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Sustainability Framework and Metric to Analyze Sustainability of Renewable Energy Systems in Nepal

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Abstract: Because of its harsh topographic conditions, rural off-grid electrification is gaining huge popularity in Nepal. Realizing the importance of renewable energy in rural areas, with the support of various development partners, Government of Nepal in its interim three year plan (2010 to 2013) considers rural electrification through renewable energy technologies as an appropriate means to enhance rural livelihoods and conserve environment in rural areas. As the aim of the installation is to increase access to energy services for livelihood enhancement, it has been realized to assess whether these systems installed and/being installed across different parts of Nepal are contributing for economic growth of society and whether these systems are sustainable or not. The overall objective of this study is to develop a framework to measure sustainability of rural and renewable energy projects and eventually assess the sustainability of renewable energy projects in Nepal that have been installed for a year or more. This study, by developing assessment/evaluation criteria that reliably measures sustainability in general and technical, economic, social and institutional and environment sustainability in particular, aims to develop standard Sustainability Metric (SM) to measure sustainability of rural energy projects.

Key words: Criteria · Metric · Nepal · Renewable energy · Sustainability

INTRODUCTION

Renewable energy technologies (RETs) were promoted in Nepal since the early seventies but these technologies have been widely disseminated only after the establishment of a dedicated organization called Alternative Energy Promotion Centre (AEPC) in 1996. With the support of various development partners and the firm commitment of the government, some 2000 micro hydro projects generating 20 MW electricity, 250,000 solar home systems, 250,000 biogas plants and 500,000 improved cooking stoves have been installed in different parts of the country [1].

Sustainable energy is defined as energy which, in its production or consumption, has minimal negative impacts on human health and the healthy functioning of vital ecological systems, including the global environment and that can be supplied continuously to future generations on earth. Such forms of energy include, but are not limited to solar thermal, solar photo-voltaic (PV), wind, hybrid wind-solar, fuel cell, geothermal, small-scale (mini and pico) hydro-electric, tidal and wave.

Sustainability is defined as the development that meets the needs of the present without compromising the ability of future generations to meet their own need (Brundtland Report, 1987). This definition has been further elaborated in the three dimensions of economic, environmental and social sustainability. To assess the sustainability of renewable energy systems, five dimensions namely technical, economic, social, environmental and institutional sustainability are considered [2].

Rural and renewable energy projects are built with a certain amount of investment subsidy from government. After installation of the energy system, it is the responsibility of the participating community or the users

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to operate maintain and manage the system. The sustainability of renewable energy projects considered largely depends on how much revenue it can generate from its users for operation, maintenance and management. Revenue from users depends upon multiple factors categorized as technical, financial/economic, social, institutional and environmental. As such, sustainability of the projects needs to be evaluated based on the multiple criterions in a holistic manner.

Studies indicate that sustainability of renewable energy projects in the Nepalese context is defined as the ability and willingness of the user that receives electricity services to cover all non-subsidized costs for the operation and maintenance of the system that provides the services. Therefore, the sustainability of renewable energy projects largely depends on how much money it can generate from its users for operation and repair and maintenance. Users can contribute money in the form of regular tariff and/or lump sum during installation but the contribution depends upon technical, economic, social, environmental and institutional factors. In this context, sustainability of the project should not be measured only in financial terms. Optimum system sizing, changes in environments and the socio- cultural set up of the societies are very important parameters to be assessed before the project is entitled as sustainable or not. The local environment, local know-how, local needs, accessibility and affordability should be analyzed while deciding the economic feasibility of the projects [3].

Sustainability of the renewable energy systems installed across different parts of Nepal is one of the main concerns for those who are involved in renewable energy sector. One of the main the obstacles to the sustainability of the rural electrification project is the cost of the systems, which has risen by over 50 percent except in solar in recent years. The cost for solar module has come down but the overall solar system cost has not been changed much. High initial investment and repair and maintenance cost have challenged rural dwellers not only to increase their access on reliable energy services but also to maintain their systems.

In addition to cost constraints, there are many cases where systems are under-used during the day when surplus power could be used to support small-scale economic activity. Many schemes are not generating the expected power and in some cases plants are not operational at all. There are many reasons for poor functioning of RE schemes but poor operating capability, inefficient management, poor feasibility and improper design have been considered as main reasons for not functioning properly. It is also not known whether the institutional arrangements at the local level are sufficiently strong to provide for the effective management of renewable energy systems that are several years old and have probably experienced the need for maintenance.

It is argued that the success or failure of such projects is largely dependent on the system configuration and sizing, social and economic environment in which they operate. Hence, the following key questions are needed to be addressed to assess sustainability of renewable energy projects installed in Nepal:

- How can sustainability of rural and renewable energy projects be measured objectively?
- Are existing renewable energy projects sustainable?
- What factors promote or hinder the sustainable operation of renewable energy projects?

MATERIAL AND METHODS

The Study in Specific Will Follow the Following Stages:
Literature Review: Extensive review is done through print, electronics and online materials. The data source of literature sources are government policy, plans, rules, regulations, laws and bylaws, project reports (various sample sizes), technical guidelines. literatures on sustainable energy development, rural and renewable energy technologies, global and Nepalese experiences, literature of economic and finance such as economic development theory, energy economics, energy planning, economic planning for enterprise development and creation of employment opportunities, financial analysis with various aspects and model are also well studied and analyzed.

Development of Framework to Measure Sustainability: Sustainability Metric (SM) has been developed to measure sustainability of rural energy projects by assigning numerical values. The SM allows objective measurement of sustainability and rank projects according to their SM value. The SM has been developed by following method:

- Identify factors affecting technical, economic, environmental, social andinstitutional sustainability criteria of rural energy projects,
- Develop equations or assign numerical values to quantify the identifiedfactors,

- Develop metric that considers each of the sustainability criterion, namely,technical, economic, environmental, social and institutional to obtain numerical values that measure sustainability.

Sustainability Framework and Metric: The theoretical framework to assess renewable energy projects for this study is drawn from the paper written by Wang *et al* (2009) on review on multi criteria decision analysis aid in sustainable energy decision making [4]. The typical evaluation criteria of renewable energy systems and framework design for evaluating sustainability of the selected Solar, MHP and biogas projects are discussed hereunder.

Principles of Criteria Selection: As discussed in the literature survey, it is not necessary to use all the criteria to measure the performance of energy system and hence sustainable energy decision-making. Mostly there are chances of repeatability and each criteria are linked or correlated with other [1]. In order to remove such aberration and create more relevancies in the criteria system, the study considers the following principles in order to select the decision making criteria:

- Systemic principle: The criteria system should be developed in terms ofcomprehensive evaluation function of multi-criteria decision making. It should represent the necessary criteria and attain the better analysis on the sustainability of the energy systems rather than evaluating each of the criteria separately.
- Measurability principle. The criteria should be measurable in quantitativevalue as possible or qualitatively expressed.
- Comparability principle. The result to be obtained after analyzing thecriteria should be comparable for each energy systems.

Selection of Evaluation Criteria

Technical Criteria: The most important technical criteria is the efficiency of the renewable energy systems [4]. Then comes the reliability which shows the capacity of the system to perform as designed.

Economic Criteria: Whether the sampled renewable projects are sustainable economically, the study shall use Benefit Cost (BC) ratio for economic evaluation of the projects.

Environmental Criteria: Similarly, the performance of the energy systems shall take into account the risks of environmental degradation such as land slide, displacement of inhabitants; impact of emission reduction and impact on the sustainability of the other sources of energy in due to renewable energy projects in order to assess environment sustainability.

Social Criteria: Social acceptability of the selected energy systems, direct and indirect creation of jobs and the social benefit shall be the major social criteria to evaluate whether project is socially sustainable. These will show the acceptance or ownership of the local population and the support of the local authorities; will create more jobs and improve living standards of local people and the level of social progress such as job, income, life expectancy, education made in the society by introducing renewable energy project(s).

Institutional Criteria: The main institutional factors affecting the sustainability of the project are the human resource availability, presence of management committee and revenue management process. This will indicate whether the skill and management of the community can properly carry out the project and look after it once it is completed.

These factors within the individual criteria, however, have been customized based on the national context of Nepal. In addition, the customization ensures that quantification of factors can be carried out so that sustainability can be measured objectively. It is anticipated that the framework developed in this research will be practically used and hence the sustainability measurement procedure is made as simple as possible in view of making it user friendly. Furthermore, this research attempts to link techno-economic analysis with multi-criteria decisions support tool [5].

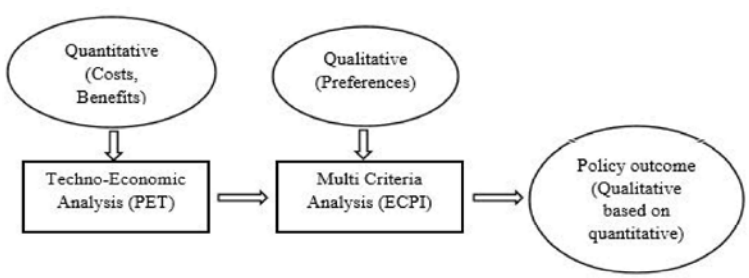

Fig. 1: Linking techno-economic analysis with multi-criteria decisions support tool

Analytical Hierarchy Process (AHP) has been adopted to prepare a framework for sustainability assessment in this research. AHP based multiple criteria analysis deals with the relative priority of importance of each factor by comparison with respect to a certain criteria. A hierarchical structure of these factors is formed by grouping them into different levels. The application of the hierarchical structure allows the factors to be broken down into details. AHP based multiple criteria analysis starts from building tree like structure with criteria at higher level and factors and sub-factors are at lower level. Objective of evaluation lies at the top and the options or alternatives to be evaluated are placed at the lowest level of the hierarchy. The AHP simplifies the process for identification and assessment of criteria, factors and sub-factors related to a problem. The hierarchical structure of goal, dimensions and factors developed for this study is adopted from the structure developed by Bhattarai *et al.* for drinking water facilities [6].

Sustainability Metrics: To quantify the sustainability, five different sustainability metrics have been developed for the each of the sustainability criteria, i.e. Technical criteria, Economic criteria, Environmental criteria, Social criteria and Institutional criteria. The maximum score allocated to each of the sustainability metric is 10. Sustainability metrics have been used widely to assess the sustainability impacts. For instance, universities in United States of America have been developing sustainability metrics for their campuses [7]. Similarly, many business companies have adopted the concept of sustainable development as a core business value [8]. For those businesses that have recognized the need to embrace sustainable development, the next step is to understand how to implement it. Putting this concept into operation requires identifying practical indicators of sustainability and understanding how they can be measured over time to determine if progress is being made. Sustainability metrics are designed to consolidate key measures of environmental, economic and social performance. The development of metrics that relate environmental and economic performance for production processes is an excellent way for many companies to begin to incorporate the goal of sustainability into management decision-making. This research develops sustainability metric to measure sustainability associated with rural and renewable energy systems.

The procedure adopted for selection of factors for quantification of sustainability criteria is literature review and preliminary site visits. Various journal papers and reports have been taken as reference to identify indicators (factors) that help measure sustainability. The indicators of retrospective and predictive assessments developed by Wang *et al* have been one of the main referencesfor indicator identification[9].

Technical Sustainability Metric: This criterion includes the measurement of SM_1, the first dimension of sustainability metric. The two important factors that affect technical feasibility have been found to be overall system efficiency (η) and breakdown (β). The total score assigned to Technical Sustainability Metric (SM_1) is 10. The value of SM_1 shall be obtained by:

$$SM_1 = f(\eta, \beta) \tag{1}$$

The efficiency of an entity (a device, component, or system) in electronics and electrical engineering is defined as useful power output divided by the total electrical power consumed (a positive fractional expression), denoted by η.

$$Efficiency = \frac{Useful\ power\ out}{Total\ power\ inp} \tag{2}$$

On the other end, breakdown is a rate that is defined as average breakdown hours in a year divided by average operation hours in a year (a positive fractional expression), denoted by β.

$$\beta = \frac{Average\ breakdown\ hours\ in\ a\ j}{Average\ operation\ hours\ in\ a\ y} \tag{3}$$

SM_1 can now be calculated as:

$$SM_1 = SM_\eta + SM_\beta \ where,$$

Sm_η = Sustainability Metric considering efficiency

Sm_β = Sustainability Metric considering breakdown

The maximum value of SM_1 shall be limited to 10. Giving equal weighting to SM_η and SM_β, the maximum value possible for SM_η and SM_β is then 5.

The boundary conditions for S_η are set such that the system efficiency can vary between 0.1 (10%) to 0.75 (75%). Solar energy systems can have efficiencies as low as 10% and Micro Hydro power plants can have efficiencies as high as 75%. The efficiency values are in line with AEPC quality assurance guidelines.

The boundary conditions taken are:

$$Sm_{\eta} = 5 \; for \; \eta = 0.75 \text{ and}$$
$$SM_{\eta} = 0 \; for \; \eta = 0.1$$

The straight line equation representing this boundary conditions are:

$$SM_{\eta} - 0 = \frac{(5-0)}{(0.75-0)} \times (\eta - 0.1)$$

$$Sm_{\eta} = 7.7\eta - 0.77 \quad (4)$$

To calculate the value of SM_{β}, the value of β shall be zero if there is no breakdown at all and the value of SM_{β} assigned for such case is 5. The breakdown would be 50%, which is very high, if the value of b is 0.5. The value of SM_{β} assigned for such case is 0.

The boundary conditions taken are:

$Sm_{\beta} = 5 \; for \; \beta = 0$ and
$SM_{\beta} = 0 \; for \; \beta = 0..5$

The straight line equation representing this boundary conditions are:

$$SM_{\beta} - 0 = \frac{(5-0)}{(0-0)} \times (\beta - 0.5)$$

$$Sm_{\beta} = 5 - 10\beta \quad (5)$$

Finally,

$SM_1 = SM_{\eta} + SM_{\beta}$
$= 7.7\,\eta - 0.77 + 5 - 10\,\beta$
$SM_1 = 7.7\,\eta - 10\,\beta + 4.23$ [For $0 \le SM_1 \le 10$] (6)

If the calculation yields the value of SM_1 less than zero (negative value), the value shall be taken as 0. Likewise, if the calculation yields the value of SM_1 greater than 10, the value shall be taken as 10.

Economic Sustainability Metric: The factor considered for the measurement of economic criteria is Benefit Cost (BC) ratio of the economic assessment. The cost recovery potentials of rural energy projects are very low and this is the reason that Government of Nepal (GoN) subsidizes rural energy projects. Hence, most renewable energy systems are expected to have BC ratio less than 1. Consequently, the value of Economic Sustainability Metric (SM_2) shall be taken 0 only when BC ratio is less than 0.5 instead of 1. As the value of SM_2 cannot be expected to be very high in rural energy systems, the value of SM_2 shall be taken as 10 for the BC ratio equal or greater than 1.5.

Mathematically, the boundary conditions are:

For BC $\le$ 0.5, $SM_2 = 0$and

For BC $\ge$ 1.5, SM_2=10

The straight line equation for SM_2 for 0.5 = BC = 1.5 is then found as:

$$SM_2 - 0 = \frac{(10-0)}{(1.5-0)} \times (BC - 0.5)$$

SM_2 = 10 * BC - 5 [For 0.5 = BC = 1.5] (7)

Environmental Sustainability Metric: The indicators developed by A.C. McBride *et al*. (2011), as shown below, have been modified to suit the national context of Nepal in this research.

Criteria for Selection of Useful Environmental Indicators [10]:

- Are easily measured,
- Are sensitive to stresses on system,
- Respond to stress in a predictable manner,
- Are anticipatory: signify an impending change in the environmental system,
- Predict changes that can be averted by management actions,
- Are integrative: the full suite of indicators provides a measure of coverage of the key gradients across the environmental systems (e.g. soils, vegetation types and temperature),
- Have a known response to natural disturbances, anthropogenic stresses and changes over time,
- Have known variability/spread in response to given environmental changes.

The environmental factors affecting the viability of rural energy projects have been identified and score for each factor has been assigned to measure the Environmental Sustainability Metric (SM_3). Table 1 has been developed to measure the numerical value of SM_3 out of 10. The value of SM_3 is obtained by the summation of individual obtained score.

Table 1: Weightage for Environmental Factors and Calculation of SM_3

SN	Environmental Factors	Max.Score
1	Risk of landslide	1
2	Impact on aquatic lives and water quality	1
3	Impact on local vegetation	1
4	Accident Prone/Cases of human casualties reported in past within Nepal	1
5	Waste disposal/Battery management issues	1
6	Impact on indoor air quality	1
7	CO_2 emission potential/Climate Change issues	1
8	Adequacy of energy fuel (energy resources) for future expansion/Future expansion potential	1
9	Availability of resources (other than energy fuel) such as cement, iron and machine components within Nepal or local community for power plant construction	1
10	Impact on forest resources or vulnerable local natural resources (if any)	1
	Total	10

Table 2: Weightage for Social Factors and Calculation of SM_4

SN	Social Factors	Max.Score
1	Ability of community to unite for common cause	3
2	Community participation in project	1.5
3	Community equity/stake in the project	1.5
4	Project contribution in economic productivity/income generation	2
5	Gender and Social Inclusion	2
	Total	10

Table 3: Weightage for Institutional Factors and Calculation of SM_5

SN	Institutional Factors	Max. Score
1	Human resources availability	2.5
2	Plant Operation & Management structure; Presence of Management Committee	2.5
3	Technical and management skill	2.5
4	Revenue management process	2.5
	Total	10

Social Sustainability Metric: The social factors affecting the viability of rural energy projects have been identified and score for each factor has been assigned by Delphi method to measure the Social Sustainability Metric (SM_4)[11]. Table 2 has been developed to measure the numerical value of SM_4 out of 10. The value of SM_4 is obtained by the summation of individual obtained score.

Institutional Sustainability Metric: The institutional factors affecting the viability of rural energy projects have been identified and score for each factor has been assigned by Delphi method to measure the Institutional Sustainability Metric (SM_5) [11]. Table 3 has been developed to measure the numerical value of SM_5 out of 10. The value of SM_5 is obtained by the summation of individual obtained score.

Overall, the hierarchical structure below shows the sustainability framework developed in this research.

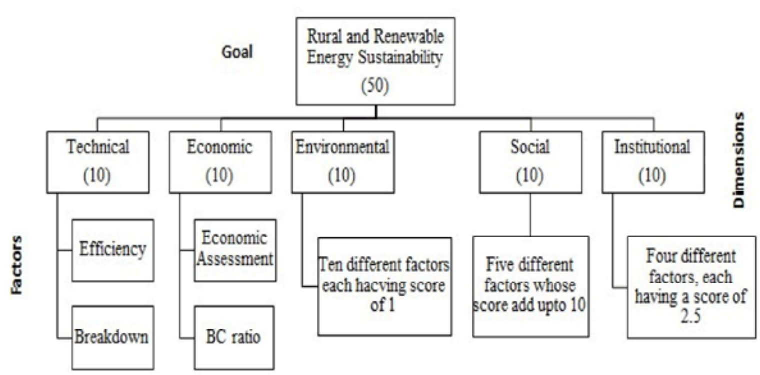

Fig. 2: Hierarchical structure of goal, dimensions and factors with their weights

Total Sustainability Metric: The Total Sustainability Metric (SM_{TOT}) is defined as the summation of all the Sustainability Metric defined above.

Mathematically,

$$SM_{TOT} = \sum_{i=1}^{5} S$$

$$SM_{TOT} = SM_1+SM_2+SM_3+SM_4+SM_5 \quad (8)$$

Such that the maximum possible value of SM_{TOT} is 50.
Similarly, Effective Sustainability (SM_{eff}) is defined in percentage value as:

$$SM_{eff} = \frac{SM_T}{50} \times 100\% \quad (9)$$

Conditions for Sustainability: The four different categories of sustainability for rural energy projects are defined as below:

Unsustainable Projects: The projects where at least two criteria have values of Sustainability Metric less than 5 and Effective Sustainability less than 50% shall be categorised under unsustainable projects.

Mathematically,

Sm_i<5 for at least two values of iwhere, i = 1, 2, 3, 4 and 5

$$\text{And,} SM_{eff} < 50\%, SM_{TOT} < 25 \quad (10)$$

Weakly Sustainable Projects: The projects where at most two criteria have values of Sustainability Metric less than 5 and Effective Sustainability equal to or more than 50% shall be categorised under weakly sustainable projects.

Mathematically,

Sm_i<5 for at most two values of i where, i = 1, 2, 3, 4 and 5

$$\text{And, } SM_{eff} \geq 50\%, SM_{TOT} = 25 \quad (11)$$

Sustainable Projects: The projects where all the criteria have values of Sustainability Metric equal to or more than 5 shall be categorised under sustainable projects.

Mathematically,

$Sm_i \geq 5$ for at least two values of i where, i = 1, 2, 3, 4 and 5

$$\text{And, } SM_{eff} \geq 50\%, SM_{TOT} \geq 25 \quad (12)$$

Highly Sustainable Projects: The projects where all criteria have values of Sustainability Metric equal to or more than 5 and Effective Sustainability equal to or more than 80% shall be categorised under highly sustainable projects.

Mathematically,

$Sm_i = 5$ for at least two values of i where, I = 1, 2, 3, 4 and 5

$$\text{And, } Sm_{eff} \geq 80\%, SM_{TOT} \geq 35 \quad (13)$$

DISCUSSION

Analytical Hierarchy Process (AHP) has been adopted to prepare a framework for sustainability assessment in this research. AHP based multiple criteria analysis starts from building tree like structure with criteria at higher level and factors and sub-factors are at lower level. To quantify the sustainability, five different sustainability metrics have been developed for the each of the sustainability criteria,i.e. Technical criteria, Economic criteria, Environmental criteria, Social criteria and Institutional criteria. The maximum score allocated to each of the sustainability metric is 10. For each sustainability metric, various sub-factors are considered with precise literature review and wisely considering the socio-environmental aspects of Nepal.

Technical Sustainability metric (SM_1) is calculated as:

$$SM_1 = 7.7\,\eta - 10\,\beta + 4.23 \text{ [For } 0 \leq SM_1 \leq 10]$$

Economic Sustainability metric (SM_1) is calculated as:

$$SM_2 = 10 \times BC - 5 \text{ [For } 0.5 \leq BC \leq 1.5]$$

The value of Environmental Sustainability Metric (SM_3) is obtained by the summation of individual obtained score considering each of the ten environmental factors.

The value of Social Sustainability Metric (SM_4) is obtained by the summation of individual obtained score considering each of the five social factors.

The value of Institutional Sustainability Metric (SM_5) is obtained by the summation of individual obtained score considering each of the four institutional factors.

The Total Sustainability Metric is given by:

$$SM_{TOT} = \sum_{i=1}^{5} S$$

$$SM_{eff} = \frac{SM_T}{50} \times 100\%$$

Then, as per the conditions of sustainability, the rural energy projects can be classified as unsustainable, weakly sustainable, sustainable or highly sustainable projects.

CONCLUSION

Five different sustainability metrics have been developed for the each of the sustainability criteria, i.e. Technical criteria, Economic criteria, Environmental criteria, Social criteria and Institutional criteria. The summations of the individual metrics give rise to the total sustainability metric. Using this sustainability framework and metric, the sustainability of each and every renewable energy technologies operating in rural Nepal can be assessed. Government of Nepal has been providing huge amount of subsidies on the renewable energy projects, plus international donors have also been providing large amount of funds in those technologies. Hence, it is of a major concern to everybody whether the investments made are going to the right track. The framework developed here accurately measures the sustainability of those projects by including all sorts of possible factors. This framework can be used for the technologies that are being operated, being installed or are on the verge of planning and installation.

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REFERENCES

1. Alterntive Energy Promotion Centre, Annual Progress Report," 2012.
2. Elisabeth Ilskog, B.K., 2008. And then they lived sustainably ever after? -Assessment of rural electrification cases by means of indicators, Energy Policy, 36(7): 2674-2684.
3. T.-P. C.D.J.K. W.O. Julia, 2014. A cross-sectional review: Impacts and sustainability of small-scale renewable energy projects in developing couuntries, Renewable and Sustainable Energy Reviews, 40(1): 10.
4. Y.-Y. J.C.-F. Z. J.-H. Z. Jiang-Jiang Wang, 2009. Review on milti-criteria decision analysis aid in sustainable energy decision-making, Renewable and Sustainable Energy Reviews, 13(9): 2263-2278.
5. A.F.M.G.G.G.A.K.E.S.S.V.Oikonomou,2011.Linking least-cost energy system costs models with MCA: An assessment of the EU renewable energy targets and supporting policies, Energy Policy, 39(5): 2786-2799.
6. Barun Kanta, S.B., 2010. Long term sustainability monitoring - WaterAid's experience in Nepal, WaterAid, Kathmandu, 2010.
7. University of Maryland, 2011. Sustainibility Metrics Report," 2011.
8. Harvard University, 2012. Sustainability at Harvard, Impact Report," 2012.
9. K.-c. L.M.K.H. W.-c. M.Q.Y. Yue Wang, 2013. Developing an indicator system to foster sustainability in strategic planning in China: A case study of Pudong New Area Shanghai, Ecological Indicators, 29: 376-389.
10. Allen C. McBride, Virginia H. Dale, Latha M. Baskaran, Mark E. Downing, Laurence M. Eaton, Rebecca A. Efroymson, Charles T. Garten Jr. Keith L. Kline, Henriette I. Jager, Patrick J. Mulholland, Esther S. Parish, Peter E. Schweizer and John M. Storey Indicators to support environmental sustainability of bioenergy systems, Ecological Indicators, 11(5): 1277-1289.
11. Navneet Bhusan, K.R., 2004. Strategic Decision Making - Applying the Analytic Heirarchy Process, 2004.