizes a small number of aspects. The concept of the pairwise matrix is the comparison in pairs of the criteria and in the end the calculation of their weigh (Saaty, 1988). The final weights are calculated as the average of the processed matrices completed by the Municipality of Rotterdam’s experts and are presented below.

A. Scope of assessment: 0.17
B. Used by authorities: 0.09
C. Used by architects, contractors, engineers and scientists: 0.04
D. Scale: 0.15
E. Used for assessing plans: 0.09
F. Time of validity of the assessment scheme: 0.04
G. Energy performance criteria: 0.2
H. Used in NL: 0.08
I. Transparency: 0.08
J. Good penetration: 0.07

We need to highlight again that the criteria, their points and their weight were produced for and by the Municipality of Rotterdam that means that for another city or another set of experts could be differ. Objectivity is not a strong aspect of this selection method. The reason of its development was not objectivity but to screen the existing tool and find out which could be closer to assess energy neutrality at a district level.

Points for the selection of existing tools’ revision

Table 1 sums the points and weights that are mentioned above of the 10 criteria and the introduction of the ideal tool. The ideal tool is the tool that fulfills the criteria 100% and it has the maximum possible points. The column of ideal tool is developed in order to set the idea of the maximum point that can be gained per criterion.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Maximum credits</th>
<th>Normalization to 10</th>
<th>Average weigh by Rotterdam’s Municipality experts</th>
<th>Ideal tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Scope of assessment</td>
<td>5</td>
<td>2</td>
<td>0.17</td>
<td>1.7</td>
</tr>
<tr>
<td>B. Used by authorities</td>
<td>1</td>
<td>10</td>
<td>0.09</td>
<td>0.9</td>
</tr>
<tr>
<td>C. Used by architects, contractors,</td>
<td>2</td>
<td>5</td>
<td>0.04</td>
<td>0.4</td>
</tr>
<tr>
<td>and scientists</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Scale</td>
<td>5</td>
<td>2</td>
<td>0.15</td>
<td>1.5</td>
</tr>
<tr>
<td>E. Used for assessing plans</td>
<td>1</td>
<td>10</td>
<td>0.09</td>
<td>0.9</td>
</tr>
<tr>
<td>F. Time validity of assessment</td>
<td>3</td>
<td>3.33</td>
<td>0.04</td>
<td>0.40</td>
</tr>
<tr>
<td>G. Energy performance criteria</td>
<td>8</td>
<td>1.25</td>
<td>0.2</td>
<td>2</td>
</tr>
<tr>
<td>H. NL used</td>
<td>1</td>
<td>10</td>
<td>0.08</td>
<td>0.8</td>
</tr>
<tr>
<td>I. Transparency</td>
<td>5</td>
<td>2</td>
<td>0.08</td>
<td>0.8</td>
</tr>
<tr>
<td>J. Good penetration use</td>
<td>5</td>
<td>2</td>
<td>0.07</td>
<td>0.7</td>
</tr>
<tr>
<td>sum</td>
<td>36</td>
<td>1</td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

Table 1: Synopsis of the 10 criteria, their maximum points their weight factors and the introduction of the score of the ideal tool
Selection and results
The choice process followed 3 steps:
57 existing tools were rated. The reason that 57 tools were chosen to be part of this selection process was to narrow down the 600+ existing assessment tools in means of time.

1st step: 57 tools were scored by using the point system explained. The input values to rate the tools are inserted based on existing literature reviews on assessment tool for building environment (Boonstra and Pettersen, 2003; Ding, 2007; Happio and Vitianni, 2007; Reed et al., 2008; Krikke, 2011; Reed and Krajnovic-Bilos, 2013; Poveda and Lipsett, 2012; Mpakati-Gama et al., 2012; Berardi, 2013) and on the official claims of the tools’ websites. ATHENA and IEA Annex 31 directory of tools will be also used to the development of the shortlist. The averages present how close are the existing assessment tools examined to the criterion fulfillment. The 57 existing assessment tools were evaluated presented in Appendix A.

2nd step: From scores of the 57 awarded tools 29 tools passed both the score of the average tool and the required tool score (ideal tool-average tool) (Appendix A)

3rd step: The top ten scored assessment tools are analyzed and presented at Table 2. The green light indicates that the criterion is fulfilled more than 67%, the yellow light indicates that the criterion is fulfilled more than 33,3% and the red light indicates that the criterion is fulfilled less than 33,3%.

<table>
<thead>
<tr>
<th>Tool name/ Criterion</th>
<th>A. Scope of assessment</th>
<th>B. Used by authorities</th>
<th>C. Used by architects, contractors and scientists</th>
<th>D. Scale</th>
<th>E. Used for assessing plans</th>
<th>F. Time validity of assessment</th>
<th>G. Energy performance criteria</th>
<th>H. NL used</th>
<th>I. Transparency</th>
<th>J. Good penetration use</th>
<th>Percentage of coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top</td>
<td>Ideal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100.00</td>
</tr>
<tr>
<td>1</td>
<td>BREEAM-NL new buildings</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>87.81</td>
</tr>
<tr>
<td>2</td>
<td>BREEAM-NL area</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>84.54</td>
</tr>
<tr>
<td>3</td>
<td>GreenCalc</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>82.70</td>
</tr>
<tr>
<td>4</td>
<td>GPR urbanism</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>81.55</td>
</tr>
<tr>
<td>5</td>
<td>LEED for neighborhood</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>81.48</td>
</tr>
<tr>
<td>mediant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80.69</td>
</tr>
<tr>
<td>6</td>
<td>CASBEE for urban development</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>79.90</td>
</tr>
<tr>
<td>average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>79.08</td>
</tr>
<tr>
<td>7</td>
<td>BREEAM area</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>76.63</td>
</tr>
<tr>
<td>8</td>
<td>Green Globes</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>75.15</td>
</tr>
<tr>
<td>9</td>
<td>CASBEE for cities</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>70.35</td>
</tr>
<tr>
<td>10</td>
<td>Green star</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>( )</td>
<td>68.23</td>
</tr>
</tbody>
</table>

Table 2: The top ten existing assessment tools against the 10 criteria, and the outcome of their evaluation (the green light indicates that the criterion is fulfilled more than 67%, the yellow light indicates that the criterion is fulfilled more than 33,3% and the red light indicates that the criterion is fulfilled less than 33,3%.

Top ten existing tools
The following paragraphs explain the score of the most high rated existing assessment tools against the 10 posed criteria and also provide the reason for further analysis or not and the reason that six of them in the end were analyzed.
1. **BREEAM-NL new building** got mainly its high score because it fulfills the scope of the assessment and it has a high rate at energy criteria fulfillment. For that reason it passed ahead of BREEAM-NL area because the weight given by the assessors is higher on the energy related criteria. The assessment tool takes much into account the energy aspects of efficiency, generation and consumption. Its use is widespread in the Netherlands and it is asked more and more from the Dutch municipalities according to their brochure. The drawback/weakness of the tool is its scale.

2. **BREEAM-NL area** has the appropriate scale but it is yellow rated to the scope and energy criteria. BREEAM is an international tool adapted to the Dutch context with the NL prefix to indicate it. It is currently already used and asked for labeling by the Dutch municipalities.

3. **GreenCalc+** is a popular assessment scheme in the Netherlands. The tool GreenCalc+ will not be analyzed as it stopped its development and propose to the clients to turn to BREEAM-NL schemes to assess their project via its site: [http://www.greencalc.com/](http://www.greencalc.com/)

4. **GPR urbanism** fulfills in great extent the ten criteria. GPR urbanism is a Dutch tool used in many case studies by the Dutch municipalities. Its scale is appropriate to assess a district.

5. **LEED for neighborhood development** because it fulfills also many aspects and gets a high score. LEED is an international well-known and also used in the Netherlands. Neighborhood level could be equivalent to a district level depending on the definition of a neighborhood which is minimum 320 acres ~1.3 km$^2$ according to the official operation brochure of LEED for neighborhood development of 2012. Another important reason to analyze BREEAM and LEED systems is that most of the international tools are based on their philosophy and scheme and it is presented in Figure 6 (Reed and Krajnovic-Bilos, 2013).

6. **CASBEE (Comprehensive Assessment System for Building Environment Efficiency) for urban development** is a scheme launched and developed in Japan. It is open source scheme and though that is used in Japan mostly and not internationally it fulfills in great extent the criteria posed. It is important to mention that the context of Japan is similar in some cases with the Netherlands as both of the countries face a problem of space and both have high ambitions for environmental procurement. Another reason that advocates the choice of CASBEE is that it differs a lot from BREEAM schemes and LEED scheme.

7. **BREEAM area** presents the almost the same characteristics with BREEAM-NL area, it has more energy performance criteria than the modified BREEAM-NL but it loses a lot of points because it is not modified for the Netherlands by the weigh of the experts of the Municipality of Rotterdam.

8. **Green Globes** is an assessment scheme developed in Canada and it dues its good scoring to the getting at least an average grade in each criterion. It will not be analyzed because it requires fees to enter its scheme and the permission to enter it without fee for educational reasons was not granted.

9. **CASBEE for cities** is a scheme that although its scope does not fit completely the energy neutrality is going to be analyzed. It fits and exceeds the scale. The energy aspects that are included to the scheme are translated to CO2 emissions in the tool and CO2 reduction is one of the Rotterdam’s Municipality aspirations.

10. **Green star** is an assessment tool used in Australia and New Zealand. It is the lowest rated among the top ten of the assessment tool that passed and it is mostly because it has a good average score to each criterion. It will not be analyzed because it requires fees to enter its scheme and the permission to enter it without fee for educational reasons was not granted.

After this brief presentation a more detailed analysis followed in order to identify why 6 of these tools (BREEAM-NL new buildings, BREEAM-NL area, GPR-urbanism, LEED for neighbourhood development, CASBEE for urban development and CASBEE for cities) are useful tools but they cannot fulfil the demands of the Municipality of Rotterdam to 100%.
Selected tools

The selected tools (BREEAM-NL new buildings, BREEAM-NL area, GPR-urbanism, LEED for neighbourhood development, CASBEE for urban development and CASBEE for cities) were thoroughly analyzed by the author and the presentation of this analysis is at the Error! Reference source not found.. GreenCalc+ is not examined as it is embedded in BREEAM-NL, BREEAM area is not analyzed because BREEAM-NL area is analyzed which is the “upgraded” version of it for the Netherlands, Green Globes and Green Star are not going to be analyzed as the permission of access to their scheme for education reasons was not granted unfortunately.

Their analysis was conducted by examining the following organizational aspects (O) and assessment scheme aspects (A)

- edition date (O)
- their scheme (type of criteria, the tool technique, the system technique, the number of categories used, the contain of the aspects of the categories used, the weighing of the categories, the weighs of the sub-categories, the benchmark credits, the credits distribution (negative, maximum, distribution, and innovation credits included or not) (A)
- complexity (certifications, bureaucracy, scheme) (A)
- level of transparency, accessibility for information to the end user (O)
- label (A)
- the use of other tools’ certificates and which (A)
- main focus derived from their assessment scheme and not their claims (A)
- types of projects aimed (A)
- certification labeling (O)
- update process (O)
- information gathering/ validation of data (O)
- property (to whom the assessment tool rights belong) (O)
- the validity of assessment, once is done when it has an expired date (A)
- presentation, how is presenting the results to the user the interface used. (A)
- Conclusion by the analysis to the most positive and the most negative aspects of the analyzed tools

Table 3 presents a summary of the analysis conducted and presented at Appendix A. The reason of presenting Table 3 is to introduce to the reader with some basic information about the existing assessment
tools that were analyzed. If the reader seeks to know more about a specific tool is strongly advised to look at Appendix A.

After the detailed analysis of the existing assessment tools selected (Error! Reference source not found.), a comparative presentation has been made between the selected tools. The aspects examined are divided to organizational and assessment scheme’s aspects. The underlined words are the aspects. The reason that the focus is not only at energy aspects as it would be expected because of energy neutrality is to gain the knowledge and the inside of the tools why they scored high and what aspects could be used in order to developed a new tool that could assess energy neutrality at a district level according to the demands and prerequisites of the Municipality of Rotterdam.

The focus is on the assessment scheme aspect because they can provide us the inside of what each tool exams and how it is related with energy neutrality. It must be clarified that energy neutrality aspects are not only aspects that contain energy are mainly the aspects that promote the energy balance of production and consumption. Therefore is not clear from the schemes how they are related with energy neutrality that is the reason that the schemes aspect are analyzed in the trial to identify the promotion of synergies, the promotion of less energy consumption in all type of buildings, the promotion of local energy production and the promotion of transition at an institutional level towards sustainability.
<table>
<thead>
<tr>
<th></th>
<th>BREEAM-NL new buildings</th>
<th>BREEAM-NL area</th>
<th>GPR-urbanism</th>
<th>LEED for neighbourhood development</th>
<th>CASBEE for urban development</th>
<th>CASBEE for cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of criteria</td>
<td>Various types of criteria</td>
<td>Various types of criteria</td>
<td>Various types of criteria</td>
<td>Various types of criteria</td>
<td>Various types of criteria</td>
<td>Various types of criteria</td>
</tr>
<tr>
<td>Tool technique</td>
<td>Checklist/toolkit</td>
<td>Checklist/toolkit</td>
<td>Excel checklist</td>
<td>Checklist</td>
<td>Excel checklist</td>
<td>Excel checklist</td>
</tr>
<tr>
<td>System technique</td>
<td>sum of positive credits</td>
<td>sum of positive credits</td>
<td>sum of positive and negative credits</td>
<td>sum of positive credits</td>
<td>Division formula BEE= Quality of urban development/ L environmental load of urban development: sum of credits of 3 categories of environmental quality/sum of credits 3 categories of environmental load in urban development</td>
<td>division formula BEE= Quality (Q) / Environmental load (L) = 25x (SQ-1)/L, SQ: sum of Q categories</td>
</tr>
<tr>
<td>Number of categories</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>number of sub categories</td>
<td>82</td>
<td>45</td>
<td>16</td>
<td>56</td>
<td>89</td>
<td>32</td>
</tr>
<tr>
<td>Weighing of categories</td>
<td>Applied to each issue category (consensus based on scientific/ open consultation)</td>
<td>different in every category</td>
<td>equal weigh</td>
<td>All credits equally weighed, although the number of related to each issue is a de facto weighing</td>
<td>Highly complex weighing applied to each category. The weightings are made to provide the result of 1 when placed to the formula</td>
<td>Highly complex weighing to each category and to each criteria future value is also taken into account</td>
</tr>
<tr>
<td>Weighing of sub-categories</td>
<td>equal weigh to the criteria of the categories different credits</td>
<td>equal weigh to the criteria of the categories different credits</td>
<td>equal weigh</td>
<td>equal weigh</td>
<td>weigh to provide 100% to each category but the maximum points awarded to each category are not equal</td>
<td>environmental aspects: 0.45, Social aspects 0.30 and Economic aspect 0.25.</td>
</tr>
<tr>
<td>Benchmark credits</td>
<td>yes to pass</td>
<td>yes to pass</td>
<td>number 6</td>
<td>Required to sub-categories of each category</td>
<td>Level 3</td>
<td>Level 3</td>
</tr>
<tr>
<td>Negative credits</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Maximum possible credits</td>
<td>149</td>
<td>153* without the innovation credits into account</td>
<td>50</td>
<td>110</td>
<td>100/100 but the optimum result BEE &gt;3</td>
<td>BEE=3 and Q&gt;50</td>
</tr>
</tbody>
</table>

*BREEAM - BREEAM - NL new buildings, BREEAM - NL area, GPR-urbanism, LEED for neighbourhood development, CASBEE for urban development, CASBEE for cities.
<table>
<thead>
<tr>
<th>Required credits</th>
<th>low</th>
<th>low</th>
<th>high</th>
<th>medium</th>
<th>high</th>
<th>high</th>
</tr>
</thead>
<tbody>
<tr>
<td>credits to innovation</td>
<td>yes credits</td>
<td>yes provision of 10% on the total</td>
<td>no</td>
<td>yes</td>
<td>yes credits</td>
<td>no</td>
</tr>
<tr>
<td>Complexity (certifications/bureaucracy)</td>
<td>medium</td>
<td>medium</td>
<td>low</td>
<td>low</td>
<td>medium (different weigh/certifications/bureaucracy)</td>
<td>high (assessment scheme)</td>
</tr>
<tr>
<td>Level of transparency</td>
<td>high</td>
<td>high</td>
<td>low</td>
<td>medium</td>
<td>very high</td>
<td>very high</td>
</tr>
<tr>
<td>Label (from low to high rated)</td>
<td>1-5 stars</td>
<td>1-5 stars</td>
<td>1/2-5 stars with a pace of 1/2 a star</td>
<td>pass, silver, gold, platinum</td>
<td>1-5 stars</td>
<td>1-5 stars</td>
</tr>
<tr>
<td>Use of other tools or certificates</td>
<td>GreenCalc+ or equivalent, certificates of the Dutch legislation</td>
<td>GreenCalc+ or equivalent, certificates of the Dutch legislation</td>
<td>EPL energy assessment tool</td>
<td>ASHRAE/Energy star/or equivalent/ ISO-IEC 17065</td>
<td>Certificates of Japanese legislation</td>
<td>Kyoto, post Kyoto convention</td>
</tr>
<tr>
<td>Main focus</td>
<td>Energy efficiency</td>
<td>Sustainability</td>
<td>Sustainability</td>
<td>Sustainability more weighed towards environment</td>
<td>Sustainability</td>
<td>Decrease of CO2 emission in cities</td>
</tr>
<tr>
<td>Types of projects aimed for</td>
<td>Frontrunners</td>
<td>Frontrunners</td>
<td>Normal projects</td>
<td>Frontrunners</td>
<td>Frontrunners</td>
<td>cities’ policies to reduce CO2</td>
</tr>
<tr>
<td>Certification labelling</td>
<td>BRE+GDBC</td>
<td>BRE+GDBC</td>
<td>GDBC (Green Dutch Building Council)</td>
<td>USGBC (US Green Building Council)</td>
<td>JSBC (Japan Sustainable Building Consortium)</td>
<td>JSBC (Japan Sustainable Building Consortium)</td>
</tr>
<tr>
<td>Update process</td>
<td>Annual</td>
<td>Annual</td>
<td>Annual</td>
<td>As required</td>
<td>As required</td>
<td>As required</td>
</tr>
<tr>
<td>Information gathering</td>
<td>expert and assessor</td>
<td>team of experts and assessors (usually up to 3)</td>
<td>Experts</td>
<td>Designed or management team or an accredited professional</td>
<td>Design/management team</td>
<td>municipalities</td>
</tr>
<tr>
<td>Property</td>
<td>Commercial and public</td>
<td>Commercial and public</td>
<td>Commercial</td>
<td>Commercial and public</td>
<td>Commercial and public</td>
<td>Commercial and public</td>
</tr>
<tr>
<td>Validity of the assessment</td>
<td>lifetime but you have to state the version</td>
<td>lifetime but you have to state the version</td>
<td>lifetime but you have to state the version</td>
<td>5 years</td>
<td>Future value taken into account. State the year of assessment</td>
<td></td>
</tr>
<tr>
<td>Presentation</td>
<td>scores, graphs and stars</td>
<td>scores, graphs and stars</td>
<td>cycle filled, stars</td>
<td>graphs and stars</td>
<td>graphs and stars</td>
<td></td>
</tr>
</tbody>
</table>
### Table 3: Summary of the analyzed tools

<table>
<thead>
<tr>
<th>Most positives</th>
<th>energy efficiency focus and deep analysis via the credits</th>
<th>Giving a lot of credits to scope and innovation, taking into account a variety of aspects</th>
<th>The final rating is more scaled so it gives a better representation of the reality</th>
<th>The way that LEED places required credits to each of its categories</th>
<th>Formula use, energy efficiency into highly consideration, time frame into consideration, types of different urban development into account</th>
<th>The future aspect in weighing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negatives</td>
<td>scaled to building level</td>
<td>not focusing on energy not even a requirement criterion therefore a project can gain points from other different categories</td>
<td>black box the requirements, lack of transparency</td>
<td>The categories are a bit mixed are taking into account many aspect in my opinion BREEM has a more logic categorization</td>
<td>Complexity to calculate the levels and the credits</td>
<td>It is focused on GHG emissions and it is complex in calculations</td>
</tr>
</tbody>
</table>
Organization aspects
The six tools that were examined are currently in use to assess the building environmental performance. Their edition date differs and it is used for reference. The updates of the assessment tools differ. BREEAM-NL schemes and GPR-urbanism are updated annually and LEED neighborhood and CASBEE schemes when it is required. The authorization to gather information and assess the projects differs. The assessor and the training and certifications that he should possess are also different. The ownership of the tool is combined with the access to the data and the framework of the assessment tool. The level of transparency played a crucial role at the analysis and also at the following comparison. All of the tools examined except of GPR urbanism had sufficient transparency to their framework.

Assessment scheme aspects
The tools examined can assess different projects according to their scale. The increment of the scale signifies an increment of complexity. The most compatible for a district level are BREEAM-NL area, GPR urbanism, LEED neighborhood and CASBEE for urban development. They all are accredited schemes and they use the method of multi-criteria (social, environmental, economical and institutional criteria). The tools’ technique in all of the cases is checklists in the form of spreadsheet. The criteria differ in all of the tools in number, categorization, weighs and requirements. More specifically, the increased scale allows the consideration of aspects like flows and synergies between the initiatives within the building environment (Berardi, 2013). Even if assessment tools’ scales are same (or almost the same), their criteria are different. All the assessment tools state that their scope is to assess sustainability. For representation reasons sustainability is divided to four sectors/axes.

1. Environmental (Figure 7)
2. Economical (Figure 8)
3. Social (Figure 9)
4. Institutional (Figure 10)

The sectors of sustainability include a number of indicators. The reason that the criteria are revised separately is to gain the inside knowledge of which of these criteria could be used to assess energy neutrality at a district level. Clarification: The weighs on the criteria are not taken into account, because the examined tools have different scale rates therefore we only count the number of the issues addressed in their schemes separated in the sectors of sustainability.

Comparison of the analyzed tools
Environmental sustainability (Figure 7): All of the tools are taken highly into account the aspects of environmental pollution. The energy aspect is addressed more in lower scale of buildings than in larger. Water, pollution and transport criteria are also numbered compared to other environmental aspects addressed. Land use is an aspect that is taken highly into account at the tools that are scale for area and urban development.
Economical sustainability (Figure 8): Business activity is relatively high an address topic at all the tools scaled higher than BREEAM-NL new buildings and it could be reasoned by the perspective of development. Local jobs and accessibility to working locations is also promoted by all of the tools.
Social sustainability (Figure 9): It is generally not highly addressed as it is difficult to be enhanced and also to be measured but aspects of social sustainability
Institutional sustainability (Figure 10): Local partnerships aspect is included to the scheme of BREEAM-NL area and CASBEE for urban development and for cities in high relatively to other institutional aspects rate.

Figure 11 shows the focus of each examined tool. Figure 11 presents that all the examined tools have a strong interested to assess environmental aspects (as they are also relatively easy to measure) that leads other sectors of sustainability are relatively lower to the environmental sustainability. The tools that are higher scaled than building level are also rating institutional sustainability.
The number of categories, sub-categories that the tools include to their framework is different. This number is highly depended on the scale, the scope, the weighing and the phrasing (criteria from different assessment tool are phrased in a different way but they have the same meaning). The criteria of BREEAM-NL new buildings are scaled up to the BREEAM-NL area. BREEAM-NL area has all the criteria of BREEAM-NL new buildings modified to the area level, on the other hand CASBEE for urban development refers to the scheme of CASBEE building to assess the buildings. GPR urbanism framework has fewer categories and more criteria to each sub category that it divides the categories.

The weighing of the categories, sub-categories and the criteria differs in each scheme. The method that they produced this weighs in no assessment scheme is clearly explained. Only BREEAM-NL says at its official site that the weighs were produced with the contribution of a large number of experts in the building field. The complexity of the tools is at a different level and it is intertwined with the philosophy of the developers. LEED neighborhood has the simplest scheme as it provides equal weigh to its categories, it emphasizes to some criteria by making them required. BREEAM-NL follows at complexity by having different weighing at the main categories and the main philosophy is to gain credits from all the fields. GPR urbanism has equal weighing to the categories but it has negative point at its credit system. Hence, GPR urbanism has the benchmark value of 6, if the projects scores below 6 it gives a negative value. CASBEE has a relative to the other frameworks complexity as it has different weighing to the categories, the sub categories, negative points if the level is lower than level 3 and also in the end the sum of the environmental quality categories are divided to the sum of the environmental load categories. All of the schemes’ weighs are not project depended; with their weighting factors they create a benchmark situation.

The user friendly environment plays also important role to the choice of a tool by a client, GPR urbanism and LEED seem to have the user friendliest environment, that gives the advantage of time for assessing project but not necessarily a better understanding of the framework.
Figure 7: Comparison of the number of environmental sustainability criteria aspects addressed to the frameworks of assessment tools studied.

Figure 8: Comparison of the number of economic sustainability criteria aspects addressed to the frameworks of assessment studied.
Figure 9: Comparison of the number of social sustainability criteria aspects addressed to the frameworks of assessment tools studied.

Figure 10: Comparison of the number of institutional sustainability criteria aspects addressed to the frameworks of assessment tools studied.
Figure 11: Comparison numbers of aspects taken into account per sector of sustainability of assessment tools studied
Conclusions Part A

Existing assessment tools

A general remark is that more and more assessment tools are developed world wide. The extent use of assessment tools could lead us to a conclusion that we are becoming more aware of the importance of relationship between building and natural environment. The common process of a tool’s structure (anatomy) provides the reason why the existing assessment tool differ and at which parts. The anatomy of the tools can be used as a selection method for selecting a number of tools that could assess in degree energy neutrality at a district level.

Selection method

The selection method as it has been mentioned is based on the tool’s anatomy. Six experts of the Municipality of Rotterdam (potential assessors) were called to facilitate this process. The method translated their opinion of which criteria should a tool for energy neutrality for a district level should have. These criteria were weighed by them. Therefore, the choices made are exclusively for the Municipality of Rotterdam and they reflect the wants of the end users (experts of Municipality of Rotterdam). Another city might have different choices of criteria set and weighs.

The process of selection was quite time consuming. Some insides gained by this process screening 57 tools were

- the ~90% of the existing tools are developed for building level;
- the scope of assessment can vary in great extent
- the means of assessment (assessment scheme) can vary a lot
- Information for the assessment schemes is not always easy to find even to elementary criteria like the ones posed.
- The criteria sometimes were hidden
- The ~80% of the tools is used by private sector for various labeling reasons; ~19% is used by scientists for scientific research and urban development purposes and only 0.1% is used by public authorities.
- Concession type of projects might increase the need of assessment tools used and developed only for public authorities

Selection and results

The six final selected tools that were analyzed are really effective tools for serving the reason that they were developed and for that reason they consider successful. Their deep analysis provided good inside information about their organizational and assessment scheme aspects. Also it provided the reasons of their scoring high or low on the posed criteria. Their comparison provided us with their similarities and differences in different sectors and to generate the following conclusions. During this process surprises occurred.

Due to the high weigh given by the experts of the Municipality of Rotterdam BREEAM-NL building was higher rated than BREEAM-NL area which was expected to be higher. We can consider this classification a bios of the selection process or just an indicator than BREEAM-NL building has more energy criteria than BREEAM-NL area.

BREEAM-NL area has a transparent scheme and has an interactive system for updating and upgrading its criteria and assessment scheme which adds to its popularity.
LEED is promoting the business development and the access to a neighborhood with its assessment scheme, aspects that are in a lot of cases scopes of urban development. GPR is popular among the Dutch organizations, it is an easy useful tool and cheaper than BREEAM-NL. European scientific literature often neglects CASBEE urban development as a complex scheme, it might seem a bit more complex than the others but after the analysis it is really well and carefully developed scheme which promotes balance between quality of urban development and environmental load produced by the urban development. CASBEE cities is the only existing assessment tool at a city level and it was interesting to see how the face the complexity of a city scale.

Lacks of existing tools that need to be covered
- Scope of labeling, commercial and marketing reasons that means that is not connected with a long term public authorities vision for spatial development.
- For some of the tools their commercial character does not allow even the visibility of their scheme criteria without subscribing a project.
- Existing assessment tools at a district level use the same weighs and criteria for every district without taking into account the specifications of the area, creating sort of a benchmark district. This makes their assessment scheme not flexible or adaptable to each new project.
- No clear explanation how these weighs are produced, lack of transparency.

Positives aspects that will be taken into account to the development of a new tool
- The criteria of existing assessment schemes are great guidelines for environmental, societal and economical benefits.
- The scoring way of credits provides a useful and simple pathway to decompose and rate a district plan.
- The anatomy of the tools produced with 8 main elements and its choices is a useful methodology for selecting, analyzing and developing an assessment tool

The conclusions presented leads us that a new assessment tool that could fulfill the requirements of the Municipality of Rotterdam need to be developed. Of course the existing successful tools selected are not useless their positive aspects are going to be taken into account and lead the way towards a tool that will fit more the Municipality of Rotterdam requirements. Based on those conclusions Part B is going to be built on.
PART B

Development method for a new concept assessment tool for energy neutrality at a district level
Part B: Development method of a concept assessment tool

This part provides the theoretical background of the new developed assessment tool for energy neutrality at a district level. It presents the way of the development of concept assessment tool for energy neutrality at a district level. The development of an assessment tool follows the 8 steps introduced and analyzed at the previous part (tools anatomy).

The 1st step is to identify the scope and the goal of the assessment tool. The scope and goal are identified by defining the end users of the concept assessment tool by examining the current assessment method. Though this presentation and the wants of the Municipality of Rotterdam which are described in main research question we reach to the completion of the 1st step.

The 2nd step is to define the system boundaries of the assessment tool. In order to identify the system boundaries, district systems and their notions are presented. This presentation helped us to gain the basic knowledge of how a district system works. Based on that knowledge we were able to define the system boundaries of the tool.

The 3rd step is to identify evaluation criteria and indicators. The evaluation criteria and indicators are called energy neutrality objectives. Energy neutrality's objectives are indentified with the help of Goal Trees Success Trees (GTST) method.

The 4th step is to fulfill the data requirements. That step is assumed that it is covered because the fulfillment of the data requirement is supposed to be conducted by the Municipal authorities of Rotterdam and the experts of the engineer office of public works.

The 5th step is aggregating and weighting the energy neutrality objectives. In order to find a suitable way to aggregate and weigh these objectives, the basic Multi-Criteria Decision Analysis (MCDA) methods were analyzed and compared against the scope of this thesis.

The 6th step is validating results and analysis. The validation of results assumed to be done by expert assessors defined by the Municipality of Rotterdam; hence no further analysis was necessary.

The 7th step is presenting the results. In order to present the results we thought an effective way and by the lessons learned from the analyzed existing assessment tool the scale 1 to 10 with 10 being energy neutral was chosen. This step is not analyzed in depth as the assessment tool was developed this way to provide the results to the scale of 1 to 10.

The 8th step and final step is to design an effective user interface. As the majority of the end users are familiar with excel spreadsheets it was decided to develop the assessment tool in excel.

1. Goal and Scope of the concept assessment tool

The end users of the concept assessment tool are going to be defined by the current assessment process. The scope of the end users is the assessment of energy neutrality but as energy neutrality concept is not yet scaled up at a district level at that point is crucial to define energy neutrality at a district level. Nevertheless, the Municipality of Rotterdam expressed further requirements to be included to the concept assessment tool. These requirements are emanated from its vision. The main vision points are going to be presented.

End users of the concept assessment tool

In order to identify the end users, to whom the concept tool will be address to it was necessary to present the current assessment method used by the Municipality of Rotterdam for concession projects.

According to the Municipality of Rotterdam, the existing assessment and decision method for district development for a concession type of project for 30 years is the following (in brief steps). Unfortunately, the

---

1 Concept word origin from the Latin word *concipire* which means "comprehend", "con-ceive" and refers to the understanding and framing.
procedure that is going to be described is relative new and it is not written down in any official documentation, I manage to identify it by a personal interview that I had with Roland van Rooyen, who is a public servant and took part in assessment process in 2013. The current procedure is described in steps. (A scheme of the Public Private Partnership (PPP) is shown at the Appendix B to provide to the reader a clearer view of the concession scheme.)

1) Municipality of Rotterdam sees the opportunity to develop a certain area and publishes its vision for developing this area with Bidboek.
2) Certain consortia claim interest for developing this area.
3) Municipality of Rotterdam runs a scan to the main check points like financial viability, past performance etc of the consortia. A number of consortia pass to the next step.
4) The consortia that passed the previous step in a closed procedure generate alternatives with their concept vision.
5) Other interested parties are called to give elevator pitches for their products; this step is called market consultation.

6)
   i. Consortia have an open dialogue with the Municipality of Rotterdam. At this step questions from both of the parties can be answered.
   ii. A team of experts in varies fields from the Municipality of Rotterdam is generating a demands document using the concept visions of the consortia that passed on step 4, named internal committee. The internal committee is playing the role of the assessors of the Municipality of Rotterdam.
7) Consortia are called to generated business models. The business models are judged by the Municipality of Rotterdam. A number of this business models is passing to the next phase.
8) Three dialogue phases occur to help consortia develop a definitive vision plan.
9) An external assessment committee is formed by experts in different fields. This external committee provides advice to consortia for further improvements of their plans and also a grade and feedback to the Municipality of Rotterdam.
10)
   i. Consortia get the advice of the external committee and also the demands document generated by the internal committee in order to develop their final plan.
   ii. The internal committee provides advice and criteria of judging to the external committee.
11) The final plans are presented and provided to the external committee. The external committee decides

After this brief presentation the end users are identified as the internal assessment committee. The internal assessment committee is composed by experts working in the Municipality of Rotterdam with various backgrounds with the majority to have a technical/ engineering background according to van Rooyen.

Scope of the concept assessment tool
The scope of assessment is determined by the general description of energy neutrality and also the vision of Rotterdam.

Energy neutrality
Energy neutrality concept is a concept widely implemented in building level. The difference of building to a district level adds to the complexity of the system but on the same hand offer more opportunities to achieve energy neutrality. The main focus of energy neutrality is the achievement of energy balance. Balance between consumption and generation that indicates the promotion of synergies between buildings infrastructures and also the demand of lowering the energy consumption so it could meet the local energy production. Another aspect that is promoted by energy neutrality is the energy grids and hubs in order to cope with the energy fluctuation of renewable energies. In short energy neutrality concept is specified only to energy aspects; it has a wider range of aspects that can affect energy
consumption and production. Energy neutrality is seeking for innovative solutions that would allow balancing energy consumption and energy production at a district level.

Rotterdam’s vision
Rotterdam has stated clear goals to be achieved towards sustainability. Rotterdam municipality’s approach through the ‘Rotterdam Programme on Sustainability and Climate Change 2010-2014 (the ambitions will be redefined in the end of 2013 but they will follow the same basis. Investing in sustainable growth is tackling 10 sustainability tasks, among these tasks the relevant with the thesis topic are the following (not that the others are not important as tasks):

- To lead the way reducing CO2 emissions within the city and port of Rotterdam by 50% in 2025 compared to 1990 (Plomp and Wetzels et al., 2013)
- To improve energy efficiency
- To make the switch to sustainable energy and the use of biomass as a raw material
- To promote sustainable mobility and transport
- To reduce noise pollution and improve air quality
- To make the city greener
- To increase investments in sustainability and to promote sustainable products
- To promote sustainability through education and research
- To prepare for the consequences of climate change
- To stimulate sustainable urban and regional development

Goal and Scope of the concept assessment tool
The end users of the concept assessment tool defined to be experts of the public authority of the city of Rotterdam with a technical/engineering background. The users’ objective is the assessment of energy neutrality plans generated by a private consortium for district development and the comparison energy neutral plans from different consortia. Energy neutrality assessment should embed and enhance the vision of Rotterdam.

2. System Boundaries of the concept tool
A tool’s system boundaries should be driven by contextualization of the problem. By contextualization we mean to present the bigger picture of the problem. The bigger picture of the problem allows identifying parameters that need to be embedded in the system boundaries of the assessment tool. The main parameters that can affect and define the system boundaries of an assessment tool are defined by the system that is going to be assessed and an assessment process. The system that is going to be assessed is a district, therefore the boundaries derived from that system need to be identified. That is the reason that the following paragraphs are dedicated to present the definition of district systems and their boundaries.

Definition of district systems and boundaries
Districts are complex and dynamic systems. Like any urban system; district is the complex system that combines resources in a form of human beings, materials, infrastructures, energy streams and all this in an urban environment (Roberts and Sykes, 2000). The fact that an urban system consists of human beings, material infrastructures and flows makes it a complex adaptive socio-technical system (Roberts and Sykes, 2000).
According to Klaasen (2004) in order to simplify an urban system, we can divide it to two sub-systems: a physical district system (lifeless/material elements) and district urban society (inspirit elements; individuals and groups of individuals) in order to see how these two sub-systems interact (Figure 12). In more detail, the physical district system is made up of spatial elements (objects) as buildings, roads, sewers, cables, stations, etc. and physical sub-sub-systems made up from these elements. The physical district system is been constructed or reconstructed in order to produce a certain effect to fulfill function on behalf of the district urban society. District urban society is consisted by individuals who, in a group connection or not, must and/or wish to embark social, economic and cultural activities, requires spatial objects to allow the mentioned activities to be carried out and accommodated (Klaasen, 2004). As Meijer (2011) states ‘A city is never finished, but evolves with society and allows its residents to develop’. With the previous phrase we understand how interconnected and interdependent are the sub-systems presented.

A district is a complex system made up of a large number of parts that interact in a non-simple way. In such systems, the whole is more than the sum of parts, not in an ultimate, metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of interaction, it is not a trivial matter to infer the properties of a whole. A district system has certain notions which are explained below. These notions are essential for function and existence of a district system. The notions provide a better understanding of the functioning of a district system.

![Figure 12: The two main sub-systems of an urban district and their main interaction processes (Klaasen, 2004).](image)

**Notions**

**Idealization:** systems are not actual entities but they are idealization or abstractions of a part of the real world, the part that someone wants to examine closer for various reasons (van Dam et al., 2011, pp 11-67). This idealization originates from people’s need to perceive the real world selectively by the use of general organization principals of simplification, categorization and generalization (Klaasen, 2004). The deeper reason of perceiving systems is to systematize and simplify the real word in order to comprehend its components, nods, relationships, patters and structure and functions (Klaasen, 2004). Idealization of district systems stems from the normative managerial control perspective of authorities. A district system is a part of a city system. In order to systematize it and simplify it usually geographical and governmental ideal boarders are placed by authorities. Both types of the boarders are placed to control in a better way the interactions between the main sub-systems of physical urban system and urban society (Figure 12).

**Multiple components:** A district system consists of buildings, infrastructures, sub-systems, material flows and human beings. It could be compared to a human body that it consists of various organs and systems connected in a way to allow the system to be functional.

**Components are interdependent:** Systems differ from unorganized heaps (which also have multiple components) by the fact that their elements are interdependent and interact in a harmonically integrated way to perform certain determined functions (van Dam et al., 2013, pp 11-67). There are some components that are interdependent or have a degree of independency at a district system. For example a heating or a sewage system is useless if there is no end users.

**Simplification:** Systems are simplified because they are developed/ conceived by:

B. Distinct point of view,
C. Giving emphasis on certain aspects of reality considered important or essential for the study of the system,
D. Omitting aspects that are considered irrelevant or with minor impact and
E. Categorizing-organizing attributes of elements

Hence, a system entails systematic incompleteness of reduction (Klaasen, 2004). A district system is developed/ conceived by
A. Distinct point of view of national and local authorities.
B. Emphasis given on geographical and governmental issues
C. Omitted aspects as social cohesion or exchange of economical and physical resources
D. Categorized- organized sub-systems as energy, water, sewage, transportation etc

Organized: The interaction and interdependence of a district’s elements is not random or unstructured, but follows a certain pattern. The pattern can be simple or not (van Dam et al., 2013, pp.11-67). The interaction of the elements and sub-systems in a district is structured in a way that could cover needs of inhabitants and visitors respectively. The development of this organization depends on aspects of randomness, historical accident, physical constraints on development, natural advantages and comparative advantages (Batty, 2005, pp1-80). The mentioned aspects make every district distinct in its organization of elements.

Boundaries: A district is an open system so in principal is unbounded (Klaasen, 2004). Marc Jacobs (2000) distinguishes ‘interaction’ between districts (may exchange people, goods and information), ‘interference’ (when the structure of one or both of the districts starts to change) and ‘system formation’ (the two or more original districts developed to one single larger system). System boundaries and restrictions must be placed to it to serve simplification process. The decision of the boundaries depends on the observer’s point of view (van Dam et al., 2013; Funtowicz and Ravetz, 1993). The boundaries are usually placed by the observer(s) and usually are placed to distinct a district from another to serve purposes of governance, planning and urban development. For that reasons authorities place imaginary boundaries in terms of geography, time and regulations. In simpler words the system boundaries of a district can be divided to geographical, governmental and chronicle.

Enduring: According to van Dam et al. (2013) a system can only be considered as a system if it last long enough to be observed or discussed. Hence, a district system exists only if humans consider it important to observe it and discuss it.

Environment: Defining a system as an observer-dependent abstraction with the relevant boundaries means that the system is a particular interpretation of a subset of the real world according to van Dam et al., 2013). The rest of the world that is left out by the system boundaries is the environment (van Dam et al. 2013). The environment everything that is not included in the district system defined by its system’s boundaries.

Feedback: Interactions between the components of the system are not only organized but could also contain loops. These loops create feed-back and feed-forward mechanisms that give rise to non-trivial behavior (van Dam et al., 2013). Feedback loops of a district system can be either material or intangible like information and data sets. Figure 11 presents the couple fitness landscape of the two main sub-system of an urban district previously presented.

Non trivial behavior: Trivial behavior could be described as an invariant mapping between the system inputs and outputs, on the other hand the different feed-back and feed-forward and other interaction loops, coupled to inputs from environment create non-trivial behavior in systems (van Dam et al., 2013). At a district system human beings are involved; the unpredictable behavior of humans could cause a non trial behavior (Roberts and Sykes, 2000; Batty, 2005, pp30-100). It is the same behavior that acts to the loop feedback and feed-foreword of the main sub-systems explained of urban society and physical urban system.

Observer dependence: Scale of observance is an important aspect and needs to be agreed or at least mentioned, including time scales and periods of interest. Each observer has its own world of view that determines what and how observations are made, observer-dependence interacts with emergence and that observer dependence affects the model creation (van Dam et al., 2013; Funtowicz and Ravetz, 1993). Define the system as a district system is by itself observer dependence notion.

Reductionism and holism: Reductionism is the idea that system behavior is determined by the system’s components’ behavior and by reducing the system into smaller is more observable. On the other hand holism...
is where a system cannot be determined or explained by its components parts alone. The whole is more than the sum of its parts, the interconnections of the system’s elements are more important from the nodes sometimes (van Dam et al., 2013). At a district system decomposition and composition of the system is an action usually used to observe and examine better the systems’ services (Johnson, 2012).

**Complexity and emergency:** Etymologically complexity comes from the Latin plexus, which means interwoven (Haken, 2012). A complex system means one made up of a large number of parts that interact in a non simple way. In such systems, “the whole is more than the sum of parts, not in an ultimate, metaphysical sense, but in the important pragmatic sense that, given the properties of the parts and the laws of interaction, it is not a trivial matter to infer the properties of a whole” (Herbert A. S, 1962). The interaction between the multiple parts gives to the ability to generate a new quality of macroscopic collective behavior, the manifestation of which is the spontaneous formation of distinctive temporal, spatial or functional structures (Moroni et al., 2012). A district system is a complex system because of the number of the elements and their interaction and characterized by its dynamics. In order to make a transition from one district system to another with different properties dynamics are necessary.

**Dynamics of complexity**

**Adaptive:** To be adaptive means to have the ability to adapt or improve over time in relation with the environment. The environment can be physical, social, technical and cultural or a combination of them that can cause the need of change adaptation (van Dam et al., 2013). Adaptation differs than evolution, while adaptations are improvements; evolution is the algorithmic process that produces these improvements. Adaptations always start with what is currently available to use, and improve it (apply new ways to it). There is no adaptation process in isolation. The time of adaption is relevant to the system and its drivers for change. Adaptation and selective pressures usually appear to the desires to go towards a particular direction which it is called attractor and can display self reinforcing effects that seem to accelerate the direction of adaptation (van Dam et al., 2013; Batty 2005). District systems are adaptive systems; they adapt to the needs of the habitants and their users in general, in order to continue developing in a positive way (Roberts and Sykes, 2000)

**Coupled fitness landscape:** As nothing adapts in isolation as mentioned, the fitness landscape can be recast as a coupled fitness landscape. There is the scheme of action-reaction or response-counter response. Another concept that attractors and fitness landscaped are theoretically related is called irreversibility or dependency path. This irreversibility applies to the overall system’s behavior, which can manifest in many ways. For example, physical systems lose mass or energy, while social systems lose information, these losses can also cause shifts in the landscape affecting possibilities of adaptation (van Dam et al., 2013). Many of the elements of a district are presenting coupled fitness like the evolution of the buildings cannot take place without the evolution of infrastructures, the consumption and generation patterns of their users. Nevertheless, the attractors that could be economical, environmental benefits must be coupled with the environment of the district. To the couple fitness planning and policy and data from the district are also an example Figure 13. Figure 13 presents on the left side how data sets generated by a real district affect policy and planning practices as also their implementation. On the right side how policy and planning as also their implementation could affect a real district system by the reflection of data sets and models generated for the real district. This creates a couple fitness landscapes which makes difficult to distinguish the direct results of policy and planning actions. Figure 13 also presents that district and policy and planning actions cannot be separated.

**Intractability:** In adaptive systems is impossible to predict with high reliability or extrude, which means we face no small task when trying to understand and steer the evolution of adaptive systems (van Dam et al., 2013). Many scholars tried to solve the mystery of urban systems intractability. The most efficient answer was given by Batty (2005) which says that in order to model the evolution of an urban system, consequently a district we must take into account aspects of randomness, historical accidents, and physical constraints on development, natural advantages and comparative advantages to the neighbor districts. Understanding the districts history could lead us to understand in more depth the way that policy measurements, ambitions and planning could affect the system and the opposite (see Figure 13). Figure 13 exhibits how policy and aspirations are correlated the district.
Socio-technical systems: Socio-technical systems are composed of two main interconnected subsystems; a social network of actors and physical network of technical artifacts; together these intertwined systems form a complex adaptive system. A complex adaptive system is a multi-actor network that determines the development, operation and management of the technical network, which in turn of systems affects the behavior of actors. At a district system the social network can be variety of actors depended on the type and size of the district. The technical system also can vary in terms of building elements, infrastructures and their use.

Emergent properties: Emergent properties are phenomena that cannot be deconstructed solely in terms of the behavior of individual agents and would not arise if isolated from the organizing whole (Morin, 1999; Jennings, 2000 cited at Klaasen, 2004). The emergent properties of a system are lost when the system is broken down into its component parts and parts removed from the system lose the emergent properties that they previously had. Self-organization is the process that the systems develop a mechanism, a structure, or a pattern without imposition of structure from a central authority even if the system displays a different output as a result of internal processes (Prigogine and Stengers, 1984 cited at Dooley, 1997; Kay 2002 cited at Wilson and Termeer, 2011). Pattern is a repetitive scheme or process of properties that stands out in contrast of the background “noise”. Emergent properties of a district system can be the identified if the district system is decompose to its components, for example a sewage system has no value to the district if it is not connected to the buildings or to other infrastructures. Self-organization at a district system is easily noticeable in the street loads for example.

Open versus closed system: Open systems, where matter and energy flow in and out and where things inside a system are affected by the environment outside of the system. A district system in a modern world (globalization) is difficult to be isolated and not affected by the neighbor district or even other areas. Hence, district system can be characterized as an open system as material, energy and human resources are exchange out of the geographical system boundaries (Klaasen, 2004).

Self-sufficient or autarkic: Self-sufficient system is systems that can the resources that it produces are sufficient to function properly and that are independent of 3rd parties concerning the quality that is characterizing them sufficient of autarkic (van Dam et al., 2013). A district system generally is not self sufficient because material and energy is imported in order the system to put through its demands and the needs of the habitants/users.
Concept tool's system boundaries

The geographical system boundary of the concept tool is the Netherlands as it is going to be developed for use by Dutch public authorities. The scale as it is thoroughly analyzed is a district level. The theoretical analysis of a district level proves that the decomposition of a district plan would not be an easy process. All types of building shall be included at the system boundaries of the concept assessment tool as a district includes various types of buildings.

The time horizon of the concept tool focuses on the aspect that the plans will have an end date in at least 30 years as the concession type of contract binds the consortia. Due to the adaptability of a district and to other parameters that are contributing to the evolution of an urban system placing the time system boundaries exceeds the means of this thesis.

The phase of life cycle of assessment is design phase as it is meant to be for assisting decision making of a project energy master plan.

The system level is building and infrastructure energy performance.

From the analysis of a district system we understand that the complexity of a district is a crucial characteristic therefore it makes every district being unique. The scope of the concept tool is to assess energy neutral district plan but on the same time take into account the identity of the district system. Hence, the assessment tool should be focus on being adaptable to fit the uniqueness of the examined district without losing the primary goal of assessment.

3. Evaluation criteria and indicators

Every assessment tool has evaluation criteria and indicators that are derived from its defined scope and its system boundaries. The overall objective of this tool is to assess energy neutral plans for district development. Therefore its objectives/criteria should promote energy neutrality at a district level. The following paragraphs are dedicated to show a method of identifying and modeling these objectives.

According to Folder (1981), modeling complex systems is rooted to the reductionism philosophy. Functional analysis is a conceptual design methodology: a systematic process of identifying, describing, and relating the functions a system has to be able to perform, in order to be successful but it does not consider how these functions are going to be performed (Viola et al, 2009). The advantage of functional analysis consists in individuating as many available options possible without forgetting any ideas (Viola et al., 2009). Some of these representations and analysis of functions are the following:

- Function tree
- Data flow diagram
- Function structure
- Fast diagramming
- Means and system diagrams

The representations mentioned consist of specifying an overall function of the product of a system under analysis and then determining and mapping the sub-functions.

Among this series of function modeling methodologies the conceptual Goal Tree Success Tree (GTST) framework is used because of it is a relatively easy process producing Backcasting scenarios of a main objective (Jalashgar, 1997). GTST was easier to explained and work with.

Goal Tree Success Tree (GTST)

Function tree analysis and more specifically conceptual Goal Tree Success Tree (GTST) are used for identifying the energy neutrality objectives at a district level. Function trees are a simple method for functional analysis. The conceptual GTST is presented at Figure 14. GTST is a functional hierarchy representation, it starts with the overall objective of the system, describe the functions and sub-functions that need to be done in order to accomplish the overall objective.

The reasons of choosing the Top-Down function tree representation are:

1. It is an easier process compared to the others,
2. Most of the complex systems are formed through some hierarchical evolution and a top-down approach is including this point of view.

3. It is involving brainstorming and because of the complexity of the district system is nice to involve more people (Aurisicchio et al., 2013; Viola et al., 2009; Modarres, 1999). Municipality experts involved with sustainability projects helped me to realize modeling.

Every function tree should cover the following aspects:

1) Have an overall objective
2) System should be modeled with functions requirements (used to capture the intended behavior of the system (Malan and Bredemeyer, 2001)
3) System should be modeled as a hierarchical structure
4) Each function should have specific relationships (Kang, 2010)
5) Ask how this function is going to be achieved
6) Move from down to the top asking the question why in order to check the sub-functions (Aurisicchio et al., 2013; Viola et al., 2009; Modarres, 1999)

GTST applied on energy neutrality

1. Overall objective
The overall objective is to achieve energy neutrality at a district level.

2. Energy neutrality system functions
According to the presented theory (Malan, 2001) steps for identifying the system’s functions and the description of the energy neutral district system the function identified are the below:

- **Functional Requirements**: There are two functional requirements identified based on the end users (individuals, companies, groups of stakeholders) of the system. Energy consumption and comfort at a low or no price. Which means that the energy generation should be always equal or higher than the energy consumption.

- **Operational Requirements**: The operational requirements are depended on the consortium that is going to develop the energy neutral district. Monitoring consumption and generation in order to
reassure the balance state. Maintenance, improvement and adaptation of infrastructures in order to maintain the balance of energy consumption and generation.

- **Technical Requirements**: The technical requirements are depended on the consortium that is going to develop the energy neutral district but also on legislation and governmental organizations, scientific community and building and energy market sector. Design that promotes energy production technical solutions towards constant energy efficiency, flexibility and storage. On the same time the design of energy production must be coupled with the design of lowering the energy consumption demands.

- **Transitional Requirements**: The transitional functions the most difficult function to be accomplished because they depend on many stakeholders. The main stakeholder that is responsible for the development and the transformation of the district system to an energy neutral district system is the consortium that will develop the district. The main transitional requirement the transition of the fossil fuel energy grid to a smart energy grid that eventually will only use renewable energy resources and infrastructures. The second important transitional function is the design of a flexible system that will give space for future adaptations and improvements. Another transitional function which is important is the users mentality that they need to change their mentality towards energy neutrality balance system and they also might need to change their way of thinking and accept energy neutrality.

**Function trees**

The function trees are generated by reviewing of literature on renewable energy and sustainable solutions on urban development, the lessons learnt by the criteria posed by existing assessment tools and brainstorming sessions. The brainstorming sessions were conducted in two meeting with experts of the Municipality of Rotterdam (O. Oung, R. van Rooyen, F. Hechevarria S. van der Ven and L. van Dijk) during January of 2014, the purpose of these brainstorming sessions was to identify the objectives of energy neutrality with the help of experts in different fields.

The function trees can be representative of the mentioned requirements but they include a high degree of subjectivity. The purpose of the energy neutrality function trees is to identify and describe the basic functions of an energy neutral district system development and show how these functions could be accomplished by presenting a series of goals/objectives. In order to develop a function tree the first step is to define the overall objective and then ask how this overall objective can be fulfilled which leads to formulation of functions. After the function identification again the question how can this function be fulfilled needs to be asked which leads to formulation of criteria. In order to check the function trees the question of why is needed to be asked. The criteria are existing solution that could serve a specific function.

- **Functional requirement**: To have energy comfort at a low or no price (Appendix B)
- **Operational requirement**: To monitor and maintain the balance (Appendix B)
- **Technical requirement**: To design a system that will be energy neutral (Appendix B)
- **Transitional requirement**: To transit from fossil fuels to renewable energy systems (Appendix B)

Criteria that derived from the objectives and functions of the trees are presented at Table 4, Table 5, Table 6 and Table 7.
<table>
<thead>
<tr>
<th>Overall objective</th>
<th>Function</th>
<th>Criterion</th>
</tr>
</thead>
</table>
| To transit from fossil fuels to renewable energy systems | To change consumption behavior | To choose appliances that consume less energy demanding | -Implementation of high efficiency appliances  
-Lease high efficiency appliances |
| | To have visible information on the result of your use | -Detailed information with an application or your end bill  
-Proposals of how you could decrease your consumption |
| | To be informed at school or at the university or through the social media | -Conduction of informative measurements over consumption patterns at schools, universities and through social media |
| | To have a non-central heating in order to adjust the temperature of the room | -Implementation of autonomous system to self-regulate the temperature according to the needs of the users  
-Implementation of a system that according to the conditions (Temperature, humidity) will regulate the space climate by using benchmark values |
| | To take into account the cultural ways of life/9-5 schedule does not always work | -Flexible use of spaces  
-Flexible schedule according to the weather |
| To promote social acceptability | To promote job creation | -Calculation of the job opportunities and vacancies short-, mid-term and long-term if it is possible |
| | To calculate environmental, social and economic benefits of the transformation of the area | -Forecasting analysis of the potential environmental, social and economic benefits and translate them into number compared to the current situation |
| | To promote transparency | -Presentation of the plan to the public  
-Involvement of the current users/stakeholders of the area  
-Evolve your plan taking into account the public opinion |
| To build according to the environment needs | To take into account the old techniques | -Building techniques specialized in the area that are proven to fit with the local environment for years |
| | To promote bio-climatic building | -Build Bio-climatic buildings |
| | To organize workshops with the stakeholders to create smart solution via symbiosis | -Workshops that will promote the exchange of energy, knowledge and data between the stakeholders via creation of synergies |
| | To identify the system boundaries | -Conduction of an extent historical literature research  
-Conduction of an extent geological and topographical research  
-Conduction different scenarios for economic urban regeneration  
-Conduction a legislation and regulation research |
| | To use specifications of the environment in a co-operative way (adaptive design) | -Build in a way that you can use the specifications of the area (see Dakpark) or the existent infrastructures (see port, shallow geothermic applications) |
| To identify the opportunity to experiment at an area | To follow the calling of the authorities | -Invest in an area that is developing |
| | To identify opportunities of using existing infrastructures of an area that | -Invest in an area that you can use its existing infrastructures |
To decide to produce energy locally

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>To identify the opportunity to be energetically autonomous</td>
<td>- Conduction of a scientific research of renewable systems implementation which used in similar cases and modification them in order to fulfill your needs</td>
</tr>
<tr>
<td></td>
<td>- Development a pilot area to Implementation and improvement of the introduced plans</td>
</tr>
<tr>
<td></td>
<td>- Calculation of the costs of Implementation of action-plan and payback period of the new system</td>
</tr>
<tr>
<td></td>
<td>- Calculation of potential fossil fuel prices</td>
</tr>
<tr>
<td>To identify the degree of technology maturity to Implementation of renewable energy</td>
<td>- Conduction of research on the existing technologies</td>
</tr>
<tr>
<td></td>
<td>- Challenge private sector and technological institutes to provide solutions</td>
</tr>
<tr>
<td>To empower social groups that what to Implementation renewable energy technologies</td>
<td>- Provide the link between the social group and consortia and public authorities</td>
</tr>
</tbody>
</table>

Table 4: Criteria derived from the function tree with main objective “to transit from fossil fuels to renewable energy systems”
## To design an area that will be energy neutral

<table>
<thead>
<tr>
<th>Overall objective</th>
<th>Function</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>To design a system to optimize energy consumption</td>
<td>To identify the limitations opportunities of the area</td>
<td>- Use the knowledge of the experts of building sector</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Conduct a study for the history of the area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Implementation of smart solutions, connect infrastructures and uses</td>
</tr>
<tr>
<td></td>
<td>To be innovative</td>
<td>- Connect academia, private sector, business and challenge them to develop solutions</td>
</tr>
<tr>
<td></td>
<td>To design sustainable transportation in order to minimize the energy consumption of cars</td>
<td>- Design a good public transportation system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Design bike lines and pedestrian roads</td>
</tr>
<tr>
<td></td>
<td>To design a smart draining system</td>
<td>- Implementation of green roofs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Implementation of breathable pavement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Have green areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Implementation of smart sewage system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Implementation of systems to reuse the water for cooling reasons</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Implementation of water solutions against flooding</td>
</tr>
<tr>
<td></td>
<td>To design a sustainable public light system</td>
<td>- Implementation of energy saving lights or new technologies like solar lights or algae lights</td>
</tr>
<tr>
<td></td>
<td>To design a sustainable waste system</td>
<td>- Use the waste to produce energy by connecting facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Re-use wastes if it is possible</td>
</tr>
<tr>
<td></td>
<td>To use waste heat</td>
<td>- Connect facilities or uses of certain infrastructures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Use the space as multi-function space (different functions different schedules example office in the morning-school in the evening)</td>
</tr>
<tr>
<td>To design a system to generate energy locally</td>
<td>To identify your system boundaries</td>
<td>- Develop a plan that will include also parts and data from the surrounding areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Develop an explicit and realistic strategic plan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Use the existing data bases and generate relevant missing data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Have multiple scenarios that will be referenced with a specific timeframe of development</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Conduct studies about the costs of Implementation of action and maintenance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Conduction of a law and urban investigation before starting planning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Have the acceptance of the public and the public authorities before Implementation of the plan</td>
</tr>
<tr>
<td></td>
<td>To design a smart grid or a hub</td>
<td>- Implementation of a smart grid or a hub that will use all the potential energy resources of the area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Connect different energy sources</td>
</tr>
<tr>
<td></td>
<td>To design a system to use the waste heat</td>
<td>- Calculation the exergy, the efficiency and the safety</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Connection of waste heat to the grid</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Connection of infrastructures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Use the energy forms from the system without the energy transformation in order not to waste heat (PV cells → electricity, shallow geothermic systems → heating or cooling)</td>
</tr>
</tbody>
</table>
Table 5: Criteria derived from the function tree with main objective “To design an area that will be energy neutral”

<table>
<thead>
<tr>
<th>Overall objective</th>
<th>Function</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>To monitor consumption and energy generation</td>
<td>To have monitoring systems</td>
<td>-Implementation of system and calculators for measuring the data of consumption and generation</td>
</tr>
<tr>
<td></td>
<td>To have collaboration of experts and users</td>
<td>-Provide technical assistance to operate the system in an optimum way</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Conduct soft measure awareness methods</td>
</tr>
<tr>
<td></td>
<td>To teach the users how to operate their energy systems</td>
<td>-Screens to provide information of the consumption and generation patterns of the building</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Create intern-jobs for the users</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Conduct workshop to enhance the dialogue between the users and the experts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Create challenges with awards to the users</td>
</tr>
<tr>
<td>To have flexible energy generation systems</td>
<td>To connect different sources to a hub</td>
<td>-Measurement the energy generation and the hub’s efficiency and capacity</td>
</tr>
<tr>
<td></td>
<td>To connect different sources to a smart grid</td>
<td>-Energy generation and the hub’s efficiency and capacity</td>
</tr>
<tr>
<td></td>
<td>To have emergency back-up system</td>
<td>-Connection to the current grid for safety reason</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Creation of energy storage</td>
</tr>
</tbody>
</table>

Table 6: Criteria derived from the function tree with main objective “To maintain energy balance”.
## To generate energy equal or more than the energy consumed

<table>
<thead>
<tr>
<th>Overall objective</th>
<th>Main function</th>
<th>Function</th>
<th>Criterion</th>
</tr>
</thead>
</table>
| To optimize use of infrastructures | To have sustainable buildings | To reduce primary energy use | - Primary energy consumption  
- Implementation of smart design  
- Implementation of energy saving appliances |
| | | To reduce energy in operation phase | - Implementation of automatisation systems  
- Implementation of monitoring  
- Organize soft measures to aware the users  
- Assign an expert to assist the user(s)  
- Educate the users who to operate optimally his energy system |
| | | To reduce electricity needs | - Substitute direct electricity for heating with heat  
- Implementation of more efficient appliances |
| | | To reduce cooling needs | - Implementation of material to isolate the building  
- Implementation of smart design or energy system |
| | | To reduce heating needs | - Implementation of material to isolate the building  
- Implementation of smart design or energy system |
| | | To identify infrastructures that can be used to generate energy | - Construction or modification infrastructures in order to generate energy  
- Amount of energy generated  
- Matching a building with its energy systems (passive houses) |
| | | To use waste heat of infrastructures | - Creation synergies the space/multifunction spaces |
| | | To use sustainable street lighting and traffic light | - Implementation of a smart design street lighting and traffic lights system |
| | | To promote and adopt low energy consumption patterns | - Implementation of a good public transport system  
- Implementation of bike lines and pedestrian roads |
| | To optimize the energy use | To create smart energy synergies | - Match waste heat of one building and make it useful heat for another building  
- Shared facilities |
| | | To generate energy from renewable resources | - Measure the energy generation  
- Connect the plan with potential research to optimize it  
- Implementation of a smart grid or hub  
- Produce an efficient amount of energy related to the calculated energy needs |

Table 7: Criteria derived from the function tree with main objective “To generate energy equal or more than the energy consumed”
4. Fulfillment of data requirements
The fulfillment of data requirements should follow the Dutch standards that are going to be opposed by the Municipality of Rotterdam as the assessor are going to be experts of different department to cover the wide range of energy neutrality objectives.

5. Aggregation and weighing
Aggregation of objectives could be done with the help of Multi-criteria Decision Analysis methods (MCDA). The concept tool will try to satisfy and embed the aforementioned characteristics in a great degree. In order to achieve that we turned to multi-criteria decision analysis methods (MCDA)\(^2\). The basic MCDA methods (AHP, MAUT, SMART, PROMETHEE and ELECTRE) are compared in order to conclude that the most appropriate to facilitate this thesis’ purpose. Analytic Hierarchy Process (AHP) is the method that could facilitate better the aggregation and weighing of the energy neutrality objectives and the reasons why are presented and explained in the following paragraphs.

Comparison of Multi-criteria decision analysis (MCDA) methods
The MCDA differ in their objectives of usage, assumptions made in their scheme and their methodology. The MCDA methods are divided to multi-attribute utility methods (AHP, MAUT, SMART) and outranking methods (PROMETHEE, ELECTRE). By indentifying differences and similarities of the mentioned methods conclusions were driven. It is important to underline that the use of different method on the same problem might provide to a user different recommendation results (Hobs and Horn, 1997; Loken, 2007). Hence, the choice of the method might significantly affect the development of the tool.

In facilitating selection of a MCDA method that fulfils the function requirements of energy neutrality objectives situation and the wanted characteristics projected by the Municipality of Rotterdam, the aforementioned MCDA methods were compared against the following elements: objectives (Table 8), assumptions (Table 9), methodology (Table 10) and advantages-disadvantages (Table 11). In the end of the analysis of each aspect the choice and the reasoning of the MCDA is presented.

Objectives of MCDA
The objectives are referring to outcomes, set of criteria/sub-criteria and ability to incorporate model outcomes of the MCDA methods (Table 8). It is crucial to identify the objectives of a MCDA method in order to understand if it could serve the new assessment tool for energy neutrality.

<table>
<thead>
<tr>
<th>Elements of comparison</th>
<th>AHP</th>
<th>MAUT</th>
<th>SMART</th>
<th>PROMETHEE</th>
<th>ELECTRE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcomes</strong></td>
<td>High +</td>
<td>High +</td>
<td>Low+</td>
<td>High-</td>
<td>High-</td>
</tr>
<tr>
<td><strong>Set of criteria/sub-criteria</strong></td>
<td>Low-</td>
<td>Low-</td>
<td>Low-</td>
<td>Low 0</td>
<td>Low 0</td>
</tr>
<tr>
<td><strong>Ability to incorporate model outcomes</strong></td>
<td>High 0</td>
<td>High 0</td>
<td>Low-</td>
<td>Low -</td>
<td>Low -</td>
</tr>
</tbody>
</table>

Table 8: Comparison of MCDA against the element of objectives, three scales are used with three levels each Low (Low -, Low 0, Low +), Moderate (Moderate -, Moderate 0, Moderate +) and High (High -, High 0, High +) (adopted table from Papadopoulos and Konidiari, 2011)

\(^2\) A MCDA method is a comprehensive, structured method designed by stakeholders’ preferences and value judgments facilitated by a scientific modeling and risk analysis. The development of such a method designates a preferred alternative and classifies provided alternatives, in a subjective order of preference, in a given situation (Lootsma, 1999; Linkov and Steevens, 2005). In simpler words a MCDA method could be characterized as an interface that translates technological performance information into decision criteria and weights using a decision matrix. The decision matrix provides a systemic approach for integrating risk levels, uncertainty, and valuation, scoping the evaluation and ranking of many alternatives allowing visualization and quantification of the trade-offs involved in the decision making process (Lahdelma et al., 2005; Linkov and Steevens, 2005).
Outcomes
All the methods are able to identify the “best” alternative out of a set of possible comparisons. Their mathematical philosophy presents great similarities as scores are assigned to different options for a number of objectives/criteria or sub criteria and then multiplied with the respectively coefficients and finally a combined to produce the total score. The differences focus on the way that the scores and weighs coefficients are combined. Different forms of data and information are required for these processes (Huang et al., 2011). According to Gamper and Turcanu (2007) multi-attribute utility methods (AHP, MAUT, SMART) aggregate all points of view into a unique function which is to be optimized while outranking methods (PROMETHEE, ELECTRE) construct and exploit a synthesizing relation based on the decision maker’s preference.

Outranking methods (PROMETHEE and ELECTRE) are based on social choice theory and they do not an axiomatic basis as the multi-attribute utility methods. ELECTRE sometimes is unable to identify the proffered alternative due a not necessarily complete system (Huang et al., 2011; Wang et al., 2009; Pohekar and Ramachandran, 2004). PROMETHEE belongs also to the same category which ELECTRE which means that its outcome is a ranking of the best and worst alternatives giving the most preferable if all the criteria are taken into consideration (Wang and Yang, 2007; Diakoulaki et al., 2007). Outranking methods provide good outcome encountering a few criteria (3 to 12) and a large number of alternatives, because they offer a clearer view of the alternatives by eliminating the most favorable ones (Wang et al., 2009; Pohekar and Ramachandran, 2004; Becalli et al., 2003; Georgopoulou et al., 2003).

Set of criteria/sub-criteria
Different needs and priorities are set depended to the problem definition that complies with the use of a certain MCDA method. No one of the revised methods has been found have already rated a set of multi-criteria towards energy neutrality district development. All of the many they have been implemented to rate parts of the concept of energy neutrality like environmental impact (Kaya and Kahreman, 2011), renewable energy planning (Meier and Mubayi, 1983; Cormico et al., 2003; Ramanadan and Ganesh, 1995 cited in Papadopoulos and Konidiari, 2011), building energy management (Klemm et al.,2000; Wright et al., 2002; Jedrzejuk et al., 2002).

Assumptions
All the methods used certain mathematical processes in concluding their results. In our case the assumptions should serve robustness, adaptability, flexibility and simplicity and Table 9 shows how they are against these elements of comparison.

<table>
<thead>
<tr>
<th>Elements of comparison</th>
<th>AHP</th>
<th>MAUT</th>
<th>SMART</th>
<th>PROMETHEE</th>
<th>ELECTRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematical background</td>
<td>High</td>
<td>High</td>
<td>Moderate 0</td>
<td>High +</td>
<td>High 0</td>
</tr>
<tr>
<td>Weigh coefficients, parameters, thresholds, indexes</td>
<td>High</td>
<td>Moderate</td>
<td>Moderate +</td>
<td>Moderate +</td>
<td>Moderate +</td>
</tr>
</tbody>
</table>

Table 9: Comparison of MCDA methods against the elements of assumptions, three scales are used with three levels each Low (Low -, Low 0, Low +), Moderate (Moderate -, Moderate 0, Moderate +) and High (High -, High 0, High +) (adopted table from Papadopoulos and Konidiari, 2011)

Mathematical background
AHP is justified mathematically based on ratio scales (Kablan, 2004; Eakin and Bojorquez-Tapia, 2008). MAUT seems to have the soundest theoretical structure of all multi-criteria techniques according to Gomez-Limon and Martinez (2006). SMART has a limitation of using maximum 16 criteria (Otean and Ashley, 2006) but on the other hand provides more robust results than MAUT (Linkov et al., 2004). PROMETHEE is a more stable method than ELECTRE (Theodorou et al., 2010) but ELECTRE has a solid scientific background (Theodorou et al., 2010). Summarizing every method has its advantages and drawbacks concerning the
mathematical background hence their combination to cover the needs of decision makers’ problem is a common practice (see mixed methods).

**Weigh coefficients, parameters, thresholds, indexes**

The main drawback of AHP, MAUT and SMART is the difficulty of decision maker to specify a trade off ratio between different criteria (Polatidis et al., 2006; Ananda and Herath, 2009; Lichtfouse et al., 2009, pp. 753-767). PROMETHEE does not have a certain mathematical procedure for defining the weigh coefficients (Wang and Yang, 2007). At ELECTRE and PROMETHEE a decision maker must decided and input upper and lower limits of a certain criterion function and a type of the function which can be a difficult procedure especially for an inexperienced decision maker (Papadopoulos and Konidiari, 2011).

**Methodology**

The methodology part of the MCDA is divided into understanding the problem, selecting the criteria and sub-criteria as well as their weigh coefficients, the measurement scale and assessment performance and finally the sensitivity analysis. These are the elements that the MCDA are compared and presented at Table 10.

<table>
<thead>
<tr>
<th>Elements of comparison</th>
<th>AHP</th>
<th>MAUT</th>
<th>SMART</th>
<th>PROMETHEE</th>
<th>ELECTRE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Methodology</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding the problem</td>
<td>High +</td>
<td>Moderate -</td>
<td>Low -</td>
<td>Moderate -</td>
<td>Moderate +</td>
</tr>
<tr>
<td>Selecting criteria/sub-criteria and determination of their weigh coefficients</td>
<td>High +</td>
<td>Moderate -</td>
<td>Low -</td>
<td>Moderate -</td>
<td>Moderate -</td>
</tr>
<tr>
<td>Measurement scale and assessment of the performance</td>
<td>High -</td>
<td>High 0</td>
<td>High 0</td>
<td>Moderate +</td>
<td>Moderate +</td>
</tr>
<tr>
<td>Sensitivity analysis</td>
<td>High -</td>
<td>High 0</td>
<td>High -</td>
<td>High +</td>
<td>High -</td>
</tr>
</tbody>
</table>

Table 10: Comparison of MCDA methods against the elements of methodology, three scales are used with three levels each Low (Low -, Low 0, Low +), Moderate (Moderate -, Moderate 0, Moderate +) and High (High -, High 0, High +) (adopted table from Papadopoulos and Konidiari, 2011)

Understanding the problem

The main objective of an energy neutral district is the balance between energy consumption and production by reducing energy consumption and increase renewable energy local production. In order to achieve this dynamic balance in a technical, institutional and economic feasible way, innovative solutions and synergies between “elements” of the district must be promoted and implemented. The number of elements and their interaction and interrelation makes the problem complex.

From all the described methods AHP presents better the problem due to its advantage to decompose the problem into its elements. AHP through its simplicity allows decision makers focus on the importance of its criterion. MAUT could also give a better understanding of the problem but is a more complex method.

SMART and SMARTER are not suitable for such complex problems. PROMRTHEE and ELECTRE could not easily give a better understanding to the problem as they do not provide opportunity to structure the problem and in case of many criteria less structure makes more confusion to the decision maker (Wand and Yang, 2007). ELECTRE’s tradeoffs among multiple attitudes are compensatory and the information contained in decision matrix is fully utilized. In addition most of ELECTRE methods demand the estimation of three kinds of threshold and weights. These factors help a decision maker to understand better the problem and form his preferences consistently. Nevertheless these features represent and abstract meaning.

Selecting criteria and sub-criteria and determination of their weigh coefficients

AHP responds better in involving stakeholders into its process. As the criteria are already formed by function trees their structure with AHP would be more appropriate. It is critical for a decision of an energy district development to involve as many as possible stakeholders in order to lower potential risks and have a “silent”
agreement of the importance of the criteria. At the involvement of different stakeholders, selection of stakeholders and their diversity plays as important role as the way that the criteria are stated. Outranking methods do not allow as easy such an involvement as they are more mathematical. ELECTRE leaves a space of uncertainty to the choice when there is no clear preference.

Measurement of scales and assessment of performance
All of the methods allow qualitative and quantitative approaches on solving a problem. MAUT and SMART have the same measurement scale using 0 for worst performance and 1 for best performance. At ELECTRE and PROMETHEE the measurement scales are depended on decision maker input and that means that the decision maker much have deep knowledge on the sector that the criterion belongs to. PROMETHEE methods can handle data with a reasonable degree of accuracy and fixed numerical values according to Behzadian et al. (2010).

Sensitivity analysis
Sensitivity analysis is included to test the robustness of the results of a method. Most of the researchers and decision makers consider it necessary and all of the aforementioned methods use it.

Advantages-disadvantages
The advantages and disadvantages of the MCDA methods are presented at the comparable table below (Table 11).

<table>
<thead>
<tr>
<th>Elements of comparison</th>
<th>AHP</th>
<th>MAUT</th>
<th>SMART</th>
<th>PROMETHEE</th>
<th>ELECTRE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages-Disadvantages</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy to use</td>
<td>High 0</td>
<td>Moderate +</td>
<td>High +</td>
<td>Moderate +</td>
<td>Moderate -</td>
</tr>
<tr>
<td>Requirements on time</td>
<td>High 0</td>
<td>High -</td>
<td>Moderate +</td>
<td>Moderate -</td>
<td>Moderate -</td>
</tr>
<tr>
<td>Applications</td>
<td>High +</td>
<td>Low+</td>
<td>Moderate -</td>
<td>Low-</td>
<td>Moderate -</td>
</tr>
<tr>
<td>Relevant Software</td>
<td>High 0</td>
<td>High 0</td>
<td>High 0</td>
<td>High 0</td>
<td>High 0</td>
</tr>
<tr>
<td>Connection with GIS</td>
<td>High 0</td>
<td>Moderate +</td>
<td>Moderate -</td>
<td>High 0</td>
<td>High 0</td>
</tr>
</tbody>
</table>

*Table 11 Comparison of MCDA methods against the elements of advantages and disadvantages, three scales are used with three levels each Low (Low -, Low 0, Low +), Moderate (Moderate -, Moderate 0, Moderate +) and High (High -, High 0, High +) (adopted table from Papadopoulos and Konidiari, 2011)*

Ease of use
An end user-decision maker feels more confident on the outcomes of a MCDA method when he has a good understanding of the method and when the method has high transparency (Loken, 2007). Since the decision process of a district development involves various specialties and cultures, the ease of use becomes an important aspect. Potential flexibility on changing aspects/criteria in order to fulfill new needs or ambitions gives also importance to the ease of use. A comparative analysis conducted by Ho et al. (2010) indicates that AHP is more easy to use and has great flexibility. MAUT was cognitively more difficult to understand and demands involvement of an expert but SMART was found easier (Pohekar and Rachmadan, 2004). PROMETHEE and ELECTRE are considered to be complicated especially due to their aggregation procedure. PROMETHEE and ELECTRE allow the introduction of new criteria or alternatives at any time during the analysis which makes them more flexible than AHP and MAUT.

Requirements on time
AHP is time consuming especially when the number of criteria is large. SMART is usually quicker but cannot handle a great number of criteria anyway. All of the methods can lead to exhaustive discussion between decision makers.

Applications
All the methods are used frequently in decision making process. AHP has a lead on applications followed by ELECTRE to sustainable energy planning decision making (Pohekar and Ramachandran, 2004, Figueira et al. 2005, pp 872-897). Application areas are indicative as their chose is mostly depended on decision’s objective but are not collateral that the method chosen was the best.
Relevant Software

There is software and application on the market based on all the methods as it is presented to every method.

Choice of MCDA method

The basic MCDA methods of AHP, MAUT, SMART, PROMETHEE and ELECTRE were analyzed (Appendix C), from their analysis and comparisons tables (Table 8, Table 9, Table 10 and Table 11) were generated. Every MCDA method has its strong and weak points in respect of the strong points that are fitting energy neutrality a selection was made.

To the objective comparison better performance have AHP and MAUT. The mathematical background differs in every method that is also the reason that which the same set of objectives they deliver different results. AHP is has a little bit better performance in weigh coefficients, thresholds, indexes and their selection which makes it more promising for aggregating objectives of energy neutrality. AHP complies better with the requirements of the evaluation because it gives a better understanding to the problem and because in determination of the weigh coefficients can involve different stakeholders and expertise. The outranking methods (PROMRTHEE and ELECTRA) and AHP provide better results at a sensitivity analysis. AHP fits better with the scope of evaluation energy neutral district plans because it is relatively easy to use although its main drawback is time consuming. According to the mentioned analyzed elements of comparison AHP is the most appropriate MCDA to facilitate the development of a concept assessment tool for energy neutrality.

MCDA methods differ in their objectives of usage, assumptions made in their scheme and their methodology. The MCDA method that according to the comparison suits better to facilitate the development of an assessment scheme for energy neutrality at a district level is AHP.

6. Validating results and analyzing

The validation of results and the analysis is going to be conducted by Municipality of Rotterdam assessors using the necessary methods according to their field expertise.

7. Presenting results

The presentation of results demanded a visible way to compare different plans and assist decision making procedure. The decomposition process of all the existing tools is made with a point system named accredited system. Therefore using the same system as it is one of the strong points of the existing assessment tools grades are more appropriate. For the presentation of the end result the ways of presenting results are either in grades, in labels, certificates or graphs. In our case that we want to compare plans the way that seemed more suitable is grades, because it can indicate easily the differences in scoring, label and certificates are dedicated to marketing reasons and it is not our scope, and graphs there are nothing more than a representation of grades. In addition to that all the existing assessment tools analyzed use grades and then are translating these grades to labels or certificates.

Hence, was decided to present the results with the scale of 1 to 10 with 10 being energy neutral. The pace was decided to be with 3 digits after the comma to provide a range of difference between plans with similar grades.

8. Designing an effective interface

Taking into account the existing tool analysis the interface should be suitable for the end users background and knowledge. In order to cover a wide range of expertise and background of assessors excel spreadsheet was decided to be the environment of development of the concept assessment tool. The information providence is done by the following Part C of this thesis and also by an operation manual and the tool itself.
Conclusions on Part B

The development method was based on the tools anatomy and its steps introduced in Part A. The developed method provides a structure way to generate an assessment tool. It can provide the possibility to develop a tool which different characteristics depended on the needs and wants of the end users, every tool is solution driven. The same procedure could be conducted possible development of any kind of assessment tool by making appropriate relevant choices in each step.

At each step choices were required to be made. These choices wish to serve the problem definition, the assessment of energy neutral plans generated by private consortia for a district level, by the Municipality of Rotterdam. For that reason we need to highlight the choices are focused to the needs and wants of the end user which is the Municipality of Rotterdam. The steps did not required the same effort that is due to the different nature of each step and the choices made that does not mean a step is less important than another. Each step provides a different aspect to the tool which is necessary to have a complete tool.

1. Goal and Scope of the concept assessment tool

Defining the end users and the end users’ scope from the assessment tool were not difficult because it was driven from the problem definition and the research question almost clearly.

2. System boundaries of the tool

The system boundaries of the tool were not difficult to be identified as they were driven from the context of the problem and the research question.

3. Evaluation criteria and indicators

This part was proven to be time consuming and difficult. Modeling complex systems is not an easy process. Functional analysis is an effective and simple methodology. The conceptual Goal Tree Success Tree (GTST) helped us to generate the energy neutrality function trees and their objectives. The fact that energy neutrality is not a concrete concept implemented at a district level added points of difficult. The unlimited different possible situation that can be occurred depended to a district individuality made us keep the objective broad so they could cover any kind of possibilities. Nevertheless, the function trees provide a Backcasting scenario of how energy neutrality can be implemented at an ideal district. The objectives of energy neutrality are vast in order to include all possible alternatives solutions that could be presented in a plan of energy neutral district development. The evaluation criteria and indicators are translated for and by the Municipality of Rotterdam.

The objectives produced are suitable for a theoretical assessment. Practically some of them are difficult to be measured. Hence a gap between theory and reality is noticed. For that reason at the implementation of the method the criteria will change to be assessable.

4. Fulfillment of requirements

The fulfillment of requirements was left at the hands of the experts of the Municipality of Rotterdam as they are the ones that should indicate what kind of standards they need for each objective.

5. Aggregating and weighs

An extent literature review was conducted to be able to compare the main MCDA methods in order to choose AHP. Difficulties were faced into the deep analysis of the MCDA methods because in some of the cases demand a strong mathematical background.

6. Validation of results

The validation of results was not a difficult process as it was defined by the main research question.
7. Presenting the results
The way chosen of the presentation of the results was not difficult as it was driven by the comparison aspect of the users’ objective and also from the decomposing method defined by the existing assessment tools’ schemes.

8. Designing an effective interface
The interface chosen is excel environment for the reason effective use and familiarity by the end users. Excel also is able to facilitate the chosen MCDA method for weighing process and could demand less time than to train the end user into another interface/ mathematical program like Mapple or Matlab.
PART C

Concept assessment tool for energy neutrality at a district level
Part C: Concept assessment tool

Part C is dedicated to the developed concept tool presentation. The scope of this chapter is to familiarize the reader/user with:

- Energy neutrality concept assessment tool
- Its basic principles and philosophy
- Its use

In order to achieve the aforementioned points, the anatomy of the concept tool and an extensive description of the tool's general concept and parts are presented.

The anatomy of the tool presents the elements that compose the tool. The description of the concept tool presents the tool components, their philosophy and principals, the way of their usage and their results.

Concept assessment scheme

A concept assessment tool for energy neutrality at a district level was developed in Excel environment and will be presented in detail in this Part.

The purpose of the presentation of the assessment scheme is that the assessment tool is adoptable to the case study/district that is examined. Therefore each time that a complete assessment is asked for a new district, the procedure should be followed from the start for the optimum results.

The following paragraphs present in detail the procedures that need to be followed for the assessment of energy neutrality. The assessment scheme based on system engineering composition and decomposition and AHP scopes to facilitate them. The assessment scheme developed uses a concept assessment tool generated in Excel environment.

The procedures that this concept tool's scheme follows are divided into two groups. The first group contains the actions that assessors' group should take (1, 2, 3, 6, 7) and the second group contains the actions that a private consortium should take (4, 5). Figure 15 schematically presents the steps of the assessment according to the concept assessment tool of energy neutrality.

1. Definition of energy neutrality’s objectives generated by GTST conceptual method. The reason that energy neutrality objectives need to be defined is to provide the guide lines of the assessment, to know exactly what it is trying to be achieved with this assessment.

2. Aggregation and weighing of the composed objectives of energy neutrality with AHP method. The aggregation is done by composing the objectives of energy neutrality function trees and generating a hierarchy. The weighing is done by using AHP comparison matrices and then average the results of each objective weigh in Excel. The reason that the objectives of energy neutrality need to be aggregated and weighed is that they are not equally contributing on the achievement of energy neutrality at a district level and that they are depended on the district that is planned to be developed.

3. Providence of the energy neutrality’s objectives and their weigh factors to private consortia that is responsible to generate alternative plans for energy neutral district development. Transparency, reciprocity and communication are the reasons of providence of the energy neutrality’s objectives and their weighs to consortia by the assessor.

4. Generation of alternative plans for energy neutral district development by private consortia. The alternative plans that are generated by private consortia could vary. The use of the objectives and their weighs as guidelines is not limiting consortia to generate alternative plans on the contrary it is scopeing to inspire them and indicate them how their plans are going to be assessed.

5. Providence of certificates and calculations for the assessment process asked by the assessors group. In order an alternative to be scored it should be accompanied with appropriate documentation which will assist the procedure of decomposition and scoring.

6. Decomposition of alternatives plans by the assessors. Each alternative is scored according to the evidence provided by the private consortium respectively, in Excel. The alternative plan is
awarded with a score that represents its rate of energy neutrality, with an optimum score of 10. For all the received alternatives the same process is done. After their scores are compared used as indicators to assist decision making process. The scope of decomposing the alternatives is to structure a complex system, in that case an energy neutral district plans in a way that their differences and similarities could be compared.

![Figure 15: Concept assessment scheme of energy neutrality at a district level](image)

**Concept tool’s anatomy**

The concept tool’s anatomy presents its elements (Figure 16).

In more detail,

1. **Scope and goal**: The scope of this concept assessment tool is to assess energy neutrality at a district level. It is meant to assess alternatives developed by private consortia with a set of criteria derived from the fulfilment of energy neutrality objectives and the vision of the Municipality of Rotterdam. It is destined for public authorities.

2. **System boundaries**: The tool is developed in the context of the Netherlands. The assessment scheme includes the assessment of all kinds of buildings and includes the judgement of all the life-cycle of a district development with a horizon of at least 30 years. Its adaptability is partially, it is adoptable for the examined area.

3. **Evaluation criteria and indicators**: The energy neutrality objectives are in great extent covering the 3Ps (People, Planet, and Profit) perspective. The focus of the criteria is energy criteria but sustainability criteria are not neglected as they were driven from the requirements of the Municipality of Rotterdam by its vision.

4. **Fulfilments of requirements**: Not much work was done on the fulfilment of requirements. To generate standards and certifications exceeded the scope and means of this thesis.

5. **Aggregating and weighs**: The energy neutrality objectives’ weights are adaptable to different district systems. Analytic Hierarchy Process (AHP) is used to make the weights of energy neutrality flexible.

6. **Validating results**: The validation of results is done by assessors working for the public authorities with various expertises background.

7. **Presenting the result**: The presentation of the result is a final score for each alternative with an optimum score of 10.
Figure 16: Anatomy of the concept tool

6. Validating results:
   a) Validation of results and analysis: standards (not yet defined)
   b) Assessors: public authorities experts in different fields

5. Aggregating and weights:
   a) Method: Credits, checklist
   b) Weighting: Different to each objective

4. Fulfillment of requirements:
   a) Standards: not yet defined
   b) Certifications: not yet defined
   c) Organizations: National
   d) Sources and methods: excel format

3. Evaluation criteria and indicators:
   a) Character: Qualitative and qualitative objectives
   b) 3Ps: Social, Environmental, Economical

7. Presenting the results
   a) Grades:
      i. Scale: 1 to 10, with ten to be 100% energy neutral
      ii. Pace: four decimals
      iii. Type: number

8. Interface and design:
   a) Method: Spreadsheet, checklist
   b) Information provision:
      Operational manual, potential workshop, the tool itself
   c) Revision of the tool: demanded because is a concept tool
   d) Fees: no fees

1. Scope and Goal:
   a) Users: Public authorities (consultants, researchers)
   b) Actors objective: Assess energy neutrality master plans & alternatives comparison

2. System boundaries of tool:
   a) Geographical: The Netherlands
   b) Scale: District level
   c) Type of buildings: All type of building
   d) Time horizon: at least 30 years
   e) Phase of life cycle: Design, construction, maintenance
   f) Adaptability: Partially
Concept tool's description

The concept assessment tool description presents the functions and its utility by presenting the scope, the users that is addressed to and the procedure that should be followed divided in its parts.

Scope

The scope of this concept tool is to assist public authorities to assess energy neutral plans (alternatives) for district development and regeneration generated by private consortia.

Users

The concept assessment tool is destined for public servants with a basic knowledge of excel. Public authorities should define a group of assessors for a specific assessment. It is proposed that the assessors should have different expertise to cover the range of energy neutrality objectives and good knowledge of the examined district. The group of assessors should also have a leader assessor to facilitate the process of assessment.

Brief description of concept tool’s parts (in steps)

The concept tool is consisted to 3 parts. The tool is based on system engineering approach of composing and decomposing and AHP multi-criteria analysis method. The concept tool can be used for an absolute assessment or also for a comparative assessment.

The parts of the assessment tool are the following:

- **Composition of energy neutrality objectives into a hierarchy**
  AHP demands an aggregation of objectives into a hierarchy in order to be able to compare them in levels and clusters. The energy neutrality objectives from chapter 4 are not in that form so they needed to be composed into a hierarchy form which is presented as a list and as a hierarchy.

- **Weights on objectives of energy neutrality**
  This step is developed in excel. The weights are generated by AHP pairwise comparison matrices which are filled in by the assessors. Each assessor has to fill in the matrices. The results of the filled spreadsheets are the input for the spreadsheet of assessors’ weighs distribution. The assessors’ weigh distribution spreadsheet generates the final weigh of energy neutrality objectives.

- **Decomposition of alternative plans and scoring**
  Potential alternative energy neutrality plans have to be decomposed and rated according to the last free objectives of the hierarchy. In order to rate the alternatives, the decomposed elements of the alternatives will be score with a scale for 1 to 10. To gain that score the consortia have to present a series of certifications which are indicated by the Municipality of Rotterdam at the calling of project. This score is weighted according to weights of preferences and the hierarchy. So in the end each alternative has a final score against energy neutrality objective with the maximum score achieve reaching the value of 10.

Figure 17 presents schematically the general concept of the energy neutrality assessment tool of a comparative assessment of three alternatives. In Figure 17 the top box of the hierarchy of objectives is energy neutrality, which is the overall objective of this scheme, the colored boxes are sub objectives, at the base of the scheme are three alternative plans created by private consortia. Each objective has a weigh that contributes to the achievement of the overall objective of energy neutrality. The weighs are posed with AHP comparison matrices to each objective by the assessors of the public authorities. Each of the generated alternatives by consortia needs to be decomposed to the “free” objectives\(^3\) of the hierarchy (like it is presented for alternative A). According to the fulfillment of the “free” objective each alternative is gaining a score against this objective, providing essential documentations and verification to the assessors. The score of every free objective is multiplied with the weigh of the objective. A composed score is generated which represents energy neutrality. The same procedure is followed for all the different alternatives in order to compare them.

---

\(^3\) “Free” objectives are the objectives that they don’t have a sub-objective.
Figure 17: Concept of energy neutrality assessment tool
Concept tool's parts

The following sections present and explain in detail the concept tool's use by presenting its parts and procedures. For all the parts there is a presentation of their basic principles and philosophy, an extent description and presentation of the layout of the spreadsheet and some instructions and tips for easier and correct use of the tool.

Composition of energy neutrality objectives into a hierarchy

Energy neutrality objectives were derived from the functions trees of energy neutrality, the requirements of Rotterdam provided by its vision and the examined existing assessment tools. The following aggregation was done following the instructions of AHP method. AHP method promotes a hierarchy that defines the objectives into levels (horizontal) and clusters (grouping).

The top objective of the hierarchy is the overall scope of the assessment, to level down the question how the overall scope could be achieved is asked. The same process is followed for every sub-objective.

The objectives are constructed to provide freedom for implementing different kind of solutions. Therefore, they could be used as guidelines to achieve energy neutrality as any solution is allow to be proposed.

The hierarchy of the energy neutrality objectives follows in a form of list a map hierarchy form. The colors of the list objectives represent the levels of the hierarchy. The hierarchy has five levels. The first level is red colored, the second level is orange colored, the third level is petrol, the fourth level purple and the fifth blue. The groups that they are occurred indicate a cluster for example one cluster is objectives 1.1, 1.2, 1.3 and 1.4.

1. Reduce energy consumption
   1.1. Reduce energy consumption in buildings (all types of buildings)
       1.1.1. Reduce primary energy consumption
       1.1.2. Reduce electricity needs
       1.1.3. Reduce energy demands in operation phase
       1.1.4. Reduce heating demands
       1.1.5. Reduce cooling demands
       1.1.6. Reduce waste heat
   1.2. Reduce energy in infrastructures
       1.2.1. Design a sustainable transportation system
           1.2.1.1. Convenience in daily life/ distance from amenities
           1.2.1.2. Access to the district
           1.2.1.3. Connection with public transport
           1.2.1.4. Bicycle paths and walking pathways
           1.2.1.5. Reduction on traffic load
           1.2.1.6. Smart traffic light system
       1.2.2. Sustainable water system
           1.2.2.1. Reduction of mains water supply load
           1.2.2.2. Reduction of rain water discarded
           1.2.2.3. Reduction of the treatment load from sewage and grey water
       1.2.3. Reduce environmental impact on microclimate
           1.2.3.1. Consideration of paving material
           1.2.3.2. Planning of building group to avoid wind blocking
           1.2.3.3. Planning of building group to avoid shading
           1.2.3.4. Consideration of building cladding material
   1.3. Sustainable urban design
       1.3.1. Geographic location specifications
1.3.1.1. Natural environment (microclimate and ecosystems)
   1.3.1.1.1. Consideration and conservation of microclimates in pedestrian space in summer
   1.3.1.1.2. Consideration of conservation the water environment
   1.3.1.1.3. Consideration of terrain
   1.3.1.1.4. Conservation and creation of natural environment
   1.3.1.1.5. Conservation and creation of the natural species
   1.3.1.1.6. Conservation of the function of the area (polder)

1.3.1.2. Creation of synergies
   1.3.1.2.1. Synergies that exchange energy
   1.3.1.2.2. Flexible use of spaces
   1.3.1.2.3. Adaptive design
   1.3.1.2.4. Stimulation of industrial symbiosis

1.3.1.3. Use of local resources
   1.3.1.3.1. Use of local industries
   1.3.1.3.2. Use of local work force
   1.3.1.3.3. Conservation and use of historical aspects
   1.3.1.3.4. Conservation and use of cultural aspects
   1.3.1.3.5. Conservation and use of natural aspects
   1.3.1.3.6. Consideration of old building techniques if they exist in the area
   1.3.1.3.7. Conservation and use of existing infrastructures
   1.3.1.3.8. Use the land efficiently

1.3.1.4. Disaster and crime prevention
   1.3.1.4.1. Understanding the risk of natural hazards
   1.3.1.4.2. Providing proper evacuation routes

1.3.2. Embrace the vision of public authorities
   1.3.2.1. Development district type
      1.3.2.1.1. Center type district
      1.3.2.1.2. Zone planning
      1.3.2.1.3. Not specific type
   1.3.2.2. Function usage
      1.3.2.2.1. Mono function
      1.3.2.2.2. Mixed- functions
   1.3.2.3. Proactive participation of stakeholders during the design and implementation phase

1.4. Environmental responsible construction management
   1.4.1. Acquisition of ISO 141001
   1.4.2. Reduction of by products during construction
   1.4.3. Energy saving activity during construction
   1.4.4. Reuse of waste products of construction
   1.4.5. Selection of material considering impact on health
   1.4.6. Consideration of urban context and scenery

2. Energy production
   2.1. Energy production from renewable energy resources
   2.2. Resource efficiency
   2.3. Effect on the local environment
      2.3.1. Social and cultural environment
      2.3.2. Natural environment
   2.4. Robustness and security of supply
      2.4.1. Fluctuations
      2.4.2. Connection with a central system
      2.4.3. Autonomous security backup system
   2.5. Energy production from infrastructures (public spaces)
      2.5.1. Resource efficiency
      2.5.2. Effect on the local environment
         2.5.2.1. Social and cultural environment
         2.5.2.2. Natural environment

3. Maintaining and monitoring the balance
   3.1. Implementation of monitoring systems
      3.1.1. Measuring energy generation
3.1.2. Measuring energy consumption

3.2. Flexibility
   3.2.1. Usage of different resources
   3.2.2. Cope with the increase of needs

3.3. Collaboration of users with experts
   3.3.1. Promotion of knowledge centers and youth employment
   3.3.2. Workshops to involve the stakeholders
   3.3.3. Other measures

4. Realistic implementation
   4.1. Time frame of implementation
   4.2. Economic feasibility
   4.3. Technological feasibility
   4.4. Securing responsibility for the achievements
Results of aggregation of energy neutrality’s objectives

Aggregation of energy neutrality objectives results a prioritization of objectives and an organization process. It is easy to identify that the sub-objectives combined are resulting their overall objectives but their percentage of contribution is not equal in many of the cases. In order to define their percentage of contribution to their overall objective they have to be weigh. The process of weighing is presented at the following section.

Weighs on objectives of energy neutrality

The weighs of energy neutrality objectives are generated by the assessors’ group and it is specified for the assessment of a certain district, using the spreadsheet of AHP pairwise comparison and the spreadsheet of assessors’ weigh distribution.

The spreadsheet of AHP pairwise comparison should be filled in by a number of assessors. The number of assessors for statistic reasons must be at least six.

Each assessor needs to fill in the spreadsheet separately. The spreadsheet is composed by 28 AHP pairwise comparisons matrices. The pairwise comparisons are made between the objectives of the same level and cluster. The comparisons are made between the shaded boxes. The assessors have to fill in all the comparison matrices. In order to fill in a matrix in a correct way the assessor needs to know the basic principles and philosophy of AHP. The result of the AHP spreadsheet is the weighs of preferences of the assessor on each objective of energy neutrality. Then these weighs are used as an input for the generation of the final weigh of each objective.

The assessors’ weighs distribution spreadsheet needs to be filled in by the leader assessor. The leader assessor copies the preference weights and consistency of the group of assessors that completed the previous spreadsheet of AHP pairwise comparisons. The scope of this spreadsheet is to calculate the average weighs of preference to each objective of energy neutrality, to enhance conversation between the assessors’ group for their extreme choices and check if there is a problem with the hierarchy. The result of this spreadsheet is the final weights of preferences that will be used for the assessment for master energy neutrality plans.

AHP pairwise comparisons

The following paragraphs describe the basic principles and philosophy of the AHP matrices in order to familiarize the reader and the user with the way of filling in the matrices. The spreadsheet is also described and presented for the same reason. It might seem theoretical but is important to know the theoretical background in order to have good results. By good results we mean results that will reflect the preferences of the assessors.

Basic principles and Philosophy of AHP

AHP by Saaty (1995) is based on relative judgments. A hierarchy of objectives has been generated afterwards judgment that compare the objectives have to be made. Relative judgments are done with pairwise matrixes. The pairwise matrixes contain the objectives that are at the same level and cluster of hierarchy, in order to be as homogenous as possible. The scale of the comparison is 1/9 to 9. In order to explain the matrix an example of 3 objectives will follow.

Example:

If we have the objectives A, B, C and we want to compare them with the AHP. We ask the questions “How important is A objective in achieving overall goal compared to B?”, “How important is A objective in achieving overall goal compared to C?” and “How important is B objective in achieving overall goal compared to C?”. So graphically with have the following pictures (Figure 18, Figure 19 and Figure 20). Figure 21 presents the pairwise matrix of this example.
Figure 18: Example of 3x3 AHP matrix pair comparison of objectives A and B

A is very strongly more important than B or else wise B is less strongly more important than A. Hence B takes the value of 1/7.

Figure 19: Example of 3x3 AHP matrix pair comparison of objectives A and C

A is very moderate more important than C or else wise C is moderate less important than A. Hence C takes the value of 1/3.

Figure 20: Example of 3x3 AHP matrix pair comparison of objectives B and C

B is between extremely strongly and very strongly less important than C or else wise C is between very strongly and extremely more important than B. Hence the value of B is 1/8 and the value of C is 8.
As it is shown in the example Figure 21, the diagonal zz’ is 1 and it separates the actual values of the upper triangle (blue) and the reciprocal values of the lower triangle part (orange), hence there is no need to complete the whole matrix just the upper part and the other is the reciprocal. The number (N) of comparisons made equals N=n*(n-1)/2, where n is the number of objectives. After the completion of the pairwise matrix a calculation matrix follows to calculate the weights of the choices which are presented at the last column bolded. From the calculations presented at Table 12 and Random Index (RI) values created by Saaty the consistency is calculated. Table 12 calculates the normalized score of each objective. Consistency is a logic test of the answer given. In his case our input is not logic; if A is very strongly more important than B, A is moderate more important than C, B cannot be between extremely less important and very strongly less important than C.

The results of preference of this example are that A is 61.41%, B is 6.32% and C is 32.27%. The consistency is not acceptable is 21.5% which is bigger than 10%.

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Normalized score</th>
<th>Normalized score</th>
<th>Normalized score</th>
<th>CUMULATIVE NORMALIZED SCORE OR ROW SUM</th>
<th>NORMALIZED RATIO SCALE OF PRIORITY</th>
<th>NORMALIZED PERCENTAGE OR PERCENT RATIO SCALE OF PRIORITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.68</td>
<td>0.44</td>
<td>0.73</td>
<td>1.84</td>
<td>0.61</td>
<td>61.41</td>
</tr>
<tr>
<td>B</td>
<td>0.10</td>
<td>0.06</td>
<td>0.03</td>
<td>0.19</td>
<td>0.06</td>
<td>6.32</td>
</tr>
<tr>
<td>C</td>
<td>0.23</td>
<td>0.50</td>
<td>0.24</td>
<td>0.97</td>
<td>0.32</td>
<td>32.27</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>3.00</td>
<td>1.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Table 12: Example calculation AHP 3x3 sample matrix

**AHP comparison spreadsheet description and presentation**

The AHP comparison spreadsheet consists of 28 pairwise AHP matrices. An example of a comparison matrix excel sheet is presented in Figure 22. The first page of the spreadsheet provides instructions of how to fill in the matrices which are also presented at the instructions and tips of AHP comparison that follows. Hierarchy page presents the list of objectives that need to be compared and gain a weight of preference. The next pages are dedicated to the actual AHP comparison matrices their names indicate the matrices that need to be filled in. On the left side of the page (Figure 22) there is the box with the values input and their explanation (more information kindly refer to the presented philosophy and basic
principles of AHP), going right there are two boxes the comparison matrix and the calculation matrix, only the light blue cells of the comparison matrix need to be filled in by the assessor the gray cells are automatically filled in, further is box titled AHP results. The box of AHP results consists of the preference weights of the assessor to the compared objectives on completing their overall goal and the consistency of the comparison matrix results. In order to be consistent the results of consistency should be less than 10%.
Figure 22: Screenshot of an AHP matrix page

Input values and their explanation

Pairwise comparison matrix example

Input values

- Objective "i" extremely less important than objective "j"
- between extremely less important and very strongly less important
- Objective "i" very strongly less important than objective "j"
- between very strongly less important and strongly less important
- Objective "i" strongly less important than objective "j"
- between strongly less important and moderately important
- Objective "i" moderately less important than objective "j"
- moderately less important and equal
- Objective "i" equal important to objective "j"
- between equal and moderately more important
- Objective "i" moderately more important than objective "j"
- between moderately more important and strongly more important
- Objective "i" strongly more important than objective "j"
- between strongly more important and very strongly more important
- Objective "i" very strongly more important than objective "j"
- between very strongly more important and extremely more important
- Objective "i" extremely more important than objective "j"

AHP results

<table>
<thead>
<tr>
<th>Preference %</th>
<th>Check your results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reduce energy consumption</td>
<td>25.00</td>
</tr>
<tr>
<td>2. Increase energy production locally</td>
<td>25.00</td>
</tr>
<tr>
<td>3. Maintaining and monitoring the balance</td>
<td>25.00</td>
</tr>
<tr>
<td>4. Realistic implementation</td>
<td>25.00</td>
</tr>
</tbody>
</table>

Consistency index: 0.0 consistent

Consistency test

Calculation matrix

Preferance % Check your results

1. Reduce energy consumption 25.00
2. Increase energy production locally 25.00
3. Maintaining and monitoring the balance 25.00
4. Realistic implementation 25.00

AHP results

0.0 consistent

Calculation matrix

Input values and their explanation

Light blue cells that only need to be filled in with the values that are left (dropdown list)

Fill in ok if you have completed and revised the matrix
Instructions and tips of AHP comparison spreadsheet

By introducing someone has already the background necessary knowledge of the AHP method but filling 28 matrices can be a tricky process so that is the reason of this section.

1. Read the instructions given in the first page of the spreadsheet.
2. For questions you can always consult the operational booklet.
3. Have the hierarchy scheme to assist you.
4. Remember that you have to fill in only the light blue cells.
5. Remember that you are comparing "i" (column) to "j" (row) objective and how much they contribute to the overall objective which is the label of each matrix.
6. Consistency rate prevents you of making logical mistakes but it does NOT mean that you have to be consistent at every matrix.
7. The objectives are broad in order to be applied to different possible alternatives and not to limit the alternatives.
8. The objectives are judged by having in mind a specific district for future development.
9. Some of the objectives might overlap but they can be relatively judged.

Assessors' weighs distribution spreadsheet

The assessors' weigh distribution spreadsheet generates the final weigh of energy neutrality's objectives. The following paragraphs describe how is this accomplished and which are the additional functions of this spreadsheet.

Basic principles and Philosophy of assessors' weighs distribution

The basic principles and philosophy of the spreadsheet of assessors' weighs distribution is based on statistics, specifically on normal or Gaussian distribution (Bluman, 2009, pp 300-398), because all continuous variables can be represented as approximately normally distributed variables. Gaussian distribution is used into many fields to explain a sample’s accuracy (Bluman, 2009, pp 300-398) and probability. The more assessor fill in the matrices the better representative results of preference are generated. The results of preference weights against one objective can be either normal curve, a normal negatively skewed or a normal positive skewed curve. The “tail” of the curve indicates the direction of skewness (right is positive, left is negative) (Figure 23) (Bluman, 2009, pp300-398). The skewness provides the information of distribution of the preferences results of all the assessors against one objective of energy neutrality. The acceptable curve by should be the normal, the two others indicate that the weighs of preferences of the assessors are not normally distributed.

Figure 23: Types of normal distribution bell curve (a) Normal, (b) Negatively skewed and (c) Positively skewed
Assessors' weighs distribution spreadsheet description and presentation
The assessor distribution spreadsheet page contains the results of all assessors' preference weights and their matrixes' consistency; also it contains statistic analysis pages. The column AO of the page of preference weights contains the check of the hierarchy, if the objectives are homogenous and can be compared. Graph pies are generated to present the weigh distribution of each sub-objective to its main objective.

Instructions and tips of Assessors' weighs distribution spreadsheet
The leader assessor can see the results of the weights and their distribution and regulate the conversation. A suggestion is to look the most important objectives and enhance the conversation between the assessor extreme choices.

Results of weigh of objectives
Each assessor indicates according to its expertise and knowledge its preference to the energy neutrality objectives using the AHP matrices. Consistency test prevents assessor of making logical mistakes.
The final weighs of the energy neutrality's objectives represent how much the assessors think that each objective should contribute to its overall and are presented to the assessors' weigh distribution spreadsheet. The percentage of contribution depends on the specific district that is planned to be assessed. The consistency test provides information on the correctness of the hierarchy, the homogeneity of objectives. The objectives and their weighs are the core of this tool. They could be used as guidelines for planning process and they are used at the decomposing and scoring of the alternatives.
Figure 24: Screenshot of assessors' preference weights
**Decomposition of alternative plans and scoring**

The decomposition of alternative plans is done by the assessors’ group. The assessors are responsible of providing the essential information to the leader assessor in order to input the score at the “free” objectives. The essential information is a result of the communication between the assessors and the consortium that is plan is being assessed.

Decomposition of alternative plans and scoring step is facilitated by the “results of assessment” spreadsheet and needs to be filled in by the leader assessor. The leader assessor copies the final preference weights after the discussion and conclusion made to the “link” page. The leader assessor has also to input the score that the “free” objectives gain. The score of each “free” objective has a scale of 1 to 10 with 10 being the optimum. The decomposed element it is matched with the fulfillment of the free objective and it is awarded according to a credit scheme which will be generated of each sub-objective\(^4\). The scope of this spreadsheet is to calculate the score of alternatives for energy neutrality district development, to assist assessor to compare the alternatives in a visible way by a composed final score of energy neutrality. The result of this spreadsheet is the final weights of preferences that will be used for the assessment for master energy neutrality plans. The score of presented with 4 decimals, the number of decimals reflect its sensitivity in scoring changes. The score of an alternative represents the degree of energy neutrality, for example a score of 6,7938 means that the alternative is rated to be 67,938% energy neutral.

**Basic principles and Philosophy of “Results of assessment” spreadsheet**

The “Results of assessment” spreadsheet is based on system engineering perspective of decomposition and composition. Assessment could be done for absolute and comparison of alternatives.

**“Results of assessment” spreadsheet description and presentation**

The “results of assessment” spreadsheet contains the pages of “link” with contains the weights of each objective, calculation of score of each alternative pages, the ideal alternative score (Figure 25), the average alternative score and the page of comparison of alternatives. The maximum score that an alternative can be awarded is 10. The maximum points that can be awarded to each objective are depended and determined on the weights preferences of the assessors, the can be seen at the sheet of the comparison of alternatives column G. In order to explain the calculation of the score an example will be provided.

Example: Consortium X and Consortium Y developed the alternative X and Y respectively. They provided the relevant documentation to the assessors and now the assessors have the score of the “free” objectives as presented in Table 13. The same process is done of completing the hierarchy of objectives for alternative X and Y. In the end the two alternatives can be compared with a final score as they can also be compared to their awarded score to each of the objectives. The maximum score for each sum is 10.

**Instructions and tips of “Results of assessment” spreadsheet**

The leader assessor has to copy paste the final weigh of the assessment and also fill in only the gray cells with the scores awards gathered from the assessors’ team. A tip is to look the page of the comparison and which objectives are below average score.

---

\(^4\) Unfortunately due to time and to the scope of this thesis this accredit scheme needs to be developed and the proposed way is presented at the recommendations.
<table>
<thead>
<tr>
<th>Overall objective</th>
<th>Weight</th>
<th>Sub-objective</th>
<th>Weight</th>
<th>“Free” Objectives</th>
<th>Weight</th>
<th>Alternative X</th>
<th>Score of the sub-objective</th>
<th>Overall objective score</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Monitoring the balance</td>
<td>12.55%</td>
<td>3.1</td>
<td>28.27%</td>
<td>3.1.1 Measuring energy</td>
<td>21.55%</td>
<td>7</td>
<td>1.51</td>
<td>4.38*28.27%=1.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Implementing</td>
<td></td>
<td>generation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>of monitor</td>
<td></td>
<td>3.1.2 Measuring</td>
<td>21.59%</td>
<td>5</td>
<td>1.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>systems</td>
<td></td>
<td>energy consumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.1.3 Stakeholders</td>
<td>40.40%</td>
<td>2</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>involved</td>
<td></td>
<td>involved</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>monitoring</td>
<td></td>
<td>monitoring</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.1.4 Transparency</td>
<td>16.46%</td>
<td>6</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>in</td>
<td></td>
<td>monitoring</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>monitoring</td>
<td></td>
<td>process</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>sum</td>
<td>100</td>
<td></td>
<td>4.38</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2</td>
<td>47.26%</td>
<td>3.2.1 Usage of different</td>
<td>75%</td>
<td>6</td>
<td>4.50</td>
<td>6.75*47.26=6.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flexibility</td>
<td></td>
<td>resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.2.2 Cope with</td>
<td>25%</td>
<td>9</td>
<td>2.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>increase of needs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>sum</td>
<td>100</td>
<td></td>
<td>6.75</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.3</td>
<td>24.47%</td>
<td>3.3.1 Promotion of</td>
<td>66.67%</td>
<td>4</td>
<td>2.67</td>
<td>5.67*66.67%=1.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Collaboration</td>
<td></td>
<td>knowledge centers and</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>of stakeholder</td>
<td></td>
<td>youth employment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.3.2 Experts coupled</td>
<td>33.33%</td>
<td>9</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>with systems maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>sum</td>
<td>100</td>
<td></td>
<td>5.67</td>
<td></td>
</tr>
</tbody>
</table>

Table 13: Example of composing overall objective score
Figure 25: Screenshot of the page of Ideal alternative score
Conclusions on Part C

The conclusion of Part C are mainly remarks because part C just presents the concept tool that was developed in an excel environment.

Concept assessment tool’s scheme

A tool is impossible to have an effective and useful assessment tool without the framework that it will be used (when, where, by whom). The assessment scheme was developed based on the needs and procedure identified by the current assessment scheme presented at a previous part. The scheme presented is a simple ideal scheme proposed by the author. Test and validation will show if this scheme is feasible and what kind of changes are needed.

Concept tool’s anatomy

The concept tool’s anatomy in this part provides with a quick look all the main characteristics of the concept tool.

Concept tool’s parts

Composition of energy neutrality objectives into a hierarchy

The composition of energy neutrality objectives generates two critical questions that need to be discussed.

1. Does the Municipality of Rotterdam aim to assess energy neutrality or sustainability to the developed plans?
2. Does energy neutrality as a design concept includes sustainability?

The answer to the first question is that the Municipality of Rotterdam with this concept tool aims to assess energy neutral plans but on the other hands certain criteria of sustainability couldn't be excluded from the assessment objectives.

The answer of the second question is that energy neutrality as a design concept at a building level promotes sustainability in a great extent. Energy neutrality at a district level promotes the balance between energy consumption and generation. Energy is embedded into many district subsystems if not to all. To achieve this balance the subsystem must co-operate or to be energy neutral by itself. In order to judge that a great set of criteria was posed. Criteria that might seem irrelevant with energy but are relevant with the achievement of the energy balance at a district level.

The common points of energy neutrality and sustainability are many. That makes difficult the distinction between them. To conclude the main focus is energy balance and the criteria are generated by the way this balance could be promoted. For that reason the weighing part was developed.

It is difficult in a complex system such as a district to define only one scope and neglect aspect like public safety or climate change.

Weighs on objectives of energy neutrality

The focus of the concept tool is the weighing process in order to promote the significance of district’s individuality. The concept tool used AHP methodology to achieve this weighing process. The decomposing method is adopted by decomposing method used by the existing assessment tools.

Decomposition of alternative plans and scoring

Decomposition of alternative plans provides a structure way of decomposing plans into their elements following the same checklist credit schemes introduced from the existing assessment tools. It provides a first attempt to show how the procedure could be done. It is not a complete part as the scoring needs to be further justified by documentation and calculations defined by a wide range of different experts which exceeds the means of this thesis.
PART D

Concept tool applied to Merwe-Vierhavens
Part D: Concept tool applied to MVH

The concept assessment tool developed was applied to Merwe-Vierhavens (MVH) district. The reason of this application was to test the concept tool and identify its adding value and usefulness as well as its parts that need to be improved so it can be use in the future. Firstly, MVH district is described to familiarize the reader with the area and the reason that lead us to choose this case study. After the introduction of MVH and the aspirations of Rotterdam for MVH, the way of test and evaluation process and the results of this application are following.

1. MVH district

MVH district’s current and future situations are described. The descriptive part is focusing on what was/is the case providing the history and the current situation of the area. The explanatory part answers the questions of how and why was and is like that. After the introduction of Merwe-Vierhavens, Municipality of Rotterdam and Rotterdam’s port authorities’ aspirations will be presented. The current assessment and decision making process of Municipality of Rotterdam will be presented because this process in addition with the aspirations dawn the path of district’s development. These parts embody the notions introduced even if they are not directly stated. The reason that are not directly stated is that in order system modeling of an urban system evolution is exceed a lot means of this thesis. Its system boundaries will be presented and discussed to prepare the reader for the next section followed by conclusions that Merwe-Vierhavens’ system boundaries could be used beneficial for developing an energy neutrality assessment tool.

Brief introduction of Merwe-Vierhavens

Merwe-Vierhavens belongs to district area Nieuw Mathenesse. Nieuw Mathenesse is a polder and a business park. It is located in the edge of the cities of Rotterdam and Schiedam as it is shown in Figure 26 (Daamen et al., 2013) and lies across Maas River. The municipal boarder between Rotterdam and Schiedam is runs the Van Deventer Street, part of Mathenesserstraat, and Van Berck Rodestraat and part of the Gustoweg in the west of the area see Figure 29. The area is characterized mostly of port activities, only a small part of it is residential. The business part belongs to city port of Rotterdam is named Stadshavens. The residential part belongs to Delftshaven. The neighborhood is characterized by high criminality rate (like the rest of Delftshaven) (Figure 29) and for the time being is mostly industrial area.
The city port areas contain harbors and industries related to harbor activities. Because of the newly reclaimed Maasvlakte 2 project, the scenery of the area is changing. Harbor activities are moving away from that area towards the seafront at west due to new economic logistics, like many other ports it follows the model presented by Hoyle (1998) (Table 14).

<table>
<thead>
<tr>
<th>Stage</th>
<th>Symbol</th>
<th>Period</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Primitive port/city</td>
<td></td>
<td>Ancient/medieval to 19th century</td>
<td>Close spatial and functional association between city and port</td>
</tr>
<tr>
<td>II. Expanding port/city</td>
<td></td>
<td>Early 20th century</td>
<td>Rapid commercial industrial growth forces port to develop beyond city confines, bulk industries</td>
</tr>
<tr>
<td>III. Modern industrial port/city</td>
<td></td>
<td>Mid-20th century</td>
<td>Industrial growth (especially oil refining) and introduction of containers require separation space</td>
</tr>
<tr>
<td>IV. Retreat from the waterfront</td>
<td></td>
<td>1960s-1980s</td>
<td>Changes in maritime technology induce growth of separate maritime industrial development areas</td>
</tr>
<tr>
<td>V. Redevelopment of Waterfront</td>
<td></td>
<td>1970s-1990s</td>
<td>Large scale modern port consumes large areas of land and water space, urban renewal of the original core</td>
</tr>
<tr>
<td>VI. Renewal of port/city links</td>
<td></td>
<td>1980s-2000+</td>
<td>Globalization and inter-modernism transform port roles, port-city associations renewed, urban redevelopment enhances port-city integration</td>
</tr>
</tbody>
</table>

Table 14: Different stages in the traditional port-city interface (Hoyle, 1998)

The port turned its ‘back’ on the city with the relocation of activities, causing a geographical separation between the city and the port and while increasing new automatic installations outside of the city produced a high rate of unemployment among the low skilled port force (Daamen et al. 2013). Finally, this relocalization is a change in the functions/activities, areas that used to be ‘city harbors’ and related industries and creation of space. Regionalization is the recorded reason of the creation of this space, which is an effect of the restructure of relationship between city and port (Notterboom and Rodrigue, 2005). The port regionalization phase follows the scheme of Figure 27. Figure 27 describes how port infrastructures evolve in time and space, case that is applied to the port of Rotterdam according to Daamen et al. (2013). This evolvement is correlated with the current situation of Rotterdam city port areas and as it is presented at Figure 27 four main steps can be indentified: setting, expansion, specialization and regionalization (Notterboom and Rodrigue, 2005). The current situation of Merwe-Vierhavens is at the state of regionalization which brings gradually harbor activities away from the area.

Figure 27: Port regionalization phases (Notteboom and Rodrigue, 2005)
The regionalization due to the new economic logistics is happening in Merwe-Vierhavens is also causing a change of ambition of both port and the city authorities. On the one hand the city of Rotterdam has to engage new strategies to develop the Merwe-Vierhavens, without compromising the safety rules of polder areas. On the other hand the port authorities of Rotterdam have to agree on these new strategies and keep some financial benefits. The area of Merwe-Vierhavens has the potential of delivering mutual gains to both sides though the authorities’ agreement a challenge (Daamen et al., 2013). Nevertheless, this makes room for implementing new concepts of urban development and redevelopments based on two main strategic planning principals as economic diversification and accommodation of housing and other non-port functions (Rijnmond, 2013).

**Aspirations of the Municipality of Rotterdam for MVH**

Municipality of Rotterdam together with the Rotterdam Port Authorities share the following aspirations and vision for the development of the area which are reflected to the official site of Stadhavens (www.stadshavenrotterdam.nl) : “The economic activities are to consist of a mix of residential, work, education and recreation. The work function will focus on the urban knowledge economy, including education, science, engineering firms and high tech companies active in the field of Clean Technology, such as energy transition and water management, driven by the Climate Campus. Other options under consideration are creative/innovative manufacturing, where schools and companies can jointly set up learning projects in water technology, energy transition and marine manufacturing.”

**System boundaries of MVH**

**Geographical**

In the case of Merwe-Vierhavens (MVH) the geographical boundaries placed by authorities for the case of governance and development does not correspond to the reality which is that the area of Merwe-Vierhavens transition is inextricably inseparable with the neighborhood areas as in every case city (Alexander 1965 cited by Batty and Marshall, 2012).

Figure 28 presents a rough scheme of the interaction cycles of the system boundaries from MVH and the neighborhood areas. If we took into account the interaction of MVH with the neighborhood system the complexity rises tremendously. For this thesis the system boundaries of MVH we assume that there is no interaction with the neighborhood areas (Figure 29). A helping factor to place the system boundaries is that the area of MVH is outside of the safety primary dikes of Rotterdam. These dikes are physical boundaries and subject to different legislation and regulation according to building activities.

Figure 29 also presents the buildings that they are marked with purple color and are going to remain to the area.
**Governmental**

At the governmental scene of MVH, main roles have the Municipality of Rotterdam, the port authorities of Rotterdam, private sector companies that based their activities in the area and a small part Schiedam Municipality. The relationship between Rotterdam Municipality and the port authorities of Rotterdam is mentioned at the previous paragraphs that present the history of MVH and its current situation. The aspiration quoted does not include that fact that the area is a polder and that safety has always a priority. The relationship between the two Dutch Municipalities is out of the scope of this thesis that is the reason that...
the Municipalities boundaries are explicitly drawn. Rotterdam Municipality to avoid conflicts will try to implement every procedure and plan with high transparency. Anno 2008, Rotterdam Municipality’s role towards private sector and district project’s development has changed regarding urban development (Rijnmond, D. 2013; Stadshavens Rotterdam.nl, 2013). The Municipality of Rotterdam gave more power and authority to the private sector by providing a set of guidelines for developing an area project for 30 years, (starting points or development framework) to consortia which is called to develop master plans for the area. The duration of the contract for developing the specific areas will be for 30 years. Consortia are called to develop plans and solutions concerning a certain project calling, the Municipality of Rotterdam is called to adapt to a new way of leadership. The consortia that will propose the best plan will be responsible for developing and maintaining the area on their own finance.

**Chronicle**

Words like planning and development are interwoven with time dimension. According to aspirations of Rotterdam and the port authorities of Rotterdam for developing the area of Merwe-Vierhavens, the master plans developed should take into account a transformation and maintenance of the area for at least 30 years. This indicates that the long term planning is obligatory. The planning must take into account that not all the area will be available for development at the same time. Land ownership indicates that the energy neutrality master plans should take into account the different times that the land will be available for use.
2. Application and evaluation (Test and response)

This chapter presents a first attempt to use the concept assessment tool. A simulation of the use of the concept assessment tool of energy neutrality was done. The stimulation was facilitated by six experts of the Municipality of Rotterdam and students of the Technical University of Delft. The simulation is a test to identify the advantages and disadvantages of the concept tool developed and presented in the previous chapter.

Application

The scope of the assessment test is to assess energy neutrality alternative plans for Merwe-Vierhavens by using the assessment schemes’ steps were introduced in Part C. The application of the scheme, due to lack of time and means, was impossible to be followed without some assumptions and “retreats”. The following paragraphs present the application of assessment scheme and tool based on the roles distributed and the steps of the assessment scheme.

Roles

Assessors

The assessors were experts from the Municipality of Rotterdam. The assessors’ group was constituted by six experts of the Municipality of Rotterdam with knowledge on Merwe-Vierhavens. The leader assessor was me. The assessors were called to declare their preference weights of energy neutrality objectives for developing Merwe-Vierhavens. The process of assessment was explained to them and using the spreadsheet of AHP comparisons of the tool was introduced to them. The spreadsheet was sent to the experts accompanied with an operation manual to facilitate the procedure. Two of the experts preferred to complete the spreadsheet being in the same room. The other experts preferred to fill in the spreadsheet isolated. In order to get their opinion they were asked to complete a questionnaire concerning their experience with filling the matrices of the concept tool and the general procedure. The answered questionnaires with the consent of assessors are presented at Appendix D. It was an attempt to familiarize assessors with the comparison matrices and use theirs critique to improve the procedure and the layout of the tool.

Consortia

The consortia were students of the Technical University of Delft and Ir. F. M. Freyre Hechavarria, expert of the Municipality of Rotterdam, and the author of this thesis.

Seven ideal plans were generated three by Ir. F. M. Freyre Hechavarria, expert of the Municipality of Rotterdam, and the author of this thesis and four by groups of students following the track master of Industrial Ecology. The reason of ideal alternatives to be used was because unfortunately there was no real plan available and that the purpose of the simulation is to evaluate the assessment tool and not the plans quality. It is taken into account that the plans were ideal so the final score was expected to be higher than a score that a real plan could gain. The use of ideal alternatives tested three purposes.

a) To see how planners use the objectives of energy neutrality and their weights.

b) To see how sensitive the concept tool is to one single design change. That is the reason that ideal alternatives A, B and C differ only at the parameter of energy type in order to have a clear response to the scoring differentiation. To facilitate that comparison a baseline plan was developed. The baseline plan assumes that no renewable energy is generated at Merwe-Vierhavens.

c) To see the response of the concept tool to completely different alternatives. Hence, the other four alternatives do not have a common base.
Procedure
The procedure of application is described following the steps of the assessment scheme (Figure 15) and they are described below.

1. The objectives of energy neutrality were taken as granted as they were generated for this thesis and presented.
2. The objectives of energy neutrality were aggregated and the six assessors weigh the objectives of energy neutrality using the concept tool.
3. The energy neutrality objectives and their weighs were provided the students (consortia)
4. The students generated ideal alternative plans for Merwe-Vierhavens.
5. The certificates and calculation were taken as granted.
6. The decomposition and scoring was done by the leader assessor
   a. Test I
   b. Test II
7. The final score and comparison was done by the leader assessor.

The scope of this application is to identify the concept tool benefits and lacks on the aggregating and weighing process and on the decomposition and scoring method.

Evaluation
The simulation conducted was evaluated. The evaluation is divided and consisted to the main parts of the concept tool that were used.

The process of aggregation of energy neutrality objectives and weighing the objectives was conducted by the assessors. Their results were revised as well as their opinion. More specifically it was examined the correctness of the hierarchy of objectives (aggregation). The aggregation of the objectives was tested by the consistency of the AHP matrices filled in by the assessors. The weighing provide information on the relevance of easiness of AHP method and layout, the process of filling in the matrices, the assistance provided, the results of filling in the matrices, the time needed to fill in the matrices, the objectivity of assessors, their overall opinion and some general remarks. The evaluation derived by the assessors’ answers to a questionnaire (Appendix D) and the experience of the leader assessor. In the end is presented the overall opinion of the assessors.

The process of decomposition of alternatives and scoring was facilitated by the students of Technical University of Delft and the leader assessor. It is examined how the concept tool response to different ideal plans.

Aggregating and weighing of energy neutrality objectives test results (assessors’ opinions)
The results of testing AHP matrices provide information on the energy neutrality objectives hierarchy, the objectives homogeneity, ease of use and adding value to the assessment process.

Aggregation
If a certain matrix inconsistency is common then something is wrong with the objectives hierarchy or the objectives homogeneity. The test showed no problem at the hierarchy and its objectives homogeneity. Some objectives were difficult to be understood from the assessors. Consistency was difficult to be kept in certain matrices, especially to the ones that had a large number of objectives to be compared or to the ones that the objectives were slightly heterogeneous.
**Easiness**
The assessors find the matrices relative easy to be filled in though they would preferred a different layout. The difficulties faced by all the assessors were focused on the objectives comparisons and consistency. The heterogeneity of some objectives made the relative comparisons even more difficult. Consistency which works as a check measurement of AHP method caused some troubles to assessors, especially in large matrixes. The majority of the assessors mentioned that they need first to do some trials in order to understand the philosophy of the matrices and after a point it was easier for them to fill in the matrixes. Questions of curiosity and often with a sense of competition were raised like “what was his consistency” or “what was his preference weigh on that certain matrix”.

**Process**
Different opinions were expressed on the question do you want to fill the spreadsheet alone or with other assessors. It was noticed that the two experts being at the same room completing the matrices tent to have a discussion of their choices and that factor influence at a certain extent their choices. On the other hand from assessor that completed the matrices alone request for help in difficult relative judgments due to lack of knowledge.

**Assistance**
The operation manual for some assessors was useful for some others not so much. Almost all asked for a workshop to see the use and get more familiar with the matrices and the objectives with combination of manual providence.

**Time**
The time that they spent completing the matrices differ from assessor to assessor and it was between 1 to 3 hours. The time and the resulted weighting differ and it can be explained by psychology and to the factors that can influence a relative judgment. The factors are the same factors that can influence a decision. These factors include their expertise and past experience (Juliussen et al., 2005), cognitive biases (Stanovich and West, 2008), age and individual differences (Bruin et al., 2007), belief in personal relevance (Acevedo and Krueger, 2004), and an escalation of commitment, influence what choices people make.

**Objectiveness**
Their actual results despite of their similar expertise background vary in great extent. The assessors were asked if they believed that their opinion would be different if the fill in again the spreadsheet. It was quite a surprise to see a variation of answers. One assessor believed that he will give again the same answers, one assessor believes that he will not give the same answers because of different mood and a third assessor believes that his judgment is influenced by the gain of new information for the area.

**Overall opinion and general remarks**
The assessors’ overall impression of using the concept tool by was positive. All of the assessors expressed that the main benefits of the method is that it can assist decision making it is improved and tested and actually more that they expected from its introduction. They all believe that aggregating objectives of energy neutrality with a multi-criteria method is a better than the current method used on assessing plans. As in the near future they will be asked to assess plans more often the concept tool could be developed as a valuable tool for assisting decision making process.

**Decomposition of alternatives plans and scoring**
In order to test better the concept tool’s part of decomposition and scoring different kind of ideal alternatives were generated and they are separated into two tests Test I and Test II.

**Test I**
The first group of alternatives generated includes the alternatives A, B, C. The planners took deeply into account the objectives and their weights to the process of planning. Both of the planners were involved at the
procedure of the development of the concept tool and the one was also an assessor. The scope of these alternatives generation was to see how the scoring is differentiated with different grading one objective. More specifically the results of test I are the following.

The concept tool is sensitive to different energy sources selection Alternative C which is the implementation of a combination of solar panels and wind energy scored higher than Alternative A (only solar panels implemented) and Alternative B (only urban windmills implemented). Though wind energy had a highest preference weigh by the assessors, solar energy alternative was awarded with a higher score. Solar energy alternative provides a better efficiency and lowers the energy consumption in buildings 400 times so generates a higher score. The detailed results are presented to Appendix D.

Test II
The second group of alternatives generated includes the alternatives D, E, F and G: The alternatives D, E, F and G were developed by students whom were not involved to the development of the tool. The reason of this testing was increase the difficulty of decomposition process and to identify how the score is generated by total different plans. This test resembled a more realistic situation than the previous test of

The alternatives design and the choices of planners differ in great extent. The decomposition process of each plan took by the leader assessor 4 hours.

More specifically the results of the testing II are the following.

Alternative F dues its high score to proposal of synergies that exchange energy, to the fact that different sources are used for energy generation, to the low consumption of energy in infrastructures and all types of buildings and finally to the consideration of the majority of the objectives in a great extent. The second graded alternative also due its score to the mix use of sources, result that confirms the sensitivity of the concept tool to the mix sources implementation. All the plans took into account water and security aspects of the district. The alternatives find a difficulty to consider the impact of demolition at the implementation process. Social aspects are also low rated. The maintenance of energy neutrality is not highly scored are the planners are not included this phase into their plans with that aspect they are turning their planning into short term planning. The alternative with the higher grade manages to consider social aspects and long term planning which gives an advantage to the concept tool. A percentage of 35% could not achieve the optimum score by the ideal alternatives generated. The comparison between Alternative F and E (highest and second highest score) showed that to the 82 objectives that are score 50% are scored the same and 50% not but their technical report analysis’ results that the same scores are achieved in a completely different way. The achievement of score with a different way implies that a high score can be gained by different choices. The detailed scores of the alternatives and their comparison spreadsheet are presented to Appendix D.

Test I & II
The two tests were combined to provide us an evaluation of the decomposition and scoring part of the concept tool. The evaluation results are towards the decomposition process and the scoring.

Decomposition
The decomposition of the alternatives remains a difficult procedure even to be done by the planners. The complexity of the alternatives could generate problems to the concept tool validity of score. The concept tool could facilitate the procedure but due to differentiation of alternatives by scoring objectives but due to complexity sometimes “logical” faults could happen. An example is presented to reflect that types of mistakes at the scoring procedure.

Example: Alternative X is compared to Alternative Y. Alternative X has at its design only bike paths and pedestrian roads. Alternative Y has bike paths, pedestrian roads and car roads. Alternative X scores 6,8470 without the implementation of sustainable traffic lights because they are not a necessity. Alternative Y scores 6,8519 and it has on its design sustainable traffic lights. If Alternative X’s planners decide to implement sustainable traffic lights even if it is not need it the scores rises to 6,8712. That shows that credits could have a potential impact to the final score of the alternatives and at their comparison stage. That leads us to the conclusion that the score of an alternative is an indicator; assessors still need to be careful to avoid this kind of “logical” faults. The concept tool decomposition process cannot substitute human critical judgment.
Scoring

All ideal alternatives were high scored but no alternative reach the optimum 10.

Table 15 presents the scores of the alternatives generated for the development energy neutrality at Merwe-Vierhavens.

Objectives of energy neutrality could be used as guide line to develop a high score alternative. Though the fact that ideal alternatives no alternative could reach the score of 10. This could reflect to the current technologies that could not cover 100% the needs of consumption. It also reflects to the fact that some objectives are contradictory so an alternative cannot implement both of them. This results a lower score. For example an alternative that scores high to the objective mono function it cannot score high to the objective mix functions. From the examined alternatives the ones that presented higher score are the ones that promote synergies of energy resources and flexible use of infrastructures. The sensitivity of the score to changes of grade depends on the objective’s weight, the higher weigh factor the higher is the impact to the final score.

<table>
<thead>
<tr>
<th></th>
<th>Test I (same base only energy type changes)</th>
<th>Test II(all the elements of plans are different)</th>
<th>Baseline Produced for MVH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total score of</td>
<td>Alternative A</td>
<td>Alternative B</td>
<td>Alternative C</td>
</tr>
<tr>
<td>energy neutrality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.67</td>
<td>6.56</td>
<td>7.15</td>
</tr>
<tr>
<td>Reduce energy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>consumption</td>
<td>2.27</td>
<td>2.09</td>
<td>2.33</td>
</tr>
<tr>
<td>Increase energy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>1.10</td>
<td>1.18</td>
<td>1.38</td>
</tr>
<tr>
<td>locally</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintaining and</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>monitoring the</td>
<td>0.49</td>
<td>0.49</td>
<td>0.63</td>
</tr>
<tr>
<td>balance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Realistic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>implementation</td>
<td>2.81</td>
<td>2.81</td>
<td>2.81</td>
</tr>
</tbody>
</table>

Table 15: Score of Alternatives of energy neutrality development of Merwe-Vierhavens

The simulation of the energy neutrality assessment was applied to Merwe-Vierhavens provided an evaluation on the concept assessment tool. The lessons learned were that the application of an assessment process without the proper means needs to be adjusted. Nevertheless, as a first approach it was more than valuable and helped to identify the benefits and lacks of the concept tool.

Table 15 provides an idea were the examined alternatives (ideal plans) focus their differences and score better or worst against the energy neutrality objectives. These numbers are indicators the selection of the highest number does not mean necessarily that is the optimum option. The reason that the concept tool should be used is to help assessor make a decision not take the decision for them.

After the application and evaluation conclusions and recommendation for the development and the improvement of the concept tool were driven and are presented.
Conclusions on Part D

MVH district
MVH district used to be a fruit port area but now the port activities are moving towards the seafront. The area that the port activities were taken place leaves room for innovative solutions and for the city to occupy these spaces. This process is called regionalization and is a process that is noticed to the major city ports of all over the world. The aspirations of the Municipality of Rotterdam for MVH are to be developed in a sustainable way promoting the main pillars of sustainability (ecology, economy and society). The system boundaries of MVH are placed as geographical, governmental and chronicile. Geographical as MVH is a polder area that means that water safety should be taken into account into the assessment process. Governmental as MVH is an area that is governed by the Municipality of Rotterdam, the Municipality of Schiedam and the port authorities of Rotterdam. These different authorities need to agree for the development that it is going to take place. Chronicle as a district cannot develop simultaneously; the concept tool is deteriorated to assess only plans which are representing the final conditions of a development.

Application and evaluation
A simulation was conducted in order to evaluate the processes of the concept assessment tool. The simulation purposed evaluate the weigh process conducted by experts of the Municipality of Rotterdam and the reaction of the concept tool at the decomposing and scoring process with ideal plans produced by the author and ir. Hechevarria and students of the Technical University of Delft following the Master of Industrial Ecology.

At weighing process, to be consistent at some matrices is difficult especially when the objectives compared are many or heterogeneous. The variety of objectives provides a whole image to the assessors of what they need to look at the plans. The transparency of weighing process enhanced the dialogue between the assessors.

The scoring procedure indicated that decomposing a district still remains a difficult process because of the district system complexity. By decomposing an alternative plan for energy neutral district development the elements of the district system and sub-system are clearer to the assessors. The scores of the objectives could enhance a dialogue between the assessors at the comparison process, as it is easier to compare single elements than a whole system. The numerical nature of the scores makes them easier than plans to be compared. The final score is a number that represent the rate of energy neutrality that could be achieved and it is an indicator that could facilitate the assist decision making process.

The concept assessment tool is not substituting the assessors’ decision. The scores provided are indicators that suppose to help decision making process but not eliminating it. The reason that no ideal plan scored a 10 is that some of the objectives are overlapped. The possibility of a plan with a little bit low score than another being better exists.
Reflections
Reflections present the personal and critical opinion of the author of her work about the following aspects:

- the project goals,
- the lessons learned from the existing assessment tools,
- the choices and actions taken towards the development of the concept tool for energy neutrality at a district level,
- the feelings of others about the concept tool,
- the outcome,
- personal strengths and weaknesses that were revealed during the thesis and
- the things that the author would like to do different next time

The project goal
The goal of this project was the development of a new assessment tool focused on the requirements giving by the Municipality of Rotterdam in order to asset MHV energy neutral. The requirements addressed were managed with the help of SSM framework.

Lessons learned
Existing assessment tools are focused on a single scope like sustainability, energy efficiency and environmental quality at a certain defined scale or type of buildings.
On the other hand, decision making does never examine a project taking in account a single scope.
The parameters used to decide if a certain project is going to be implemented have to include efficiency, adaptability, security, robustness, accessibility, and economical value.
For example, it’s not affordable to have an energy efficient building if it is not accessible or if it is really expensive. It is too difficult to address all these parameters in one tool. That is the reason that assessment tool used scores as indicators by the decision making.
These indicators are really useful because they break down a complex problem into pieces. At the end the decision makers have to make choices. The choices include part of their experience and intuition. As the scale of the project wanted to be assessed is increasing the more complex it becomes to be assessed that is the reason that there are not many existing assessment tool at district or city level.

In order to standardize their assessment process and make it less time and means consuming, the existing assessment tools develop a benchmark. That means that the tool is not adjustable to the case study that is examined.
This benchmark has the same configuration used for a project assessment, the user just need to define the scale and the type of the building.
At building scale this system works really well as the existing tools cover all the range of needs and possible combinations. At a neighborhood and district scale level the benchmark system has some drawbacks. The drawbacks are originated by the different combinations of functions and the complexity rise from it. For example a district scale it’s has a different function and therefore needs from a commercial district in the city center.

Choices and actions
Method of tool choice: The developed method of tool choice provide the opportunity to see the vast range of existing assessment tools and give an overview of the tools applications fields. This overview provided many ideas of how to shape out the concept tool.

District uniqueness:
The concept of assessment tool developed aimed to maintain the individuality and character of a district and made focus on energy neutrality. Every district is unique mainly commanded by its geographical location and its geomorphology. To implement energy neutrality on a district level its specific characteristic need to be taken into account. Therefore the assessment tool should treat every district as a different case. The concept tool has to be adapted for every assessment. The adaptation is done by using the AHP matrices. AHP is relevant easy and fits with the objectives of the assessment tool that we wanted to develop.
Energy neutrality objectives:
A critical choice was made when the objectives of energy neutrality not only cover this topic in the broadest sense of the words but also include social, environmental and some other economical aspects. That does not mean the dismissing of the main focus of energy neutrality, but quite the opposite it is states that in order to achieve this goal all these parameters have to be taken into account.
Energy consumption, energy production and energy maintenance are the main objectives of energy neutrality that are on the top of the hierarchy their sub-objectives might be related to energy, to infrastructures, to water, to accessibility, to transportation and so on. All these not energy parameters contribute to the main objectives of energy neutrality hence the focus remains on energy because the sub objectives will always weigh a percentage of these three aforementioned aspects.

The feelings of others
The feelings of others about the concept tool are controversial. As a conceptual idea they found it nice. The ones that tested the tool mentioned difficulty on assigning weigh of preferences on the objectives of energy neutrality. I agree with their complaints. This difficulty could be explained by the fact that AHP methodology was new to all the assessors and that the objectives are in many cases difficult to be compared even by assessors with great experience at their field and high level of judgment.
The time that was consumed to fill in the AHP matrices depends on the assessor judgment and his or her feeling of responsibility to feel with accuracy the matrices.
My professors were quite judgmental on the objectives of energy neutrality. As I mentioned before, I forced to take into account other parameters than only energy related parameters. Nevertheless, the AHP matrices provide a hierarchy of objectives, all the non-energy parameters are contributing to the main energy parameters. Though I agree that the focus could be more concentrated to energy and make my work easier but I strongly believe that the result is much better including these parameters. I try to match the real situation so close as possible.

Outcomes
The outcomes are:
- A selection method of existing assessment tools,
- An analysis and comparison of the most relevant to energy neutrality existing assessment tools,
- A development method for assessment tool,
- A concept assessment tool for energy neutrality and its first test/evaluation.

1. Selection method of assessment tool
The selection method of assessment tool was is a simple method to scan and identify what exactly are the expectations and requirements of the end users. In our case was used for two reasons. The first reason was to identify the most relevant tools with the scope of assessment of energy neutral plans for district development by Dutch public authorities, the second reason was to prove that we needed to proceed with the development of a new assessment tool.
The benefit of this thesis have being proved at the moment that I was able to identify the requirements posted by the Municipality of Rotterdam which became in concordance with the driving expectations of the assessors at the moment that the tool was tested.
The conclusion after the development of the concept tool was that the criterion of scale was more important than the energy criteria included into the scheme of an assessment tool.

2. Analysis and comparison of existing assessment tools
The comprehensive analysis and comparison of existing assessment tools contributed really beneficial to the development of the concept tool.
From the analysis and the comparison of the relevant existing assessment tools I identified the good points of their assessment framework and take them into account to the development of the concept tool.
The parts of decomposing a district system and scoring a plan were taken and modified to the concept tool.
These are the parts that are common and make the well known existing assessment tools like BREEAM, LEED and CASBEE valuable tools into their field.
In that way I wanted to highlight their contribution to the concept tool, without this comprehensive analysis the concept tool could not be developed.
3. Development method
The development method provides general guidelines of how to develop an assessment tool. These guidelines are steps defined by the tools anatomy. This development method could be used to develop a tool with a different focus by making different choices to each step of the anatomy that would reflect the requirements of the end user.

The fact that in every step choices must be made in order to proceed, make the development method flexible but also leaves space to scientific community to argue for the choices being made. At this case the choices are reasoned nevertheless readers might have different opinion on certain choices which of course could contribute to further developments and improvements of the concept tool.

4. Concept assessment tool
The concept assessment tool was developed to face an assessment of energy neutrality at a district level and it is specified to the requirement posted by the Municipality of Rotterdam, it is not a complete tool so it cannot be used without further reflections. It is a first approach, in order to be a useful and valuable tool for the Municipality of Rotterdam needs improvements and testing. As a first approach it is good because it provides the main guidelines of where the focus should be addressed to. The way that benefits the Municipality of Rotterdam was to identify the challenges which need to be faced in the foreseeing future. These challenges are:

a. Identification of the main scope of the assessment tool. We want everything, energy efficiency and robustness, economic, environmental and social beneficial plan. Unfortunately all these aspect are difficult to be addressed at the same time all in a tool, some compromising are needed to be done.

b. Identification of the objectives that the Municipality wants to address to the private consortia that will develop plans for energy neutral district. It is difficult to identify the objectives because of the complexity of a district and the fact the objectives are dynamic (change during time).

c. Translate these objectives to weigh of preferences.

d. Assessing a plan that might affect decision making process about the future of the area for the living of thousands of people.

e. The change of power from Municipality planning to consortia planning

The concept tool provide to the Municipality of Rotterdam an overview of what needs to be done and the possible a way to achieve it. This work contributed also in a change of mind set of the Municipality towards the existing assessment tools as it was shown to them that existing tool might have good results but are not fulfilling 100% their requirements. A tool provides accurate results when the user uses it for the purpose that it was developed. If the user uses it for other reasons some useful results could occur but embeds dangers that the result is answering a different posted question. That is simple, it is a conflict between the framework and the problem. To be more specific and a bit critical, the Municipality of Rotterdam uses BREEAM-NL area to assess district plans. BREEAM-NL area can provide good indicators for labeling or promoting the social acceptance of a project. The Municipality of Rotterdam needs to think if the output of the BREEAM-NL area is the output that they want

Personal strengths and weaknesses
Throughout the whole process of the thesis project the personal strengths and weaknesses were revealed.

Strengths: The personal skills revealed during the comprehensive analysis of the existing tools, the analytic skills used to compare them, the work independency and the devotion to the aim.

Weaknesses: The personal skills that need to be improved according to my supervisors are to be more organized and to justify more my work.

Things to do differently next time
Next time I would like to involve more and different expertise to assist me. Devote more time in writing and do more testing and evaluation to each process step.
Final Conclusions and Recommendations

This thesis has three deliveries
1) A comparative analysis of existing assessment tool against energy neutrality at a district level (Part A)
2) A development of a method to generate an assessment tool for energy neutrality at a district level (Part B)
3) A concept tool for energy neutrality (Part C) tested and evaluated for MVH district. (Part D)

Conclusion and recommendation are presented according to the three aforementioned deliveries.

Existing assessment tools (Part A)
Part A is answering the question: *At what extent the existing assessment tool can evaluate energy neutrality at a district level?*

Existing assessment tools cannot evaluate energy neutrality at a district level because:

- a. The majority of the assessment tools are dedicated to building level
- b. They have a simple assessment scheme, check list with the same weighting factors No differentiation between districts. Their assessment scheme is based on the assumption that every district has the same functions and needs.

Existing assessment tools vary in great extent. Their number is increasing showing that there is an increcent of the concern for the “symbiosis” of natural and building environment.
The majority of the existing assessment tool is focusing in a building level. The last decade the assessment tool scaled up to neighborhood, district even to a city level. A positive aspect that leads us to the conclusion that organization and institutes are interested in using assessment tools.
The few assessment tools that are higher scaled have similarities and differences. Their similarities are identified mainly to the fact that they all are accrediting schemes developed for labeling projects. Their way of assessment is transparent but the way that their credits and weighs were initially assigned to their schemes remains a mystery. The examined assessment tools create a benchmark. This benchmark is the same for every assessment. The positive of this standard benchmark is that is saves time and money from creating a new every time that you need an assessment. The standard benchmark works well also in the cases of building level as the complexity of a building is much lower than the complexity of a district.
The existing assessment tool scope labeling and marketing but in many cases are used for comparing development plans. The reason that is used for comparing development plans is to make use of their positive aspect is the structured decomposition of a system (building, neighborhood, district or city).
The elements of part A that contribute for the further development of a method to generate an assessment tool for energy neutrality at a district level were the tools’ anatomy and the structured decomposition provided for the existing assessment tools’ schemes.

Developed method (Part B)
A method for development of an assessment tool for energy neutrality at a district level is developed.
The method follows the steps of defining the scope and the system boundaries of the tool, defining the objectives of energy neutrality using a modeling method and finally aggregating the objectives with an MCDA method. Each step provided useful information that was used to the development of the concept assessment tool.

- a. Defining the scope and system boundaries.
  It is impossible to have an assessment tool that could be used by all the stakeholders because different stakeholders have different aspirations and scopes.
Districts are not isolated systems therefore some boundaries must be placed to assess development plan dedicated to them. These boundaries could be geographical, governmental or chronicle.

The current assessment method is rather complicated method. It is lacking a systematic decomposition of plans which could have possible negative results on the assessment process, like dancing table effects or no promotion of dialogue between the assessors.

b. Defining the objectives of energy neutrality

Defining the objectives of energy neutrality even with GTST modeling was not an easy process as we had to model a system that does not exist. GTST involves brainstorming processes therefore is a time consuming and creativity challenge with an objective result. In simpler words the goal trees can be numerous and there is no distinction of wrong or right.

c. Aggregating the objectives

The analysis of MCDA methods require a good mathematical background, their comparison lead us to the result that the method chosen should be the one that meets our requirements. A different choice than AHP could lead in a totally different assessment framework.

The advantage of the proposed method is that can be applied in different overall objectives.

Concept assessment tool (Part C+ Part D)

The concept assessment tool is proposed based on system engineering composition and decomposition, AHP and the decomposition scheme of existing assessment tools. The new assessment scheme scopes to facilitate the assessment of energy neutral plans for district development by public authorities.

The new assessment scheme can be divided to the three following main procedures:
1. Aggregation of energy neutrality objectives into a hierarchy
2. Weights of objectives of energy neutrality
3. Decomposition of alternatives plans and scoring.

The concept tool was tested and evaluated for MVH. The results of this evaluation were to identify its strengths and its lacks.

The strengths of the concept assessment tool are:
1. Its transparency. Each step can be accessed by the assessors and justified.
2. Promotion of dialogue and equality of opinion between assessors. The weighs of the assessors are independent of their expertise.
3. It is flexible as it makes a distinction of districts with weigh on the objectives of energy neutrality.
   The concept tool that was tested in Merwe-Vierhavens can be used for assessing energy master plans for different districts if assessors fill in the matrices of AHP spreadsheet having in mind a different district.
4. The objectives could be used as guidelines by planners. This could lead to a strategic behaviour but this kind of strategic behaviour is wanted.
5. The concept tool can be used for absolute assessment and for comparative assessment.
6. Promotes equality and objectiveness judgment of different alternatives
7. Provides guidelines for the decomposition of complex plans
8. Provides a good visualization of results, a single number
9. The main strength of the concept assessment tool is that it is taking into account the uniqueness of the district

The drawbacks of the concept assessment tool are:
1. To be consistent at the matrices is difficult especially when the objectives compared is many or if the objectives are heterogeneous.
2. The score of each objective it is not based in proofs and regal documentation only in the justification derived by the technical report.
3. Some of the objectives are conflicting making the score of ideal alternatives less than the designed optimum 10.
4. It is not tested with real plans.
5. The score of an alternative is an indicator for an alternative to be better than another still assessor need to be critical and recognise “logical” mistakes. It does not mean automatically that if alternative A is higher scored than alternative B that A is the optimum choice.

Specific Recommendations
The recommendations concern the further development and improvement of the concept assessment tool and not the method of development because in the case of the method if GTST or AHP choice change it is a different method with can lead to a different assessment scheme with results that cannot be comparable.

Decomposition
The decomposition of an alternative is done based on the “free” objectives of the hierarchy. These free objectives are standard for all the alternatives. The positive part is that they are like a pathway that can be followed; the negative part is that sometimes they cannot distinguish different situations. They free objectives could provide points in case that the alternative does not need to implement this objective, causing “logical” mistakes. An example is with sustainable traffic lights, there is no need of a traffic light if there are only pedestrian roads and bike lines into the area. A system could be developed to prevent “logical” mistakes on scoring procedure that could possibly lead to different rating of alternatives.

Scoring
The score of each objective it is not based in proofs and regal documentation only in the justification derived by the technical report. The choice of the legal documentation and the scoring process is a necessary process that needs to be developed. This process demands co-operation of experts from different fields and stakeholders that are involve to sustainable urban development.

Testing
The concept tool for further improvements needs to be tested by more experts, for different district and for real situation.

Further developments
The concept tool could be connected with decision making tools or it could be expiated to a decision making tool by implementing monetary or value aspects in its scheme. It is strongly proposed the tool to be connected with GIS as GIS could provide a better visualization of the scores and help the assessors to their decision process.

General Recommendations
For future development of an assessment tool and not a concept assessment tool is proposed a scrum framework (adopted from product development) applied on the steps of SSM. The reason of scrum framework proposed is that during the development of the concept assessment tool for energy neutrality it was noticed that too many aspects from different backgrounds needed to be taken into account. That raised the level of difficulty for the author. Hence, a future assessment tool of energy neutrality is proposed to be developed by a team of experts with various backgrounds that could facilitate every step of the tools anatomy.
Scrum is a framework that provides a structure of roles artifacts and meetings. The scrum development is based on a cross functional self organizational team. This cross functional organizational team is divided into
three roles the product owner (Municipality of Rotterdam, the scrum development team (experts for development) and the scrum master (a consultant). The Municipality of Rotterdam is focused more on what and less than how, has the vision of what it needs and the requirements less than the clear structured way to develop an assessment tool. The experts for development of the assessment tool should be team 4-9 experts who could facilitate with their expertise the development process. The scrum master should act like a facilitator between the Municipality of Rotterdam and the team of experts.

Epilogue
A concept assessment tool was developed based on the SSM framework. It differs from the existing assessment tools because it can assess energy neutrality alternatives at a district level. The assessment objectives and weighs were generated by tested and approved methodologies of GTST and AHP providing to it a scientific side. It promotes transparency as in its assessment scheme every involved stakeholders could access the results of the concept tool. It is a flexible tool as the weighs of the energy neutrality objectives can be adjusted to the district that is wanted to be developed. It provides a good indicator (final score of alternative) that could facilitate the process of decision making of public servants. On the other hand is a concept tool that is not complete. Its scheme needs to be improved and tested with real alternatives in order to be a robust assessment tool of energy neutrality at a district level.

Like any other assessment tool it does not substitute human factor in the assessment process. At the process of decomposition of alternatives and scoring the assessors need to be critical, careful and maybe trained. The result of the assessment tool is a final score for each alternative. This final score is an indicator that could assist decision making process.

Over all I want to close this thesis “borrowing” a conclusion made by Maarten Nijpels project manager of the Municipality of Rotterdam.

“The tool was impressive. Still perhaps too “excel-.like” or technical for some experts. But as a start for a tool: very good!”
References


buildings. *BRE, March.*


Voss, K., & Musall, E. (n.d.). *Net zero energy buildings* (1st ed.).


Bibliography


Mousseau, V., & Dias, L. (2004). Valued outranking relations in ELECTRE providing manageable


Voss, K., & Musall, E. (n.d.). *Net zero energy buildings* (1st ed.).


