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ECONOMIC ANALYSIS OF ENERGY ALTERNATIVES: AN INTEGRATED APPROACH COMPRISING FACTORS MATRIX, DIGITAL ATTENUATION AND NEWTON-COTES INTEGRATION PROCESSES

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Abstract

Economic decision making is an intricate matter in the modern era as many explicit and implicit socio-economic and environmental factors affect choice of alternatives. This complexity is more pronounced in case of energy alternatives for Pakistan as many socio-economic and environmental factors influence the choice. Our country is blessed with many energy alternative sources and we have to select feasible alternative source for implementation to reduce exiting gap between energy supply and demand. Economic analysis of alternatives using cost benefit analysis (CBA) does not cater for the implicit factors such as social, ethical and environmental aspects. Therefore, this research was aimed to develop a versatile and comprehensive framework for the economic analysis of the energy alternatives based on factors matrix of socio-economic and environmental factors. A combination of three approaches were used for economic analysis of energy alternatives; the statistical analysis of factors matrix to obtain trend and ratings, digital analysis of the data by computer assisted qualitative data analysis software (CAQDAS) and quantitative analysis of ratings by Newton-Cotes integration process. Paper is a unique combination of theoretical, digital and mathematical economics.

Keywords: Economic analysis, energy, alternatives, factors, attenuation, integration

1. INTRODUCTION

Pakistan is suffering from the worst economic crisis as the gap between energy supply and demand is consistently increasing. One of the reasons for this crisis is that till now we could not select the most appropriate energy alternative in spite of the fact that our country is blessed with many energy alternatives. Decision to select appropriate energy alternative is complicated one in the context of Pakistan since many socio-economic, ethical, environmental and political aspects influence this decision. All these factors were required to be meshed into a factors matrix for economic analysis of energy alternatives. By doing so, the exact and rigid quantitative economic analysis process of cost benefit analysis was converted into a wholesome, comprehensive, flexible participatory process based on the opinion of people. The paper uses an integrated approach comprising statistical analysis

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factors matrix, digital analysis of the data by using Computer Assisted Qualitative Data Analysis Software (CAQDAS), and quantitative analysis by Newton-Cotes integration process.

2. Literature Review

As explained in [19], it is a well-known fact that economic environment in modern era focuses on selection of suitable economic alternative which is beneficial to society. When this selection is done then suitable input factors are chosen to achieve the desired out put through a conversion process. The cycle of all these four activities formulate an economic environment which is shown in Figure 1. It can be seen in the Figure that if the selection of alternative is wrong, the whole process gets flawed. This clearly shows the significance of economic analysis to select the best alternative.

In [18] the author has indicated that economic decision making is a critical aspect which is taken in a socio-economic environment after analysis of various alternatives. Now, the questions is what is an alternative? As defined by [8], an alternative is an available option for implementation. In [1] the author has explained that alternative is a standalone option that can be adopted. Current literature indicates that there are three types of alternatives; mutually exclusive, independent and do nothing. In [6], the author has elucidated that alternatives are said to be mutually exclusive if they are related to each other so that the acceptance of one has effect on others. Selection of one excludes the others. In [20] the author has indicated that an alternative is independent when the acceptance of the alternative has no influence on any other alternative. The selection of one has no effect on the acceptance of any other alternative. Each alternative is analysed independently. In [9] the author has explained that when we don't consider an option worth implementing and we don't select an alternative, the do nothing alternative is selected by default. In [3] the author in his work on economic analysis has indicated that due to scarcity of resources we need to make choices and select the best based on comparison of the alternatives. Similarly in [11] the author has explained that economic analysis is a process of evaluating different factors influencing the alternative. In [12] the author has elucidated that socio-economic factors cannot be ignored in economic analysis. The three most important ingredients of economic analysis process as highlighted by [13] is shown in Figure 2.

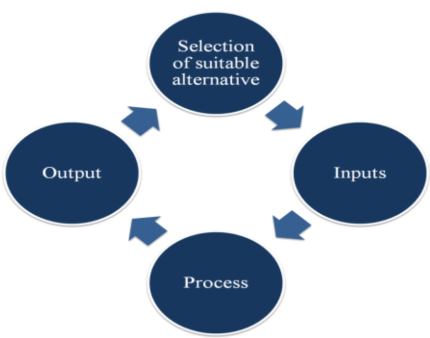

Figure 1: Ingredients of economic environment

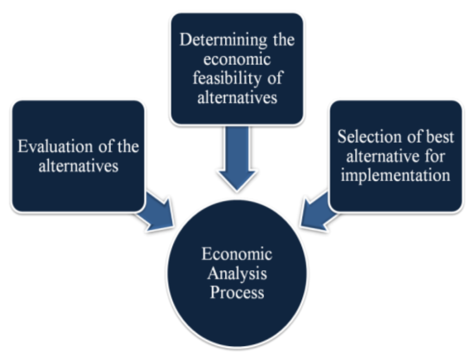

Figure 2: Economic Analysis Process

In [10] the author has clearly indicated that economic analysis assesses and analyses various alternatives to conclude about an economic activity. Similarly as per [14], economic analysis is the detailed evaluation of each factor influencing the economic activity. In [17] author has indicated that most of the existing economic analysis methods have quantitative framework. Brief description of these methods is given in Table 1.

Table 1: Methods of economic analysis and evaluation

Methods	Description
Present worth analysis	Find value of cash flows at time zero (present). This method is popular because it easy to determine the economic advantage of one alternative over another. [21]
Future worth analysis	Find value of cash flows at time "n"[4]
Internal rate of return analysis	Internal Rate of Return (IRR) is the minimum limit of rate of return that an investor will have in mind while investing funds in an initiative [2].
Capitalized cost analysis	Capitalized cost is the present worth of an everlasting public sector alternatives [5]
Payback period analysis	The payback period is the estimated time, to recover the estimated revenues and other economic benefits [7]
Cost benefit analysis	Ratio of economic benefits to economic costs [16]

3. Research Methods

To develop a spectacular framework, socio-economic factors affecting the particular alternative were selected and a factors matrix was constructed. A questionnaire was formulated to obtain opinion of respondents using Itemized Rating Scale (IRS) for the survey. Field visits and selected interviews were also conducted. The data obtained was analysed statistically to obtain the trends and ratings. Then, the data was fed into latest digital software "CAQDAS" (computer assisted qualitative data analysis software) and digital graphs were obtained after digital iteration and attenuation of the data obtained. The resultant trend and respective equations were also concluded for each alternative. This was followed by application of Newton-Cotes integration formula to obtain quantified value for rating of each alternative. Specific steps are enumerated in the diagrammatic scheme of research methodology shown in Figure 3. Steps of methodology will be explained one by one in detail in the succeeding sections.

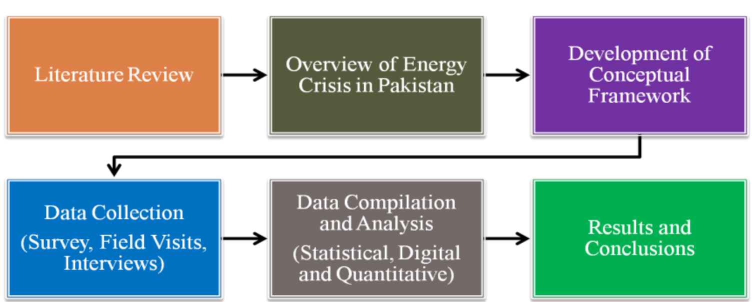

Figure 3: Diagrammatic scheme of research methodology

4. Overview of Energy Crisis in Pakistan

Pakistan is suffering from consistent energy crisis. The gap between demand and supply of energy is ever increasing owing to increase in the consumption. Currently, the demand is in excess of 20000 Mega Watts while the supply is around 14000 Mega Watts. To cater for this huge shortfall, Government of Pakistan needs to undertake energy initiatives for which suitable energy alternatives are required to be selected. With the rapid growth of economy and population, the energy requirements are also increasing almost at the same pace. Figure 4 shows the energy supply, demand and gap between supply and demand situations in Pakistan.

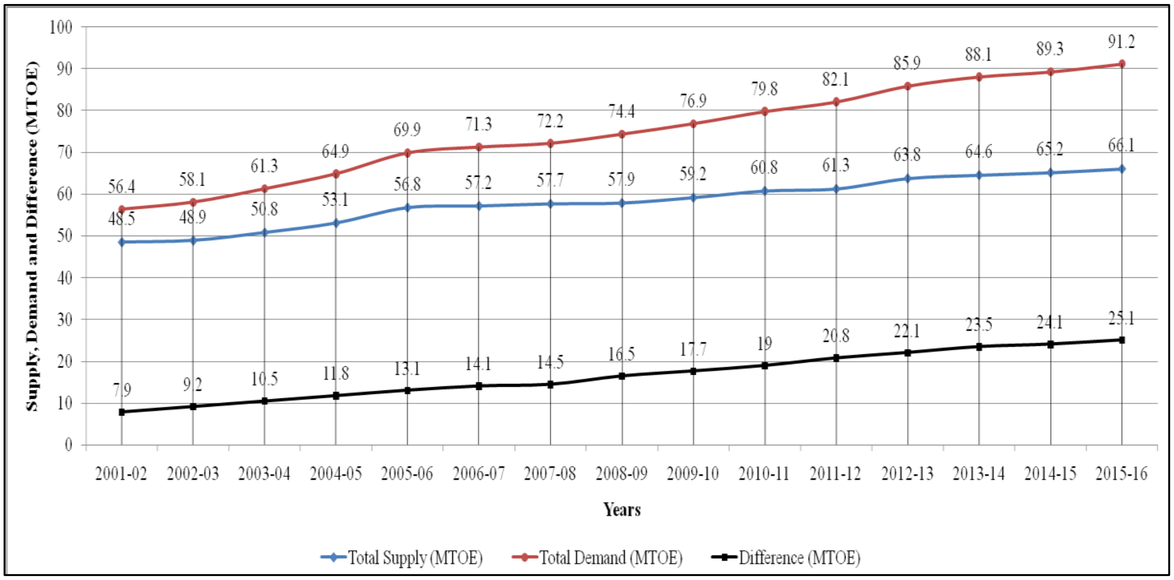

Figure 4: Energy supply, demand and gap between supply and demand situation in Pakistan (Data (Source: Economic Survey of Pakistan, 2014)

It takes no time to understand that the gap between supply and demand is continuously increasing and currently it is 24.1 MTOE (Million Tons of Oil Equivalent) which is 40% of the current energy supply. In Pakistan energy is produced from different sources such as gas, oil, coal, hydro and others. Current energy mix shows that maximum energy is produced by gas, followed by oil as shown in Figure 5. Figure shows that current energy mix had very small share of renewables such as solar, biomass and wind (0.8%). Only hydro is being used for energy generation to some extent (11%). On the contrary, these sources are being exploited optimally by advanced countries in the world. Considering importance of renewable energy sources, this study focuses on renewables as alternatives for energy generation as shown in Figure 6.

5. Conceptual Framework

In the modern era, the scope of economic analysis has enlarged and it is more complex than before. In the same context, a new framework has been proposed in this research. All relevant socio-economic and environmental factors were included in a representative matrix as shown in Figure 7. Similarly, Itemized Rating Scale was used for assessment of socio-economic and environmental factors as shown in Table 2. The third step for development of framework was the formulation of questionnaire with a set of questions for respondents to answer. The purpose was to gather people's opinion about a particular factor. A questionnaire comprising 26 questions was designed.

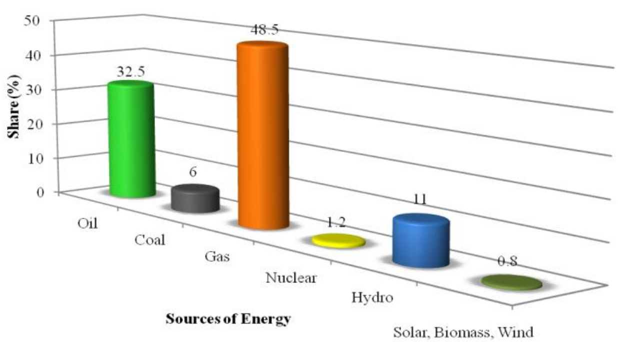

Figure 5: Energy mix of Pakistan (Data Source: Economic Survey of Pakistan, 2014)

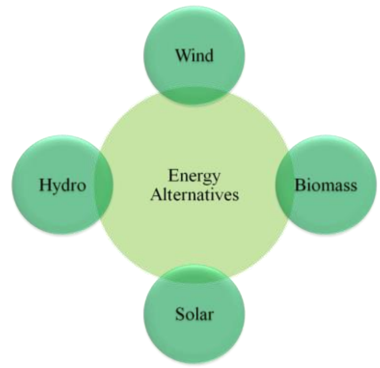

Figure 6: Energy alternatives for Pakistan

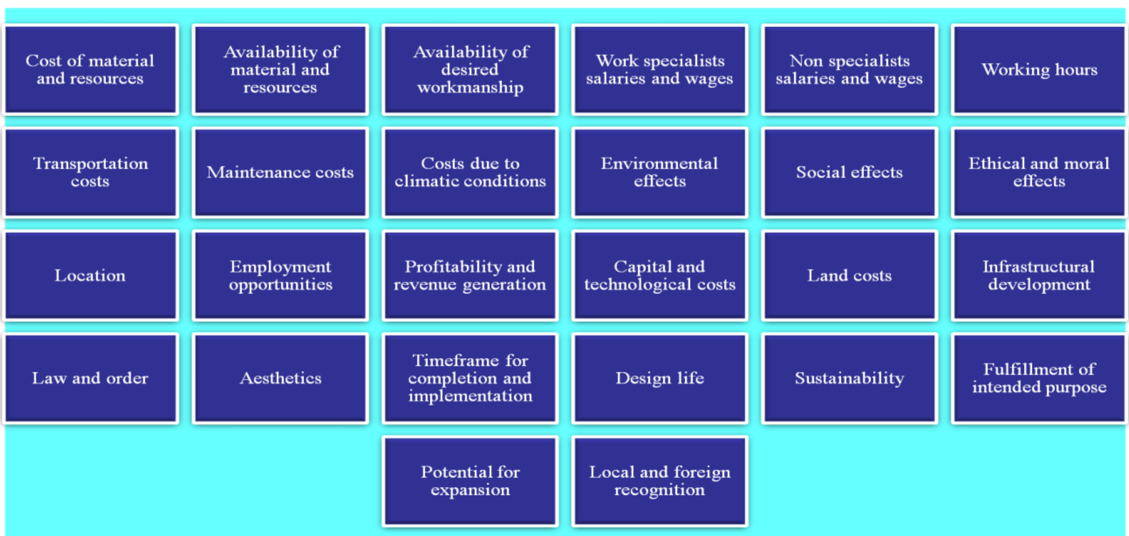

Figure 7: Factors matrix for evaluation of the alternatives

Table 2: Description of the Itemized Rating Scale, its meaning and arithmetic range

Scale	1	2	3	4	5
Meaning	Bad	Slightly Good	Good	Better	Best
Range	0 to 0.99	1 to 1.99	2 to 2.99	3 to 3.99	4 to 4.99

6. Collection of Data

Field visits to 14 energy projects were made by the author(s). Moreover, 20 experts were interviewed. Questionnaires were distributed to a simple random sample of 500 respondents in six cities making a total sample size of 3000 respondents. The data collection process took about three month time.

7. Compilation and Summation of Data

After collection of data, it was compiled and tabulated for each alternative. For all the alternatives different percentage of people gave different rating to the different factors of the newly formulated matrix. Table 3 shows summary of data obtained through questionnaires.

Table 3: Factors matrix for analysis of energy alternatives

Socio-economic and Environmental Factors	Alternative 1 Wind					Alternative 2 Bio Mass					Alternative 3 Solar					Alternative 4 Hydel				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	Rating of socio-economic and environmental factors by percentage of population sample																			
Cost of material and resources	10	75	5	5	5	7	8	10	60	15	10	10	70	5	5	10	15	70	3	2
Availability of material and resources	10	65	15	5	5	10	10	20	50	10	10	8	60	7	15	5	5	65	10	15
Availability of desired workmanship	20	50	10	10	10	20	20	10	45	5	30	15	40	10	5	20	10	60	5	5
Work specialists salaries and wages	10	50	10	20	10	5	60	15	10	10	10	15	60	8	7	10	10	70	7	3
Non specialists salaries and wages	15	55	20	10	5	5	55	10	5	60	10	10	40	25	15	10	10	60	10	10
Working hours	5	5	10	60	20	10	70	10	5	5	30	15	40	10	5	10	10	10	60	10
Transportation costs	10	20	10	55	5	10	10	10	60	10	20	20	50	5	5	10	10	60	10	10
Maintenance costs	10	10	70	5	5	10	10	10	50	20	10	10	50	20	10	5	10	65	10	10
Costs due to climatic conditions	10	10	70	5	5	20	20	10	45	5	5	5	65	10	15	10	10	10	60	10
Environmental effects	10	10	10	50	20	10	15	15	50	10	10	10	10	10	60	10	10	10	60	10
Social effects	5	10	10	50	25	5	5	10	60	20	10	10	10	10	60	5	20	10	5	60
Ethical and moral effects	5	10	10	50	25	5	10	10	50	25	10	10	10	20	50	10	20	10	20	40
Location	10	15	60	10	5	10	40	25	10	15	15	15	50	10	10	10	10	60	10	10
Employment opportunities	20	60	10	5	5	5	60	15	10	10	10	10	50	20	10	10	10	60	10	10
Profitability and revenue generation	10	70	10	5	5	5	60	15	10	10	10	10	50	10	20	10	10	60	10	10
Capital and technological costs	15	55	20	10	5	5	20	10	60	5	10	15	60	10	5	10	20	50	10	10
Land costs	10	10	60	10	10	10	10	20	40	20	10	10	50	10	20	5	10	10	70	5
Infrastructure development	10	10	60	10	10	10	10	10	60	10	10	10	50	10	20	20	10	10	50	10
Law and order	7	8	60	10	15	10	60	10	10	10	10	10	60	10	10	10	10	10	50	20
Aesthetics	10	10	10	60	10	10	60	10	10	10	20	5	10	60	5	20	10	10	40	20
Timeframe for implementation and completion	10	15	10	60	5	20	40	20	10	10	10	10	10	60	10	5	10	50	15	20
Design life	10	10	60	10	10	5	50	10	25	10	10	10	40	25	15	10	20	60	5	5
Sustainability	10	10	40	25	15	20	50	10	10	10	10	10	70	5	5	10	20	40	10	20
Fulfillment of intended purpose	15	20	40	15	10	10	50	10	20	10	10	10	40	25	15	10	10	60	10	10
Potential for expansion	20	10	60	5	5	5	50	10	10	25	10	10	60	10	10	10	10	60	10	10
Local and foreign recognition and acceptance	10	10	70	5	5	5	50	10	10	25	10	10	70	5	5	10	10	60	10	10

8. Data Analysis

Three approaches were used for analysis of the data; first the statistical analysis of factors matrix by using latest SPSS 22 software, second digital analysis of the data to obtain the iterated and attenuated digital models of the trend by using CAQDAS software, third using Newton-Cotes integration formula to quantify the rating trend of alternatives. Statistical analysis was done to find out descriptive statistics and understand the rating trend of alternatives as shown in table 5. Descriptive statistics as shown in table 5 indicated peculiar statistical trends which are explained below.

- Based on the average rating (or mean) obtained for the four alternatives, alternative 4 (hydro) has been rated as better than the others.
- Negligible difference between mean, mode and median for all the alternatives was observed.
- The standard deviation value for biomass (1.107) was high followed by wind (0.977) showing that the data was more scattered around the mean in case of these two alternatives.
- The confidence interval was high for the biomass energy being used by the masses with no other means of energy available.
- Alternatives had positive skewness which meant that data set contained few low values. It reflected respondent's confidence in renewable alternatives.
- Data set for wind and biomass had negative kurtosis value and curve for these alternatives was flatter than normal distribution curve (fewer observations

clustered near average and more observations populated on extremes). For solar and hydro, kurtosis values were positive and curve was slimmer than normal distribution curve (more observations clustered near average and fewer observations populated on extremes).

Table 5: Analysis of factors matrix for energy alternatives

Socio-economic and Environmental Factors	Alternative 1 Wind	Alternative 2 Bio	Alternative 3 Solar	Alternative 4 Hydel
Descriptive Statistics				
Average	3.077	2.923	3.308	3.385
Mode	3	2	3	3
Median	3	2	3	3
Standard Deviation	0.977	1.017	0.679	0.637
Variance	0.954	1.034	0.462	0.406
Confidence Interval	0.375	0.391	0.261	0.245
Skewness	0.674	0.164	2.017	1.474
Kurtosis	-0.458	-2.174	2.365	1.000

After analysis of factors matrix, the data was fed to CAQDAS software for digital analysis. Based on the digital analysis of the data, the iterated and attenuated rating trends of the four alternatives were determined which are shown in Figure 8, 9, 10 and 11. After the digital attenuated rating trends of alternatives, the qualitative rating was quantified by application of Newton-Cotes integration formula as shown in equation 1.

$$\text{Rating of an alternative, RoA} \ = \int_{\text{n}=1}^{\text{n}=26} \text{eqn} + \text{C} \quad (1)$$

where "n" is the number of socio-economic and environmental factors which were 26 in this study. The term "eqn" is the equation of polynomial trend that we obtained through digital attenuation. C is constant which caters for the error and missing variables. The equations for the quantified values of rating for four alternatives were as under.

$$\text{Rating of wind, RoAw} \ = \int_{n=1}^{n=26} -0.04x^2 + 0.62x \ + 0.89 \quad (2)$$

$$\text{Rating of biomass, RoAb} \ = \int_{n=1}^{n=26} -0.007x^3 + \ 0.125x^2 \ - \ 0.804x \ + \ 4.721 \quad (3)$$

$$\text{Rating of solar, RoAs} \ = \int_{n=1}^{n=26} -0.014x^2 + 0.234x \ + \ 2.457 \quad (4)$$

$$\text{Rating of hydro, RoAh} \ = \int_{n=1}^{n=26} -0.006x^2 + 0.170x \ + 2.563 \quad (5)$$

Each equation was solved and quantified value of rating for the alternatives was determined. For example solution of equation 2 is as under.

$$Rating\ of\ wind, RoAw \ = \int_{n=1}^{n=26} (-0.04x^2 + 0.62x \ + 0.89)dx \quad (6)$$

$$\text{Rating of wind, RoAw} \ = \ Limit 1 \rightarrow 26 \left(\frac{-0.04x^3}{3} + \frac{0.62x^2}{2} + \ 0.89 + C \right) \quad (7)$$

where C is a constant which accounted for all the missing variables and error. By putting the limits in the equation we obtained the quantified value of rating.

RoA_w = [-0.04 $(26)^3$/3 + 0.62$(26)^2$/2 + 0.89 (26) + C] - [-0.04 $(1)^3$/3 + 0.62$(1)^2$/2 + 0.89 (1) + C]

RoA_w = [-234.35 + 209.56 + 23.14 + C] - [-0.013 + 0.31 + 0.89 + C]

RoA_w = -1.65 + C - 1.187 – C, RoA_w = -2.837

which means the area is below the x -axis and this is not a desirable situation. This shows that people were not confident about wind energy. After solving equations 3, 4 and 5 for biomass, solar and hydro respectively, results of the quantified values of ratings for the alternatives were summarized in table 6. Experts and respondents were least confident about biomass and its rating was in minus (-220.73). Similarly, they were also not in favour of using wind energy since its rating was also in minus (-2.837), though better than biomass. They were confident about solar energy as its rating was positive (58.39). They were most confident and in favour of hydro energy as its rating was the highest (86.30).

Table 6: Results of digital attenuation and Newton-Cotes integration process

Alternatives	Number of Socio-economic and Environmental Factors (n)	Rating of Alternatives	Numerical Value Obtained
Wind	26	RoA_w	-2.837
Biomass	26	RoA_b	-220.73
Solar	26	RoA_s	58.39
Hydro	26	RoA_h	86.30

9. Conclusions

After thorough analysis of the data results were compiled. For energy initiative by Government of Pakistan, energy generation by hydro sources is a better alternative than others, followed by generation of energy from solar source. Summary of results is reflected in Figure 12. Following pertinent conclusions and policy recommendations were drawn from the results of research.

- Pakistan should focus on renewable energy sources to ensure socio-economic and environmental viability and long term sustainability of energy generation initiatives.
- The highest rating was obtained for hydro energy generation (alternative 4). Government of Pakistan should start energy generation from hydro sources. Pakistan is blessed with natural hydro sources all over its landscape. We need to explore the vast natural hydro sources to coup up with existing energy crisis.
- After hydro, solar (alternative 3) got the highest rating. Pakistan is located in the maximum solar radiation belt which is yet to be explored fully. We need to expedite the exploration of solar source for energy generation.
- The two most feasible alternatives, hydro and solar, if implemented in combination simultaneously, can create favourable energy environment for Pakistan.
- Wind and biomass have not been liked by the people and experts. Their rating was below the desired level. Wind projects are costly while biomass is complicated and unreliable source of energy.

We had to select the best available energy alternative. For selection of best alternative, economic analysis of the alternatives was required for which we needed an efficient method which could cater for socio-economic and environmental factors and also for the opinion of masses. This could not be ensured by traditional cost-benefit analysis (CBA). Therefore, a new method of economic analysis based on socio-economic and environmental factors matrix, digital analysis and Newton-Cotes integration formula was proposed in this research. By using this method, energy alternatives for Pakistan were analysed and the method was validated successfully

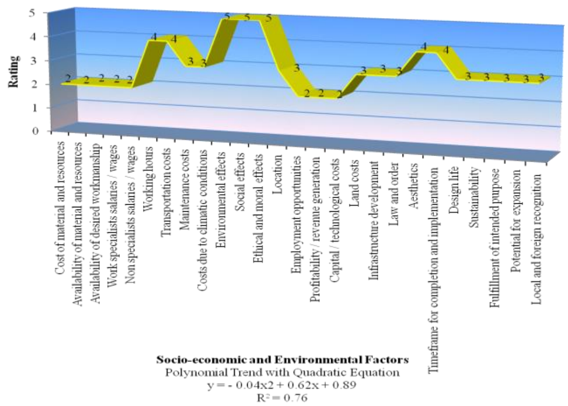

Figure 8: Digital attenuated rating of wind

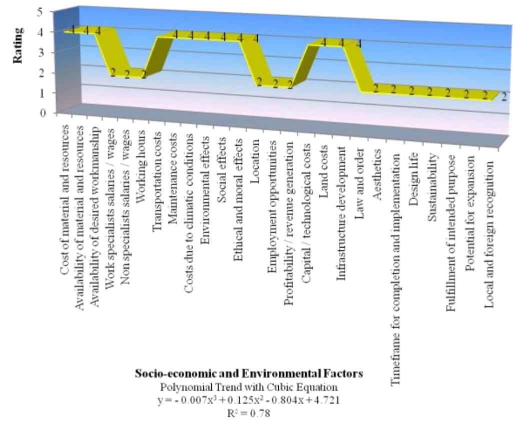

Figure 9: Digital attenuated rating of biomass

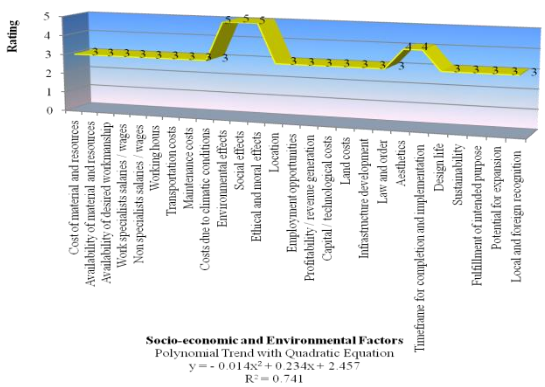

Figure 10: Digital attenuated rating of solar

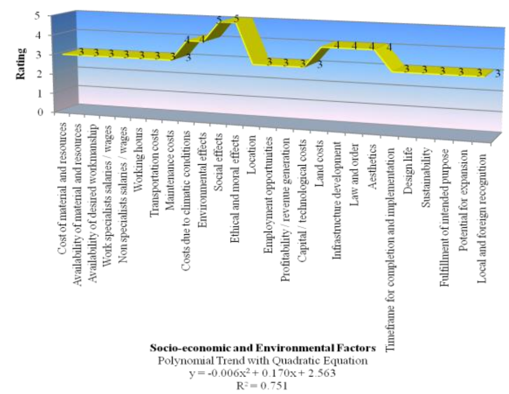

Figure 11: Digital attenuated rating of hydro

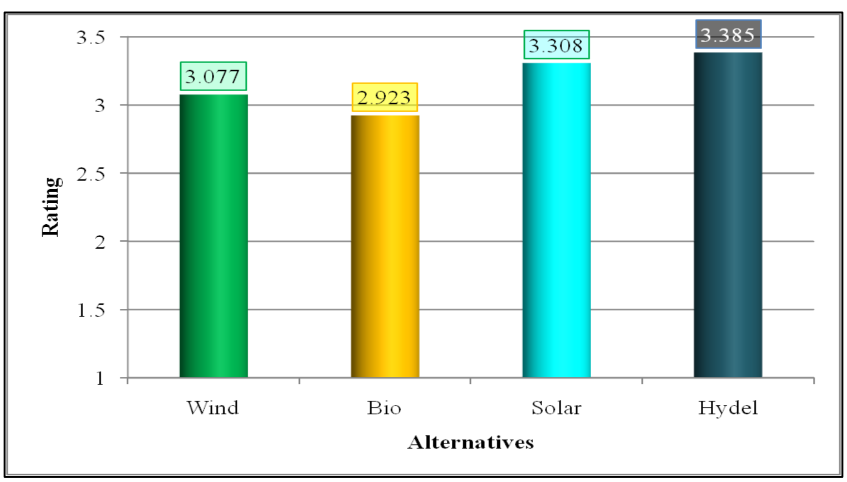

Figure 12: Result of economic analysis of energy alternatives

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