Sustainability Assessment of Rural Solar PV Water Pumping System in Nepal

Ram Prasad Dhital[1*], Bishal Parajuli[2], Tri Ratna Bajracharya[1], Rajendra Sthrestha[1]

[1] *Institute of Engineering, Central Campus, Pulchowk*

[2] *Alternative Energy Promotion Centre, Ministry of Science, Technology and Environment, Nepal*

[*]Corresponding Email: rpdhital@yahoo.com

Abstract: Rural off grid electrification via different technologies is experiencing rapid market growth. The Government of Nepal with the help of donor agencies has been providing various supports in different renewable energy technologies. However, questions have been raised every now and then on sustainability of government led projects and if they are actually pushing the right technology. This paper focuses on the current scenario and sustainability of solar PV water drinking projects that the government has been supporting. Multi-criteria decision analysis method (AHP) is used in this article for the analysis purpose as they have become increasingly popular in decision making for sustainable energy. With respective selection of the criteria comprising technical, environmental, financial and institutional indicators the assessment of selected alternatives is carried out. The assessment procedure has taken off grid energy technologies like PV, diesel gen-set, wind, PV with battery back-up and micro/mini hydro into consideration as the potential alternatives for water pumping systems. The proposed evaluation will help to select the most suitable alternative assisting policy makers to form opinion on sustainability of considered energy systems and make decisions on optimum alternative. Material and results described in this paper are derived from Government supported projects.

Keywords: Sustainability, Analytical Heirarchy Process, Rural Water Pumping, MCDA

1. Introduction

Sustainability has been a key focus in the last decade and also has been the subject of wide ranging discussion and debate within government, non government and academic circles, being major focus of national and international agendas [1-3]. According to the European Union Sustainable Development Strategy (EUSDS), Sustainable Development envisages the continuous improvement of the quality of life of citizens through sustainable communities that manage and use resources efficiently and tap the ecological and social innovation potential of the economy, to ensure prosperity, environmental protection and social cohesion [30]. Sustainable development has also been defined as satisfying the present needs without compromising the ability of future generations to meet their own demands [5].

Energy sector plays a key role in achieving sustainable development and in the future, the energy production system is expected to take the lead in meeting sustainability goals [6]. Alternative Energy Promotion Centre (AEPC) is the government organization dedicated to promoting energy technologies in rural areas of Nepal. According to its annual budget, around 2 billion Nepalese rupees (21 million USD) is spent on renewable energy technologies in rural areas. Amongst the various energy projects, rural solar water drinking project (RSWDP) is one of the projects supported by AEPC. 136 Photovoltaic Pumping System (PVPS) have been installed under various projects implemented till 2010 [12]. Out of which, 30 PVPS have been installed under Renewable Energy Programme (REP), which was also a part of AEPC's program. The program carried out various studies in Water Pumping projects and prepared a guideline for its future implementation. With the support from the KfW (Kreditanstalt für Wiederaufbau), Energy Sector Assistance Programme (ESAP) alone had supported 25 Solar Drinking Water Pumping Project with total capacity of 39.1 kW in various rural area of Nepal. Under a new program called National Rural and Renewable Energy Program, 42 different installations are underway and within the program AEPC aims to promote 300 PVPS by mid 2017 [12].

With such ambition, considerable amount of monetary and time investment is likely to be spent for these projects. Therefore, it has been a great concern amongst the policy makers if they are pushing the right technology or are there other better ways of providing energy for such projects. For this reason, assessment of sustainability has been seen quite important.

Measuring sustainability is a major issue as well as driving force of the discussion on sustainability development [13]. Developing tools that reliably measure sustainability is a prerequisite for identifying non sustainable processes, informing policy makers of the options for sustainable processes. When aiming at sustainable development new challenges for strategic decision making arise from multi dimensionality of the sustainability goal, from the complexity of techno-economic systems. The current trend of rising fossil fuel prices and observed climate change, and other adverse environmental and societal impacts of energy use, make the exploration of more sustainable ways to sue energy more important than ever [14].

Analytical Hierarchy Process (AHP) is widely used for practical Multi Criteria Decision Analysis (MCDA) method in various domains, such as social, economic, agricultural, industrial, ecological and biological systems, in addition to energy systems [11, 17-20]. It is a descriptive decision analysis methodology that calculates ratio-scaled importance of alternatives through pair-wise comparison of evaluation criteria and alternative. It involves decomposing a complex decision into a hierarchy with goal (objective) at the top of the hierarchy, criteria and sub-criteria at levels and sub-levels of the hierarchy, and decision alternatives at the bottom of the hierarchy [15]. This paper identifies various possible factors relating to sustainability of renewable energy projects carried out by AEPC. AHP is used to prioritize different energy systems in terms of sustainability.

2. Availability of Energy Sources in Nepal

Solar Photovoltaic

Solar energy is the radiant energy produced by the sun in the form of light and heat. Solar PV systems are gaining popularity in some parts of Nepal. The estimated market potential is huge and about 8278.9kW of PV power is currently being used in various public and private sectors in Nepal [12]. On average Nepal has 6.8 hours of sunshine per day with the intensity of solar insolation ranging from 3.9 to 5.1kWh/m^2 (national average is about 4.kWh/m^2/day [21].

Diesel Generator

Diesel generator has been a very easy option of remote communities for their energy requirements. Diesel generators are a major source of backup power not only in rural areas but also in urban areas of Nepal. On 2012/2013, 721,203 kilo liters of diesel were imported in the country which is 10.34% increment compared to the previous year [22]. One quarter is expected to be used up in residential and agricultural activities of which water pump is also a major activity [23].

Wind

Wind energy is one of the most unharnessed energy resources in Nepal. Due to its extreme topography and variation in meteorological conditions, it is difficult to generalize wind patterns in the country. The Solar and Wind Energy Resource Assessment (SWERA, 2002–2007) project reported a potential area of about 6074 sq. km with a wind power density greater than 300W/m2, and total commercial potential of 300MWwind power considering the installed capacity of 5MWper sq. km.

Hydro

The theoretical and commercial potentials of hydropower in Nepal are estimated to be about 83,000 MW and 42,000MW respectively. Despite this huge potential, Nepal has only been able to tap less than 2% of its total potential supplying only 578.65 MW of power in the fiscal year 2012/2013 [25]. As of 2011, there are about 2510 hydro schemes installed in various part of the country with total installed capacity of about 36.78 MW [12]. The installation of micro-hydro plants increased significantly due to the subsidy policy implemented by AEPC/Energy Sector Assistance Program (ESAP) after year 2000.

3. Methodology

This paper investigates the sustainability using a MCDA tool. The analytic hierarchy process (AHP), a well-known MCDA approach, has been applied to work out the exercise. A group of experts from universities, independent consulting firms and AEPC experts were selected to work on the methodology. Major steps used in AHP which are described as follows:

1. Describing evaluation issues: This includes structuring hierarchy of goal, criteria, sub-criteria and alternatives, with goal at the top of the hierarchy, criteria and sub-criteria at lower levels and alternatives at the bottom of the hierarchy.
2. Identify all criteria which affect the issues: This step indulges with selecting related performance criteria and selection of appropriate criteria based on the process of reviewing and the relevant literature and interviewing experts. Selected criteria are shown in table 2.
3. Construction of hierarchy Structure: A hierarchy structure, in general, can be established from the top through the intermediate levels to the lowest level which usually contains the list of alternatives.
4. Pair-wise comparison: The criteria within each hierarchy should be evaluated against their corresponding criteria in the level above, and then compared in pairs between themselves. If there are "n" criteria in one hierarchy, decision-makers must conduct paired comparisons by n (n-1)/2. The establishment of paired matrices will lead to determining the weights of the criteria within each hierarchy [26].

$$\mathbf{A} = \begin{bmatrix} 1 & a_{12} & & a_{1n} \\ a_{21} & \cdots & a_{ij} & \cdots \\ \cdots & a_{ji} = 1/a_{ij} & \cdots & \cdots \\ a_{n1} & \cdots & \cdots & 1 \end{bmatrix}$$

Where, a_{ij} is the comparison between element i and j. Saaty recommends using "the fundamental scale of AHP" which uses 1-9 scale measurements and eigenvector approach [28] which is reproduced in table 1.

5. Consistency test: The purpose of consistency tests is to ensure whether the calculation fit the condition of transitivity in priority. Consistency ratio (CR) is used to verify the credibility and reasonability of evaluation, and to check whether there is inconsistent causality or conflicts in subjective judgments. The CR is acceptable if it does not exceed 0.1 [28]. The definition of consistency index showed as follows:

$$CI = (\lambda_{max} - n)/(n-1) and CR = (CI / RI_n)$$

6. Normalization: This study normalized the weight of the interval level and connected the local weight to acquire the global weights of the criteria in each hierarchy after calculating the weights of all criteria [26].

Table 1: The fundamental scale of absolute number [27]

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	A reasonable assumption
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

4. AHP

After careful study of renewable energy sources in Nepal, AHP based decision methodology was formulated to assess the sustainability of resources for water pumping specific projects. Sustainability, being the prime objective of this study, four criteria and 10 sub-criteria were identified that have major impact on the goal of the decision model. Selected criteria, sub-criteria and their brief introduction are given in table 2.

Hierarchy structure was then modeled as shown in fig 1. Sustainability is the placed on the top of as the goal of the study. Criteria are placed below the goal. Technical, Institutional, economic and environmental are the selected criteria. Sub-criteria are placed directly below the criteria. This model includes four steps comprising of goal, criteria, sub-criteria and alternatives. Alternatives lie at the bottom of the hierarchy.

Table 2: Criteria and Sub-criteria for sustainability assessment

Criteria	Sub-criteria	Description	References
Technical	Efficiency	Efficiency of a power plant refers to the ratio of the output energy to the input energy.	[29]
	Reliability	Reliability is defined as the ability of a system to perform as intended/designed under stated conditions for a specific period of time; or a ability to "fail well".	[15], [31], [32]
	Maturity	Maturity of a system refers to how well spread a technology is both nationally and internationally.	[33], [34], [35]
Economic	Initial cost	Initial cost consists of total expenditure occurred in establishing a power plant including the equipment, labor, installation, infrastructure and commissioning cost.	[36], [37], [31], [32], [15]
	O&M Cost	Operation and Management cost consists of two major parts. One is wages and funds spent for energy, other is the maintenance cost	[38], [39]
Environmental	CO2 Emission	It was reported that CO2 comprises of 9-26% of greenhouse gas (99). It is mainly released through combustion of coal/lignite and fossil fuels.	[40], [36]
	Land Requirement	The land required by each plant is a matter of great concern for evaluations.	[33], [41]
	Impact on vulnerable local natural resources	It is a measure of environment friendliness and impact of the power plan on the environment.	[42],[43],[44]
Institutional	Human Resource Availability	Ability to properly install and run the energy systems.	
	Plant operation and management structure	Often projects stop running because of incapable management and lack of operation capability. It is an important criterion for sustainability of a system.	

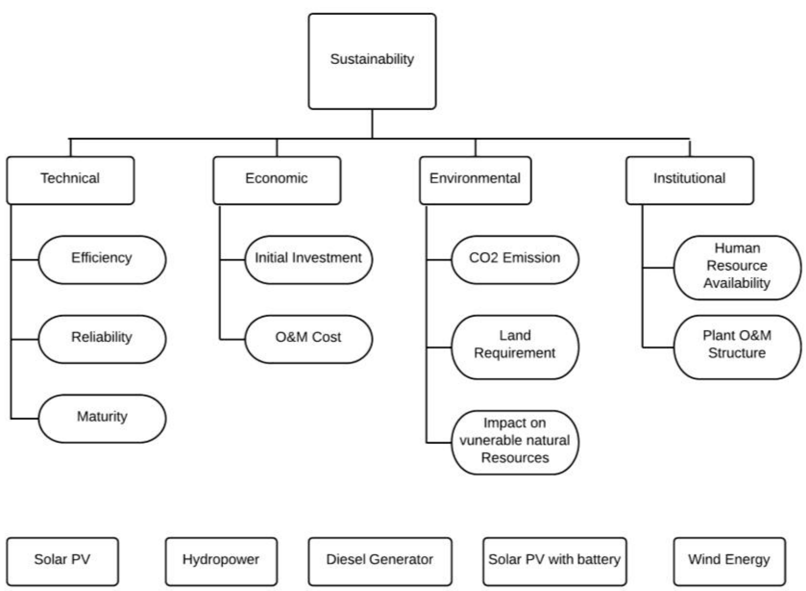

Figure 1: Hierarchy model of AHP

Table 3 shows the quantitative data related to Solar PV, wind energy, hydropower and diesel generator. Efficiency, average operating days per year, capital cost and operation and management (O&M) cost have been extracted from internal component reports from AEPC. Efficiency is the overall system's efficiency for a given technology. Average operating cost is based on the cost allocated by AEPC for O&M for its projects. For diesel generator, O&M cost includes annual fuel cost as well which has been calculated on current diesel price in the country of NRP 130/liter. Data for CO2 Emission and land requirement data have been extracted from Afgan, 2002.

Table 3: Data collected for various sub-criteria for alternatives based on the data collected from AEPC and [45]

Type of Power Plant	Efficiency (%)	Average Operating days/year	Capital Cost (NPR/W)	O&M cost (NPR/kWh)	CO2 (kgCO2/kWh)	Land Requirements (km^2/kW)
PV	10	300	160	4.5	0.1	0.12
Diesel Gen-Set	60	350	75	92	0.82	0.4
Wind	28	300	315	4.3	0.02	0.79
PV with Battery	9	300	400	6.2	0.12	0.14
Micro-hydro	66	330	430	26.25	0.04	0.13

5. Results and Discussion

After AHP methodology was formulated and all necessary instruments were developed for the process, a group of experts were brought together for the assessment. First, pair-wise comparisons were made to state the importance of one element over the other. Initially, pair-wise comparison of criteria with respect to the goal was done. Results of the weight obtained for different is shown in table 4. Technical criterion is identified as the most important criteria (48.68%). Environmental criterion has the lowest weight amongst all criteria. For each comparison, judgment was only finalized once a common agreement was reached between all experts. Respondents were asked to express their initial judgment and evaluate it with rest of the expert's impression and reach to a common conclusion. Overall inconsistency of judgments was less than 0.01.

Table 4: Relative weights of criteria with respect to the goal

Criteria	Technical	Economic	Environmental	Institutional
Score	48.68	32.57	4.42	14.33

Relative weights of criteria and sub-criteria with respect to the goal of the decision model are shown in table 5. System reliability is the most important sub-criterion with highest global weight. It comes from a very simple fact that if the systems keep failing consistently in rural areas, time and cost of repair and maintenance will jeopardize the sustainability of the project. O&M cost is the second most important sub-criterion. Initial investment only weighs 6.51%. Current trend of the rural development projects is that most of the initial investment is covered by either government bodies or donor agencies and user committees are responsible for operation and looking after the project. Higher O&M cost can lead to rural population not being able to afford its operation which again puts sustainability into risk. Hence, O&M has higher weight in comparison to the initial investment and is the second most important sub-criterion. Efficiency of the energy system comes third with 13.98% weight. It is followed by user operation and management structure which has been very crucial in the past experiences. There are plenty of development projects that have been dysfunctional because of lack of management capability. Land requirement is the least important criterion since there are plenty of unproductive lands available in rural areas. CO2 emission is also not amongst the priority criterion because lack of strict government policies on GHG emissions.

Table 5: Weight received by alternatives for each criterion

Alternatives	Priority	Environmental	Economic	Technical	Institutional
Solar PV	22.93	1.63	10.18	7.45	3.67
Diesel Generator	15.27	0.28	3.57	10.82	0.59
Solar PV with Battery Backup	18.08	1.15	6.91	7.2	2.83
Hydropower	23.93	0.58	2.04	14.74	6.58
Wind Energy	19.79	0.79	9.86	8.48	0.66

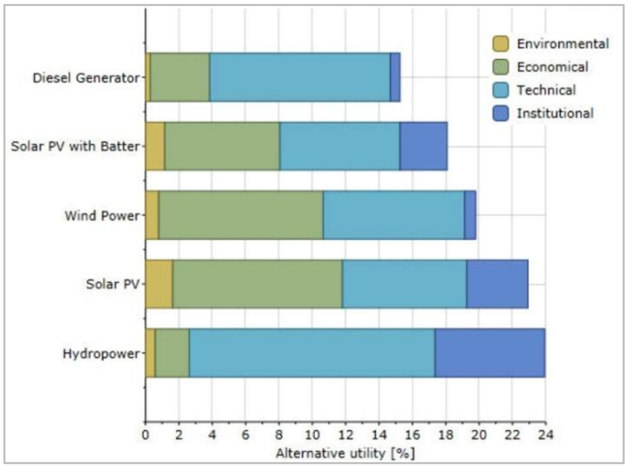

Figure 2: Ranking of alternatives with respect to sustainability

Based on the relative weights of the sub-criteria, priority of weights of each alternative has been calculated as shown in table 5, which is graphically presented in figure 2. This calculation of priority weights ranking is partly based on the actual objective data related to the sub-criteria. However, quantitative data for some of the sub-criteria was not available and through pair-wise comparison from experts, subjective data was obtained. Due to very efficient, reliable and mature technology with high institutional capability present in the country, hydropower has the highest priority weight (23.93%). Solar PV isn't very far off and has the second highest priority (22.93%) followed by wind energy and solar PV with battery backup. Diesel Generator is the least sustainable technology because of very high O&M cost and very low environmental benefits.

6. Conclusions

Five different technologies have been evaluated and compared for sustainable electricity generation for water pumping projects in rural areas. Multi criteria decision analysis was used to evaluate these technologies since traditional single criteria analysis would fall short when numerous factors come into consideration. AHP was MCDA technique that was chosen to conduct this assessment. In the model, several criteria and sub-criteria were identified for the selection and ranking of the most sustainable alternative. Experts quantified that technical is the most influential criteria with economical as the second most influential. Data were obtained from desk research and different projects that AEPC has executed.

The technical, economic, environmental and institutional importance of energy planning, to meet the ever increasing energy demand with an adequate energy supply, renders the evaluation of different energy projects a major challenge for policy makers. Results indicated that hydropower and solar PV technology are the most sustainable technologies with hydropower edging solar PV by only a fraction. Pushing these technologies will enhance energy sustainability for the country and reduce dependence on expensive and imported fuels. Wind power is the third most sustainable technology and also can play an important role in providing sustainable way out for water pumping projects. Diesel generator has been deemed the most unsustainable technology because of various factors like higher operating cost, insecure fuel supply and environmental unfriendliness.

The study aims to contribute on the debate on sustainability of solar water drinking projects, taking into account what policy makers need to continue to supply energy to these projects. It is however, limited to few criteria and sub criteria. There are other factors like social and political that could be included in future studies.

Acknowledgment

The authors are grateful to the AEPC for providing us with the valuable data. Further, this paper is largely based on various published papers and project reports as mentioned in references. University of Nottingham (UoN) and AEPC have provided the financial aid needed for study and publishing the article.

References

[1] Bilgen S, Keles S, Kaygusuz A, SarI A, Kaygusuz K. Global warming andrenewable energy sources for sustainable development: a case study in Turkey. Renewable and Sustainable Energy Reviews 2008;12:372–96.

[2] Omer AM, Energy. environment and sustainable development. Renewable and Sustainable Energy Reviews 2008;12:2265–300.

[3] Yusel I. Hydropower in Turkey for a clean and sustainable energy future.Renewable and Sustainable Energy Reviews 2008;12:1622–40.

[4] Klevas V, Streimikiene D, Grikstaite R. Sustainable energy in Baltic States.Energy Policy 2007;35:76–90.

[5] WCED. WCoEaD, our common future.Melbourne: OxfordUniversity Press; 1987

[6] Painuly J.P. (2001), *Barriers to renewable energy penetration; a framework for analysis,* Renewable Energy 24, pp 73-89

[7] Vera I., Langlois L., (2007) *Energy indicators for Sustainable Development.* Energy 32. pp 875–882

[8] KC S., Khanal S.K, Shrestha P., Lamsal B., *Current status of renewable energy in Nepal: Opportunities and*

challenges, Renewable and Sustainable Energy Reviews 15 (2011) 4107–4117

[9] WSSD 2011. *Water Supply, Sanitation and Hygine*: Sector Status Report. Water Supply & Sanitation Division, Sector Efficiency Improvement Unit, Ministry of Physical Planning and Works, pp 3 (128), Policy Document.

[10] WASH 2011. Retrieved on "24 April, 2014, Available at "http://www.moppw.gov.np/pdf/WASH-Sector-Status-Report-2011-for-WEB.pdf"

[11] Poladitis H, Haralambopoulos DA, Munda G, Vreeker R, (2006), *Selecting an appropriate multi-criteria decision analysis technique for renewable energy planning*, Energy Sources, Part B, 1:181-193

[12] Alternative Energy Promotion Centre (2011). AEPC Annual Report for 2010 (www.aepc.gov.np)

[13] Afgan N.H, Carvalho M.G , (2004) *Sustainability assessment of hydrogen energy systems*, International Journal of Hydrogen Energy 29 pp 1327-1342

[14] Kowalski K., Stagl S., Madlenar R., Omann I., (2009) *Sustainable energy futures: Methodological challenges in combining scenarios and participatory multi-criteria analysis*, European Journal of Operational Research 197 pp 1063–1074

[15] Wang et. al. (2009) *Review on multi criteria decision analysis aid in sustainable energy decision making*, Elsevier Renewable and Sustainable Energy Reviews 13 (2009) 2263-2278.

[16] Wilkens I., Schmuck P., (2012) *Transdisciplinary Evaluation of Energy Scenarios for a German Village Using Multi-Criteria Decision Analysis*, Sustainability, 4, pp 604-629

[17] Pilavachi PA, Stephanidis SD, Pappas VA, Afgan NH. Multi-criteria evaluation of hydrogen and natural gas fuelled power plant technologies. Applied Thermal Engineering 2009;29:2228–34.

[18] Georgopoulou E, Lalas D, Papagiannakis L. A multicriteria decision aid approach for energy planning problems: the case of renewable energy option. European Journal of Operational Research 1997;103:38–54.

[19] Chatzimouratidis AI, Pilavachi PA. Sensitivity analysis of the evaluation of power plants impact on the living standard using the analytic hierarchy process. Energy Conversion and Management 2008;49:3599–611.

[20] Chattopadhyay D, Ramanathan R. A new approach to evaluate generation capacity bids.. IEEE Transactions on Power Systems 1998;13:1232–7.

[21] Shrestha JN. *Solar radiation in Nepal: its implications in telecommunication services*. In: Proceedings of first national conference in renewable energy technology for rural development. 2006.

[22] Import of petroleum products, (2014), Retrieved on 'April 22, 2014', Available at "http://www.nepaloil.com.np/Import-and-Sales/22/"

[23] WECS 2011, *Water Resources of Nepal in context of Climate Change*. Kathmandu, Nepal. Available at <http://www.wecs.gov.np>

[24] Wind Energy Technology, 2014, Retrieved on "April 21, 2014", Available at 'http://www.aepc.gov.np/?option=renewable&page=subrenewable&mid=2&sub_id=13&id=2'

[25] A year in review – fiscal year 2012/2013, (2014), Retrieved on '26 April, 2014', Available at 'http://www.nea.org.np/images/supportive_docs/A-Year-in-Review-FY-2012-13.pdf'

[26] Fu H., Lin S., (2009) *Applying AHP to analyse criteria of performance measurement for national energy promotion projects*, International Journal of Electronic Business Management, Vol. 7, No. 1, pp. 70-77

[27] Bahurmoz A.M.A, (2006) *The Analytic Hierarchy Process: A Methodology for Win-Win Management*, JKAU: Econ. & Adm., Vol. 20 No. 1, pp: 3-16

[28] Saaty TL. (1980) *The analytic hierarchy process: planning, priority setting, resource allocation*. McGraw Hill International

[29] Prindle B, Eldridge M, Eckhardt M, Frederick A. The twin pillars of sustainable energy: synergies between energy efficiency and renewable energy technology and policy; American Council for an Energy Efficient Economy, ACEEE Report number E074, Washington DC, 2007.

[30] European Commission. 2011 monitoring report of the EU sustainable strategy, 2011. European Commission.

[31] Akash BA, Mamlook R, Mohsen MS, (1999) Multi criteria selection for a wind observation station location using analytical heirarcy process. Electr Power Syst Res, 52, pp 29-35

[32] Kahraman C, Kaya I, Cebi S.(2009), A comparative analysis for multi-attribute selection among renewable energy alternatives using fuzzy axiomatic design and fuzzy analytic hierarchy process. Energy; 24, pp 1603-1616

[33] Wang J-J, Jing Y-Y, Zhang C-F, Shi G-H, Zhang X-T. A fuzzy multi-criteria decision-making model for trigeneration system. Energy Policy (2008);36:3823–32.

[34] Beccali M, Cellura M, Mistretta M. Decision-making in energy planning. Application of the electre method at regional level for the diffusion of renewable energy technology. Renewable Energy 2003;28: 2063–87.

[35] Cavallaro F, Ciraolo L. (2005), A multicriteria approach to evaluate wind energy plants on an Italian island. Energy Policy ;33:235–44.

[36] Jovanovic M, Afgan N, Radovanovic P, Stevanovic V. Sustainable development of the Belgrade energy system. Energy 2009;34:532–9.

[37] Doukas HC, Andreas BM, Psarras JE. Multi-criteria decision aid for the formulation of sustainable technological energy priorities using linguistic variables. European Journal of Operational Research 2007;182: 844–55.

[38] Pilavachi PA, Stephanidis SD, Pappas VA, Afgan NH. Multi-criteria evaluation of hydrogen and natural gas fuelled power plant technologies. Applied Thermal Engineering 2009;29:2228–34

[39] Chattopadhyay D, Ramanathan R. A new approach to evaluate generation capacity bids.. IEEE Transactions on Power Systems 1998;13:1232–7.

[40] Kiehl JT, Trenberth KE. Earth's annual global mean energy budget. Bulletin of the American Meteorological Society 1997;78:197–208.

[41] Huang Fu Y, Wu JY,Wang RZ, Huang XH. Study on comprehensive evaluation model for combined cooling heating and power system (CCHP). Journal of Engineering Thermophysics 2005;26:13–6.

[42] Kablan M., (1997) Prioritization of decentralized electricitiy options available for rural areas in Jordan, Energy Convers Management 38;1515-21

[43] Nava MR, Daim TU. (2007), Evaluating alternative fuels in USA: A proposed forecasting framework using AHP and scenarios. Int J Automoot Technol management 7;289-313

[44] Nigim K, Munier N, Green J. (2004), Pre-feasibility MCDM tools to aid communities in prioritizing local viable renewabl energy sources. Renewable energy 29;1775-91

[45] Afgan NH, Carvalho M, (2002*)*, *Multi-criteria assessment of new and renewable energy power plants*, Energy 27, pp739-755