EFFECTIVE SELECTION OF COUNTRIES IN SUB-SAHARAN AFRICA FOR INDEPENDENT WIND POWER PRODUCERS USING A MULTIPLE CRITERIA DECISION ANALYSIS

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Abstract

Subjective decision making can lead to results that are difficult to justify in cases where the outcome is unfavourable. This is the case in the wind energy industry where wind independent power producers (IPPs) assess new market entry opportunities. Decision analyses methods can assist decision makers when faced with difficult choices such as which market to enter.

Multi Criteria Decision Analyses or MCDA is one of the most preferred of many different decision analyses methods. MCDA ranks a set of criteria in order of importance and then, based on the results, ranks alternatives. There are many MCDA methods available and the most often used include the analytical hierarchy process (AHP), multi-attribute utility theory (MAUT), preference ranking organization method for enrichment evaluation (PROMETHEE), elimination and choice translating reality (ELECTRE) and technique for order preference by similarity to ideal solution (TOPSIS).

In this study a combination of MCDA methods are used to rank Sub-Saharan African countries based on preference for new market entry for wind IPPs. Nineteen different criteria were identified through a thorough literature review that were included in the analyses. The nineteen criteria were categorised into economic, technical, political and social criteria. The study was divided into two phases. In the first phase an industry expert survey was concluded and resulting from this survey the AHP was used to rank the criteria in order of importance. In the second phase PROMETHEE was used to rank seven Sub-Saharan African countries from most to least favourable for IPP market entry.

The expert survey and AHP showed that political and economic criteria are considerably more important than technical and social criteria. Governments have the ability to change both the economic and political landscape and should do so if they want to attract wind IPPs. On the other hand, technical and social criteria are more difficult for governments to change but these do not have as significant impact on market attractiveness.

The PROMETHEE model ranked South Africa as the most favourable market for wind IPPs to enter followed by Ethiopia, Namibia, Kenya, Mozambique, Nigeria and lastly Zambia. The top

two countries both have very strong natural wind resources and South Africa is the only country with incentives specifically and exclusively for on grid renewable energy. The least favourable two countries, namely Nigeria and Zambia, have almost no wind resource and a weak economic environment.

Future research can use MCDA methods, such as AHP and PROMETHEE, to assist in the evaluation of different market entry opportunities. These methods can also be adapted to investigate opportunities at country level i.e. analyse and compare different states/provinces with each other.

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Abbreviations

°C:	Degree Celsius
AHP:	Analytic hierarchy process
BAU:	Business-as-usual
CI:	Consistency index
CR:	Consistency ratio
CO_2:	Carbon dioxide
CBA:	Cost-benefit analysis
ELECTRE:	Elimination and choice translating reality
GW:	Gigawayy
GWh:	Gigawatt hours
IPP:	Independent power producer
kWh:	Kilowatt hours
MADM:	Multi-attribute decision-making
MAUT:	Multi-attribute utility theory
MCDA:	Multi criteria decision analysis
MCDM:	Multi criteria decision making
MODM:	Multi-objective decision-making
MW:	Megawatt
MWh:	Megawatt hours
NOx:	Nitrogen oxide
NPV:	Net present value
PROMETHEE:	Preference ranking organization method for enrichment evaluation
RAE:	Regulatory Authority for Energy
REIPPPP:	Renewable energy independent power producer procurement programme
RI:	Random consistency index
SSA:	Sub-Saharan Africa
SWOT:	Strengths Weaknesses Opportunities and Threats
TOPSIS:	Technique for order preference by similarity to ideal solution
TWh:	Terawatt hours

Glossary

Bankable: a project or contract is said to be *bankable* if it comprises a level or risk allocation which would be generally acceptable to lenders. (Power Africa, 2016)

Baseload Power: generating capacity within a national or regional grid network that the offtaker or grid operator intends to dispatch or utilise on a continuous basis. (Power Africa, 2016)

Cost-reflective tariffs: tariffs charged to end consumers which reflects the true cost of generation, transmission, distribution and supply to end consumers. (Power Africa, 2016)

Independent Power Producer / IPP: privately-owned producer of electricity. (Power Africa, 2016)

Grid: a system of high tension cable by which electrical power is distributed throughout a region. (Power Africa, 2016)

Grid Code: a technical specification which defines the parameters a facility connected to a public electric network has to meet to ensure safe, secure and economic proper functioning of the electric system. The facility can be an electricity generating plant, a consumer, or another network. Wikipedia

Megawatt: a measurement of power meaning 1,000,000 watts. (Power Africa, 2016)

Offtaker: the party to a PPA (see below) whose obligation is to purchase the capacity made available and the electricity generated by the power plant, subject to the terms and conditions of the PPA. Also referred to as the Buyer. (Power Africa, 2016)

Power Purchase Agreement / PPA: a contract between two parties, one which produces or generates power (seller/producer) for sale and one which purchases power (buyer/offtaker), this agreement can also be referred to as an offtake agreement. (Power Africa, 2016)

Chapter 1: Introduction

1.1 Introduction

Energy is one of the most important factors for a country's economic and socioeconomic growth (Eggoh et al., 2011). Generally energy demand and economic growth increase at the same rate, illustrating the relationship and strong dependence on each other (Eberhard et al., 2008). The historic growth in electricity generation and consumption worldwide has been tremendous, increasing nearly fourfold from 6 131 TWh to 23 322 TWh in the past 40 years (1973 to 2013) (IEA, 2015). Energy demand will continue to rise as the global population size increases and if current consumption patterns persist, the world's energy demand will increase a further 50% by 2030 (Sahu, 2015).

The majority (approximately 80%) of this energy is produced from fossil fuels which have severe impacts on the environment and are widely known to be a leading cause of global warming (Jacobsson and Bergek, 2004). Carbon dioxide (CO_2) emissions have more than doubled between 1973 and 2013, from 15 515 Mt of CO_2 to 32 190 Mt of CO_2 as a direct result of oil, coal and natural gas usage (IEA, 2015). To reduce impacts on the environment countries around the world agreed to ambitious CO_2 emission reduction targets which will see participating countries taking great steps to reduce greenhouse gas emissions by moving away from fossil fuels towards renewable energy with the overall aim of restricting global warming to less than 2^oC. To achieve this the share of renewable energy in the global energy mix has to double by 2030 and energy efficiency efforts have to double annually (IRENA, 2016a).

1.2 Background

Energy in sub-Saharan Africa

Sub-Saharan Africa (SSA) is undoubtedly one of the regions with the biggest energy challenges (Karekezi and Kithyoma, 2002). While most developing countries face energy shortages, SSA countries lag even further behind other developing countries because of the slow pace of 1.7% at which new generation has been developed and brought online (Bazilian et al., 2012, Deichmann et al., 2011). While 13% of the world's population live in SSA, it only accounts for

4% of the world's energy demand and of the more than 900 million people living in SSA only about a third have access to electricity as shown in Figure 1(a) (IEA, 2014b, Eberhard et al., 2008, IRENA, 2016b). In 2012 roughly half of the 90GW generation capacity of SSA was located in one country, namely South Africa (IEA, 2014b). It is not just the lack of generation which is a hindrance to supplying the region with electricity, but also the poorly developed and maintained grid and substation infrastructure (with the exception of South Africa). Less than 25% of people in SSA are grid-connected and if the current slow pace of grid expansion continues, this figure will remain below 40% by 2050 (Eberhard et al., 2008, Brew-Hammond, 2010).

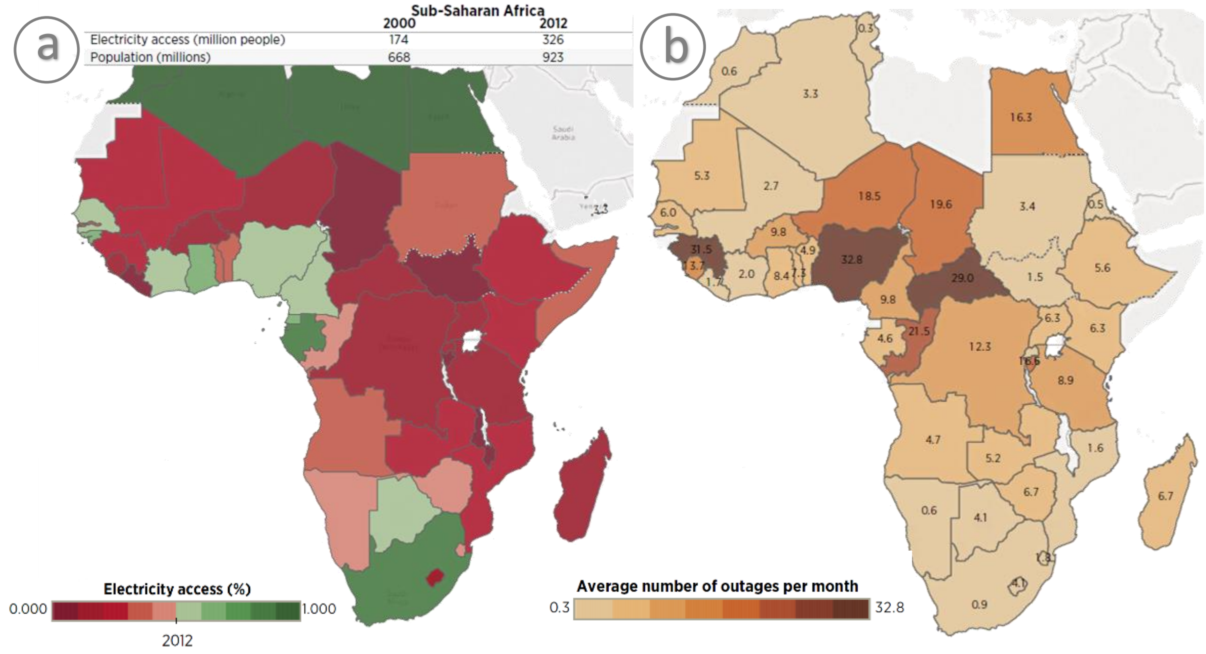


Figure 1: a) Electricity access and b) average number of outages per month in Africa taken from IRENA (2016)

The small percentage of people in SSA who are connected to the grid experience unreliable electricity supply as illustrated in Figure 1(b). If a guaranteed constant supply of electricity is needed an expensive back-up generator will be required (Eberhard et al., 2008). Without back-up supply, manufacturers in SSA typically experience 56 days of power outages per year, which is extremely high especially when compared to the United States who in comparison experience one every ten years (Eberhard et al., 2008). The lack of generation, grid infrastructure and reliable supply result in an extremely low per capita electricity usage of

457kWh and if South Africa is removed from this figure it drops to 124-155kWh (Eberhard et al., 2008, Bazilian et al., 2012). To put this into context, the average per capita usage in other developing countries is 1,155kWh and in developed countries this figure is around 10,000kWh (Eberhard et al., 2008).

The severe energy shortage in SSA is undermining the economic and socioeconomic growth of the continent (Eberhard and Shkaratan, 2012). Energy access is not only important for economic growth, but also increases the general quality of life of people by improving their healthcare, education and economic opportunities (IEA, 2014a, Deichmann et al., 2011). If the African continent wants to overcome its poverty challenges the energy shortage will have to be addressed as a primary concern (Brew-Hammond, 2010, Bazilian et al., 2012, Deichmann et al., 2011). To achieve this a tremendous amount of investment will be required - it is estimated that the power sector in Africa will need around $40.8 billion a year (Eberhard and Gratwick, 2011).

Meeting sub-Saharan Africa’s energy needs

Research suggest that renewable energy should take centre stage in the drive to increase electricity generation across SSA and it is estimated that by 2040 about half of new generation will come from renewable energy (IEA, 2014b, Bazilian et al., 2012, Deichmann et al., 2011, Suberu et al., 2013). Hydropower is the only renewable energy source that has been rolled-out on a large scale in SSA with a current installed capacity of over 20GW, but potential for hydropower remains vast with about 93% of the continent’s economically feasible hydropower not utilised (IEA, 2014b, Eberhard et al., 2008, Karekezi, 2002). However, Africa’s reliance on hydro power has caused problems as droughts struck several countries on numerous occasions, dramatically reducing generation output. This has highlighted the importance of a diversified energy mix, especially expanding wind and solar generation. Countries in SSA have predominantly turned to solar power to achieve a diversified energy mix due to the high solar resource in most countries, the simplicity of development and the significant price reduction of 65% since 2010 (which is expected to continue to decline) (IEA, 2016). Another advantage of solar power is that it can address energy needs both on and off-grid and varying sizes, from a few kWs to 100’s of MWs.

While SSA is making strides in exploring hydro, with 20GW installed, wind and solar as renewable energy sources remain underutilised (IEA, 2014a). The total wind potential for SSA is estimated to be around 1300GW, more than fourteen times the current installed capacity (IEA, 2014a). Wind development is more complex than solar development, has different and often greater environmental impacts and the resource is not at a similar level with some countries having a high wind resource and others barely any. However, while wind energy is more restricted and complex to develop it still has great potential on the African continent and can provide energy at a cheaper cost than solar. For example projects commissioning between 2016 and 2019 show lower prices for wind compared to solar. In South Africa wind is USD52/MWh while solar is USD65/MWh. In the United States wind prices are USD47/MWh and solar prices between USD65-70/MWh, and similarly in Peru wind is USD38/MWh while solar is USD49/MWh (IEA, 2016). Onshore wind had price reductions of 30% from 2010 to 2015, not as much as solar but overall the technology is still cheaper than solar (IEA, 2016).

While it is clear that there is plenty of renewable energy resources to utilise, there are still many challenges hindering development of these resources in SSA countries. The list of challenges is long and has been studied and highlighted in literature (Painuly, 2001, Beck and Martinot, 2004). The most common non-financial challenges include: grid infrastructure constraints, non-cost reflective tariffs, a lack of political will, policies and stability, high levels of corruption, lack of renewable energy knowledge and credit worthiness of state-owned utilities who act as the electricity offtakers.

- Grid infrastructure is one of the biggest problems when considering the energy situation of SSA (Bugaje, 2006). As mentioned, most people in SSA are not yet grid connected (Fig 1 (a)) and therefore before adding large scale renewable energy (or any other technology) to the grid, infrastructure has to be upgraded and expanded to ensure the quality and quantity of electricity supply.
- Electricity tariffs are high in SSA, however they remain lower than the average operational cost. Very few customers pay cost reflective tariffs, currently the average tariff is US0.17/kWh while the cost reflective tariff is around US0.27/kWh (Eberhard et al., 2008). Governments remain reluctant to increase tariffs to reflect full cost because it is met with resistance from the end users and governments are afraid of becoming unpopular (especially leading up to elections). Non-cost reflective tariffs

negatively influences the investor confidence level with regards to an offtaker's ability to meet payment obligations (Power Africa, 2016).

- Political will, political stability and clear policies are also largely missing in SSA. The first step for renewable energy addition is a political will to do so (Deichmann et al., 2011). Hand-in-hand with this are clear policies and regulatory frameworks to assist and direct renewable energy developers (Power Africa, 2016).
- While corruption is a global problem, it is magnified in Africa. It is not restricted to the power industry, but is prominent in all industries. Companies are wary to enter markets with high corruption levels and 86% of African CEO's are concerned about bribery and corruption illustrating the extent of the problem in Africa (PwC, 2016).
- A greater understanding of renewable energy will assist in adding additional MWs to the grid. Knowledge on how to integrate wind or solar into the grid is essential but many utilities are unfamiliar with renewable energy grid integration and simply reject the possibility (Beck and Martinot, 2004). Most countries in SSA do not even have a renewable energy grid code to guide developers and use a standard grid code for both base load and intermittent power.
- Generally the offtakers for power projects in SSA are state-owned utilities with weak credit ratings and high inefficiencies (Eberhard and Shkaratan, 2012). The result is that the power producer requires a sovereign guarantee to ensure bankability of the power purchase agreements. The first step to a solution for this problem is to unbundle a utility's generation, transmission and distribution division, however SSA has been slow at best to do this and some countries are not interested in this reform at all. If these divisions are unbundled it will introduce competition and open the door for the private sector to participate in not only generation, but also distribution of electricity (Eberhard and Gratwick, 2011, Williams and Ghanadan, 2006, Besant-Jones, 2006).

The role of independent power producers

To exploit its vast renewable potential SSA countries will need to increase the participation of independent power producers (IPPs). Slowly but surely countries are procuring wind (and solar) from IPPs and the most common mechanisms are feed-in tariffs or competitive tenders. This focus on renewable energy and IPPs is changing the energy sector, shifting investment into the sector from traditional government and international donors to independent companies and banks (Martinot et al., 2002).

South Africa has arguably been the most successful SSA country to add large scale renewable energy to the grid by introducing IPPs to the market. South Africa procured wind, solar and other technologies through a competitive tender called Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) which started in November 2011 and is still continuing to date. This programme is a government run programme under the Department of Energy and an independent office has been setup to administer the IPPs (2010). In REIPPPP IPPs compete on both price and socioeconomic development (SED), thus resulting in numerous benefits not just restricted to energy generation. In total 79 wind and solar PV projects with an accumulative capacity of 5649MW have been awarded through this programme. Many of these projects are already in the operational phase while others are in construction or in the process of reaching financial close.

Other successful programmes include the World Bank IFC's Scaling Solar programme and KfW's GetFit programme which have been implemented in Uganda, Zambia, Senegal and Madagascar and is expected to launch in other SSA countries including Ethiopia, Namibia and Mozambique. These programmes are not run by the Governments as is the case with the South African REIPPPP, but they do work together with the government and utilities. Both Scaling Solar and GetFit are attractive for IPPs because independent financial institutions, offering a well-structured and proven programme with the key-elements required to ensure bankability, run it. However these programmes only procure solar and there are no equivalent procurement programmes for wind in any countries in SSA. If countries want to add wind energy to the grid they will have to run a similar procurement programme as REIPPPP in South Africa. Alternatively they can negotiate bilateral deals directly with IPPs, but competitive tenders are more likely to result in the lowest possible tariffs. The success of tender programmes depend on their ability to attract market-leading IPPs to increase the competition.

Unfortunately IPP's can't enter every market because of the costs, risks and low success rate associated with these procurement programmes forcing them to be selective on the markets they enter. For example, in REIPPPP the success rate is extremely low. In round 1 of REIPPPP, 53 bids were submitted and 28 awarded (success rate of 53%), in round 2 the success rate decreased to 24% with 79 bids submitted and 19 awarded and in round 3 it decreased even further to 18% with 93 bids submitted and only 17 awarded (Eberhard et al., 2014). Therefore, while governments are hoping to attract IPPs to the country's energy market, IPPs have to look for the best markets with the highest possibility of success and lowest risks.

IPPs have to consider many factors when investigating a market entry opportunity. The factors will vary in importance from an IPPs perspective and will consequently be weighted and compared against each other (Beim and Lévesque, 2006, Gokmenoglu and Alaghemand, 2015, Wijnja, 2014). Factors under considerations for market entry (in the case of wind energy) include a wide variety that can broadly be categorised into four categories namely social, economic, political and technical (Wijnja, 2014). The importance of these categories and their subcategories have been investigated in numerous studies for various industries, but never for onshore wind in SSA (Beim and Lévesque, 2006, Nganga and Maruyama, 2015, Wijnja, 2014). Wijnja (2014) did look at some of these factors for airborne wind in many countries globally, however airborne wind is a young technology, which is not yet commercially viable, and hence these factors will be weighted differently. Airborne wind works on the same principle as conventional ground based turbines to generate energy from wind. The difference is that a tether substitutes the turbine tower and the rotor blades are replaced with a flying structure. The concept of airborne wind technology is attractive because it uses less material and can reach higher altitudes, therefore they have potential to generate energy at a lower cost.

The difficulty IPPs (and companies from other industries) face is that it is hard to compare different factors between countries because of the way they interact with each other and consequently shape a unique market for each country (Nganga and Maruyama, 2015). The problem that arises from this difficulty and the problem which forms the basis of this research, is that more often than not the decision whether or not to enter a new market is done on a subjective and gut-feel basis rather than on an objective and analytical basis (Beim and Lévesque, 2006). While a subjective opinion can be informative it is clear that the complexities of comparing similar factors across different markets will require a more analytical and objective approach. Formal analytical decision making approaches, such as multi criteria decision analysis (MCDA), include the formulation and measurement of knowledge about the decision making process and investigates different outcomes, providing a more reliable and consistent outcome which can be re-applied to different situations. Analytical approaches are often time-consuming, difficult to understand and the data required is not always freely and easily available. In addition to this, the academic literature investigating the attractiveness of SSA countries for multinational enterprises is very limited (Nganga and Maruyama, 2015).

As more and more SSA countries initiate or increase renewable energy procurement, IPPs are faced with the daunting task of deciding which new markets to enter. If decisions are made on an ad-hoc and subjective basis it is difficult to defend the market choice in the unfortunate event that market entry fails. A more formal decision making process, such as MCDA, will assist in reducing market entry risk. This research will assist IPPs who specialise in wind energy and who evaluate new markets entry in SSA.

1.3 Problem statement

The research problem that will be addressed in this research is:

Wind IPPs generally subjectively assess new markets and insufficient attention is paid to important criteria that are analysed in an unstructured manner. The result is a subjective decision that is difficult to justify if market entry fails or if an opportunity was missed.

1.4 Research questions

The research questions this research aims to answer are:

1. In what ways can the use of decision analysis and more specifically MCDA provide a more rigorous assessment for comparing entry of new markets for renewable energy in SSA?
2. What are the criteria IPPs consider when comparing new markets for renewable energy and how do these criteria rank in terms of importance?
3. Based on these ranked criteria, which markets in SSA are most attractive for wind IPPs?
4. In what ways, by using the established criteria for market identification, are countries able to create a more favourable environment for wind IPPs?

1.5 Research aim

The aim of this study is to determine and rank the most important criteria when evaluating market entry and then, using these ranked criteria, to determine which selected countries in SSA are most favourable for wind IPPs.

1.6 Research proposition

The research proposition tested in this study is that by using an analytical method, such as MCDA, to assess criteria for new market selection, market selection will be more successful compared to only using subjective opinions.

1.7 Objectives

The research objectives of this study are to:

1. Identify the criteria wind IPPs currently consider when evaluating new markets.
2. Expand and assess these criteria and determine their ranking of importance through a survey and the AHP weighting method.
3. Survey and evaluate the extent to which selected SSA countries meet these criteria.
4. Rank various SSA countries based on their attractiveness for wind IPPs using a MCDA.
5. Make recommendations for countries to create a more favourable environment for wind IPPs.

1.8 Research methodology

The first phase of the study will identify which criteria wind IPPs consider important when evaluating a new market. A list of market selection criteria will be developed from the reviewed literature such as Wijnja (2014) and others. The selected criteria will be incorporated into a survey that will require key business developers in the wind IPP industry to rank these based on their perceived importance of the criteria. The next step will be to weight the criteria using an analytical method called the AHP method. The AHP method was developed by T.L. Saaty in 1971 to 1975 as a theory of measurement used to derive ratio scales (Saaty, 1987). The advantages, drawbacks and limitations of the AHP method will be discussed in the literature review (Chapter 2).

In the second phase of the study a comparative analysis of the energy market of seven SSA countries will be conducted to rank them from most to least favourable based on the criteria and weighting determined in the first phase. The selected countries are Ethiopia, Kenya, Mozambique, Namibia, Nigeria, South Africa and Zambia. Each of these countries will be assessed in full for their renewable energy (and more specifically wind energy) readiness with regards to IPPs. These countries will subsequently be ranked from most to least favourable using a MCDA.

Many methods are available to rank countries including cost-benefit analysis, Delphi techniques, SWOT (strengths, weaknesses, opportunities and threats) analysis and lastly multi-criteria decision analysis (MCDA). These various ranking techniques will be evaluated and reviewed in more depth in the literature review (Chapter 2). MCDA has become extremely popular in renewable energy studies in recent years and is preferred to the other methods in this study. The cost-benefit analysis was rejected because of the assumption that all attributes can be converted to a monetary amount. SWOT analyses is appropriate for assessing each market individually, but is rejected because of its lack of ability to compare different markets to each other. Delphi techniques are rejected because they have a lower scientific justification compared to the other methods. Therefore a multiple criteria decision analysis (MCDA) method will be used to rank the countries in order of attractiveness for wind IPPs.

1.9 Limitations

This study is subject to the following limitations:

1. This study does not consider the vast off-grid and self-production market and purely focuses on grid connected energy generation.
2. This study is limited to analysing countries in SSA for potential wind energy investment.
3. This study will be subject to the limited size of the wind IPP industry.

1.10 Outline of research dissertation

This dissertation is divided into five chapters of which this is the first. The remaining four chapters will cover the following:

Chapter 2 is a literature review on the decision making process and the different methods available for ranking market selection criteria and country selection. In addition, the current criteria considered important for new market selection in the energy sector is reviewed.

Chapter 3 introduces the methodology (survey and AHP method) and data analysis for identifying and weighting the market selection criteria. Also in this chapter the methodology (MCDA method) and data analysis for ranking the SSA countries is presented.

Chapter 4 presents the results of the analyses described in chapter 3 and ranks the SSA countries based on the weighting of criteria.

Chapter 5 concludes the research of the dissertation and makes recommendations for countries who wish to create a more attractive market for IPPs.

Chapter 2: Literature Review

The objective of this study is to identify the most favourable countries for IPPs to enter, which is as a problem IPP decision makers face and therefore requires decision analysis. The attractiveness of markets (alternatives) have to be compared with each other using various criteria (economic, technical, environmental and social). Different decision analysis methods including cost-benefit analysis, Delphi techniques, SWOT and MCDA are reviewed to determine the preferred method for comparing and ranking countries based on criteria identified in literature. MCDA is considered to be the most favourable method and the various different MCDA methods (AHP, MAUT, PROMETHEE, ELECTRE and TOPSIS) is discussed further.

Decision analysis

Keeney (1971) defined decision analysis as a concept and procedure for systematically analyzing problems in a rational manner designed to improve the decision making process. Decision analysis is arguably the most important and most risky aspect of running a business and therefore researchers have spent a lot of time to understand how we make decisions (Hammond et al., 1998b). Complex decision problems normally have high stakes, complicated structures, there is no overall expert and most importantly, decision makers need to be able to justify their decisions (Keeney, 1982). Research shows that we use unconscious routines, known as heuristics, to make decisions in complex situations (Hammond et al., 1998b). Heuristics work in most situations when we make simple day to day decisions (Hammond et al., 1998b), for example judging the distance of an object. However when it comes to more complex decisions, heuristics can have detrimental consequences, for example when a pilot judges an object further away than it is on a foggy day.

Decision makers are prone to common mistakes hindering the decision analysis process, Hammond et al. (1998b) list the most common mistakes including anchoring, status quo, sunk costs and estimating and forecasting. Anchoring occurs when a person disproportionally weights the initial information received. Status quo refers to favouring alternatives that perpetuate the existing situation. Sunk costs are choices made to justify past failed decisions. Estimating and forecasting is when a person is overly influenced by memories (Hammond et al., 1998b). The biggest problem with these “mistakes” is that decision makers are unaware of them in most instances.

Making a decision is not straightforward and apart from the common mistakes outlined above, various factors contribute to making problem solving more complex. Keeney (1982) lists these factors which include multiple objectives, difficulty of identifying alternatives, intangibles, long time horizons, many impacted groups, risk and uncertainty, risk to life and limb, interdisciplinary substance, decision makers value trade-offs, risk attitude and the sequential nature of decisions (see Table 1 below). Although not all of these factors are present in every problem, it illustrates the factors that can contribute to complexity. Of these factors multiple attributes and uncertainty are arguably the most common and important to consider. A simple decision is one where there is only a single attribute to consider, for example, a municipality that wants to procure the cheapest energy source with coal or solar power being the two available options. In this scenario the municipality is only concerned with a single attribute namely cost, so it only has to address whether coal or solar will be cheaper. A multiple attribute problem would be if the municipality wants to procure the cheapest energy and have the lowest impact on the environment, now the municipality has two attributes to consider namely cost and environmental impact and the answer is not as simple as in the first scenario where only cost was considered. In life most problems are multiple attribute problems as opposed to single attribute. Adding uncertainty to the mix complicates this further. Uncertainty is introduced when the outcome is not guaranteed, for example will a company enter a market where there is a 50% chance of a 1 billion US dollar profit or where there is a 20% chance of a 10 billion US dollar profit. Uncertainty is attached to all complex problems people are faced with.

The decision analysis process can be divided into four steps (see Table 1 below): structure of the problem to be analysed, assess the possible impacts of alternatives, determine preferences of the decision makers and evaluate and compare each alternative (Keeney, 1982).

In the first step, *structure of the problem to be analysed*, objectives are outlined, alternatives are created and their importance relative to each other is identified (in the case of more than one objective) (Keeney, 1982). Keeney (1996) describes how to set the objectives for a decision analysis. He firstly distinguishes between fundamental and means objectives.

Fundamental objectives are the essential reasons for interest in the situation while mean objectives help to achieve the fundamental objectives (Keeney, 1996). Fundamental objectives are the primary objectives while mean objectives are secondary objectives. After identifying the objectives the alternatives are created. The alternatives illustrate the dynamic nature of the decision analysis in that it does not just address the action to be taken now, but also the future action points and the events that will occur in between (Keeney, 1982).

During step two, *assess the possible impacts of alternatives*, an in-depth evaluation of all consequences for each alternative is carried out. In this step it is important to spend time making sure all possible consequences are identified. The next aspect of this step is to determine the chances or probability of each of the consequences occurring (Keeney, 1982).

Step three, *determine the preferences of the decision makers*, involves the issue of trade-offs. It is highly unlikely in complex problems that one alternative will give the best consequence for all objectives. Instead each alternative is likely to have some undesired potential consequence, the result is that it must be questioned whether the potential benefit is worth the risk, if things go wrong. Weighting the trade-offs is not an easy or straight forward task. While certain methodologies have been proposed to assess and weight trade-offs, in most instances assessment use personal instinct, common sense and guess-work (Hammond et al., 1998a). Even when quantitative methods are used, these do not necessarily give the right answer and tend to over simplify assumptions (Keeney, 1971).

The fourth step, *evaluate and compare alternatives*, require that all the information from the first three steps is combined and the different options are compared by creating a utility for each alternative, thereby creating a ranking system (Keeney, 1982). Inherently all decisions have a degree of subjectivity attached to them as illustrated by Von Neumann and Morgenstern (2007), Pratt et al. (1964) and Mahalanobis (1954). They highlight that the attractiveness of alternatives will depend on the likelihood of the consequences of each alternative and secondly on the decision maker's preference for these consequences. Therefore, while it is impossible to make a decision without any subjectivity, the key is to have an objective conclusion or answer.

The four steps in the decision analysis process and the complexities faced in each step is given in Table 1 below. An explanation of each complexity is also provided. This table is effectively a summary of the decision analysis section.

Table 1: Steps in the decision making process and accompanying complexities (adapted from Keeney (1982))

Step in decision analysis	Complexity	Explanation
Structure of problem to be analysed	Multiple objectives	In an ideal scenario multiple objectives are achieved with one alternative, however since this mostly not the case, the importance of each objective should be identified and also the degree to which each alternative satisfy the objectives.
	Difficulty of identifying good alternatives	Different factors affect the desirability of an alternative and creativity is required to come up with unique and strong alternatives
	Intangibles	This involves the difficulty of evaluating and measuring nonmaterial issues, for example the moral of a workforce
	Many impacted groups	A decision often involves and affects groups with different priorities and values and therefore it is important to be fair and impartial.
	Sequential nature of decisions	In most cases decisions are linked to one another, a decision made today will affect the alternatives in future and their attractiveness.
Assess the possible impacts of alternatives	Long-time horizons	A decision's consequences is sometimes only realised after a long time. Therefore the future consequences of alternatives should also be taken into consideration in the decision making process.
	Risk and uncertainty	It is impossible to predict all consequences of an alternative so each alternative involves a level or risk and uncertainty.
	Risk to life and limb	This refers to the concern that the decision can result in fatalities or morbidity.
	Interdisciplinary substance	No single person has expertise in all fields, instead qualified professionals should be used to supply information.

Determine preferences of decision maker	Several decision makers	It is rarely up to one person to make a decision, instead a few people with different outlooks are involved.
	Value trade-offs	Since not all objectives can be achieved in most cases, decisions require trade-off between values reflecting desirability. For example impact on the environment for economic gain.
	Risk attitude	Different firms have different risk appetites and this determines the chances people will take. It should be clear what the risk appetite is when considering alternatives and associated risk.
Evaluate and compare each alternative		

Decision analysis in renewable energy

Decision making in the energy sector was initially a single criteria decision framework only concerned with achieving the lowest cost, however the increasing impact on the environment changed this (Pohekar and Ramachandran, 2004). Fossil fuels are a significant contributor to the increase in carbon dioxide in the atmosphere, which is a leading driver of climate change. The results of climate change include the melting of glaciers and the Greenland and Artic ice sheet which is happening faster than ever before (Solomon et al., 2009, Wijnja, 2014). The melting of glaciers and ice sheets along with ocean thermal expansion increases the sea level and so increases the risk of large scale flooding (Wijnja, 2014). These are just some of the severe environmental impacts associated with carbon dioxide emissions that led to the change in thinking in the energy sector. The energy sector is now not only concerned with the lowest cost, which is the economic consequence, but also technical, environmental and social factors (Painuly, 2001). There are many methods suitable to assess these factors and make informed decision. The most commonly used methods include cost-benefit analysis (CBA), Delphi techniques, strengths, weaknesses, opportunities and threats analysis (SWOT) and multi-criteria decision analysis (MCDA).

Cost-benefit analysis

Credit for the development of the CBA is given to the French engineer Dupuit and his publication in 1844. Dupuit established the foundation for marginal analysis, defining how costs and benefits should be measured and introducing what is the crux of CBA, namely that in an investment decision the benefits should outweigh the costs (Pearce, 1998). The CBA method estimates a monetary value for the costs and benefits, calculating the net present value (NPV) of each alternative over the entire lifetime of the project. The NPVs for different alternatives are then compared with each other and the alternative with the highest NPV is the preferred option. An extension of the traditional CBA is the social cost benefit analysis which attempts to incorporate the social aspect of alternatives, for example the traditional CBA would not take into account the air pollution as a by-product of a coal fired power plant, whereas the social CBA will.

CBA features frequently in renewable energy decision making. CBA is an effective tool in evaluating the financial feasibility of a project. Moran and Sherrington (2007) used CBA to determine the economic feasibility of a wind farm in Scotland, taking positive and negative externalities into account, for example greenhouse gas emissions from conventional fossil fuel, carbon dioxide released through deforestation for wind farm site preparation and visual and noise impacts of wind farms. Their conclusion was that in all but one scenario the wind farm was financially viable, returning a positive NPV. In Snyder and Kaiser (2009) CBA is used to compare offshore wind with onshore wind and conventional fossil-fuelled energy. The authors note the difficulty of comparing environmental impacts between these different technologies because they impact completely different ecosystems, making it impossible to directly compare. Decreasing commodity cost and enforcing legislation capping greenhouse gas emissions will make offshore wind more profitable, but not compared to onshore wind. Until land use conflicts increase or technology more favours offshore turbines, onshore wind will remain cheaper than offshore wind. With regards to conventional fossil-fuelled energy, if a premium is imposed on coal-fired power to offset carbon emissions, offshore wind might become competitive versus coal. Coal uses more water than offshore wind which has a significant environmental impact. However to balance this offshore wind has a greater ecological impact with regards to bird and bat mortalities and therefore the authors settle that it is difficult to say which will be preferred. They concluded that in most cases offshore wind will be more expensive than onshore wind and conventional fossil-fuelled energy, but noting that it is case specific due to the economic and ecological cost that will differ between sites.

The effectiveness of CBA is not restricted to measuring the feasibility of a project or technology, but is also used in energy planning. For example, Diakoulaki and Karangelis (2007) used CBA and MCDA to evaluate four scenarios, each including a different technology mix for the expansion of the electricity system in Greece. The four scenarios were developed by official authorities. The scenarios included business-as-usual (BAU) drawn up by the Regulatory Authority for Energy (RAE) of Greece, assuming a continuation of recent trends and is linked to the long term use of conventional fuels. The second scenario was created by the Power Public Corporation who represents the biggest energy players in the market. This scenario assumed the use of both lignite, a type of coal, and renewable energy. The third scenario, drawn up by the National Observatory of Athens, is the climate change reduction scenario aiming to fight climate change and thus has the highest penetration of renewable energy of the four scenarios. The fourth scenario is the unsteady condition scenario, also drawn up by RAE and assumed a faster increase in electricity demand than the BAU scenario. This scenario used even higher levels of lignite than BAU. Taking economic, technical and environmental criteria into consideration both CBA and MCDA evaluations showed that the scenario with the highest renewable energy penetration was optimal.

CBA presents an effective way to compare different alternatives with each other. It is also a useful tool to assess projects on their own, by determining a positive or negative NPV which illustrates the viability of a project. The main limitation of CBA is that it assumes a monetary value can be quantified for all attributes which, in reality, is unrealistic to achieve (Wijnja, 2014). For example, many have raised the issue of whether a monetary value can be assigned to human life and what the consequent moral and ethical principles are (Brans and Vincke, 1985, Kelman, 1981).

Delphi technique

The Delphi technique was mostly developed by Dalkey and Helmer in the 1950s at the RAND Corporation, www.rand.org, while involved in a project sponsored by the U.S. Air Force (Dalkey and Helmer, 1963). This method was introduced to study topics that had a high level of uncertainty for example military potential of future technology, war prevention, weapon systems and potential political issues (Gordon, 1994, Wijnja, 2014). The end goal is to obtain the most reliable consensus of opinion of risk levels of a group of experts. The technique gathers information from experts via a series of two or more surveys, with the end goal of reaching general consensus. There are four features that are required for successful general consensus using the Delphi technique (Rowe and Wright, 1999). The first is anonymity in answers, which is achieved by allowing a participant to answer questions and express views privately, eliminating potential social pressure. The second is several iterations, meaning more than one round of input and feedback, thereby allowing participants to modify their opinions. The third is controlled feedback. After every iteration, feedback on the group's overall response is given to each participant ensuring that everyone's opinion is heard and not only the most vocal person. Fourth is the statistical aggregation of responses, the group's overall view is recorded as the average of the participants in the final round, therefore equal weighting is given to the participants' opinions.

Delphi techniques are less frequently used in renewable energy decision making than CBA, but is still valuable for certain scenarios. For example, Varho et al. (2016) used the Delphi technique to study the opportunities and challenges of distributed small-scale renewable energy in Finland. They used 26 experts within the renewable energy industry to provide input over two survey sequences. Five very different scenarios were produced highlighting the uncertainty of distributed renewable energy in Finland. The main barriers identified preventing expansion and growth of distributed renewable energy included underdevelopment of key business concepts, a lack of information available, a shortage of essential professional services, insufficient profit margins of small-scale energy sales and production cost. In Celiktas and Kocar (2010) the Delphi technique was used to evaluate the future renewable energy market in Turkey. The participants included sector representatives and two sequences of questionnaires with response rates of 20.1% and 84.9% respectively. They concluded that Turkey will reach 50GW installed renewable energy by 2020 and that 50% of Turkey's energy demand will be met with renewable energy by 2030. The study also showed that all renewable energy technologies will provide economic and environmental benefits. In addition to this it will also increase the living standard for most people by improving health and safety, education, employment, interrelationship and cultural and recreational opportunities.

The Delphi technique is based on the assumption that the opinion and input of experts results in the most widely considered and therefore accurate outcome, however critics have argued that this technique has a low scientific basis (Murray, 1979, Pill, 1971, Tichy, 2004, Welty, 1972). However, these studies also acknowledge that if there is limited data available inhibiting the use of other methods, the Delphi technique is considered the best solution.

SWOT analyses

The exact history of SWOT analysis is unknown. Some claim it was developed during the 1960s and 1970s through research led by Albert Humphrey, however there is no academic reference thereof and the first academic reference is that of Learned et al. (1969) (Wijnja, 2014, Helms and Nixon, 2010). With this method, strengths and weaknesses are indicators for the internal environment whereas opportunities and threats are indicators for the external environment.

SWOT analysis is frequently used for renewable energy assessment, especially in energy planning. This is illustrated in Terrados et al. (2007) where SWOT analysis was used to evaluate and expand the energy plan for the province Jaén, located in southern Spain. The energy plan was focused on implementing renewable energy resources. The authors note the success of the current expansion of renewable energy and acknowledge that the province of Jaén is addressing its weaknesses. For example, electricity generation capacity improved through the installation of an additional 80MW. The study highlights that SWOT analysis is efficient and suitable for evaluating energy planning through highlighting problems and illustrating future action lines for further enhancement of renewable energy at the local level.

In Markovska et al. (2009) SWOT analysis is used to understand the current energy market and to plan towards sustainable energy development in Macedonia. The study highlights the achievements to date and identified problems areas before concluding with several recommendations for sustainability in the energy market. The adoption of the European Union's energy policy and regulations is the biggest accomplishment in the energy sector. The study listed the biggest hurdles in the energy sector as energy production from domestic low-quality lignite, under-valued electricity prices, low levels of energy efficiency in generation and demand and lastly a lack of institutional and personnel capacities. Steps toward energy sustainability include an energy strategy incorporating climate change principles, changing the energy mix and including a higher use of natural gas, cost reflective energy rates, implement energy efficiency on users, adopt a renewable energy strategy with specific targets, enforcement EU standards and lastly building capacity in the energy sector.

Chen et al. (2014) used SWOT analysis to determine the ability of Japan, South Korea and Taiwan to advance renewable energy policies and technologies, expand renewable energy installation and becoming net exporters of clean energy. The study identified opportunities for additional renewable energy construction in all regions. Further this study highlights the importance for the countries to work together to be able to grow and compete in the global renewable energy market with the end goal of becoming net exporters of renewable energy. While these countries have similar supply structures, their energy policies are vastly different. Sharing experience and best practice guidelines between countries could help improve their policies, similarly sharing technology would also help advance renewable energy in these countries.

SWOT analysis is a principle method for assessing individual opportunities and providing an in-depth review of the opportunity at hand. This method however is not able to evaluate different alternatives to enable a comparison of these.

MULTI CRITERIA DECISION ANALYSIS

Multi-criteria decision analysis (MCDA) or multi-criteria decision making (MCDM) was first recorded by Benjamin Franklin an American Statesman in 1772, but the first researcher whose work can be classified as MCDA was an economist, Vilfredo Pareto whose main work was published in the 1890's (Köksalan et al., 2013, Wijnja, 2014). When the energy industry changed from purely focusing on lowest cost to also including environmental, technical and social factors, MCDA become a very useful analysis technique, especially since 1995 (Wang and Poh, 2014). Wang et al. (2009) list the different aspects of MCDA that can be used in the energy sector as energy planning and selection, energy resource allocation, energy exploitation, energy policy, building energy management and transportation energy systems. MCDA has proved its usefulness in the decision making process for these different aspects with more than 100 examples illustrated in Wang et al. (2009) and Pohekar and Ramachandran (2004). The most popular MCDA methods and examples of successful application for the analysis of energy and specifically renewable energy opportunities is reviewed in the next section.

Table 2 below summarizes the section above discussing the different methods for decision analysis in renewable energy. It combines the reviewed literature highlighting the advantages and disadvantages of each method.

Table 2: Decision making methods and their advantages and disadvantages

Method	Description	Advantages	Disadvantages
Cost-Benefit Analysis (CBA)	Estimates a NPV for the cost and benefits of each alternative	• Easy to compare alternatives with each other	• Assumes a monetary value can be quantified for all attributes
Delphi technique	Gathers information from experts through two or more surveys rounds, with the end goal of reaching general consensus	• Valuable when there is limited data to analyse	• Very low scientific level • Success depends on the quality of the participants • Risk of imposing personal views by researchers analysing data
SWOT (Strengths, Weaknesses, Opportunities and Threats)	Evaluates the current and future strength and weaknesses of an opportunity	• Thoroughly evaluates an opportunity/market/ nation and identifies shortcomings and problem areas	• Difficult to compare alternatives against each other
Multi-criteria Decision Analysis (MCDA)	Various methods available to firstly rank criteria and then to rank alternatives based on the ranking of criteria	• Can handle both qualitative and quantitative data • Can compare alternatives with each other	• Complex compared to other methods

Decision analyses: strategy used to identify the most favourable countries for wind IPPs to enter

The objective of this study is to identify the most favourable countries for IPPs to enter. Therefore the attractiveness of markets (alternatives) have to be compared with each other using various criteria (economic, technical, environmental and social). Based on the review of the different methods, MCDA is the preferred method because it ranks the criteria based on importance and has the ability to compare alternatives. The Delphi technique is not preferred because of its low scientific method, SWOT is not preferred because it is difficult to compare markets against each other and lastly the CBA analysis is not preferred because it is difficult to quantify the factors into a monetary amount.

MCDA methods

MCDA methods can broadly be classified into two classes: multi-objective decision-making (MODM) and multi-attribute decision-making (MADM). In MODM the decision problem will consist of multiple and competitive objectives which have to be optimized against a set of constraints. MADM evaluates a set of alternatives against a set of criteria and is the most popular method for solving problems with numerous different perspectives (Taha and Daim, 2013). In other words, MODM has more than one goal which needs to be optimized, whereas in MADM there is only one goal, but multiple criteria, therefore MODM tries to optimise a situation whereas MADM selects the best alternative. Selecting the best market for renewable energy IPPs to enter can therefore be considered under MADM, each country (alternative) is evaluated against a set of criteria, the importance of this criteria being determine by different people and therefore different perspectives. Only MADM methods are discussed further. The most well-known MADM methods include AHP, MAUT, PROMETHEE, ELECTRE and TOPSIS and is individually discussed below.

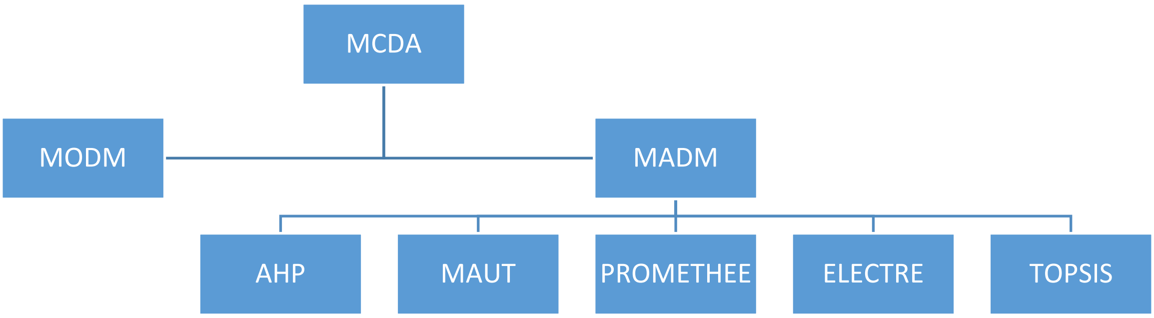


Figure 2: Multi-criteria decision analysis methods, created based on Taha and Daim (2013)

Analytical hierarchy process (AHP)

The AHP method was developed by Saaty (1987). This method structures the problem into a hierarchy, with the main criteria at the top, sub-criteria in the middle and different alternatives at the bottom (Taha and Daim, 2013). It uses pair-wise comparison both to compare alternatives against each other and to estimate the weighting of criteria (Saaty, 1987). AHP has been widely used in the energy sector and is considered the most popular method for project evaluation (along with MAUT), due to its ease of use, because it is not as data intensive as other methods, it doesn't have bias with regards to decision making, it can include different data types and it is easy to see the importance of criteria (Velasquez and Hester, 2013).

Examples of its application in renewable energy include Stein (2013) where different renewable (wind, solar, geothermal, biomass and hydropower) and non-renewable technologies (nuclear, oil, natural gas and coal) were ranked based on technical, financial, environmental and socio-economic criteria sourced from government and academic literature. The results of the study supports renewable energy with wind, solar, geothermal and hydro top ranked. There results impact the public and private sector with regards to policy and decision makers in energy. The authors urged that subsidies for conventional technologies should be removed and incentives for renewables expanded.

Similarly Chatzimouratidis and Pilavachi (2009) also ranked different renewable and non-renewable technologies based on similar criteria, but excluded environmental criteria. The criteria included efficiency (energy output to energy input), availability of the power plant, capacity (amount of electricity it produces) and reserves-to-production (availability of fuel) under technical and sustainability. Criteria under economic included capital cost, operations and maintenance costs, fuel cost and external cost. The results also supports renewable energy which are again ranked top while nuclear and fossil-fuel ranked in the bottom five.

AHP is also used in policy planning evaluation. Yi et al. (2011) used AHP along with benefit, opportunity, cost, and risk (BOCR) to determine the best energy policy for South Korea to assist North Korea with their energy shortage. Cost was identified as the most important criteria by the panel which consisted of engineers, political scientists and Korean Peninsula security experts. The result of the study is that renewable energy, specifically wind energy is the best solution for South Korea to assist North Korea.

Similarly Erol and Kılkış (2012) also used AHP to facilitate energy resource planning activities in Aydin, Turkey. The results indicate that solar energy can be realised by both local residents and the government and is the main priority where investment should be channelled. They also mention that industry and government should make large investments into geothermal and lignite coal. However the most important conclusion accordingly to the authors is that no single technology is the only answer, but rather hybridization of several technologies.

AHP has also been popular in technology selection. For example, Pilavachi et al. (2009) evaluated nine different types of energy generation options that used natural gas or hydrogen as a fuel, based on seven established criteria which consist of CO_2 emissions, NOx emissions, efficiency, capital cost, operation and maintenance costs, service life and produced electricity cost. The results show that the hydrogen turbine is the optimal solution and ranked first. However hydrogen combustion turbines are still under research and hence the most preferred option that is currently available, is the natural gas combined cycle.

Multi-attribute utility theory (MAUT)

MAUT was developed by Keeney and Raiffa (1976) and was based on the principle of assigning a utility to all consequences and calculating the highest utility. Utility theory is a systematic method for incorporating a person’s preferences in a quantitative way.

Examples of the use of MAUT in renewable energy assessment include Kaya and Kahraman (2011a) who used MAUT to evaluate different renewable energy alternatives (solar, wind, hydropower, biomass, and geothermal) for Turkey, establishing 4 main attributes and 17 sub-attributes.

Golabi et al. (1981) used MAUT to select between portfolios of solar application experiments in the United States to support the Department of Energy. The method used in the study was very successful and the authors note that is has been applied in four similar procurement programmes.

Jones et al. (1990) used this method to study different energy-policy options in the United Kingdom. The study incorporated four stages. The first involved participants to select fifteen attributes they regard as important for policy planning. Next the relative importance of each attribute was determined. Then the participants were asked to rank five policy options for the UK. Lastly the results were presented to the participants in a graphical manner and they were allowed to explore and modify the graphics. The authors conclude that this model is more accurately described as presenting different opinions as opposed to a decision analysis tool.

McDaniels (1996) presented MAUT as an approach to determine an index for the environmental impact of electricity utilities using a Canadian electric utility, BC Hydro, as a case study. They note four main advantages of using this method. Firstly, there is a clear distinction between the technical and value components of a decision, allowing technical input from specialist and value judgement from decision makers and stakeholders. Secondly, it allows value judgement from different viewpoints. Thirdly, the value judgements incorporated are closely linked to the issue of environmental impact. Lastly, decisions can be defended as the approach is well structured and has a clear framework. However the authors do note the limitation of only using the views of a few to determine an index.

Lastly, Voropai and Ivanova (2002) used MAUT as a method for electric power system expansion with the Unified Electric Power System of Russia as a case study. The authors conclude that it is impossible to have one procedure that is complete and formalised for each electric power system choice to be made, they rather suggest having a set of decision making procedures of which the most applicable can be selected given the decision problem.

Preference ranking organization method for enrichment evaluation (PROMETHEE)

PROMETHEE is an outranking method of assessment developed by Mareschal et al. (1984). This method uses the outranking principle to rank alternatives and then performs a pair-wise comparison of the alternatives to rank them in order based on the established criteria. This method is popular for its ease of use and is widely applied in the evaluation of energy projects and planning.

Terrados et al. (2009) used PROMETHEE along with SWOT and Delphi techniques to contribute to renewable energy planning at the regional level to achieve long term sustainability in Crete, Greece.

Diakoulaki and Karangelis (2007) used this method along with cost-benefit analysis to evaluate four different scenarios of electricity expansion in Greece. Economical, technical and environmental criteria were included in the analysis. The results showed that the highest penetration of renewable energy is the optimal solution for the Greek energy sector.

Tsoutsos et al. (2009) evaluated different technologies based on economic, technical, social and environmental criteria. The authors note the incompetency of methods such as cost-benefit analysis to fully incorporate all elements for effective energy planning, but explain that MCDA overcomes these limitations and is an appropriate decision analysis tool that offers adequate support for the decision maker. The results of the exploratory study offer assistance for energy planners at regional level to achieve sustainable energy planning.

Another example is Topcu and Ulengin (2004) who evaluated different energy technologies with the objective of optimising the selection of electricity generation for Turkey. The authors note the importance for each country to design their own energy policies and regulations due to different environmental and political factors. The study provides authorities with a framework to select the most suitable multi-attribute method, the ranking of alternatives and robustness analysis. The study concludes that for Turkey, wind energy is the optimal solution for addressing Turkey's energy demand in future.

Elimination and choice translating reality (ELECTRE)

ELECTRE is another outranking method first developed by Roy (1996). Since the initial development of ELECTRE various other versions of the method have been developed including: ELECTRE I ELECTRE II, ELECTREIII, ELECTRE IV and ELECTRE TRI. ELECTRE focuses on the dominance relationship between alternatives using pairwise comparison. Even though this is a more complex method it is still widely used in the energy sector.

Papadopoulos and Karagiannidis (2008) used this method for the optimisation of decentralised energy systems taking technical, financial, environmental and social factors into account. The authors state the ability of MCDA to integrate different aspects uniformly for evaluation purposes. The study shows the high potential for renewable energy resources in remote areas such as islands. They conclude that wind energy specifically has by far the greatest potential due to the low initial and operational cost, constant performance and the availability and maturity of the technology.

Georgopoulou et al. (1997) showed how this method can be applied at regional level to choose between different alternative energy policies and to address energy problems. The authors note the strength of MCDA methods that allow decision makers to incorporate a large number of often conflicting criteria. They also recognise the ability of the method that allow the analyst to see the impact of subjective issues such as visual impact. They note the problem of subjectivity but state that it is unavoidable.

Similarly Beccali et al. (2003) showed how ELECTRE can be used at regional level for the deployment of renewable energy, using the island of Sardinia as a case study. They used twelve criteria and three different scenarios, the first scenario assigns a high priority to environmental factors, the second scenario prioritises social and economic factors and in the third scenario focuses on energy saving. The study points out that the reduction of fossil fuels and the technical needs of the energy system are the most important factors.

This method can also be used for project selection as illustrated by Haurant et al. (2011). The Corsica Islands shifted focus to renewable energy as set out in their energy policy, consequently numerous projects are proposed which need to be evaluated and the best selected. This study used ELECTRE to successfully select the four best solar projects out of an initial sixteen options by using eight financial and geological criteria.

Technique for order preference by similarity to ideal solution (TOPSIS)

The TOPSIS method was developed by Hwang and Yoon (2012). With this method the chosen alternative is the one that has the highest value for all criteria. Essentially it is the alternative that is closest to the positive ideal solution and furthest from the negative ideal solution. TOPSIS has been used in various renewable energy studies.

Cavallaro (2010) used this method to compare different heat transfer fluids to test the feasibility of utilizing molten salt as a storage option. The results are that while molten salt has potential to reduce storage cost in an environmentally friendly way, the operations and maintenance aspect presents challenges due to the high freezing point of molten salt. Innovation is required to solve this problem so that molten salt can be utilised as a cheap and environmentally friendly storage solution.

Kaya and Kahraman (2011b) used the modified fuzzy TOPSIS to determine the best energy technology alternative taking technical, economic, environmental and social attributes with nine criteria into account and then applied it to energy planning. The AHP method was used to determine the weighting of the criteria. The results show that wind energy is the best alternative followed by biomass, solar and conventional energy coming in last.

Şengül et al. (2015) used the modified fuzzy TOPSIS to rank different renewable energy option in Turkey to make recommendations to Government. The study included technical environmental, economic and social criteria with nine criteria. The results revealed that the amount of energy produced is the most important criteria, which led to hydro power being the selected preferred alternative.

The Table 3 below highlights the different MCDA methods discussed in the section above and briefly summarises their advantages and disadvantages.

Table 3: Different MCDA methods and their advantages and disadvantages

Method	Advantage	disadvantage
AHP	• Easy to use • Not as data intensive as MAUT • Flexible intuitive and checks inconsistencies • No bias in decision making • Easy to see importance of each element. • Can include different data types	• Additive aggregation is used, so important information may be lost • Unidirectional relationship cannot handle the complexity of many problems • Relies on judgements of expert to derive priority scales • Interdependence between criteria and alternatives • Susceptible to rank reversal if alternatives is added at the end of the process • Does not deal well with uncertainty
MAUT	• Takes uncertainty into account • Easy to see importance of each element.	• Data intensive • Can be subjective because the preferences of decision maker is incorporated. • Complex method and hard to use
PROMETHEE (outranking method)	• Can include different data types • Easy to use • Takes uncertainty into account	• No weight factor calculation
ELECTRE (outranking method)	• Can include different data types • Takes uncertainty into account	• Complex method • No weight factor calculation
TOPSIS	• Simple process • Easy to use	• Difficult to weigh attributes and keep consistency of judgment • Susceptible to rank reversal if alternatives is added at the end of

	• Number of steps remains the same regardless of the number of attributes • Can include unlimited number of alternatives and criteria	the process – can remove this by having a limited amount of alternatives to begin with.

These MCDA methods each have their unique advantages and disadvantages, which makes the different methods useful for different applications, depending on what the questions, or desired outcome is.

MAUT takes data uncertainty into account and can accommodate different data types. However it lacks the ability to rank criteria and is considered a complex model. AHP is unable to deal with uncertainty, it is however an easy to use model and can accommodate different data types and has the ability to assign weights to criteria. PROMETHEE deals well will data uncertainty and can include different data types, however it is not capable of ranking the criteria. The model is relatively easy to understand and use. ELECTRE is similar to PROEMTHEE with regards data uncertainty, accommodating different data types and its inability to rank criteria, however the model is more complex to understand and use than PROMETHEE. The last model, TOPSIS, does not take uncertainty into account and cannot rank criteria, however it can accommodate different data types and is an easy model to understand and use. Table 4 below summarizes the advantages and disadvantages of the different MCDA methods.

Table 4: Summary of the advantages and disadvantages of MAUT, AHP, PROMETHEE, ELECTRE and TOPSIS (expanded and adapted fromWijnja (2014))

	MAUT	AHP	PROMETHEE	ELECTRE	TOPSIS
Data uncertainty	+	-	+	+	-
Different types	+	+	+	+	+
Weighting	-	+	-	-	-
Model complexity	-	+	+/-	-	+

Criteria for IPPs considering business opportunities

As has been highlighted earlier in the literature review, after the 1980's the energy sector did not only incorporate economic factors in the decision analysis, but also technical, environmental and social factors (Pohekar and Ramachandran, 2004). Numerous studies have reviewed the main- and sub-criteria incorporated into renewable energy decision making, examples include Wang et al. (2009), Afsordegan et al. (2016), Lee et al. (2009). However additional criteria outside the energy industry should be considered when studying market entry as illustrated in Beim and Lévesque (2006) who also included for example, political stability, lack of crime and corruption and GDP growth rate. Therefore studies highlighting criteria for international business opportunities were also reviewed and include Cheng et al. (2011), Mekking (2008), Swoboda et al. (2007), Beim and Lévesque (2006). The criteria for this study is based on Wijnja (2014) and is expanded to include additional criteria which are also considered important for wind IPP market entry. The decision to use Wijnja (2014) is justified as the study investigated which global markets are most attractive for airborn wind technology and consequently addresses the same questions as this study, but for a different technology, however still utilising the same resource i.e. wind. Having considered the above-mentioned studies that used decision analyses which incorporated effective and applicable criteria, the criteria for this study used to determine the most favourable new market for IPPs entry is justified and shown in Table 5.

Table 5 below sets out the criteria and sub-criteria that will be used in this study. The criteria are not taken from a single study, rather they are a combination of criteria used in several studies which researched either renewable energy decision making, wind farm selection or international business opportunities. Although the criteria is gathered from various studies, the base was taken from (Wijnja, 2014). References are also given for studies in which these criteria were applied.

Table 5: Criteria for this study and associated references

Category	Criteria	Sub-Criteria	References
Technical	Wind climate	• Wind resource • Maximum capacity factor	Lee et al. (2009), Wijnja (2014)
	Grid system	• Grid stability • National electrification rate	Wijnja (2014)
Economic	Cost of electricity	• Electricity tariff • Electricity cost	Wijnja (2014), (Wang et al., 2009)
	Corporate tax rate		Wijnja (2014)
	Country credit rating		Swoboda et al. (2007)

	Country forex reserve		
	Ease of doing business		Wijnja (2014)
	Market size	• Current generation capacity • Future demand	Beim and Lévesque (2006), Wijnja (2014), Swoboda et al. (2007), Cheng et al. (2011)
	PPA quality	• Payment guarantee • PPA term	
Political	Government support	• Renewable energy targets • Incentives (specifically and exclusively) for on-grid RE	Lee et al. (2009) Beim and Lévesque (2006), Wijnja (2014), Cheng et al. (2011)
	Political stability	• Political risk • Safety in-country	Beim and Lévesque (2006), Wijnja (2014), Mekking (2008), Swoboda et al. (2007)
Social	Market acceptance		Lee et al. (2009) Wang et al. (2009) Cheng et al. (2011)

Referring to Table 5 above, the technical criteria include wind climate and grid system. Wind climate is divided into (1) wind resource and (2) maximum capacity factor. Wind resource is a measure of a country's potential to harvest wind energy, whereas maximum capacity factor is the wind potential of the area with the highest potential for wind energy in the country. The higher the wind resource and the maximum capacity factor, the more attractive the market will be for wind IPPs.

The grid system criteria is divided into (1) grid stability and (2) national electrification rate. Grid stability refers to the condition of the grid including the number of interruptions and voltage fluctuations. The more stable the grid, the more attractive it will be for IPPs. The electrification rate refers to the degree of households and businesses connected to the grid, the higher the electrification rate, the higher the demand for energy and thus the higher the potential for IPPs.

The economic criteria include cost of electricity, corporate tax rate, country credit rating, country forex reserve, ease of doing business, market size and PPA quality.

Cost of electricity is broken up into (1) electricity tariff and (2) electricity cost. Electricity tariff is the estimated national electricity tariff (average for residential, commercial and industrial users) paid by users. Electricity cost refers to the average electricity production cost of a country. The higher these tariffs, the more likely it will be that renewable energy technologies will be cost competitive and therefore it will be a more attractive entry market.

The corporate tax rate is the income tax for companies. A lower tax rate will enable companies to keep a greater portion of their revenues and hence will be more attractive for IPPs.

Country credit rating is a measure of a country's investment grade and hence an indication of the likelihood for defaulting and country risk. State utilities are closely linked to the government and therefore in most instances the country's credit rating is a reflection of the credit rating of the state-owned utility which is the off-taker. A higher credit rating will be more attractive for IPPs as it gives them comfort that they will be paid.

Country forex reserve links to the country's ability to pay for its needs and liabilities such as PPAs. PPAs are often paid in US dollars or in local currency and linked to the US dollar. An IPP will try to convert to US dollars as soon as possible as many of the African countries have depreciating currencies. The higher the forex reserve, the more attractive the market will be for an IPP.

Ease of doing business is an index created by the World Bank Group, higher rankings indicate better, usually simpler, regulations for businesses and stronger protections of property rights. The higher the ranking of a country, the more attractive that country will be for IPPs.

The market size is split into (1) current generation capacity and (2) future demand. Current generation capacity refers to the portion of the consumed electricity that is produced locally. Future demand is the expected growth per year for energy demand. The higher these criteria, the more electricity is required, thus the larger and consequently more attractive the market will be for IPPs.

PPA quality is a criteria which was not included in the reviewed studies highlighted in Table 5, however it can be linked to the *ease of profit repatriation* criteria used in Beim and Lévesque

(2006) because the PPA will guide how the IPP is paid and what provision are in place to ensure payment. PPA quality is divided into (1) payment guarantee and (2) PPA term. A payment guarantee is offered by the government and guarantees the IPP that they will be paid even if the utility defaults, in which case the government will step in and pay the IPP. PPA term refers to the length of the contract, a longer term means that the project will receive income for a longer period and is thus more attractive for an IPP.

Political criteria include government support and political stability. Government support is divided into (1) renewable energy targets and (2) Incentives specifically and exclusively for on-grid renewable energy. Renewable energy targets are published targets either in policies or development frameworks which are specific for renewable energy technologies (including wind). Incentives specifically and exclusively for on-grid renewable energy are any incentives, such as tax benefits, that are offered for renewable energy and is not applicable to other technologies and industries. If a country has specific targets for renewable energy and also has incentives it is an indication of the seriousness of the government to make renewable energy a reality and therefore the market will be more favourable for IPPs.

Political stability can be divided into (1) political risk and (2) safety in-country. Political risk is the risk an investment could suffer as a result of political changes or instability. Safety in-country refers to the safety of personal working in the country. The lower the political risk and the higher the safety in country the more attractive the market will be for IPPs.

Social criteria include market acceptance which is a measure of how well the market adopts renewable energy and supports the implementation of it.

Conclusion

Decision analysis is critical to improve the decision making process in order to make better decisions which can be justified. Various common mistakes creep into the decision making process which the decision maker should be aware of. On top of this numerous factors also increase the complexity of decision problems. In the energy sector many methods have been proposed as decision analysis methods to mediate these mistakes and complexities and include CBA, SWOT, Delphi techniques and MCDA. For the purpose of this study the MCDA methods PROMETHEE and AHP are considered the best methods to analyse the importance of the criteria listed in Table 5 and to determine which countries are most suitable for wind IPPs in SSA.

Chapter 3: Methodology

The previous chapter reviewed various decision analysis methods and concluded that the best method to address the questions in this study is multi criteria decision analysis (MCDA), specifically the AHP and PROMETHEE model. The PROMETHEE method is the preferred method because it deals well with data uncertainty and can include different data types (qualitative and quantitative). However PROMETHEE is not capable of raking the criteria and therefore it needs to be used in conjunction with a method that is able to rank. AHP is the chosen companion because it is easy to use, can also accommodate both qualitative and quantitative data and has the ability to rank criteria. Wijnja (2014) similarly used the PROMETHEE and AHP combination, using AHP to rank criteria and PROMETHEE to rank the countries based the criteria ranking of the AHP.

This chapter gives an overview of the three main research approaches before delving into the research approach applicable in this specific study, namely the mixed methods approach. Next the methodology of the study is outlined in two sections. The first section is the ranking of criteria using an expert survey and the AHP. Details of the survey are provided and the principles and inconsistencies of the AHP is discussed in detail. The second section is the ranking of countries using the PROMETHEE model. In this section the PROMETHEE model is described and detail is given on the preference functions for each criteria.

General research approaches

There are three accepted research approaches namely qualitative, quantitative and mixed methods approach. While it has been debated in history whether the mixed methods approach should be included, it is now accepted and included as the third approach (Creswell, 2013, Johnson et al., 2007). Creswell (2013) describes the qualitative and quantitative approaches as different ends of a continuum with the mixed methods approach in the middle as it incorporates elements from both sides of the continuum. In other words, research is mostly not pure quantitative or qualitative but rather contains elements of both and should be considered as more quantitative than qualitative or vice versa, see Figure 3, taken from Johnson et al. (2007), for a visual explanation.

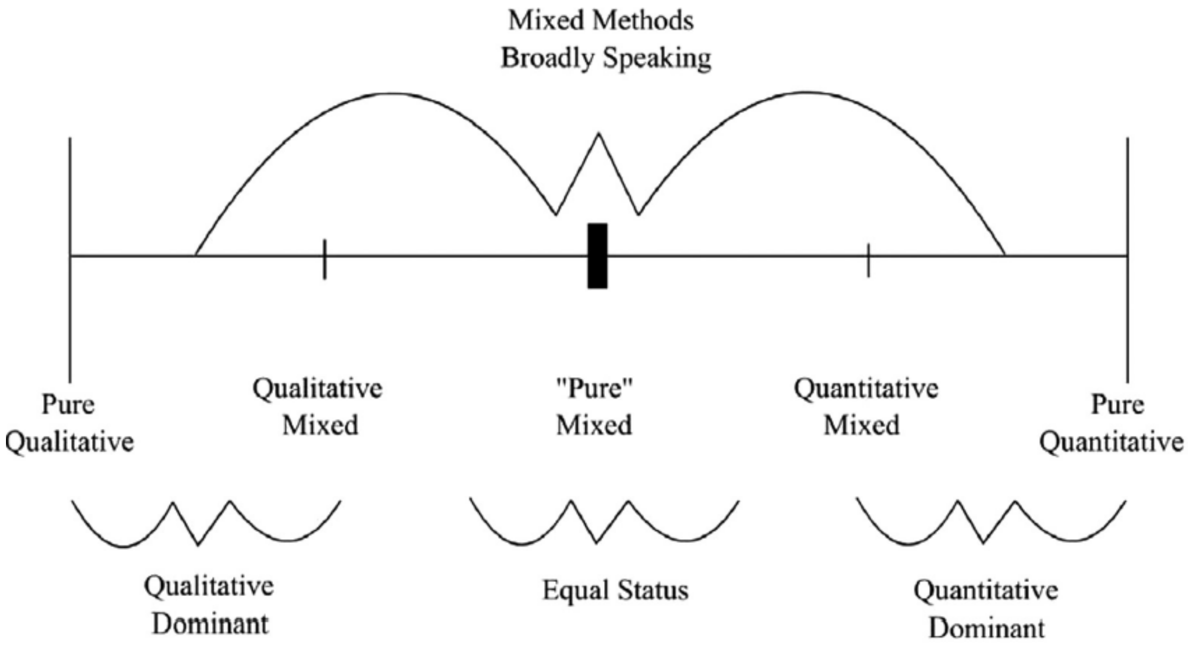


Figure 3: Graphical presentation of the three main research approaches namely qualitative, quantitative and mixed methods approach taken from Johnson and Onwuegbuzie (2004).

Qualitative research, as described by Creswell (2013), aims to explore and understand the view individuals or a group assign to a social or human problem. The researcher draws conclusions based on the data collected from these individuals or groups. There are three kinds of qualitative data namely interviews, observations and fieldwork and lastly documents. Qualitative research is useful when there are only a few cases to study and it has the ability to describe complex phenomena. It creates an understanding to explain people's personal views and experiences of phenomena. Qualitative research however does have drawbacks. It generally takes more time to collect and analyse the data and it does not easily test hypotheses and theories. Arguably the biggest drawback of this type of research is that it is easily influenced by a researcher or participant's biases. Johnson and Onwuegbuzie (2004) provide a full list of strengths and weaknesses of qualitative method research.

Quantitative research, as described by Creswell (2013), tests objective theories by examining the relationship among different variables. The variables are measured to obtain numerical data which is analysed through statistical methods. Quantitative research is considered more analytical than qualitative research. It has the ability to test hypotheses and theories about why specific phenomena occur. It is especially useful for studying large numbers of people as it is quicker to collect and analyse data. Findings can be generalised if the study is replicated for various populations and subpopulations. The main drawback of quantitative research is that a researcher may miss out on identifying phenomena occurring, because focus is purely on theory and hypothesis testing instead of theory and hypothesis generation. Johnson and Onwuegbuzie (2004) provide a full list of strengths and weaknesses of quantitative method research.

Mixed methods research is a reasonably new approach and collects both qualitative and quantitate data (Creswell, 2013). While there are varying definitions for mixed methods, Johnson et al. (2007) on page 113 describe it as "*an approach to knowledge (theory and practice) that attempts to consider multiple viewpoints, perspectives, positions, and standpoints (always including the standpoints of qualitative and quantitative research)*". The core assumption of this approach is that a combination of qualitative and quantitative elements lead to a more complete understanding of the research problem than either approach on its own (Creswell, 2013). Mixed methods and its advantages and limitations are further described below.

The three research approaches discussed are guided by many different strategies of data gathering. The five main strategies for data gathering are experiments, surveys, archival analyses, histories and case studies (Rowley, 2002). The research strategy and methodology for a study will depend on the objectives and questions to be addressed, which will in turn determine the data required and therefore which research strategy to use.

This study aims to rank countries from most to least favourable for IPP market entry. Both quantitative and qualitative data are used in this study and therefore the mixed methods approach is applied. The next section describes the mixed methods approach in more detail.

Mixed methods approach

Many different terms have been given to describe the mixed methods approach and while "*mixed methods approach*" is the most popular, other terms include integrating or integrating research, blended research, synthesis, quantitative and qualitative methods, triangulated studies, multi/multiple method and mixed methodology (Creswell, 2013, Johnson et al., 2007). The mixed methods approach is a relatively new approach which originated in the late 1980s and early 1990s. In 2003 Tashakkori and Teddlie published the *Handbook of Mixed Methods in the Social and Behaviour Sciences* which provides a comprehensive overview of the mixed methods approach and in 2010 a second edition of the handbook was published

(Tashakkori and Teddlie, 2010). Although this is a new approach is has progressed through the various development stages including the formation stage, general process development, withstanding philosophical debates and expanding its uses to various disciplines (Creswell, 2013).

An increasing number of researchers are turning to the mixed methods approach as it provides a bridge between the two methods, it allows the researchers to incorporate the strengths of both methods and mediate their weaknesses (Creswell, 2013, Onwuegbuzie and Leech, 2006). This method is ideal when both quantitative and qualitative data is available to answer the research questions and in doing so provides a more complete understanding.

The main strength of the mixed methods approach is its ability to incorporate the strengths of both qualitative and quantitative approaches. The method gives researchers the ability to answer broader questions as it isn't limited by a single approach. It is clear that the approach has a lot of strengths and advantages, but it also suffers from certain challenges. In general this method is more time consuming as it requires extensive data collection and analyses of both qualitative and quantitative data and thus necessitates the researcher to be familiar with both quantitative and qualitative forms of research (Creswell, 2013). Johnson and Onwuegbuzie (2004) provide a full list of strengths and weaknesses of mixed method research.

According to Johnson and Onwuegbuzie (2004) most mixed method designs can fall within one of two categories namely *mixed-models* and *mixed-methods*. Mixed-models combine qualitative and quantitative approaches within or across the different stages of the research process, whereas mixed-methods have a separate qualitative and quantitative phase in the research study. Johnson and Onwuegbuzie (2004) describe six mixed-model designs and further distinguishes between *within-stage mixed-model* (mixing takes place within a research phase) and *across-stage mixed-model* (mixing takes place between different stages). The authors also describe nine mixed-method designs. They stress that these designs are not exhaustive and that more user specific or more complex models can be developed by researchers, for example researchers can include elements of both *mixed-method* and *mixed-model* designs. Table 6 provides a summary of the different types of mixed method designs and expands into the subcategories of each.

Table 6: Categories and subcategories of mixed method designs adapted from Johnson and Onwuegbuzie (2004)

Design category	Description of design category	Subcategories	Description of subcategory
Mixed-models	Combines qualitative and quantitative approaches within or across different stages	Within stage mixed-model	Mixing takes place within a phase
		Across-stage mixed-model	Mixing takes place over different phases
Mixed-methods	Separate qualitative and quantitative phases	Concurrent (equal or dominant)	Takes place concurrently
		Sequential (equal or dominant)	Takes place sequentially

Research approach in this study

This study aims to rank countries from most to least favourable for wind IPP market entry. Both quantitative and qualitative elements are used in this study and therefore a mixed methods approach is used.

A survey was sent to the relevant experts asking them to rank one criteria over another (for all criteria) on a scale from less important, to equal, to more important. There are a relatively small group of experts available due to the limited size of the industry. The experts contacted consisted of eleven appropriate survey respondents identified and included either business developers in wind IPP companies, or individuals who work for companies that focus on increasing IPPs entry in African countries. The respondent was required to rank a criteria to another by moving the marker on the scale. The location of the marker correlates to a number which is then assigned to each answer, the number ranges between one and nine. This number is then incorporated in the AHP method to determine the weighting of the specific criteria which will be used as input into the PROMETHEE model. This section represents a *within-stage mixed-model design* because the survey requires participants to rank qualitative and quantitative criteria on a summated rating scale. More information on the survey and the AHP method is given in the section below titled Phase one: Ranking the Criteria.

The next section ranks the countries in order of IPP preference for new market entry, based on the quantitative and qualitative criteria, with the weighting determined in the first section.

The specific criteria are identified in the literature reviewed and are highlighted in Table 5 (Chapter 2) and Figure 4 below. The criteria data for each country was sourced from public documents, literature research and various websites. The PROMETHEE model was identified as the preferred method to rank the countries based on the criteria and more information is given in the section below title Phase two: Ranking the Countries. This section is also *within-stage mixed-model design* because the data incorporated into the model includes both qualitative and quantitative data.

To summarise, the research is conducted in two separate phases, both of which use qualitative and quantitative data and both of which can be classified as *within-stage mixed-model designs*. A visual outline of the research approach for the study is given in Figure 5 below.

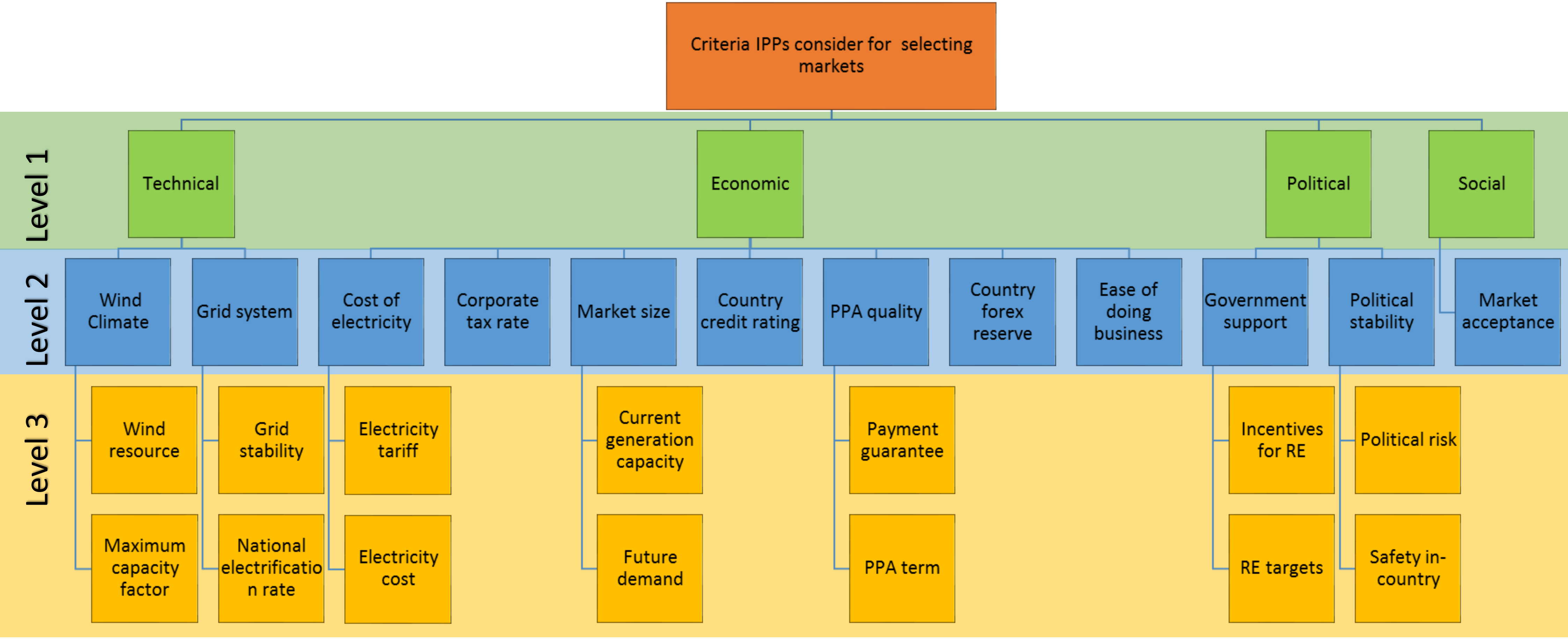


Figure 4: Hierarchy of the research problem of this study

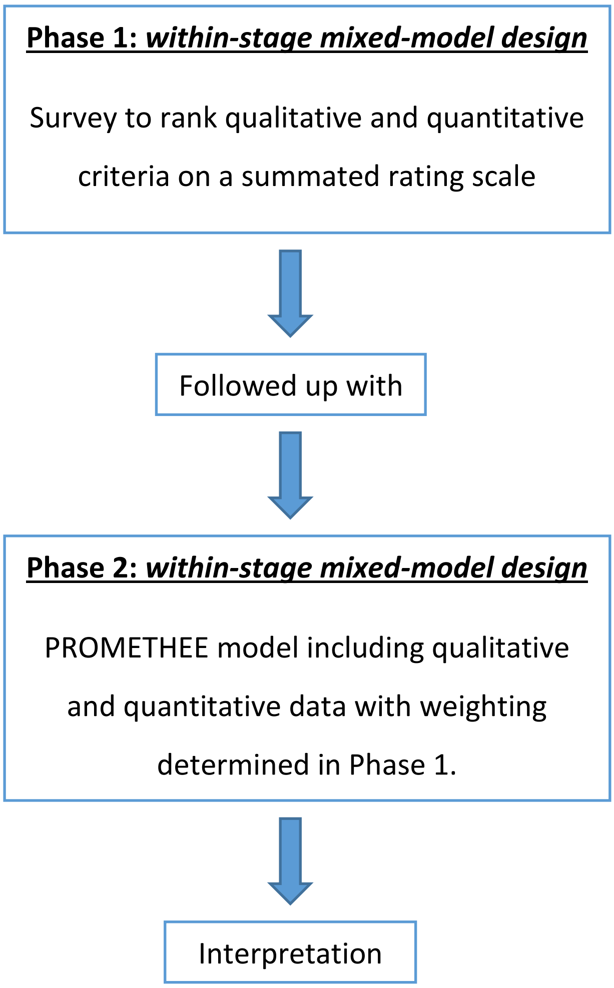


Figure 5: Mixed methods used in the two phases of this research study, created after consulting various sources (Creswell, 2013, Johnson and Onwuegbuzie, 2004, Johnson et al., 2007)

Phase one: Ranking the Criteria

In the first phase, criteria are weighted from the least to most important. The ranking of criteria is done through an expert survey and the AHP. Chapter 2 highlighted that the AHP method is the preferred method for ranking the importance of various criteria and to assign a weighting to each of them. The criteria that will be used for this study are outlined in Figure 4. The first step in the weighting process is the expert survey and the second step is incorporating the results of the survey into the AHP.

Expert survey

The objective of the survey is to obtain expert market opinion required for the weighting of the criteria using the AHP and is attached as annexure A. The survey includes both quantitative and qualitative data and can therefore be considered under the *within-stage mixed-model design* proposed by Johnson and Onwuegbuzie (2004).

The survey was created in Survey Monkey (https://www.surveymonkey.com/) and takes approximately fifteen minutes to complete. Participants were emailed a covering letter with a link to the survey and were informed of the estimated time to complete the survey. Respondents were assured of their anonymity and the responses to the survey are kept in a safe and secure place. The wind renewable energy industry is a small industry and the companies and professionals who meet the criteria for this survey are limited. The survey was sent to eleven experts in total, seven business developers and four professionals who work for companies that specifically focus on increasing IPPs entry in African countries. The seven business developers work for three different developing companies who meet the criteria for this survey. These criteria are for companies who develop wind energy farms, who are active in the African market, who are actively developing projects in more than one African country and who are looking to expand into other markets. The four professionals work for companies who assist governments to create a favourable market for IPPs, either though the establishment of bankable procurement processes or through the drafting of regulations and policies. Similarly, as with companies who are able to meet necessary criteria outlined above, identifying individuals who work for companies who assist governments to create a favourable market for IPPs are even more limited.

Based on the above limitations, it was considered that for this level of research, eleven survey experts, with a response rate of above 50% was sufficient for the purposes of the research, that is, to test whether using a multi criteria decision analysis model can improve decision making and therefore the ranking of countries.

AHP

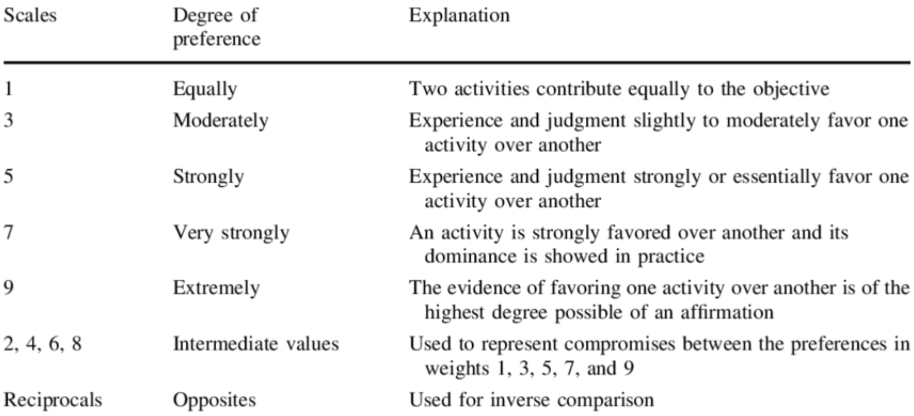
The AHP method requires a hierarchy or network structure to represent the problem, the hierarchy for this study is shown in Figure 4. Level one includes the overarching criteria, these being technical, economic, political and social. Level two contains the sub-criteria of the overarching criteria and similarly level three contains the sub-criteria of the level two sub-criteria.

Next a pairwise comparison determines the relationship and therefore importance of criteria within the structure. Level 1 is pairwise compared to arrange the overarching criteria from most to least important, the outcome is a pairwise comparison matrix, an example of the level one pairwise matrix is shown in Figure 6 below.

	Technical	Economic	Political	Social
Technical	1	T/E	T/P	T/S
Economic	E/T	1	E/P	E/S
Political	P/T	P/E	1	P/S
Social	S/T	S/E	S/P	1

Figure 6: Pairwise comparison matrix of the level 1 criteria, adapted from the example in Saaty (1987) on page 164

In row 2, column 3 (2, 3) the relative importance of technical criteria is compared to the importance of economic criteria (T/E). The criteria are scored in terms of the fundamental scale developed by Saaty (1987), shown in Figure 7 below. For example, if technical criteria are more important than economic criteria, the value in (2, 3) will be greater than one (the higher the number, the more important technical criteria is compared to economic criteria). If however economic criteria are more important than technical criteria, the value would be the reciprocal, between $\frac{1}{2}$ to $\frac{1}{9}$ depending on how much more important economic criteria is than technical criteria, where $\frac{1}{2}$ would indicate only slightly more important and $\frac{1}{9}$ would indicate much more important.



Scales	Degree of preference	Explanation
1	Equally	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly to moderately favor one activity over another
5	Strongly	Experience and judgment strongly or essentially favor one activity over another
7	Very strongly	An activity is strongly favored over another and its dominance is showed in practice
9	Extremely	The evidence of favoring one activity over another is of the highest degree possible of an affirmation
2, 4, 6, 8	Intermediate values	Used to represent compromises between the preferences in weights 1, 3, 5, 7, and 9
Reciprocals	Opposites	Used for inverse comparison

Figure 7: Saaty's fundamental scale used in the pairwise comparison of criteria, taken from Saaty (1987) on page 163

The next step is a pairwise comparison for the level two sub-criteria belonging to each level one main criteria, resulting in four additional pairwise matrices. Then the level three sub-criteria under each of the level two sub-criteria are compared resulting in seven additional pairwise matrixes. Note that not all of the level two sub-criteria have criteria below them, therefore it is seven and not twelve matrixes which would've been the case if each level two sub-criteria had more than one criteria below them.

The axioms of the AHP method

The four axioms guiding problem solving through the AHP method is reciprocal, homogeneity, synthesis and expectation (Saaty, 1987, Saaty and Kułakowski, 2016, Saaty, 1986).

The reciprocal axiom

The reciprocal axiom states that if object A is 5 times heavier than object B, then object B is $\frac{1}{5}$ the weight of object A. This is relevant to the structure of the AHP in that it uses pairwise reciprocal comparisons.

The homogeneity axiom

Homogeneity is required for comparison because we are not able to compare extremely different elements. For example comparing the size of an apple with the size of a grain of sand. Objects must rather be placed in clusters which have similar elements to ensure that they can be compared. Again this is relevant to the structure of the AHP as it uses clusters the group criteria.

The hierarchy axiom

The hierarchy axiom states that in a hierarchy there are levels: level 1 (L_1), level 2 (L_2) which is under level 1, level 3 (L_3) which is under level 2 etc. up until level h, L_h. The outer level is not dependent the level below, i.e. L_1 (criteria) are not outer dependent on level L_2 (alternatives). But each sub level is outer dependent on the level above, i.e. L_2 (alternatives) are dependent on L_1 (criteria).

The expectation axioms

The expectation axiom states that a person's beliefs and/or opinions are not accepted to be rational but it is accepted that there is a reason for it and it should be represented in the model so that it is reflected in the hierarchy.

Inconsistency in the AHP method

When using the AHP method it is important to check for consistency and the interpretation of results should take any inconsistencies into account. Normally inconsistencies of approximately less than 10% are allowed.

Two challenges that lead to inconsistencies are the fact that Saaty's scale is discrete and that it is capped. An example highlighting the discrete scale dilemma is if A=2*B and A=5*C, then B = $\frac{2}{5}$ C, however $\frac{2}{5}$ is not on the scale of 1 to 9 and therefore this is inconsistent. This will only have a marginal effect on the level of inconsistency and is allowed. The capped scale can be explained by saying that if A=3*B and B= 4* C, then A =12*C however Saaty's scale only goes until 9 and will therefore be inconsistent. Hence at times the Saaty scale forces a person to be inconsistent, while this is allowed, the inconsistencies should be limited to <10%. To avoid or limit inconsistencies the literature recommends that no more than 9 items should be compared in a single AHP pairwise comparison.

To test for the level of inconsistency (consistency ratio) the formula CR=$\frac{CI}{RI}$ is used, where CI is the consistency index and RI is the random consistency index. The RI is show in Table 7 below.

Table 7: Values of the Random Index (RI), taken from Saaty (1987) on page 171

n	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.9	1.12	1.24	1.31	1.41	1.45	1.49

To calculate CI the following formula is used CI = $\frac{\lambda \max - n}{n-1}$, where:

λ_{max} is the largest of the principle eigen values on the pairwise comparison matrix and *n* is the number of criteria being compared.

Example of determining CI

Step 1: pairwise compare the criteria, in this example A, B and C

	A	B	C
A	1	$\frac{1}{3}$	5

B	3	1	7
C	$\frac{1}{5}$	$\frac{1}{7}$	1

Step 2: sum the total value of each column, adding a new row.

	A	**B**	**C**
A	1	$\frac{1}{3}$	5
B	3	1	7
C	$\frac{1}{5}$	$\frac{1}{7}$	1
	$\frac{21}{5}$	$\frac{31}{21}$	13

Step 3: divide each value by the sum of the column, for example row 1, column 1 (A, A) currently has the value 1. Now this value is divided by $\frac{21}{5}$ to get to $\frac{5}{21}$ in (A, A).

	A	**B**	**C**
A	$\frac{5}{21}$	$\frac{7}{31}$	$\frac{5}{13}$
B	$\frac{15}{21}$	$\frac{21}{31}$	$\frac{7}{13}$
C	$\frac{1}{21}$	$\frac{3}{31}$	$\frac{1}{13}$
	1	1	1

Step 4: calculate the average of each row by adding the values and dividing it by the amount of criteria being analysed.

	A	**B**	**C**
A	$\frac{5}{21}$	$\frac{7}{31}$	$\frac{5}{13}$
B	$\frac{15}{21}$	$\frac{21}{31}$	$\frac{7}{13}$

=

Average (sum of A, B and C divided by 3)
0.2828
0.6434

C	$\frac{1}{21}$	$\frac{3}{31}$	$\frac{1}{13}$		0.738

Step 5: insert the values into the formula into λ_{max}

$\lambda_{max} = \frac{21}{5}(0.2828) + \frac{31}{21}(0.6434) + 13\,(0.738) = 3.0967$

So CI = $\frac{\lambda\max - n}{n-1}$, thus CI = $\frac{3.0967-3}{3-1}$ = 0.04835

Now the CI can be plugged into the consistency ratio formula (CR=$\frac{CI}{RI}$), therefore CR =$\frac{0.04835}{0.58}$ = 8.3%. Since the CR is less than 10% the inconsistencies in this hypothetical example is allowed.

The date collected from the expert survey will be incorporated into an online AHP Priority Calculator which automatically calculates the weighting of each criteria and the consistency ratio. The online programme address is http://bpmsg.com/ahp-online-calculator/ on the Business Performance Management Singapore website (http://bpmsg.com/). The results of the survey (average for each answer) is entered on the website which then calculates the consistency ratio and the weighting of the criteria.

Phase two: Ranking the Countries

In the second phase the countries are ranked from most to least preferred for IPP market entry. The focus of the study is not to rank all SSA countries, but rather to test whether using a multi criteria decision analysis model can improve decision making and therefore the ranking of countries. Seven SSA countries are included in the analyses and consist of Ethiopia, Kenya, Mozambique, Namibia, Nigeria, South Africa and Zambia. Seven countries were considered sufficient for the purposes of this research and the countries were selected to incorporate a broad diversity with regards to the criteria used in this study.

The PROMETHEE outranking method within MCDA is used to rank the countries in order of preference with the weighting identified with an expert survey and the AHP in the previous section. The PROMETHEE I for partial ranking and PROMETHEE II for complete ranking was developed by Brans (1982). Various different version of PROMETHEE have since been developed. There are two defining steps in the PROMETHEE model, firstly selecting the weighting of the criteria and secondly selecting the preference function for each criteria. The weighting was determined in the previous section using an expert survey and the AHP method. The PROMETHEE model is run through the visual PROMETHEE version 1.4 software

(VPSolutions, 2013). This section will discuss selecting the preference function and running the PROMETHEE model.

The country forex reserve, payment guarantee and power purchase agreement (PPA) term criteria are not included in the PROMETHEE analyses as there is either no data available (payment guarantee and PPA term) or the data is not available for all countries (country forex reserve). The criteria were still included in the ranking of criteria as it illustrates their importance which is useful in advising policy makers and governments wishing to procure renewables.

PROMETHEE preference functions

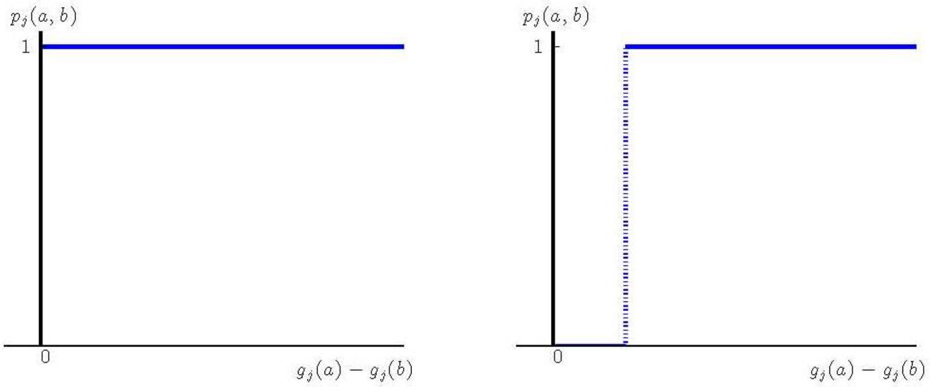
Selecting the correct preference function is essential in the PROMETHEE model and determined by specifying the indifference threshold (q) and preference threshold (p). The indifference threshold represents the maximum deviation between two scores that can be considered negligible when comparing two criteria. The preference threshold on the other hand is the minimum deviation between two scores that can be considered significant when comparing two criteria.

Brans and Vincke (1985) propose six different preference functions to choose from which are shown in Figure 8. The six preference functions are usual (type I), u-shape (type II) v-shape (type III), level (type IV), linear (type V) and Gaussian preference (type VI). These preference functions can be separated for qualitative and quantitative data.

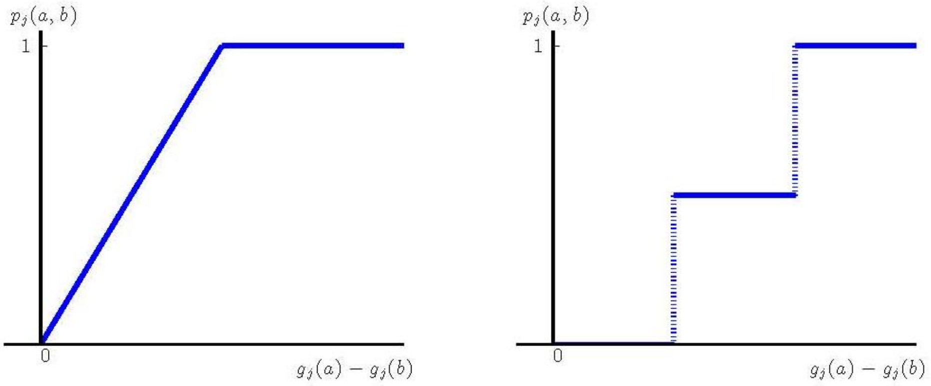
Quantitative data is best described by the v-shape (type III), linear (type V) or Gaussian preference functions. For data with lower uncertainty the v-shape is best and does not include an indifference threshold. The linear preference function includes both an indifference threshold and preference threshold. The Gaussian preference function is significantly more difficult to parameter and is excluded from similar studies (example Wijnja (2014)), it is therefore also excluded from this research. Therefore only v-shape or linear preference functions will be considered for quantitative data.

Qualitative data is best described by the usual (type I), u-shape (type II), and level (type IV) preference functions. Level preference function is used when you want to differentiate smaller deviations from larger ones. The usual preference function is used when there is a small amount of levels for the criteria (i.e. yes/no or up to a 5 pint scale) and when the levels are considered very different from each other. The u-shape preference function is a special case of the level one.

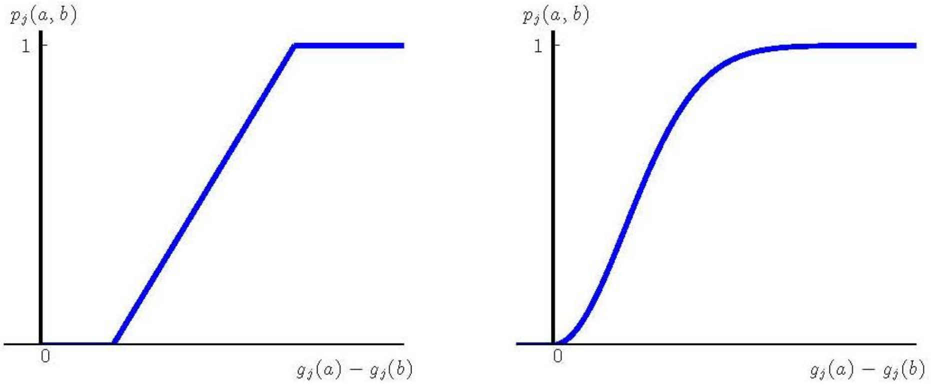
In the section below the preference function of the criteria shown in Figure 4 are discussed in detail. These preferences functions are built into the PROMETHEE model.



(a) Type I; usual criterion (b) Type II; u-shape criterion



(c) Type III, v-shape criterion (d) Type IV, level criterion



(e) Type V, linear criterion (f) Type VI, Gaussian criterion

Figure 8: PROMETHEE preference function taken from Wijnja (2014)

Wind resource

The wind resource for each country was taken from Lu et al. (2009) and is a measurement of the potential amount of energy (petawatt hours) that can be produced per annum through wind energy. The study limited wind energy to areas with a capacity factor of over 20% and non-forested, ice-free and nonurban areas. For the selected countries that data ranges from 0.5PWh to 10PWh.

Wind resource is quantitative data with higher levels of uncertainty and the linear preference function with an indifference threshold of 0.5 and a preference threshold of 10 is applied for this data.

Maximum capacity factor

The maximum capacity factor for each country was also taken from Lu et al. (2009). In the study the capacity factor is visually presented and includes ten different categories. Therefore there can be a wide range of capacity factors over different areas in a single country, for the purposes of this study the highest capacity factor presented in the country was selected. The maximum capacity factor for the countries included in this study ranged from 19% to 81%. A numerical value is assigned to each country reflecting its maximum capacity factors.

Table 8: Capacity factors taken from Lu et al. (2009) and the numerical value assigned to each percentage range

Capacity factor (%)	Numerical value
0-4	1
5-10	2
11-15	3
16-19	4
20-24	5
25-29	6
30-34	7
35-40	8
41-51	9
52-81	10

Maximum capacity factor is quantitative data with higher levels of uncertainty and the linear preference function with an indifference threshold of 1 and a preference threshold of 6 is best suited for this data.

Grid stability

The grid stability data is sourced from the Global Competitiveness Report 2016-2017 (Baller, 2016). In this report the quality of electricity supply was measured for all countries. It was measured in the form of a survey asking participants to rank how reliable the electricity supply in their country is on a scale of 1 (extremely unreliable) to 7 (extremely reliable). The values representing the quality of electricity supply for the selected countries range between 1.4 and 5.5, therefore a difference of 4.1.

Grid stability is quantitative data with lower levels of uncertainty and the v-shape preference function with a preference threshold 4.1 is best suited for this data.

National electrification rate

The national electrification rate for the selected countries is sourced from the Renewables 2016 Global Status Report (REN21, 2016). The electrification rate is given as a percentage and range between 13% and 85% for the selected countries, hence a difference of 72% between the maximum and minimum percentages.

The national electrification rate is quantitative data with higher levels of uncertainty and the linear preference function with a preference threshold of 72% and an indifference threshold of 5% is best suited for this data.

Electricity tariff

The electricity tariff was obtained from Rosnes and Shkaratan (2011) and is the average of the residential, commercial and industrial tariffs measured in c/kWh. It is noted that the data is rather dated and that the electricity tariffs would've changed substantially in the last six years. However this study is one of the only studies which review the electricity tariff of various countries on the exact same basis. Electricity tariff rage between 3.27c/kWh and 17.20c/kWh for the selected countries.

Electricity tariff is quantitative data with higher levels of uncertainty and the linear preference function with a preference threshold of 13.93 and an indifference threshold of 1 is best suited for this data.

Corporate tax rate

The corporate tax rate is sourced from a single website namely trading economics (http://www.tradingeconomics.com/). The corporate tax rates for the selected countries range from 28% to 35%.

Corporate tax rate is quantitative data with lower levels of uncertainty and hence the v-shape preference function with a preference threshold of 7% is best suited for this data.

Country Credit rating

The country credit rating is sourced from a single website namely trading economics (http://www.tradingeconomics.com/). The credit rating is assigned by Fitch and all analysed countries fall within BBB- and CC. A numerical value is assigned to each of the credit ratings as shown in below.

Table 9: Credit ratings applicable for this study and the various numerical values assigned to each rating

Credit rating	Numerical value
BBB-	1
BB+	2
BB	3
BB-	4
B+	5
B	6
B-	7
CCC+	8
CCC	9
CCC-	10
CC+	11
CC	12

Country credit rating is qualitative data with lower levels of uncertainty and the level preference function with scores between 1 and 12 is best suited for this data.

Ease of doing business

Ease of doing business was taken from a single website namely trading economics (http://www.tradingeconomics.com/) who obtain their data from the World Bank (http://www.doingbusiness.org/rankings). Each country is ranked on a list from the best countries for doing business to the worst, therefore the value assigned to a country is its position on the list. The selected countries ranked from 74 to 169, a difference of 95.

Ease of doing business is qualitative data with lower levels of uncertainty and the level preference function with scores between 74 and 169 is best suited for this data.

Current generation capacity

The current generation capacity for each country was taken from Bloomberg New Energy Finance (www.bnef.com/core) and is expressed as TW/h. The generation capacity for the selected countries range from 3.76 to 227.

Current generation capacity is quantitative data with lower levels of uncertainty and the v-shape preference function with a preference threshold 2 is best suited for this data.

Future demand

The future energy demand for each country was taken from various sources namely Clyde&Co (2016), SAAEA (2016), NACOP (2016), Spintelligent (2014) and is expressed as MW per year. Not all sources projected future demand for the same year (i.e. some projected for 2025 and others for 2030 etc.). To overcome this problem the total growth projected was divided by the number of years over which this was projected, giving an annual MW growth demand. The future demand for the selected countries range from 90MW/annum to 2727MW/annum.

Future energy demand is quantitative data with higher levels of uncertainty and the linear preference function with a preference threshold of 2637 and an indifference threshold of 10 is best suited for this data.

Renewable energy targets

Whether a country has renewable energy targets was determined on the IEA website (www.iea.org) and is indicated by yes or no.

Renewable energy targets is qualitative data and the usual preference function is best suited for yes/no criteria.

Incentives specifically and exclusively for on-grid RE

Whether a country has incentives specifically and exclusively for on-grid renewable energy was determined on the Bloomberg New Energy Finance website (www.bnef.com/core) and is indicated by yes or no. Incentives include for example tax exemptions, tax holidays etc.

Incentives for renewable energy is qualitative data and the usual preference function is best suited for yes/no criteria.

Political risk

The political risk of a country was taken from The Global Economy website (http://www.theglobaleconomy.com/rankings/wb_political_stability/). The political index ranges from -2.5 (low political stability) to 2.5 (strong political stability). The countries for this study ranges from -2.13 to 0.59, a difference of 2.72

Political risk is expressed as quantitative data with higher levels of uncertainty and the linear preference function with a preference threshold of 2.72 and an indifference threshold of 0.1 is best suited for this data.

Safety in-country

A country's safety for employees in country was measured using the Global Peace Index of the Institute of Economics and Peace (http://static.visionofhumanity.org). Each country is ranked from most to least peaceful, therefore the value assigned to the countries is its position on the ranked list. The selected countries ranges between 40 and 149, a difference of 108

Safety in-country is expressed as quantitative data with higher levels of uncertainty and the linear preference function with an indifference threshold of 1 and a preference threshold of 108 is best suited for this data.

Market acceptance (%)

Market acceptance is measured by the current installed capacity divided by the overall installed capacity. The market acceptance for the analysed countries ranges between 0 and 9.

Market acceptance is quantitative data with higher levels of uncertainty and the linear preference function with an indifference threshold of 1 and a preference threshold of 9 is best suited for this data.

Conclusion

This chapter discussed the methodology for this research, starting by highlighting the three research approaches. The data for this research is not only quantitative or qualitative but includes elements of both and is therefore considered a mixed methods approach. The details around the weighting of criteria using the AHP was discussed before turning focus to the PROMETHEE model. The different preference functions are described in detail after which a preference function was allocated to each criteria. The results of the PROMETHEE model is presented in the next chapter.

Chapter 4: Criteria Survey and Country Ranking Results and Discussion

In this chapter the results of the expert survey, AHP and PROMETHEE are presented. Firstly the results of the ranked criteria for all three levels are presented and a percentage of the total weighting is assigned to each criteria. Next the result of the PROMETHEE model, ranking countries from most to least favourable, are given. Lastly an action profile for each country is shown which visually illustrates whether criteria contributed positively or negatively to the country's overall ranking.

Phase one: Ranking the Criteria

Expert survey

The survey was sent to eleven people in total, seven business developers from three different companies and four professionals who work for companies tasked with increasing IPPs entry in African countries. Four business developers from two companies responded to the survey, two of each company. Two of the four professionals responded to the survey and they work for two different companies. A third individual responded but did not complete the entire survey and therefore the response was not included in the analyses.

AHP

The results of the survey were entered into the online AHP Priority Calculator (http://bpmsg.com/academic/ahp_calc.php) and the weighting, and thus importance, of each criteria was determined. All results met the AHP consistency ratio test and were well under the 10% cut-off (1.68% for level 1 and a maximum of 3.88% for all level 2 and level 3 criteria).

The results for the first level indicate that political criteria are the most important criteria at 39.46%, economic criteria very closely second at 36.06%. Technical and social criteria are shown to be considerably less important at 13.76% and 10.72% respectively (see Table 10 below).

Political criteria survey results

The results highlight that for political criteria, government support is significantly more important than political stability at 75% and 25% respectively. Within government support, incentives specifically for on grid renewable energy (75%) is more important than renewable energy targets (25%). Lastly within political stability, political risk (80%) is considerably more important than safety in country (20%).

Economic criteria survey results

The results for the second level criteria within the economic criteria reveal that the PPA quality is by far the most important (28.95%). Also important is a country's credit rating (19.55%), the market size (17.66%) and the FOREX reserve (12.38%). The least important criteria are ease of doing business (8.87%), cost of electricity (7.72%) and corporate tax rate (4.88%). With regards the most important criteria, PPA quality, having a PPA payment guarantee (80%) is much more important than the PPA term (20%). Within the cost of electricity, electricity tariff (75%) is more important than the generation cost of electricity (25%). Lastly with regards to the market size, future demand (66.7%) is relatively more important than the current generation (33.3%).

Technical criteria survey results

Within technical criteria, the wind climate and the grid system are equally important at 50% each. The results show that within wind climate, wind resource (75%) is more important than the maximum capacity factor (25%) and within the grid system, grid stability (86.7%) is significantly more important than the national electrification rate (13.3%).

These results of the AHP discussed above are summarised in Table 10 below. The table shows the percentage of the total weighting associated with each criteria in the three levels.

Table 10: Criteria ranking results based on the AHP

Category		**Criteria**		**Sub-criteria**	
Technical	13.76%	Wind climate	50%	Wind resource	75%
				Max capacity factor	25%
		Grid system	50%	Grid stability	85.70%
				National electrification rate	13.30%

Economic	36.06%	Cost of electricity	7.72%	Electricity tariff	75%
				Electricity generation cost	25%
		Corporate Tax rate	4.88%		
		Market size	17.66%	Current generation	33.30%
				Future demand	66.70%
		Country credit rating	19.55%		
		PPA quality	28.95%	Payment guarantee	80%
				PPA term	20%
		Country FOREX reserve	12.38%		
		Ease of doing business	8.87%		
Political	39.46%	Government support	75%	Renewable energy targets	25%
				Incentives specifically and exclusively for on grid renewable energy	75%
		Political stability	25%	Political risk	80%
				Safety in country	20%
Social	10.72%				

Phase two: Raking the Countries

The first step in the country ranking process was to collect the information for the criteria for each country. Various academic and non-academic literature publications and on-line website were used to gather the data. The information for each country and the associated reference(s) are given in Table 11 below.

Table 11: Data for the nineteen criteria included in this study for Ethiopia, Kenya, Mozambique, Namibia, Nigeria, South Africa and Zambia

Category	Criteria	Sub-criteria	Ethiopia	Kenya	Mozambique	Namibia	Nigeria	South Africa	Zambia	Reference
Technical	Wind climate	Wind resource (0-10)	6	6	1	1	0.5	10	5	Lu et al. (2009)
		Maximum capacity factor (0-10)	9	10	5	7	4	7	4	Lu et al. (2009)
	Grid system	Grid stability (1-7)	3.4	3.9	2.8	5.5	1.4	3	2.5	Baller (2016)
		National electrification rate (%)	24	20	39	13	64	85	26	REN21 (2016)
Economic	Cost of electricity	Electricity tariff (c/kWh)	5.70	17.20	6.63	13.10	4.50	4.67	3.27	Rosnes and Shkaratan (2011)
		Electricity cost (c/kWh)	8.5	14.2	9	11.3	9.7	5	6.5	
	Corporate tax rate (%)		30	30	32	32	30	28	35	Trading Economics, http://www.tradingeconomics.com/
	Country credit rating		B	B+	CC	BBB-	B+	BB+	B	Trading Economics, www.tradingeconomics.com
	Country forex reserve (US dollar)									

Category	Criteria	Sub-criteria	Ethiopia	Kenya	Mozambique	Namibia	Nigeria	South Africa	Zambia	Reference
	Ease of doing business		159	92	137	108	169	74	98	Trading Economics, www.tradingeconomics.com
	Market size	Current generation (TWh)	9	9	16	3.76	37	227	16	Bloomberg New Energy Finance, www.bnef.com/core
		Future demand (MW/year)	1637	1168	100	90	2051	2727	175	Clyde&Co (2016), SAAEA (2016), NACOP (2016), Spintelligent (2014)
	PPA quality	Payment guarantee								
		PPA term								
Political	Government support	RE targets	yes	yes	yes	Yes	yes	yes	no	IEA, www.iea.org
		Incentives specifically and exclusively for on-grid RE	no	no	no	no	no	yes	Yes, but does not include wind (no)	Bloomberg New Energy Finance, www.bnef.com/core

Category	Criteria	Sub-criteria	Ethiopia	Kenya	Mozambique	Namibia	Nigeria	South Africa	Zambia	Reference
	Political stability	Political risk	-1.48	-1.29	-0.58	0.59	-2.13	-0.18	0.15	The global Economy, http://www.theglobaleconomy.com/rankings/wb_political_stability/
		Safety in-country	119	131	68	55	149	126	40	Institute of Economics and Peace, http://static.visionofhumanity.org/
Social	Market acceptance		9	0	0	0	0	1	0	Bloomberg New Energy Finance, www.bnef.com/core

Country ranking results

The second step in the process of ranking the countries was to build the PROMETHEE model using the weighting determined in phase 1 along with the data collected for each country for the nineteen criteria. The PROMETHEE model was built in the programme Visual PROMETHEE.

After the model was built the results were analysed. The model showed that South Africa is the most favourable country for wind IPPs followed by Ethiopia in second place and Namibia in third. Kenya came in fourth, Mozambique fifth, Nigeria sixth and Zambia seventh. The results are shown in Figure 9 below, the top half of the figure illustrate the PROMETHEE ranking and the bottom half show the weighting of the criteria.

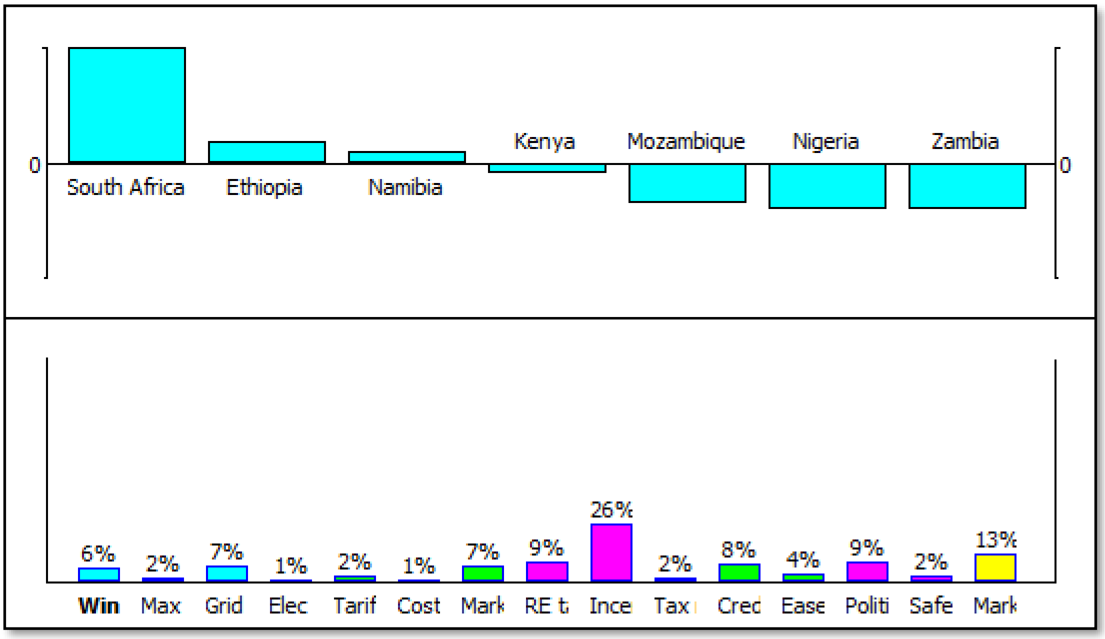


Figure 9: Country ranking from most to least favourable based on sixteen criteria with weights defined for each criteria. Figure auto-populated from Visual PROMETHEE.

If the weighting is removed and thus all criteria are considered equally important (see Figure 10 below), South Africa would still be the most attractive market and Zambia the least attractive. Namibia moves to second, Kenya third and Ethiopia to fourth position. The bottom three countries however remain unchanged whether equal or calculated weights are used.

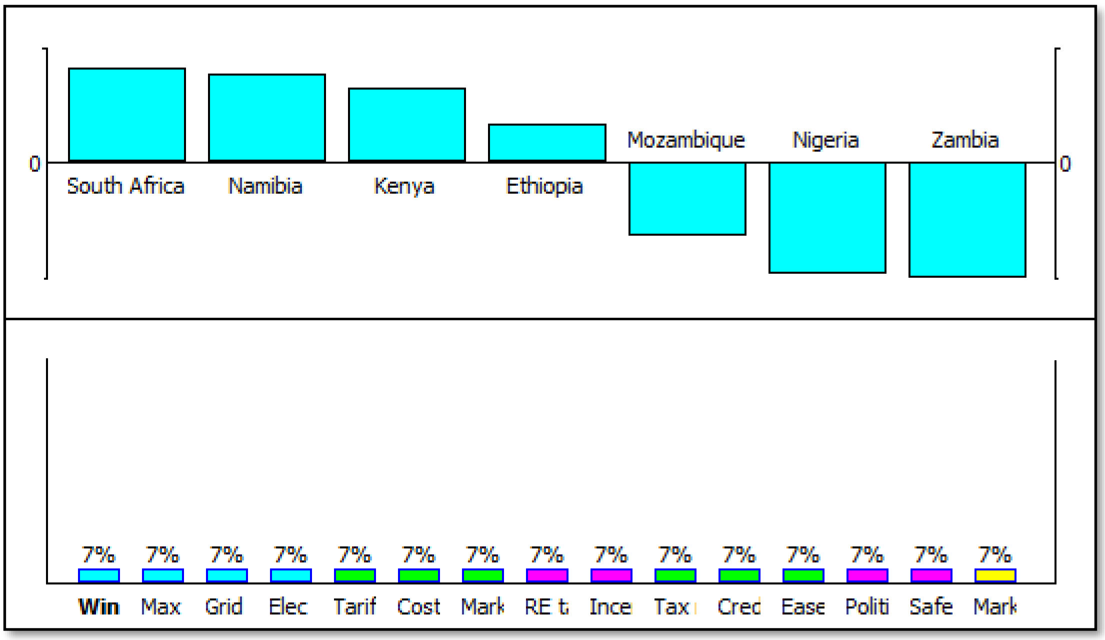


Figure 10: Country ranking from most to least favourable based on the sixteen criteria with equal weights. Figure auto-populated from Visual PROMETHEE.

Individual country results

An action profile was created for each country, the action profile shows which of the criteria contributed positively and which contributed negative to the country's overall ranking.

South Africa

South Africa is the top ranked country and this is evident when considering the criteria, see Figure 11 below. The wind climate criteria are significantly positive. Some of the economic and political criteria also contribute positively with market size, incentives for on grid renewable energy, credit rating and political risk all notably positive. However, even though it is the top ranked country not all criteria are positive, the tariff and generation cost are substantially negative. Ease of doing business, safety in country and market acceptance are also all slightly negative.

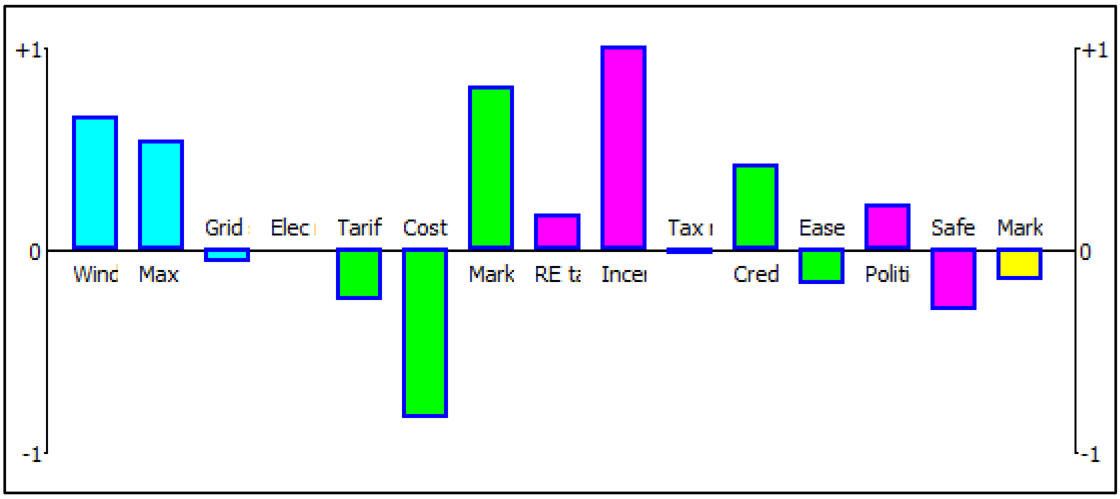


Figure 11: Action profile for South Africa

Ethiopia

In Ethiopia's case, the second most favourable country, see Figure 12 below, it is clear to see that the market acceptance is the biggest positive criteria followed by the wind climate (wind resource and maximum capacity factor). The drawbacks for Ethiopia seem to be the political criteria, specifically political risk and safety in country but tariff and incentives for renewable energy is also negative.

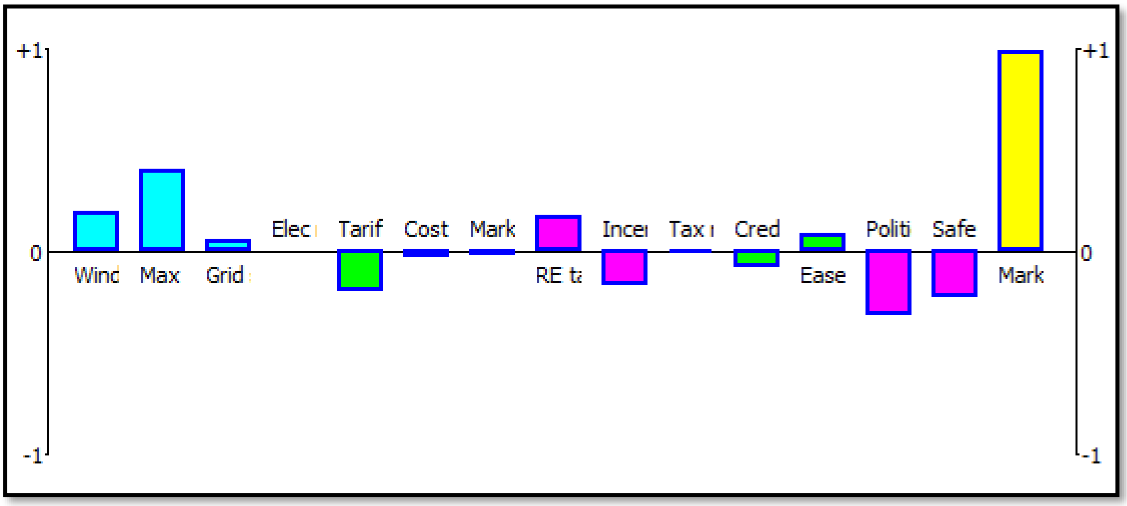


Figure 12: Action profile for Ethiopia

Namibia

Namibia scored highly for most criteria, see Figure 13 below, which is why it secured third place. However the wind resource, renewable energy incentives and especially the market size prevent the country from taking first or second place.

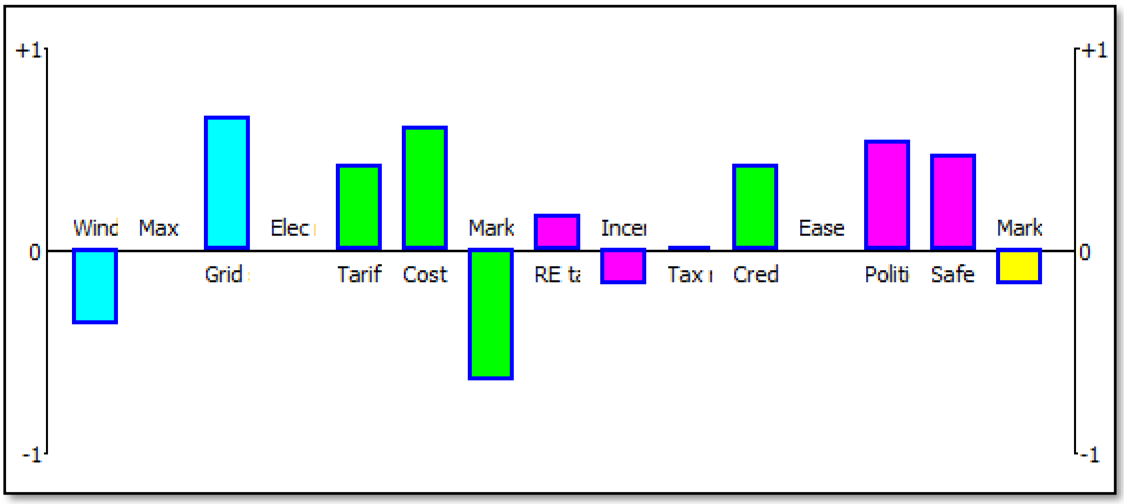


Figure 13: Action profile for Namibia

Kenya

Kenya, see Figure 14 below, scores well in almost all technical criteria, but its main positives are economic criteria namely tariff and generation cost. Kenya is held back by its political and social criteria which are all mostly negative.

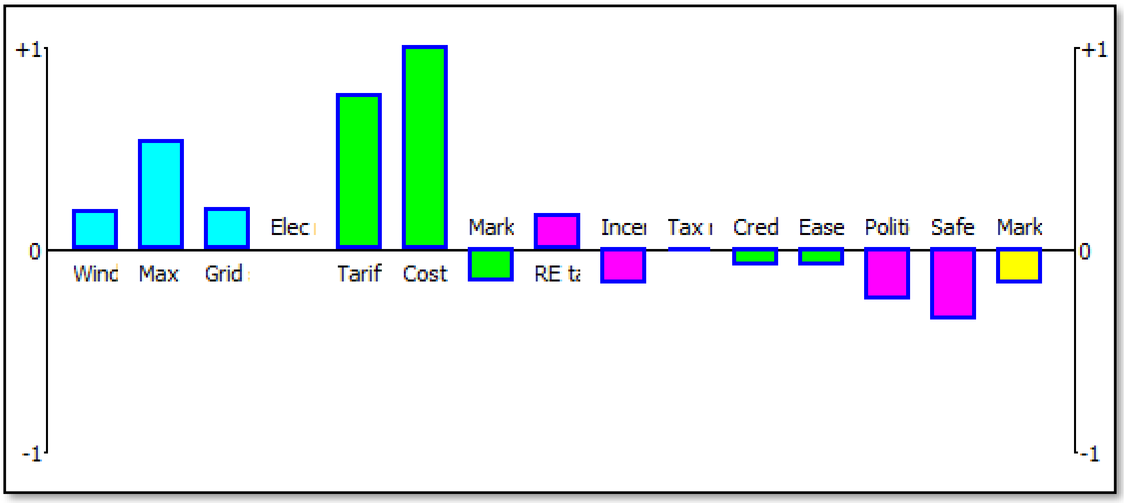


Figure 14: Action profile for Kenya

Mozambique

Mozambique, see Figure 15 below, has very view positive criteria which explain why it is so low down on the list. Mozambique scored low in all technical, social and economic criteria. The political criteria is the only positive, specifically safety in country and renewable energy targets.

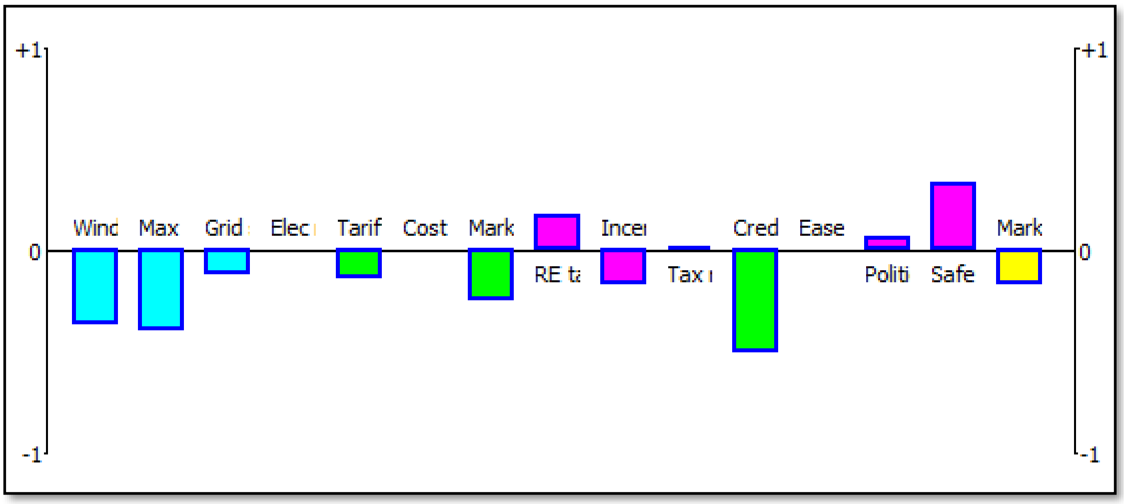


Figure 15: Action profile for Mozambique

Nigeria

Nigeria, see Figure 16 below, is the sixth ranked country with most of the criteria scoring negatively. All technical and most political data score significantly negative. The most positive criteria for Nigeria is the market size, second only to South Africa. Other positive criteria include ease of doing business, cost of electricity and renewable energy targets.

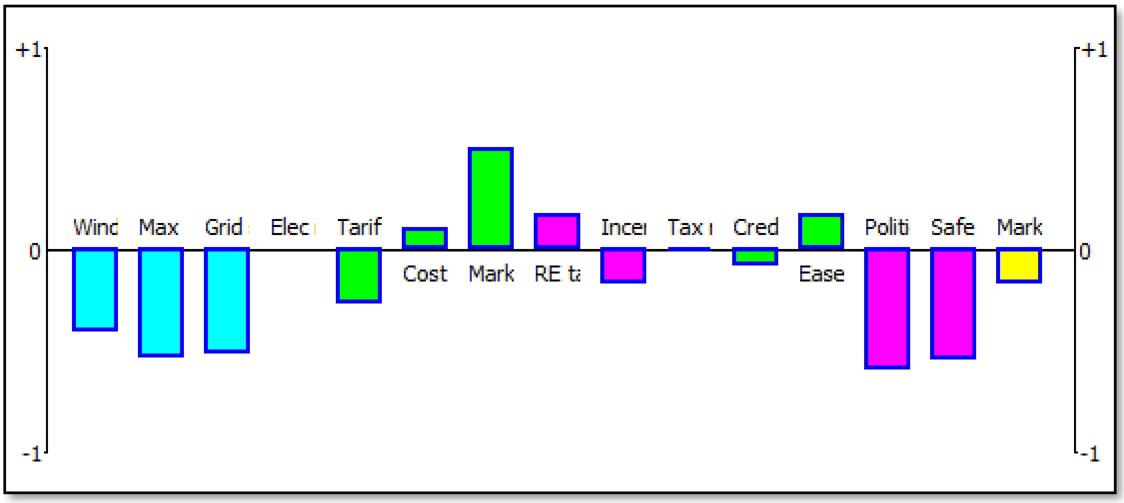


Figure 16: Action profile for Nigeria

Zambia

Zambia, see Figure 17 below, is the lowest ranked country of the seven considered with only political risk, safety in country and limited wind resource adding to a positive score. All other criteria score negative, especially the economic criteria which are all significantly negative.

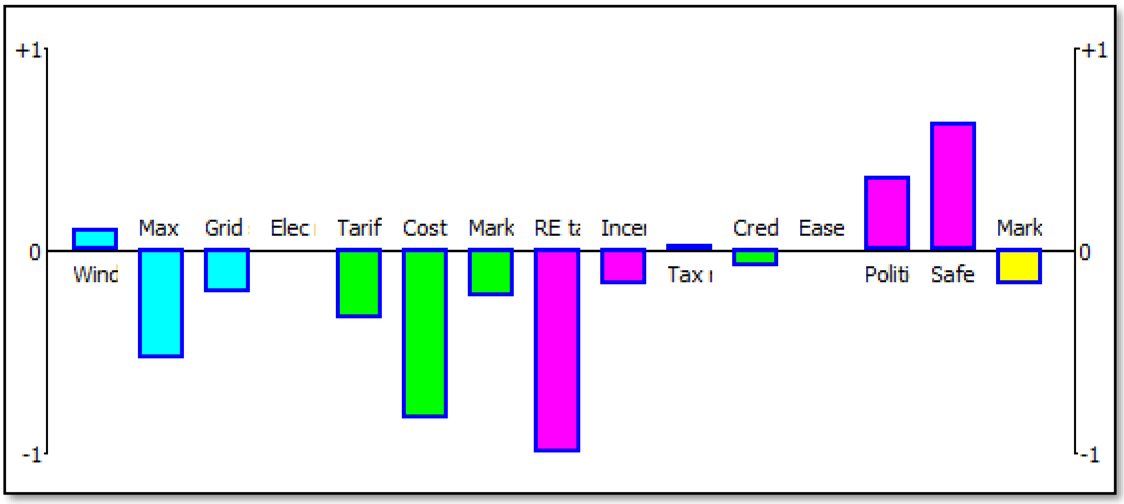


Figure 17: Action profile for Zambia

The first section of the chapter presented the results of the expert survey, AHP and PROMETHEE model. In the following section the implications of these results are discussed. First the AHP, which weighted the criteria, is discussed and recommendations are made to governments in SSA who want to attract wind IPPs. Next the ranking of the seven countries, as determined by the PROMETHEE analyses, is compared with results of similar studies and potential explanations for the differences are given. Following this, each country is discussed individually, analysing its strengths and weaknesses and recommending improvements to become more attractive for wind IPPs.

Criteria

Seventeen of the nineteen criteria used in this study were selected based on previous research and the two criteria for power purchase agreement (PPA) quality was included for the first time. These criteria were weighted with regards to their importance using and expert survey and the AHP. The weighted criteria were then incorporate into the PROMETHEE model.

Political and economic criteria were significantly more important, accounting for a resultant weighting of 76% overall, while technical and social criteria accounted for the remaining 24%. This is an indication to governments in SSA that if they are committed to attracting IPPs to their country, they should focus on improving the economic and political landscape. Governments do have the power and ability to change both the political and economic climate. However on the other hand, technical criteria, such as wind climate, is out of the governments' control, and accounts for only 13.76% weighting. Governments also do not control market acceptance and while they can attempt to improve it, it is not entirely in their hands to change. This only contributes 10.72% weighting. Therefore governments are in a position to significantly change a country's attractiveness for IPPs as they can improve the criteria which account for 76% of the successful impact.

Within the political criteria, government support through incentives specifically and exclusively for on grid renewable energy will go a long way to increase market attractiveness. Creating incentives is relatively easy and straight forward to achieve. Incentives can be either simple or more complex and costly. Examples of incentives used internationally include tax exemptions, accelerated depreciation, financial subsidies, credit facilities and third party financing mechanisms (Painuly, 2001). Incentives could also be indirect for example compelling utilities to buy "green" energy (Menanteau et al., 2003). Also important under the political criteria is political risk and this is in the hands of governments to manage. There are many ways governments can improve political risk, for example, privatisation, ensuring government stability (i.e. the ability of government to achieve its policies and to remain in office), reducing internal conflict and ethnic friction (i.e. due to race, language, etc.), ensuring basic democratic rights and ensuring law and order through a strong and independent legal system (Perotti and Van Oijen, 2001, Busse and Hefeker, 2007).

Within economic criteria the PPA quality and the country credit rating are the two most important criteria at 28.95% and 19.55% weightings. This justifies the PPA quality criteria being included in the analyses and it is recommended that all future studies involving IPPs should include PPA criteria. Providing a PPA payment guarantee is complex as there is a trade-off which the government will need to consider. While a PPA payment guarantee will make the market more attractive for IPPs, it also increases a country's fiscal risk (Cangiano et al., 2006). An improved country credit rating is beneficial for all parties and influences the debt financing available to projects (Chowdhury and Charoenngam, 2009). Most countries in Africa, and all but one in this study, have sub-investment grade ratings. Improving the credit rating will directly improve the economic environment and allow IPPs better financing terms to develop power projects, which will also translate into lower tariffs. If the country is sub-investment grade however it would need multiple agreements and guarantees to make a project attractive (Chowdhury and Charoenngam, 2009). Also important under economic criteria is market size which was weighted 17.66%. Market size is difficult for a government to change. Countries with small populations will find it hard to compete with the larger countries who will naturally have a higher demand for power. For economic criteria, governments should therefore focus on providing PPA guarantees (taking fiscal risk into account) and improving their credit rating rather than trying to increase the overall demand of the country for energy.

Comparison with other studies

The results of this study can be compared with the results of Wijnja (2014), Nganga and Maruyama (2015) and Beim and Lévesque (2006). Although not all the same countries were included in the studies and different methods were used for the ranking, these are the most applicable studies to compare with.

Wijnja (2014) ranked countries based on attraction for airborne wind using the AHP and PROMETHEE methods, similar to this study. The overlapping countries include South Africa, Ethiopia, Kenya, Nigeria and Mozambique. Namibia was excluded from the analyses due to lack of information and Zambia was excluded due to a lack of wind potential. The results of this study differ substantially from the results of Wijnja (2014). While both studies rank South Africa the most attractive for wind power potential of all countries, the rest of the countries are ranked very differently. The remaining four countries which were included in both studies were ranked in the following order in this study: Ethiopia, Kenya, Mozambique and lastly Nigeria, whereas the Wijnja (2014) ranked the order of attraction as: Kenya, Mozambique, Nigeria and Ethiopia.

The Nganga and Maruyama (2015) study ranked SSA countries in order of market attractiveness using technical, political, social, economic and infrastructure criteria. They used the SWOT and AHP methods as their ranking method. This study was not specific to the energy industry and therefore their technical criteria would be very different to the technical criteria of this study. The results in Nganga and Maruyama (2015) ranked the overlapping countries in the following order of attractiveness: South Africa, Nigeria, Namibia, Zambia, Kenya, Ethiopia and lastly Mozambique.

The Beim and Lévesque (2006) study also used MCDA method to rank countries from most to least favourable. Again this study was not focused on the energy market specifically so criteria would differ substantially. Only South Africa and Nigeria were included of the countries considered in this study. Six different weighting settings were analysed and all showed that South Africa is more favourable than Nigeria.

The results are not uniform across the four studies (including this study), in fact the country ranking varies significantly. This can be explained by a number of differences. Firstly the different objectives of the studies. Not all of them focus on renewable energy. Secondly the different criteria, for example adding infrastructure criteria and different sub-criteria. Thirdly the difference in weighting of criteria and lastly the methods used for the ranking (SWOT, AHP, PROMETHEE). There is however a single consistent result and that is that South Africa was considered the most attractive of the other six countries in all the studies.

Country individual discussion

In this section each country's results is analysed individually to discuss the country's ability to attract wind IPPs, to identify the areas where governments can improve and to identify the positive criteria which currently promote investment.

South Africa

South Africa is the most attractive country for wind IPPs based on the results of this and other studies. The attractiveness of the country can partly be attributed to the fact that it is the only country with incentives specifically and exclusively for on grid renewable energy, one of the most important criteria. When this criteria is excluded from the analyses South Africa is only slightly more favourable than Ethiopia, with the margin of preference decreasing significantly. The incentive in place for renewable energy is a tax break, allowing accelerated depreciation for capital equipment over three years, 50% in year 1, 30% in year 2 and 20% in year 3. Also attractive in the South African market is the natural wind resource. South Africa has the highest average wind speed and equal highest maximum capacity factor. The third important attraction is the current generation and future demand which is the highest of all countries analysed.

The greatest drawback for South Africa is the historic cheap generation cost at 6c/kWh which is the lowest of all countries analysed. The low current generation cost is due to the cheap cost of coal in South Africa making it more difficult for renewable energy sources to compete effectively and thus less attractive for IPPs to enter the market. However the cost of new coal is currently much higher, approximately 1R/kWh (Tobias Bischof-Niemz, 2016). This is a tariff which renewable energy can compete with if one considers the average prices achieved in the latest renewable energy auctions of 0.62c/kWh (Tobias Bischof-Niemz, 2016).

PPA quality was included only in this study and analyses. It is widely known that South Africa has a very high quality PPA which includes a payment guarantee from Treasury, a tariff linked to US dollar and a term of 20 years (Eberhard and Naude, 2016). Most countries in Africa aren't willing or not in a position to offer a PPA of this quality. Additional insurance will be required for a lower quality PPA which will increase the project cost and therefore the tariff, hence the quality of the PPA directly affects the tariff and thus the competitive ability of IPPs.

Ethiopia

Ethiopia is the second most attractive country, this can be attribute to its social acceptance and technical advantage. Ethiopia is rich in renewable energy potential and is one of the few countries which has exploited some of this potential. Currently 13% of Ethiopia's installed capacity is wind energy which speaks both to its wind resource and social acceptance (Bloomberg New Energy Finance, www.bnef.com/core). If social acceptance is excluded from the analyses Ethiopia drops two places into fourth position, it is therefore essential that Ethiopia maintain this level of social acceptance to stay attractive for IPPs.

The greatest drawback for Ethiopia is the political criteria, which is also one of the most important criteria. Specifically political risk and safety in country score negatively compared to the other criteria. The current state of emergency in Ethiopia, which started in October 2016, is an example of the political unrest in the country (Aljazeera, 2017). For Ethiopia to become more attractive for IPPs the government will have to create a more stable and safe environment which is conducive for investment. The country should also prioritise increasing the current electricity tariff to become cost reflective which will allow IPPs to be competitive and hence more able to enter the market.

Namibia

Namibia is the third most attractive country. Namibia scores high for most of the criteria but the areas which the country does not score well are difficult, if not impossible, to improve. The market size and the wind resource are the major disadvantages for Namibia, and neither of these are areas the Government can improve. The Government cannot change the natural wind resource, but it does have ample solar resource which it can exploit. Similarly the market size is difficult to increase given the country's small population of 2.44 million. Even if the GDP increased, which could increase the demand for power, it would still be impossible to compete with larger markets such as South Africa and Ethiopia which have a much larger population and greater wind resource.

Namibia has the best credit rating of the countries analysed, has the lowest score for political risk and scores highly for safety in country. So while the Government of Namibia has created a safe and stable environment for investors, it is unable to compete with other markets based on scale and natural resource. There are however opportunities for other renewable energy such as solar energy to be considered.

Kenya

Kenya is fourth on the list of most attractive countries. Kenya is in a similar position to South Africa and Ethiopia when it comes to wind potential. It has a high maximum capacity factor and wind resource. Kenya scored the highest of all countries in electricity tariff and generation cost, creating an attractive market for IPPs. The high cost of generation accompanied by the high tariff make it easier for wind IPPs to be competitive with conventional and hydro power.

Unfortunately the political criteria scores are mostly negative, thus creating an unfavourable market due to uncertainty regarding safety in country and high political risk. The political situation is something that can be improved to attract more IPPs to the market.

Mozambique

Mozambique currently scored low on all criteria except political. The country is in a similar situation as Namibia in that it has created a favourable environment from a political risk and safety in country perspective, however the wind resource is not favourable for investment. Mozambique also scored badly in all economic criteria. This is something which can be improved by the Government. If Mozambique focuses on improving the economic environment, especially the country's credit rating, it would go a long way to making the country more attractive for investment.

Even though Mozambique has a lower potential for exploiting wind energy, it should strive to increase its renewable energy generation and attract IPPs by creating an economically attractive market with higher, cost reflective tariffs and an investment grade credit rating.

Nigeria

Nigeria is ranked the sixth attractive country based on the analyses. The scores were significantly negative in all technical criteria and most political criteria. All other criteria except current generation and future demand scored either slightly positive or slightly negative. Current generation and future demand, which is the second highest after South Africa, prevented Nigeria from being ranked the least attractive market.

Nigeria can certainly improve its ranking if the Government prioritised political stability and increased safety in the country. It is important to note that Nigeria is a country whose political situation differs greatly across the different states. On the UK Government website regarding traveling advice to Nigeria (https://www.gov.uk/foreign-travel-advice/nigeria), certain parts of the country are green, others orange and some red. Green represent safe areas, orange represent a recommendation advising against all but essential travel and red represent a recommendation advising against all travel. It is difficult to see the country as a single unit with such vast difference between states and it would be interesting if future research analysed each state individually to determine attractiveness for IPPs.

The technical criteria for Nigeria will remain problematic however as the country can only improve the grid stability and not the natural wind resource. Nigeria had the worst score for the overall wind resource and the tied worst score with Zambia for the maximum capacity factor. Unfortunately it is impossible to improve the wind resource but there are many other areas, such as solar power, where the Government of Nigeria can increase its attractiveness for IPPs.

Zambia

Zambia is the lowest ranked country with regards to attractiveness for wind IPPs. The country scored negatively for most of the criteria and especially badly with regards to economic criteria. From a political criteria perspective, Zambia is the only country without any renewable energy targets.

However, Zambia is addressing certain of the criteria in which they currently have low scores. For example in an effort to have cost reflective tariffs, the government is increasing the electricity tariff by 75% this year (LusakaTimes.com, 2017). Although Zambia does not have a specific policy stating renewable energy targets, it is making an active effort to increase renewable energy through programmes such as Scaling Solar.

Therefore, while Zambia currently ranks the lowest, with current improvements underway Zambia will certainly become a more attractive country for IPPs.

Conclusion

In this chapter the results were presented and discussed in length. First the criteria were ranked from most to least important after which the seven SSA countries where ranked. Political criteria was revealed to be the most important followed by economic criteria technical and social. With regard to the country ranking, South Africa was ranked the most favourable followed by Ethiopia, Namibia, Kenya, Mozambique, Nigeria and Zambia.

Chapter 5: Conclusion

The aim of this study is to determine and rank the most important criteria when evaluating market entry and then, using these ranked criteria, to determine which selected countries in SSA are most favourable for wind IPPs. The study is divided into five chapters of which this is the final chapter.

In chapter one background to the wind IPP market and market entry was given and the research problem statement, research questions, aim, proposition, and objective of the study was stated. The research questions addressed in this study are:

1. In what ways can the use of decision analysis and more specifically MCDA provide a more rigorous assessment for comparing entry of new markets for renewable energy in SSA?
2. What are the criteria IPPs consider when comparing new markets for renewable energy and how do these criteria rank in terms of importance?
3. Based on these ranked criteria, which markets in SSA are most attractive for wind IPPs?
4. In what ways, by using the established criteria for market identification, are countries able to create a more favourable environment for wind IPPs?

In chapter two a literature review of different decision analyses methods was conducted. The main decision analyses approaches (cost-benefit analysis, Delphi techniques, SWOT and MCDA) were reviewed by outlining the history and broad principles of each methods and highlighting their strengths and weaknesses. Next the different MCDA methods (AHP, MAUT, PROMETHEE, ELECTRE and TOPSIS) were reviewed and discussed in a similar manner. Lastly the different criteria IPPs consider when evaluating new market entry options was reviewed and concluded the chapter.

In chapter three the methodology for the study was outlined and it was explained that the study is split into two phases. The first phase would rank the criteria using an expert survey and then analyse the survey results using the AHP. In the second phase the countries would be ranked in order of preference using the PROMETHEE model. Both the AHP and PROMETHEE methods were defined and explained in detail.

In chapter four the results were presented and discussed. The criteria data collection process was presented after which the criteria were ranked using the expert survey and the AHP. The results of the criteria ranking was studied in detail. In the following section the countries were ranked in order of IPP preference using the PROMETHEE model and the results of the model was discussed. The next section compared the results of this study with other studies after which each country's market attractiveness was discussed individually.

Answering the research questions

In this section the research questions presented in chapter one is answered. The key results relevant to the question is highlighted, if applicable, and the related chapter dealing with the question is provided.

1. In what ways can the use of decision analysis and more specifically MCDA provide a more rigorous assessment for comparing entry of new markets for renewable energy in SSA?

In chapter two different decision analysis methods were reviewed and it was highlighted that by using a decision analyses method, such as MCDA, a decision maker can justify the choice made in cases where an opportunity was missed or market entry failed.

Detailed decision analyses methods, such as MCDA, allow a decision maker to include the opinion of numerous experts and professionals in the field, which will lead to a better-informed decision. This was demonstrated in this study. A survey was used to gather the opinion of several experts and professionals in the field and these results were then analysed using the AHP (a MCDA model). The AHP ranked the criteria thereby providing the decision maker with an understanding with regards to the importance of different criteria. Next the PROMETHEE model (a MCDA model) was used to rank the countries in order of preference for market entry. Using a model removed the subjectivity associated with making the decision. Therefore, using MCDA methods, like the AHP and PROMETHEE model, allow the decision makers to understand the impact of the selected criteria by consulting various experts and also removes any subjectivity.

2. What are the criteria IPPs consider when comparing new markets for renewable energy and how do these criteria rank in terms of importance?

In chapter two the criteria IPPs consider for new market entry was reviewed and presented. This was done through an academic literature review including various studies that focused on market entry. The table below was compiled as a summary of the criteria identified.

Table 12: Criteria identified in this study as important for IPPs when considering new market entry.

Category	Criteria	Sub-Criteria	References
Technical	Wind climate	• Wind resource • Maximum capacity factor	Lee et al. (2009), Wijnja (2014)
	Grid system	• Grid stability • National electrification rate	Wijnja (2014)
Economic	Cost of electricity	• Electricity tariff • Electricity cost	Wijnja (2014), (Wang et al., 2009)
	Corporate tax rate		Wijnja (2014)
	Country credit rating		Swoboda et al. (2007)
	Country forex reserve		
	Ease of doing business		Wijnja (2014)
	Market size	• Current generation capacity • Future demand	Beim and Lévesque (2006), Wijnja (2014), Swoboda et al. (2007), Cheng et al. (2011)
	PPA quality	• Payment guarantee • PPA term	
Political	Government support	• Renewable energy targets • Incentives (specifically and exclusively) for on-grid RE	Lee et al. (2009) Beim and Lévesque (2006), Wijnja (2014), Cheng et al. (2011)
	Political stability	• Political risk • Safety in-country	Beim and Lévesque (2006), Wijnja (2014), Mekking (2008), Swoboda et al. (2007)
Social	Market acceptance		Lee et al. (2009) Wang et al. (2009) Cheng et al. (2011)

In chapter four the ranking of these criteria was shown and is based on an expert survey and the AHP. A summary of the results is presented in the table below.

Table 13: Importance of the criteria included in this study based on the AHP method.

Category		Criteria		Sub-criteria	
Technical	13.76%	Wind climate	50%	Wind resource	75%
				Max capacity factor	25%
		Grid system	50%	Grid stability	85.70%
				National electrification rate	13.30%
Economic	36.06%	Cost of electricity	7.72%	Electricity tariff	75%
				Electricity generation cost	25%
		Corporate Tax rate	4.88%		
		Market size	17.66%	Current generation	33.30%
				Future demand	66.70%
		Country credit rating	19.55%		
		PPA quality	28.95%	Payment guarantee	80%
				PPA term	20%
		Country FOREX reserve	12.38%		
		Ease of doing business	8.87%		
Political	39.46%	Government support	75%	Renewable energy targets	25%
				Incentives specifically and exclusively for on grid renewable energy	75%
		Political stability	25%	Political risk	80%
				Safety in country	20%
Social	10.72%				

3. Based on these ranked criteria, which markets in SSA are most attractive for wind IPPs?

Seven countries in SSA was ranked in order of IPP preference for new market entry using the results of the criteria ranking and the PROMETHEE model. A summary of results of the

PROMETHEE model is presented in Figure 18 below and the full discussion of the results is included in chapter four.

South Africa is the most attractive market followed by Ethiopia. Both of these countries have strong positive technical criteria due to the high natural wind resource and South Africa is the only country with incentives specifically for on grid renewable energy. Namibia is the third ranked country, Kenya the fourth and Mozambique the fifth. The least attractive markets are Nigeria and Zambia. Nigeria has almost no wind resource and Zambia has a weak economic environment and is the only country without renewable energy targets. A more detailed individual discussion for each country is included in chapter four.

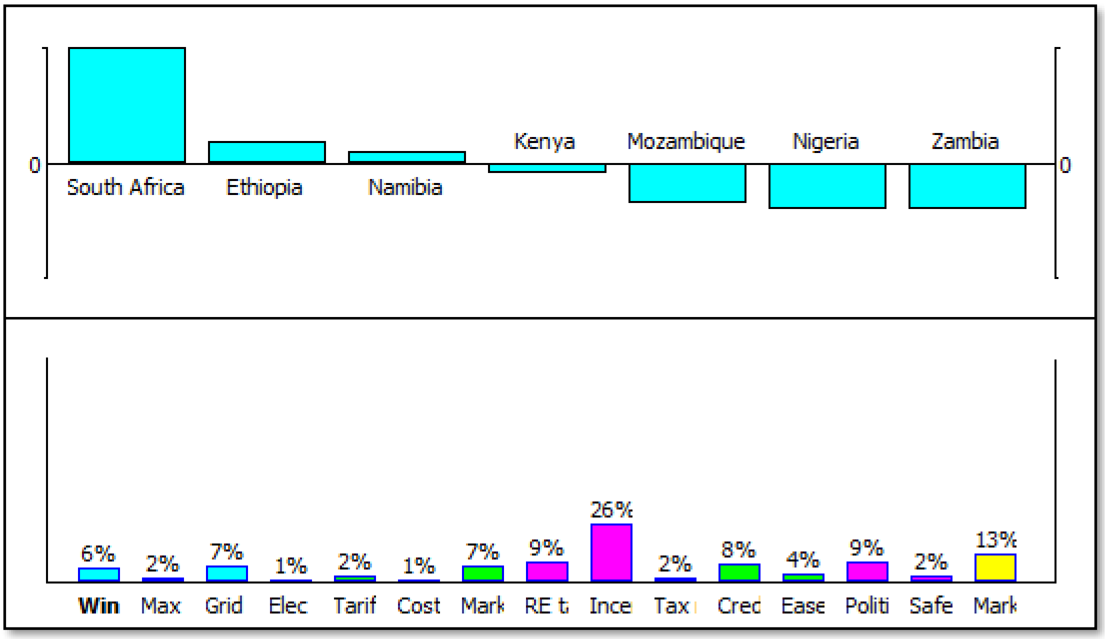


Figure 18: Results of the PROMETHEE model ranking countries for IPP market entry attractiveness

4. In what ways, by using the established criteria for market identification, are countries able to create a more favourable environment for wind IPPs?

The expert survey and the AHP showed that IPPs consider political and economic criteria much more important than technical and social. Governments have the ability to change the economic and political landscape of a country and should do so if they want to attract wind IPPs. Specifically governments can offer payment guarantees, provide incentives for grid connected renewable energy, decrease political risk and strive to improve the country's credit rating.

Governments can improve their economic and political environment, but there is nothing they can do to increase the wind potential. Instead countries with no wind resource should focus on procuring alternative renewable energy from IPPs such as solar or hydro energy. Similarly a country with a small population has limited scope to increase market demand and hence attractiveness for IPPs.

An in-depth discussion on how governments can improve the attractiveness of a country for wind IPPs is included in chapter four.

Research proposition achievement

The research proposition tested in this study is that by using an analytical method, such as MCDA, to assess criteria for new market selection, market selection will be more successful compared to only using subjective opinions.

This study showed that by using MCDA methods, such as AHP and PROMETHEE, a decision maker has the ability to include opinions of different experts and professionals in the industry. Different and numerous informed opinions will result in a better-informed decision that can be justified. MCDA methods also allow the decision maker to remove personal biases when making a decision, thereby making it an objective decision. Having an objective and better-informed decision is likely to lead a more successful outcome.

Research objective achievement

The objectives set in chapter one of this research were all achieved. Below each objective is listed and it is described how it was achieved.

The first research objective was to identify the criteria wind IPPs currently consider when evaluating new markets. This was achieved in the literature review (chapter two), and the results are highlighted in Table 12 above.

The second objective was to expand and assess these criteria and determine their ranking in order of importance through a survey and the AHP weighting method. This was achieved in chapter four which ranked the criteria based on an expert survey and the AHP, the results are summarised in Table 13 above.

The third objective was to survey and evaluate the extent to which selected SSA countries meet these criteria. This was achieved through the criteria data collection for the seven SSA countries researched in this study. Table 11 in chapter four summarises these results.

The fourth objective was to rank various SSA countries based on their attractiveness for wind IPPs using a MCDA. This was done using the PROMETHEE model and the results are presented in chapter four and highlighted in Figure 18 above.

The fifth objective was to make recommendations for countries to create a more favourable environment for wind IPPs. This was done in chapter four. The results of the AHP was presented and the importance of the different criteria discussed. Recommendations were made to governments regarding how they can improve on important criteria.

Contributions to the research problem

The research problem as described in 1.3 Problem statement is: wind IPPs generally subjectively assess new markets and insufficient attention is paid to important criteria which are analysed in an unstructured manner. The result is a subjective decision that is difficult to justify if market entry fails or if an opportunity was missed.

The research contributed in the following manner to address the research problem:

- Chapter one explained how decision analyses methods, such as MCDA, can assist decision makers to make better decision that they can justify.
- The different criteria IPPs consider for new market entry was reviewed in chapter two.
- In chapter four the importance of the identified criteria was determined using an expert survey and the AHP.
- In chapter four a MCDA method, PROMETHEE, was used to illustrate how subjective decision making can be avoid.

Recommendations for further research

Future research can use and adapt this study and methods to not only compare countries, but also states/provinces within countries. For example, Nigeria’s political situation differs dramatically between the different states. Some of the states could be very favourable while others should best be avoided. A more in-depth look will also allow better resolution with regards to wind resource and this will create a more accurate reflection of a country’s potential.

The methods used in this study is not restricted to the wind industry and can be expanded to different technologies and industries to assist with decision making in difficult scenarios.

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Annexure A: Cover letter and Survey

SURVEY: NEW MARKET ENTRY FOR INDEPENDENT POWER PRODUCER

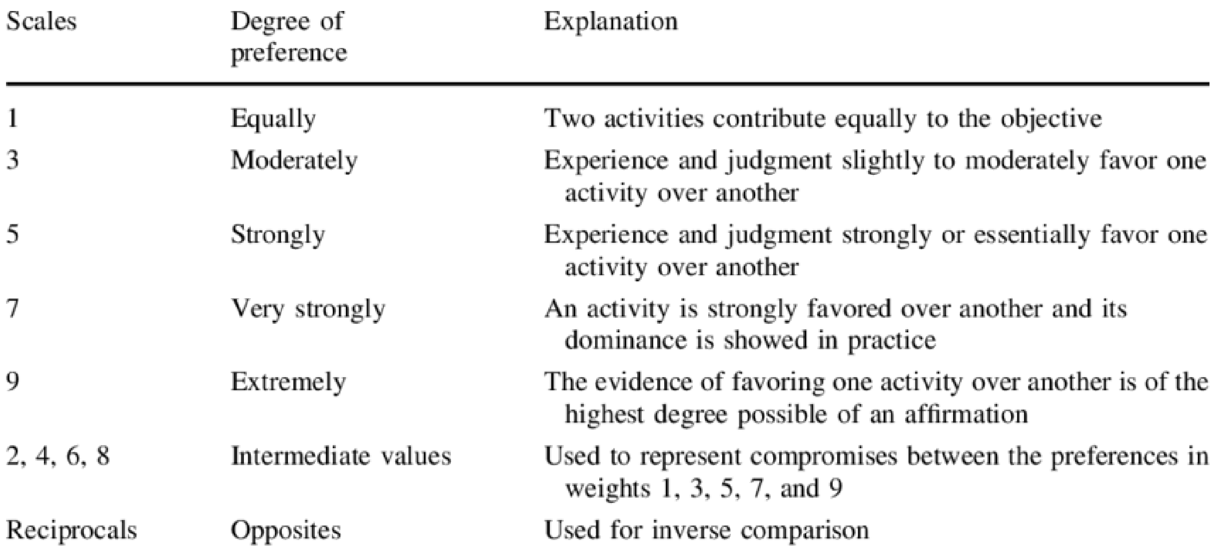
Dear participant

Thank you very much for taking the time to complete this expert survey. **I want to start by saying that your identity and the company or institution for which you work will be kept anonymous at all times and will under no circumstances be mentioned in my research**.

This survey forms part of my MSc research which focuses on new market (country) selection for independent power producers. The research consists of two phases, the first ranks various new market selection criteria from most to least important using the analytical hierarchy process (AHP) and the second ranks various sub-Saharan African countries from most to least favourable using the preference ranking organization method for enrichment evaluation (PROMETHEE), based on the results of the first phase. My research will be freely available to you and I will be happy to send you a copy of the study once it is completed. If you would like a copy of the research please send me an email at enelge.gildenhuys@gmail.com.

The survey is part of the process of ranking criteria from most to least important and **takes approximately 15 minutes to complete**. The criteria included in this study is highlighted in Table 1 and Figure 2. The survey will ask you whether you think one criteria is more, equal or less important than another. You will answer this by dragging a marker on a scale (please see example of question on the last page). Once you have placed the marker on the scale a number will appear in the right hand box next to the scale, you do not have to take note of this number, it is only for my attention as I will use it for the data analyses as a requirement of the analytical hierarchy process (AHP).

As mentioned, the number in the right hand box is required for the AHP. It is based on Saaty's scale (see below) which ranges from 1 to 9. A value of 5 will indicate that the criteria A is strongly more important than criteria B, whereas a value of -5 will indicate that the criteria A is strongly less important than criteria B.



Scales	Degree of preference	Explanation
1	Equally	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly to moderately favor one activity over another
5	Strongly	Experience and judgment strongly or essentially favor one activity over another
7	Very strongly	An activity is strongly favored over another and its dominance is showed in practice
9	Extremely	The evidence of favoring one activity over another is of the highest degree possible of an affirmation
2, 4, 6, 8	Intermediate values	Used to represent compromises between the preferences in weights 1, 3, 5, 7, and 9
Reciprocals	Opposites	Used for inverse comparison

Figure 1: Saaty's scale which is used in the Analytical hierarchy process (AHP)

The criteria I will be using in my study (and asking you to rank) is shown in the table below.

Table 1: Criteria incorporated in my study for new market selection for independent power producers

Category	Criteria	Sub-Criteria
Technical	Wind climate	• Wind resource • Maximum capacity factor
	Grid system	• Grid stability • National electrification rate
Economic	Cost of electricity	• Electricity tariff • Electricity cost
	Corporate tax rate	
	Country credit rating	
	Country forex reserves	
	Ease of doing business	
	Market size	• Current generation capacity • Future demand
	PPA quality	• Payment guarantee • PPA term
Political	Government support	• Renewable energy targets • Incentives (specifically and exclusively) for on-grid RE
	Political stability	• Political risk • Safety in-country
Social	Social acceptance	

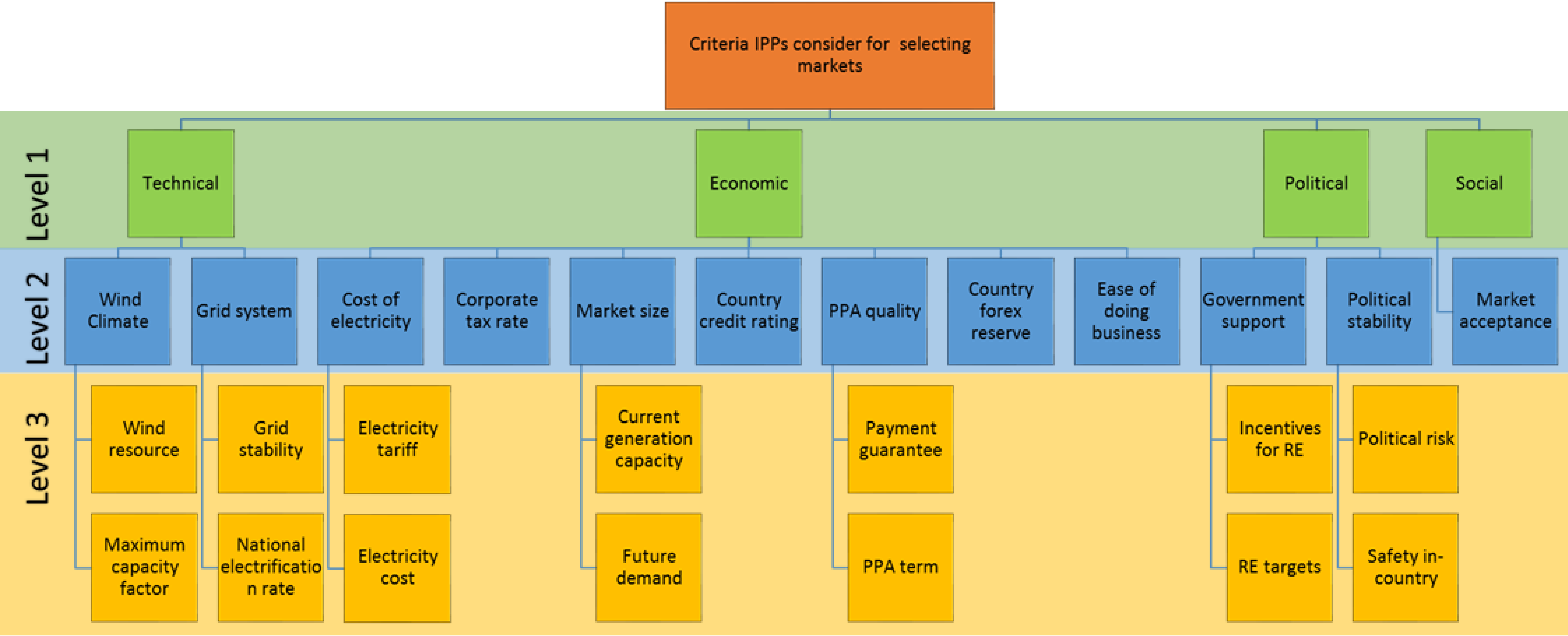
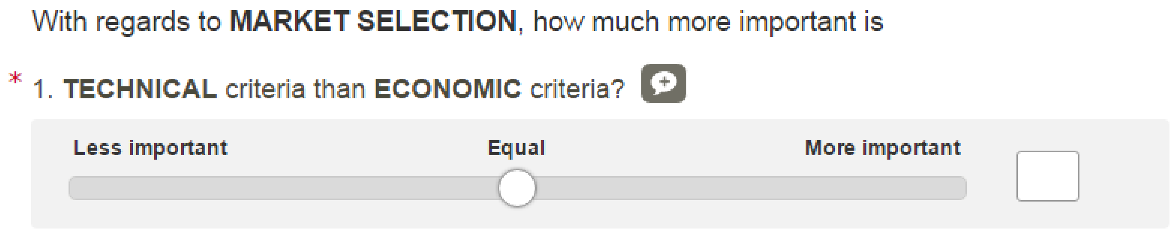


Figure 2: Hierarchy of the criteria incorporated in my study for new market selection for independent power producers

Example of question:

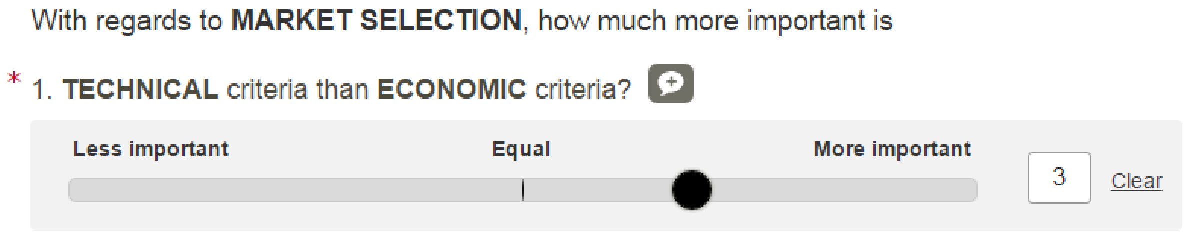
Example of an unanswered question below:



With regards to **MARKET SELECTION**, how much more important is

* 1. **TECHNICAL** criteria than **ECONOMIC** criteria?

Example of an answered question below indicating than technical criteria is moderately more important than economic criteria.



With regards to **MARKET SELECTION**, how much more important is

* 1. **TECHNICAL** criteria than **ECONOMIC** criteria?

3

If you have questions at any time about the survey or the procedures, please feel free to contact me via email enelge.gildenhuys@gmail.com or on my mobile +27605798405.

Thank you again for your participation.

Kind regards,

Enelge de Jongh

SURVEY: Phase 1 of New Market Entry for IPPs, see Table 1 and Figure 2 for categories, criteria and sub-criteria and also the levels of these for the research.

Ranking criteria for wind IPP market selection

Level 1 of 3: **MARKET**

With regards to **MARKET SELECTION**, how much more important is

* 1. **TECHNICAL** criteria than **ECONOMIC** criteria?

Less important	**Equal**	**More important**	☐

* 2. **TECHNICAL** criteria than **POLITICAL** criteria?

Less important	**Equal**	**More important**	☐

* 3. **TECHNICAL** criteria than **SOCIAL** criteria?

Less important	**Equal**	**More important**	☐

* 4. **ECONOMIC** criteria than **POLITICAL** criteria?

Less important	**Equal**	**More important**	☐

* 5. **ECONOMIC** criteria than **SOCIAL** criteria?

Less important	**Equal**	**More important**	☐

* 6. **POLITICAL** criteria than **SOCIAL** criteria?

Less important	**Equal**	**More important**	☐

SURVEY: Phase 1 of New Market Entry for IPPs, see Table 1 and Figure 2 for categories, criteria and sub-criteria and also the levels of these for the research.

Ranking criteria for wind IPP market selection

Level 2 of 3: **TECHNICAL**

With regards to **TECHNICAL** criteria for **MARKET SELECTION**, how much more important is

* 7. the **WIND CLIMATE** than the **GRID SYSTEM**?

Less important **Equal** **More important**

○ ☐

SURVEY: Phase 1 of New Market Entry for IPPs, see Table 1 and Figure 2 for categories, criteria and sub-criteria and also the levels of these for the research.

Ranking criteria for wind IPP market selection

Level 2 of 3: **ECONOMIC**

With regards to **ECONOMIC** criteria for **MARKET SELECTION**, how much more important is

* 8. **COST OF ELECTRICITY** than the **MARKET SIZE**?

Less important **Equal** **More important**
○ ☐

* 9. **COST OF ELECTRICITY** than **CORPORATE TAX RATE**?

Less important **Equal** **More important**
○ ☐

* 10. **COST OF ELECTRICITY** than the **COUNTRY CREDIT RATING**?

Less important **Equal** **More important**
○ ☐

11. **COST OF ELECTRICITY** than the **POWER PURCHASE AGREEMENT QUALITY**?

Less important **Equal** **More important**
○ ☐

* 12. **COST OF ELECTRICITY** than the **COUNTRY FOREX RESERVE**?

Less important **Equal** **More important**
○ ☐

* 13. **COST OF ELECTRICITY** than **EASE OF DOING BUSINESS**?

Less important **Equal** **More important**
○ ☐

* 14. **CORPORATE TAX RATE** than the **MARKET SIZE**?

Less important	Equal	More important	
○			☐

* 15. **CORPORATE TAX RATE** than the **COUNTRY CREDIT RATING**?

Less important	Equal	More important	
○			☐

* 16. **CORPORATE TAX RATE** than **POWER PURCHASE AGREEMENT QUALITY**?

Less important	Equal	More important	
○			☐

* 17. **CORPORATE TAX RATE** than the **COUNTRY FOREX RESERVE**?

Less important	Equal	More important	
○			☐

* 18. **CORPORATE TAX RATE** than the **EASE OF DOING BUSINESS**?

Less important	Equal	More important	
○			☐

* 19. the **MARKET SIZE** than the **COUNTRY CREDIT RATING**?

Less important	Equal	More important	
○			☐

* 20. the **MARKET SIZE** than the **POWER PURCHASE AGREEMENT QUALITY**?

Less important	Equal	More important	
○			☐

* 21. the **MARKET SIZE** than the **COUNTRY FOREX RESERVE**?

Less important	Equal	More important	
○			☐

* 22. the **MARKET SIZE** than the **EASE OF DOING BUSINESS**?

Less important	Equal	More important	
○			☐

* 23. the **COUNTRY CREDIT RATING** than the **POWER PURCHASE AGREEMENT QUALITY**?

Less important	Equal	More important	
○			☐

* 24. the **COUNTRY CREDIT RATING** than the **COUNTRY FOREX RESERVE**?

Less important	Equal	More important	
○			☐

* 25. the **COUNTRY CREDIT RATING** than the **EASE OF DOING BUSINESS**?

Less important	Equal	More important	
○			☐

* 26. the **POWER PURCHASE AGREEMENT QUALITY** than the **COUNTRY FOREX RESERVE**?

Less important	Equal	More important	
○			☐

* 27. the **POWER PURCHASE AGREEMENT QUALITY** than the **EASE OF DOING BUSINESS**?

Less important	Equal	More important	
○			☐

* 28. the **COUNTRY FOREX RESERVE** than the **EASE OF DOING BUSINESS**?

Less important	Equal	More important	
○			☐

SURVEY: Phase 1 of New Market Entry for IPPs, see Table 1 and Figure 2 for categories, criteria and sub-criteria and also the levels of these for the research.

Ranking criteria for wind IPP market selection

Level 2 of 3: **POLITICAL**

With regards to **POLITICAL** criteria for **MARKET SELECTION**, how much more important is

* 29. **GOVERNMENT SUPPORT** than **POLITICAL STABILITY**?

Less important **Equal** **More important**

SURVEY: Phase 1 of New Market Entry for IPPs, see Table 1 and Figure 2 for categories, criteria and sub-criteria and also the levels of these for the research.

Ranking criteria for wind IPP market selection

Level 3 of 3

With regards to

* 30. **WIND CLIMATE**: how much more important is the **WIND RESOURCE** than the **MAXIMUM CAPACITY FACTOR**?

Less important **Equal** **More important** ☐

* 31. **GRID SYSTEM**: how much more important is **GRID STABILITY** than the **NATIONAL ELECTRIFICATION RATE**?

Less important **Equal** **More important** ☐

* 32. **COST OF ELECTRICITY**: how much more important is **ELECTRICITY TARIFF** than the **ELECTRICITY GENERATION COST**?

Less important **Equal** **More important** ☐

* 33. **MARKET SIZE**: how much more important is **CURRENT GENERATION** than **FUTURE DEMAND**?

Less important **Equal** **More important** ☐

* 34. **POWER PURCHASE AGREEMENT QUALITY**: how much more important is a **PAYMENT GUARANTEE** than the **POWER PURCHASE AGREEMENT TERM**?

Less important **Equal** **More important** ☐

* 35. **GOVERNMENT SUPPORT**: how much more important is **RENEWABLE ENERGY TARGETS** than **INCENTIVES SPECIFICALLY AND EXCLUSIVELY FOR ON-GRID RENEWABLE ENERGY**?

Less important	Equal	More important	
○			☐

* 36. **POLITICAL STABILITY**: how much more important is **POLITICAL RISK** than **SAFETY IN-COUNTRY**?

Less important	Equal	More important	
○			☐

Annexure B: Assessment of Ethics in Research Projects form

EBE Faculty: Assessment of Ethics in Research Projects

Any person planning to undertake research in the Faculty of Engineering and the Built Environment at the University of Cape Town is required to complete this form before collecting or analysing data. For more info regarding the procedure of completing the form please log onto http://www.ebe.uct.ac.za/research/ethics/.
When completed it should be submitted to the supervisor (where applicable) and from there to the Head of Department. If any of the questions below have been answered YES, and the applicant is NOT a fourth year student, the Head should forward this form for approval by the Faculty EIR committee: submit to Ms Zulpha Geyer (Zulpha.Geyer@uct.ac.za; Chem Eng Building, Ph 021 650 4791).
Students must include a copy of the completed form with the thesis when it is submitted for examination.

Name of Principal Researcher/Student:
Eneige Gildenhuys

Department:
Construction Economics and Management

If a Student: Degree: **MSc Property Studies** Supervisor: **Kathleen Evans**

If a Research Contract indicate source of funding/sponsorship: **NA**

Research Project Title:
Effective selection of countries in sub-Saharan Africa for independent wind power producers using a Multiple Criteria Decision analysis

Overview of ethics issues in your research project:

Question 1: Is there a possibility that your research could cause harm to a third party (i.e. a person not involved in your project)?	YES	☒ NO
Question 2: Is your research making use of human subjects as sources of data? If your answer is YES, please complete Addendum 2.	☒ YES	NO
Question 3: Does your research involve the participation of or provision of services to communities? If your answer is YES, please complete Addendum 3.	YES	☒ NO
Question 4: If your research is sponsored, is there any potential for conflicts of interest? If your answer is YES, please complete Addendum 4.	YES	☒ NO

If you have answered YES to any of the above questions, please append a copy of your research proposal, as well as any interview schedules or questionnaires (Addendum 1) and please complete further addenda as appropriate.

I hereby undertake to carry out my research in such a way that

- there is no apparent legal objection to the nature or the method of research; and
- the research will not compromise staff or students or the other responsibilities of the University;
- the stated objective will be achieved, and the findings will have a high degree of validity;
- limitations and alternative interpretations will be considered;
- the findings could be subject to peer review and publicly available; and
- I will comply with the conventions of copyright and avoid any practice that would constitute plagiarism.

Signed by:

	Full name and signature	Date
Principal Researcher/Student:	Eneige Gildenhuys	25/04/2017

This application is approved by: Supervisor (if applicable):	Signed by candidate signature removed	28/04/2017
HOD (or delegated nominee): Final authority for all assessments with NO to all questions and for all undergraduate research.		
Chair : Faculty EIR Committee For applicants other than undergraduate		10 May 2017