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GREENING BUILDINGS: ACTION BASED ON IDENTIFICATION OF RETROFITTED PARAMETERS

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Abstract— The Sustainable Development implies fulfilling the needs of the present without negotiating the ability of the future needs [1]. As on 31.03.2016, out of total 302 GW of electricity generated, approx 43 GW (only 14%) was generated by Renewable Energy Sources [2]. In the National Budget (2015), it was declared that approx five-time increase of Renewable Energy (RE) would be targeted to 175 GW by 2022 from 43 GW at 2016 [3]. Generally, lots of space exists within a company/ institution for conflicting opinions in implementing the retrofitting alternatives. Some of the decision makers may prioritize the financial criteria - Energy Savings (kWh/ Year) in top, some again may arrange the projects based on priority in Annual Investment (Rs.) or Annual Savings (Rs. /Year) or Payback Period (Years). Hence it is needed to obtain the prioritization table scientifically by the application of AHP, where an overall ranking of the energy alternatives is obtained by the combined effect of all of the financial/ doable criteria. In our present study, AHP has been chosen as an action based retrofitting parameter in selecting the priority of doable projects in a descending order of ranking provided by the system, in a MCDM environment. Moreover, to validate our experimental result of AHP, a 2nd stage survey was conducted to the beneficiary experts only of the respective company/ institution, who participated in the 1st round survey. This validation signifies that the Action Based Greening Building Procedure – i.e. the 'AHP' applied in the present paper is very much scientific and universal.
Keywords — Sustainable Development, Renewable Energy, Priority of Doable Projects, Multi-Criteria Decision Making, AHP, Action Based Greening Building Procedure.

I. INTRODUCTION

A green campus is a place, where environmental friendly practices and education combine to promote sustainable and eco-friendly practices in the campus. The green campus concept offers an institution, where the opportunity is taken to lead in redefining its environmental culture and developing new paradigms (a pattern or model) by creating sustainable solutions to environmental, social and economic needs of the mankind [4].

Greening the campus is all about sweeping away wasteful inefficiencies and using conventional sources of energies for its daily power needs, correct disposal handling, purchase of environment friendly supplies and effective recycling program. The institute has to work out the time bound strategies to implement green campus initiatives. These strategies need to be incorporated into the institutional planning and budgeting processes with the aim of developing a clean and green campus [4]. There are a variety of solutions and services available in the market, that impact building design, appliances, operation and maintenance of building components etc. Various stakeholders like the industry, government and academic institutions are engaged in the development of these solutions. Improving the energy efficiency of the existing buildings not only generates energy savings with attractive pay back periods, it also improves a nation's energy security and makes buildings more liveable. BEE's (Bureau of Energy Efficiency) national level programme for energy efficiency in government buildings is required to convert famous buildings around the capital into energy efficient premises by retrofitting and thereby set a standard [5].

II. METHODOLOGY

A. Research Approach

The respondents are the experts of the respective fields, interested to cooperate in the survey.

B. Sampling Method

The respondents have gone through an in depth interview (1st Stage and 2nd Stage) procedure for this study, limited only to the experts of two educational institutions and two charitable organizations.

C. Data Collection Method

- Since our study followed the Qualitative or Exploratory Research, the sample size was typically small (twelve) and individual depth interviews were conducted (1st and 2nd stage).
- Primary data has been collected through questionnaires to the financial experts of respective institutions.
- Judgments were made among the alternatives on a scale of 1 – 5, by each expert individually.
- The overall priorities of the energy savings alternatives were found out by the application of Analytical Hierarchical Process (AHP).

D. Data Analysis Method

- All data (primary mainly) have been analysed by the scientific tool AHP and IBM SPSS Statistical Software (Version 20).
- A second stage interview also was conducted, through another set of questionnaires, among those thirteen respondents, participated in the first stage interview of the respective institutions, for the validation of our AHP outcome.

III. APPLICATION OF METHODLGY THROUGH CASE STUDIES

A. Case-I: Ramakrishna Mission Vivekananda Centenary College (RKMVCC), Rahara [6]

TABLE - I

Financial Parameters for different Energy Saving Alternatives at RKMVCC, Rahara

Sl.No.	Energy Saving Measures	Investment in Rs.	Annual Savings in Rs. /Year	Annual Savings in kWh /Year	Payback Period (Yrs.)
1.	T12 is Replaced with LEDs (20 W) (Philips)	701.60	604.8	100.8	1 yrs. 2 months
2.	T12 is Replaced with CFLs (30 W)	51.84	432	72	1.4 months
3.	T12 is Replaced with T5 (33 W)	300.34	380.16	63.36	9.5 months
4.	Ordinary Fan (75 W) is replaced with BEE Star Rated Fan (55 W)	600.65	380.16	63.36	1 yrs.7 months
5.	Ordinary Fan (75 W) is replaced with Super Fan (35 W)	1596.67	691.2	115.2	2 yrs.4 months
6.	30 kW rooftop SPV	3000000	243000	40500	12 yrs.

B. Case-II: Indian Institute of Social Welfare & Business Management, Kolkata [7]

TABLE II

FINANCIAL PARAMETERS FOR DIFFERENT ENERGY SAVING ALTERNATIVES AT IISWBM

S.No.	Measure/ Proposal	Present Situation	New Situation	Annual Savings (Rs.)	Investment (Rs.)	Payback Period
		Electricity Bill (Rs.)	Electricity Bill (Rs.)			
1	Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with new meter (Rs. 6.66/kWh)	1,35,384	86,154	49,231	36,000	9 months
2	Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with old meter (Rs. 2.40/kWh)	48,787	31,046	17,741	36,000	2 years
3	Replacement of 10 nos. TL/60 W bulb – operating 8 to 10 hrs. per day–with 11/14W CFL (new meter Rs. 6.66/kWh)	8,440	1,969	6,471	1,500	3 months
4	Switching off 31 TLs in Computer Lab Room No. 115	21,606	10,803	10,802.88	NIL	Immediate
5	A/C Load Management	1,38,442	93,266	45,176	NIL	Immediate
6	Replacing an old 2 ton A/C with new Energy Efficient one in Computer Lab.	--	—	3953.60	22000	5 years 6 months

IV. RESULTS & DISCUSSIONS

A. Need for application of the AHP

TABLE III

USE OF PROPOSED ACTION BASED RETROFITTING PARAMETERS NEEDED DURING SELECTION OF DOABLE PROJECTS IN THE DECISION MAKING PROCESS

Criteria/ Objective	Decision – Prioritization of Doable Projects
To maximize the Energy Savings (kWh)	Arrange the projects in descending order of Energy Savings, e.g. project in sl. #6 in Ramakrishna Mission Vivekananda Centenary College assures highest priority.
Scarcity or Insufficiency of Fund (Rs.)	Arrange the projects in ascending order of Investment needed to Implement the Projects e.g. project in sl. #2 in Ramakrishna Mission Vivekananda Centenary College and sl. #3 in IISWBM, assures highest priority.
To maximize the Monetary Saving (Rs./Year)	Arrange the projects in descending order of Annual Savings, e.g. project in sl. #6 in Ramakrishna Mission Vivekananda Centenary College and sl. #1 in IISWBM assures highest priority.
To maximize the Long Term Benefit (Years) from Investment	Arrange the projects in ascending order of Payback Period, e.g. project in sl. #2 in Ramakrishna Mission Vivekananda Centenary College and sl. #3 in IISWBM assures highest priority.

Generally, lots of space exists within the decision makers of a company/ institution for conflicting opinions e.g. one may prioritize the alternatives based on payback period (yrs.), another one may prefer to prioritize the same alternatives based on annual savings (Rs./year) or annual savings (kWh) or investment (Rs.) or CO_2 emission in the environment and so on. Hence, it is needed to obtain a prioritization table in a more scientific way, where an overall ranking of the energy alternatives is obtained by the combined effect of all of the financial/ doable criteria. The retrofitting in greening building is being developed through 'appropriate algorithm' or application of 'AHP' (Analytic Hierarchy Process) that would be an action based strategic implementation to offer conclusive decisions in MCDM (Multi Criteria Decision Making) circumstances. However, in reality, more complex situation makes the decision making difficult and/ or complicated, which can be easily solved by the AHP.Now, we will apply the AHP for each of the above two cases and will examine the outputs individually, considering the retrofitting alternatives of each cases against the three financial criteria.

B. Application of AHP in the Case Study of Ramakrishna Mission Vivekananda Centenary College, Rahara
Here, we consider six alternatives and three criteria for each of the six alternatives.

Alternatives:

A1: T12 (40W Tube) is replaced with LEDs (20 W) (Philips).
A2: T12 (40W Tube) is replaced with CFLs (30 W).
A3: T12 (40W Tube) is replaced with T5 (33 W)
A4: Ordinary Fan (75 W) is replaced with BEE Star Rated Fan (55 W) &
A5: Ordinary Fan (75 W) is replaced with Super Fan (35 W).
A6: 30 kW Rooftop Solar Photo Voltaic at Centenary College

Criterions:

C1: Investment in Rs.
C2: Annual savings in Rs. /Year &
C3: Payback period in Year.

TABLE IV
PAIR WISE COMPARISONS MATRIX AMONG THE THREE CRITERIA OR FINANCIAL PARAMETERS FOR RKMVCC

Criteria	Investment in Rs.	Annual Savings in Rs./Year	Payback Period (Yrs.)
Investment in Rs.	1.00	1.19	0.94
Annual savings in Rs./Year	0.84	1.00	0.69
Payback Period (Yrs.)	1.07	1.45	1.00

TABLE V
FINDING OUT CONSISTENCY RATIO FROM THE RESPONSES FOR RKMVCC

Weights (w) or Priority Vector (obtained by Geometric Mean)	Consistency Measure	Ratios (Consistency Vector)	λmax	Consistency Index (CI)	Consistency Ratio (CR) = CI / RI
0.342	1.027	3.002	3.141	0.071	0.08
0.275	1.027	3.733			
0.382	1.027	2.688			

The consistency ratio (C. R.) calculated for the financial parameter, i.e. C.R. obtained in above Table - V, is less than 0.1, indicating sufficient consistency. Therefore the experimental result is validated for application of the action based retrofitting for greening building strategies.

TABLE VI
RELEVANT VALUES OBTAINED FROM THE CASE STUDY OF RKMVCC, RAHARA

Criteria / Alternatives	Investment in Rs.	Annual Savings in Rs./Year	Payback Period (Yrs.)
T12 is Replaced with LEDs (20 W) (Philips)	701.60	604.8	1.167 yrs.
T12 is Replaced with CFLs (30 W)	51.84	432	0.117 yrs.
T12 is Replaced with T5 (33 W)	300.34	380.16	0.792 yrs.
Ordinary Fan (75 W) is replaced with BEE Star Rated Fan (55 W)	600.65	380.16	1.583 yrs.
Ordinary Fan (75 W) is replaced with Super Fan (35 W)	1596.67	691.2	2.333 yrs.
30 kW rooftop SPV	3000000	243000	12 yrs.

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TABLE VII

COMPUTATIONS FOR FINDING OUT THE RELATIVE INDEXES OF INDIVIDUAL FINANCIAL PARAMETERS CORRESPONDING TO DIFFERENT RETROFITTING ALTERNATIVES FOR RKMVCC

Criteria / Alternatives	Investment in Rs.	Relative Index (R. I.) of Investment	Annual savings in Rs./Year	Relative Index (R. I.) of Annual Savings	Payback Period (Yrs.)	Relative Index (R. I.) of Payback Period
T12 (40W Tube) is replaced with LEDs (20 W) (Philips)	701.60	0.00023	604.80	0.002	1.167	0.065
T12 (40W Tube) is replaced with CFLs (30 W)	51.84	0.00002	432.00	0.002	0.117	0.007
T12 (40W Tube) is replaced with T5 (33 W)	300.34	0.00010	380.16	0.002	0.792	0.044
Ordinary Fan (75 W) is replaced with BEE Star Rated Fan (55 W)	600.65	0.00020	380.16	0.002	1.583	0.088
Ordinary Fan (75 W) is replaced with Super Fan (35 W)	1596.67	0.00053	691.20	0.003	2.333	0.130
30 kW rooftop SPV	3000000	0.99892	243000	0.990	12	0.667
TOTAL	3003251.1	1.0000	245488.32	1.0000	17.992	1.0000

TABLE VIII

FINAL COMPARISON OR JUDGMENT MATRIX SHOWING FINAL PRIORITY OF INDIVIDUAL RETROFITTING ALTERNATIVES IN THE STUDY OF RKMVCC

Criteria / Alternatives	Relative Index (R. I.) of Investment [0.342]	Relative Index (R. I.) of Annual Savings [0.275]	Relative Index (R. I.) of Payback Period [0.382]	Final Priority	Ranking
T12 (40W Tube) is replaced with LEDs(20 W) (Philips)	0.00023	0.002	0.065	0.026	4th
T12 (40W Tube) is replaced with CFLs (30 W)	0.00002	0.002	0.007	0.003	6th
T12 (40W Tube) is replaced with T5 (33 W)	0.00010	0.002	0.044	0.017	5th
Ordinary Fan (75 W) is replaced with BEE Star Rated Fan (55 W)	0.00020	0.002	0.088	0.034	3rd
Ordinary Fan (75 W) is replaced with Super Fan (35 W)	0.00053	0.003	0.130	0.050	2nd
30 kW rooftop SPV	0.99892	0.990	0.667	0.869	1st
TOTAL	1.000	1.000	1.000	1.000	-

As per the final ranking of the energy saving alternatives shown in Table -VIII above, the last alternative i.e. 30 kW rooftop SPV has achieved the highest rank followed by the alternatives - the Ordinary Fan (75 W) replaced with Super Fan (35 W), Ordinary Fan (75 W) replaced with BEE Star Rated Fan (55 W), T12 (40W Tube) replaced with LEDs (20 W) (Philips), T12 (40W Tube) replaced with T5 (33 W) and the T12 (40W Tube) replaced with CFLs (30 W) respectively, in the study of Ramakrishna Mission Vivekananda Centenary College, Rahara. Now all the Ordinary Fan (75 W) in the college if replaced with Super Fan (35 W), instead of BEE Star Rated Fan (55 W), since the Super Fan occupies the highest rank between these two alternatives. Similarly, all T12 (40W Tube) are replaced with LEDs (20 W) (Philips) instead of T5 (33 W) and CFLs (30 W), as a correction to avoid duplication error. Similarly, the final judgment matrix for the other case study discussed above, is presented below and the subsequent discussions about the output of rankings generated is also revealed accordingly in this paper.

C. Application of AHP in the Case Study of IISWBM, Kolkata

TABLE IX

FINAL COMPARISON OR JUDGMENT MATRIX SHOWING FINAL PRIORITY OF INDIVIDUAL RETROFITTING ALTERNATIVES IN THE STUDY OF IISWBM

Criteria / Alternatives	Relative Index (R. I.) of Investment in Rs. [0.302]	Relative Index (R. I.) of Annual Savings in Rs./Year [0.377]	Relative Index (R. I.) of Payback Period (Yrs.) [0.275]	Final Priority	Ranking
Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with new meter (Rs. 6.66/kWh)	0.38	0.64	0.09	0.38	1st
Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with old meter (Rs. 2.40/kWh)	0.38	0.23	0.23	0.26	3rd
Replacement of 10 nos. TL/60 W bulb – operating 8 to 10 hrs. per day–with 11/14W CFL (new meter Rs. 6.66/kWh)	0.02	0.08	0.03	0.04	4th
Replacing an old 2 ton A/C with new Energy Efficient one in Computer Lab	0.23	0.05	0.65	0.27	2nd
TOTAL	1.000	1.000	1.000	1.000	-

In this case, alternatives 'Switching off 31 TLs in Computer Lab Room No. 115' and 'A/C Load Management' – have no initial Investment and additionally Annual Savings incur for the both. Hence, without applying the AHP, decision makers can finalize the ranking between these two, depending upon the value of Annual Savings only.

Now, for the prioritization among the remaining four alternatives in a MCDM environment, the decision makers have to apply the AHP. It may be noted that, nowadays, LED has come out to be a more attractive and useful lighting solution in compared to CFL in most of the applications. Therefore the 4th or lowest rank secured by the Energy Conservation Measures (ECMs) in this study, i.e. the replacement of Tube Light/60 W Bulb with CFL (new meter Rs. 6.66/kWh), could be justified as the study was conducted much earlier, when LED was not installed in IISWBM nor available in the market at affordable prices and convenient places.

D. Application of Statistical Software IBM SPSS for Validation of the AHP Outcomes by Non Parametric Test

The Pearson Chi square test is used to test whether a statistically significant relationship exists between two categorical variables e.g. Professional Qualification achieved by the respondents and Suggestion for Validation expressed by them. It comes with a cross tabulation between the two variables.

Null Hypothesis (H_0)

H_0: 'Suggestion for Validation of AHP' is not related to 'Professional Qualification' achieved by the respondents.

against **Alternative Hypothesis (H_1)**

H_1: 'Suggestion for Validation of AHP' is related to 'Professional Qualification' achieved by the respondents.

TABLE X
CASE PROCESSING SUMMARY OF CHI-SQUARE TEST

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Qualification of Respondents vs. Suggestion for Validation of AHP	12	100.0%	0	0.0%	12	100.0%

TABLE XI
QUALIFICATION VS SUGGESTION FOR VALIDATION CROSS TABULATION

			Suggestion for Validation of AHP			Total
			Neutral	Yes	No	
Qualification achieved by the Respondents	Undergraduate	Count	0	0	1	1
	Graduate	Count	0	1	3	4
	Master Degree	Count	0	3	1	4
	PhD	Count	1	1	1	3
	Total	Count	1	5	6	12

In the cross tabulation matrix output, the Suggestions for Validation are presented in the columns and the Qualifications are presented in the rows. Within each cell the observed values are listed (labelled as "Count" in the row heading). The row and column totals are also presented. Out of 12 respondents, 1 is Undergraduate, 4 respondents are Graduate, 4 respondents having qualification Master Degree and the remaining 3 respondents possess PhD. Here, one respondent out of twelve, refused to participate in the AHP validation survey (represented by '1' in qualification row = 'PhD' and column = 'Neutral', in the cross tabulation matrix). Column 'Yes' indicates that total 5 out of 12 respondents (i.e. 42%) suggest for increasing more number of retrofitting alternatives in the present cases and column 'No' implies that total 6 respondents (i.e. 50%) are satisfied with the present number of alternatives in the study done, they need no requirement for further improvement of the Overall Process of Ranking Performed by AHP here. But these (5+6 or) 11 respondents out of 12, i.e. 92% are satisfied with the AHP method and the ranking executed by it. Moreover, the significance value i.e. p-value = 0.373 > 0.05(5% alpha level), so we are unable to reject the null hypothesis (H_0). Thus H_0 is accepted and therefore, it can be finally concluded that, there is no significant relationship between the Suggestion for Validation of AHP and the Professional Qualification achieved by the Respondents of the respective institutions/ organizations. They have only suggested their weightages in the second stage questionnaire (validation survey), viewing the beautiful outcome of AHP in the MCDM, depending on their professional experience.

V. CONCLUSION

Therefore, according to the present study, the views of the respective organization's experts on three selected criteria (Investment, Annual Savings and Payback Period) have been reflected when applied on the two individual case studies, as presented above. Solar energy being an alternative for fossil fuels and such renewable resource driven systems, where given as an option to the finance experts/decision makers of the organization, have achieved the highest rank in our present study (Case I - Ramakrishna Mission Vivekananda Centenary College, Rahara). Accordingly, if IISWBM takes initiative to install Rooftop SPV, then after adding this alternative to the case study of IISWBM, is expected to come in the top priority in the Final Judgment Matrix of AHP.

The respondents i.e. the decision makers for implementation of the Measures for Greening of Campus (MGC) were interviewed for the second time along with the result obtained from the procedure developed and applied in the present study, using the information provided by those respondents during the first meeting. Analytical Hierarchy Process (AHP) has been fruitfully employed, as a multi criteria decision making process, in the present study, to prioritize the available retrofitting options or alternatives. The initially created apparently contradictory opinions (based on single criteria) were later on replaced by the ranking performed by the final judgment matrix of AHP and also accordingly were accepted by the respondents in the second stage survey questionnaires. Almost 92% respondents (11 respondents out of 12) are satisfied with the AHP method and the ranking executed by it and thus validates the outcome. Thus, the methodology developed in the present study is also validated for its effectiveness in application in field to yield fruitful result. Therefore, the approach would help decision makers in companies, planners in governments and organizations with confidence based on actions.

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