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Research Article

Energy Audit of a Residential Building to Reduce Energy Cost and Carbon Footprint for Sustainable Development with Renewable Energy Sources

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Electricity is a crucial part of our everyday lives. A limited number of resources can be utilized to generate power; hence, one must save these resources or electricity for future utilization. This is only possible by using energy most efficiently. For sustainable development and energy conservation, energy auditing plays an indispensable role. The energy audit is an extensive study that helps to identify energy use among different services and provides opportunities for energy conservation. The literature showed various energy audits conducted at various locations with its analysis. Few were shown that the appliances are responsible for high energy consumption, and few talked about the cost analysis with energy-saving methodologies. This work is proposed to combine the integration of renewable energy sources in a building and the cost-saving due to energy-efficient appliances. This paper tries to observe, infer, and analyze the patterns of energy usage of a residential complex and various measures to reduce energy consumption and cost-saving. A case study is included to analyze the reduction in consumption of energy per unit to make the building energy efficient. A feasibility study is executed to observe the increments in costs. Calculations for auditing will reduce the building's carbon footprint and benefit residents in the form of cost savings in the long run.

1. Introduction

In the residential segment across India, the present electricity consumption is about 25% of the total electricity consumption according to data published (2018-19). The electricity demand in residential buildings is at a simple annual growth rate of 10–14%. This is because of the increasing population economic and technological developments. To ensure that energy usage does not become unmanageable, which now poses a present-day challenge, the issue also provides an opportunity to address and resolve energy management problems in different areas. Energy auditing is efficiently done for energy conservation. The various steps involved are performed by inspecting, surveying, and analyzing energy flow in a building, framework, or system. The result has increased based on analyzing the energy consumption of Two-story buildings in France. In an academic institution located in Nigeria, a study was conducted to project energy consumption on various time scales such as daily, weekly, and annual. It was concluded that HVAC (heating, ventilation, and air conditioning appliances) and gadgets driven by electrical motors consumed 36% and 61.9% of the total energy supplied [1].

The electrical energy consumption at Airport, in Egypt, was analyzed by considering various indoor parameters such as temperature, illuminance, and relative humidity. It was shown that there was a 24.5% reduction in total energy consumption by increasing the air cooler temperature by 2°C

[2]. The energy audit process-based case study in Australia identified the main factors of energy consumption as design, physical conditions, and social-economic buildings' status [3]. In the energy audit carried out in Italy, energy efficiency measures have been selected for identifying the retrofit interventions in the renovation stage of a building. This study and analysis were carried out in a detailed manner with simulation studies and cost analysis. It was observed that the output was not meeting the nZEB (net-zero energy building) criteria; hence, the inclusion of renewable sources has been done with additional cost [4].

Energy auditing can help an individual or a group to identify areas where the amount of energy input into the system can be reduced without adversely affecting the output. The crucial step in energy auditing is identifying opportunities to reduce carbon footprints and energy costs in commercial and industrial real estate applications. An energy audit examines how much energy a household consumes and then develops a method to optimize energy consumption by increasing efficiency. The various coefficients such as annual demand and the cost of the primary source of energy are identified for getting information on the energy-saving methods and its analysis [5]. A large amount of money can be saved in the long run by maximizing the energy efficiency of a residential unit. The usage of energy-efficient devices could help us reduce the cost of energy consumption having the same power output. In [6], the comparative study of efficient and inefficient appliances has been done in Nigeria's residential building. Around 48 percentage savings were obtained in replacing the old with new devices. Moreover, the greenhouse gas emissions and carbon-di-oxide emissions should also be analyzed with the existing components in the building. It is necessary to take steps further to reduce these [7]. It has been observed that the structure of the building and the selection of device are more significant in the power consumption.

The energy consumption purely depends on the architecture with the design and the maintenance due to the usage of the devices. Lighting and thermal play a vital role in energy consumption patterns [8]. An energy audit conducted at Leverett Elementary School revealed that the suggested alternative methods for HVAC systems have given more efficient solution in various aspects such as social, environmental, and economical way [9]. An innovative model based on a multilevel approach was introduced in [10] using a regression model with a combined bottom-up and top-down model approach for residential energy demand in France. Though this paper has given an overview of various factors, there are more challenges such as data collection, reforming the policies, the measures of incentives, enhancement of technical capacity, and the reforms to be considered at the institutional level. The energy usage outline has been evaluated at the buildings located at Central Queensland University, Australia [11]. The survey analyzed the indoor temperature and humidity based on indoor heating and cooling loads. The auditing resulted in a hike in almost 7-8% of the cost to increase 2-3% in energy consumption. The change in energy was mainly due to the temperature and humidity increase in the outside environment.

Energy audit conducted at Maharaja Surajmal Institute of Technology, Janakpuri, New Delhi for the hostel and mess buildings had given effective energy conservation measures to reduce the cost of energy [12]. It was observed that the replacement of conventional lamps with advanced devices reduced energy usage by one-fourth; the payback period for the replacement was also very economical. Various case studies were carried out in a detailed manner in [13] by taking building construction materials, survey, baseline model, evaluating the energy conservation opportunities, and finally submitting the recommendations for the cost savings. Identifying the utilities having less efficiency was also a major point of consideration. It was given more weightage in the article [14] by carrying out an audit at a residential building in Old Mahabalipuram Road (OMR), Chennai. It was recommended to change the separate cooling systems by centralized cooling units.

Making awareness among the public living in the residential building about energy conservation is the art and heart of energy saving. The study's objective in [15] was to create awareness for the residential building sector and minimize carbon footprint. The simulation was carried out in integrated environmental solution (IES) for the building audit following the guidelines of ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers). From the suggestion, there was an energy saving of 6.12% and a cost saving of 24.78% for the simulated building. Most educational institutions could save energy during semester holidays by conducting an energy audit. The six-month data collected from University Tun Hussein Onn Malaysia (UTHM), Johor, Malaysia, namely Kolej Kediaman Tun Dr. Ismail (KKTDI) on four blocks, showed around 88% increase in energy consumption in the semester compared to the holiday period. This study was carried out by considering the building energy index and energy intensity as the main factors for analysis [16].

For small power load estimation, the Morris method is adopted in [17] to deal with the uncertainty of TM22 and TM54 models from a building service of Chartered Institute of Building Service Engineers. It helps the auditors select an optimal assessment strategy for small load estimations. Using the data obtained from the weather stations of various departments, the energy analysis of the photovoltaic plant at the University of Calabria was carried out in TRNSYS simulation software [18]. The results were compared with the Siegel method showing a payback period of five years with cost benefits. An overview of the innovative technological solutions for enhancing the energy performance of a building for energy consumption reduction has been presented in [19]. The authors have given various methods to realize zero energy buildings that could be incorporated into the design stage of a building itself and improve the efficacy of the building energy. The review article [20] elaborated on the data exchange for commercial buildings for the development of BuildingSync during energy audits to support various case studies.

Overview of various standards, roadmaps, and measures for the government's energy savings was reviewed in [21], and the evaluation of various methods, strategies, and applicability to the existing buildings was also presented. The usage of renewable energy sources has become an energy substitution method nowadays. The energy policy related to renewable energy sources with its modelling was given in [22] as a review article by considering the five major countries such as the United States, Germany, Denmark, China, and the United Kingdom. The best two methods for satisfying the energy demand are producing energy by classical and renewable energy methods and enhancing the efficiency of available energy systems [23].

The highlights of the paper are as follows:

(i) Energy audit implementation of a real-time project on a newly constructed building

(ii) Load calculation and distribution analysis for this building with economical cost analysis for various types of flats such as single, double, and triple

(iii) Proposed alternative energy-efficient appliances for the conventional loads for the cost reduction and improved sustainable environment

(iv) Analysis of renewable energy sources such as solar with cost analysis and energy-saving and payback period

This paper aims to conduct the energy audit of an under-construction residential project to optimize the electrical energy consumption and, therefore, make the project more energy-efficient. The energy audit provides a standard or reference point for accessing and overseeing energy consumption throughout the building and provides the methods for guaranteeing optimized energy use across the building. This helps develop ways to decrease energy consumption per unit of product output or lower operating costs and, hence, execute energy auditing [24].

This paper is started with an introduction in the first chapter, which deals with the previously available literature. The second chapter discusses the methodology and the building explanation for the case study. In this chapter, a comparison of conventional energy consumption and energy-efficient equipment consumption is being made. The next chapter includes the integration of renewable energy sources with the payback period calculation. Chapter four discusses the results and inferences, and the importance of GRIHA (Green Rating for Integrated Habitat Assessment) is presented in chapter five. The conclusion is given in chapter six.

2. Methodology

A review program will help focus on variations in the energy costs, availability, and reliability of energy supply, help decide on the appropriate energy mix, identify energy conservation technologies, and retrofit for energy conservation gear. The information and paperwork required during the detailed audit and analysis include energy consumption by type of appliance and usage, energy cost, and tariff data, energy management procedures. In the first stage of auditing, it means to reduce energy use in areas where energy is wasted and reductions will not cause disruptions to the various functions are introduced. This includes replacing less efficient (1 star rated) appliances and lighting systems with more efficient ones (5 stars rated). Each appliance gets rated between one to five stars, with 5 stars meaning it is extremely efficient and provides the best cost savings in the long run. These star labels are issued by the Bureau of Energy Efficiency (BEE) under the Standards and Labelling (S&L) program. The objective is to help the consumer to have an informed choice about the energy savings and thereby the cost-saving potential of household and other equipment that will save the electricity bill. The energy consumption in each case using conventional loads is computed and compared to the energy consumption using energy-efficient loads instead. This comparison has been made in terms of electrical consumption and monetary expenditure. A load distribution can also be inferred from this to see the degree of influence of the particular load on the total electrical consumption. The second stage is to add a solar power system to the building to offset costs further and decrease the building's overall energy and carbon footprint in the long run.

This comparison can be concluded by reducing energy consumption by assessing the difference in total project electrical consumption with efficient appliances. This reduction will give a cost-saving which will be used to see the payback period for the said investments.

2.1. Data Collection. The project is named "Cosmo Empire," developed by Cosmo Group in Gwalior, Madhya Pradesh at around 48 Crore as shown in Figure 1. The site's address is Cosmo Empire, Sirol Main Road, Gwalior, Madhya Pradesh-474001.

The details of the project with its floor plan are given in Figure 2, and its description is as follows:

(i) 8 floors with 16 flats per floor (1BHK-1 flat, 2BHK-9 flats, 3BHK-6 flats)

(ii) Total of 128 flats (1BHK-8 flats, 2BHK-72 flats, 3BHK-48 flats)

(iii) Common area with shops

The floor plan is used to find the number of each type of appliance in a flat and then on a floor and finally the whole building.

2.2. Energy Audit Strategy. Identification of energy consumption and other parameters has been made using detailed calculations, analysis, assumptions, and approximations. First, the load of the building per day with conventional (1-star rating or less efficient) appliances is evaluated and then calculated by replacing them with improved (5 stars rated or more efficient) appliances. Then, the estimation of the cost and payback period for a 40 kW solar power system is done. Finally, the results will be laid out by combining the above measures.

Figure 1: Rendering of the finished project.

Figure 2: Floor plan.

2.3. Data Analysis

2.3.1. 1BHK (Bedroom-Hall-Kitchen). The layout for the single bedroom is given in Figure 3, and the load calculation with the conventional appliance is presented in Table 1. Load distribution is presented as a chart in Figure 4.

Tables 1 and 2 compare the electricity consumption per day of 1BHK flat type and the estimated appliance cost. The pie chart in Figure 4 shows the percentage distribution of electricity usage per appliance in 1BHK flats. Air conditioning uses 47.8%, followed by the refrigerator, which uses 36.4% of the daily energy. The rest of the appliances are a very small percentage compared to these two. Hence, most energy can be saved if these two appliances are more efficient.

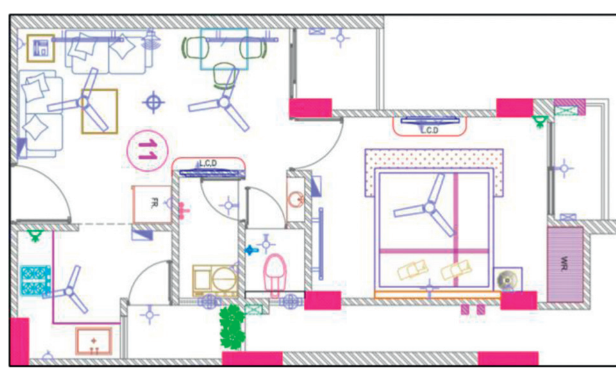

Figure 3: 1BHK flat layout.

2.3.2. 2BHK. Figure 5 shows the layout for a double bedroom flat. Tables 3 and 4 compare the electricity consumption per day of the 2BHK flat type and the estimated appliance cost.

The pie chart in Figure 6 shows the percentage distribution of electricity usage per appliance in 2BHK flats. Air conditioning uses 63.7%, followed by the refrigerator, which uses 24.3% of the total energy used per day. Compared to 1BHK flats, the air conditioning percentage has increased as 2BHK flats have 2 AC units. Hence, most energy can be saved if these two appliances are more efficient. The rest of the appliances are a very small percentage compared to these two.

2.3.3. 3BHK. Figure 7 presents the layout and floor plan for the three-bedroom buildings. Tables 5 and 6 compare the electricity consumption of 3BHK flat type per day and the estimated appliance cost.

Table 1: Load calculation—conventional—1BHK.

S. No.	Load type	Load of one appliance (W)	Hours	Nos. per flat	Nos.	Total load of the building (Wh)	Cost per appliance (₹)	Total cost appliance (₹)
1	Tube light	36	7	3	24	6048	54	1296
2	Ceiling fans	78	4.5	4	32	11232	1425	45600
3	LED TV	80	4	1	8	2560	28990	231920
4	Exhaust fans	45	0.5	2	16	360	1150	18400
5	Ceiling light	28	7	1	8	1568	120	960
6	Washing machine	500	2	1	8	8000	17000	136000
7	Refrigerator	359	24	1	8	68928	19600	156800
8	AC	1615	7	1	8	90440	41890	335120
		Total				189136	—	9,26,096

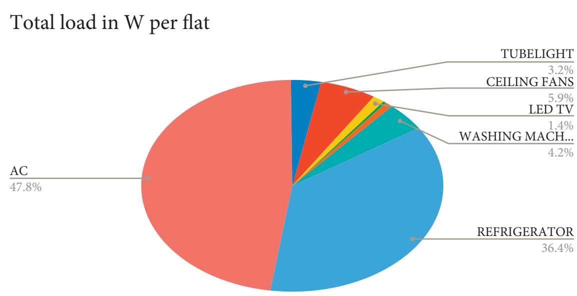

Figure 4: Load distribution—conventional loads—1BHK.

Table 2: Load calculation—improved appliances—1BHK.

S. no.	Load type	Load of one appliance (W)	Hours	Nos. per flat	Nos.	Total load of the building (Wh)	Cost per appliance (₹)	Total cost appliance (₹)
1	Tube light	20	7	3	24	3360	235	5640
2	Ceiling fans	28	4.5	4	32	4032	3800	121600
3	LED TV	80	4	1	8	2560	28990	231920
4	Exhaust fans	35	0.5	2	16	280	1184	18944
5	Ceiling light	16	7	1	8	896	282	2256
6	Washing machine	360	2	1	8	5760	14441	115528
7	Refrigerator	298	24	1	8	57216	34500	276000
8	AC	1440	7	1	8	80640	55990	447920
		Total				154744	—	12,19,808

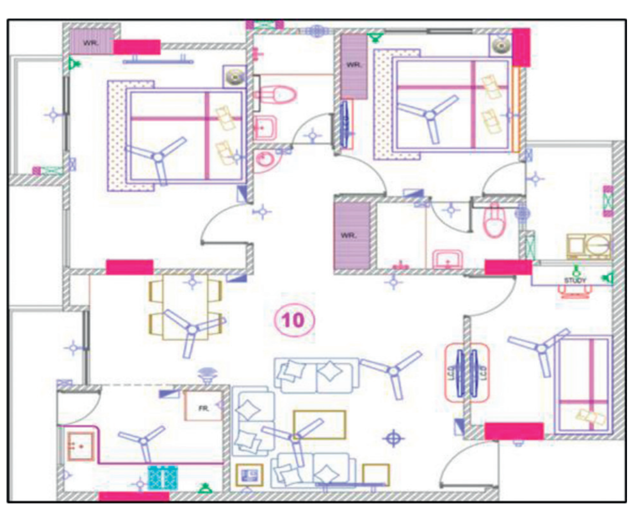

Figure 5: 2BHK flat layout.

Table 3: Load calculation—conventional—2BHK.

S. no.	Load type	Load of one appliance (W)	Hours	Nos. per flat	Total nos.	Total load of the building (Wh)	Cost per appliance (₹)	Total cost appliance (₹)
1	Tube light	36	7	4	288	72576	54	15552
2	Ceiling fans	78	4.5	4	288	101088	1425	410400
3	LED TV	80	4	2	144	46080	28990	4174560
4	Exhaust fans	45	0.5	2	144	3240	1150	165600
5	Ceiling light	28	7	1	72	14112	120	8640
6	Washing machine	500	2	1	72	72000	17000	1224000
7	Refrigerator	359	24	1	72	620352	19600	1411200
8	AC	1615	7	2	144	1627920	41890	6032160
		Total				2557368	—	1,34,42,112

Table 4: Load calculation—improved appliances—2BHK.

S. no.	Load type	Load of one appliance (W)	Hours	Nos. per flat	Nos.	Total load of the building (Wh)	Cost per appliance (₹)	Total cost appliance (₹)
1	Tube light	20	7	4	288	40320	235	67680
2	Ceiling fans	28	4.5	4	288	36288	3800	1094400
3	LED TV	80	4	2	144	46080	28990	4174560
4	Exhaust fans	35	0.5	2	144	2520	1184	170496
5	Ceiling light	16	7	1	72	8064	282	20304
6	Washing machine	360	2	1	72	51840	14441	1039752
7	Refrigerator	298	24	1	72	514944	34500	2484000
8	AC	1440	7	2	144	1451520	55990	8062560
		Total				2151576	—	1,71,13,752

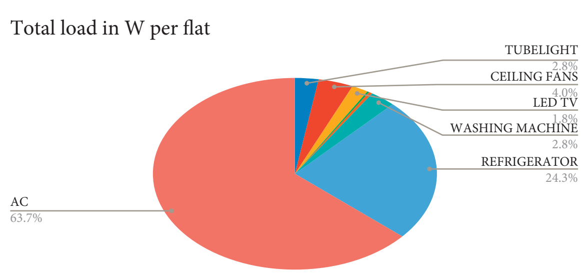

Figure 6: Load distribution—conventional loads—2BHK.

The pie chart in Figure 8 shows the percentage distribution of electricity usage per appliance in 3BHK flats. Air conditioning uses 61.8%, followed by the refrigerator, which uses 23.6% of the total energy used per day. The rest of the appliances are a very small percentage compared to these two. Compared to 2BHK flats, the AC energy usage has decreased by around 1% as 3BHK flats have more lights and fans.

2.3.4. Common Area. Tables 7 and 8 compare the common area's electricity consumption per day and the estimated appliance cost.

2.3.5. Load Comparison per Flat Type. The various loads with conventional power consumption and replaced new appliances power consumption for all single, double, and triple bedroom flats are shown in Table 9. The cost-wise comparison for all the flat types with old and new appliances is shown in Figure 9. Energy consumption with the replaced appliances and its cost and payback period are presented in Tables 10 and 11, respectively.

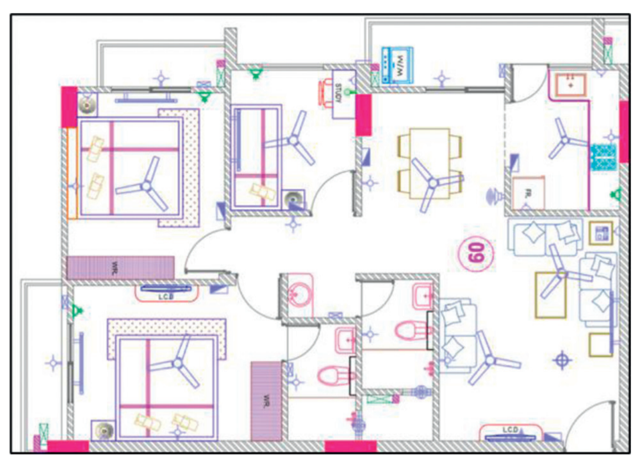

Figure: 7: 3BHK floor plan.

2.3.6. Energy Consumption Details.

2.3.7. Cost and Payback Calculations. The unit rate of electricity is ₹9/unit.

Table 5: Load calculation—conventional—3BHK.

S. no.	Load type	Load of one appliance (W)	Hours	Nos. per flat	Nos.	Total load of the building (Wh)	Cost per appliance (₹)	Total cost appliance (₹)
1	Tube light	36	7	4	192	48384	54	10368
2	Ceiling fans	78	4.5	7	336	117936	1425	478800
3	LED TV	80	4	2	96	30720	28990	2783040
4	Exhaust fans	45	0.5	2	96	2160	1150	110400
5	Ceiling light	28	7	1	48	9408	120	5760
6	Washing machine	500	2	1	48	48000	17000	816000
7	Refrigerator	359	24	1	48	413568	19600	940800
8	AC	1615	7	2	96	1085280	41890	4021440
		Total				1755456	—	91,66,608

Table 6: Load calculation—improved appliance—3BHK.

S. no.	Load type	Load of one appliance (W)	Hours	Nos. per flat	Nos.	Total load of the building (Wh)	Cost per appliance (₹)	Total cost appliance (₹)
1	Tube light	20	7	4	192	26880	235	45120
2	Ceiling fans	28	4.5	7	336	42336	3800	1276800
3	LED TV	80	4	2	96	30720	28990	2783040
4	Exhaust fans	35	0.5	2	96	1680	1184	113664
5	Ceiling light	16	7	1	48	5376	282	13536
6	Washing machine	360	2	1	48	34560	14441	693168
7	Refrigerator	298	24	1	48	343296	34500	1656000
8	AC	1440	7	2	96	967680	55990	5375040
		Total				1452528	—	1,19,56,368

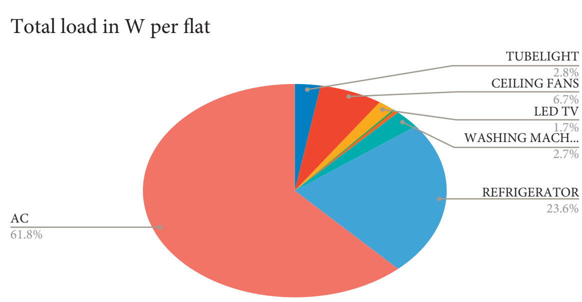

Figure 8: Load distribution—conventional loads—3BHK.

Table 7: Load calculation—conventional—common area.

Load type	Location	Load of one appliance (W)	Nos.	Hours/day	Total load (Wh)	Cost per appliance (₹)	Total cost (₹)
Lift	—	4600	3	24	331200	—	—
Lift	—	6000	1	24	144000	—	—
Tube light	Parking	36	120	8	34560	54	6480
Tube light	Streetlight	36	30	10	10800	54	1620
Tube light	Floor lobby	36	48	10	17280	54	2592
		Total			537840	—	10,692

Table 8: Load calculation—improved appliances—common area.

Load type	Location	Load of one appliance (W)	Nos.	Hours/day	Total load (Wh)	Cost per appliance (₹)	Total cost (₹)
Lift	—	4600	3	24	331200	—	—
Lift	—	6000	1	24	144000	—	—
Tube light	Parking	20	120	8	19200	235	28200
Tube light	Streetlight	20	30	10	6000	235	7050
Tube light	Floor lobby	20	48	10	9600	235	11280
		Total			510000	—	46,530

Table 9: Load comparison—conventional vs improvised appliances.

	Conventional appliances total (Wh)	New appliances total (Wh)
1BHK	23642	19343
2BHK	35519	29883
3BHK	36572	30261

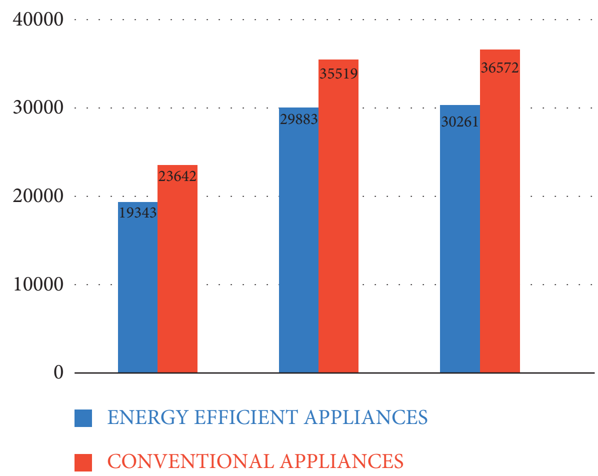

Figure 9: Difference between energy consumption when conventional loads are used and when improvised appliances are used for 1BHK, 2BHK, and 3BHK.

Table 10: Energy usage calculations.

Total project electrical consumption conventionally	5039.800 kWh
Total project electrical consumption with efficient appliances	4268.848 kWh
Reduction in electrical consumption per day	770.952 kWh
Percentage reduction in electrical consumption	15.3%

Table 11: Cost saving and payback calculation.

Cost saved	₹6,938.568
Investment	₹67,90,950
Payback period	2.68 years

3. Production of Renewable Energy by the Photovoltaic System (Solar Power)

A proposal is made to put a PV system to produce 40 kW to generate electrical energy. With a 40 kW per day PV system, renewable energy production is above 9% of the total energy usage.

3.1. Working. This system is connected to the electrical grid and allows residents/buildings to use solar energy and power from the grid. In this system, solar PV panels produce direct current (DC) and are fed into a solar inverter that converts it to useable 230V-50 Hz AC. When the panels generate adequate energy, the solar inverter uses no power from the grid. If the power generated by panels is insufficient, the inverter compensates by drawing power from the grid at night. It will completely switch to the main grid. If the power is in excess, it can be fed to the grid under net metering. The battery is not used for this system as the grid is used as a backup. Solar PV cost quotation and cost savings with payback calculation are shown in Tables 12 and 13.

4. Results

The final cost-saving and its payback period are calculated by taking the electricity unit rate as Rs. 9/unit and given in Table 14. The previously shown results prove that the substitution of energy-efficient appliances in place of conventional equipment has given more cost-saving and energy consumption. In this chapter, the cost reduction is further achieved by integrating renewable energy sources. As shown in Table 14, it is shown that the reduction in energy consumption has been achieved by replacing the appliances and incorporating the solar system. It saves around 2.5 lakhs rupees, which will be getting back in three years as a payback period.

It can be concluded from this project that there is a huge amount of energy and cost-saving potential in the residential sector. By simply swapping less efficient appliances with more efficient ones and installing a PV system, there was a reduction of around 16% in energy consumption, including over 9% of renewable energy production. This was achieved with a surplus cost of around 1.76% of the project's total estimated cost.

Over the next 10 years, the measures are calculated to provide an estimated saving of over 26 crore rupees. In 20 years, the cumulative savings will surpass the total investment made for the construction of the building. As is evident by the data, air conditioning is the single biggest power consumer in the residential power sector. Hence, installing/upgrading to more efficient 5-star rated ACs is a great investment in the long run. It was also observed that huge improvements in energy usage are due to more efficient technologies like BLDC (brushless DC) fans which consume only 28 W of energy compared to normal fans which consume around 80 W.

5. Green Rating for Integrated Habitat Assessment (GRIHA)

The crux of the initiative is "what gets measured." GRIHA attempts to quantify aspects such as energy consumption, waste generation, and renewable energy adoption, to manage, control, and reduce the same to the best possible extent. GRIHA is an independent body now even referred to as a society that looks forward to many architectural aspects of construction projects.

GRIHA is a rating tool that rates a building on certain parameters according to international and national standards and then gives a star rating. Many government bodies regulate India's construction process, whether residential or commercial spaces. This star rating is now getting accepted.

Table 12: PV system cost quotation.

Item	Capacity (kWp)	Rate per kWp (₹)	Total price (₹)
Design, manufacture, and supply of 40 kW grid-connected solar PV system complete with a solar module, and other accessories and connecting cables	40	42000	16,80,000
Total			16,80,000

Table 13: PV system cost savings and payback calculation.

Per unit cost of grid electricity	9	Rupees
Total energy generated by the PV system per year	**52,800**	kW
Total saving per year	**475200**	Rupees
Project cost	**16,80,000**	Rupees
Payback period	**3.53**	**Years**

Table 14: Final cost savings and payback calculation.

Daily energy usage (no energy-saving measures in place)	5039.8 kWh
Reduced energy usage per day (using efficient appliances)	4268.848 kWh
Energy generated by the PV system per day (peak)	40 kWh
Effective total energy usage per day	4228.848 kWh
Reduction in daily total energy usage	810.952 kWh
Reduction in yearly total energy usage	295997 kWh
Percentage reduction in energy usage	16.09%
Total investment cost	8470950 ₹
Total daily savings	7298.568 ₹
Yearly savings	2663977.32 ₹
Payback period	3.179 years

According to the star rating, government bodies provide many incentives so that the construction company and users get a boost while considering the concern of environmental causes. Moreover, many recent real-estate projects have now started taking certification from GRIHA. It is observed that customers prefer many GRIHA rated compared to non-GRIHA affiliated projects.

5.1. Benefits

(i) Energy consumption is reduced without sacrificing the comfort levels of the consumer

(ii) The destruction of natural areas, habitats, and biodiversity is reduced, and soil loss from erosion is also reduced

(iii) Air pollution and water pollution are reduced

(iv) Water consumption is reduced

(v) Waste generation linked to recycling and reuse is limited

(vi) Pollution loads are reduced

(vii) User productivity is increased

(viii) Image and marketability are enhanced to increase the engagement of customers

Therefore, it is recommended that the construction company looks forward to all these incentives and considers all the norms while developing a greener and energy-efficient residential building.

6. Conclusion

The BEE star rating program has successfully spread awareness among the consumers as this rating was very helpful during this project. Data collection about the appliances that did not have the rating proved difficult and ambiguous as most manufacturers do not easily make the energy usage information accessible. This real-time project has been chosen to make the public aware of the importance of energy saving. The various loads in single, double, and three bedrooms, hall, and kitchen rooms have been studied. The cost comparison of all the loads for conventional and energy-efficient devices has been attempted and proved the best method. Solar output has met the load demand, and the building has a better payback period. Hence, it is suggested to have a prior study of the building construction with the cost analysis which will be helpful to reduce the electricity billing and cost reduction. This project proves that investment in energy-saving equipment provides cost benefits in the long run and is better for the planet.

Data Availability

The data used to support the findings of this study are included in the article. Should further data or information be required, these will be made available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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