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SUSTAINABILITY APPROACH IN GREENING BUILDINGS BY AN ADVANCED UNBIASED SCIENTIFIC TOOL

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Abstract— Energy is now an indispensible resource for any activities in our day to day life. Optimum use of energy is more and more discovered today to be the secret of technological, economic and social supremacy of any nation in general and sustainability of human civilization to be more specific. Appropriate Energy Policy for the international and national bodies is at an evolving stage as research has revealed that sustainability of any organization is directly related to optimum use of energy which is reflected in Sustainability Index. Such policies on implementation through planning and analysis of energy intensive processes and gadgets, often stalled at a point of ambiguity because of lack of scientific parameters to help in the decision making process. For example, in energy studies and energy audit, the recommendations seems to be better with respect to other on certain parameters, such as, energy saving, CO2 emission reduction, monetary saving, pay-back-period, return-on-investment, internal-rate-of-return, etc. However, different parameters often suggests different order of preference for such recommendations leading to conflicts and stalling the implementation process and thus retarding the sustainability march of the body in particular and nation as well as globe in general. The present paper also finds a scientific solution to turn the conflict into a binding force by incorporating each opinion in a Multi-Criteria Decision Making Process leading to obvious ranking of alternatives through application of tools, such as AHP and ELECTRE. The various cases also presented in the paper confirm the validity of the process in University Campus, Greening of Buildings and Industry.

Keywords— Sustainability Index; Multi-Criteria Decision Making (MCDM); ELECTRE; AHP; Greening of Buildings and Industry;

I. INTRODUCTION

Each stage of economic development in India has been accompanied by a characteristic energy transition from one major fuel source to another. Till today, fossil fuels like coal, oil and natural gas, are by far the dominant energy source in industrial economies, and the main source of energy production growth in developing economies. But today's and future century is already bearing in mind the start of the next great transition in energy sources - away from fossil fuels towards renewable energy sources. This transition is motivated by many factors, including apprehensions about environmental impacts (particularly climate change), limits on fossil fuel supplies, prices, and technological changes [1]. Moreover, a number of studies are continuously being carried out by various organizations like Indian Renewable Energy Development Agency (IREDA), Ministry of New and Renewable Energy (MNRE), The Energy and Resources Institute (TERI), National Environmental Engineering Research Institute (NEERI) etc., with the aim of further development in the field of alternative resources of energy - thus to accomplish 'greening buildings' projects more fruitfully [2].

Industrial Sustainability Index (ISI) in terms of the sustainable development philosophy helps to identify the issues that have to be addressed in order to get the industry closer to a sustainable performance. For this purpose multi criteria decision making theory was chosen as the methodology that provided the methodology to analyze in a decision tree. The main three branches were divided into economic, social, and environmental attributes. Through this index, it is possible to evaluate the economic-financial situation of an industry, as well as the well being of its workers, and its surroundings considering the environmental, economic and social systems. Hopefully the MCDM solving tools, discussed in our study will play a vital role in this transitional zone to solve these types of prioritization problems diplomatically and also to help the decision makers to select the right alternative of power generation by viewing the rankings generated at the output of the tool/algorithm used. It can be predicted also that these types of attractive MCDM tools/ algorithms will help the decision makers by resolving conflicts generated, for coming 100 years also in the area of power generation.

II. LITERATURE REVIEW

Bhatt et al (2010) used AHP approach for Criteria Ranking of Sustainable Building Assessment and made a case study of India [3]. They used AHP to investigate priority ranking for Issues-Categories-Parameters for a Sustainable Building assessment. Survey Questionnaire was circulated to get feedbacks from experts of various fields. The result of their study was useful to develop a comprehensive sustainable building assessment model India. They suggested that other countries can develop set of criteria ranking with their approach to suit their regional context for real sustainable development.

III. PROBLEM STATEMENT/ TESTING OF HYPOTHESIS

In the present study the following hypothesis has been tested:-

A. Null Hypothesis (H_0):

The different MCDM solving tools do not have unbiasedness in finding out the outcomes of rankings of different energy saving alternatives in greening buildings against,

B. Alternative Hypothesis (H_1):

The different MCDM solving tools persistently have unbiasedness in finding out the outcomes of rankings of different energy saving alternatives in greening buildings.

IV. STUDY OF ADDITIONAL GREENING BUILDING CASE STUDIES

TABLE I - FINANCIAL PARAMETERS FOR DIFFERENT ENERGY SAVING ALTERNATIVES AT IISWBM, KOLKATA [5]

S.No	Measure/ Proposal	Investment (Rs.)	Annual Savings (Rs./ Year)	Payback Period
1	Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with new meter (Rs. 6.66/kWh)	36,000	49,231	9 months
2	Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with old meter (Rs. 2.40/kWh)	36,000	17,741	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)	1,500	6,471	3 months
4	Switching off 31 TLs in Computer Lab Room No. 115	NIL	10,802.88	Immediate
5	A/C Load Management	NIL	45,176	Immediate
6	Replacing an old 2 ton A/C with new Energy Efficient one in Computer Lab	22000	3953.60	5 years 6 month

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TABLE II- FINANCIAL PARAMETERS FOR DIFFERENT ENERGY SAVING ALTERNATIVES AT NABO JIBON MC BROTHERS [4]

S.No.	Energy Saving Measures	Investment in Rs.		Annual Savings in Rs./Year	Reasons for Implementing the Measures	Payback Period	Annual Energy Savings
1	Replacement of 60 Watt incandescent lamps by 30 Watt CFL	Rs.2,600/-		Rs. 1,402/-	A 30 Watt CFL can save 50% more energy than a 60 Watt incandescent Lamp & a CFL has an average life span of 8000 hours When the incandescent lamp has an average life span of 1200 hours.	1 year 11 months	259.2 kWh
2	Replacement of conventional Tube Lights(T8) by T5	Rs.15,980/-		Rs.7,417/-	A 28 Watt T5 can save upto50% more energy than a 40 Watt conventional Tube Light (with conventional ballast of 15 Watt) & a T5 has an average life span of 35000 hours When the conventional Tube Light has an average life span of 800 hours.	2 years 2 months	1370.52 kWh
3	Replacement of conventional ceiling Fan by Super Fan	Rs.1,38,000/-		Rs.49,277/-	A 35 Watt Super Fan can save more than 50% energy than an 80 Watt Conventional Ceiling Fan.	2 years 10 months	9108 kWh
4	Installation of Rooftop Solar Photo Voltaic System(With subsidy)	a) For Standalone System	With subsidy 4,38,900/-	Rs.20,320/-	A 3.3 kW Rooftop Solar Photo Voltaic System with battery is sufficient to fulfil minimum energy requirement.	21 years 8 months	3756 kWh
			Without subsidy Rs.6,27,000/-			30 years 11 months	
		b) For Grid Connected System	With subsidy Rs. 3,64,000/-	Rs.44,575/-	A 2.7 kW Rooftop Solar Photo Voltaic System without battery is sufficient to minimize the chargeable unit consumption.	9years	
			Without subsidy Rs. 5,20,000/-			12years 10 months	
5	Installation of 1No. of 15 m3 Biogas Plants	With subsidy Rs. 57,562.50/-		Rs.60,921/-	1 No. of 15 m3 Biogas Plant will save 63 no. of LPG cylinder (approx) per year.	1year	890.6kg
		Without subsidy Rs.87,562.50/-		Rs.60,921/-		1year 6 months	
6	Rain water Harvesting	Rs. 62,756/-		Rs. 1175/-	This system will minimize the requirement of water through the pumping system & it will save 0.596 kWh energy per day.	53 years	217.54 kWh
7	Installation of Solar water heating system	a) ETC Type	With subsidy Rs. 1,40,000/-	Rs.12, 984/-	It will provide 500 liter hot water per day without using electrical energy.	10years 10 months	2400 kWh
			Without subsidy Rs.2,00,000/-			15 years 5months	
		b) FPC Type	With subsidy Rs. 1,54,000/-			11 years 11 months	
			Without subsidy Rs.2,20,000/-			17years	

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TABLE III -FINANCIAL PARAMETERS FOR DIFFERENT ENERGY SAVING ALTERNATIVES AT RKMVCC, RAHARA [6]

A further detail with analysis of the above case study would be available in the paper submitted for publication in

S.No.	Energy Saving Measures	Investment in Rs.	Annual Savings in Rs./Year	Annual Savings in kWh/Year	Payback Period
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.

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TABLE III - FINANCIAL PARAMETERS FOR DIFFERENT ENERGY SAVING ALTERNATIVES AT ISKCON, SRI MAYAPURDHAM ([7] & [8])

S. No.	Energy Saving Measures	Investment in Rs.	Annual Savings in Rs. /Year	Payback Period (Yrs.)
1.	Assessment of the Potential of Biomass based Cogeneration	15501750	5304562.50	2.92
2.	Potential of Rooftop Solar System	139500000	13332747	7.33
3.	Sintex Floating Type Biogas Plant in Gada Kitchen	60000	20732	2.92
4.	34 Nos. 400 W Street Lights replaced with 33 Nos. 55 W LED	479902	361328.10	1.33

V. RESULTS & DISCUSSIONS

A. Application of 'ELECTRE' method in the Case Study of Indian Institute of Social Welfare & Business Management (IISWBM), Kolkata

Here, we consider four alternatives and three criteria for each of the four alternatives.

Alternatives:

A1: Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with New Meter.
A2: Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with Old Meter
A3: Replacement of 10 nos. TL/60 W bulb with 11/14W CFL &
A4: Replacing an old 2 ton A/C with new Energy Efficient one in Computer Lab.

Criterions:

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

The alternatives under sl. no. 4 and 5 (Table I), come in the top priority without applying any MCDM scientific tool, because without any investment, annual savings are incurred, also along with an immediate payback period. Now, in order to find out the rankings of remaining four alternatives 'ELECTRE' method is to be applied in the present study.

TABLE V - PAIR WISE COMPARISONS MATRIX FOR IISWBM (PREPARED FROM THE RESPONSES IN THE QUESTIONNAIRES)

Criteria	Investment in Rs.	Annual Savings in Rs./Year	Payback Period (Yrs.)
Investment in Rs.	1.00	1.17	0.75
Annual savings in Rs./Year	0.86	1.00	2.00
Payback Period (Yrs.)	1.33	0.50	1.00

TABLE VI - FINDING OUT THE CONSISTENCY RATIO FROM THE RESPONSES FOR IISWBM

Weights (w) or Priority Vector	Consistency Measure	Ratios (Consistency Vector)	λmax	Consistency Index (CI)	Consistency Ratio (CR) = CI / RI
0.302	0.948	3.145	3.034	0.017	0.02
0.377	0.948	2.513			
0.275	0.948	3.443			

The consistency ratio (C. R.) calculated for the financial parameter, i.e. C.R. obtained in above table (Table VI), is less than 0.1, indicating sufficient consistency. Therefore the experimental result is validated for application of the scientific tool 'ELECTRE', for prioritization among the energy saving alternatives.

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TABLE VII - DECISION MATRIX FOR IISWBM, KOLKATA

Criteria / Alternatives	Investment in Rs.	Annual savings in Rs./Year	Payback Period (Yrs.)
Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with new meter (Rs. 6.66/kWh)	36,000	49,231	0.75
Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with old meter (Rs. 2.40/kWh)	36,000	17,741	2
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)	1,500	6,471	0.25
Replacing an old 2 ton A/C with new Energy Efficient one in Computer Lab	22,000	3,953.60	5.5

TABLE VIII - NORMALIZED DECISION MATRIX FOR IISWBM, KOLKATA

Criteria / Alternatives	Investment in Rs.	Annual Savings in Rs./Year	Payback Period (Yrs.)
A1: Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with new meter (Rs. 6.66/kWh)	0.6489	0.9311	0.1258
A2: Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with old meter (Rs. 2.40/kWh)	0.6489	0.3355	0.3355
A3: 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)	0.0270	0.1224	0.0386
A4: Replacing an old 2 ton A/C with new Energy Efficient one in Computer Lab	0.3965	0.0748	0.9328

TABLE IX - WEIGHTED NORMALIZED MATRIX FOR IISWBM, KOLKATA

Criteria / Alternatives	Investment in Rs. [0.302]	Annual Savings in Rs./Year [0.377]	Payback Period (Yrs.) [0.275]
A1: Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with new meter (Rs. 6.66/kWh)	0.196	0.351	0.035
A2: Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with old meter (Rs. 2.40/kWh)	0.196	0.126	0.092
A3: 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)	0.008	0.046	0.011
A4: Replacing an old 2 ton A/C with new Energy Efficient one in Computer Lab	0.120	0.028	0.257

TABLE X -FORMATION OF CONCORDANCE SET FOR IISWBM, KOLKATA

Alt. / Alt.	A1	A2	A3	A4
A1	0	0.679	1	0.679
A2	0.577	0	1	0.679
A3	0	0	0	0.377
A4	0.275	0.275	0.577	0
Sum	0.852	0.954	2.577	1.735

TABLE XI - FORMATION OF CONCORDANCE DOMINANCE MATRIX FOR IISWBM, KOLKATA

Alt. / Alt.	A1	A2	A3	A4
A1	0	1	1	1
A2	0	0	1	1
A3	0	0	0	0
A4	0	0	0	0

TABLE XII - FORMATION OF DISCORDANCE SET FOR IISWBM, KOLKATA

Alt. / Alt.	A1	A2	A3	A4
A1	0	0.258	0	0.687
A2	1	0	0	1
A3	1	1	0	1
A4	1	0.598	0.073	0
Sum	3.000	1.856	0.073	2.687

C Bar = (0.852+0.954+2.577+1.735) /10 = 6.118 / 10 = 0.6118~ 0.612 (since, there are 10 numbers in the above matrix, except '0')

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D Bar = (3.000+1.856+0.073+2.687) /10 = 7.617 / 10 = 0.7617~ 0.762 (since, there are 10 numbers in the above matrix, except '0')

TABLE XIII – FORMATION OF DISCORDANCE DOMINANCE MATRIX FOR IISWBM, KOLKATA

Alt. / Alt.	A1	A2	A3	A4
A1	1	1	1	1
A2	0	1	1	0
A3	0	0	1	0
A4	0	1	1	1

TABLE XIV- AGGREGATION OF CONCORDANCE AND DISCORDANCE DOMINANCE MATRIX FOR IISWBM, KOLKATA

Alt. / Alt.	A1	A2	A3	A4
A1	0	1	1	1
A2	0	0	1	0
A3	0	0	0	0
A4	0	0	0	0

The rankings of the energy saving alternatives depend on the total number of '0'-s appeared in the respective columns in the 'aggregation of concordance and discordance dominance matrix'. Now, since the alternative 'A1' has all '0' values throughout its column, it is the best alternative, followed by the alternatives, 'A2' = 'A4' (single '1' value) and lastly followed by the alternative 'A3' (two '1' values). Thus, A1 > A2 = A4 > A3. Therefore, the alternative 'Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with new meter (Rs. 6.66/kWh)' has secured the top position followed by the alternatives, 'Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with old meter (Rs. 2.40/kWh)' = 'Replacing an old 2 ton A/C with new Energy Efficient one in Computer Lab' and '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)' respectively. Now the comparative table of solving the MCDM problem in order to rank the alternatives by 'AHP' and 'ELECTRE' is given below:

TABLE XV- COMPARATIVE TABLE SHOWING FINAL RANKINGS OF ALTERNATIVES USING 'AHP' AND 'ELECTRE' FOR IISWBM, KOLKATA

Alternatives	Final Rankings obtained from 'AHP' [10]	Final Ranking obtained from 'ELECTRE'
A1: Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with new meter (Rs. 6.66/kWh)	1st	1st
A2: Replacing Magnetic Choke with Electronic Choke of 200 TLs connected with old meter (Rs. 2.40/kWh)	3rd	2nd
A3: 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)	4th	3rd
A4: Replacing an old 2 ton A/C with new Energy Efficient one in Computer Lab	2nd	2nd

The rankings of the alternatives 'A1' and 'A4' remain unaltered for both the MCDM solving methods, 'AHP' and 'ELECTRE'. The 3rd position held by the alternative 'A2' in 'AHP' has been ranked 2nd in the 'ELECTRE' method. Finally, the alternative 'A3' holds the last position in both the methods of ranking (4th position in the 'AHP' and 3rd position in the 'ELECTRE' respectively).

B. Application of 'ELECTRE' method in the Case Study of Ramakrishna Mission Vivekananda Centenary College (RKMVCC), Rahara

TABLE XVI - COMPARATIVE TABLE SHOWING FINAL RANKINGS OF ALTERNATIVES USING 'AHP' AND 'ELECTRE' FOR RKMVCC, RAHARA

Alternatives	Final Rankings obtained from 'AHP' [9]	Final Rankings obtained from 'ELECTRE'
A1: T12 (40 W) is Replaced with LEDs (20 W) (Philips)	4th	3rd
A2: T12 (40 W) is Replaced with CFLs (30 W)	6th	4th
A3: T12 (40 W) is Replaced with T5 (33 W)	5th	5th
A4: Ordinary Fan (75 W) is replaced with BEE Star Rated Fan (55 W)	3rd	3rd
A5: Ordinary Fan (75 W) is replaced with Super Fan (35 W)	2nd	2nd
A6: 30 kW rooftop SPV	1st	1st

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Here, the alternatives can be arranged in the descending order depending on the generation of '0'-s in respective columns, i.e., A6 > A5 > A1 = A4 > A2 > A3. Thus, alternative '30 kW Rooftop Solar Photo Voltaic at Centenary College' has secured the top position followed by the alternatives, 'Ordinary Fan (75 W) is replaced with Super Fan (35 W)', 'T12 (40W Tube) is replaced with LEDs (20 W) (Philips)' = 'Ordinary Fan (75 W) is replaced with BEE Star Rated Fan (55 W)', 'T12 (40W Tube) is replaced with CFLs (30 W)' and 'T12 (40W Tube) is replaced with T5 (33 W)' respectively. Thus, the 1st, 2nd, 3rd and 5th rank occupied by the alternatives in both the methods, 'AHP' and 'ELECTRE', remains unchanged, which in turn establishes the more unbiasedness of the MCDM solving tools.

C. Application of 'ELECTRE' method in the Case Study of International Society for Krishna Consciousness (ISKCON), Sri Mayapurdham

TABLE XVII - COMPARATIVE TABLE SHOWING FINAL RANKINGS OF ALTERNATIVES USING 'AHP' AND 'ELECTRE' FOR ISKCON, SRI MAYAPURDHAM

Alternatives	Final Rankings obtained from 'AHP' (Majumdar, Choudhury, 2017)	Final Rankings obtained from 'ELECTRE'
A1: Assessment of the Potential of Biomass based Cogeneration	2nd	2nd
A2: Potential of Roof Top Solar System	1st	1st
A3: Sintex Floating Type Biogas Plant in Gada Kitchen	3rd	3rd
A4: 34 Nos. 400 W Street Lights replaced with 33 Nos. 55 W LED	4th	

In this case study, the alternative 'A2' i.e. 'Potential of Roof Top Solar System' has held the top position (1st) in both the solution techniques – 'AHP' & 'ELECTRE', 2nd position/ rank has been occupied by the alternative 'A1' i.e. 'Assessment of the Potential of Biomass based Cogeneration' by both the techniques and finally the last rank (3rd) in 'ELECTRE', which has been occupied by the alternative 'A3' & 'A4'simultaneously, has been also ranked 3rd in the method 'AHP' for the alternative 'A3' i.e. 'Sintex Floating Type Biogas Plant in Gada Kitchen'. Thus, the relative positions of the outcomes generated by the methods 'AHP' and 'ELECTRE' establishes the reliability among the MCDM solving tools for their unbiased outcomes of rankings.

Another application is to use this tool for identification of industrial ranking. This prioritize options will help corporate to become aware of their energy usages and encourage corporations to be ethically responsible. The result will also aim to help corporate to assess and improve energy usages, as well as, to inform policymaker's and analysts about the status of energy conditions. It is expected that corporate will be directly benefited by assessing their sustainability for long term interest of business and to track their progress towards nationally defined sustainable development goals. This scientific model would be designed to estimate sustainable energy usages and to represent an integrated approach to energy and policy analysis at the national level. It is also expected that the outcome of the research will also be used as an important instrument for energy planning and decision making.

VI. CONCLUSIONS

In our present study, by applying the 'ELECTRE' method for three different 'greening building' case studies, it has been proved, viewing the comparative tables of the case studies discussed, that the MCDM solution techniques have unbiased outcomes of prioritization of alternatives. This consecutively reveals our present study to violate the null hypothesis (H_0) and accept the alternative hypothesis (H_1). However, this conclusion can be more definitely conveyed by performing the comparative techniques discussed in the present study on more number of greening building case studies and viewing the outputs generated for those cases, applying the methods/ techniques discussed. It is further a situation to draw the interest of readers that, rooftop solar photovoltaic, wherever applied, has ranked the alternative in top position as discussed in our present study in the cases of RKMVCC, Rahara and ISKCON, Sri Mayapurdham. Thus the unbiasedness of the scientific MCDM tools presented here has reflected the current market situation in way of greening the existing buildings.

VII. THE WAY FORWARD

In future, we can continue our same study with the other MCDM solving tools like ANP (Analytic Network Process), TOPSIS (Technique for Order Preference by Similarly to Ideal Solution), Fuzzy AHP and PROMETHEE, in order to compare the outputs generated by 'AHP' and 'ELECTRE' with the rankings of the same energy alternatives, that will be generated by the application of the above mentioned new techniques. Moreover, we can also apply our already established MCDM tools 'AHP' and 'ELECTRE' in a wide range of MCDM problems in the field of Energy Management to increase the efficiency in consumption in buildings and also in the field of electricity generation in Thermal Power Plants, Hydel Power Plants and Nuclear Power Plants etc. to save our natural energy resources.

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