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DETERMINING THE MOST IMPORTANT FACTORS FOR SUSTAINABLE ENERGY TECHNOLOGY SELECTION IN AFRICA: APPLICATION OF THE DELPHI TECHNIQUE

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The supply of sustainable energy is crucial for poverty reduction and economic development in Africa. Such supply to the private sector and to households is necessary to improve productivity and efficiency and ensure that all members of society are economically active. Further, Africa has limited skilled human resources; thus the selection of successful, integrated technological systems is imperative. This study focused on the identification, and prioritisation, of the factors that must be taken into account when identifying the most sustainable technological systems in the African context. The study utilised the Delphi technique. The questionnaire of the first round was based on factors identified during a focus group exercise with energy experts. Respondents were asked to comment on the factors, add new factors, and rate all the factors. The results were fed back during the second round where respondents were again asked to rate the factors for feasibility, desirability and importance. The final result is the identification of the most important factors for the selection of sustainable energy technologies, which can be used by decision makers to ensure better selection of projects. The top five factors identified in this study are: Ease of maintenance and support over the life cycle of the technology; Suitable site readily available for pilot studies; Project Management; Economic development; and Access to suitable sites can be secured.

Keywords: Project selection, system selection, technology assessment, sustainable energy, Delphi research, South Africa,

Introduction

Africa has limited human and financial resources and thus it is imperative that the technologies selected for implementation are successful. In order to provide decision makers with assistance when selecting sustainable energy projects in Africa, the study documented in this article was undertaken.

Sustainable technologies enable humans to meet their needs with minimum impact on the environment (Perdan, 2004:10). Sustainable energy technologies will thus take into account social, ecological and economic factors as well as the short and long term advantages and disadvantages of the technology. This research study subsequently focussed on identifying the factors that need to be taken into account when selecting sustainable energy technologies for implementation in Africa.

The study consisted of a focus group, Delphi survey and a case study. This paper addresses the Delphi study only.

The Delphi method was originally used to forecast technological developments, thus like an oracle of the future, hence the name Delphi which relates to the Oracle at Delphi in Greek mythology (Anon, 2006). The main advantage of the Delphi Method is that participants can reconsider judgments and that the technique is especially useful when the problem does not lend itself to precise analytical techniques (Crichter and Gladstone, 1998). Determining the factors for sustainable energy project selection in Africa fits the description of not lending itself to precise analytical techniques.

The Delphi method is summarized in Mullen (2003), as a process that has a number of rounds where feedback is given to the participants between rounds after which they are given an opportunity to modify their responses, the responses are anonymous, Delphi studies vary in application in panel size, composition and selection of panel, questionnaire design, number of rounds, form of the feedback and how consensus is treated. For a successful Delphi study, good research practice both in terms of qualitative and quantitative research should be followed, which includes piloting of questionnaires, application of statistical techniques etc.

Objectives of this study

According to Turoff (1970), the possible objectives of a Delphi study include the determination or development of a range of possible alternatives, the exploration or exposition of underlying assumptions or information leading to differing judgments, the seeking out of information that may generate a consensus of judgments on the part of the participants, the correlation of informed judgments on topics spanning a wide range of disciplines, the education of respondent groups as to the diverse and interrelated aspects of a topic. There are two primary objectives for the study described in this paper:

(i) Identifying a range of possible factors that should be taken into account during selection of sustainable energy projects in Africa.
(ii) Prioritising the factors taking into account the feasibility, desirability and importance of each factor.

Some secondary objectives included categorisation of factors, update of the factor descriptions as determined during the focus group and obtaining suitable sites for case studies for the next phase of the study.

Study design

The approach that was followed is shown in Figure 1. The Delphi study was preceded by a focus group with three industry experts. The objectives of the focus group were:

(i) Identification of factors important during the selection of sustainable energy projects in Africa.
(ii) Categorisation of the identified factors.
(iii) Preliminary prioritisation of the factors.
(iv) Determination of experts that could participate in the Delphi study.

Careful consideration must be given to the nature of the research problem before deciding to use the Delphi method as the Delphi method is only appropriate for certain research problems (Hasson et al., 2000). The decision to employ the Delphi technique must be based on the appropriateness of the possible alternatives (Hasson et al., 2000). The other available techniques must also be considered. For example, if a big enough sample is available then a comprehensive survey method must be considered. If the participants are not geographically dispersed the interview or focus group method can be considered.

In this case it was decided to use the Delphi method in conjunction with the focus group and case study techniques. The focus group technique was applied to a group of South African experts who were geographically co-located. The use of the survey, interview or focus group method could not be used as an alternative for the Delphi method as respondents throughout Africa and other parts of the developing world were required. The sample available was also not big enough to obtain statistically valid results when using the survey technique.

The Delphi study consisted of two rounds. In pioneering Delphi studies, more rounds were used than in more recent studies. In recent literature the use of as few as two and as many as five rounds is reported (Crichter and Gladstone, 1998). The more refined the initial questionnaire, the quicker consensus can be reached and most researchers report that the positions of the respondents are unlikely to change after two or three rounds (Critcher and Gladstone, 1998). Repeated rounds may lead to fatigue in respondents and increased respondent attrition (Mullen, 2003).

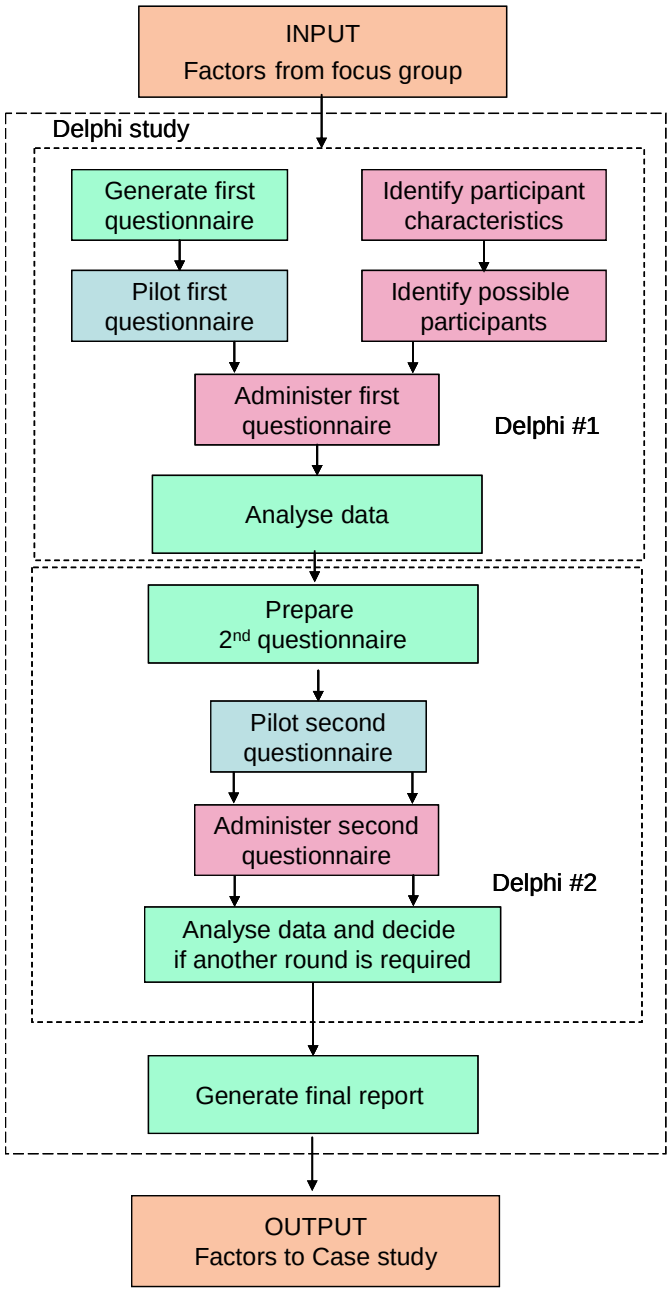

Figure 1: Block diagram of the Delphi process

Due to the fact that the first Delphi survey was informed by the factors identified during the focus group, the first round Delphi questionnaire was refined.

In the study done by Boynton (2006) Delphi questions were presented via the Survey Monkey Web site (www.surveymonkey.com). This allowed the respondents to access the internet when they had the opportunity and allowed the researcher to collect the responses in an efficient and effective manner. Other electronic methods that have been used include an e-mail survey (Griffith et al., 2006; Okoli and Pawlowski, 2004) and a web-based questionnaire (Miro et al., 2007; Okoli and Pawlowski, 2004). Surveys can also be returned via fax (Okoli and Pawlowski, 2004). A questionnaire can be designed in the same study for different methods of

response but care must then be taken that the questionnaires have the same measures (Okoli and Pawlowski, 2004). In this study, the questionnaires for the two Delphi rounds were each implemented in Survey Monkey (www.surveymonkey.com). This facilitated data gathering as responses did not need to be manually entered into a database thus eliminating data capture errors. The Delphi study will be followed by case studies of several sustainable energy projects in Africa in order to validate that the factors identified are indeed correct.

Respondent population

The definition of an expert for the Delphi process is a contentious issue in the literature. Much of Sackman's (1974) criticism of the method is based on the contention that expert cannot be properly defined. Definitions of an expert in the literature include, anyone with relevant input to the Delphi topic being studied (Mullen, 2003), any individual with relevant knowledge and experience in a particular topic (Cantrill et al., 1998), a wide range of experts from different backgrounds as Delphi enables disagreements in a constructive forum that ensures equal participation (Crichter and Gladstone, 1998), and individuals with prior experience with the issue at hand (Alberts, 2007).

A knowledge resource nomination worksheet can be used for the selection of experts; this worksheet identifies classes of experts first in terms of the most appropriate disciplines, organizations and literature for obtaining experts, after which it is populated with actual names of potential experts for the Delphi (Okoli and Pawlowski, 2004). A knowledge resource nomination worksheet approach was followed in this study.

The first class of experts identified was the contacts that were obtained during the focus group. This included the list of energy researchers in Africa as compiled by the Council for Scientific and Industrial Research (CSIR) as well as various contact persons that the focus group members personally recommended. The second class of experts was the contacts obtained at the networks of expertise in energy technology workshop of the international energy agency. These contacts included the International Energy Agency, South African universities, and the South African National Energy Research Institute (SANERI). The last group of experts was identified from an internet search. The focus of this search was South African universities involved in renewable energy research, the South African department of minerals and Energy renewable energy case studies and employees, attendees from sub-Saharan Africa of the Renewables 2004 conference held in Bonn,, the World Energy Council members who operate in sub-Saharan Africa as well as members listed on the renewable energy online database who operate in sub-Saharan Africa.

The selection of respondents resulted in a list of 62 possible respondents. The respondents were well distributed throughout Africa and the developing world with the majority of respondents from South Africa as shown in Figure 2. Those experts identified in Europe are currently involved in establishing sustainable energy technology in sub-Saharan Africa.

One of the very contentious issues surrounding Delphi in the literature is what the size of the Delphi panel of participants, i.e. the sample size, should be. The sample size should be governed by the purpose of the investigation (Cantrill et al., 1998). The sizes of Delphi panels vary from three to five hundred (Wild and Torgensen, 2000), four to three thousand (Cantrill et al., 1998), six (Griffith et al, 2006), six to twelve (Mullen, 2003), a minimum of seven (Mullen, 2003), seven to twelve (Mullen, 2003), ten to fifteen (Delbecq et al., 1975), ten to eighteen (Okoli and Pawlowski, 2004), ten to fifty (Turoff, 1970), (Crichter and Gladstone, 1998) and twenty to twenty-seven (Bijl, 1992). Due to the specialized nature of the information required by this study, it was decided at the outset that only a minimum of seven respondents were required during each round which translates to a response rate of about ten percent.

Delphi studies must not be confused with conventional surveys where statistically large numbers are required for validity (Mullen, 2003). The optimal size seems to be between seven and thirty as Mullen (2003) states that with a panel size of smaller than seven the accuracy deteriorates and Delbecq et al. (1975) state that no further new ideas are generated once the panel exceeds thirty participants.

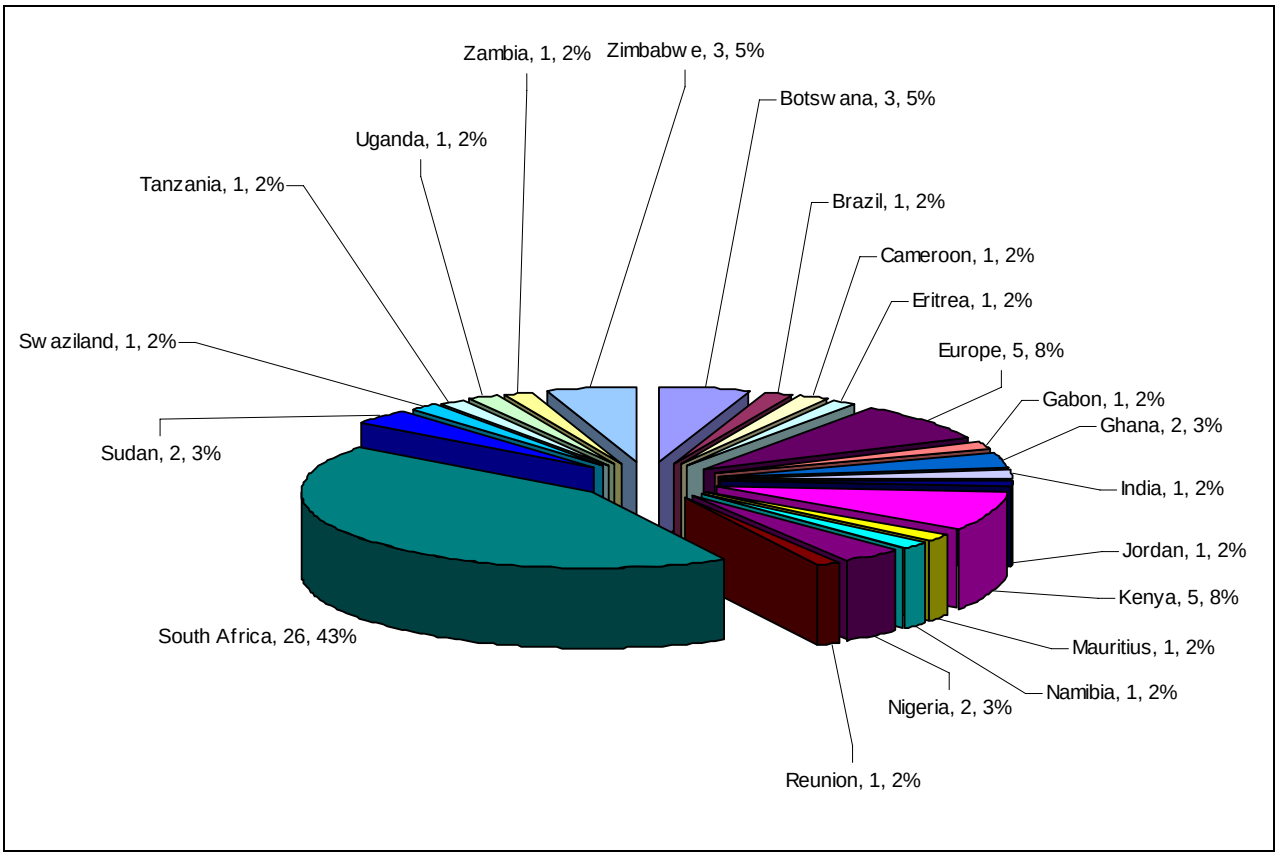

Figure 2: Geographical distribution of identified respondents

Misgivings in terms of self-selection bias seem to be unfounded as a study to determine bias found no compelling difference between characteristics of nominees that were willing to take part and those who were not (Mullen, 2003).

Questionnaires

The development of a Delphi questionnaire should conform to professional standards for questionnaire design (Mullen, 2003). The materials must be well-prepared beforehand, there should be no grammatical or spelling errors in the questions or cover letter, the task instructions should be unambiguous and thoroughly tested, the one page cover letter should thank the individual for participating, explain why the person's inputs are required and explain how the results of the Delphi will be used, how the questionnaire is to be completed and what the response date for the questionnaire is (Delbecq et al, 1975).
Guidelines on internet research recommend that the description and nature of the research should always include the identity of the researcher, the reasons why the respondent has been chosen to participate, the likely benefits of participation and a statement on how privacy will be handled during the study (Esomar, 2005).

First questionnaire

According to the literature anonymity in Delphi studies ranges from very rigid where panel members are unknown to each other and to the researcher, where essential anonymity is maintained i.e. when responses are anonymous to other panel member to the other extreme where the final round consists of a face to face meeting

with the panellists and the researcher or even very controversially having the first round as a face to face meeting (Mullen, 2003). In this study, respondents were anonymous to each other but not to the researcher. This enabled the researcher to follow up with non-respondents.

In the first section of the first questionnaire, the study objectives, anonymity of respondents, study leaders, result distribution, number of rounds and time to complete the study were presented to the respondents.

According to the literature, as much biographical information as possible should be obtained on each expert, such biographical information should include number of papers published, presentations made at conferences, length of years in the field etc (Okoli and Pawlowski, 2004). In this study the following biographical information was captured: e-mail address, geographical area, type of organisation, years of experience in the energy field, publications in the energy field, highest qualification, monetary value of projects. According to the ethics requirements of the University of Pretoria, respondents were also informed of their right not to choose to participate and also of the fact that the output of the study would be published. Respondents could opt out of the study at this point.

The first round Delphi study was presented next. In this study a modified version of the five point Likert scale definitions of desirability, feasibility and importance as reported by Jillson (1975) was used. The modified version was presented to the respondents in table form which is shown in Table 1.

It has been proposed that Delphi questionnaires follow three steps where step one involves generating as many ideas as possible, step two the narrowing down of the list to the most important items and step three being the ranking of the list according to the most important factors (Okoli and Pawlowski, 2004).

The first question can take on one of two forms namely a broad question where participants create subcategories and variables themselves on the other hand the questionnaire can also approximate survey research where variables are already developed and concern is only with refinement and movement towards consensus (Delbecq et al, 1975).

In this study, the first round questionnaire used the factors identified during the focus group as a starting point. Respondents were asked to comment on the category in which a factor was placed, the wording of a factor as well as to rate the feasibility, desirability and importance of the factor. Respondents were also given the opportunity to add up to six new factors in each category as well as rate these new factors in terms of feasibility, desirability and importance.

Table 1: Table for evaluating desirability, feasibility and importance

	Desirability scale	**Feasibility scale**	**Importance scale**
1	• Highly desirable. • Factor has positive and little or no negative effect on success of implementation • Factor justifiable on own merits	• Highly feasible to gather information during proposal phase • Minimum additional resource required • No major political roadblocks in utilising this factor	• Highly relevant. First order of priority • Factor has direct bearing on major issues for technology selection • Must be resolved, dealt with or treated.
2	• Desirable. • Factor has positive and minimum negative effect on success of implementation • Factor justifiable in conjunction with other	• Feasible to gather information during proposal phase • Some additional resource required • Some political roadblocks in utilising	• Relevant factor. Second order of priority • Factor has significant impact on issues for technology selection • Does not have to be

	Desirability scale	**Feasibility scale**	**Importance scale**
	factors	this factor	fully resolved.
3	• Neither desirable nor undesirable. • Factor has equal positive and negative effect on success of implementation • Factor justifiable in conjuction with other factors desirable and highly desirable factors	• Contradictory evidence that informatation can be gathered during proposal phase • Increase in resource required • Political roadblocks in utilising this factor	• May be relevant factor. Third order of priority • Factor may have impact on issues for technology selection • May be a determining factor to a major factor.
4	• Undesirable. • Factor has little or no positive effect on success of implementation • Factor may be justifiable in conjuction with other highly desirable factors	• Some indication that informatation cannot be gathered during proposal phase • Large scale increase in resource required • Major political roadblocks in utilising this factor	• Factor insignificantly relevant. Low order of priority • Factor has no impact on issues for technology selection • Not a determining factor to a major factor.
5	• Highly undesirable. • Factor has major negative effect on success of implementation • Not justifiable	• Informatation required cannot be gathered during proposal phase • Unprecedented allocation of resources required • Politically unacceptable	• Factor not relevant. No priority • Factor has no impact on issues for technology selection • Factor should be dropped.

In some studies a self-rating of experts is included in the questionnaires. This self-rating can take many forms for example measurement of confidence in responses from 0 to 10 (Ishikawa, 1993), describing knowledge in area eg awareness, reading or working knowledge (Mullen, 2003). Evaluation of familiarity with each item is rated as fair, good or excellent (Mullen, 2003) or rating degree of knowledge or mastery as high, medium or superficial for each question (Landeta, 2006), asking experts to assign 100 points over 10 areas in order to self-rate expertise (Jillson, 1975). Ratings may be used to weigh responses or as filters to determine inclusion of respondents in subsequent rounds (Mullen, 2003). However, efficacy of self-rating is disputed by Pill (Mullen, 2003) as it is a subjective rather than an objective measure.

In line with this self rating, in this study participants were asked how pertinent their answers are to the objectives of the study, whether they were still motivated to continue, and whether the study would have value in their organisation.
On the final screen of the survey, participants were asked to estimate the time taken to complete the survey, and to add any other comments that they have on the study.
Piloting of questionnaires must conform to professional standards. For a pilot study the respondents are asked to complete the questionnaire, pilot studies frequently result in substantial revisions being made in the survey design (Dillman, 2007).
Piloting should enable one to have better estimate for the time to complete a questionnaire (Crichter and Gladstone, 1998). The questionnaire can be shortened or questions deleted if the time taken to complete the pilot study is found to be too long (Crichter and Gladstone, 1998), (Jillson, 1975).
The first questionnaire in this study was piloted by six participants. The participants included the study leaders, the statistics department and practicing energy experts. Several changes were made to the questionnaire after the pilot. The changes were mostly to ensure that the questions were understandable and that there was no duplication of factors.
To ensure maximum motivation the first questionnaire should be sent to the participants on the day that the person agrees to participate (Delbecq et al, 1975), (Okoli and Pawlowski, 2004). A dunning letter should be sent after one week and after that non-respondents should be telephoned (Okoli and Pawlowski, 2004), (Crichter and Gladstone, 1998).
The first questionnaire was sent to respondents via e-mail together with the letter asking them to participate. Of the 62 initially selected participants, the e-mail addresses of 11 were incorrect. Thus the final list of respondents was 51. Regular reminders were sent out every week of the three weeks within which the respondents had been asked to respond. By the end of the three weeks, only three respondents had participated. Personal reminders were then sent out to the participants outside of South Africa by one of the study leaders. Reminders were sent to those respondents who had started the survey and not completed it. Finally an extension to the survey was created and sent out to all the selected respondents. A printable The .pdf version (*.pdf) of the survey questions was also sent this time with instructions of how to fax back the results. In the end more than 7 respondents had answered the questions, which translates to a response rate of 13%. The reason for the low response rate is that the questionnaire took very long to complete and, due to the lack of telephone numbers, it was not possible to contact each respondent personally. In retrospect the section where the respondents were requested to change the categories in which the factors were place should have been left out as this was only a secondary objective of the study.
Walker and Selfe (as cited in (Mullen, 2003)) refer to an unacceptable 8 % to an excellent 100% response rate and recommend that for rigour a minimum of 70% is required although there is no support for this statement.
Typical response rates in the literature are 85% for round one and 62% for round two, 82% for round one and 57% for round two (Cantrill et al., 1998), 69% for round one and 71% for round two (Jillson, 1975), 58 % in round one and 85% in round two (Crichter and Gladstone, 1998) and in an internet survey 39% in round one, 39% in round two and 35% for round three.
Response rates typically range between half and two thirds of respondents for each round (Crichter and Gladstone, 1998). Concern has been expressed over bias resulting from low response rates and high attrition rates between rounds (Mullen, 2003).

Second questionnaire

Results should be promptly compiled and analyzed as they are returned, to ensure correct understanding and improve turn-around time (Gibson and Miller, 1990).
The data of the first round Delphi were promptly analysed and the second questionnaire was compiled. The time to complete the second questionnaire was limited to fifteen minutes in an effort to obtain better response rates.
Apart from the feedback justification which will be mostly numerical or statistical some form of aggregated group response should also be included (Mullen, 2003). In terms of the qualitative data (Schmidt, 1997) advocates the consolidation of responses from the first round into one single response list which must be verified by the participants in order to be able to establish the validity of the list. In addiction to the one

sentence explanation of each factor, an explanatory glossary must be included to define and explain each factor based on the information submitted by the respondents on the first questionnaire as well as the exact copy of the responses given by the experts to the first questionnaire (Okoli and Pawlowski, 2004). In terms of statistical feedback medians with minima, maxima, quartiles and/or inter-quartile ranges are usually used while some studies use means often accompanied by standard deviation and or range (Mullen, 2003). Other statistical data normally fed back includes numerical and graphical frequency distributions (Mullen, 2003), (Cantrill et al, 1998), (Okoli and Pawlowski, 2004), mean rank of each item for all items (Okoli and Pawlowski, 2004), an indication of the level of consensus using Kendall's W (Okoli and Pawlowski, 2004), box and whisker diagrams (Mullen, 2003) and a breakdown of how each proposition fared (Gibson and Miller, 1990).

The second questionnaire consisted of an introduction where the background of the study, the estimated time for completion and the due date were given. Respondents were given access to the detailed report on the first round of the Delphi study which included the rating of each factor by each respondent, the mean, median, maximum, minimum and histogram of each factor's rating as well as the motivation given by each respondent for the rating of factors. Respondents were then given the opportunity to opt out of the study if they preferred.

The introduction was followed by the capturing of similar demographic information as in the first study. This was followed by factor evaluation. In this section, the factors were presented to the respondents as rated during the first round questionnaire first in terms of feasibility, then desirability followed by importance. The same description for the rating of each category on a five point Likert scale, was used as in the first round Delphi (refer to Table 1). Respondents could click on each factor in order to obtain the report on the results of the first round Delphi. After the factor evaluation, respondents were then asked if they wished to comment on the factor description wording. If they responded "yes" they were taken to the section to comment. If they responded "no", they were directed to the final comments.

At the end of the survey participants were asked how long it took to complete the survey. At the end of the last round, a very broad, open-ended question should be included in order to give the participants a final opportunity to summarize the entire study (Gibson and Miller, 1990). The respondents were also requested to give any comments on the study as a whole. The next phase of this study involved a case study to validate the factors identified during the focus group and Delphi study. For this reason, respondents were asked to recommend suitable sites for the case study.

The second round questionnaire was piloted with four respondents who did not form part of the Delphi panel but included study leaders and two members of the department of statistics at the University of Pretoria. No changes to the questionnaire were recommended during the pilot study.

The second round should be sent to everyone originally nominated, regardless of whether they participated in the first round, as some people uncomfortable with open-ended questions (Gibson and Miller, 1990). During the first round, one participant had opted to be excluded from the study. The second round questionnaire was then sent to the original list of 50 respondents. Regular reminders were sent out during the two weeks which respondents had to complete the questionnaires. At the end of the allocated time, only 5 respondents had completed the questionnaire. An e-mail reminder was once again sent to the respondents outside of South Africa and where telephone numbers were available, the respondents in South Africa were reminded telephonically. This resulted in 8 respondents completing the questionnaire, which translates to a response rate of 16%.

Results

Usually propositions are judged against desirability, feasibility, importance and confidence (Crichter and Gladstone, 1998). The key measures were found to be feasibility and reliability, with importance used in their study as a check for final recommendations (Crichter and Gladstone, 1998). In order to force respondents to take a stance, at least two of these measures should be used and the scale used should not contain neutral points (Turoff, 1970).

In Jillson's study (Jillson, 1975) ratings on feasibility and desirability were translated into group scores by summing the scale values and dividing the total by the number of ratings. This procedure treats nominal scales as interval data. By reviewing the frequency distribution and scale scores Jillson was able to identify significant voting differences between those who rated themselves experts and those who did not.

The issue of when to halt iterations is determined by two objective statistical criteria namely, strong consensus i.e. larger than 0.7 measured by using a consensus index or in the absence of strong consensus when the consensus index stabilizes (Kumaraswamy and Anvuur, 2007).
The list of issues must be reduced by eliminating the issues not selected by the majority of the respondents and the list of issues should then be meaningfully ranked which means that the list must be bounded statistically rather than arbitrarily or else the mean ranks will show little variation (Schmidt, 1997). that the panel of experts must be well described in order to give the reader the tools to judge the reliability and relevance of the panel, the response rate for the initial call must be given as well as the number of panellists for each round so that the relevant statistics can be confirmed and indications of flagging of interest can be highlighted (Schmidt, 1997).

First questionnaire

Of the eleven respondents that completed the first part of the survey including the factor evaluation, ten (91%) were from Africa and one (9%) was from South America. Africa and South America are both seen as third world continents, so the respondent from South America can share lessons learned in this continent, which will also be applicable to Africa. 27% of respondents operate at micro level and 73% at macro level. The majority of respondent were from research organizations or universities (28%) followed by three groups of 18% that are project developers/implementers or from government or from energy consultancy firms. There were two groups with 9% of respondents in petrochemical companies and energy (electricity companies).
The total years' of experience in the energy field came to 201, with an average of 20.5, a minimum of 10 and a maximum of 38. This means that the respondents have a lot of experience in the energy field. Respondents were asked how many publications they have in the field of energy. Publications include journal papers, conference papers and books. Three respondents did not answer this question with one indicating that he/she has lost count. Of the nine respondents that did respond, the total number of publications is 373, the average 41.5, the minimum 3 and the maximum 135. This indicated that the panel is by and large respected by their peers in the field. The majority of respondents (55%) have a masters' degree, followed by 27% with PhDs and 18% with bachelors' degrees.
The projects in which the respondents are involved in vary from 4 (40%) of respondents involved in projects between $1 million to $ 10 million to 1 (10%) respondents involved in projects of more than $1 billion.
The means of all the factors for feasibility, desirability and importance as determined during the first round Delphi are summarised in Table 2.

Table 2: Factors sorted in terms of feasibility, desirability and importance

Number	Short description	Feasibility	Desirability	Importance
T2	Ease of maintenance and support over the life cycle of the technology	1.56	1.78	1.56
SS3	Suitable site readily available for pilot studies	1.71	1.71	1.43

Number	Short description	Feasibility	Desirability	Importance
I4	Compliance for green funding	1.71	1.86	2.29
T1	Maturity or proven track record of technology in the world	1.78	1.78	1.89
I3	Positive Environmental Impact Assessment	1.86	1.71	1.57
E4	Reliability of energy supply in the African context	1.89	1.78	1.56
I5	Degree of environmental impact of the technology	1.89	2.00	1.56
A1	Project Management	2.00	1.50	1.67
A2	Human resource capacity	2.00	1.67	1.67
E6	Availability of finance	2.00	1.71	1.71
T6	Must match available resources	2.11	1.67	1.67
SS1	Local champion to continue after implementation	2.14	1.71	2.00
I2	Must contribute to, not detract from national energy security	2.14	1.86	1.86
T3	Ease of transfer of knowledge and skills to relevant people in Africa	2.22	1.89	1.78
E1	Implementation of technology must be profitable	2.29	1.71	1.57
SS2	Adoption by community	2.29	1.71	1.71
I1	Does it fit under national priorities	2.29	1.86	2.14
S1	Create employment/ not eliminate jobs	2.43	2.14	2.43
A5	Political capacity	2.50	1.83	1.67
T5	Replicability (i.e. the possibility of up scaling)	2.56	2.11	2.00
E5	Existence of tax and other financial incentives	2.57	1.57	1.71
S3	Local labour used and new industries created	2.57	1.71	1.57
A4	Financial capacity	2.67	1.83	1.50
T4	Synergy of technology with other available technologies	2.67	1.89	2.11
A3	Technological capacity	2.67	2.17	2.00
E7	Possibility of equity financing by local partners	2.71	1.71	2.43
E2	Economic development	2.71	2.14	2.29
E3	Synergy with other types of projects	2.83	2.50	2.33
S2	Share holding equity – income for more than one sector of the economy	3.00	2.00	2.57
SS4	Access to suitable sites can be secured			

An updated scoring system (see Table 3), based on the system applied by Jillson (1975) was used to evaluate the factors.

Table 3: Scoring system for prioritisation

Mean value	Feasibility	Desirability	Importance
Less than 1.8	Highly feasible	Highly desirable	Highly important
Less than 2.6 and equal to or greater than 1.8	Feasible	Desirable	Important
Less than 3.4 and equal	Neither feasible nor	Neither desirable nor	Neither important nor

to or greater than2.6	infeasible	undesirable	unimportant
Less than 4.2 and equal to or greater than3.4	Infeasible	Undesirable	Unimportant
Less than 4.2	Highly infeasible	Highly undesirable	Highly unimportant

No factors were rated to be of indeterminate importance or indeterminate desirability, infeasible, highly infeasible, undesirable, highly undesirable, unimportant or highly unimportant.

A summary of the number of factors that were rated highly feasible is shown in terms of desirability and importance in Table 4. No factors were rated to be of indeterminate importance or indeterminate desirability.

Table 4: Summary of desirability and importance ratings for highly feasible factors

	Highly important	Important	Indeterminate importance
Highly desirable	3	1	0
Desirable	0	1	0
Indeterminate desirability	0	0	0

The highly feasible factors with high desirability, high importance or importance are shown in Table 5.

Table 5: Factors rated highly feasible, highly desirable, highly important or important

Factor No	Short description	Highly desirable and Highly Important	Highly desirable and Important
SS3	Suitable site readily available for pilot studies	X	
T1	Maturity or proven track record of technology in the world		X
T2	Ease of maintenance and support over the life cycle of the technology	X	

A summary of the number of factors that were rated feasible is shown in terms of desirability and importance in Table 6. No factors were rated to be of indeterminate importance or indeterminate desirability.

Table 6: Summary of desirability and importance ratings for feasible factors

	Highly important	Important	Indeterminate importance
Highly desirable	1	1	0
Desirable	3	4	0
Indeterminate desirability	0	0	0

The feasible factors with high desirability, high importance, desirability or importance are shown in Table 7. These factors are evenly distributed amongst the factor categories.

Table 7: Factors rated feasible, highly desirable, highly important, desirable or important

Factor No	**Short description**	Highly desirable and Highly Important	Highly desirable and Important	Desirable and Highly important	Desirable and Important

Factor No	**Short description**	Highly desirable and Highly Important	Highly desirable and Important	Desirable and Highly important	Desirable and Important
A1	Project Management	X			
A2	Human resource capacity	X			
E1	Implementation of technology must be profitable	X			
E4	Reliability of energy supply in the African context	X			
E5	Existence of tax and other financial incentives	X			
E6	Availability of finance	X			
I3	Positive EIA	X			
S3	Local labour used and new industries created	X			
SS1	Local champion to continue after implementation		X		
SS2	Adoption by community	X			
T6	Must match available resources	X			
T3	Ease of transfer of knowledge and skills to relevant people in Africa			X	
A5	Political capacity			X	
I5	Degree of environmental impact of the technology			X	
I1	Does it fit under national priorities				X
S1	Create employment/ not eliminate jobs				X
T5	Replicability (i.e. the possibility of up scaling)				X

A summary of the number of factors that were rated neither feasible nor infeasible is shown in terms of desirability and importance in Table 8.

Table 8: Summary of desirability and importance ratings for factors with indeterminate feasibility

	Highly important	Important	Indeterminate importance

Highly desirable	0	1	0
Desirable	1	6	0
Indeterminate desirability	0	0	0

The feasibility of seven factors was indeterminable. The reason for this was either due to polarisation (A4, A3 and E7) as some respondents rated the factor feasible while others rated it infeasible and those that are truly indeterminate as the modal response is neither desirable nor undesirable (3). The distribution of these indeterminable factors is shown in Table 9.

Table 9: Distribution of indeterminable factors

Number	Description	Very high	High	Indeterminate	Low	Very low	Mode	Mean
A4	Financial capacity	16.67%	33.33%	16.67%	33.33%	0.00%	2	2.666667
T4	Synergy of technology with other available technologies	0.00%	33.33%	66.67%	0.00%	0.00%	3	2.666667
A3	Technological capacity	0.00%	50.00%	33.33%	16.67%	0.00%	2	2.666667
E7	Possibility of equity financing by local partners	14.29%	28.57%	28.57%	28.57%	0.00%	2	2.714286
I4	Compliance for green funding	14.29%	28.57%	28.57%	28.57%	0.00%	3	2.714286
E2	Economic development	14.29%	14.29%	57.14%	14.29%	0.00%	3	2.714286
E3	Synergy with other types of projects	0.00%	14.29%	71.43%	0.00%	0.00%	3	2.833333
S2	Share holding equity – income for more than one sector of the economy	0.00%	28.57%	42.86%	28.57%	0.00%	3	3

During the first round, the factors were also categorised and the factor descriptions updated according to the comments made by the respondents. This information is not however shown here as these were secondary objectives of the study.

Second questionnaire

Of the eight respondents that completed the survey 7 (87%) of respondents were from Africa and one (13%) was from South America. The same South American respondent took part whereas the number of African respondents decreased. The micro to macro level representation changes from 27:73 to 50:50. The number of types of organisations decreased with the number of research organisation or university participants increasing by 1 to 4; whereas there are no petro-chemical, developers/implementers or government respondents. The number of energy (electrical utility) respondents increases by 1 to 2. The number and percentage of respondents per type of organisation is shown in Figure 3.

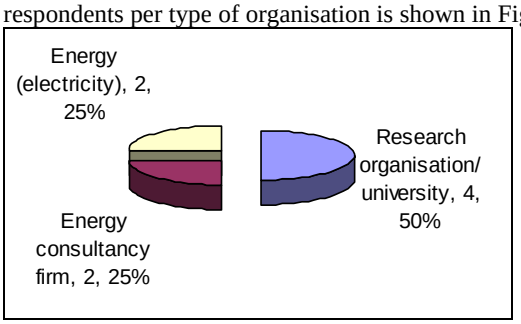

Figure 3: Number and % of respondents per type of organisation

The total years of experience in the energy field came to 181, with an average of 22.6, a minimum of 10 and a maximum of 328. This means that on average the respondents in the second round had more experience thatn those in the first round. The total number of publications is 239, the average 28.8, the minimum 10 and the maximum 70. This indicated that the panel is by and large respected by their peers in the field. The majority of respondents (50%) have a PhDs, followed by 25% with Masters and 25% with bachelor's degrees. This indicates an increase of one in PhDs and a decrease of two in Masters when compared to the first round Delphi.

The projects of the respondents vary from 1 of respondent having projects of less than $100,000 to 2 respondents having projects of between $100 million and $1 billion.
None of the factors scored highly feasible in the second round Delphi questionnaire. A summary of the desirability and importance ratings of the factors that scored feasible is shown in

Table 10: Summary of desirability and importance ratings for feasible factors

	Highly important	Important	Indeterminate importance
Highly desirable	11	9	0
Desirable	1	4	
Indeterminate desirability	0	0	0

The eleven factors that scored feasible, highly desirable and highly important are shown in Table 11.

Table 11: Factors rated "Feasible", "Highly desirable" and "Highly Important"

Number	Short description	Feasibility	Desirability	Importance
T2	Ease of maintenance and support over the life cycle of the technology	2.000	1.000	1.250
SS3	Suitable site readily available for pilot studies	2	1.625	1.75
A1	Project Management	2.125	1.375	1.375
E2	Economic development	2.125	1.5	1.625
SS4	Access to suitable sites can be secured	2.125	1.625	1.625
A3	Technological capacity	2.25	1.25	1.5
SS1	Local champion to continue after implementation	2.25	1.375	1.375
T3	Ease of transfer of knowledge and skills to relevant people in Africa	2.25	1.75	1.5
SS2	Adoption by community	2.375	1.625	1.75
E6	Availability of finance	2.5	1.625	1.75
A4	Financial capacity	2.5	1.75	1.5

The ten factors that scored feasible and highly important and desirable or highly desirable and important are shown in Table 12.

Table 12: Factors rated "Feasible" and, "Highly desirable" and "Important", or "Highly important" and "Desirable"

Number	Short description	Desirable and Highly important	Highly desirable and Important
E1	Implementation of technology must be profitable		X
E4	Reliability of energy supply in the African context		X
I2	Must contribute to, not detract from national energy security	X	
I3	Positive EIA		X
I5	Degree of environmental impact of the technology		X
S1	Create employment/ not eliminate jobs		X

Number	Short description	Desirable and Highly important	Highly desirable and Important
S3	Local labour used and new industries created		X
T1	Maturity or proven track record of technology in the world		X
T4	Synergy of technology with other available technologies		X
T5	Replicability (i.e. the possibility of up scaling)		X

The feasibility of five factors and the importance of one factor were indeterminable. The reason for this was either due to polarisation as some respondents rated the factor feasible while others rated it infeasible and those that are truly indeterminate as the modal response is neither desirable nor undesirable. The distributions of these indeterminable factors are shown in Table 13. This means that there is no consensus on factor A4: Human resource capacity. At the outset the decision was made to only implement two Delphi rounds. The fact that there is only lack of consensus on one of the factors supports this decision.

Table 13: Distribution of indeterminable factors

Factors indeterminate in terms of feasibility		Very high	High	Indetermin	Low	Very low	Mode
A2	Human resource capacity	0.0%	50.0%	25.0%	25.0%	0.0%	2
I4	Compliance for green funding	0.0%	25.0%	62.5%	12.5%	0.0%	3
S2	Share holding equity – income for more than one sector of the economy	0.0%	0.0%	100.0%	0.0%	0.0%	3
E7	Possibility of equity financing by local partners	0.0%	12.5%	62.5%	25.0%	0.0%	3
A5	Political capacity	0.0%	62.5%	62.5%	25.0%	0.0%	3
Factors indeterminate in terms of importance							
S2	Share holding equity – income for more than one sector of the economy	12.5%	12.5%	62.5%	12.5%	0.0%	3

It is interesting to note that none of the respondents to the second round Delphi wanted to comment on the descriptions of the factors. The following sites for suitable case studies were identified during the second round Delphi by the respondents:

(i) NuRa concession rural energy utility in South Africa;
(ii) Kuis community project in South Africa;
(iii) Increasing Access to Sustainable Biomass Energy Products and Services in the Lake Victoria Basin, Wakiso District, Uganda;
(iv) Multi function platforms in West Africa (e.g. Mali), West Africa; and
(v) Multifunctional platforms, Tanzania.

Conclusions and recommendations

The response rates in this study were low with a response rate of 13 % for the first round followed by a response rate of 16% in the second round. However, due to the fact that the first questionnaire was informed by outputs from a focus group and that the Delphi study will be followed by a case study to confirm the factors identified, the integrity of the study is not in question. The demographic information on the experts also points to the fact that highly qualified respondents participated.

The eleven most important factors are listed in order of priority in Table 11. The top five factors identified in this study are: Ease of maintenance and support over the life cycle of the technology; Suitable site readily available for pilot studies; Project Management; Economic development; Access to suitable sites can be secured. The descriptions of these top five factors are shown in Table 14.

Table 14: Full descriptions of top five factors identified

Number	Short Description	Full description

Number	Short Description	Full description
T2	Ease of maintenance and support over the life cycle of the technology	Ease of maintenance and support means that the security of supply is enhanced. It also implies that spares are affordable and can be easily acquired.
SS3	Suitable site readily available for pilot studies	Pilot studies are necessary to demonstrate technology to decision makers
A1	Project Management	This relates to the performing organisation having the project management capacity and procedures in place to ensure that the implementation of technology can be done successfully
E2	Economic development	Economic development translates into the community being able to pay for services and economic sustainability.
SS4	Access to suitable sites can be secured	Access to sites where the technology can be implemented must be secured up front.

This Delphi study is to be followed up by case study research to validate the factors identified and prioritised in the Delphi study. The project contact persons for all projects provided will be contacted in order to determine if these projects are suitable candidates for the case studies.

The case study research should focus on determining which factors were taken into account when selecting sustainable energy projects in Africa, and also on determining whether information was available at project selection for the top factors that were identified in the Delphi study.

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