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Energy Audit and Renewable Energy System Modelling

K. Balachander and A. Amudha

Department of EEE, Karpagam University, Coimbatore, India

Abstract: This paper deals with managing lighting load and optimal cost analysis of Hybrid Renewable Energy System (HRES) in Karpagam University (KU) Middle block, Karpagam University, Coimbatore, India. It is an intensive attempt in achieving improved energy performances. This study aims to highlight several opportunities to create and implement an energy management plan within KU Middle Block. The audit was conducted and suitable- strategies of adjusting and optimizing energy were suggested so as to reduce energy requirements and hence, the total cost spent towards energy consumption and recommends suitable- Renewable Energy System (RES) model. In this paper work, real time optimal cost analysis of HRES is done based on the load profile, solar radiation and wind speed which were collected from KU Middle Block, Coimbatore, India. Hybrid Optimization Model for Electric Renewable model (HOMER) is used here to optimize the system based upon the Total Net Present Cost (TNPC). Moreover, the optimization of system is obtained by varying the sensitivity variables like solar radiation, wind speed etc. Cash flow summary of the HRES system is obtained which will be useful for the optimal cost allocation of each individual component present in the system.

Key words: Energy Audit · Energy Conservation · Hybrid System · Optimization

INTRODUCTION

The present electricity consumption in the commercial buildings sector in India is about 8-10% of the total electricity. The electricity demand in commercial buildings is growing annually by 11-12% due to demands for providing international level comforts and facilities. This presents a challenge to ensure that energy growth in commercial building does not become unmanageable, but at the same time, also presents an opportunity to influence and address energy management issues in various commercial buildings and facilities. In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), materials and labour. Among these costs, energy cost invariantly emerges as a top ranker [1].

Present Energy Scenario in Ku Um Block: There are 42 Lecture Hall, 17 Labs, 1 Exam Cell, 3 Dean Office, 14 Staff Rooms. Location wise and Load wise power consumption details shown in Figure 1. The total lighting load from the above is 15 kW and the connected fan load is 24.57 kW.

Table 1: Present Energy Scenario in KU Middle Block

	Light (40W)		Fan (70W)		Computers				Printer (600W)		Water Doctor (150W)	
	No. of Load	Working Hrs.	No. of Load	Working Hrs.	CRT (65W)	Working Hrs.	LCD (18W)	Working Hrs.	No. of Load	Working Hrs.	No. of Load	Working Hrs.
Corridor	90	3										
Dean Office	9	6	5	6			4	5	3	3		
Exam Cell	5	6	5	6			2	5	1	3	3	20
Labs	83	4	94	6			246	6	5	3		
Lect. Hall	194	3	194	8					0			
Staff Room	71	3	68	5	28	4	6	4	17			
Toilet	14	3							0			
Grand Total	466		366		28		258		26		3	
Total Watts consumed [Inst.]	18640		25620		1820		4644		15600		450	

Corresponding Author: K. Balachander, Department of EEE, Karpagam University, Coimbatore, India.

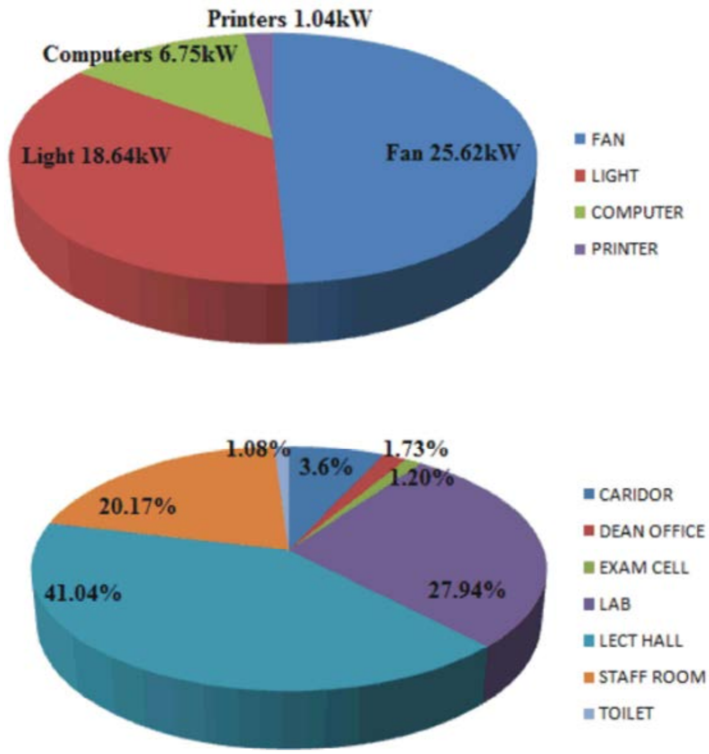

Fig. 1: Location wise Power Consumption

As the chart suggests, major lighting load consuming areas are lecture halls (41.04%).

Connected Load Details:

Total connected Fluorescent Lamp (40W)	= 466x40
	= 18.64kW
Total fan connected (70W)	= 366 x 70
	= 25.62kW
Total Computer Load (CRT Monitor 65W)	=28x 65
	= 1.82kW
Total Computer Load (LCD Monitor 18W)	=258x18
	= 4.64kW
UPS Load	= 40kVA
Rectifier Load	= 20kVA

Recorded Energy Details:

Total energy consumed in UM Block	= 120 Units/Day
Energy consumed for Lab Load	= 280 Units/Day
Maximum demand reached	= 17 kW
Power factor recorded	= 0.95

Recommendations for Better Energy Efficiency: Based on the recorded data the energy efficient measures are suggested in KU Middle Block Lighting Loads.

Fluorescent Lamp

Table 2: Fluorescent Lamp - 40W/36Lumens (Existing)

Hall	No. of Load (Nos.)	Approximate total running Hours	Total energy consumption per day (W)	Total Units Consumption per day (kWhr)
Dean Office	9	6	2,160	2.16
Exam Cell	5	6	1,200	1.2
Staff room (FT)	71	3	8,520	8.52
Staff room (PT)	35	1	1,400	1.4
Lecture Hall (FT)	194	3	23,280	23.28
Lecture Hall (PT)	120	3	14,400	14.4
Lab (FT)	83	4	13,280	13.28
Lab (PT)	25	3	3,000	3
Corridor	90	3	10,800	10.8
Toilet	14	3	1,680	1.68
Total	646		79,720	79. 72 ~ 80

Table 3: Proposed Lignting1: Compact Fluorescent Lamps - 18Watts/85Lumens (Excluding PT Lecture Hall)

Hall	No. of Load (Nos.)	Approximate total running Hours	Total energy consumption per day (W)	Total Units Consumption per day
Dean Office	9	6	972	0.972
Exam Cell	5	6	540	0.54
Staff room (FT)	71	3	3,834	3.834
Staff room (PT)	35	1	630	0.63
Lecture Hall (FT)	194	3	10,476	10.476
Lab (FT)	83	4	5,976	5.976
Lab (PT)	25	3	1,350	1.35
Corridor	90	3	4,860	4.86
Toilet	14	3	756	0.756
Total	526		29,394	29.394 ~ 29

Savings/day = 80 – 29 = 51 Units.
Cost of one unit – HT – Rs. 5.50
Saving per day (51 x Rs. 5.50) = Rs. 280.50
Saving per month (51 x 5.50 x 30) = Rs. 8415/-
Cost of CFL lamp – Rs. 161/-

Total amount required – 466 X 161 = 75,026/-
Approximate Resale value of old Fluorescent Lamps and fittings – 466 x 40 = 18, 640/- Balance cost required (75, 026 – 18, 640) = Rs. 56, 386/-
Payback period for this amount: 6½ Months.

Table 4: Proposed Lighting2: LED- 8W/800Lumens (including PT Load)

Hall	No. of Load (Nos.)	Approximate total running Hours	Total energy consumption per day (W)	Total Units Consumption per day
Dean Office	9	6	432	0.43
Exam Cell	5	6	240	0.24
Staff room (FT)	71	3	1,704	1.70
Staff room (PT)	35	1	280	0.28
Lecture Hall (FT)	194	3	4,656	4.66
Lecture Hall (PT)	120	3	2,880	2.88
Lab (FT)	83	4	2,656	2.66
Lab (PT)	25	3	600	0.60
Corridor	90	3	2,160	2.16
Toilet	14	3	336	0.34
Total	646	35	15,944	15.94 ~ 16

Savings/day = 80-16 = 64 Units.
Cost of one unit – HT – Rs. 5.50
Saving per day in rupees (64 x Rs. 5.50) = Rs. 352/-
Saving per month (64 x 5.50 x 30) = Rs. 10,560/-
Cost of LED Lamp – Rs. 600/-
Total amount required – 466 X 600 = 2, 79, 600/-
Approximate Resale value of old Fluorescent Lamps and fittings - 466 x 40 = Rs. 18, 640/-

Balance cost required (2, 79, 600 – 18, 640) = Rs. 2, 60,960/-
Payback period for this amount: 2 Years.

Ceiling Fan with Resistance Regulator– 60W (Existing):

Table 5: Ceiling Fan with Resistance Regulator– 60W (Existing)

Hall	No. of Load (Nos.)	Approximate total running Hours	Total energy consumption per day (W)	Total Units Consumption per day
Dean Office	5	6	1,800	1.8
Exam Cell	5	6	1,800	1.8
Lab (FT)	94	6	33,840	33.84
Lab (PT)	25	3	4,500	4.5
Lect. Hall (FT)	194	8	93,120	93.12
Lect. Hall PT)	96	3	17,280	17.28
Staff Room (FT)	68	5	20,400	20.4
Staff Room (PT)	20	1	1,200	1.2
Grand Total	507		1,73,940	173.94 ~ 174

Table 6: Proposed - Super Fan Model A1/35W

Hall	No. of Load (Nos.)	Approximate total running Hours	Total energy consumption per day (W)	Total Units Consumption per day
Dean Office	5	6	1050	1.05
Exam Cell	5	6	1050	1.05
Lab (FT)	94	6	19740	19.74
Lab (PT)	25	3	2625	2.625
Lect. Hall (FT)	194	8	54320	54.32
Lect. Hall PT)	96	3	10080	10.08
Staff Room (FT)	68	5	11900	11.9
Staff Room (PT)	20	1	700	0.7
Grand Total	507	38	101465	101.47 ~ 102

Savings/day = 168-102 = 66Units.
Cost of one unit – HT – Rs. 5.50
Saving per day in rupees (66 x Rs. 5.50) = Rs. 363/-
Saving per month (66 x 5.50 x 30) = Rs.10, 890/-
Cost of Super Fan – Rs. 2500/-

Total amount required – 366 X 2500 = Rs. 9, 15, 000/-
Approximate Resale value of old Fan (@ Rs. 250/-) – 366 x 250= 91, 500/-
Balance cost required (9, 15, 000 – 91, 500) = Rs. 8, 23, 500/-
Payback period for this amount: 6½ Years[2-20].

Computers
System with CRT Monitor 15inch - 65W (Excising):

Table 7: System with CRT Monitor 15inch - 65W (excising)

Hall	No. of Load (Nos.)	Approximate total running Hours	Total energy consumption per day (W)	Total Units Consumption per day
Staff room (FT)	28	4	7280	7.28

System with LCD Monitor 15inch - 18W (Proposed):

Table 8: System with LCD Monitor 15inch - 18W (proposed)

Hall	No. of Load (Nos.)	Approximate total running Hours	Total energy consumption per day (W)	Total Units Consumption per day
Staff room (FT)	28	4	2016	2.07

Savings/day = 7.28 – 2.07 = 5.21 Units.
Cost of one unit – HT – Rs. 5.50
Saving per day in rupees (5.21 x Rs. 5.50) = Rs. 29/-
Cost of LCD Monitor - Rs. 3000/-
Total amount required – 28 X 2500 = Rs. 70, 000/-
Approximate Resale value of old CRT Monitor (@ Rs. 300/-) – 28 x 300= 8,400/-
Balance cost required (70, 000 – 8, 400) = Rs. 61, 600/-
Payback period for this amount: 6 Years

Use of Motion Sensors in Corridors and Toilets: Energy can be saved in large potential by the use of automation tools in corridors and toilets. Motion sensors can be used there to automatically switch on the light when there is any movement and switch off the light when there is no movement. This can greatly reduce the total load in corridors and toilets.

Cost Analysis of Installing Motion Sensors in Corridor:
Average number of tube lights in a corridor = 15/floor
Average power of the tube lights = 40W
Average number of motion sensors required = 3
Average reduction in usage per day by motion sensor = 2h
Total energy saved in corridor per year = (90 x 40 x 2 x 365)/1000 = 2628kWh
Saving in Rs. Per year = 2628 x 5.50 = Rs. 14454/-
Cost of installation per motion sensor = Rs. 250/-
Total cost of installing motion sensors in a corridor = 3 x 250 x 6 = Rs. 4500/-
Capital Cost Recovery Time = (4500/14454) = 3 Months.

Hence, the capital cost recovery time for installing motion sensors in corridors is 3 months. Corridors also have comparable capital cost recovery time. Hence, this is a highly recommended step to largely reduce the consumption in corridors[21-30].

Cost Analysis of Installing Motion Sensors in Toilets:
Total number of tube lights in Toilets (6 floors) = 14
Average power of the tube lights = 40W
Average number of motion sensors required = 6
Average reduction in usage per day by motion sensor = 2h
Total energy saved in corridor per year = (14 x 40 x 2 x 365)/1000 = 409kWh
Saving in Rs. per year = 409 x 5.50 = Rs. 2250/-
Cost of installation per motion sensor = Rs. 250/-
Total cost of installing motion sensors in a corridor = 6 x 250 = Rs. 1500/-
Capital Cost Recovery Time = (1500/2250) = 8 Months.

Use of Master Switch Outside Each Room: Installation of a master switch outside the room can make it easy for a person to switch off all the appliances of a room in case someone forgets to switch off while leaving the room. This can help improving energy efficiency.

Table 9: Solar and Wind data of KU

Month	Solar Insolation (kWh/m^2/day)	Wind Velocity (m/s)
January	5.68	3.69
February	6.24	3.52
March	6.66	3.74
April	6.12	3.89
May	5.49	4.48
June	4.04	5.96
July	4.25	5.59
August	4.72	5.34
September	5.36	4.44
October	4.85	3.57
November	4.92	3.3
December	5.22	4.04
Average	5.296	4.297

Implimentation of Homer for Ku Um Block Load: The availability of renewable energy resources at Karpagam University, Coimbatore is the main factor to develop the hybrid system. Many places in India Solar energy and Wind energy are abundantly accessible. The renewable energy sources are discontinuous and naturally available. Weather data are important factor for pre- feasibility study of renewable hybrid energy system for any site. Here the Wind and Solar energy resources data are taken from NASA shown in Table 9. The daily solar radiation in KU UM Block varies from 4.04 to 6.66 kWh/m^{2}Day. The average wind speed is 4.297 m/s and scaled annual average wind speed is 3 m/s.

Hybrid Energy System Components and Cost Assessment: The proposed hybrid system consists of Photovoltaic, Wind turbine, DG Set and battery storage. Specifications and cost of the system is shown in Table 10. The project life time is estimated 25 years and annual fixed interest is fixed at 8%.

Location and Load: The site of the proposed hybrid renewable electric system is Karpagam University Middle Block, Karpagam University, Coimbatore (Latitude 10° 92' N, Longitude 76°98' E). The lighting load profile (8am to 6am) was taken in KU Middle block Lecture halls, Labs, Dean office, corridor, toilets and part time class load (6pm to 9pm) 24kWh/day, 4.3kW peak and average hourly load profile was used in this study shown in Fig. 3.

Hybrid System Design: Considering the solar and wind resources available at this location, the proposed hybrid system will be based on the combination of PV

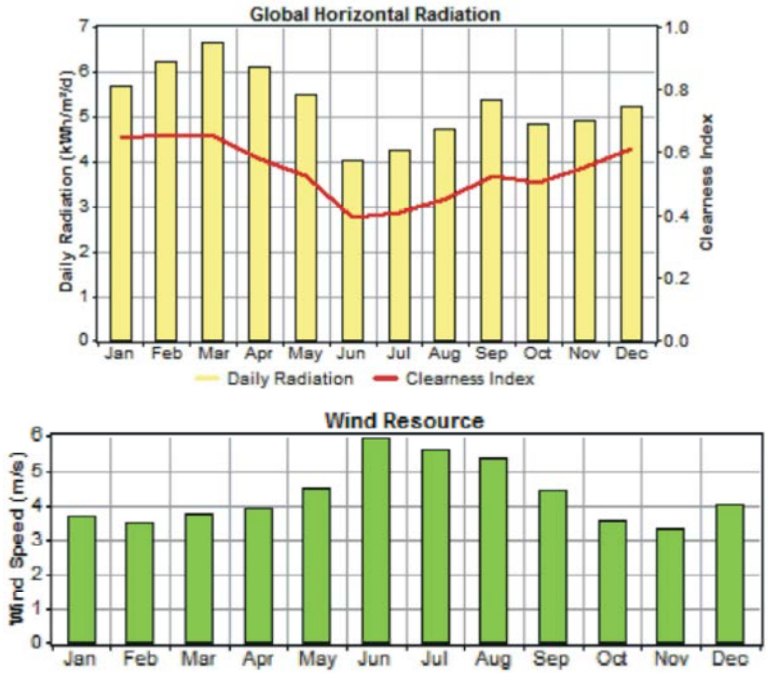

Fig. 2: Solar Radiation and Wind Resource

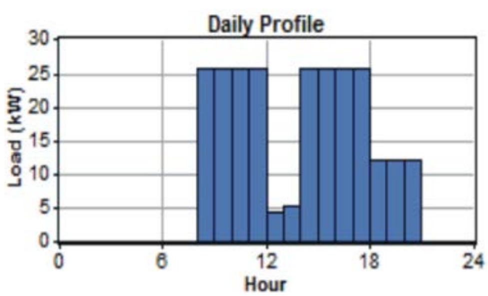

Fig. 3: Hourly Load Profile of KU UM Block

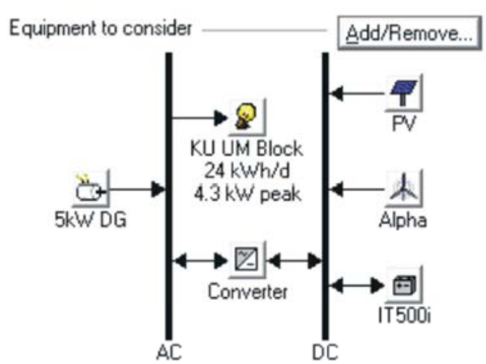

Fig. 4: Schematic of the proposed system

panels, wind turbines, diesel generators and storage batteries. Figure 5 shows the HOMER schematic diagram of the system showing all possible components. The final system configuration is decided after performing the optimization.

Hybrid System Control Parameters and Constraints: For the forecasted demand, load is dispatched by optimizing the use of RES using HOMER model. Two cases are considered to apply HOMER model. Case (i) To dispatch power to meet our fore casted demand. (ii) To dispatch power with 5% shortage in supply of demand forecasted.

Optimization Results

100% Capacity (Maximum Capacity Shortage 0%): Under this scenario, 100% annual load requirements are supplied. According to the sensitivity results, PV, DG with battery storage appears as the optimal configuration. Fig. 6 shows the categorized list of the most feasible system. Maximum capacity shortage 5%:

Under this scenario, 5% of annual capacity shortage can be allowed. Fig. 7 shows the feasible configuration ranking of the system.

Simulation Results: The simulation results for hybrid systems are presented below. Table 11 shows the optimum hybrid system components consisting of PV modules, Battery and Converter to meet the load demand for two scenarios. The cost of energy for proposed hybrid renewable energy system is found to be is 15.67 INR for case i and 13.85 INR for case ii. The annual electric energy production and energy consumption is tabulated in Table 12 [31-36].

Wind Speed (m/s) 3 | Diesel Price ($/L) 0.7 | Max. Annual Capacity Shortage (%) 0

Double click on a system below for simulation results. ◉ Categorized

PV (kW)	ALP	Dsl (kW)	IT500i	Conv. (kW)	Disp. Strgy	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Diesel (L)	Dsl (hrs)
8		5	4	4	LF	$ 19,880	252	$ 22,569	0.241	0.98	0.00	158	200
10			8	4	CC	$ 21,360	229	$ 23,805	0.255	1.00	0.00		
8	1	5	4	4	LF	$ 23,780	438	$ 28,458	0.304	0.98	0.00	146	184
10	1		8	4	CC	$ 25,260	426	$ 29,812	0.319	1.00	0.00		
		5	4	2	CC	$ 9,180	3,111	$ 42,391	0.453	0.00	0.00	3,565	2,631
10		5		4	CC	$ 21,600	2,044	$ 43,424	0.464	0.80	0.00	2,125	2,676
	1	5	4	2	CC	$ 13,080	3,296	$ 48,269	0.516	0.01	0.00	3,546	2,636
10	1	5		4	CC	$ 25,500	2,239	$ 49,406	0.528	0.80	0.00	2,122	2,674
		5			CC	$ 8,000	4,041	$ 51,140	0.547	0.00	0.00	4,383	4,745
	1	5		2	CC	$ 12,200	4,257	$ 57,639	0.616	0.01	0.00	4,376	4,745

Fig. 5: Optimization results for feasible configuration (0% capacity shortage)

Wind Speed (m/s) 3 | Diesel Price ($/L) 0.7 | Max. Annual Capacity Shortage (%) 5

Double click on a system below for simulation results. ◉ Categorized

PV (kW)	ALP	Dsl (kW)	IT500i	Conv. (kW)	Disp. Strgy	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Diesel (L)	Dsl (hrs)
8			4	4	CC	$ 17,880	137	$ 19,347	0.213	1.00	0.04		
8		5	4	4	LF	$ 19,880	252	$ 22,569	0.241	0.98	0.00	158	200
8	1		4	4	CC	$ 21,780	335	$ 25,354	0.279	1.00	0.04		
8	1	5	4	4	LF	$ 23,780	438	$ 28,458	0.304	0.98	0.00	146	184
		5	4	2	CC	$ 9,180	3,111	$ 42,391	0.453	0.00	0.00	3,565	2,631
10		5		4	CC	$ 21,600	2,044	$ 43,424	0.464	0.80	0.00	2,125	2,676
	1	5	4	2	CC	$ 13,080	3,296	$ 48,269	0.516	0.01	0.00	3,546	2,636
10	1	5		4	CC	$ 25,500	2,239	$ 49,406	0.528	0.80	0.00	2,122	2,674
		5			CC	$ 8,000	4,041	$ 51,140	0.547	0.00	0.00	4,383	4,745
	1	5		2	CC	$ 12,200	4,257	$ 57,639	0.616	0.01	0.00	4,376	4,745

Fig. 6: Optimization Table- for feasible configuration (5% capacity shortage)

Table 10: RES Components and Cost

Component	Specification		Cost
PV Cell	Output Current	DC	
	Rated power	1KW DC	Rs. 84,500/-
	De rating factor	90%	
	Slope	12.85°	
	Life time	25Years	
Wind Turbine System	Make: Alpha		
	Rated power	2.7kW DC	Rs.2,53,500/-
	Hub height	20m	
	Life time	15Years	
Diesel Generator	Make: Honda		
	Rated power	5 kW AC	Rs. 1,30,000/-
	Life time	15000(Operating Hrs.)	
	Fuel	Diesel	
	Minimum Load Ratio	30%	
	Diesel Price		Rs. 45.50
Battery	Make: Exide IT500i		
	Nominal capacity	1505Ah	Rs. 14,300/-
	Nominal voltage	12V	
	Batteries per string	1 (6V Bus)	
	Max. Charge rate	1 A/Ah	
	Max. charge current	67.5 A	
	Life time throughput	31,730 kWh	
	Float life	12Years	
Converter	Life time	20 Years	Rs. 9,750/-
	Efficiency	90%	

Table 11: Optimal Cost Table

Model	PV (kW)	ALP 2.7kW (Nos.)	Dsl-Gen (kW)	IT500i	Converter (kW)	Initial Capital (INR)	Operating Cost (INR/Year)	COE (INR/kWh)
I (100% capacity)	8	-	5	4	4	12,92,200	16,380	15.67
II (5% annual capacity shortage)	8	-	-	4	4	11,62,200	8,905	13.85

Table 12: Simulation Results

Case i		Case ii	
Production		Production	
PV Array (kWh/Yr)	13,340	PV Array	13,340
5kW DG (kWh/Yr)	314	Total	13,340
Total	13,654	%	100
%	100		
Consumption	Consumption		
AC Primary Load (kWh/yr)	8,760	AC Primary Load (kWh/yr)	8,496
Excess Electricity (kWh/yr)	3,238	Excess Electricity (kWh/yr)	3,196
Unmet electric load (kWh/yr)	0.0000209	Unmet electric load (kWh/yr)	264
Capacity Shortage (%)	0	Capacity Shortage (%)	5
Renewable fraction	.977	Renewable fraction	1

CONCLUSION

In present scenario the energy conservation plays an important role. It is because consumption of energy is increasing day by day and the generation is not matching with it. The energy conservation helps in reducing the energy consumption and provides the savings, by adaptingproper measures as suggested in the paper. It is also reported that the audit was aimed at conservation of energy in one of the blocks of Karpagam University and also the optimized RES were presented. This study indicates that for the selected location, the most feasible system consists of 8kW PV, 5kW DG Set and battery storage if no capacity shortage is demanded.

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