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Research materials for

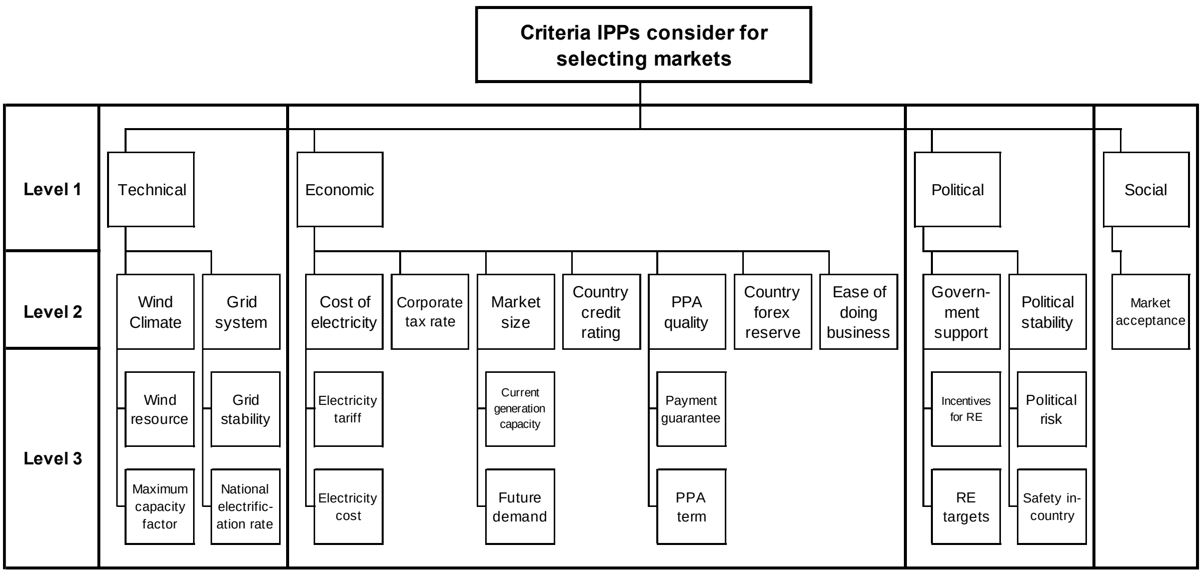
Effective selection of countries in Sub-Saharan Africa for new market entry by independent wind power producers

Carsten Lausberg, **Kathleen Evans**, **Enelge de Jongh**

PROMETHEE preference functions

(see reference to this supplementary information in the research article above, METHODOLOGY – Research approach in this study - Phase Two: Ranking the criteria and data collection)

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.



Copied for ease of reference from Research Article, Figure 2: Hierarchy of the research problem of this study

These preference functions of the criteria shown in Figure 2 of the Research Article, are built into the PROMETHEE model. Each of these is discussed below in detail.

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. There can, therefore, 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 1: 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 is sourced from the Global Competitiveness Report 2016-2017 (Baller et al., 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, a difference therefore 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 have changed substantially in the last six years. However, this study is one of the few studies which reviewed the electricity tariff of various countries on the exact same basis. Electricity tariff range 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.

Credit rating

The 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 Table 6.

Table 2: 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) 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 target

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 target 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 range 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.

Consistency in the AHP method

(supplementary information to section 3.2.3)

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 $A = 2 \cdot B$ and $A = 5 \cdot C$, 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 $A = 3 \cdot B$ and $B = 4 \cdot C$, then $A = 12 \cdot C$, 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, and while this is allowed, the inconsistencies should be limited to less than 10%. To avoid or limit inconsistencies the literature recommends that no more than nine 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 shown in Table 7 below.

Table 1: Values of the Random Index (RI), taken from Saaty (1987, p. 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 formula $CI = \frac{\lambda_{max} - n}{n-1}$ is used, 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.

Table 2: Hypothetical example of determining CR

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

	A	B	C
A	1	1/3	5
B	3	1	7
C	1/5	1/7	1

Step 2: sum the total value of each column

	A	B	C
A	1	1/3	5
B	3	1	7
C	1/5	1/7	1
Total	21/5	31/21	13

Step 3: divide each value by the sum of the column

	A	B	C
A	5/21	7/31	5/13
B	15/21	21/31	7/13
C	1/21	3/31	1/13

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	Averag e
A	5/21	7/31	5/13	0.2828
B	15/21	21/31	7/13	0.6434
C	1/21	3/31	1/13	0.738

Step 5: insert the values into the formula

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

So $CI = \frac{\lambda_{max} - n}{n-1} = \frac{3.0967-3}{3-1} = 0.04835$ and $CR = \frac{CI}{RI} = \frac{0.04835}{0.58} = 8.3\%.$

This is less than 10%, so the inconsistencies in this example are allowed.

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