SUSTAINABILITY EVALUATION FRAMEWORK FOR ENERGY POWER PLANTS IN SRI LANKA

S. D. Wijesooriya
CBFA – Burj Khalifa, UAE

Y. G. Sandanayake* and K. M. G. K. Konara
Department of Building Economics, University of Moratuwa, Sri Lanka

ABSTRACT

Energy is essential for economic and social development of a country. Ever increasing energy demand forces public and private sector to install energy power plants without giving much attention to the sustainable issues. Existing power plants evaluation mechanisms were limited to few factors such as energy efficiency, economic aspects and quality of life. Therefore, the aim of this study is to develop a multidimensional framework to evaluate sustainability of energy power plants in Sri Lanka.

A comprehensive literature review and a preliminary survey were carried out to identify sustainability criteria and indicators. The study identified eight sustainability criteria and 37 indicators. Eight criteria include economic aspects, technological aspects, air quality, water quality, waste management, health, safety and social issues, energy resource, and land, forest and wildlife issues. Structured interviews with industry practitioners were used to prioritise the criterion and indicators. Data was analysed using Analytic Hierarchy Process (AHP) tool and the findings were used to develop a multidimensional framework to evaluate sustainability of energy power plants in Sri Lanka.

Results obtained from the survey showed that, 'economic aspects' followed by 'technological aspects' and 'air quality' are the most important criteria and 'land, forest and wildlife issues' is the least important criteria among the eight sustainability criteria studied. Survey findings further revealed 'availability of renewable energy resources' followed by 'plant process efficiency' as the most critical sustainability indicators among the 37 indicators. This multidimensional framework can be used to evaluate the sustainability of energy power plants and also in the approval granting process for the power plant projects in Sri Lanka.

Keywords: *Energy Power Plants, Sustainability Evaluation Framework, Sustainability Criteria, Sustainability Indicators, Analytic Hierarchy Process Tool.*

1. INTRODUCTION

Energy is a vital commodity to eradicate poverty and to improve present day human welfare and living standards. Further to Jovanovic et al. (2010), energy is essential for economic and social development. There are many environmental costs associated with the generation and utilisation of energy, ranging from the loss of a local wild river to the potentially enormous effects of global warming (Wright, 1991). As a result, current energy usage and supply patterns are considered unsustainable (UN, 2001).

Sustainability has been reinvented as the key word to describe a political discourse concerning quality of life issues, limitation of natural resources and the sense of commitment to the future generations (Afgan and Carvalho, 2008). Conversely, many major environmental problems are derived from the production and consumption of energy. Wright (1991) exemplified that, it is extremely critical to measure the impacts of energy use on the 'sink' functions of the environment.

Athanasios and Pilavachi (2007) claimed that the operation of a power plant causes both positive and negative effects on employees as well as on local communities and have shown that harmful phenomena such as the release of gases, soil and water contamination and radioactivity were ignored or undervalued while economic aspects were given higher priority, disregarding the concept of sustaining towards future.

* Corresponding author: E-mail: yasangee@yahoo.com

In order to complement the effort of the commission on sustainable development and to provide a higher resolution on energy, the International Atomic Energy Agency (IAEA) commenced a long term programme addressing Indicators for Sustainable Energy Development (ISED) in 1999 (Vera *et al.,* 2005). Energy indicators are defined as combination of basic economic data, social activities, technological characteristics and measurements or estimates of energy production and consumption.

Many organisations and institutions across the world have emphasised on the consideration of sustainable issues in electricity power generation. Sustainability in power generation has not been highlighted in power plant evaluation processes or processes of giving approvals for the establishment of electricity power plants. Conversely, the main concern thus far was about energy usage and energy efficiency. Decision making on developing new power plants should not be just driven by the demand, but sustainability and impacts from each and every alternative should also be thoroughly considered.

There is therefore a need to introduce a multidimensional approach to evaluate sustainability of energy power plants in Sri Lanka. Thus, the aim of this paper is to introduce a generic and multidimensional framework to evaluate sustainability of energy power plants with prioratised sustainability criteria and indicators.

The paper structure begins with an introduction to the study and followed by a literature review on sustainability of energy power plants. Section three presents the five-steps approach of developing the multidimensional sustainability evaluation framework including data collection carried out using survey method and data analysis using Analytic Hierarchy Process (AHP) tool. The final section summarises conclusions derived from the research findings and presents recommendations.

2. SUSTAINABILITY OF ENERGY POWER PLANTS

Sustainability is a concept emerged with the establishment of the World Commission on Environment and Development (WCED) by the United Nations in 1983. One of the first and the best definitions of sustainable development were made in "our common future", the report of the WCED (1987) as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The general concept of sustainability is often introduced in the literature using Brundtland statement; which is "humanity has the ability to make development sustainable, to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs'' (Carew and Mitchell, 2008).

Michelle *et al.* (2008) stated that sustainability assessments range from single indicators to prescribed sets of multi-disciplinary indicators focusing on either the whole system or parts of the system, such as the economy, society or environment. Each of these approaches has advantages and limitations. For example, single indicators, such as the ecological footprint (Wackernagel *et al.*, 1993), are able to provide information about the sustainability of part of the system, highlighting specific sustainability issues. The five sustainability assessment methods are ecological footprint, wellbeing assessment, quality of life, ecosystem health and natural resource availability (Michelle *et al.*, 2008).

The sustainability evaluation framework provides a structure for developing a valid and reliable system that achieves sustainability through institutionalisation (Robert *et al.*, 2006). Many approaches for measuring sustainable development have led to very detailed frameworks, where long lists of indicators have been derived. United Nations Department for Policy Coordination and Sustainable Development (UNCSD) indicator set comprises over 130 indicators (UNCSD cited Andreas and Daniel, 2006). UNCSD further stated that the indicator set developed by UNCSD have the advantage of covering most sustainable development issues and providing detailed insights. However, due to the large number of indicators, these sets are complex, difficult to interpret, and cannot provide a concise general overview of system behaviour.

Energy production is one of the vital areas to be concerned and utmost priority should be given to the aspects of economical sustainability. Three types of power plants considered in this research study are hydro power plants, thermal power plants and wind power plants. As a developing country, Sri Lanka is rapidly increasing the energy supply through both government and private sector. At present, the total primary energy requirement of the country is met with biomass (47.4%), hydropower (9.5%) and imported petroleum (43.0%), while electricity remains the main secondary energy source (Sri Lanka Energy Balance, 2007). Further, the total amount of electricity generated during 2007 was 9,901 GWh out of which 60% was from oil burning thermal power plants while the balance 40% was almost entirely from hydropower. Share of electricity generation from nonconventional sources remained very small.

The necessity of power plant development and operation in our everyday life cannot be argued, but a balance between development and sustainability should be found, so that electricity production no more harms public health and its negative effects are minimised (Athanasios and Pilavachi, 2007). In 2007, Athanasios and Pilavachi built a hierarchy to evaluate power plants by considering living standards respect to power plants. In following year, Athanasios and Pilavachi (2008) built another hierarchy model to evaluate power plants. In this model earlier key aspects were removed and new parameters (technology and economic) ware introduced. Further, in 2009, Carrera and Mack developed some key indicators to evaluate power plants. However, the study was mainly focused on limited parameters like quality of life, socioeconomically impacts, political stability and continuity of energy service. However, the power generation efficiency and environment impact due to air and water pollution are not considered in their study.

3. Steps of Sustainability Evaluation Framework Development Process for Energy Power Plants

A five step approach was adapted to develop the sustainability evaluation framework for energy power plants as follows;

(1) Identify of key sustainability criteria and indicators with related to energy power plants

(2) Refine identified sustainability criteria and indicators

(3) Develop an energy power plant sustainability evaluation hierarchy integrating sustainability criteria and indicators

(4) Data analysis using Analytic Hierarchy Process (AHP) tool

(5) Develop a framework for multidimensional evaluation of sustainability of energy power plants

3.1. Step 1: Identification of Sustainability Criteria and Indicators

A comprehensive literature review was conducted using journals, conference proceedings, books and web sites to identify the sustainability criteria and indicators. According to the literature review sixteen sustainability indicators were identified under seven main criteria namely economic aspects, technological aspects, social aspects, air quality, water quality, land requirement and waste issues. Given the ambiguity surrounding the terminologies used by the different authors, the best judgment has been used in categorising the sustainability indicators.

3.2. Step 2: Refine Identified Sustainability Criteria and Indicators

A preliminary survey was conducted to refine the criteria and indicators identified through literature survey and to identify new sustainability criteria and indicators applicable to the Sri Lankan context. Semi structured interviews were carried out with eight (08) industry practitioners who are having remarkable experience at power generation authorities and approval granting authorities in Sri Lanka.

Importance of the criteria and indicators was obtained depending on relevance of the indicators and preference of the respondents to use the sustainability criterion and indicator to evaluate the sustainability of energy power plants. Most of the criteria and indicators were recommended by the industry practitioners as important when evaluating the sustainability of power plant. Few criteria and indicators were removed due to less applicability and few were added and altered according to the suitability to the Sri Lankan context. ‘Energy Resource’ criterion was added to the model, while ‘social aspects’, ‘land requirement' and 'waste issues' were changed as 'health, safety and social issues', 'land, forest and wildlife issues' and 'waste Management', respectively.

3.3. STEP 3: DEVELOP AN ENERGY POWER PLANT SUSTAINABILITY EVALUATION HIERARCHY

Based on the results of the critical literature review and the preliminary survey findings, hierarchy was developed to evaluate sustainability of energy power plants. Figure 1 is the hierarchy developed to evaluate sustainability of energy power plants which consists with 37 sustainability indicators under the eight criteria.

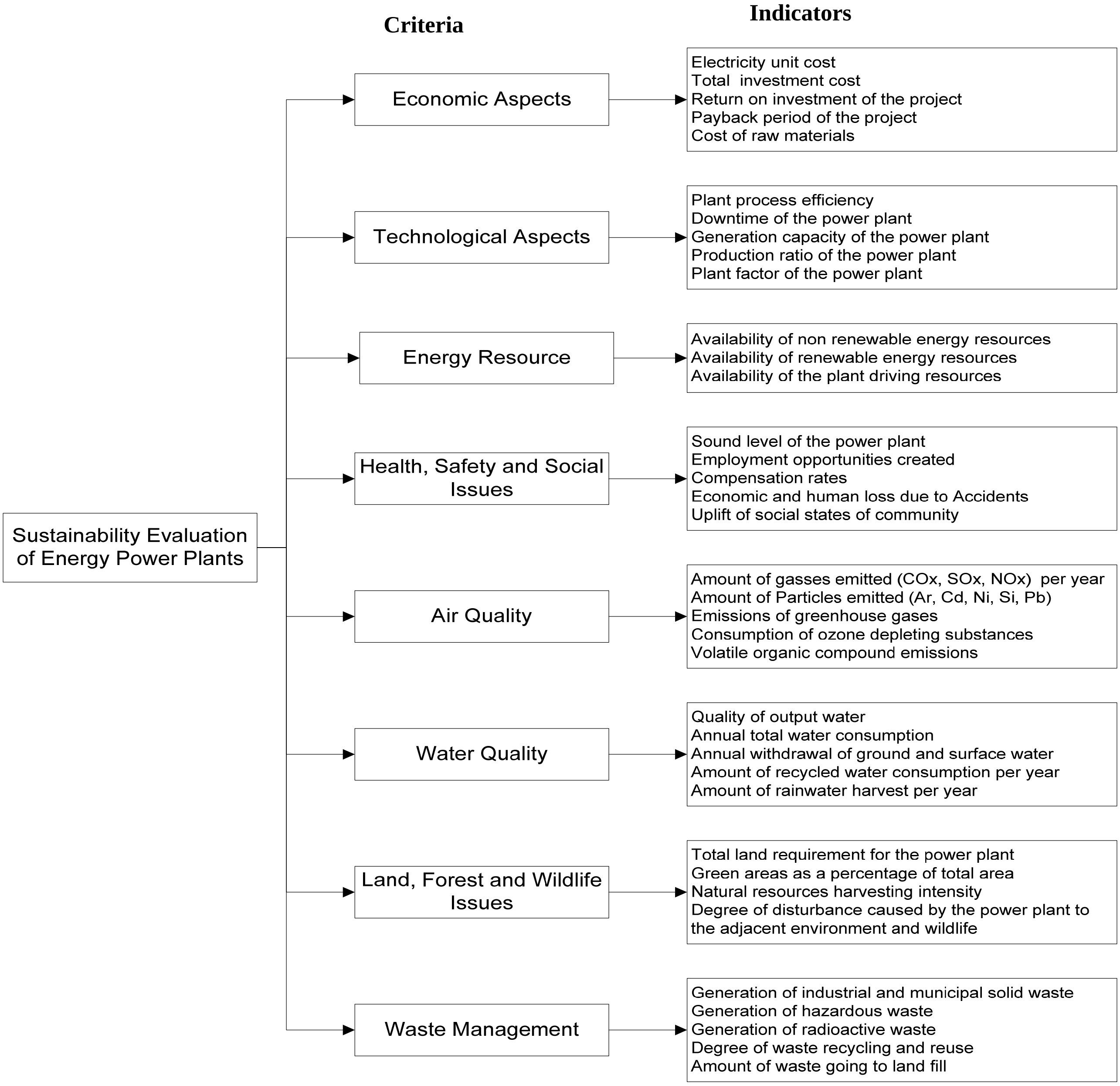

Figure 1: Energy Power Plant Sustainability Evaluation Hierarchy

3.4. STEP 4: DATA ANALYSIS USING ANALYTIC HIERARCHY PROCESS (AHP) TOOL

Analytic Hierarchy Process (AHP) is a multi-criteria decision making tool, which provides a room to select the most important criteria between two folds (Saaty, 1994). In the manufacturing industry, Partovi (1992) presented a methodology and corresponding model for the strategic selection of processes for benchmarking in a manufacturing setting. Wu *et al.* (2007) applied AHP to determine the priority of the accessibility criteria. Teo and Yng Ling (2006) used AHP method to assess safety management in construction industry. Having considered the research context and objectives of the study, AHP tool was selected for data analysis.

The structured questionnaire was prepared based on the AHP hierarchy and the survey was performed among various disciplines related to power generation authorities and approval granting authorities. The purposeful and snowball sampling was used in this study. Questionnaires were distributed among 40 respondents and were asked to give their individual opinion and to indicate the magnitude of the importance placed on each criterion and indicator using the one-to-nine ratio scale.

Indicator in each level was compared pair wise with respect to their importance to a criterion in the next higher level and starting at the top of the hierarchy and working down. For all decision alternatives, geometric mean was calculated from the allocated weights by the participants; the mean for each alternative was considered in the analysis. Comparisons in a matrix may not be consistent as in eliciting judgments. This gives rise to multiple comparisons of an element with other elements that leads to numerical inconsistencies. Cheng and Li (2001) concluded that the consistency calculation is a critical component of AHP, and it makes AHP more reliable and useful as decision-making tool.

Table 1 shows pair wise comparisons of the sustainability criteria. The weightings of Table 1 are then normalised and presented in Table 2. The comparison matrix is normalised by dividing each entry by the sum of the entries in relevant column. After normalising the entries in the pairwise comparison matrix, sums of each row will be calculated. The averages of each row will be calculated in order to obtain the "sustainability score", which will allow the researcher to compare and prioritise each sustainability criterion and indicator. The consistency calculations are given in Table 3 and Eq: 01.

Table 1: Pair-Wise Comparisons of the Main Sustainability Criteria

Main Criteria	Economic aspects	Technological aspects	Energy resource	Health, safety and social issues	Air quality	Water quality	Land, forest and wildlife issues	Waste Management
Economic aspects	1.00	0.92	1.80	2.21	1.32	1.30	2.14	0.54
Technological aspects	1.09	1.00	0.97	1.70	1.04	1.07	2.54	1.18
Energy resource	0.55	1.03	1.00	1.11	0.96	0.87	0.65	0.36
Health, safety and social issues	0.45	0.59	0.90	1.00	0.96	0.89	1.05	1.52
Air quality	0.76	0.96	1.04	1.04	1.00	1.30	1.80	3.00
Water quality	0.77	0.93	1.04	1.13	0.77	1.00	1.64	3.80
Land, forest and wildlife issues	0.47	0.39	1.53	0.95	0.56	0.61	1.00	1.70
Waste management	1.87	0.85	2.78	0.66	0.33	0.26	0.59	1.00
SUM	**6.96**	**6.67**	**11.06**	**9.79**	**6.94**	**7.31**	**11.41**	**13.10**

Table 2: Pair-Wise Normalised Comparisons of the Main Sustainability Criteria

Main Criteria	Economic aspects	Technological aspects	Energy resource	Health, safety and social issues	Air quality	Water quality	Land, forest and wildlife issues	Waste Management	SUM	Sustainability Scores
Economic aspects	0.14	0.14	0.16	0.23	0.19	0.18	0.19	0.04	**1.27**	**0.16**
Technological aspects	0.16	0.15	0.09	0.17	0.15	0.15	0.22	0.09	**1.18**	**0.15**
Energy resource	0.08	0.15	0.09	0.11	0.14	0.12	0.06	0.03	**0.78**	**0.10**
Health, safety and social issues	0.07	0.09	0.08	0.10	0.14	0.12	0.09	0.12	**0.81**	**0.10**
Air quality	0.11	0.14	0.09	0.11	0.14	0.18	0.16	0.23	**1.16**	**0.15**
Water quality	0.11	0.14	0.09	0.12	0.11	0.14	0.14	0.29	**1.14**	**0.14**
Land, forest and wildlife issues	0.07	0.06	0.14	0.10	0.08	0.08	0.09	0.13	**0.74**	**0.09**
Economic aspects	0.27	0.13	0.25	0.07	0.05	0.04	0.05	0.08	**0.93**	**0.12**
SUM									**8.00**	

Table 3: Consistency Calculations for the Main Sustainability Criteria

Main Criteria	Economic aspects	Technological aspects	Energy resource	Health, safety and social issues	Air quality	Water quality	Land, forest and wildlife issues	Waste Management	SUM	SUM ÷Sustainability Scores
Economic aspects	0.16	0.14	0.18	0.22	0.19	0.19	0.20	0.06	**1.33**	**8.40**
Technological aspects	0.17	0.15	0.10	0.17	0.15	0.15	0.24	0.14	**1.26**	**8.54**
Energy resource	0.09	0.15	0.10	0.11	0.14	0.12	0.06	0.04	**0.81**	**8.32**
Health, safety and social issues	0.07	0.09	0.09	0.10	0.14	0.13	0.10	0.18	**0.88**	**8.78**
Air quality	0.12	0.14	0.10	0.10	0.15	0.18	0.17	0.35	**1.31**	**9.01**
Water quality	0.12	0.14	0.10	0.11	0.11	0.14	0.15	0.44	**1.32**	**9.23**
Land, forest and wildlife issues	0.07	0.06	0.15	0.09	0.08	0.09	0.09	0.20	**0.83**	**8.95**
Economic aspects	0.30	0.12	0.27	0.06	0.05	0.04	0.05	0.12	**1.01**	**8.74**

$$CR = \{(\lambda_{max} - n) / (n - 1)\} \times (1/RI) = \{(8.75 - 8) / (8 - 1)\} \times (1/0.11) = \mathbf{0.08} \qquad \text{(Eq: 01)}$$

Where *CR* is Consistency Ratio, *n* is size of matrix (e.g.: Number of sustainability criteria), λ_{max} is the average of SUM/Sustainability Score column and *RI* is Random Index for *n* number of matrices.

According to Saaty (1994), consistency ratio of 0.10 or less is a positive evidence and acceptable, and therefore above data can be considered as consistent and valid.

A similar exercise was applied towards the sustainability indicators in each sustainability criterion and responses were collected from the parties related to each criterion.

3.5. STEP 5: DEVELOP A FRAMEWORK FOR MULTIDIMENSIONAL EVALUATION OF SUSTAINABILITY OF ENERGY POWER PLANTS

The final step in this approach is to develop a prioritised framework to evaluate sustainability of energy power plants. The results of all pair-wise matrices were synthesised to achieve the overall ranking of the sustainability criteria and indicators. The results of this analysis are presented in Table 4.

Table 4: Prioritised sustainability evaluation framework for energy power plants

Main Sustainability Criteria and Indicators	Sustainability Scores	Overall Sustainability Scores	Rank
Economic Aspects	**0.1583**		
Electricity unit cost	0.2323	0.0368	**5**
Cost of raw materials	0.2243	0.0355	**6**
Return on investment of the project	0.2015	0.0319	**10**
Payback period of project	0.1772	0.0281	**14**
Total investment cost	0.1647	0.0261	**17**
Technological Aspects	**0.1471**		
Plant Process efficiency	0.2597	0.0382	**2**
Plant factor of power plant	0.2107	0.0310	**11**
Plant production ratio	0.1930	0.0284	**13**
Power plant downtime	0.1741	0.0256	**19**
Plant Generation capacity	0.1624	0.0239	**23**
Air Quality	**0.1452**		
Emissions of green house gases	0.2532	0.0368	**4**
Consumption of ozone depleting substances	0.2231	0.0324	**9**
Amount of Particles emitted	0.1923	0.0279	**15**
Volatile organic compound emissions	0.1734	0.0252	**21**
Amount of gasses emitted	0.1580	0.0230	**26**
Water Quality	**0.1425**		
Annual total water consumption	0.2605	0.0371	**3**
Amount of recycled water per year	0.2312	0.0330	**7**
Annual withdrawal of ground and surface water	0.1888	0.0269	**16**
Amount of rainwater harvest per year	0.1783	0.0254	**20**
Quality of output water	0.1413	0.0201	**31**
Waste Management	**0.1157**		
Generation of radioactive waste	0.2221	0.0257	**18**
Generation of industrial and municipal solid waste	0.2130	0.0246	**22**
Generation of hazardous waste	0.2025	0.0234	**24**
Amount of waste going to land fill	0.1917	0.0222	**27**
Degree of waste recycling and reuse	0.1707	0.0197	**32**
Health, Safety and Social Issues	**0.1007**		
Employment opportunities created	0.2304	0.0232	**25**
Uplift of social states of community	0.2101	0.0212	**30**
Economic and human loss due to Accidents	0.1943	0.0196	**33**
Sound level of power plant	0.1900	0.0191	**35**
Compensation rates	0.1752	0.0176	**36**
Energy Resource	**0.0976**		
Availability of renewable energy resources	0.4921	0.0480	**1**
Availability of the plant driving resources	0.3106	0.0303	**12**
Availability of non renewable energy resources	0.1973	0.0193	**34**
Land, Forest and Wildlife Issues	**0.0928**		
Total land requirement for the power plant	0.3537	0.0328	**8**
Degree of disturbance caused to the adjacent environment and wildlife	0.2316	0.0215	**28**
Natural resources harvesting intensity	0.2287	0.0212	**29**
Green areas as a percentage of total area	0.1860	0.0173	**37**

The second column of Table 4 presents the local priorities representing the relative weights of sustainability indicators with respect to relevant sustainability criterion. The overall ranking, shown in the third column of the table, were obtained by multiplying the performance scores of the each sustainability indicator by the sustainability scores of the relevant sustainability criterion.

According to Table 4, the highest sustainability score (0.16) has been obtained by the 'economic aspects' becoming the most significant criterion in the framework to evaluate sustainability in power plants. At the same time 'technological aspects' and 'air quality' have obtained an equal second highest score (0.15). Further, 'water quality' has become the fourth with a score of 0.14.The fifth, sixth and the seventh places have been obtained by 'waste management' (0.12), 'health, safety and social issues' (0.101) and 'energy resource' (0.098) respectively. According to the research the least important criterion was the 'land, forest and wildlife issues' with 0.093 sustainability score.

According to the sustainability scores, 'electricity unit cost' has become the most important sustainability indicator in the 'economic aspects' criterion where 'total investment cost' has become the least important indicator within the criterion. In 'technological aspects', 'plant process efficiency' and 'plant factor of the plant' have obtained the highest sustainability scores and 'plant generation capacity' has become the least important indicator among 'technological aspects'. According to findings, 'availability of renewable energy resources' indicator has become the most significant indicator among 'energy resource' with 0.49 sustainability scores. That weight is almost half of the total weight of 'energy resource'. 'Availability of non renewable energy resources' has become the least important indicator with 0.20 sustainability score. Results emphasise that importance of 'availability of renewable energy resources' indicator is two times more important than 'availability of non renewable energy resources' indicator in measuring sustainability of energy power plants.

'Employment opportunities created' has become the most significant indicator while 'compensation rates' has become the least important indicator from all the five indicators in determining the sustainability of power plants in 'health, safety and social issues'. In 'air quality', 'emissions of green house gases' has become the most important indicator in evaluating sustainability of power plants with sustainability score of 0.25 where the least important indicator is 'volatile organic compound emissions' with 0.16 sustainability score. Most important 'water quality' indicator to evaluate sustainability of electricity power plants is 'annual total water consumption' with 0.26 sustainability score. 'Amount of recycled water per year' has become the second important one with 0.23 importance level. 'Quality of output water' level has graded as the least important indicator with about more than 200% less important from the 'amount of recycled water per year' indicator.

'Total land requirement for the power plant' has become the most important indicator to evaluate the sustainability in power plants in aspects of 'land, forest and wildlife issues', while 'Green areas as a percentage of total area' has become the least important indicator. 'Generation of radioactive waste' has become the most important indicator in 'waste management' sector with 0.22 sustainability score level. 'Degree of waste recycling and reuse' has become the fourth important indicator with 0.19 sustainability score and 'amount of waste going to land fill has become the least important aspect with 0.17 sustainability score.

According to the overall sustainability scores, 'availability of renewable energy resources' is the most significant indicator with relative sustainability score of 0.048. Since the world is moving towards renewable energy sources the utmost importance should be given to the renewable energy provisions. Second most importance indicator is the 'plant process efficiency'. Plant process efficiency has been identified as a primary indicator in previous studies on power plant evaluations namely Afgan and Carvalho (2008), Athanasios and Pilavachi (2008) and Carrera and Mack (2009). 'Annual total water consumption' has been rated as the third important sustainability indicator to evaluate sustainability of energy power plants while 'emissions of green house gases' and 'electricity unit cost' have been rated as fourth and fifth respectively.

'Availability of non renewable energy resources' has become the 34th indicator in framework, where it can be identified as the 4th most insignificant indicator to evaluate sustainability of power plant. The 'Availability of renewable energy resources' indicator can be identified as 150% important than this indicator. This indicator will de-motivate the developers and investors to use fossil fuels as primary energy source.

Third most insignificant indicator is 'sound level of power plant'. Most of the times hydro plants are constructed at country sides and the disturbances occurred may very less concerned to other sustainability aspects. Although studies like Afgan and Carvalho (2008), Costa and Pagan (2006) used 'compensation rates' as a power plant evolution criterion, it has become the 2nd most insignificant indicator in framework. 'Green areas as a percentage of total area' has become the most insignificant indicator among the all 37 sustainability indicators. This is nearly 180% less significant than the first ranked sustainability indicator. As a tropical country most of the power plants are developed on country side green areas. Only few thermal plants are located in urban areas due to ease of fuel transportation. Hence, in most of the power plants, additional green plots are not necessary since they are located in green plots surroundings.

4. Conclusions and Recommendations

Energy is the source of survival of human life. Energy conservation and management has become the key inspirational practices in many industries in 21st century. Contemporarily sustainability development has also gained extraordinary attention with the recent environmental changes. Power plant evaluation involves great number of criteria whose selection and weighting is decided in accordance with the socioeconomic and political framework or the area in which they are established. Though there have been over 500 adhoc sustainability indicators were found, none of the studies were concentrating on multidimensional aspects of sustainability related to the generation of electrical power. Thus, the aim of this study was to develop a multidimensional framework to evaluate sustainability of energy power plants in Sri Lanka.

Five-step implementation approach was used to develop the sustainability evaluation framework for energy power plants. The evaluation hierarchy was developed according to the findings of the literature review and preliminary survey. The hierarchy consisted of eight sustainability evaluation criteria namely economic aspects, technological aspects, health, safety and social issues, air quality, water quality, land, forest and wild life issues and waste management and 37 sustainability indicators.

The identified sustainability criteria and indicators were then prioritised using AHP tool. According to survey findings, 'economic aspects' was ranked as the top most important criterion and 'technological aspects' and 'air quality' were ranked as the second and third with close relative sustainability score levels. 'Water quality' became the fourth main sustainability criterion with higher sustainability scores. 'waste management', 'health, safety and social issues' and 'energy resource' were ranked at fifth, sixth and seventh important criteria respectively. The framework ranked 'land, forest and wildlife issues' as the least important criterion from the eight criteria in evaluating sustainability of energy power plants in Sri Lanka. According to the overall sustainability scores, 'availability of renewable energy resources' became the most important indicator while 'green areas as a percentage of total area' became the most insignificant indicator among the 37 sustainability indicators.

The developed framework can be used to categorise sustainability of different power plants in Sri Lanka and to measure the sustainability of existing plants in order to grade their level of sustainability.

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