SUN, SEA, LEISURE, AND ENERGY

The knowledge of experts used for the decision making of renewable energies in urban development areas in the North-Eastern part of Morocco, using AHP.

Colophon

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CONTENTS

PREFACE

This research my final step to become 'Master of Science' in the field of Construction, Management and Engineering at Eindhoven University of Technology.

The choice of my research is in the first place encouraged by my interest in environmental pressure and the way of minimizing this in urban development projects. A way to do this is by implementing renewable energies. Morocco, my entire life Nador was a place for holidays for me. To give something back to my holiday location, and learn more about the environment and the people in the professional setting, I choose this place as a case study for my graduation research.

During my graduation research Wim Schaefer and Brano Glumac were people who brainstormed with me and helped me through struggles. I would like to give my *thanks* to both of them. I *highly appreciate* Peter van der Waerden and Bauke de Vries, who took, in the last phase, place in my graduation commission, which made it possible for me to graduate early in June 2015. *Merci* to Sami Bouhmidi for the opportunity to do my graduation research at MarchicaMed. I am much obliged. I would also like to *appreciate* the experts who participated in the questionnaire of this research. *Dank* to the classmates I met during my study and the colleagues I met during my graduation. You made my study and graduation time more interesting, challenging, and fun. My *thanks* to Gert Regterschot for his help during my study.
Baraka'Allahou fiek to my family, my loving parents Mohamed and Yamina. The two raised me, gave me unconditional love, and supported me during all the good times and struggles during my study time. *Shoukran* to the other family members which believed in me, and especially my dear friends.
My *praise* to my grandparents Ahmed and Thlaitmas. You were my parents, my home, my support, and my best friends during my stay in Morocco. Especially my grandmother Thlaitmas, her believe in my ability was a big support for me. Unfortunately, unexpectedly, she passed away during my stay and graduation in Morocco. I would like to dedicate this research to my loving henna.

Life, and everything in life, has a begin and an end. After years of studies, classes, train journeys, project deadlines, and exams, it is now time for professional experiences, with new challenges for me. Let's (ex)change the wor(l)d!

Uasima Chaïbi
Papendrecht, June 1st, 2015

Part I – Framework

1 INTRODUCTION

The world population is growing, the energy demand is growing as well, in contrast the fossil energy sources are exhausting. The oil and gas resources will be exhausted in about fifty years. With the growing knowledge in the technology alternatives for the fossil resources in are upcoming and necessary to postpone the exhausting of the fossil energy resources.
The City of Two Seas is a new touristic city in the North-Eastern part of Morocco. This city covers an development area of 14.5 ha (MarchicaMed, 2013). This city will be developed by MarchicaMed. Since buildings are big consumers of energy it is interesting to analyse the possibilities in the design of buildings to reduce the needed amount of energy. Besides the reduction of the demand of energy it is at least equally interesting to examine possibilities for renewable energy resources as well.
The goal of this research is to find alternatives for fossil energy implementation in urban development areas in North-Eastern of Morocco. MarchicaMed gave the possibility to do this research with the possibility to use the City of Two Seas as an case study. Since this project is still not started, the exact numbers of the project are not included in this research.
The research is divided in two parts. The first part, the literature study, is done in the months September 2014 until February 2015 at the MarchicaMed office in Nador, Morocco. The second part, the research application, is done in the months February 2015 till May 2015 at Eindhoven, University of Technology, the Netherlands.

This first chapter of the research report will be an introduction to the research, and describes the research justification. Paragraph 1 includes the research context, and the motivation for doing this research. The positioning of the subject with a brief analysis of the problem will follow in paragraph 2. Finally this chapter will give some background information of the project.

1.1 Context

1.1.1 Research background

Morocco is an upcoming country with a fast growing market (Cherkaoui, 2006). One of the side factors that influenced the economy is the growing tourism (Roudies, 2013). Because of the growing economy and tourism the willingness of Morocco is to invest more in construction projects and especially more in tourism projects. The northern part of Morocco has developed seasonal economic activities weakly, especially in tourism. This was one of the reasons for the kingdom to invest in tourism in this region and other economic activities. One of current largest construction projects in Morocco is the project Marchica in the North-East of Morocco (*figure 1*). This project includes a unique lagoon, located in the Nador Province, at the heart of the Rif region. This lagoon is called Marchica, also the name of the entire project. The Marchica lagoon has become part of great sustainable development projects with a strong environmental vocation (MarchicaMed, 2014). The Marchica project includes the lagoon itself and the area around the lagoon, this is in total good for 20 000 ha.

The lagoon and the characteristics of this area gives opportunities for Nador to become competitive in the touristic branch at national level (Ben Chekroun, 2012).

The entire Marchica project will be developed by MarchicaMed. This agency has been founded in 2010 by the Moroccan authorities, who have all the legal powers. The Marchica project includes seven touristic cities, which are unique and complementary. While offering an architecture and equipment insuring comfort, quietude and modernity, with preserving the authentic character of the site and the lagoon, style, properties, fauna and flora (MarchicaMed, 2014). Due to these characters and goals this project will be a complex challenge.

Figure 1: Morocco and Nador

One of the objectives of MarchicaMed is to preserve the authentic character of the site. To achieve this objective it is required to develop the project with awareness regarding the area characteristics. This can be strengthened by developing the project within sustainable principles. One of the goals of this project is therefore to develop this project within a sustainable vision. The sources that will be used for the different sub-projects will be in the construction area. One of the seven projects is the project City of Two Seas, this project includes the development of a total new touristic city on the cordon. The ambition of this project is to develop the project to a zero-carbon city (MarchicaMed, 2014). Zero-carbon cities are characterised by eliminating, or rather minimize, the environmental impact while maintaining optimal living conditions.

Energy in Morocco

Morocco is an energy deficient country which means that the country is now heavily dependent on energy import from other countries (*figure 2*) (Frotzsche, 2011) (Supersbergera, 2011). However, the North African electricity markets are in a phase of rapid transformation. Soaring electricity demand, caused by

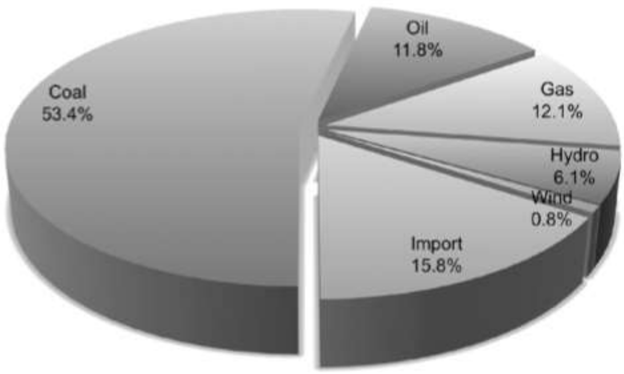


Figure 2: Power production in Morocco (ONE, 2007) (Supersbergera, 2011)

economic growth, demographic changes and progressing urbanization, urge countries in the region to increase their power generation capacity massively and upgrade their power grids (Zingerle, 2010). One way to achieve the protection of the area is by implementing renewable energies. Since Morocco has no oil reserves, Morocco has the necessary assets to focus more on energy independence, sustainable development and environmental perspective to have a high renewable share in this supply chain (Belakhdar, 2014).
At the moment, Morocco is mostly dependent on other countries to get the amount of energy needed for the whole country (Al-Sharqi, 2014). However, Morocco has the purpose for the future to produce at least 42% of the whole energy demand from renewable energy (Al-Sharqi, 2014). Morocco is located in one of the most suitable regions in the world with regard to renewable energy potentials, especially solar power is a form of renewable energy with high potential in this region (Frotzsche, 2011). Morocco has been engaged in a sustainable development and renewable energy strategy since 2009 (Rimi, 2012). The coming years Morocco will invest more than € 8.1 billion (Al-Sharqi, 2014) in renewable energy. Particularly in developing free carbon energies, mainly solar, wind and geothermal renewable energies (Rimi, 2012).

Nador West Med

A second gigantic project in this area is Nador West Med (NWM). NWM is a maritime port in the Betoya Bay with a scope of 850 ha and an investment of almost € 930.- million is located 30 km at the west of the city of Nador at the Bay Betoya (*figure 3*). This port will be an enlargement of Tanger Med, currently one of the largest ports in Africa. The first phase of the port will be completed in 2019.

Figure 3: Location of Nador West Med

The choice for Betoya Bay is an ideal location for a major port. Furthermore this location has several advantages, like the mild exposure to waves, favourable for the construction of topographical structures and bathymetric conditions, a prime location on the maritime routes and the infrastructure of Morocco as well.

Tanger Med improved the performance of Morocco on water ways from 78th on the global list in 2004 to the 17th position after its completion in 2011. Due to this, the expectations for the Nador West Med port are high. Morocco expects that the Moroccan connectivity will be in the top 10 on the global water ways list by finishing NWM. The initial start date was in 2010. However, environmental and seismic studies over the project took more time than expected.

The port of NWM will be connected by rail, and motorways will be improved. The new port of Nador will replace the work of the current port of Beni Ansar. The port of NWM will then compete with the ports of Spanish Melilla, Ceuta, Malaga, and Almeria.

The construction of the port results in better roads and highways, rail connections and greater openness to the national economy and the Mediterranean as well, in particular commerce and industry (Amiar, 2014).

NWM will have a big influence on the energy industry of Morocco. The port will be used for the import and export of energy in the form of oil and coal. However, since the share of fossil fuels is expected to decrease internationally (Amiar, 2014), Morocco intends to increase the amount of energy produced from renewable resources.

1.1.2 Relevance

Energy mix diversification in Morocco is a priority area of intervention to alleviate such dependency, notably by developing local renewable energy resources (ONEC, 2014). The governmental goals regarding renewable energy are clear. MarchiaMed has the same goals for the development of City of Two Seas. For this project the type of renewable energy is still not determined. Considering the location of this project all renewable energy resources are potential here. The goal of this research is to find out which renewable energy resources will fit, according to experts, best for this project, according to the technical and financial subjects.

1.2 Positioning of the subject

Morocco has no oil reserves, this makes it necessary to invest in sustainable development and renewable energies. Morocco has been engaged in a sustainable development and renewable energy strategy programs since 2009 (Rimi, 2012). Morocco will invest the coming years more than € 8.1 billion (Al-Sharqi, 2014) in renewable energies. Morocco invests mainly in solar, wind and geothermal energy (Rimi, 2012). For the future they have the ambition to gets 42% (Al-Sharqi, 2014) of the whole energy used in Morocco from renewable energy resources that comes from Morocco itself. The Moroccan government translates this in different programs to generate their own energy in Morocco.

The whole area around the Marchica lagoon will be developed. The location where the City of Two Seas is planned, has unique authentic conditions and is therefore most interesting of all the places in this region. The goal for this area is to develop it in a way that the environment will be protected as much as possible. Some measurements will be taken to realise this. The materials that will be used in the buildings come from the construction site or the Nador region. The infrastructure will be minimized by excluding cars from this area. The single possibility to come to this area is by water. Another ambition of this project is to use renewable energy resources for the energy demand.

The project is an environmental project, which makes the main goal not to make profit with this project. The protection of the site is more important for MarchicaMed. However, since the MarchicaMed has a limited budget, the project should be at least financially and technically feasible. According to the developers of MarchicaMed is a project that can be mentioned as 50% sustainable more desirable than a project with 0% sustainability. The feasibility of the renewable energy resources should be studied in a literature survey.

Owing to its special geographical and geological position, the North-Eastern part of Morocco, which is endowed by a natural bounty of sunshine and geothermal resources (Rimi, 2012), has a lot of opportunities for solar and geothermal energy. Since MarchicaMed has ambitions to develop the City of Two Seas sustainably, it is necessary to do a feasibility research to find which renewable energy resource is most interesting for this project.

1.3 Background information

The initiation of the development of the Marchica lagoon has its origin in 2007 and is initiated by the Moroccan King Mohamed VI. The first ideas were to develop some touristic areas around the lagoon. The big environmental program in 2007 resulted in the recovery of the lagoon (Philippe, 2012). Over time, this lagoon has been subjected to an increasing anthropogenic pressure owing to the economic activities in the adjacent zones and the growing population (Ben Chekroun, 2012). During the first researches by MarchicaMed, MarchicaMed found that the city of Nador needs a boost as well (MarchicaMed, 2013). The difference between the rich touristic domain and the general habitants of the city of Nador should not be big. The researches included studies of the economic, social, environmental and infrastructural aspects. From all these studies the government set three main goals to stimulate the socio-economic field in this area. The three main goals are:

- Protection of the ecological environment of the Marchica lagoon;
- To create a unique touristic place;
- To help the social and economic development of the region (MarchicaMed, 2013).

From this idea the current plan of the seven cities has been developed (Alaa-Eddine, 2014).

The development of these projects requires an investment of € 4.1 billion (46 billion dirhams) in the period of 2008-2025 (MarchicaMed, 2014). This financial support is mainly for the projects the City of Atalayoun and the City of Two Seas (MarchicaMed, 2013). A part of this investment will be done by the Ministry of Economy and Finances and the Hassan II Fund, which is founded to support economic developments (MarchicaMed, 2013). The further investments will be public-public and public-private as well (MarchicaMed, 2014).

1.3.1 The seven cities of Marchica

The Marchica project (*table 1*) exist of the following seven cities: The City of Atalayoun, The City of Two Seas, The Fishermen's Village, Flamingos Bay, Marchica Sport, The Orchards of Marchica, and The New Area of Nador (*figure 4*). Each city has its own character. The ambition in general is to conjugate regional development, quality tourism and sustainable development of this site. This gigantic project shows the evolution of the spirit of the Plan Azur in its second phase Horizon 2020. It combines economic and social development, protection of environment and its ecosystems, innovative town planning, construction in local materials, recycling of waste water, waste management, energy savings and renewable energies between tradition and modernity (Beuthe, 2014). As a whole, each city contributes in its own way to the ambitions of this urban development. The cities are really diverse with completion of hotel zones, fishing harbours, marinas, and spaces dedicated to water sport and other leisure. Given the scale of the program, and the lack of financial funds the project will be spread about a long duration. The first two cities that are planned and be developed will be the City of Atalayoun and the the City of Two Seas. These cities will be described further in Appendix A.

Budget	€ 4.1 billion
Ground space	8 000 ha, 20 000 ha including the Marchica lagoon
Maritime space	11 550 ha
Beds	101 200
Villas	1 000
Apartments	2 400
Marinas	7
General developer	Marchica Med s.a.

Table 1: Marchica project in figures

Figure 4: The seven cities of Marchica

1.3.2 Sustainability

A project based on renewable energy is also known as a sustainable project. However, a sustainable project not always implements renewable energy. These terms are often confused. The renewable energy should refer to the nature of a resource, while sustainability should refer how it is used (Axelsson, 2010). Sustainability can be defined as "a response to environmental decay of the planet and leaving a legacy to future generations of a reduced quality of life” (Frey, 2002). The conclusion can be made about the project of City of Two Seas that this project is a sustainable project as well. The aim of the project is to keep the environment in the original condition.

When the goal of the City of Two Seas gets compared to the definition of sustainable development from the report entitled ‘Our Common Future’ the purposes of the project fit the following definition as well: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Frey, 2002). The purpose of the development of the City of Two Seas is a development without having a negative impact on the environment.

Renewable energy

Since renewable energy can become the major energy supply option in low-carbon energy economies (Verbruggen, 2009) the main topic of this research is renewable energy. To start, it is important to have clear what renewable energy means and includes.

By analysing renewable energy it is important to check what description a dictionary gives. From an online dictionary, following description has been found: “any naturally occurring, theoretically inexhaustible source of energy, as biomass, solar, wind, tidal, wave, and hydroelectric power, that is not derived from fossil or nuclear fuel”. This description indicates a few things. Firstly, it focuses on naturally resources. This excludes nuclear resources of energy. Thereby, it says that the form of energy should be inexhaustible. The CO2 emissions of these energy sources are 0 or almost 0 during the production phase. This makes these sources better for the environment than sources like oil. Another explanation of renewable energy is from the US Energy Department. They explain renewable energy in most simple words: “Renewable energy comes from things that do not run out -- wind, water, sunlight, plants, and more. These are things that can be reused over and over again” (Stover, 2011). Like the dictionary gives this quote an common description of renewable energy and can be stated that renewable energy comes from natural resources that are not exhaustible.

Zero energy

It seems likely that the project will be a project with a zero energy character. To come to this conclusion the definition should be known and discussed. One of the best known situations where zero energy is implemented is in the ‘nearly zero energy buildings’. Since the City of Two Seas includes buildings where this principle is implementable. Voss gives the following definition for nearly zero-energy buildings: Nearly zero-energy building means a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby. Since the ambition for the City of Two Seas is to use energy from sources on-site or nearby it can be concluded that the project fits in a nearly zero-energy building principle.

1.4 Conclusions

The coming years Morocco invests billions in projects in the North-Eastern of the Kingdom. These investments will be made in the cities of Marchica and the harbour Nador West Med. One of the subjects in these projects is energy. This research will focus on the renewable energy possibilities in the City of Two Seas. To find the financial, and technical feasibilities for renewable energies in the City of Two Seas a few researches will be done. The researches will be conducted from the viewpoint of MarchicaMed as a problem owner and decision maker. The input for the decision maker comes from an analyst, and experts in the field of renewable energies in Morocco. In the end the findings will be presented and some recommendations will be given.

1.5 Reading instructions

This research report consists of four parts. The first part, the framework, includes the first chapter, which exist of the introduction of the research, and the second chapter, which includes the research methodology. Part II is about the contextual orientation of this research. The chapters include background information of the Nador and the environment, the City of Two Seas, computations of the energy consumption in the City of Two Seas, and at least an description of renewable energy resources. Part III the research application includes, a description of the research methodology of MCA and AHP, and the application of this research methodology on the case study. The results of this application can be found in this part as well. Finally in part IV the conclusions and recommendations of this research, followed by the discussion.

2 RESEARCH DESIGN

2.1 Problem description

Morocco has no oil reserves, this makes it interesting for now and for the future to invest in sustainable development and renewable energies. Morocco has been engaged in sustainable development and renewable energy strategy programs since 2009 (Rimi, 2012). Morocco will invest the coming years more than € 8.1 billion (Al-Sharqi, 2014) in renewable energy. They invest mainly in solar, wind and geothermal energy (Rimi, 2012). However, in the future the government would like to realize a 42% (Al-Sharqi, 2014) share of energy in Morocco from renewable energy sources within Morocco. The Moroccan government had translated this mission in different programs to generate their own energy in Morocco.

The whole area around the Marchica lagoon will be developed. However, the landscape of the total area of the Cordon and the island of the City of Two Seas has a variety of vegetation's and cultures. Therefore this area is one of the most interesting places to investigate.

The City of Two Seas is an governmental project, so it does not require profits with this project. The protection of the site is most important. However, the project should be at least financial, and technical feasible since the government has a limited budget. This limited budget sets some restrictions to the possibilities of implementation of renewable energy in this project. Achievement of a fully sustainable project is not the most important goal for MarchicaMed. The balance between the financial, technical feasibility and the sustainable aspects is more desirable.

The problem for this study project can be stated as follows: It is not yet clear which technologies for sustainable energy will be most feasible for application in the urban development of the City of Two Seas. Also combining these technologies, in order to make an optimal mix for sustainable development, lacks sufficient knowledge.

2.1.1 Relevance

Energy mix diversification is a priority area of intervention to alleviate such dependency, notably by developing local renewable energy resources (ONEC, 2014). The governmental goals regarding renewable energy are clear. The development of City of Two Seas has the same goals. The type of renewable energy for this project is still not determined. Since solar energy is widely implemented in Morocco. This resource is popular for implementation in projects. MarchicaMed has preferences for solar energy as well. The blind choice for solar energy will limit the project, since the area of this project gives opportunities for other sources of renewable energy as well. It is for MarchicaMed financial and technical interesting to find the most favourite renewable energy resources for the City of Two Seas according to experts in the field of renewable energies. Thereby this research contribute positively to the sustainable image of the City of Two Seas.

2.2 Research questions

The previous paragraph discusses the position of the subject. The following key words describe the research: renewable energy, solar energy, wind energy, geothermal energy, hydro energy, urban development, MCA, AHP, case study, Morocco

The central question of this research is:
What would be the most interesting combination of renewable energy resources in a new touristic city. Considering the characteristics of the area, technical possibilities and financial aspects.

To answer this central question several sub-questions are defined:

1. *What are the characteristics of Nador and the Marchica lagoon?*
2. *What kind of project is the City of Two Seas?*
3. *What are the interesting renewable energy resources for the Marchica lagoon area?*
4. *Which renewable energy resource is most interesting for the City of Two Seas project according to experts in the field of renewable energy?*

2.3 Research boundaries

This paragraph discusses the research boundaries. This includes the research objectives, followed by the focus of the research, and finally by the expected results.

2.3.1 Research objectives

The goal of this research is to find the most interesting renewable energy for the City of Two Seas project. The renewable energy resources will be compared to each other in the field of technical, and financial aspects. The possibility exists that the implementation of energy supply from fossil resources, economical more interesting is for this project than implementing of renewable energy resources is. However, this research has the purpose to find the most interesting renewable energy resource. The choice to whether implement the advised resource from the research on this project or not is up to the project developers.

2.3.2 Demarcation of the research

This research focuses on renewable energy resources which could be implemented in the City of Two Seas. This research will constrain to this project, which make the Marchica lagoon and its cordon the topographical boundaries of this research. Other boundaries of this research will be the number of renewable energy resources. From analysis of the environment of Nador and the Marchica lagoon are the four renewable energy resources solar energy, wind energy, hydro energy, and geothermal energy found as most promising renewable energy resources in this environment. This research will compare these four renewable energy sources on the technical, and financial requirements.

2.3.3 Expected results

At the end of this research, an advice for the implementation of a specific renewable energy form or a mix of renewable energy resources in this project will be given to the management of MarchicaMed.

The expectations at this moment are that geothermal energy is an interesting form of energy. This is mainly because of the permanent character of this renewable energy form. Solar energy is a form of renewable energy that is mainly mentioned by MarichaMed. However, multiple resources of renewable energy have potential in this area. Hydro energy because of the location near the passage between the lagoon and sea, solar energy because of the amount of sun hours in this area and wind energy because of the open field. From this it can be concluded that this area has extensive possibilities for renewable energy resources. The expectation is that the financial outcomes would have great influences on selecting a specific or multiple renewable energy resources.

2.4 Research method

To answer the different questions, a few research techniques will be used. In this paragraph the sub-questions will be linked to the most suitable research methodology. In total, exists the research of four parts with each a specific role and purpose.

2.4.1 Research design

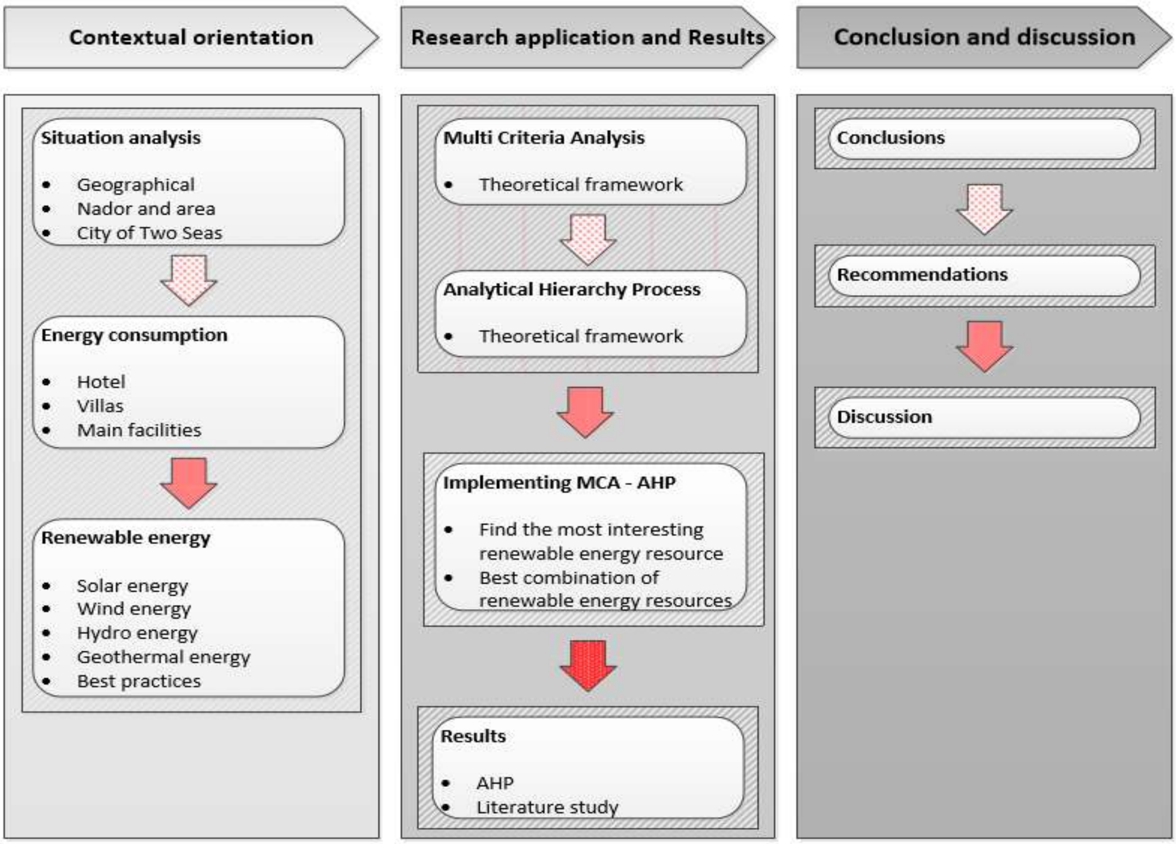


Figure 5: Research design

There will be three different roles during the entire research. The first part, the contextual orientation, exists of two subparts. In the first part, the role of the problem owner will be the most important. The goal of this subpart is to analyse the situation and get clear what the problem is, and why this is a problem. The research approach that will be implemented here is literature study. The second subpart of the contextual orientation, includes the role of an analyst. The characteristics of the project environment, the scope of the project and the characteristics of the project will all be studied through literature study. The main goal in this part is o clarify what the situation exactly is. In the second part, research application, is the role of the problem solver dominant. The techniques of MCA and AHP will be used to solve this problem. The third part, results and findings, will present the results, and an advice for a mix of renewable energy resources for the project of the City of Two Seas can be given. At least in part four, conclusion and discussion, the overall conclusion will be of the research be given and discussed. Figure 5 present schematic the research design.

2.4.2 Linking research methods to the sub-questions

As mentioned before, four sub-questions have been defined to answer the research question. The research methods that will be implemented are mainly literature study. This will be the dominant part of the research as a descriptive research. At the end an advice will be given to the project developers for the implementation of a renewable energy resources. The advice should be scientific, therefore a research methodology has been implemented. Since the research includes qualitative and quantitative subjects as well, a Multi Criteria Analysis (MCA) is implemented. The methodology that suits best for weigh the criteria in this research is the Analytic Hierarchy Process (AHP). AHP weighs criteria and help to find the most feasible technology for this project. Part III of this research discusses the question: "*How does the Multi Criteria Analysis and Analytic Hierarchy Process will be used to answer the research question?*".
The study approach of each sub-question is explained below.

1. *What are the characteristics of Nador and the Marchica lagoon?*

Answering this question will be done by doing a literature study. The subjects that will be searched for in the literature are geographic characteristics of the area, sun hours, wind speeds, hydro-energy, geothermal energy, etc. Background information about the environment will be found by implementing literature study, mainly information from articles will be used.

2. *What kind of project is the City of Two Seas?*

The question: "What will be developed in this area?" will be answered. Information about the project would be found by doing a literature study from documents that will be provided by the MarichaMed. When some information is missing, interviews will be taken supplementary.

3. *What are the interesting renewable energy resources for the Marchica lagoon area?*

From the information that is found by answering sub-questions 1 and 2, some renewable energy resources could have been selected for this project. The answer of this sub-question exists of a description of these renewable energy resources. The four renewable energy resources will be discussed and analysed. The financial, reliability and environmental characteristics will be highlighted here. This information will be gained from literature studies. Further an description will be given of (best) practice projects and the renewable energy resources which have been implementation in these projects.

4. *Which renewable energy form is the best solution for the City of Two Seas project according to experts in the field of renewable energy?*

Some criteria would be found from the literature study. These criteria will be used to compare the four renewable energy resources in the decision-making. By implementing Multi Criteria Analysis an Analytic Hierarchy Process will be modelled. The input for this model is some data that will be generated from an online questionnaire, which will be sent to experts in the field of renewable energy resources in Morocco.
The results from the Analytic Hierarchy Process would be compared with the needs and demands of the project. From this comparison the proposition can be made for the most interesting renewable energy resource or combination of resources for this project. From these findings, some recommendations will be made toward the project developers.

2.5 Conclusions

Information about the project area and the project itself will be found trough literature study. The information about renewable energy resources will be found trough literature study as well. These findings will be the basis input for the Multi Criteria Analysis. With the MCA a few criteria will be selected. The criteria will be weighed by experts in the field of renewable energy resources by pairwise comparison with the Analytic Hierarchy Process approach. On basis of the outcomes of these models an advice can be given.

Chapter 1 and 2 give an introduction to, and the structure of the whole research. The second part of this research include more literature studies on Nador and environment, the City of Two Seas, the energy demand in this project, and the renewable energy resources solar, wind, hydro, and geothermal energy.

Part II – Contextual Orientation

3 NADOR AND THE MARCHICA LAGOON

As described in chapter 1 Morocco is an upcoming economy. The population, and tourism is growing. The demand of energy is therefore growing too. Since the fossil resources are limited in Morocco, Morocco looks for alternative resources. Renewable energy sources are of a high potential in Morocco.

The city Nador is located in the North-Eastern part of Morocco (*figure 1*). This area undergoes large investments in the field of urban development. These are mainly tourism related. Like any built environment, this project needs energy as well. Since the developers have the purpose to develop a sustainable project, the possibilities for renewable energies should be analysed.

This chapter presents a description of Nador and the construction site. The description should help to identify the renewable energy resources with potential in this area.

3.1 The geographical context of Nador

The geographical situation of Nador has high importance for creating a perception of the environment. In this paragraph the city will be analysed from different points of view. The infrastructural position and the natural area are the main viewpoints to be discussed.

3.1.1 Infrastructure of Nador

The infrastructural position of Nador is very diverse. In this sub-paragraph the meaning of this word is related to the position of Nador in relation to the major cities in Morocco and Europe. Nador lies in North-Eastern of Morocco and is, due the banking character, the airport and the harbours, one of most important cities of Morocco. The nearest cities are at the west, the coastal city Al Houceima, a bigger city at the east near the border with Algiers is Oujda, and at the north side of Nador lies the Spanish enclave Melilla.

Motorways

The connection with the cities Tanger, Oujda, Fes and Al Houceima is over land. Between Melilla and Nador exists a motorway which connects the two cities directly. In 2002 the new coastal motorway N16 has been constructed in the north of Morocco. This motorway connects the cities Oujda in the east, and Tanger in the west with each other. The motorway goes from Saidia trough the cities Nador, Al Houceima, Tetouan to Tanger. The other important motorway to Nador is the N15 (*figure 6*). This motorway connects Nador with the south of the country.

Figure 6: The N16 (coastal blue line), the N15 (the red line)

Infrastructure of Nador

Nador is a city with about 265 000 residents in the North-East of Morocco. This city has undertaken a huge growth in the last decennium. One of the reasons is the great impulse in this part of Morocco by the government. With a growing population it is obviously that the number of residences is growing as well. This makes the infrastructure of the city important.

Figure 7: The R610 and N19 in Nador

Nador knows two important motorways in the city. The R610 and the N19 (*figure 7*). All main roads in the city are connected to these two motorways. These two motorways are connected with the N15 and N16.

Train connection

In 2009 new train stations opened in Nador and area. These train stations connect Nador better with other big cities in Morocco. The cities which are directly connected with Nador are Casablanca, Tanger, Fez and Taorirt. From these cities switches are possible to travel by train to the Moroccan cities Rabat, Casablanca, and Marakkech.

Nador Port (Beni Ensar)

At the coast of Nador, near the Spanish enclave Melilla, lies a harbour. This harbour is a commercial port on the Mediterranean Sea and servicing the northern part of Morocco and especially the Rif area. The harbour is good for the transportation of people and goods. The specialisation of the harbour are fish, the ferries, good for almost 600 000 travellers per year, between Nador and multiple Spanish coastal cities, hydrocarbons and general goods.

Airport of Nador (Arouit)

Since 1999, there are multiple international flights between the Nador airport and several European cities. The airport connects Nador with multiple cities in Belgium, Spain, France, Germany, and the Netherlands. There are also some national flights to the Moroccan cities Al Houceima, Casablanca, and Tanger. The airport was good for more than 600.000 passengers in 2014.

3.1.2 Natural area of Nador

This sub-paragraph discusses the natural area of Nador and the environment. The subjects that will be discussed are the plate tectonics, the mountains, and the waters in and near Nador. These aspects are important for finding potential renewable energy resources and selecting the resources.

Plate tectonic

The northern part of Morocco uses to have small or intensive earthquakes. These earthquakes have their origin in the plate tectonics. Morocco lies on the African plate (*figure 8*) which has his cleavage in the Mediterranean Sea. The plates are in movement now and then. These movements generate lots of energy and possible damage.
Another side effect are the many hot springs in this area. These hot springs have a constant stream of hot water of 24 degrees Celsius (Rimi, 2012).

Figure 8: Plate tectonic

Waters

Nador is a coastal city at the Mediterranean Sea. However, between the Mediterranean Sea and Nador lies the Marchica lagoon. The Marchica lagoon has an area of about 115km^2 (25 km by 7.5 km) and with a depth not exceeding 8 m. This lagoon is separated from the sea by a 24km long belt of dunes, also called the cordon. The lagoon still connects with the Mediterranean Sea through a new artificial channel. The connection of the lagoon with the Mediterranean Sea is 300 meters wide and 6.5 meters deep.
This lagoon has been subjected to an increasing anthropogenic pressure over time. The main reasons were the economic activities in the adjacent zones and the growing population (Ben Chekroun, 2012).
Except the stream from the Mediterranean Sea, a continental input exists as well. This input comes from the Salouane River, Bou Areg and the channel that drains the Bou Areg plain (Ben Chekroun, 2012).

Mountains

Nador lies in a valley and is surrounded by different sides with mountains. The best known mountains are the Rif mountains. These mountains extend from the city Tanger until almost Nador. Closer to Nador are in the west the mountains of Gourougou with a height up to 900 meters, and in the east the mountains of Kebdana with an average height of 800 meters.

3.2 The characteristics of Nador area

This paragraph includes the characteristics of the research area. The characteristics of the area to be analysed are the sun hours, wind speed, water stream, and the geothermal aspects. These characteristics are important to study the different resources of renewable energy. Besides these aspects the climate will be discussed.

3.2.1 Coastal climate

This area is characterized by a coastal climate, also known as the Mediterranean climate. The Mediterranean climate is characterized by warm, dry summers and mild winters.
This climate gives a lot of sun hours yearly. However, despite of the dry summers and mild winters the location in a valley is a big disadvantage, and in the same time an advantage as well. Nador is surrounded by a lot of open fields, which gives strong winds during the year. Like the water stream and the amount of sun hours the wind is an opportunity as well to use it to generate renewable energy.

3.2.2 Geothermal surface

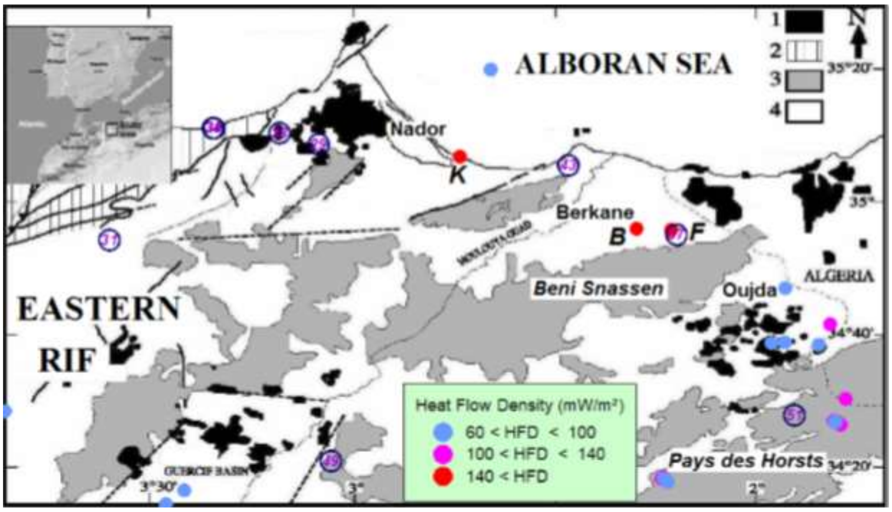


Figure 9: Hot springs in North-Eastern of Morocco

North-Eastern Morocco is a system of plains, plateaus and mountain ranges extending on the eastern parts of the Meseta-Atlas and Rif domains. This fact has been indicating promising and significant geothermal potentials in the North-Eastern part of Morocco and made this area to one of the most important geothermal fields in the country (Rimi, 2010) (Rimi, 2012). The evaluation of the financial aspects for the development of a geothermal system depends in general strongly on a proper site characterization. However, no geothermal project was developed despite the potential market concerning electricity production and some direct uses such as agriculture, mining, industrial processes and tourism activities. Currently multiple projects are known where the geothermal water is used for hot pools and baths (Barkaoui, 2013).
To make geothermal energy economic interesting, an area must possess high average geothermal gradients to create high temperatures at depths over a significant area (Rimi, 2012). In the area of the City of Two Seas there are a few hot springs. The nearest hot spring is the one in Kariat Arekman (*figure 9*) (Rimi, 2010). In a drillhole in this area water temperatures are measured of 96ºC at a depth of about 700 meter (Rimi, 2010) (Rimi, 2012).

3.2.3 Waters

The area includes different waters. At one side of the cordon there is the water of the Marchica lagoon. At the other side there are the waters of the Mediterranean Sea. The waters in the lagoon and sea have different characters. A more specific description of the characters of the waters in the lagoon and sea follows.

Marchica lagoon

The water in this lagoon is composed by three types of hydrological resources: the marine waters from the Mediterranean Sea passing through the artificial inlet, this water source is its dominant source. This gives a strong marine input influence the tidal. Secondly the hydrogeological contributions from two aquifers are important sources. These are the Gareb, located southern Selouane, and Bou Areg, situated near the southern margin of the lagoon. The third and last main source are the surface water inputs, with the periodic flows of ten small streams (oueds) (Ruiz, 2006).

The lagoon exchanges water flow with the Alboran Sea (Benkhaldoun, 2012). However, the original opening between the lagoon and the Alboran Sea was not good enough to circulate, and renewal the lagoon water well enough. From this findings the developers agreed on make a new entrance between the Alboran Sea and the Marchica lagoon.

Mediterranean Sea

The external hydrodynamics of the area at the coastal depends on the prevailing waves of the Mediterranean Sea, the tidal regime, and the littoral drift currents. The tidal regime of this Mediterranean region can be classified as micro tidal. The micro tidal increase toward the eastern and reaching 0.35 meter near the lagoon inlet. The mean wave height is 1 meter, with a mean period of 5 seconds for these directions (Ruiz, 2006). In the Mediterranean Sea the tidal waves are minimal.

3.2.4 Sunshine hours

The country is characterized by an intensive solar radiation. In the north of Morocco the annual duration of sunshine hours is about 2700 (Frotzsche, 2011). The sunshine hours are not constant over the year. In figure 10 the average sunshine hours per day and month are presented. As a seasonal effect, are the sunshine hours per day not constant over the year.

Figure 10: Average daily sunshine hours in Nador

Besides the sunshine hours is it interesting to know how many Wh/m^2 can be produced per day. With an average of 55% clearness, the average over the year is 5540 Wh/m^2 per month. Appendix B presents the potential Wh/m^2, and % clearness per month in the city of Nador.

3.2.5 Wind

Since Nador lies in a valley, and is from three sides surrounded with mountains and on the fourth side bordered by the Marchica lagoon and Mediterranean Sea, it can be called an open field. The wind is an abundantly resource in the coastal region. The wind varies from 4.8 m/s up to 5.74 m/s at the Nador coastal region.

Due the total open field at the sea the wind speed is higher at the Mediterranean Sea. Figure 11 shows the average wind speed in front of the coast of Nador.

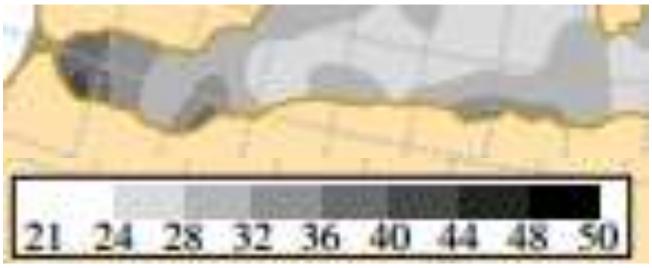


Figure 11: Average wind speed (m/s) at the Mediterranean Sea

3.3 Conclusions

Owing to its special geographical and geological position, the North-Eastern part of Morocco, which is endowed by a natural bounty of sunshine and geothermal resources (Rimi, 2012), has a lot of opportunities for solar and geothermal energy. The position near the Mediterranean Sea gives opportunities for implementing hydro and wind energy as well. This makes the renewable energies solar, wind, hydro, and geothermal resources the most interesting for this environment and therefore for the City of Two Seas.

4 CITY OF TWO SEAS

4.1 The project

One of the seven projects is the City of Two Seas. This project is situated at the cordon between the Mediterranean Sea and the Marchica Lagoon. This project illustrates the innovative challenge of the program Marchica, or how to combine economic development of a region and environment-friendly tourism (Agence-Marchica, 2014). The landscape of the island of the City of Two Seas has a variety of vegetation and cultures. This variety of landscape formed the inspiration to define different strategies and possibilities to develop Eco tourism (Architecture, 2011). The main goal was to develop an ecological strategy for this project. This project can be pointed out as an eco-resort that will fit the international standards of comfort and sustainable construction (Agence-Marchica, 2014).

The City of Two Seas (*figure 12*) reaches a development area of 14.5 ha (MarchicaMed, 2013). The landscape of the total area of the Cordon and the island of the City of Two Seas has a variety of vegetation and experiences. Based on different qualities and characteristics of the site, four different approaches have been determined for these four resorts (Architecture, 2011). Some new land reclamation in the lagoon and hills (varying from +2m to +25m) on the cordon (Architecture, 2011) have been made to strengthen the local character. To minimize the impact of the buildings on the site, a strategy is developed. One of the ways to do this is by embedding the buildings in the landscape, this results in buildings, which blend in with nature (Architecture, 2011).

The main purpose for the City of Two Seas is to reproduce and staging of historical, cultural and natural environments of the Mediterranean environment creating a full authenticity and symbolic atmosphere (MarchicaMed, 2013). This makes the project a dynamic and therefore a complex project.

Since this project is still not started, the exact numbers of the project are not included in this research.

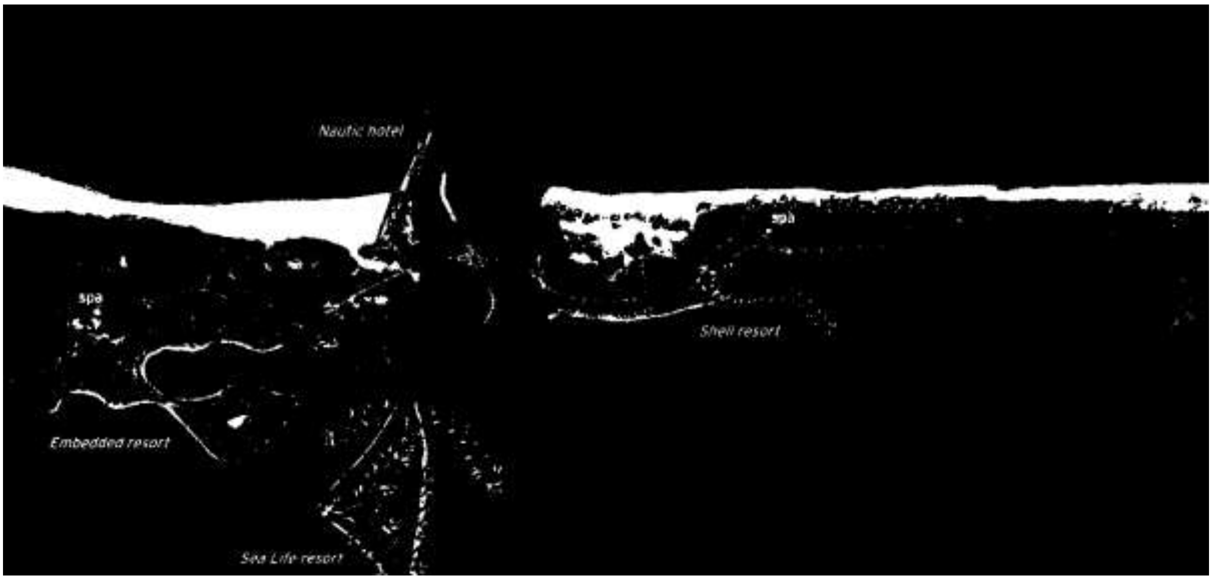


Figure 12: Overall plan of the four resorts in the City of Two Seas (Architecture, 2011)

The City of Two Seas exists of four resorts. Each resort has its own characteristics and scope. Table 2 gives the total square meters of each resort.

Resort	
Embedded resort	
Shell resort	
Sea Life resort	
Nautic resort	
Total	**50 000 m^2**

Table 2: The total square meters of the buildings in the City of Two Seas

In appendix C the exact numbers of the buildings are given.

4.2 The four resorts

The four resorts are inspired by and based on the different qualities and characteristics of the site. The resorts vary in level of luxury. The guideline that has been used as principle for the design is *The Six Senses strategy* for luxury eco resorts. *The Six Senses strategy* includes activities that are associated with providing accommodations, dining, excursions, wellness, sports and aquatic activities. In line with this strategy each resort consists of some main facilities as restaurants, bars, receptions, shops, wellness facilities and of course a series of hotel villas or rooms (Architecture, 2011).

In the following a brief description of the four resorts of the City of Two Seas.

Embedded resort:

Figure 13: Embedded resort (Architecture, 2011)

Figure 14: Sphere impression Embedded resort (Architecture, 2011)

Nautical central hotel:

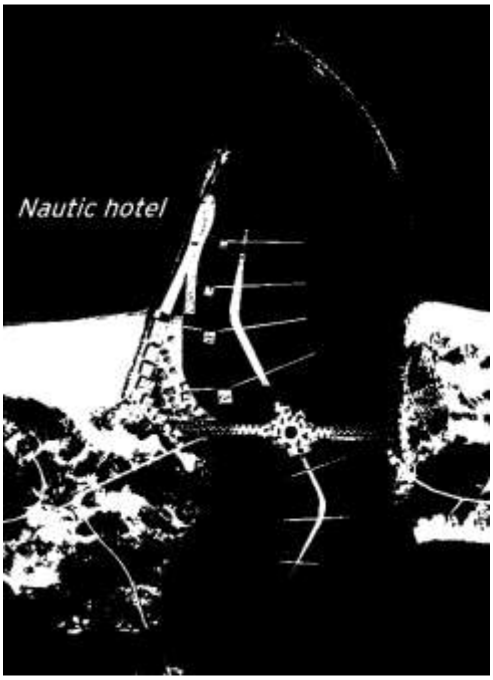


Figure 15: Nautic hotel (Architecture, 2011)

Figure 16: Sphere impression Nautic hotel (Architecture, 2011)

Sea life resort:

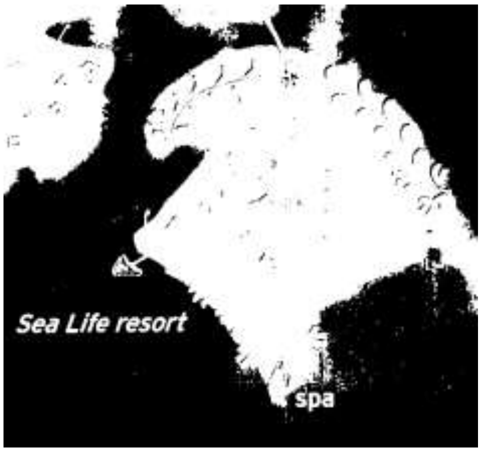


Figure 17: Sea Life resort (Architecture, 2011)

Figure 18: Sphere impression Sea Life resort (Architecture, 2011)

Shell resort:

Figure 19: Sphere impression Shell resort (Architecture, 2011)

Figure 20: Shell resort (Architecture, 2011)

4.3 Energy infrastructure

Because of the sustainable character of this project the energy will not be from fossil resources. The purpose is to implement renewable energy in this project. This research has the purpose to find which renewable energy sources could be interesting in this environment and project. In this paragraph the first design of the energy infrastructure will be discussed. Together with the findings from chapter 3 a few possibilities will be adduced.

One of the purposes is to develop a sustainable environment. This means inter alia that some energy and climate goals have to be defined. These goals can be achieved by matching the energy market to the modern energy infrastructure.
The infrastructure is the system that brings the energy from A to B. In this case from the supplier to the households in Nador. In Nador the energy infrastructure is currently mainly traditional. This means for Nador and environment that the energy is delivered by Office National de l'Electricité (ONE). The sources that are used by producing energy in Morocco are mainly gases and oil. The energy comes to the households via an over ground smart grid. However, by driving through Nador al lot of households have a solar hot water collector on the roofs. The rise of using sustainable energy in the households is already happening in Nador.

Despite the fact that the implementation of renewable energy in Nador, the implementation of renewable energy is still not a standard. The ambitious goal of MarchicaMed with the project of the City of Two Seas is to be first in the environment with a city that will implement renewable energy for 100%.
The reasons for implementing renewable energy in this project is not totally driven by the sustainable view only. The City of Two Seas is developed on a cordon between the Marchica lagoon and Mediterranean Sea. Between the City of Two Seas and the cities Arekman and Nador, there is some distance.

Strategy
For the energy infrastructure a strategy is designed in the master plan for the resorts (*figure 21*). This strategy will be described in this paragraph. This energy infrastructure was the first design, and independent of the research in this report. On the other hand the research is in this report independent to the master plan.
The infrastructure can be divided in four sub-categories. The first category included a passive design, the second category includes energy efficiency, the third category includes renewable energy and the last category includes the smart grid.
Besides the sustainable design some parts will be designed in a traditional way. The most important part is the water supply. This will be brought to the City of Two Seas through pipelines from the nearest city, Arekmane.

Figure 21: Sustainability strategies (Architecture, 2011)

Passive design
The passive design means the design of the buildings which influence the energy consumption of the project, during both construction and use. In the passive design the selection of construction materials is important. The materials that will be used by the construction of the buildings will come in the first place from near the construction site. The walls are made of local desert sand. This material has a high thermal mass and martial porosity to increase the heat purge during the night and potentially aids the evaporative cooling mechanism (Architecture, 2011).
In brief, the thermal mass, night ventilation and small micro tidal waves in the sea and lagoon water will be used for the passive design.

Energy efficiency
The energy consumption will be efficiently designed. In this context efficiency means the reduction of energy used in the buildings and environment. This will be done by

implementing LED to all the light, the equipment in the buildings will be highly efficient and the third way of implement energy efficiency will be done by minimize the cooling solar heat storage by using salt brines.
These integrated aspects will help saving energy and making the project more efficient.

Renewable energy

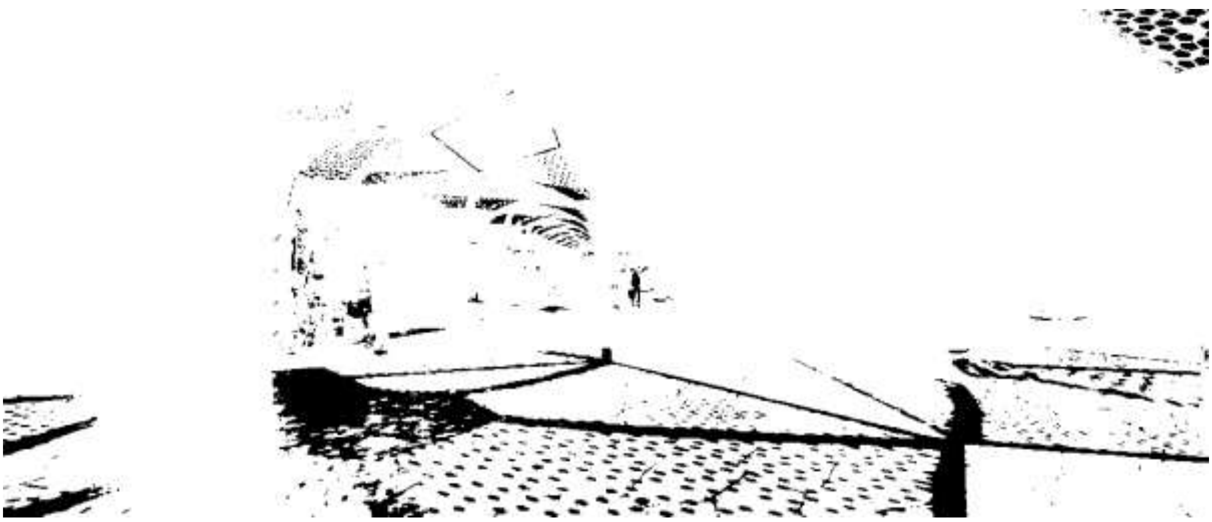


Figure 22: Solar PV panels of parasol structures at the Nautic hotel (Architecture, 2011)

The sources for renewable energy are: solar, wind, hydro, biomass, and geothermal heat. Considering the location of the project most of these sources are largely available. Since the distance between the site and the mainland and the absence of biomass, biomass could not be interesting for this project. The implementation of solar, wind, hydro en geothermal energy could be interesting. In this research an approach of all these renewable energies will be made to find which renewable energies are most interesting and suitable for the City of Two Seas.

Smart grid

In the master plan the smart grid is mainly designed of batteries for energy storage. From this all buildings will be integrated with Solar plus batteries. Thereby the eco-tower will be connected to batteries which will store energy when demand for energy is low and supply is high. However, this solution is very expensive. This research will approach the most suitable combination of renewable energies. The outcome will give potentially a solution where expensive batteries are less necessary.

4.4 Entrance

The Marchica lagoon is connected to the Mediterranean Sea. This entrance is currently moved more to the left side of the cordon (*figure 23*). The reason for this was the condition of the waters of the lagoon. Research found that the circulation of the waters in the lagoon had big influence on the quality of the waters of the lagoon. The original circulation of the waters in the lagoon was not of great quality. Therefore the constructors decided to improve the entrance between the lagoon and the Mediterranean Sea. This resulted in a completely new entrance which improves the circulation and the renewal of the lagoon waters (Dredging, 2014).

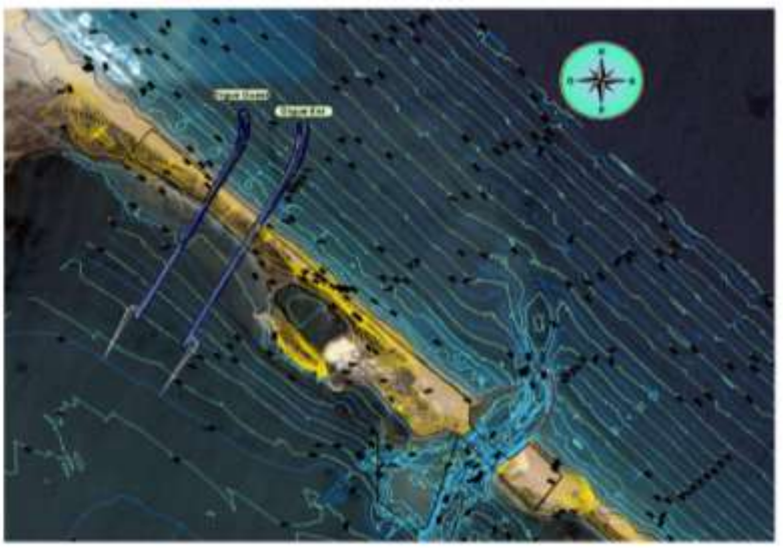


Figure 23: On the left the new entrance and on the right the old entrance

4.5 Conclusions

The City of Two Seas (*figure 12*) reaches a development area of 14.5 ha (MarchicaMed, 2013). The City of Two Seas exist of four resorts with. The net total of the buildings includes about 50 000 square meters. Each resort has its own characteristics and scope but still suits the goals and ambitions of MarchicaMed.

5 ENERGY CONSUMPTION

To know how much energy should be produced each year by the renewable energy resources, the amount of energy is required in the City of Two Seas should be computed.
The computations of the required energy has multiple approaches. The computation method that will be used in this approach is the same as used for the City of Atalayoun. The numbers used for this research have been given by the energy supplier Office National de l'Electricité et de l'Eau Potable (ONEE) in Nador.

5.1 Situation

In principal the resorts of the City of Two Seas are open during the whole year. However, the resort will have some peak months and some months with less visitors. Therefore is the amount of energy needed for in the resort not constant during the whole year. The months April until October will be known as the months of the high season.
During the day here are some peaks too. As seen in figure 24 the consumption of energy in a general hotel room is high during the afternoon and evening.

Figure 24: Energy consumption during the day in a general hotel room

In Morocco the power standards are not equal to the European standards. E.g. in the Netherlands he voltages are between 220V and 240V for domestic and commercial use. The differences with Morocco are minimal. In Morocco the power voltages for domestic use are between 210V en 220V. In commercial use this is 220V constant.

5.2 Computation

The computation for the City of Atalayoun is made for Kilo Volt Ampere (KVA). A more used unit is the kWh. The computation method used for the City of Atalayoun will be used and later be translated to the kWh. This will be done by using the formulas: $P(kW) = S(kVA) \times PF$ and $E(kWh) = P(kW) \times t(hr)$.

The computation can be done per bed or per square meter. By compute per square meter the different functional uses have other resuls. Table 3 gives the values used for the computations.

Space	Value KVA	Value kWh
Hotel per bed	1.61 KVA	1.29 kWh
Villa 250 m2	3.4 KVA	2.72 kWh
Villa 250 – 450 m2	4 KVA	3.2 kWh
Villa 450 m2	6 KVA	4.8 kWh
Public room per m2	0.06 KVA	0.05 kWh

Table 3: Computation values (Consultants, 2010)

Appendix D includes all the computations for the energy demand of the spaces.

5.3 Conclusions

This chapter approaches the amount of energy that will be consumed in the City of Two Seas and therefore should be produced each year. The calculation gives 2200 kWh (*table 4*) that should be produced by the renewable energy sources in order to meet the demand for energy in the City of Two Seas.

City of Two Seas		
Hotel		
Villas		
Main facilities		
TOTAL	**60 000 m2**	**2200 kWh**

Table 4: Total amount of energy demand

The total amount of energy is computed based on the given numbers from ONEE. These numbers indicate an average. However, the average and deviation over the year and day is not constant. In the high season more people are at the resorts and more energy is needed. This makes that the production of energy in the months April until October to be higher than in the other months of the year.

Some differences can be made in these months as well. The consumption during the day is neither constant. Compared to the night and morning is the consumption of energy intensified in the afternoon and evening.

By selecting the renewable energy sources fact that the energy demand is not constant could be taken in to account. Probably some recourses are more intensive and produce more energy in the afternoon and evening. This can be very important by selecting a combination of renewable energy sources.

6 Renewable energy

Renewable energy can be described as any naturally occurring, theoretically inexhaustible source of energy, as biomass, solar, wind, tidal, wave, and hydroelectric power, that is not derived from fossil or nuclear fuel. Renewable energy can have a positive influence on climate change, energy security, and universal access to modern energy services (OECD/IEA, 2011).

Renewable energy technologies are resources that consume primary non-carbon energy resources that are not subject to depletion (Frey, 2002). Renewables energies harm the world in a minimum way. The best known renewable energy resources are solar and wind energy. Geothermal, hydropower and biomass follow these renewable energy resources as well known resources (Karytsas, 2014). Solar energy, as the word says, have the sun as the source. Wind energy, as the word states too, the wind. Hydro energy has streaming waters as sources. The geothermal warmth is the source for geothermal energy. Bio-mass is the source for the last renewable energy form.

Since purpose of the City of Two Seas is to have a sustainable character, it is logical that the energy sources in this project will be renewable. Selecting the potential new energy sources requires that the sources should be: renewable, locally available, and environmentally friendly (Kazem, 2011). This chapter will give a more specific description of the renewable energy resources with potential in this environment of the City of Two Seas. These renewable energy resources are solar energy, wind energy, hydro energy, and geothermal energy. Besides the description of renewable energy sources also a description will be given of a few projects where the implementation of renewable energies was a high success and can be seen as best practice examples. Finally the findings will be presented in a conclusion with i.a. a few suggestions for implementing combinations of renewable energy resources.

6.1 Renewable energy resources

As mentioned before the energy form should fit at least the characteristics of being renewable, should be locally available, and be environmentally friendly. Since the environment is rich of possibilities most of these renewable energies are possible to be implemented in this project. The energy resources that are chosen to analyse during this research are wind energy, solar energy, hydro energy and geothermal energy. These renewable energy resources will be chosen on the basis of the most potential success in this environment.

6.1.1 Solar energy

Since the country has a very high solar potential with more than 3200 hours of sunshine per year, and an average daily isolation of 5 to 5.5 kWh/m2 (Saidi, 2014), the climatic conditions in Morocco are favourable for the development of solar energy due to the abundant sunshine throughout the year. The source solar energy gets the input from the sun, the radiation light hold a certain heat and radiation. This can be used in the implementation of technologies such as solar heating, solar thermal energy, photosynthesis and photovoltaics (OECD/IEA, 2011). The future expectations of solar energy are ambitious. By an efficient and growing implementation of solar energy, solar energy could account for 8 to 15% of global electricity, at the moment this solar energy is good for 3 to 6% of the total demand in Europe. This makes solar energy an important source of renewable energy and its technologies are, as mentioned before, broadly characterized as either passive solar energy or active solar. The difference between active and passive energy depends on the way the technologies capture and distribute solar energy or convert it into (solar) energy. A typical active technology is i.a. photovoltaic systems. More passive is the design of the building with taking in to account the solar possibilities. For example the orientation of the living area on the south for heating these spaces (*table 5*).

6.1.1.1 Resources

The two common and most known solar energy technologies are described below.

Photovoltaic (PV)

Photovoltaic, better known as PV is one of today's most wide spread renewable energy technology system that is connected to the general distribution networks. However, the PV is also suitable to design in off-grid and rural desert areas (Kazem, 2011). The PV plants are characterized by uncertainty in the production, which makes them less competitive in the electrical energy market and limit their further commercial expansion (Ippolito, 2013). Another characteristic of PV is the ability to directly use resources from the sun without concerns for fuel supply or environmental impact. Solar power is produced silently with minimum maintenance, no pollution and no depletion of resources. One of the strengths of PV is cutting the costs of transporting the energy (Stambouli, 2012). The costs of PV systems could be very high (Stambouli, 2012). However, the panels have a life span of 25 years or more, but need some maintenance and periodic cleaning during the life span.

Solar water heating

Another solar energy is heating. Solar water heating is the conversion of sunlight into renewable energy. The system normally used for this conversion is a solar thermal collector. The solar water heating technologies are increasing in the worldwide use.

Solar water heating principal exists of a solar collector with either a tank horizontally mounted immediately above, or a tank below the level of the collectors. The first system is also known as the passive system, and the second system is a variant of an active system. With a passive system, a tank above the collector, the water is heating in a natural way by rising tempeature. With an active system, a tank below the collector, a circulating pump moves water between the tank and the collectors. This kind of systems is designed to deliver hot water during most time of the year. However, in winter sometimes there may not be sufficient hot water. In those cases the traditional way is usually used of water heating. Usually the passive systems are cheaper than the active systems. The maintenance costs of a passive system are less as well.

Characteristics	Solar energy
Costs per kWh	€ 0,13
Life span	25 years
Simple infrastructure	Small distance between the plant and the buildings, easy maintenance, and a direct conversion to useable energy.
Environmental pressure	Between 0 and 0,05 acres of land use per MW, low impact on flora and fauna, life-cycle global warming emissions between 0 and 0.1 (pounds of CO2 per kWh).

Table 5: Characteristics of Solar energy

6.1.2 Wind energy

The wind is also an abundant resource in this coastal region. Wind energy is interesting because of the intensity and the constant character of the source (Frotzsche, 2011). Since wind energy has a high potential it is interesting to check the possibilities for intense renewable energy plant such as wind turbines (Boubaker, 2012).
Since the minor impacts on the environment is wind energy considered as a green power technology (Stambouli, 2012). Wind is more or less a constant, however the velocity is not constant. Since the amount of energy produced by a wind turbine depends primarily on the speed of wind but also on the area swept by the blades and the air density the amount of energy that is produced by a wind turbine is not constant for every wind turbine, and depends on the location of the wind turbine as well (Stambouli, 2012) (*table 6*).

6.1.2.1 Onshore

Onshore wind turbines are high plants with big blades which rotate trough the wind speed. By an intense wind, the rotations per minute are more than by a less intense wind. The intensity of the wind is, besides the shape and measurements of the blades, the determining factor in the amount of energy that can be produced by a wind turbine. By a growing intensity and a bigger blade, the energy production is growing.
The onshore wind turbines are generally around 50 meters high, and are usually situated far from the cities since they make a lot of noise. Also the view is often a called disadvantage.

6.1.2.2 Offshore

The offshore systems have the same principals as the wind energy plants at land. However, related to the plants at land offshore plants some benefits. In general the offshore plants are bigger, up to 85 meters high, than the onshore plants, therefore the plants usually are more expensive. However, offshore noise is the not a problem, and the land less expensive to hire or buy. The life span of an offshore plant is up to 5 years longer. Further the distance between the buildings and the plant in case of the offshore plant is bigger.

Characteristics	Wind energy
Costs per kWh	€ 0.12
Life span	25-30 years
Simple infrastructure	A large distance between the plant and the buildings, difficult maintenance of the plant (few times per year, specific maintenance, difficult to maintain (in the water, underground, high)), energy not direct converted to useable energy, and the renewable energy plant is big.
Environmental pressure	Middle: between 0.05 and 0.10 acres of land use per MW, middle impact on flora and fauna, life-cycle global warming emissions between 0.1 and 0.25 (pounds of CO2 per kWh).

Table 6: Characteristics of Wind energy

6.1.3 Hydro energy

Hydro energy is the energy that comes from the normal flow of water (Kazem, 2011). Hydropower is a mature renewable energy technology which is commercially viable and generates the second largest share of energy from renewable sources. In long term, hydropower stores large amounts of energy. At low cost energy can be adjusted to meet consumer demand making important and significant economic contributions to human development (Stambouli, 2012). The life span of the general hydro plants is around 20 years and can be up to 30 years (*table 7*).

6.1.3.1 Tidal energy

Land constrictions such as straits or inlets can create high velocities at specific sites, which can be captured with the use of turbines. These turbines can be horizontal, vertical, open, or closed. Usually these turbines are placed near the bottom of the water column. The generated energy can be transported from these plants to the energy supplier. In contrast with power plant onshore is the infrastructure for these kind of plants more complex.

6.1.3.2 Rivers

This form of hydro energy includes the speed in a river. The natural flow of a river or stream is used to drive a turbine. When the water passes a dam, the speed could be translated to energy. One of the systems has a lot of in common with wind turbines. The higher the speed and the bigger the blades, the higher the energy production. However, since water is more intense than the wind is a small hydro plant good for equal energy from a wind turbine. However, underwater it is more difficult to do maintenance.

Characteristics	Hydro energy
Costs per kWh	€ 0.08
Life span	20 years
Simple infrastructure	A large distance between the plant and the buildings, difficult maintenance of the plant (few times per year, specific maintenance, difficult to maintain (in the water, underground, high)), energy not direct converted to useable energy, and the renewable energy plant is big.
Environmental pressure	Low: between 0 and 0.05 acres of land use per MW, low impact on flora and fauna, life-cycle global warming emissions between 0 and 0.1 (pounds of CO2 per kWh).

Table 7: Characteristics of Hydro energy

6.1.4 Geothermal energy

Geothermal energy is available when heat emits from within the earth crust. This is mostly in the form of hot water or steam. The hot water can be used directly in district heating, bathing and agriculture. However, the possibility to translate the hot water into renewable energy is an option as well (Kazem, 2011). The best known geothermal systems are hydrothermal, hot dry rock, geo-pressured and magmatic (Barbier, 2002). The hot water is accessed by depth drillings. These geothermal drillings are very expensive and can be even more expensive than onshore oil and gas drillings (Barkaoui, 2013) (*table 8*).

Characteristics	**Geothermal energy**
Costs per kWh	€ 0.05
Life span	20 years
Simple infrastructure	A large distance between the plant and the buildings, difficult maintenance of the plant (few times per year, specific maintenance, difficult to maintain (in the water, underground, high)), energy not direct converted to useable energy, and the renewable energy plant is big.
Environmental pressure	Middle: between 0.05 and 0.10 acres of land use per MW, middle impact on flora and fauna, life-cycle global warming emissions between 0.1 and 0.25 (pounds of CO2 per kWh).

Table 8: Characteristics of Geothermal energy

6.2 Storage of energy

In energy the demand is not constant and also not equal to the supply of energy. The surplus of energy can be stored for a while until the demand of energy is higher than the production. Multiple possibilities for the leftover energy exists. A possibility is to sell the surplus energy to an energy supplier in the region of Nador. Since the monopoly on energy this is not a feasible possibility. Another scenario which is more interesting for the project is to find a way to restore the energy for a while and use the energy when the project need the energy. At the moment there exist a lot of methods to store energy. These methods can be clustered in a few groups. Following the main groups:

- Mechanical storage include i.a. hydroelectricity, pumped-storage hydroelectricity and flywheel energy storage;
- Thermal storage include i.a. thermal energy storage and seasonal thermal energy storage;
- Electrochemical storage include i.a. rechargeable batteries, flow battery and super capacitors;
- Other chemical storage are storage systems based on hydrogen, power to gas method and biofuels.

In this paragraph will be looked for some ways to store the residue energy for a specific term.

6.2.1 Dam

The energy will be transported through big cables to a big lake. The water will be pumped to a higher level. When the energy demand is lower than the energy supply could the water get out the lake. As a result of the stream will produce energy. In this method some energy will be lost. However, in the case of a loss of all energy or a part of it, this storage form is more interesting than loss of all surplus energy.

Morocco has experience with this principle. The best known dam in Morocco is the storage dam of Beni Mellal. In Nador and area this principle is not implemented.

6.2.2 Batteries

Batteries are an electrochemical storage system. Batteries can be placed in buildings and store a specific amount of energy. This energy can be used at a moment when the energy demand is higher than the energy production. By implementing only solar energy in a building batteries are needed. The batteries give the opportunity to store the energy for a short time and use the energy in a later stadium. Besides this kind of low capacity storage can apply for all renewable energy systems.

6.2.3 Underground storage

A well-known form of storage in the Netherlands is underground storage of heat. This principle is that some heat will be pumped with pipelines in the soil at a specific depth. Mostly is this done in the summer months. In the winters, when the heat is needed for warming the buildings or for the warm water, the hot fluids are pumped with another pipeline from below.

6.3 Best practices

This paragraph will give some background information of projects where renewable energy is implemented. These best practices could help in making a choice for combination of renewable energy resources, and also give an idea of the systems that are commonly implemented in other projects.

The most famous zero carbon city is Masdar City in Abu Dhabi. Another zero carbon city is Dongtan in China. Beside these two zero carbon cities, there exist plenty of projects, cities which have a renewable character. In this paragraph the zero carbon project Masdar City would be discussed and the most important characters of a few projects with renewable character will be listed.

6.3.1 Best practices I – Masdar City


Figure 25: Masdar City, Abu Dhabi

Masdar City (*figure 25*) is a new city situated in Abu Dhabi, capital of the United Arab Emirates. The total project covers 6 km2 and will get an investment of € 22 billion. This city will be developed as a carbon neutral, zero waste development. The ambition for the city is to be 100% carbon free. This means i.a. that cars will be not allowed in the city. A smart transport system will be totally functioning by solar energy. Besides this aim, the following goals are settled down for Masdar City:

- Use of sustainable construction material in the building of the city;
- Construction with substantial waste diversion from landfill;
- Low-carbon footprint during operational life of the city;
- Renewable energy powered;
- Significant reduction in construction footprint (Martens, 2011).

The energy will be generated from the following sources:

Shams 1	A 100MW concentrated solar power project.
10MW PV	Masdar City's 10MW solar PV array in Abu Dhabi.
1MW rooftop	Masdar City's 1MW rooftop installations.
100MW PV	100MW photovoltaic plant in Al Ain.
Wind	30MW onshore wind farm on Sir Bani Yas island.

Table 9: Masdar City renewable energy

6.3.2 Renewable energy projects

Table 10 give some findings about other renewable energy projects. To get an impression of the mostly implemented renewable energy resources the table will be short and brief.

Name	Characteristics of the project
Dongtan – China	- Heat and power plant, - Wind, - Solar panels, - Biogas.
BedZEd – UK	- Solar panels on the roof, - Biomass, - Zero-energy.
City of the sun – Netherlands	- Solar panels, - CO2-emission neutral.
UC Davis West Village – US	- Biogas energy system, - Solar photovoltaic system.
Malmö Bo01 – Sweden	- Solar panels, - Solar cells, - Underground thermal mass storage, - Wind turbines, - Water pump for heating and cooling the buildings.
District Vauban – Germany	- Solar photovoltaic system.
Sun island Almere – Netherlands	- Solar panels.

Table 10: Projects with implementation of renewable energy resources

6.4 Conclusions

The characteristics of renewable energy technologies are broad and can be implemented in a plenty different situations. The most important characteristics that could help by the decision making for renewable energy resources is given in table 12, a more detailed description is attached in Appendix E. Since the renewable energy resources have a broad range, ranges are put down with a specific description. All renewable energy resources fit in one of the ranges. The Costs per kWh for hydro and geothermal energy are surprisingly much lower than the Costs per kWh of solar and wind energy. When the Costs per kWh have a high weighing, could this result in a favourability for either hydro or geothermal energy. Chapter 8 will give more information on these characteristics and how they will help by the decision making for a renewable energy form in the City of Two Seas.

Criteria	Range 1	Range 2	Range 3
Costs per kWh	€ 0.05 - € 0.08	€ 0.09 - € 0.12	€ 0.13 - € 0.16
Life span	>20 years	20 – 25 years	25 – 30 years
Simple infrastructure	Class A	Class B	Class C
Environmental pressure	Low	Middle	High

Table 11: Ranges per criteria and the characteristics of the renewable energy resources

The description of the best practices gives an overview of the most implemented renewable energy resources and in which combination. The renewable energy resources of solar energy seems like to be the best to implement in projects. The renewable energy resources hydro, biogas and wind energy are also implemented. However, geothermal energy is not implemented at all in these projects. It seems likely that this kind of renewable energy form is more used in big projects and in general renewable energy generation, and not specific in combination with urban development projects. This should be considered by giving an advice for the implementation of this renewable energy form in the City of Two Seas.

Furthermore it is interesting to look to the possibilities of a combination of multiple renewable energy resources. A energy could make it less necessary to use expensive and low capacity storage methodologies. One combination that is possible is the combination of hydro energy and geothermal energy. Following table give the characteristics of these renewable energies combined.

Characteristics	**Combination of Hydro energy Geothermal energy**
Costs per kWh	€ 0.08 + € 0.05 = € 0.13
Life span	20 years
Simple infrastructure	A large distance between the plant and the buildings, difficult maintenance of the plant (few times per year, specific maintenance, difficult to maintain (in the water, underground, high)), energy not direct converted to useable energy, and the renewable energy plant is big.
Environmental pressure	Middle: between 0.05 and 0.10 acres of land use per MW, middle impact on flora and fauna, life-cycle global warming emissions between 0.1 and 0.25 (pounds of CO_2 per kWh).

Table 12: Characteristics of the combination of Hydro energy and Geothermal energy

Part III – Research Application and Results

7 METHODOLOGY

The literature study is not enough to enable the assessment of the research question. In this research Multi Criteria Analysis (MCA) is the key methodology. Combining weighs with evaluation scores of alternatives is the evaluation method of this research methodology. Analytic Hierarchy Process (AHP) will be used to find the weighs of the selected criteria by asking experts from Morocco in the field of renewable energy to prioritize decision criteria by using pairwise comparisons. The experts have been required to score the sub-criteria and ranges in the same way. Finally, the qualitative dominance scores are used to synthesize the weights and evaluation scores. From these results the alternatives are prioritized regarding the criteria.

This chapter gives the background information and the application description of the Multi Criteria Analysis (MCA) and the Analytic Hierarchy Process (AHP) methodology.

7.1 Multi Criteria Analysis (MCA)

In situations when judgement depends on more than one criterion MCA offers a range of evaluation techniques that assists decision makers. (MCA, 2014) MCA is the umbrella of all kind of decision-making methods using multiple criteria. The MCA method became more popular nowadays in sustainable energy decision making because the distinctive power of MCA method.

The decision making of renewable energy resources in the City of Two Seas is a complex question. For this kind of problems MCA can be used as a tool. The goal of MCA is to help the decision maker to approach the problem by using a specific guideline which helps to achieve the long-term objectives. This guideline helps the decision maker to make the research as effective and efficient as possible, and maintain some measure of consistency (Stewart, 1992). This research approach can be used by a research which includes a number of alternatives, which can be described by its criteria. These criteria can be weighed using a questionnaire. By using the weighs of criteria found, an overall performance can be calculated. From these findings the alternative with the best performance in this situation can be found.

MCA includes three main groups of techniques. The first group is the goal programming and reference point approaches. This group can be characterized by the close interaction between the MCA analyst and a single decision maker. Usually a very large number of alternatives is discussed. The second group includes descriptive methods and outranking methods, these are often used when it is difficult to compare between different performance areas. The last group is the value function approach. This group is the most implemented group and is generally very easy to understand and effective. This group presents a full ranking of alternatives. This is mainly done by normalized and weighed criteria. One alternative will have the highest overall scores, and will be the most preferred alternative (MCA, 2014).

7.2 Analytic Hierarchy Process (AHP)

AHP is a MCA weighing methodology and is a method to derive ratio scales from paired comparisons (Teknomo , 2015). AHP is a structured technique for organizing and analyzing complex decisions. The AHP is developed in the early '70's by Saaty. This methodology became popular throughout a wide field of applications such as government, business, industry, healthcare, education, and construction situations. AHP is a systematic methodology for multi criteria systems and quantitatively treating complex. This method is able to deal with qualitative decision criteria as well as quantitative criteria. AHP can be used to decompose complex problems into simple solvable layers and factors, as well as efficient compare and calculate weighs (Xu, 2011). According to a set of criteria and sub-criteria that are arranged in a hierarchical structure, AHP compares and ranks the alternatives. The comparison is trough natural language and from this the differences between different criteria become visible and will be turned into numerical preference values(Ruiz, 2010), also called ranks.

7.2.1 AHP procedure

The AHP procedure consists of six steps (Wiel, 2011) (Glumac, 2014). Each step has his own purpose, which are described below.
Before the first step of the whole AHP procedure, it is important to make the decision problem clear and identify the problem as well.

Step 1

Decomposition, creating a hierarchy structure of the decision problem and relevant criteria (hierarchy element levels: objective, criteria, sub-criteria and/ or alternatives. Figure 26 shows an example of an hierarchy structure of a decision problem.

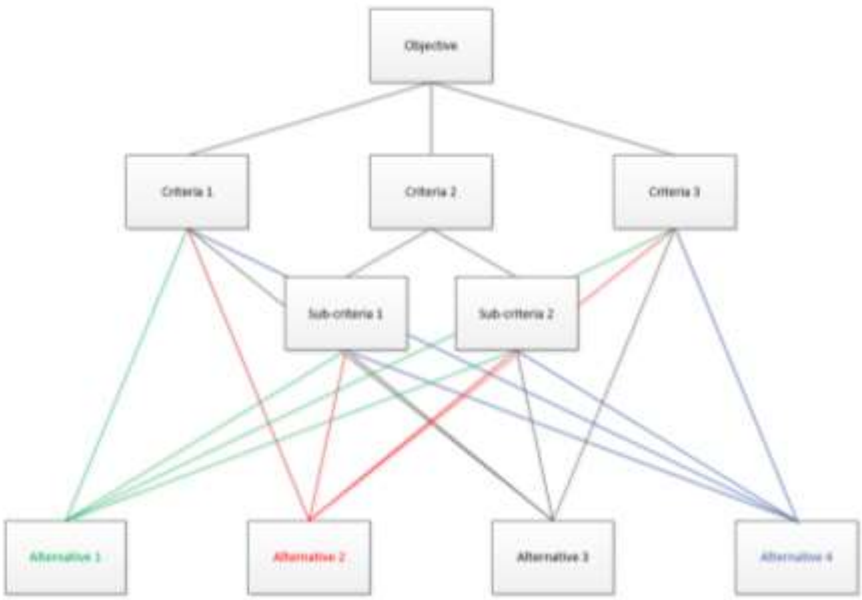


Figure 26: AHP Structure

The factors that influence the decision problem are called criteria. These criteria are located in the level immediately below the objective. The criteria have been formulated using a bottom-up approach. This means that the criteria contain of the information of the already known alternatives. A third layer represents the various ranges of the criteria which relate the criteria direct to the alternatives. Finally, in the bottom level of the hierarchy are the alternatives are located.

Step 2

The criteria are used to label rows and columns of the pairwise matrix, called the comparison matrix. At each level of the hierarchal structure, a pairwise matrix is created according to the corresponding (sub-) criteria. From this the matrixes for paired comparison and measurement of the weights of criteria can be established.

Step 3

The next step is to fill the intersections between them with a numerical preference value. These preferences values can be obtained by stakeholder judgments by means of a questionnaire, and resulting in the establishment of priorities of the alternatives. Usually the questionnaire exists of pair-wise comparisons to perform comparative judgment on the different criteria. The scale implemented to this pair-wise comparison is usually the scale of Saaty, which varies in both directions from least to most important (*figure 27*).

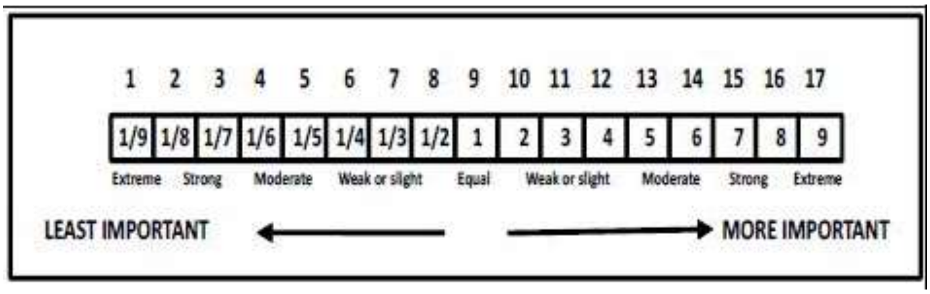


Figure 27: Scale of importance of Saaty

Step 4

The judgments are checked for consistency. Thereafter, the matrixes most significant eigenvector is calculated by normalizing the values of each row. The resulting eigenvector is the principal eigenvector elucidating the relative preferences for each of the alternatives. The alternative with the highest value of the normalized weight indicates the best one.

Step 5

Finally a decision for a specific or multiple alternatives can be made according to the results in step 4. A high score on the criterion has a positive influence and has therefore an increasing or either an decreasing participation rate. In case of positive influence is the participation rate increasing, in case of negative influence the participation rate is decreasing.

7.3 Conclusions

MCA is a good methodology to select criteria, and AHP is a strong methodology to weigh the selected criteria. Together are these methodologies a good combination to rank the renewable energy resources on most favorable according to the experts.

8 APPLICATION TO RESEARCH

Chapter 7 explains how to implement the research method in a specific research. In this chapter the Analytic Hierarchy Process will be applied on the research question to get some results. All the procedures of AHP will be discussed and implemented on the research, in the end the result will be presented.

8.1 Objective

First of all the problem should be understood. When the problem is clear, the goal can be defined and the research can be designed. The goal of this research is to find which combination of renewable energy resources is the most interesting and suitable for the City of Two Seas project. The four renewable energy resources will be compared with each other by the implementation of AHP. The most critical decision out of these tends to be renewable energy selection which if not properly may result in heavy loss for the whole project. This makes the objective of the research as follows: *Which (combination of) renewable energy resources is the most interesting for the City of Two Seas* (*figure 28*).

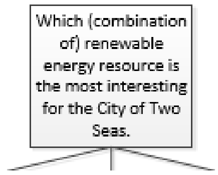


Figure 28: Objective

8.2 Decomposition

To achieve the goal a structure of criteria, sub-criteria, and alternatives is needed. In AHP this is translated in a hierarchy design. This paragraph presents the hierarchy design for the objectives in the goal.
First the alternatives should be defined. In this case there are four alternatives which can be defined as solar energy, wind energy, hydro energy, and geothermal energy (*figure 29*).

Figure 29: Alternatives

8.2.1 Criteria

In order to be in a better position to select the best renewable energy for the City of Two Seas, it is first necessary to identify all key criteria which can impact the decision making for the renewable energy selection. To find these criteria a literature study has been done. There are many references about the suggested criteria for assessing sustainable energy decision-making. From the literature study the following criteria have been found which are suggested to assess a sustainable energy plan. There are four important criteria proposed to measure the energy issue: technical criteria, economic criteria, environmental criteria and lifetime criteria (Wang, 2009). For this research the following three main criteria have been selected: technical, economic and environment.

Quantity does not always give the required quality. In case of the criteria a selection of a few good criteria is helpful for the decision making. For the implementation of AHP three main criteria are a good number to use for decision making (Wang, 2009).

Economic criteria should be one of the most important criteria to be considered by the decision makers (Wang, 2009) (Verbruggen, 2009). Aspects such as manufacturing costs, shipping, installation, maintenance, and environmental costs are essential for certain actors. All these criteria are combined in the cost price per kWh. To make the research simple and clear it is good to stick on *the more is not better* principle. Therefore is chosen for overall criteria instead of multiple sub-criteria (*figure 30*). Since MarchicaMed the supplier and the consumer is, are these costs the costs for producing the energy and the costs that should be paid by MarchicaMed.

The second main criteria is technical criteria, these criteria include life time. One of the technical criteria was considered for this research is reliability. Reliability of energy systems may be defined to the capacity of a device or system to perform as designed; the resistance to failure of a device or system; the ability of a device or system to perform a required function under stated conditions for a specified period of time; or the ability of something to 'fail well' (fail without catastrophic consequences) (Wang, 2009). These criteria also mean how the energy plant will suit the local situations, in this case the City of Two Seas. Therefore, the geographical suitability should be emphasized regarding the ability of the new energy plant to perform in the future and how the new energy plant suit the climate as well.

Environmental criteria are important aspects to be considered, especially since the establishment of environmental impact assessment (Wang, 2009) (MarchicaMed, 2014). Certain pollution that affects the quality of life, as the residue of the energy plant must be considered before the decision is made. The most important aspects to be considered are noise, air quality and the impact towards the habitat of local flora and fauna.

Figure 30: Criteria

8.2.2 Sub-criteria

In this research not a lot of sub-criteria have been implemented. Criteria may not apply uniformly, but may have graded differences. Little sweetness is enjoyable but too much sweetness can be harmful for people (Mansoor, 2015). Therefore the criteria sets are limited to a few relevant criteria.

The main criteria present and include the most important criteria. For the criteria reliability two sub-criteria are designed (*figure 31*). Namely, life span and simple infrastructure. Life span can be defined as the average expected period of use in service in years. The simple infrastructure includes the design of the energy system and the of complexity of the design.

Figure 31: Sub-criteria

8.2.3 Ranges of (sub) criteria

All criteria and sub-criteria have three ranges of (sub) criteria. These ranges of the (sub) criteria exist of ranges which are defined based on the characteristics of the four alternatives: solar energy, wind energy, hydro energy, and geothermal energy.

The ranges of Costs per kWh for example has three ranges. These ranges are shown in figure 32. In the description of the renewable energy resources in chapter 6 is the following found. The cost per kW/h for solar energy has an average of € 0.13, for off-shore wind energy is this € 0.12, hydro energy € 0.08 and geothermal energy € 0.05. The range for these renewable energy resources is € 0.05 – € 0.13. To include these ranges in three intervals is chosen for the three intervals: € 0.05 – € 0.08, € 0.09 – € 0.12, and € 0.13 – € 0.16.

This principle is implemented for the criteria life span too. For the other two criteria descriptions are made which include different levels of ranges.

The ranges of (sub) criteria include de characteristics of the four renewable energy resources. Table 13 present the meaning of the different ranges in the criteria.

Criteria	**Range 1**	**Range 2**	**Range 3**
Costs per kWh	1 kWh costs between 5 and 8 euro cents.	1 kWh costs between 9 and 12 euro cents.	1 kWh costs between 13 and 16 euro cents.
Life span	A life span less than 20 years.	A life span between 20 and 25 years.	A life span between 25 and 30 years.
Simple infrastructure	Small distance between the plant and the buildings, easy maintenance, and a direct conversion to useable energy.	A large distance between the plant and the buildings, difficult maintenance of the plant (few times per year, specific maintenance, difficult to maintain (in the water, underground, high)), energy not direct converted to useable energy, and the renewable energy plant is big.	In order to gain renewable energy other sources (coal, oil, etc.) are needed. The new infrastructure is linked to the old infrastructure.
Environmental pressure	Low: between 0 and 0.05 acres of land use per MW, low impact on flora and fauna, life-cycle global warming emissions between 0 and 0.1 (pounds of CO2 per kWh).	Middle: between 0.05 and 0.10 acres of land use per MW, middle impact on flora and fauna, life-cycle global warming emissions between 0.1 and 0.25 (pounds of CO2 per kWh).	High: 0.10< acres of land use per MW, high impact on flora and fauna, life-cycle global warming emissions 0.25< (pounds of CO2 per kWh).

Table 13: The ranges of the (sub) criteria

The design in the hierarchy is as follows in figure 32.

Figure 32: Ranges of (sub) criteria

8.2.4 Hierarchy

The hierarchy exists of three hierarchy levels (Aker, 2013). The first hierarchy level has a single objective. The priority value is assumed to be equal to unity (Saaty, 1986). The second hierarchy level has three (main) criteria and the third level one (main) criterion has two sub-criteria. The priorities of these levels are derived from a matrix of pairwise comparisons with respect to the objective of the first level, and for the sub-criteria to the second level (Saaty, 1986). The fourth hierarchy level sets the ranges of (sub) criteria. The object is to determine the impact of the sub-criteria on the decision making through the intermediate second level. Thus their priorities with respect to each objective in the second level are obtained from a pairwise comparison matrix. The resulting three priority vectors are then weighed by the priority vector of the second level to obtain the desired composite vector of priorities of the renewable energy resources (Saaty, 1986).

Figure 33 presents the whole hierarchy design.

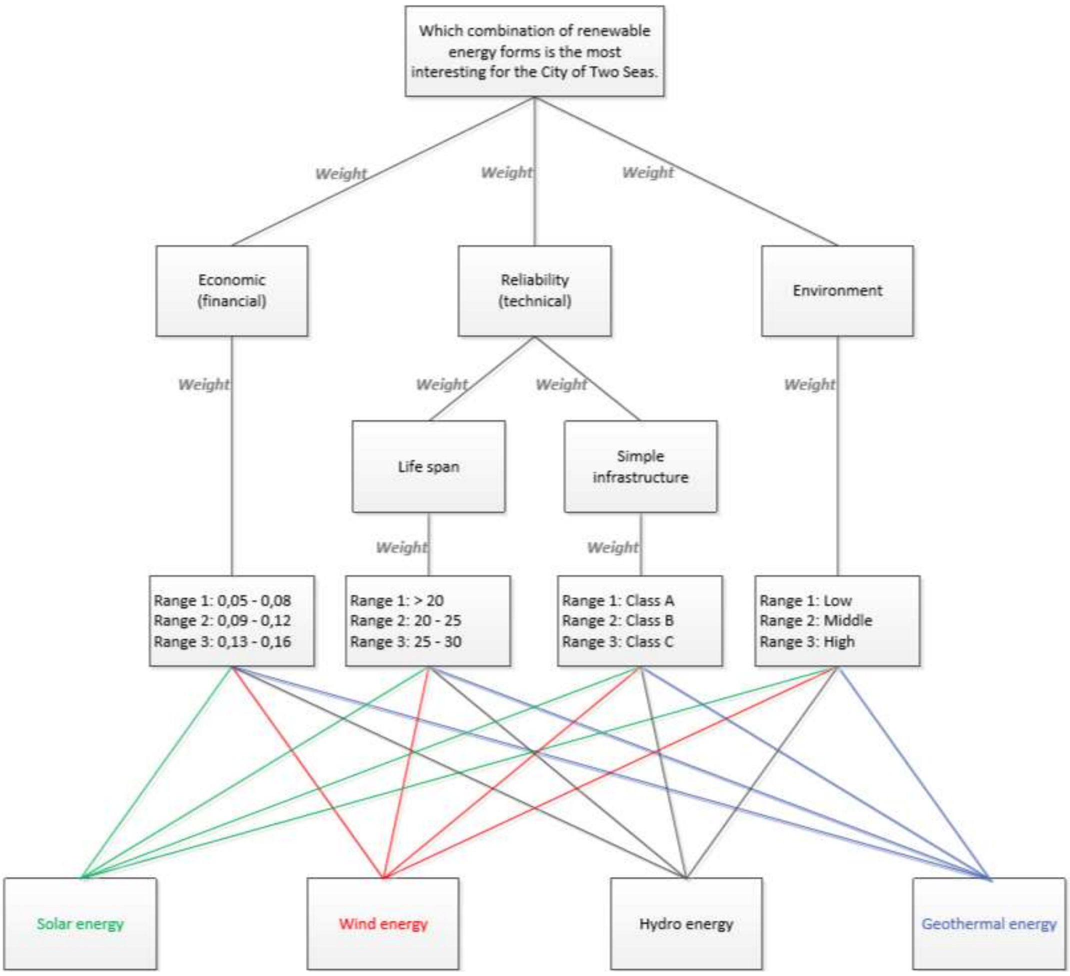


Figure 33: AHP Hierarchy design

8.3 Comparison matrix

The comparison in AHP is pairwise-comparison. The question that is asked is: *Which of the criteria is more important for the decision making, and how much more important in comparison with the other criteria?*. The experts score the criteria on the grade of importance. In these results it can be seen that the expert thinks that the criteria Costs per kWh is moderately more important than the criteria Environmental pressure. The expert also has this opinion for the comparison of Costs per kWh and Reliability. The criterion Environmental pressure and Reliability are in the opinion of the expert equally important(*figure 34*).

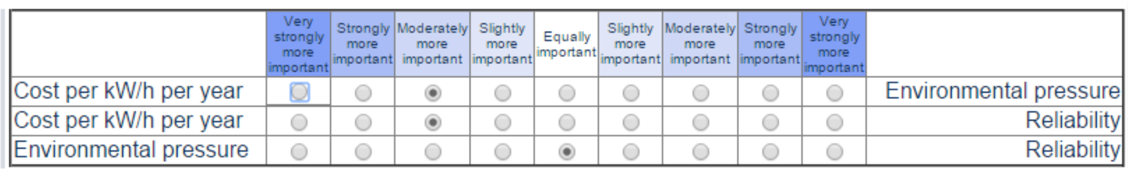


Figure 34: Comparison matrix main criteria

8.4 Pair-wise comparison

Table 14 shows the numeric rating of the rate of importance also known as the pairwise comparison scale (Wiel, 2011). The numeric rating can be used by weighing the different criteria. From the comparison can found that one criteria is more important than the other criteria. The numeric rating in that case is dominant and includes the whole numbers 3, 5, 7, and 9. When the criteria are equal to each other, is the scale 1. In order of dependence of importance, the numbers are reciprocal 1/3, 1/5, 1/7, and 1/9. 3 and 1/3, and so on are each other's reciprocal. The higher the number, the bigger the rate of importance assigned to the other criterion (*table 14*).

Intensity of importance	**Definition**	**Explanation**	**Numeric rating**	**Reciprocal**
			Dominant	Dependent
1	Two aspects contribute equally to the objective.	Equal	1	1
3	Experience and judgment slightly favour one aspect over another.	Weak or slight	3	1/3 (0.33)
5	Experience and judgment moderately favour one aspect over another.	Moderate	5	1/5 (0.2)
7	Experience and judgment strongly favour one aspect over another.	Strong	7	1/7 (0.143)
9	As aspect is favoured very strongly over another.	Very strong	9	1/9 (0.11)

Table 14: Pairwise comparison scale (Wiel, 2011)

8.4.1 Questionnaire

The purpose with this questionnaire is to weigh the selected criteria for the decision making in this research. The main question is therefore *Which of the criteria is more important in the decision making, and how much more important in comparison with the other criteria?*. Appendix F includes the questionnaire.
First the main criteria will be compared. Secondly the sub-criteria will be compared, and finally the ranges of the characteristics of the renewable energies will be compared with each other. All data can be used by weighing the criteria and the ranges of the characteristics.

8.4.2 Data collection

The data collection has been done through an online questionnaire. The questionnaire has been constructed using *Berg Enquête System 2007*. This is a digital survey tool developed by Eindhoven University of Technology. This questionnaire has been sent to experts in the field of renewable energy. The scope of the research was Morocco, Moroccan experts with experience in one or more in this research investigated renewable energy resources in Morocco are the experts examined. The experience of the expert lies mainly in renewable energies. Thereby some experts have experience in the field of urban development as well.

How the data found

Most experts have been invited to participate in this research by email. The first group of these experts, were contacted during the research period in Morocco. A second group consists of people who has written an article about renewable energies and Morocco. The experience taught that the second group of people were very helpful. They shared names and contact information of people which could participate in the research. A third group of experts has been contacted via LinkedIn. These are people who work in the renewable energy field in Morocco.

8.4.2.1 Respondent characteristics

Descriptive statistics

The experts have been asked three personal questions:

- How many years of experience do you have with renewable energies?
- How many years of experience do you have in urban development?
- How many years of experience do you have outside Morocco?

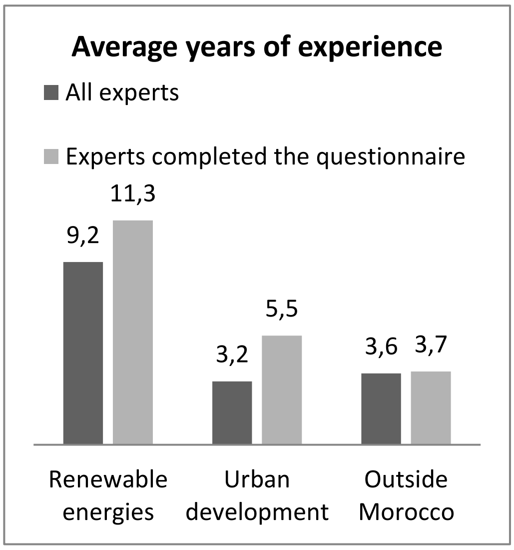


Figure 35: Descriptive statistics

Figure 1 presents the average outcomes of the answers of the asked questionnaires. As the figure shows the average experience with renewable energies in general is much higher than the experience in urban development. The experts have high positions and experience in diverse commercial fields.

Which period and how many people

The questionnaire has been sent on May 6th, 2015. In the following graph per day the response of the questionnaire. The first line presents the amount of people who opened the questionnaire. The second line presents the amount of completed questionnaires. The third line presents the amount of not totally completed questionnaires. The questionnaires not completed all were completed until question three.

Appendix G shows that the first days the people who opened the questionnaire was significantly higher in the beginning. After sending a reminder on May 18th, 2015 a few experts opened the questionnaire. However, just one expert completed the questionnaire.

With a total of 39 experts, 26 started the questionnaire, from which 12 completed the questionnaire. All people who completed the questionnaire are interested to receive a summary of the total research.

8.5 Data quality

Criteria weighs influence the decision-making results of energy plant's alternative. Generally there are two weighing methods: equal weighing method and rank-order method. Rank-order method such as AHP is getting more popular because of its simplicity and understandability in application. Besides, equal weigh tends to relatively ignore the importance of some criteria. In this research, the weigh decided based on questionnaire results that have been filled by experts, the three criteria can be defined by which one is more favorable according to their expertise. Therefore, subjective weighing methods were used in this research.

8.5.1 Normalisation

To weigh the criteria, the option is to derive these weighs from ranks. This is done by ranking first the criteria by implementing pairwise comparison. After the collection of the rank numbers (data), the weigh can be computed from this order by normalising the rank numbers. Normalisation means dividing the raw weights by their total sum, and assures the weighs are between 0 and 1.

For example the normalisation of the main criteria (*table 15*).

After this comparison are these results presented as followed in table 15.

	C1 Costs per kWh	C2 Reliability	C3 Environment
C1 Costs per kWh	1	5.17	2.56
C2 Reliability	0.19	1	0.97
C3 Environment	0.39	1.030928	1
	1.584049	7.200928	4.53

Table 15: Reciprocal Matrix main criteria

The boxes with the same criteria have always the value 1. The value of the other boxes depends on the outcomes from the pairwise comparison. In the comparison of Costs per kWh with Reliability for example. Costs per kWh is more important with a value 5.17 on the scale. In table 15 the number 5.17 is given in the box that refers to dominance of Costs per kWh according to Reliability. In the box which refers to the dominance of Reliability according to Costs per kWh the value 1/5.17 is entered. This gives the relation between the two criteria.

As mentioned in chapter 7 the calculation of the eigenvector will be implemented to find the results. The technique to do this is by squaring the reciprocal matrix. This means that the each box in the matrix should be divided by the total of the column. For example the first box: 1 / 1.584049 = 0.631294. Table 16 presents the matrix with all the outcomes of the main criteria.

	C1 Costs per kWh	C2 Reliability	C3 Environment	Eigenvector (EV)
C1 Costs per kWh	0.631294	0.717963	0.565121	1.914378
C2 Reliability	0.12	0.14	0.21	0.475106
C3 Environment	0.25	0.14	0.22	0.610516
Total	1	1	1	3

Table 16: Calculation of the eigenvector (EV)

The normalization of the eigenvector (NEV) is implementing the formula:

(1 / total EV) * EV criteria.

(1 / 3) * 1.914378 = 0.638126

This results in the following NEV of each criteria (*table 17*).

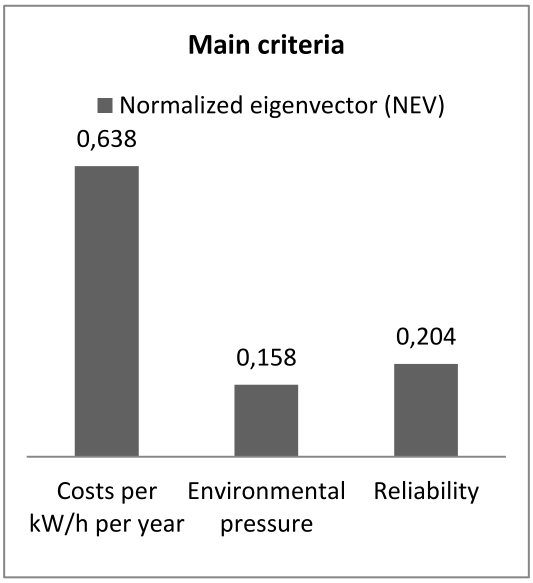
	Normalized eigenvector (NEV)
C1 Costs per kWh	0.638126
C2 Reliability	0.158369
C3 Environment	0.203505
Total	1

Table 17: Normalization EV

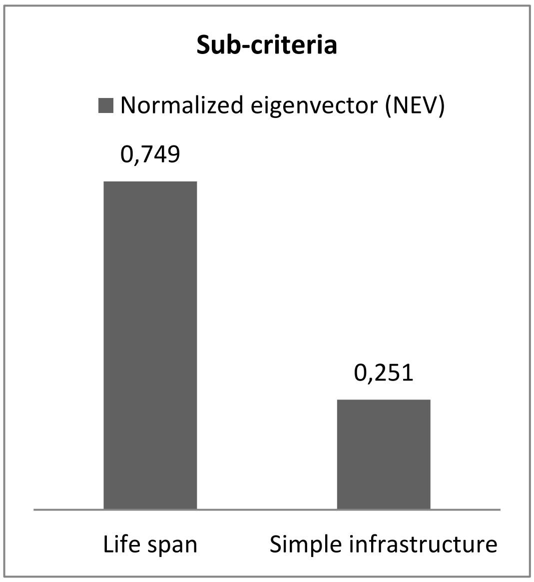
With this calculation the eigenvector is calculated, and from this the weighing has been done. The criteria with the highest value of the normalized weigh indicates the highest ranked alternative (Srdjevic, 2013). For the main criteria is the Costs per kWh, according to the experts, significantly more important than the other two main criteria. In Appendix H are all the computations included.

Main results

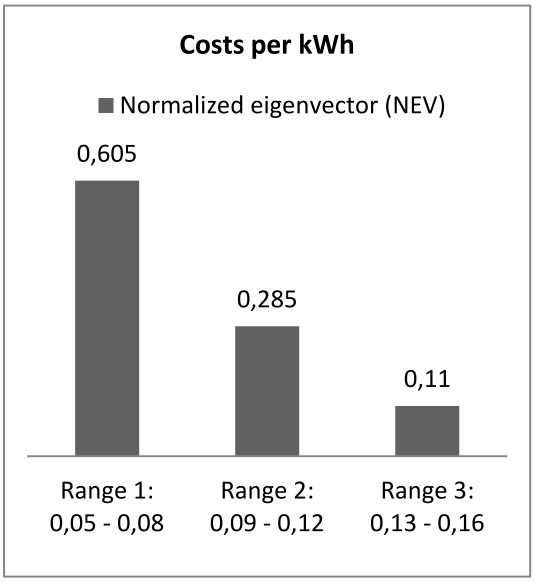
This paragraph presents the results of the questionnaire. This will be done at each hierarchy level. Firstly the results of the main criteria will be presented, followed by the sub-criteria and finally the ranges of the (sub) criteria.



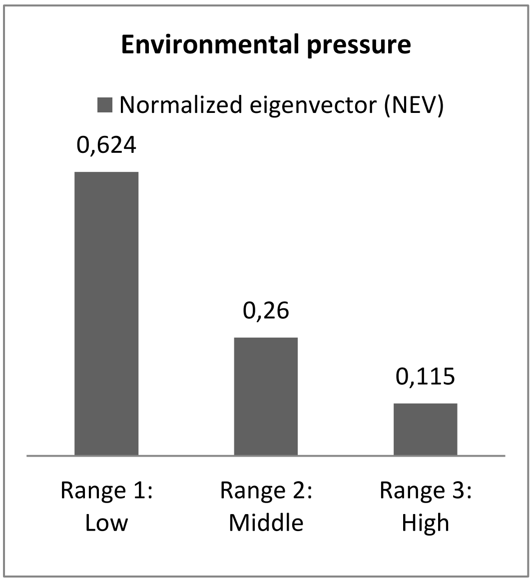
The division of the Main criteria is as shown in the figure. The first column stands for the financial criteria: Costs per kWh. Since this is the highest value, 0.638, this aspect is most important in the decision making according the experts in the renewable energy branch. The difference between the financial criteria and the other criteria is significantly bigger than the other two main criteria. With 0.204 is Reliability the second important criteria according to the experts. Environmental pressure is least important of these criteria with a NEV of 0.158.



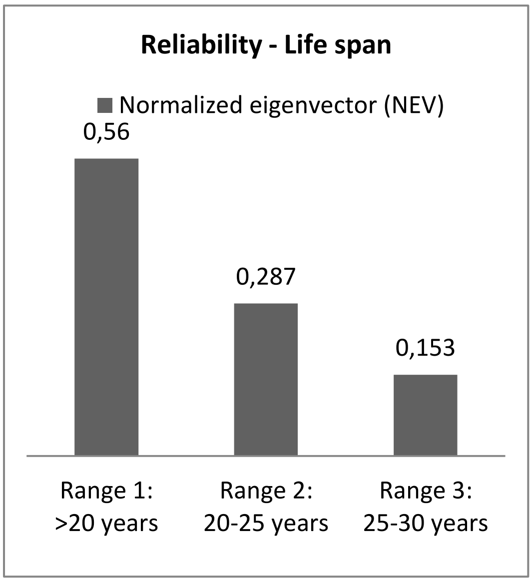
Reliability has two sub-criteria. These two sub-criteria are weighed too. As shown in the figure according to the experts in the field of renewable energies Life span, with an NEV of 0.749, significantly is more important than Simple infrastructure, with an NEV of 0.251, by the decision making.



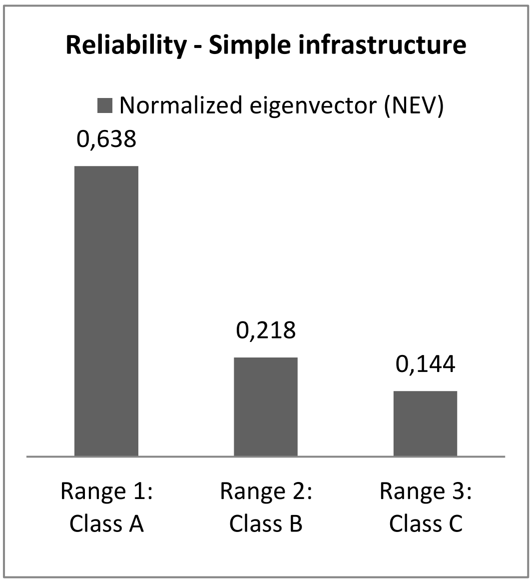
The third level includes the ranges of the (sub) criteria. All these criteria have three ranges. When it comes to the Costs per kWh it is obvious that the smallest range. As shown in the figure is the smallest range € 0.05-€ 0.08, with an NEV of 0.605, the most favourable according to the experts. Followed by the range € 0.09-€ 0.012, with a NEV of 0.285, and as least the range € 0.13-€ 0.16 with a NEV of 0.11.



The second set of ranges of the (sub) criteria is Environmental pressure. The ranges of there criteria are described in chapter 6. The range Low, is the least harmful for the environment, and the range High the most. The range Low is, with an NEV of 0.624, most favourable according the experts. With a NEV of 0.26 is Middle secondly favourable and as least the range High with a NEV of 0.115. The range High is least favourable according to the experts. The difference between the range High and the other two ranges is larger than the other two ranges.



The first set of ranges of the sub-criteria of Reliability are the ranges of the Life span. Not logical is a shorter Life span, according to the experts, more favourable. A Life span less than 20 years is most favourable with a NEV of 0.56. A Life span between 20 and 25 years is secondly favourable with a NEV of 0.287. Least favourable is the largest Life span with a range between 25 and 30 years and a NEV pf 0.153.



The last set of ranges of the sub-criteria are the ranges of sub-criteria of Reliability. The ranges are defined by Classes A until C. A is the most simple infrastructure, and C the most complicated infrastructure. According to the experts is the Simple infrastructure with Class A most significantly favourable with a NEV of 0.638. Secondly is Class B most favourable with a NEV of 0.218. Least favourable is Class C, with a small difference with Class B, with a NEV of 0.144.

8.5.2 Consistency analysis

After the normalization a consistency analysis should be done. AHP allow some small inconsistency in judgement. This is because human can never be always consistent. The ratio scales are derived from the principal Eigenvectors and the consistency index is derived from the principal Eigenvalue (Teknomo , 2015).

The quality of the data was determined by implementing the consistency check. The formula used for the consistency check is: CI/RI.

$$CI = \frac{\lambda \max - n}{n - 1}$$

	Computations
ƛmax	3.0731
n	3
Consistency Index (CI)	0.03655
Random Consistency Check (RI)	0.58
Check	0.06 (6%)

Table 18: Consistency check

From this consistency check it can be concluded that main criteria pass the check. The outcome of the consistency analysis should be smaller than 10%. From the calculations (Appendix H – computations) are the following consistencies found *(table 19)*:

Variable	**Consistency analysis**
Main criteria	6%
Sub-criteria	n.a.
Ranges of (sub) criteria: Costs per kWh	22%
Ranges of (sub) criteria: Environmental pressure	31%
Ranges of (sub) criteria: Reliability – Life span	16%
Ranges of (sub) criteria: Reliability – Simple	36%

Table 19: Consistency check

As table 19 shows, are the main criteria consistent. The sub-criteria are not consistent. The reason therefore is the RI. For the number of 2 criteria is the RI 0. Dividing by 0 is not possible and gives an error.

All the ranges are inconsistent. This is possibly caused by the selected interval definitions for the ranges.

8.6 Conclusions

How favourable each alternative, renewable energy form, is can now be calculated.

By compute all the alternatives, are the following outcomes follows (*table 20*):

Alternative:	**Solar**	**Wind**	**Hydro**	**Geothermal**	**Hydro and Geothermal**
Total:	0.17511	0.25745	0.57752	0.52001	0.2042
Normalized total:	0.10097	0.14845	0.333	0.29984	0.11774
Rank:	5	3	1	2	4

Table 20: Rank of the alternatives

From the results of the questionnaire and the calculation it can be said that hydro energy is most favourable. With geothermal energy in second place, and wind energy third. As fourth is a combination of hydro energy and geothermal energy favourable. Least favourable is solar energy.

PART IV – CONCLUSIONS AND DISCUSSION

9 Conclusions and Discussion

9.1 Conclusions

Since many years renewable energies have been implemented in urban development projects. The decision making for the choice between resources have been done in different ways. In this research the knowledge of experts with an average of 11.5 years' experience in renewable energies is used. Multi Criteria Analysis is used to select the criteria, Analytic Hierarchy Process is used to weigh the technical and financial criteria. With this methodology it has been found which renewable energy source or a combination of sources is most favourable for the case: the City of Two Seas. The forecast of this research and preference of MarchicaMed gives solar energy as most favourable. In reference projects isolar energy is implemented most in projects as well.

The City of Two Seas is a new touristic city in the North-Eastern part of Morocco. This city is designed on basis of the Six Senses Strategy, which include activities that are associated with providing accommodations, dining, excursions, wellness, sports and aquatic activities.
The location of Nador near the Mediterranean Sea and the presence of water streams, amount of sunshine hours, violence, and geothermal heat give opportunities for renewable energies. The renewable energies that are most interesting for this area are therefore the renewable energies solar, wind, hydro, and geothermal. These renewable energies have been compared on different criteria. The selection of the criteria has been done by implementing popular MCA decision making tool. The selected criteria are Costs per kWh, Environmental pressure, Life span, and Simple infrastructure. These criteria have been found and suggested to assess a sustainable energy plan. AHP is used for the weighing of the criteria. The weighed criteria influence the favourability of the renewable energies. The weighs are conducted by experts who participated in an online questionnaire.

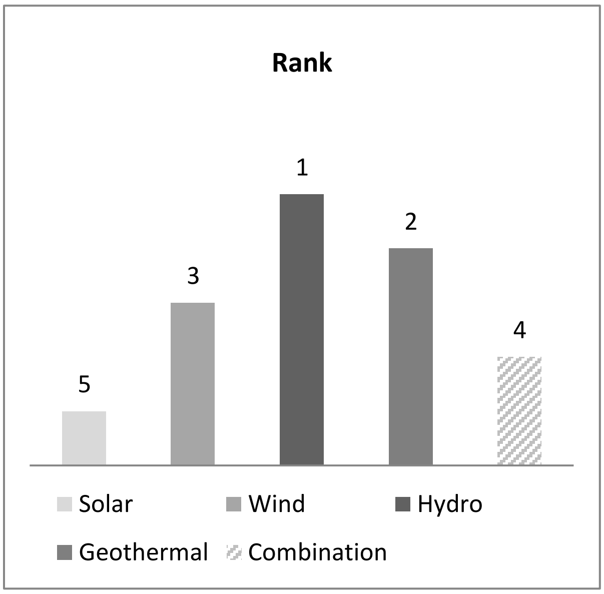


Figure 36: Rank of the renewable energies

According to the experts the criteria Costs per kWh is significantly more important than the other criteria. That determines the rank of the renewable energies highly. The criterion with the lowest Costs per kWh are therefore most favourable. The criterion Environmental pressure has the lowest weight, and therefore this criterion is least important in decision making. Reliability has got a low weight as well. Solar and wind energy score in contrast to the criterion Costs per kWh favourable in these two criteria. Despite of favourable scores in two out three criteria these renewable energies

are nevertheless least favourable. Remarkable is that most favourable renewable energies, hydro and geothermal energy, are not favourable when they are combined.
In this research the most favourable renewable energy resource for North-Eastern of Morocco and therefore for the City of Two Seas is studied. From this research it can be concluded that hydro energy is most favourable. The stream between the Marchica lagoon and Mediterranean Sea is permanent and therefore is the production of renewable energy by implementation of hydro energy always potential. In economic terms for MarchicaMed it is interesting to consider the implementation of hydro energy in the City of Two Seas. Since the ambition of MarchicaMed is to be sustainable and durable, it suits the image of MarchicaMed well to consider the implementation of hydro energy as well.

This research shows that the implementation of MCA and AHP is a good tool in decision making in renewable energies. The use of MCA and AHP, with input from appropriated experts, facilitates the decision making of renewable energies in urban development.

9.2 Discussion

The world population grows fastly, the demand of energy is growing even more. With the knowledge of exhausting fossil energies within about fifty years it is wise to look now for possibilities to postpone the exhausting of the fossil energies, and alternative inexhaustible resources which can be used as a source for the longer term. An additional advantage of using alternatives for fossil resources is the reduction of carbon emissions. Some alternatives exists at the moment, however this is still not always implemented in construction projects globally. Especially not in leisure projects. With this research renewable energies get a platform. This platform could contribute to convince and inspire decision makers to implement renewable energies in construction projects, and especially in leisure.

Decision making is for every construction project a challenge. The way of selection of the decision criteria in this research with the use of MCA could be seen as a starting point that can be used in other similar projects. This project as a reference, and the criteria and model as a template, this research can contribute faster decision making in renewable energies in other urban development projects. In that way this research contributes to the awareness of possibilities to take renewable energies as possible resources in urban development with a leisure character. Furthermore conduct this research that AHP is a methodology that is able to help decision makers by finding an optimal solution in construction projects, and especially projects related to renewable energies and urban development.

The contribution of this research to MarchicaMed is two folded. First the tunnel vision of having solar energy as most favourable and usually as most interesting called renewable energy gets discussed. This broadens the view of MarchicaMed with a new viewpoint about renewable energies in the first place, and in the second place the question *WHY* solar energy is favourable will be asked and discussed. Secondly this research provides a new way of decision making in construction projects. In this research AHP is used in the topic renewable energies. However, this methodology could be generalised and used in other decision making processes within MarchicaMed as well. Overall this research contributes to an open discussion about the existing way of decision making and also important the preferred choice for solar energy as source.

The forecast of this research and preference of MarchicaMed gives solar energy as most favourable. In reference projects solar energy is most implemented in projects as well. In contrast to this, the results in this research show that solar energy is least favourable. By starting the research the expectation was that solar energy could be favourable. Since the permanent character and opportunities of geothermal energy this was a potential favourable renewable energy source. During the research it was found that geothermal and hydro energy were the most economical renewable energy sources. However, during the research it was not directly clear that this would be decisive for the most preferable energy sources. According to the experts hydro energy is most favourable. This outcome was not totally expected since hydro energy has not been implemented as an energy resource in the reference projects.

The restrictions of this research are related to the model in the first place. Firstly the selection of the criteria was very hard to do. The selection of criteria is the same for all projects and depends on the viewpoint of the decision maker. Therefore this research is not for all projects directly useable. However, the selected criteria have been found in literature as very important decision criteria. Secondly it was not possible to do the consistency check for the sub criteria. Furthermore the results of the consistency check of the ranges haven not all been satisfied. This indicates that the ranges were not selected well enough. The selection of the ranges should be done in a proper way. This will minimize the errors in the consistency check. At least the limitations are related to the experts. The experts have huge influence in the outcomes of the results. In this research the experts were limited and did not come from the company itself but from several Moroccan companies. More expert would give more results. Thereby could MarchicaMed have another view on the different criteria and have other weighing of the criteria as a result.

9.3 Recommendations

The restrictions of this research give opportunities for further research. Following some researchers it the model can be improved: e.g.,

- Twelve experts participated in this research. The more experts participate in the research, the more significant the outcomes of the research will be. Simulate this model with at least 30 experts will influence the outcome.

- Simulate this model in the company. The decision makers within the company should answer the questionnaire. These results could be compared to the outcomes of this research. It is interesting to find if the way of thinking of the experts in the broad field are in line with the decision makers in MarchicaMed.
- It is clear that the criteria Costs per kWh is very important in decision making. it could be interesting to select a few criteria without the economic criteria and simulate this model. This could give other outcomes for the criteria and other findings which will influence the results as well. Use only the criterion Costs per kWh for the decision making is an option as well. From this could the different costs be defined for the renewable energies and weighed. This could result in new, other results.
- With the consistency check it is found that the ranges were not set in a proper way. System Dynamics could be used for simulate as a tool to find the criteria with most influence. Set new ranges and find new data with those ranges could give better outcomes in the consistency check.
- Instead of a 9-points scale, implementation of a 3-points scale. The decision maker indicates in this way only whether a criterion is more, less or equally important to another criterion.
- Implementation of MCA in combination with AHP could be implemented in other decision making processes within MarchicaMed. Implement this way of decision making could help MarchicaMed in complex processes.
- This research is done in the North-Eastern part of Morocco. Construction and urban development projects are globally conducted. It could be interesting to implement this model on other projects in similar areas elsewhere, around the Mediterranean Sea.

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APPENDIXES

Appendix A – Master plan of City of Two Seas

The City of Atalayoun and the Atalayoun Golf Resort (La Cité d'Atalayoun)

The first project of MarchcaMed is the City of Atalayoun. This project is a touristic resort of international class with the possibility to exercise many leisure activities such as golf, sailing, and boating in a unique natural environment. Beside these leisure activities, the site is enriched with hotels, villas, ryads, apartments, offices and shops.

The City of Atalayoun is designed according to the principles of ecological development. In this project, there the priority was given to renewable energy, providing plenty of room for wind and solar energy use. Recycling of waste water in irrigation water has been applied and the use of local rock helped minimize external inputs (MarchicaMed, 2007).

The City of Two Seas (La Cité des deux Mers)

The name of this city indicates the location of this project. This project will be built on the dunes of the lagoon, near the channel between the lagoon and the Mediterranean Sea. The project, spread over an area of hundreds of hectares, includes the construction of tourist accommodation, hotels as well as two marinas. This project, located on a natural dam made of dunes extending 25 km, the City of Two Seas serves as a gateway to the Mediterranean, while preserving the intimate and quiet atmosphere of the lagoon. This project allows the Marchica opening to the outside world, and visitors to enter the Marchica lagoon and Morocco (MarchicaMed, 2007).

The project has a few sustainable aspects in the master plan. The buildings are located far from each other. This makes the building intensity not large. The architecture of the buildings is very natural and fits this area and becomes one with nature. In this way the affection of the natural view and environment will be limited. The typology for the hotel villas is based on the ancient typology of houses in the Rif region mountains. The outer walls of the structures are proposed to be made from the local sandstone with the traditional masonry alternating bigger and smaller stones (Architecture, 2011). Through this way of design the buildings are the traditional dwellings in the Rif in the summer able to maintain sufficient coolness and keep the heat inside in the cold winters.

The Fishermen's Village (Le Village des Pêcheurs)

This new village is one of the villages designed at the cordon. This city includes a unique type of housing facing the sea. The dwellings create the authentic atmosphere of the world of fishing and other aqua activities. The development should start in 2014 and should be completed in 2018. However, this aim was too ambitious and incurs now a delay of a few years (MarchicaMed, 2007).

Flamingos Bay (La Baie des Flamants)

The Flamingos Bay also has its own character. This city is focused on accommodation, facilities, and services, and offers a wide range of activities in the lagoon, sea, boating and golf tourism. The development was meant to start in 2015. However, like some of the other cities this project delayed for a couple of years as well (MarchicaMed, 2007).

Marchica Sport

As the name suggests this city will be in the theme of sports. The site will be equipped with modern facilities available for professional and amateur sports disciplines as well. The project should be launched from 2017. This project has a delay as well (MarchicaMed, 2007).

The Orchards of Marchica (Les Vergers de Marchica)

The Orchards of Marchica is planned to be the last project that would be launched. This city is one with a natural character also known as a natural park. This space is designed for various but specific types of accommodation like mobile homes, villas and farmhouses (MarchicaMed, 2007).

The Nador New Area (La Ville Nouvelle de Nador)

This project is located in the old city of Nador and includes residential purposes in the village and a marina. Tradition and modernity meets here in perfect harmony. The development will be launched in 2011 and currently supposed to be completed in 2020 (MarchicaMed, 2007).

Phase	Nom de la cité	Shon m²	Nombre de lits	Prévision démarrage	Prévision achèvement
1	Cité d'Atalayoun	452 000	14 000	2009	2014
2	La cité des deux mers	150 000	3200	2010	2014
3	La ville nouvelle de Nador	763 000	32 000	2012	2020
4	Le village des pêcheurs	168 000	6000	2014	2018
5	La baie des flamants	767 000	29 000	2015	2020
6	Marchica sport	141 000	5 000	2017	2022
7	Les vergers de Marchica	139 000	12 000	2020	2025
	Total	**2 580 000**	**101 200**		

* le nombre de lit programmé concerne des quartiers résidentiels, des résidences touristiques et des établissements hôteliers

Figure 37: The initiated plans for the seven Marchica cities (MarchicaMed, 2007)

Beside the colossal project in the Marchica lagoon, there is also a real vision for the development of the North-Eastern region of the Kingdom. This project should contribute to the development of the local tourism potential, and will provide economically profitable and innovative dynamics to its inhabitants. The Marchica project will be an examplary project, with high environmental requirements, the project will be a sustainable development and fully integrated for the long term future (MarchicaMed, 2007).

Appendix B – Characteristics of Nador in tables

Month	$Wh/m^2/day$	%	m/s
January	3100	51	5.52
February	4040	51	5.72
March	5420	54	5.74
April	6770	54	5.69
May	7340	60	6.37
June	7620	61	5.45
July	7130	60	5.59
August	7140	57	5.04
September	6030	55	4.84
October	4470	54	4.80
November	3300	50	5.35
December	2770	51	5.58
Annual	5540	54.8	5.39

Table 21: Potential $Wh/m^2/day$ in Nador (Ahmed Ouammi, 2014)**, Percentage of the brightess of the days per month** (Diabaté, 2009)**, Wind speed per m/s in Nador** (Gaisma, 2014)

Appendix C – Square meters of the buildings of City of Two Seas

City of Two Seas, MarchicaMed

Building	Interior area	Amount	Total
Embedded resort			
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
		Total	m2
Shell resort			
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
		Total	m2
Sea Life resort			
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2
			m2

	Total	m2
Nautic resort		
		m2
		m2
		m2
		m2
		m2
		m2
		m2
		m2
		m2
		m2
		m2
		m2
		m2
		m2
		m2
		m2
		m2
		m2
		m2
	Total	m2
TOTAL		
	Total	m2
TOTAL ROOFS		
	Total	m2

Appendix D – Computation energy

Hotel rooms

In the case of hotels the calculation can be used by calculate based on the number beds and public rooms. We take the assumption that each room has two beds.

Nautic resort	**m2**	**nr.**		
				kWh
				kWh
				kWh
TOTAL		Total	m2	kWh

Villas

The calculation for the villas are not based on the numbers of beds. The calculation is done by identify three groups with different square meters. Villas up to 250m2 the amount calculated is 2,72 kWh. Villas between 250 and 450m2, 3,2 kWh. And villas bigger than 450m2 4,8 kWh.

Embedded resort	**m2**	**nr.**		
				kWh
				kWh
				kWh
				kWh
		Total	m2	kWh
Shell resort	**m2**	**nr.**		
				kWh
				kWh
				kWh
				kWh
		Total	m2	kWh
Sea Life resort	**m2**	**nr.**		
				kWh
				kWh
				kWh
				kWh
		Total	m2	kWh
TOTAL			m2	kWh

Main facilities

For the main facilities are the calculation given per square meter. In the public rooms is 0,05 kWh per m2 used for the calculation.

Embedded resort	**m2**	**nr.**		
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
		Total	m2	kWh

Shell resort	**m2**	**nr.**		
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
		Total	m2	kWh

Sea Life resort	**m2**	**nr.**		
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
		Total	m2	kWh

Nautic resort	**m2**	**nr.**		
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh
				kWh

			kWh
			kWh
	Total	m2	kWh
TOTAL		m2	kWh

Appendix E – Ranges per criteria

Criteria	Range 1	Range 2	Range 3
Costs per kWh	1 kWh costs between 5 and 8 euro cents. (Hydro and Geothermal)	1 kWh costs between 9 and 12 euro cents. (Wind)	1 kWh costs between 13 and 16 euro cents. (Solar)
Life span	A life span less than 20 years. (Hydro and Geothermal)	A life span between 20 and 25 years. (Solar)	A life span between 25 and 30 years. (Wind, and Hydro and Geothermal combined)
Simple infrastructure	Small distance between the plant and the buildings, easy maintenance, and a direct conversion to useable energy. (Solar)	A large distance between the plant and the buildings, difficult maintenance of the plant (few times per year, specific maintenance, difficult to maintain (in the water, underground, high)), energy not direct converted to useable energy, and the renewable energy plant is big. (Wind and Hydro)	In order to gain renewable energy other sources (coal, oil, etc.) are needed. The new infrastructure is linked to the old infrastructure. (Geothermal)
Environmental pressure	Low: between 0 and 0,05 acres of land use per MW, low impact on flora and fauna, life-cycle global warming emissions between 0 and 0,1 (pounds of CO_2 per kWh). (Solar and Hydro)	Middle: between 0,05 and 0,10 acres of land use per MW, middle impact on flora and fauna, life-cycle global warming emissions between 0,1 and 0,25 (pounds of CO_2 per kWh). (Wind and Geothermal)	High: 010< acres of land use per MW, high impact on flora and fauna, life-cycle global warming emissions 0,25< (pounds of CO_2 per kWh).

Table 22: Ranges per criteria and the characteristics of the renewable energy resources

Appendix F – Questionnaire

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MarchicaMed

Implementation of renewable energy forms on a urban development project

Introduction

Dear respondent,

I am currently performing my graduation research in co-operation with MarchicaMed, which is an urban development company based in Morocco, and the Technical University of Eindhoven based in the Netherlands. The topic of this research is "The implementation of renewable energy forms in urban development areas". For this research I would like to ask for a few minutes of your time to share your knowledge and experience about this topic. Your input will help find all relevant factors that are important to take into account for the decision making needed in this project. Your input will also be used to weight factors in order to form a solid recommendation for the most effective combination of renewable energy forms in the Northern part of Morocco.

Because of your valuable experience with renewable energy (systems), you are among a selected group of people who are asked to take part in this research. In order to provide me with useful input, it is important to complete the survey and fill in all questions.

In case you are interested in the results of this research, you will have the possibility to provide me with your e-mail address at the end of this questionnaire.

The questionnaire is anonymous and should not take more than 10 minutes to complete. Your cooperation in this regard will be highly appreciated.

Kind regards,

Uasima Chaïbi

How many years of experience do you have in the field of renewable energies?

How many years of experience do you have in the field of urban development?

How many years of experience do you have, in these fields, outside of Morocco?

Next

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Explanation questionnaire

Explanation of the questionnaire, please read this carefully.

The purpose of this questionnaire is to assess which factors, in the field of renewable energy in Morocco, are most important to take into account for the decision making. As you are a Moroccan expert in this field, I kindly ask if you would be willing to fill out this questionnaire.

You will constantly see a table in this questionnaire. This table presents two variables at each side, in a pairwise fashion. The question that should be answered is: 'Which variable is more important in the decision making for renewable energies in Morocco?'. For example: if variable A is, in your opinion, moderately more important than variable B you should tick the box neighbouring 'variable A' as done below.

Question: Compare the variables: which variables are, in your opinion, more important.

	Very strongly more important	Strongly more important	Moderately more important	Slightly more important	Equally important	Slightly more important	Moderately more important	Strongly more important	Very strongly more important	
A	○	○	●	○	○	○	○	○	○	B

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This questionnaire exist of three main variables: Financial, Environmental and Reliability variables. These variables will be compared in a pairwise manner. The main variable, Reliability, has two sub-variables: Life span and Simple infrastructure. These sub-variables will be compared as well. All these four variables exist of three sub-(sub)variables. These sub-(sub)variables will be compared with each other too.

The description of each main and sub-variable is given on the next page, and can be found at the bottom of each page where the variables will be compared. The sub-(sub)variables are described only on the pages where comparison takes place.

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Explanation variables

You will compare three main variables and two sub-variables with each other in this questionnaire. Bellow an description of the three main variables and two sub-variables.

COST PER KW/H PER YEAR: The cost per kW/h is calculated with take into consideration the costs of manufacture, shipping, installation, maintenance, and environmental costs. This means that all the costs that will be made by purchase and the costs that will be made during the implementation are considered in this calculation and the given costs. The costs are given in European euros (€).

ENVIRONMENTAL PRESSURE: The pressure of the renewable energy sources on the environment. The pressure is given in the classes Low, Middle, and High. The definition of these classes are given on page 7 of this questionnaire.

RELIABILITY: The reliability of energy systems may be defined to the capacity of a device or system to perform as designed. The reliability includes i.a. the quality of the equipment for a specified time, and the design of the energy system. This research includes the following two sub-variables.

Life span: The average expected period of use in service. The life span is given in years.

Simple infrastructure: The design of the energy system, how complicated is the design. The simple infrastructure is given in classes. The classes are defined on page 8 of this questionnaire.

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Main variables

Compare the variables: which variables are, in your opinion, more important?

	Very strongly more important	Strongly more important	Moderately more important	Slightly more important	Equally important	Slightly more important	Moderately more important	Strongly more important	Very strongly more important	
Cost per kW/h per year	○	○	○	○	○	○	○	○	○	Environmental pressure
Cost per kW/h per year	○	○	○	○	○	○	○	○	○	Reliability
Environmental pressure	○	○	○	○	○	○	○	○	○	Reliability

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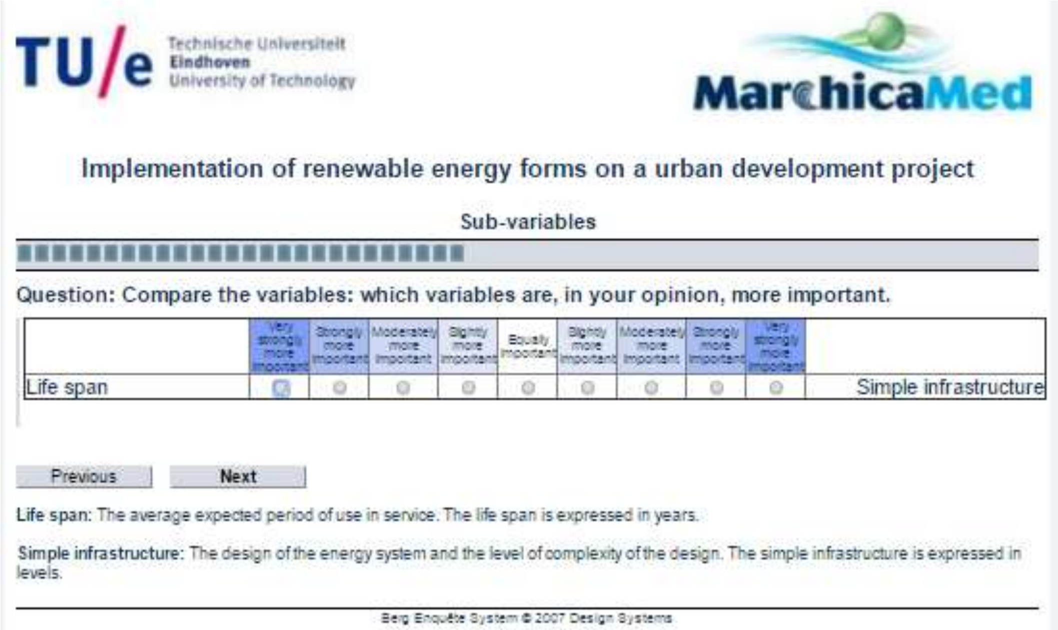
Cost per kW/h per year: The cost per kWh is calculated by taking into consideration the costs of manufacture, shipping, installation, maintenance, and environmental costs. This means that all the costs that will be made through purchase and the costs that will be made during the implementation are considered in this calculation and the given costs. The costs are expressed in European euros (€).

Environmental pressure: The pressure of renewable energy sources on the environment. The pressure is expressed in the levels: Low, Middle, and High.

Reliability: The reliability of energy systems can be measured by the level and extent to which a device or system performs as designed. The reliability includes i.a. the quality of the equipment for a specified time, and the design of the energy system.



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Implementation of renewable energy forms on a urban development project

Sub-variables

Question: Compare the variables: which variables are, in your opinion, more important.

	Very strongly more important	Strongly more important	Moderately more important	Slightly more important	Equally important	Slightly more important	Moderately more important	Strongly more important	Very strongly more important	
Life span										Simple infrastructure

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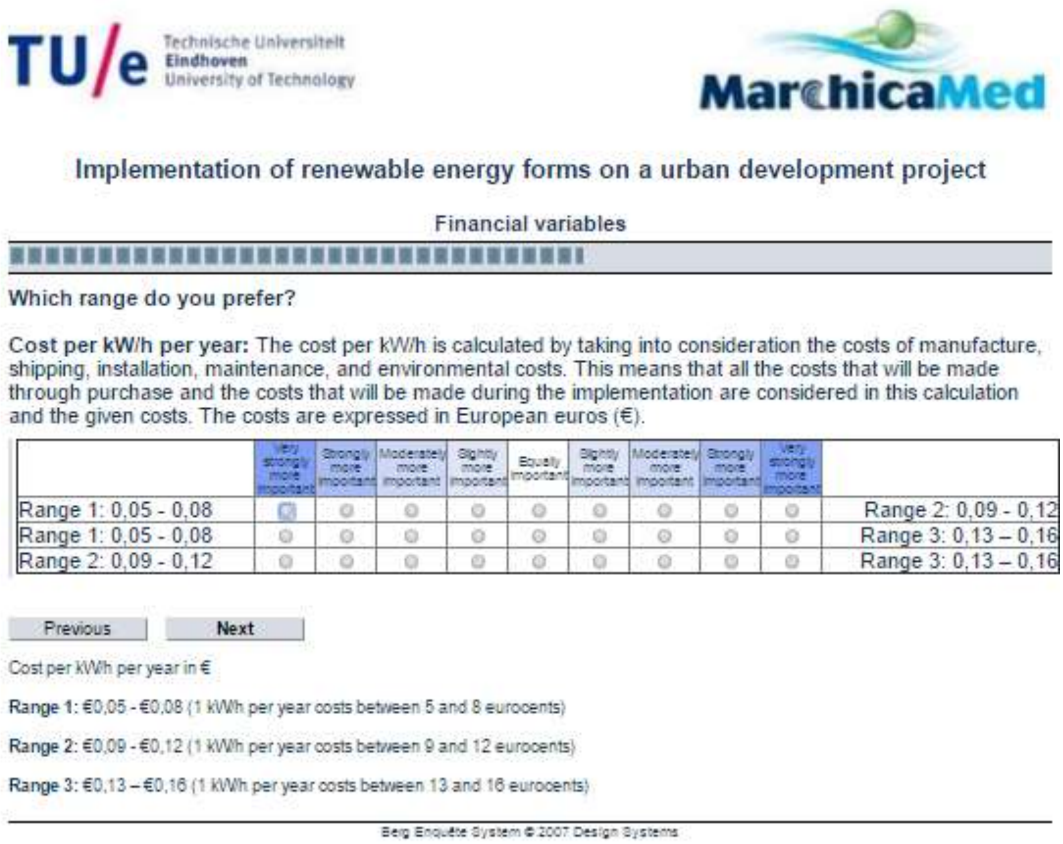
Life span: The average expected period of use in service. The life span is expressed in years.

Simple infrastructure: The design of the energy system and the level of complexity of the design. The simple infrastructure is expressed in levels.

Berg Enquête System © 2007 Design Systems



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Implementation of renewable energy forms on a urban development project

Financial variables

Which range do you prefer?

Cost per kW/h per year: The cost per kW/h is calculated by taking into consideration the costs of manufacture, shipping, installation, maintenance, and environmental costs. This means that all the costs that will be made through purchase and the costs that will be made during the implementation are considered in this calculation and the given costs. The costs are expressed in European euros (€).

	Very strongly more important	Strongly more important	Moderately more important	Slightly more important	Equally important	Slightly more important	Moderately more important	Strongly more important	Very strongly more important	
Range 1: 0,05 - 0,08										Range 2: 0,09 - 0,12
Range 1: 0,05 - 0,08										Range 3: 0,13 – 0,16
Range 2: 0,09 - 0,12										Range 3: 0,13 – 0,16

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Cost per kWh per year in €

Range 1: €0,05 - €0,08 (1 kWh per year costs between 5 and 8 eurocents)

Range 2: €0,09 - €0,12 (1 kWh per year costs between 9 and 12 eurocents)

Range 3: €0,13 – €0,16 (1 kWh per year costs between 13 and 16 eurocents)

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Implementation of renewable energy forms on a urban development project

Environmental variables

Which range do you prefer?

Environmental pressure: The pressure of renewable energy sources on the environment. The pressure is expressed in the levels: Low, Middle, and High.

	Very strongly more important	Strongly more important	Moderately more important	Slightly more important	Equally important	Slightly more important	Moderately more important	Strongly more important	Very strongly more important	
Range 1: Low	○	○	○	○	○	○	○	○	○	Range 2: Middle
Range 1: Low	○	○	○	○	○	○	○	○	○	Range 3: High
Range 2: Middle	○	○	○	○	○	○	○	○	○	Range 3: High

Low: (0 and 0,05 acres of land use per MW, low impact on flora and fauna, life-cycle global warming emissions between 0 and 0,1 (pounds of CO_2 per kWh))

Middle: (0,05 and 0,10 acres of land use per MW, middle impact on flora and fauna, life-cycle global warming emissions between 0,1 and 0,25 (pounds of CO_2 per kWh))

High: (0,10< acres of land use per MW, high impact on flora and fauna, life-cycle global warming emissions between 0,25< (pounds of CO_2 per kWh))

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Reliability variables

Which range do you prefer?

Life span: The expected period of use in service. The life span is expressed in years.

	Very strongly more important	Strongly more important	Moderately more important	Slightly more important	Equally important	Slightly more important	Moderately more important	Strongly more important	Very strongly more important	
Range 1: >20										Range 2: 20 - 25
Range 1: >20										Range 3: 25 - 30
Range 2: 20 - 25										Range 3: 25 - 30

Range 1: >20 (a life span less than 20 years)

Range 2: 20 - 25 (a life span between 20 and 25 years)

Range 3: 25 - 30 (a life span between 25 and 30 years)

Which range do you prefer?

Simple infrastructure: The design of the energy system and the level of complexity of the design. The simple infrastructure is expressed in different levels.

	Very strongly more important	Strongly more important	Moderately more important	Slightly more important	Equally important	Slightly more important	Moderately more important	Strongly more important	Very strongly more important	
Range 1: Class A										Range 2: Class B
Range 1: Class A										Range 3: Class C
Range 2: Class B										Range 3: Class C

Range 1: Level A (Small distance between the plant and the buildings, easy maintenance, and a direct conversion to useable energy.)

Range 2: Level B (A large distance between the plant and the buildings, difficult maintenance of the plant (few times per year, specific maintenance, difficult to maintain (in the water, underground, high)), energy not direct converted to useable energy, and the renewable energy plant is big.)

Range 3: Level C (In order to gain renewable energy other sources (coal, oil, etc.) are needed. The new infrastructure is linked to the old infrastructure.)

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Implementation of renewable energy forms on a urban development project

Afterword

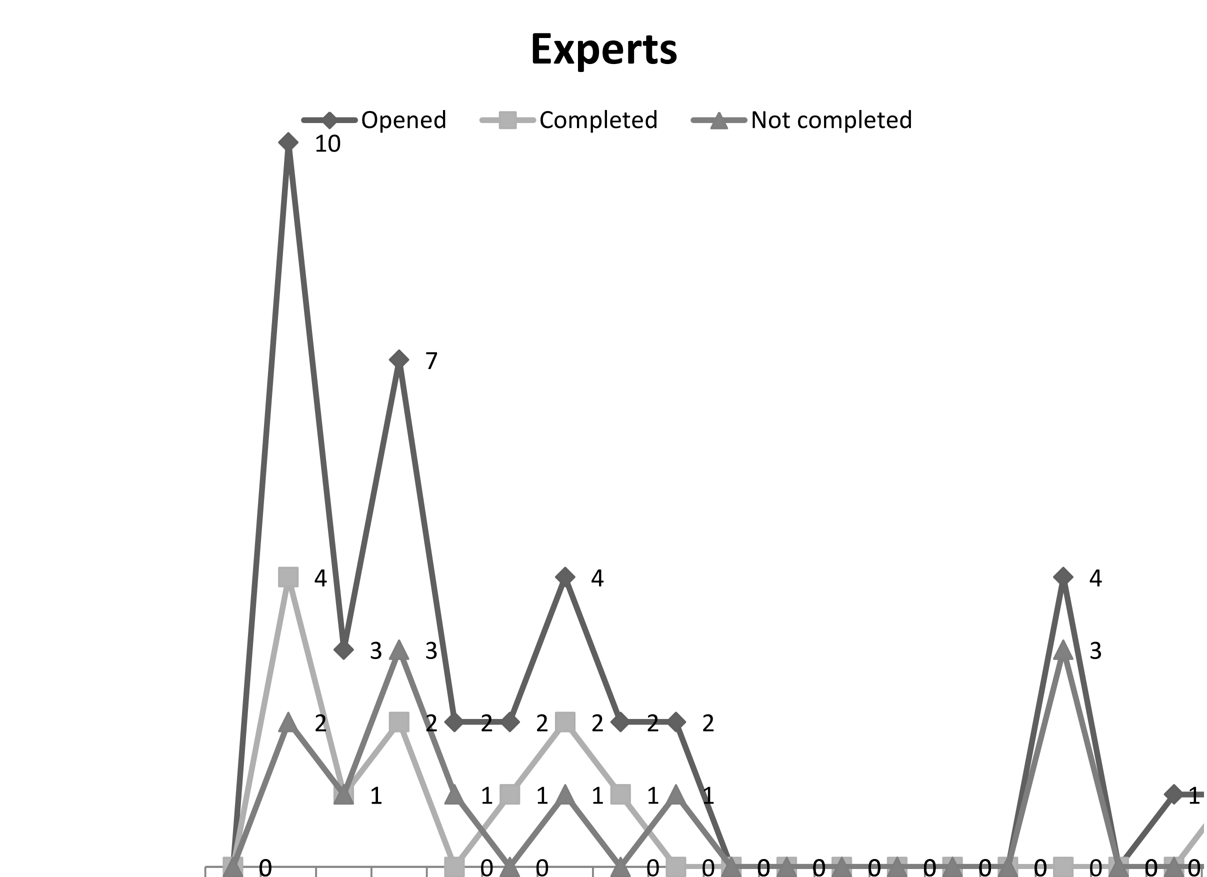
Thank you very much for your time, your help is very much appreciated!

It is now possible for you to submit your answers. In case you would like to receive the results of this research, please provide me with your email address in the box below.

Fill in your e-mail

Previous Submit

Appendix G – Timeline experts



	6-5	7-5	8-5	9-5	10-5	11-5	12-5	13-5	14-5	15-5	16-5	17-5	18-5	19-5	20-5	21-5	22-5	23-5
Opened	0	10	3	7	2	2	4	2	2	0	0	0	0	0	0	4	0	1
Completed	0	4	1	2	0	1	2	1	0	0	0	0	0	0	0	0	0	0
Not completed	0	2	1	3	1	0	1	0	1	0	0	0	0	0	0	3	0	0

Figure 38: Timeline of the response

Appendix H – Computations

Main criteria

	C1 Costs per kWh	C2 Reliability	C3 Environment
C1 Costs per kWh	1	5.17	2.56
C2 Reliability	0.19	1	0.97
C3 Environment	0.39	1.030928	1
Total	1.584049	7.200928	4.53

Table 23: Data input

	C1 Costs per kWh	C2 Reliability	C3 Environment	Eigenvector (EV)
C1 Costs per kWh	0.631294	0.717963	0.565121	1.914378
C2 Reliability	0.12	0.14	0.21	0.475106
C3 Environment	0.25	0.14	0.22	0.610516
Total	1	1	1	3

Table 24: Computation Eigen vector (EV)

	Normalized eigenvector (NEV)
C1 Costs per kWh	0.638126
C2 Reliability	0.158369
C3 Environment	0.203505
Total	1

Table 25: Computation Normalized Eigen vector (NEV)

	Computations
λmax	3.0731
n	3
Consistency Index (CI)	0.03655
Random Consistency Check (RI)	0.58
Check	0.06 (6%)

Table 26: Consistency check

Sub-criteria

	SB1 Life span	SB2 Simple infrastructure
SB1 Life span	1	2.85
SB2 Simple infrastructure	0.32	1
Total	1.32	3.85

Table 27: Data input

	SB1 Life span	SB2 Simple infrastructure	Eigenvector (EV)
SB1 Life span	0.757576	0.74026	0.757576
SB2 Simple infrastructure	0.242424	0.25974	0.242424
Total	1	1	1

Table 28: Computation Eigen vector (EV)

	Normalized eigenvector (NEV)
SB1 Life span	0.756098
SB2 Simple infrastructure	0.243902
Total	1

Table 29: Computation Normalized Eigen vector (NEV)

	Computations
ƛmax	1.955238
n	2
Consistency Index (CI)	-1.04476
Random Consistency Check (RI)	0
Check	ERROR

Table 30: Consistency check

Ranges – Costs per kWh

	Range 1: 0,05 - 0,08	Range 2: 0,09 - 0,12	Range 3: 0,13 - 0,16
Range 1: 0,05 - 0,08	1	3.43	3.89
Range 2: 0,09 - 0,12	0.29	1	4.05
Range 3: 0,13 - 0,16	0.26	0.246914	1
Total	1.548615	4.676914	8.94

Table 31: Data input

	Range 1: 0,05 - 0,08	Range 2: 0,09 - 0,12	Range 3: 0,13 - 0,16	Eigenvector (EV)
Range 1: 0,05 - 0,08	0.645738	0.73339	0.435123	1.814251
Range 2: 0,09 - 0,12	0.19	0.21	0.45	0.855098
Range 3: 0,13 - 0,16	0.17	0.05	0.11	0.330651
Total	1	1	1	3

Table 32: Computation Eigen vector (EV)

	Normalized eigenvector (NEV)
Range 1: 0,05 - 0,08	0.60475
Range 2: 0,09 - 0,12	0.285033
Range 3: 0,13 - 0,16	0.110217
Total	1

Table 33: Computation Normalized Eigen vector (NEV)

	Computations
ƛmax	3.254938
n	3
Consistency Index (CI)	0.127469
Random Consistency Check (RI)	0.58
Check	0.219774 (22%)

Table 34: Consistency check

Ranges – Environmental pressure

	Range 1: Low	Range 2: Middle	Range 3: High
Range 1: Low	1	4.29	3.69
Range 2: Middle	0.23	1	3.78
Range 3: High	0.27	0.26455	1
Total	1.504103	5.55455	8.47

Table 35: Data input

	Range 1: Low	Range 2: Middle	Range 3: High	Eigenvector (EV)
Range 1: Low	0.664848	0.77234	0.435655	1.872843
Range 2: Middle	0.15	0.18	0.45	0.78129
Range 3: High	0.18	0.05	0.12	0.345867
Total	1	1	1	3

Table 36: Computation Eigen vector (EV)

	Normalized eigenvector (NEV)
Range 1: Low	0.624281
Range 2: Middle	0.26043
Range 3: High	0.115289
Total	1

Table 37: Computation Normalized Eigen vector (NEV)

	Computations
ƛmax	3.362052
n	3
Consistency Index (CI)	0.181026
Random Consistency Check (RI)	0.58
Check	0.312114 (31%)

Table 38: Consistency check

Ranges – Reliability: Life span

	Range 1: >20	Range 2: 20-25	Range 3: 25-30
Range 1: >20	1	2.94	2.65
Range 2: 20-25	0.34	1	2.77
Range 3: 25-30	0.38	0.361011	1
Total	1.717495	4.301011	6.42

Table 39: Data input

	Range 1: >20	Range 2: 20-25	Range 3: 25-30	Eigenvector (EV)
Range 1: >20	0.582243	0.68356	0.412773	1.678576
Range 2: 20-25	0.20	0.23	0.43	0.86201
Range 3: 25-30	0.22	0.08	0.16	0.459414
Total	1	1	1	3

Table 40: Computation Eigen vector (EV)

	Normalized eigenvector (NEV)
Range 1: >20	0.559525
Range 2: 20-25	0.287337
Range 3: 25-30	0.153138
Total	1

Table 41: Computation Normalized Eigen vector (NEV)

	Computations
ƛmax	3.179966
n	3
Consistency Index (CI)	0.089983
Random Consistency Check (RI)	0.58
Check	0.155143 (16%)

Table 42: Consistency check

Ranges – Reliability: Simple infrastructure

	Range 1: Class A	Range 2: Class B	Range 3: Class C
Range 1: Class A	1	5.53	2.98
Range 2: Class B	0.18	1	2.56
Range 3: Class C	0.34	0.390625	1
Total	1.516402	6.920625	6.54

Table 43: Data input

	Range 1: Class A	Range 2: Class B	Range 3: Class C	Eigenvector (EV)
Range 1: Class A	0.659456	0.799061	0.455657	1.914174
Range 2: Class B	0.12	0.14	0.39	0.655183
Range 3: Class C	0.22	0.06	0.15	0.430643
Total	1	1	1	3

Table 44: Computation Eigen vector (EV)

	Normalized eigenvector (NEV)
Range 1: Class A	0.638058
Range 2: Class B	0.218394
Range 3: Class C	0.143548
Total	1

Table 45: Computation Normalized Eigen vector (NEV)

	Computations
ƛmax	3.41778
n	3
Consistency Index (CI)	0.20889
Random Consistency Check (RI)	0.58
Check	0.360155 (36%)

Table 46: Consistency check

Ranking the alternatives

	Weighted		Solar energy	Wind energy	Hydro energy	Geothermal energy	Combination of Hydro energy and Geothermal energy
Costs per kWh	0.638						
Range 1	0.605				0.38599	0.38599	
Range 2	0.285			0.18183			
Range 3	0.11		0.07018				0.07018
Environmental pressure	0.158						
Range 1	0.624		0.098592		0.098592		
Range 2	0.26			0.04108		0.04108	0.04108
Range 3	0.115						
Reliability	0.204						
Life span	0.749	0.152796					
Range 1	0.56				0.085566	0.085566	0.085566
Range 2	0.287		0.043852				
Range 3	0.153			0.023378			
Simple infrastructure	0.251	0.051204					
Range 1	0.638		0.032668				
Range 2	0.218			0.011162			
Range 3	0.144				0.007373	0.007373	0.007373
			0.175113	**0.25745**	**0.577521**	**0.520009**	**0.204199**
Normalized			**0.100971**	**0.148447**	**0.333001**	**0.299839**	**0.117742**
			10%	**15%**	**33%**	**30%**	**12%**
			5	**3**	**1**	**2**	**4**

Table 47: Rank of the alternatives

Appendix I – Other literature

Literature

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Appendix J – English summary

SUN, SEA, LEISURE, AND ENERGY

The knowledge of experts used for the decision making of renewable energies in urban development areas in the North-Eastern part of Morocco, using AHP.

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ABSTRACT

This paper is on decision making in urban development in Morocco in the field of renewable energies. Morocco has the ambition to produce 42% of the total demand of energy from renewable energies in 2020. With the growing implementation of solar and wind energy the application of renewable energies in Morocco is a fact. This research investigates these two renewable energy sources together with hydro energy and geothermal energy. This is done by literature study, application of AHP with i.a. a survey distributed around experts in renewable energies, and a case study.

The most important conclusions of this research were that financial aspects are most important in the decision making, and environmental pressure is not important at all in the decision making in the field of renewable energies. The research ends with weighing of different criteria which could help by choosing a renewable energy form for a specific project in Morocco.

Keywords: renewable energy, solar energy, wind energy, geothermal energy, hydro energy, urban development, MCA, AHP, case study, Morocco

INTRODUCTION

The world population is growing, the energy demand is growing even faster, in contrast the fossil energy resources are exhausting. The oil and gas resources will be exhausted in about fifty years. With the growing knowledge in technology alternatives for the fossil resources are upcoming and necessary to postpone the exhausting of the fossil energy resources.

The City of Two Seas is a new touristic city in the North-East of Morocco. This city covers a development area of 14.5 ha (MarchicaMed, 2013). This city will be developed by MarchicaMed. Since buildings are big consumers of energy it is interesting to analyse the possibilities in the design of buildings to reduce the required amount of energy. Besides the reduction of the demand of energy it is at least equally interesting to exam possibilities for renewable energy resources as well.
The goal of this research is to find alternatives for fossil energy implementation in urban development areas in North-Eastern part of Morocco, since solar energy is widely implemented in Morocco.
MarchicaMed has preferences for solar energy as well. The blind choice for solar energy will limit the project, since the area of this project gives opportunities for other sources of renewable energy as well. It is for MarchicaMed financially and technically interesting to find the most favourite renewable energy resources for the City of Two Seas according to experts in the field of renewable energies.

RESEARCH DESIGN

The aim of the research is to find and select criteria to be used in the decision making. These criteria will be weighed through the outcomes from a questionnaire. These outcomes will be implemented on a case study. This leads to the following main research question: *What would be the most interesting combination of renewable energies in a new touristic city. Considering the amount of energy needed, the characteristics of the area, technical possibilities and financial aspects.*
Since the advice should be scientific, this research methodology is implemented. Since the research includes qualitative and quantitative subjects, Multi Criteria Analysis (MCA) is implemented. The MCA tool that suits best for weighing the criteria in this research is the Analytic Hierarchy Process (AHP). This research methodology weighs criteria and help to find the most feasible technology for this project. The AHP is developed in the early '70's by Saaty. This methodology became popular throughout a wide field of applications in fields such as government, business, industry, healthcare, education, and construction. AHP is a systematic methodology for multi criteria systems and quantitatively treating complex situations. AHP can be used to decompose complex problems into simple solvable layers and factors, as well as efficiently compare and calculate weights. According to a set of criteria and sub-criteria that have been arranged in a hierarchical structure, AHP compares and ranks the alternatives. The comparison is through natural language and, from this the preferences of different criteria become ranked.
With the implementation of AHP the most preferred renewable energy system will be found. After this an attempt will be made for a combination of renewable energy systems in this case study. This result will be compared with the result from best practice. The results and conclusions derived from the research components lead to recommendations for the implementation of renewable energy sources in the case study.

NORTH-EASTERN PART OF MOROCCO

The northern part of Morocco is used to have small and sometimes intensive earthquakes. These earthquakes have their origin in the plate tectonics. Morocco lies on the African plate which has his cleavage in the Mediterranean Sea. The plates are in movement now and then. These movements generate lots of energy and possible damage. Another side effect are the many hot springs in this area. These hot springs have a constant stream of hot water of 24 degrees Celsius (Rimi, 2012).

Nador is a coastal city at the Mediterranean Sea. However, the Marchica lagoon lies between the Mediterranean Sea and Nador. The Marchica lagoon has an area of about 115km^2 (25 km by 7.5 km) and a depth not exceeding 8 m. This lagoon is separated from the sea by a 24km long belt of dunes, also called the cordon. The lagoon is still connected to the Mediterranean Sea through a new artificial channel. The connection of the lagoon with the Mediterranean Sea is 300 meters wide and 6.5 meters deep. Except the stream from the Mediterranean Sea, a continental input exists as well. This input comes from the Salouane River, Bou Areg and the channel that drains the Bou Areg plain (Ben Chekroun, 2012).

The North-Eastern part of Morocco is characterized by a coastal climate, also known as the Mediterranean climate. The Mediterranean climate is characterized by warm, dry summers and mild winters. This climate gives a lot of sun hours yearly. The country is characterized by an intensive solar radiation. In the North-Eastern part of Morocco the annual duration of sunshine hours is about 2700 (Frotzsche, 2011). With an average of 55% clearness, the average over the year is 5540 Wh/m^2 per month. Furthermore the wind is an abundantly resource in the coastal region. The wind varies from 4.8 m/s up to 5.74 m/s at the Nador coastal region.

Owing to its special geographical and geological position, the North-Eastern part of Morocco, which is endowed by a natural bounty of sunshine and geothermal resources (Rimi, 2012), has a lot of opportunities for solar and geothermal energy. The position near the Mediterranean Sea gives opportunities for implementing hydro and wind energy as well. This makes the renewable energies solar, wind, hydro, and geothermal resources the most interesting for this environment and therefore for the North-Eastern part of Morocco.

RENEWABLE ENERGIES

Renewable energy technologies are resources that consume primary non-carbon energy resources that are not subject to depletion (Frey, 2002). Renewable energies harm the world in a minimum way. The best known renewable energy resources are solar and wind energy. Geothermal, hydropower and biomass follow these renewable energy resources as well-known resources. The aim of the City of Two Seas is to have a sustainable character. It is logical that the energy sources in this project will be renewable. Selecting the potential new energy sources gives that the sources should be: renewable, locally available, and environmentally friendly. The renewable energies that have been selected as most promising and interesting in North-Eastern part of Morocco are solar, wind, hydro, geothermal energy. The most important characteristics that could help by the decision making for renewable energy forms are described in table 1. Since the renewable energies have broad ranges, ranges have been settled down with a specific description. All the renewable energy forms fit in one of the ranges.

Characteristics	**Solar energy**	**Wind energy**	**Hdyro energy**	**Geothermal energy**
Cost per kWh	€ 0.13	€ 0.12	€ 0.08	€ 0.05
Life span	25 years	25-30 years	20 years	20 years
Simple infrastructure	Small distance between the plant and the buildings, easy maintenance, and a direct conversion to useable energy.	A large distance between the plant and the buildings, difficult maintenance of the plant (few times per year, specific maintenance, difficult to maintain (in the water, underground, high)), energy not direct converted to useable energy, and the renewable energy plant is big.	A large distance between the plant and the buildings, difficult maintenance of the plant (few times per year, specific maintenance, difficult to maintain (in the water, underground, high)), energy not direct converted to useable energy, and the renewable energy plant is big.	A large distance between the plant and the buildings, difficult maintenance of the plant (few times per year, specific maintenance, difficult to maintain (in the water, underground, high)), energy not direct converted to useable energy, and the renewable energy plant is big.
Environmental pressure	Between 0 and 0.05 acres of land use per MW, low impact on flora and fauna, life-cycle global warming emissions between 0 and 0.1 (pounds of CO2 per kWh).	Middle: between 0.05 and 0.10 acres of land use per MW, middle impact on flora and fauna, life-cycle global warming emissions between 0.1 and 0.25 (pounds of CO2 per kWh).	Low: between 0 and 0.05 acres of land use per MW, low impact on flora and fauna, life-cycle global warming emissions between 0 and 0.1 (pounds of CO2 per kWh).	Middle: between 0.05 and 0.10 acres of land use per MW, middle impact on flora and fauna, life-cycle global warming emissions between 0.1 and 0.25 (pounds of CO2 per kWh).

Table 48: Characteristics of renewable energies

From a description of best practices it has been found that the most implemented renewable energy is solar energy, which seems to be the best to implement in projects. The renewable energy resources hydro, biogas and wind energy can also be also implemented. Furthermore it is interesting to look at the possibilities of a combination of multiple renewable energy resources. An energy could make it less necessary to use expensive and low capacity storage technologies. One combination that is possible is the combination of hydro energy and geothermal energy. Table 2 gives the characteristics of this renewable energy combination.

Characteristics	**Combination of Hydro energy Geothermal energy**
Costs per kWh	€ 0.08 + € 0.05 = € 0.13
Life span	20 years
Simple infrastructure	A large distance between the plant and the buildings, difficult maintenance of the plant (few times per year, specific maintenance, difficult to maintain (in the water,

	underground, high)), energy not direct converted to useable energy, and the renewable energy plant is big.
Environmental pressure	Middle: between 0.05 and 0.10 acres of land use per MW, middle impact on flora and fauna, life-cycle global warming emissions between 0.1 and 0.25 (pounds of CO2 per kWh).

Table 49: Characteristics of the combination of Hydro energy and Geothermal energy

DECISION MAKING

In this research Multi Criteria Analysis (MCA) is the key methodology. Combining weights with evaluation scores of alternatives is the evaluation method of this research methodology. Analytic Hierarchy Process (AHP) will be used to find the weights of the selected criteria by asking experts from Morocco in the field of renewable energy to prioritize decision criteria by using pairwise comparisons. The experts have been required to score the sub-criteria and ranges in the same way. Finally, the qualitative dominant scores are used to synthesize the weights and evaluation scores. From these results the alternatives are prioritized regarding the criteria.

The goal of this research is to find which combination of renewable energy resources is the most interesting and suitable for the City of Two Seas project. The most critical decision tends to be renewable energy selection which if not properly done may result in heavy loss for the whole project. This makes the objective of the research as follows: *Which (combination of) renewable energy resources is the most interesting for the City of Two Seas*.

Quantity does not always give the required quality. In case of the criteria a selection of a few good criteria is helpful for the decision making. For the implementation of AHP three main criteria are a good number to use for decision making (Wang, 2009). Figure 1 shows the AHP hierarchy design for this research.

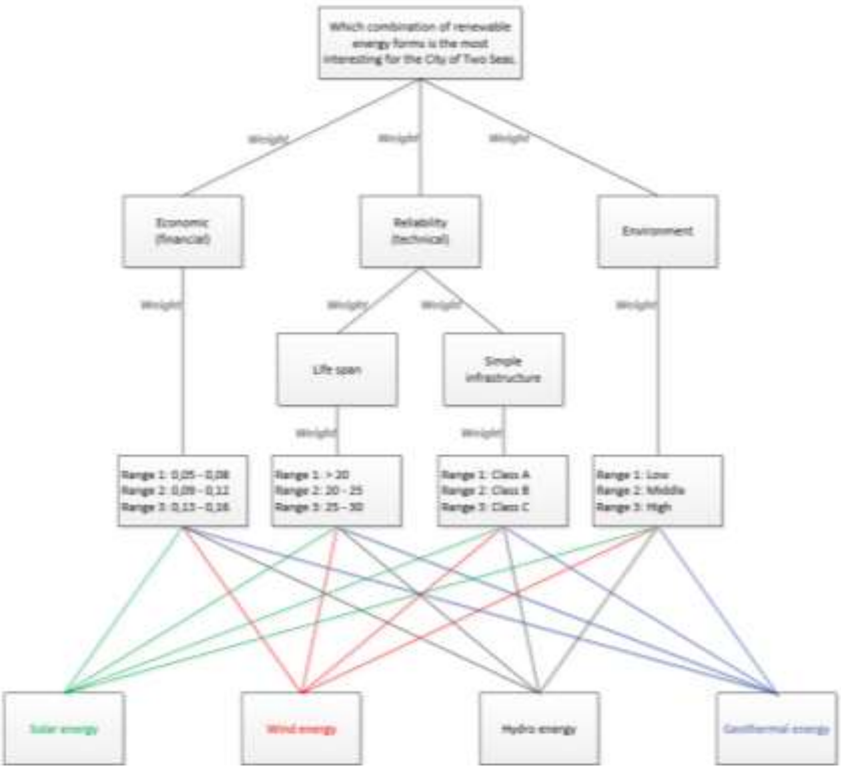
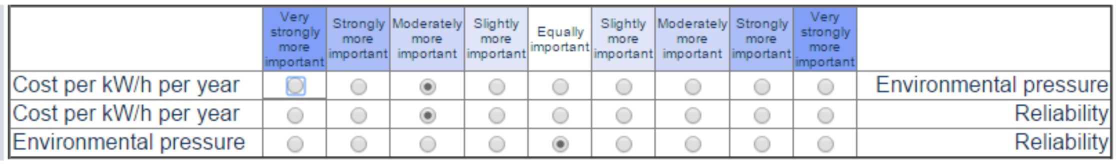


Figure 39: AHP Hierarchy design

CASE APPLICATION

The comparison in AHP is pairwise comparison. The question that is asked is: *Which of the criteria is more important for the decision making, and how much more important in* *comparison with the other criteria?*. The experts score the criteria on the grade of importance. In these results it can be seen that the expert thinks that the criteria Costs per kWh is moderately more important than the criteria Environmental pressure (*figure 34*).



	Very strongly more important	Strongly more important	Moderately more important	Slightly more important	Equally important	Slightly more important	Moderately more important	Strongly more important	Very strongly more important	
Cost per kW/h per year	○	○	◉	○	○	○	○	○	○	Environmental pressure
Cost per kW/h per year	○	○	◉	○	○	○	○	○	○	Reliability
Environmental pressure	○	○	○	○	◉	○	○	○	○	Reliability

Figure 40: Comparison matrix main criteria

The weighing of this answer gives that Costs per kWh are 13 times more important than Environmental pressure. First the main criteria will be compared in this way. Secondly the sub-criteria will be compared, and finally the ranges of the characteristics of the renewable energies will be compared with each other. The data collection has been done through an online questionnaire. The questionnaire has been constructed using *Berg Enquete System 2007*. This is a digital survey tool developed by Eindhoven University of Technology. This questionnaire has been sent to experts in the field of renewable energy In this research is the knowledge of experts with an average of 11.3 years of experience in renewable energies used, and an average of 5.5 years of experience in urban development projects. All the data can be used by weighing the criteria and the ranges of the characteristics.

Normalisation

To weigh the criteria, the option is to derive these weighs from ranks. This is done by ranking first the criteria by implementing pairwise comparison. After the collection of the rank numbers (data), the weight can be computed from this order by normalising the rank numbers. Normalisation assures the weights are between 0 and 1. Following example illustrates the normalisation of the main criteria.

	C1 Costs per kWh	C2 Reliability	C3 Environment
C1 Costs per kWh	1	5.17	2.56
C2 Reliability	0.19	1	0.97
C3 Environment	0.39	1.030928	1
	1.584049	7.200928	4.53

Table 50: Reciprocal Matrix main criteria

In the box which refers to the dominance of Reliability according to Costs per kWh the value 1/5.17 is entered. This gives the relation between the two criteria. Add the whole row gives the Eigenvector (EV). Table 4 shows the result of all these computations.

	C1 Costs per kWh	C2 Reliability	C3 Environment	Eigenvector (EV)
C1 Costs per kWh	0.631294	0.717963	0.565121	1.914378
C2 Reliability	0.12	0.14	0.21	0.475106
C3 Environment	0.25	0.14	0.22	0.610516
Total	1	1	1	3

Table 51: Calculation of the eigenvector (EV)

The normalization of the eigenvector (NEV) is implementing the formula:

(1 / total EV) * EV criteria.

(1 / 3) * 1.914378 = 0.638126

	Normalized eigenvector (NEV)
C1 Costs per kWh	0.638126
C2 Reliability	0.158369
C3 Environment	0.203505
Total	1

Table 52: Normalization EV

With this calculation the eigenvector is calculated, and from this the weighing has been done. The criterion with the highest value of the normalized weigh indicates the highest ranked alternative (Srdjevic, 2013). For the main criteria the Costs per kWh is, according to the experts, significantly more important than the other two main criteria.

Main results

The division of the Main criteria is as follows. Costs per kWh has got the highest value, 0.638, this aspect is most important in the decision making according the experts in the renewable energy branch. The difference between the financial criteria and the other criteria is significantly larger than the other two main criteria. With 0.204 is Reliability is the second important criterion according to the experts. Environmental pressure is the least important of these criteria with a NEV of 0.158.

Reliability has two sub-criteria. These two sub-criteria are weighed too. Life span, with an NEV of 0.749, is significantly more important than Simple infrastructure, with an NEV of 0.251, by the experts.

The third level includes the ranges of the (sub)-criteria. All these criteria have three ranges. When it comes to the Costs per kWh it is obvious that the smallest range € 0.05-€ 0.08, with an NEV of 0.605, is most favourable according to the experts, followed by the range € 0.09-€ 0.012, with a NEV of 0.285, and at last the range € 0.13-€ 0.16 with a NEV of 0.11.

The second set of ranges of the (sub) criteria is Environmental pressure. The range Low, is the least harmful for the environment, and the range High the most. The range Low is, with an NEV of 0.624, most favourable according the experts. With a NEV of 0.26 is Middle secondly favourable and as least the range High with a NEV of 0.115. The range High is least favourable according to the experts. The difference between the range High and the other two ranges is larger than the other two ranges.

The first set of the sub-criteria of ranges of Reliability are the ranges of the Life span. Not logical a shorter Life span, according to the experts, is more favourable. A Life span less than 20 years is most favourable with a NEV of 0.56. A Life span between 20 and 25 years is secondly favourable with a NEV of 0.287. Least favourable is the largest Life span with a range between 25 and 30 years and a NEV pf 0.153.

The last set of ranges of the sub-criteria of Reliability. The ranges are defined by Classes A to C. A is the most simple infrastructure, and C the most complex infrastructure. According to the experts is the Simple infrastructure with Class A most significantly favourable with a NEV of 0.638. Secondly is Class B most favourable with a NEV of 0.218. Least favourable is Class C, with a small difference with Class B, with a NEV of 0.144.

Consistency analysis

After the normalization a consistency analysis should be done. AHP allow some small inconsistencies in judgement. This is because human can never be always consistent. The ratio scales are derived from the principal Eigenvectors and the consistency index is derived from the principal Eigenvalue.

The quality of the data was determined by implementing the consistency check. The formula used for the consistency check is: CI/RI.

$$CI = \frac{\lambda \max - n}{n - 1}$$

	Computations
ƛmax	3.0731
n	3
Consistency Index (CI)	0.03655
Random Consistency Check (RI)	0.58
Check	0.06 (6%)

Table 53: Consistency check

From this consistency check it can be concluded that main criteria pass the check. The outcome of the consistency analysis should be less than 10%. From the calculations are the following consistencies found *(table 19)*:

Variable	Consistency analysis
Main criteria	6%
Sub-criteria	n.a.
Ranges of (sub) criteria: Costs per kWh	22%
Ranges of (sub) criteria: Environmental pressure	31%
Ranges of (sub) criteria: Reliability – Life span	16%
Ranges of (sub) criteria: Reliability – Simple	36%

Table 54: Consistency check

As table 7 shows, the main criteria are consistent. The sub-criteria are not consistent. The reason therefore is the RI.

All the ranges are inconsistent. This is possibly caused by the selected interval definitions for the ranges.

CONCLUSIONS

According to the experts the criteria Costs per kWh is significantly more important than the other criteria. That influences the rank of the renewable energies highly. The criterion with the lowest Costs per kWh are therefore most favourable. The criterion Environmental pressure has the lowest weight, and therefore this criterion is least important in decision making. Reliability has got a lower weight as well. In contrast to the criteria solar and wind energy score favourable on both criteria. Despite of favourable scores in two out three criteria are these renewable energies nevertheless least favourable. Remarkable is that the most favourable renewable energies, hydro and geothermal energy, are not favourable when they are combined.

In this research the most favourable renewable energy resources for North-Eastern of Morocco and therefore for the City of Two Seas are studied. From this research it can be concluded that hydro energy is most favourable. In economic terms for MarchicaMed it is interesting to consider the implementation of hydro energy in the City of Two Seas. Since ambition of MarchicaMed is to be sustainable, it is good for the image of MarchicaMed to consider the implementation of hydro energy as well.

This research shows that the implementation of MCA and AHP is a good tool in decision making for renewable energies. The use of MCA and AHP, with input from appropriated experts, facilitates the decision making of renewable energies in urban development.

DISCUSSION

The world population grows fastly, the demand of energy is growing even faster. With the knowledge of exhausting fossil energies within about fifty years it is wise to look now for possibilities to postpone the exhausting of the fossil energies, and alternative inexhaustive resources which can be used as supply for the longer term. With this research renewable energies gets a platform. This platform could contribute to convince and inspire decision makers to implement renewable energies in construction projects, and especially in leisure.

Decision making is for every construction project a challenge. The way of selection of the decision criteria in this research with the use of MCA coulsd be seen as a starting point that can be a contribution to decision making in other similar projects.

The limitations of this research are in the first place related to the model. The AHP model has some restrictions in the field of criteria selection, range selection, and the consistency check. It will be interesting to simulate the some model better selected criteria and find if the consistency check satisfies. Furthermore experts have huge influence in the decision making. In that way it is interesting to simulate this model with decision makers within MarchicaMed and compare the results with other results in this field.

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This report would not exist without the help of the people who helped me with their knowledge, and experience. My graduation committee Wim Schaefer, Brano Glumac from Eindhoven University of Technology, and Sami Bouhmidi from MarchicaMed. I would also like to thank the experts who participated in the questionnaire of this research.

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PERSONAL INFORMATION

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This summary is the result of my graduation thesis about decision making in urban development and renewable energies, in Morocco. This research was done as completion of the master track Construction, Management and Engineering at Eindhoven University of Technology and in collaboration with MarchicaMed, an urban development firm. The results led to recommendation for the implementation of renewable energies in urban developments in Morocco.

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2012-2013	Education board member, of CoUrsE!
2012-2014	Certificate programs Management in Technology, and Technology Entrepreneurship, Eindhoven University of Technology
2014-2015	Graduation intern, MarchicaMed
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Appendix K – Dutch summary

ZON, ZEE, LEISURE EN ENERGIE
De kennis van deskundigen op het gebied van duurzame energie toegepast in besluitvorming in gebiedsontwikkelingsproject in het noordoosten van Marokko, met toepassing van AHP.

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SAMENVATTING

Dit paper beslaat het onderwerp van besluitvorming in gebiedsontwikkeling op het gebied van duurzame energie. Marokko heeft de ambitie om in 2020 zichzelf aan de hand van duurzame energie van 42% van de totale energievraag zelf op te wekken. Met de groei van toepassing zoals zonne-energie en windenergie gaat het in Marokko die kant al op. Dit onderzoek doet een studie naar deze twee duurzame energievormen samen. Daarnaast komen de duurzame energievormen water en geothermische energie ook aan bod. Dit onderzoek zal verricht worden aan de hand van literatuurstudie, toepassing van Analytic Hierarchy Process (AHP) met o.a. een enquête onder deskundigen op het gebied van duurzame energie gehouden en tot slot een case studie.

De meest belangrijke conclusies van deze studie zijn in de eerste plaats de bevinding dat de economische criterium het meest belangrijk zijn in besluitvorming. Daarentegen zijn gevolgen voor het milieu bij besluitvorming in veel mindere maten belangrijk. Aan het eind van dit onderzoek zijn de criteria gewogen. Dit kan een bijdrage leveren bij het kiezen van een duurzame energievorm in Marokko.

Trefwoorden: duurzame energie, zonne-energie, windenergie, geothermische energie, waterenergie, gebiedsontwikkeling, MCA, AHP, case studie, Marokko

INTRODUCTIE

De wereldpopulatie is groeiende, daarmee is de energievraag ook groeiende. Daarentegen raken de fossiele brandstoffen over ongeveer vijftig jaar uitgeput. De groeiende kennis op het gebied van techniek is van belang voor het tegengaan van de uitputting van fossiele brandstoffen en uitstoot van CO2. De City of Two Seas is een nieuw te ontwikkelen gebied in het noordoosten van Marokko. Het project beslaat een gebied van 14,5 ha en wordt door MarchicaMed ontwikkeld. Gezien het doel van MarchicaMed om het gebied duurzaam te ontwikkelen, is het in belang van het project om verschillende duurzaamheidsaspecten te onderzoeken. Daarmee is het doel van dit onderzoek om een bijdrage te leveren bij de besluitvorming op het gebied van duurzame energie in gebiedsontwikkeling in Marokko.

ONDERZOEKSOPZET

Het onderzoek zal in de eerste plaats een literatuurstudie naar het gebied, het project en duurzame energiebronnen omvatten. Vervolgens zullen aan de hand van deze bevindingen enkele duurzame energiebronnen geselecteerd worden die in dit gebied kansrijk zijn. Aan de hand van Multi Criteria Analysis (MCA) zullen enkele criteria geselecteerd worden waarop deze energiebronnen met elkaar vergeleken zullen worden. Deze vergelijking geschied op basis van AHP. Dit houdt in dat de criteria door deskundigen op het gebied van duurzame energie gewogen worden en vervolgens worden deze resultaten op de geselecteerde energiebronnen toegepast.

NOORDOOSTEN VAN MAROKKO

Marokko wordt in het noorden door de Middellandse zee begrensd. Dit brengt met zich mee dat in het noorden van Marokko een Mediterrane klimaat heerst. Deze klimaat kenmerkt zich aan warme, droge zomers en milde winters. Over het gehele jaar zijn er gemiddeld in dit gebied per maand 2700 zonuren. Boven zee, aan de kust van Nador, kan de windsnelheid tot bijna 6 m/s oplopen. Een andere eigenschap van dit gebied is de ligging nabij een breuklijn. Marokko ligt op de Afrikaanse plaat en daaraan grenzend in het noorden ligt de Euro-Aziatische plaat. Deze platen schuiven langs elkaar heen wat tot gevolg heeft dat er zo nu en dan aardverschuivingen in dit gebied zijn. Een andere bijkomstigheid is de aanwezigheid van warmwaterbronnen en ondergrondse warmte. Tussen de Middellandse zee en grenzend aan de stad Nador bevindt zich de Marchica lagune. Deze lagune heeft een oppervlakte van 115 km^2 en wordt middels een ingang naar de Middellandse zee voorzien van watervernieuwing.

DUURZAME ENERGIE

Gezien de eigenschappen van het gebied in het noordoosten van Marokko zijn er enkele duurzame energiebronnen in dit gebied kansrijk. Deze energiebronnen kunnen tot de bronnen zonne-energie, windenergie, waterenergie en geothermische energie worden teruggebracht. De eigenschappen van deze energiebronnen, die invloed hebben op de besluitvorming, staan in tabel 1 per bron weergegeven. Deze energiebronnen kunnen apart en ook in combinatie met elkaar toegepast worden. Dit zorgt echter voor hogere kosten per kWh dan op het moment dat ze onafhankelijk worden toegepast. De combinatie van waterenergie en geothermische energie komt bijvoorbeeld neer op € 0,13.

Eigenschappen	Solar energy	Wind energy	Hdyro energy	Geothermal energy
Kosten per kWh	€ 0,13	€ 0,12	€ 0,08	€ 0,05
Levensduur	25 jaar	25-30 jaar	20 jaar	20 jaar
Simpel infrastructuur	Simpel	Gemiddeld	Gemiddeld	Gemiddeld
Milieu vervuiling	Laag	Gemiddeld	Gemiddeld	Gemiddeld

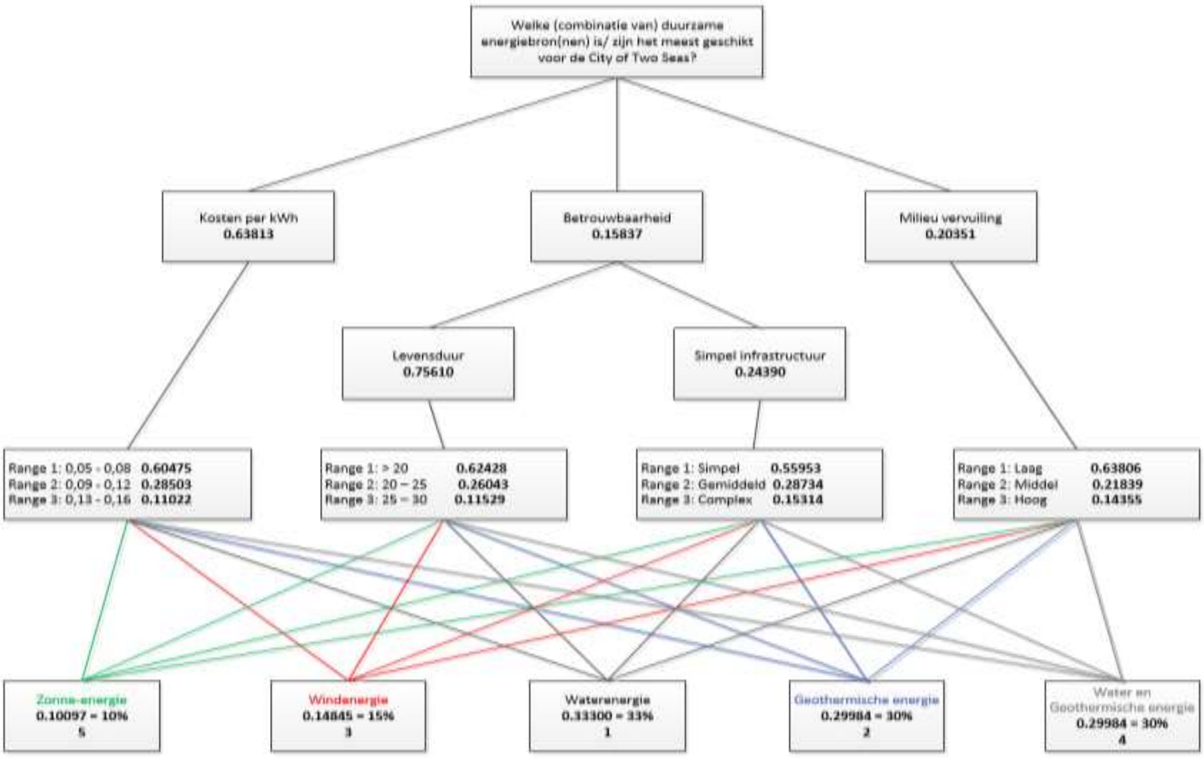
Figuur 1: Karaktereigenschappen van duurzame energiebronnen

BESLUITVORMING

Aan de hand van MCA en AHP wordt onderzocht welke duurzame energiebron of een combinatie van meerdere bronnen voor dit gebied het meest voordeligst zijn. Hiervoor zijn de criteria Kosten per kWh, Betrouwbaarheid en Milieu vervuiling geselecteerd. Deze criteria zullen aan de hand van een online enquête, die ingevuld wordt door deskundigen op het gebied van duurzame energie in Marokko, gewogen worden.

TOEPASSING OP EEN CASE

Door middel van het toepassen van deze uitkomsten op de City of Two Seas, zal onderzocht worden in hoeverre deze besluitvormingsmethode bij de besluitvorming bijdrage levert. Bij gebruik van de normalisatie formule van AHP en de gevonden data komen de uitkomsten naar voren zoals deze in figuur 2 terug te lezen zijn. Uit de figuur kan opgemaakt worden dat waterenergie als meest voordeligst naar voren komt. Twee duurzame energiebronnen gecombineerd, heeft geen voordelen tot gevolg.



Figuur 2: Hiërarchie en resultaten

CONCLUSIES

Volgens de deskundigen is het criterium Kosten per kWh beduidend belangrijker dan de andere criteria. Dit criterium beïnvloedt de rank van de duurzame energiebronnen het sterkst. De energiebron met de laagste kosten per kWh zijn daarom het meest gunstig. Het criterium milieu vervuiling heeft de laagste weging en daarom is dit criterium in de besluitvorming het minst belangrijk. Betrouwbaarheid heeft eveneens een lage weging. Zonne- en windenergie scoren voordelig op deze criteria. Dit in tegenstelling tot het criterium Kosten per kWh. Ondanks de gunstige scores in twee van de drie criteria zijn deze hernieuwbare energiebronnen toch het minst gunstig bevonden. Opmerkelijk is dat de meest gunstige hernieuwbare energiebronnen, waterkracht en geothermische energie, wanneer ze worden gecombineerd niet gunstig zijn.
In dit onderzoek wordt een studie voor het noordoosten van Marokko naar de meest gunstige duurzame energiebron gedaan en daarmee ook voor de City of Two Seas. Uit dit onderzoek kan geconcludeerd worden dat waterenergie het meest gunstig is. Economisch gezien is het voor MarchicaMed interessant om de toepassing van waterenergie in de City of Two Seas te overwegen. Gezien de missie en ambitie van MarchicaMed om duurzaam te ontwikkelen, is het tevens goed voor het imago van MarchicaMed om de toepassing van waterenergie te overwegen.
Dit onderzoek toont aan dat de toepassing van MCA en AHP een goed hulpmiddel bij de besluitvorming in duurzame energie is. Het gebruik van MCA en AHP, met inbreng van deskundigen, draagt bij aan de besluitvorming in duurzame energiebronnen in gebiedsontwikkeling.

DISCUSSIE

De wereldbevolking groeit exponentieel, daarmee groeit de energiebehoefte ook. Met de kennis van de uitputting van fossiele energie over ongeveer vijftig jaar geschied, is het verstandig om nu naar de mogelijkheden, om de uitputting van de fossiele energiebronnen uit te stellen, te kijken. Dit kan onder andere door nu onderzoeken naar alternatieve duurzame energiebronnen, die als bron gebruikt kunnen worden, te verrichten. Met dit onderzoek krijgt duurzame energie een platform. Dit platform zou kunnen bijdragen aan het overtuigen van besluitvormers en inspireren om duurzame energie in de gebiedsontwikkelingsprojecten toe te passen.
Besluitvorming is voor elk gebiedsontwikkelingsproject een uitdaging. De manier van de selectie van de beslissingscriteria in dit onderzoek met het gebruik van MCA kan als een uitgangspunt voor besluitvorming in soortgelijke projecten worden gezien.
Helaas zijn er in dit model nog wel beperkingen. Zo heeft het AHP model een aantal beperkingen op het gebied van criteria selectie, vaststellen van de ranges en de consistentie analyse. Het zal interessant zijn om in een nieuw model beter geselecteerde ranges te simuleren, waarna de consistentie controle wel voldoet. Verder hadden de deskundigen grote invloed op de uitkomsten. Interessant is om dit model met besluitvormers binnen MarchicaMed te simuleren en de resultaten met resultaten uit dit onderzoek te vergelijken.