Feasibility Study of Replacement of Hybrid Renewable Energy – A Case Study

Motupalli Priyanka, Niranchana R, S Selvakumar, Nithya Venkatesan

Abstract: ***In the recent years, the world has witnessed a major shift from fossil fuels to renewable energy sources. Renewable energy facilitates cost-effective solutions for prevailing energy issues faced by numerous countries. With the increase in costs of the fuels, depleting reserves of conventional sources of energy and the issue of oil crisis, renewable energy seems to be an excellent alternative with its abundance, potential to produce pollution free energy, minimize carbon footprint, and greenhouse emissions and ensure energy security. This research describes the potential study of making a feasibility assessment of switching the conventional grid connected system into a renewable energy system which could be used as a possibility for supplying power to VIT located at Chennai. The idea for this research study is to make VIT, Chennai energy self-sufficient in such a way that it meets its load requirements though roof top installed solar panels and installing small-scale domestic wind turbines. First the ability to meet the load requirements from solar standalone system is analyzed followed by a wind stand-alone system. Following this the feasibility analysis of a hybrid system involving solar and wind energy sources has been done. The primary objective is to minimize the cost and the components' size of the RES system and arrive at an optimal solution to meet the load demand throughout the day. Initial Costs, the Operating cost, Net Present Cost(NPC) and Levelized Cost of Energy(COE)have been used as the basis for Cost analysis. The results in this study show that the integration of this hybrid system into the existing campus provides a cost savings of $ 3, 59,087 (2, 50, 58,634.93 ₹) NPC and $ 28,442.01 (1984805.76 ₹) operating cost when compared to the cost of grid. The above results are obtained by doing the analysis using the HOMER software***

Keywords: ***VIT University. Energy consumption. Hybrid Energy system. Optimization analysis. Homer Software***

Abbreviations

npc Net Present Cost ($/year)

CRF Capital Recovery Factor

cann,tot Total Cost per year ($/year)

In Interest Rate (%)

LCE Levelized cost of Energy ($/kWh)

N Project Lifetime (years)

Eprim ,DC DC load provided annually (kWh/year)

Eprim, AC AC load provided annually (kWh/year)

Ewnd Electricity from wind (kWh)

Epv Electricity from solar panel (kWh)

I. INTRODUCTION

Vellore Institute of Technology (VIT) is a leading Engineering Institution in India with international collaborations, extensive focus on research with an emphasis on providing a project based learning. It has campuses in Vellore, Chennai, Bhopal and Amravati. For this study, VIT University located in the city of Chennai which is situated on Vandalur- Kelambakkam road is considered. In this Chennai campus, post-graduation in academic programs in engineering, applied sciences, technology and management programs [1,2].

VIT, Chennai has started the construction of its buildings in the year 2010 initially with only two buildings known as admin and academic block I. In the consecutive years it has grown up by adding two number of boys' hostel, one girls' hostel with one more academic block2. The existing buildings with the recent infrastructure needs further development to enhance the energy efficiency. Moreover, VIT Chennai campus has been awarded as a Green Campus in the year 2016 by Indian Green building council which clearly points that it is essential to reduce the energy consumption. Therefore, there comes a necessity to establish either a smart metering system or to integrate/ introduce a renewable hybrid system for a better energy usage. However, plenty of constraints come into play. For instance, Agdas *et al*. [3] analyzed the campus buildings by using Leadership in Energy and Environmental Design (LEED) to develop the policies for sustainable management. Eriksson *et al*. [4] estimated the current development of campus retrofitting in three of the campuses of the university .Tan *et al*. [5] carried out the green campus initiative wherein he placed paramount focus on management of energy and resources. This current research work establishes an optimal solution to replace the consumption of energy in the campus by renewable energy systems like either solar, wind or by hybrid combination of the two by analyzing using Homer software. Kayo *et al*. [6] performed the campus sustainable development for enhancing the energy efficiency and concocting functionality of the properties. The study dealt with integration of campus buildings and working out optimization techniques of the local energy systems for energy management for a site where there is significant emphasis on renewable energy. Thus, this study attempts the approach of distributed generation and the prospective of energy saving ideas by idealizing the data measured.

In working towards attaining sustainable development, energy efficiency and mitigation of pollution, several countries have placed emphasis on the creation of low carbon systems. In many nations, there are legal limits on amount of electricity generation through fossil fuels. For instance, Vidal *et al*. [7] worked on analyzing the MTMC method to assist the several possible energy configuration for conversion of the energy system in Mexico where

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renewable energy meets three fourth of the demand of electricity. The target is attained with reduction of the installed capacity in the system.

Zhang *et al*. [8] investigated the inclusion of solar power in a hybrid system in Croatia using CSPs, to meet a significant portion of the energy demand by exploiting the high solar irradiance in the area. Aoife *et al*. [9] described the current advances of wind forecasting because it aids in balancing supply and demand in any electrical system. Karl *et al*. [10] suggested that using RES to generate high revenue requires a consideration of ecological condition in the area.

II. OBJECTIVES

This research outlines the investigation of energy replacement of existing campus buildings using renewable energy generation and its impact on energy improvements based on the cost analysis using Homer software.

III. METHODOLOGY

A Selection of a case study

The scope of this case study as mentioned earlier is the campus buildings of VIT, Chennai. The campus includes more than five buildings as shown in Figure 1. The electricity in the campus is supplied through conventional commercial grid.

Fig.1 Picture of the VIT, Chennai Campus

IV. COMPILATION OF BUILDING DATA

Considering the possibility of introduction of renewable energy as a replacement to the existing energy based on the consumption this research study has taken utmost care in assuming all the academic teaching class rooms, laboratories, conference halls, research laboratories, boy's hostel , girls hostel and health care facilities. Categorizing based on the usage of space in different buildings, the load list is given in Table 1, the power consumption of each block is given in Table 2 and the electricity cost for each month is shown in Table 3.

Table 1 Load List of Each Building

BLOCKS	OVERALL NUMBER OF ROOMS	FLOORS	TOTAL LOAD (in KW)
Admin Block	21	8	101.588
Academic Block 1	154	8	662.397
Academic Block 2	59	7	177.925
Boys Hostel A	775	15	339.409
Boys Hostel B	389	15	339.4
Boys Hostel C	428	11	248.89
Girls Hostel	376	15	331.1205

Table 2 Power Consumption of Each Building

BLOCKS	TOTAL UNITS(in KW)
Admin Block	17897
Academic Block 1	89920
Academic Block 2	34633
Boys Hostel A	137712
Boys Hostel B	38530
Boys Hostel C	12,600
Girls Hostel	119130

Table 3 Total Cost for Each Month

BLOCKS	COST (in INR)
Admin Block	125279
Academic Block 1	629440
Academic Block 2	242431
Boys Hostel A	963984
Boys Hostel B	269710
Boys Hostel C	81,900
Girls Hostel	833910

V. ANALYSIS USING HOMER

HOMER Software is used to model, optimize and analyze all the campus buildings in VIT Chennai. Generally this software is used for the purpose of designing and evaluating the various possible options for both off-grid and on-grid power systems in remote, stand-alone and DG applications. Using this software, we can also calculate the technical and cost parameters.

Apart from the above mentioned, this software can determine whether the available sources can satisfy the load demand throughout the year for every hour in which the simulations can be carried out at time interval which is less than 60 sec. In this software, Jittery time intervals are also allowable for estimation which places emphasis on individual load requirements. Moreover, in case the primary resources is insufficient to meet the load demand, homer will automatically identify the other secondary sources which need to be incorporated into the system to satiate the demand required by the user.

Usually, Energy calculations are made for every 8760 hours a day. This will determine the demand that is capable of being supplied within an hour and calculate the energy flows in each component. [11]

This software also finds the cost of energy sources that are controlled by using hourly fixed cost and hourly energy cost. These costs will determine the cost for the generating energy at any time. It searches for the all the various possible combination of sources to meet the load and then identifies which system among others meets the goal with minimum cost and thereby arrives at the optimal solution [12].

Mostly, the analysis of cost is performed using Net Present Cost (NPC), Levelized Cost of Energy (COE) and the Renewable Fraction (RF).

The NPC determines the current value of installation and operation of the system over the entire project lifetime, commonly called Life cycle cost which is given by,

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$$NPC = \frac{cann,tot}{CRF} \quad (1)$$

Where, Cann, tot is the total cost per year ($/year) which includes the capital, replacement, annual operating and maintenance, and fuel costs.

CRF is the capital recovery factor, which is used to calculate the present value of a series of equal annual cash flows, where In is the real interest rate (%) and N is the project lifetime (in number of years)

$$CRF = \frac{(1+i)^{-N}}{i+1} \quad (2)$$

Levelised Cost of Energy: The Levelised cost of energy is the average cost per kilowatt hour ($/kWh) of useful electrical energy produced by the system which is given by

$$LCE = \frac{cann,tot}{EprimAC+EprimDC} \quad (3)$$

Here, Cann,tot is Total Cost per year ($/year), Eprim,AC is the AC load provided annually (kWh/year) and Eprim,DC is the DC load provided annually.

Finally using this software, there is a possibility to calculate the Renewable Energy Fraction, which is given by,

$$PV\ Fraction = \frac{Epv}{Ewnd+Epv} \quad (4)$$

$$Wind\ fraction = \frac{Ewnd}{Epv+Ewnd} \quad (5)$$

Where Epv is the Energy from the solar panel

And Ewnd is the Energy from wind

The above discussed parameters are used in this research work for the replacement of renewable energy in the existing VIT, Chennai campus.

VI. FEASIBILITY OF WIND ENERGY STANDALONE SYSTEM

In India, in the recent years, the use of wind turbines for production of electricity has burgeoned. Over the years Wind energy has met and exceeded the target in several countries. However, the existing units do face several problems pertaining to grid integration, operation with poor capacity utilization and under-evacuation factors. In order to improve this situation, government policies that reward optimum utilization is essential [13].

Wind turbines are capable of producing electricity with no deleterious impacts on global environment. They do not induce harmful pollutants into the water bodies. They do not release harmful gases .In addition to this the fuel costs and pollution associated combustion are absent .However certain limitations are encountered while using wind energy as the only standalone system for power generation.[14]

.Sufficient wind speeds are required for the optimal performance .In order to meet the desired power requirements for the entire institute more wind turbines would be required. This would increase installation costs and would require more land area to ensure sufficient distance between the turbines.

Chennai being close to the shore receive frequent winds with sufficient speeds throughout the year. There is a resource potential available at the VIT University for power generation from wind turbines. Table 4 illustrates the average monthly wind speed observed in the Vandalur – Kelambakkam area where the institute is located.

The maximum wind speed is observed during April with speed of 12 mph on an average and maximum of 17 mph. From the above data, it clearly demonstrates a system comprising of wind energy and another RES source can definitely contribute to renewable energy fraction (100% for wind based system with converter) which reduces the fossil fuel dependence and brings down the greenhouse emissions. Based on the data mentioned above we could recommend the replacement of the entire grid system with wind-based systems so that we will be able to save money .Approximately savings of $3,58,466(24669594.27 ₹) NPC and $28,316(1948704.29 ₹) operating costs is possible with the replacement of a wind-based system with a converter

Table 4 Average wind speed at VIT, Chennai for the Year

S.No	Month	Wind speed (avg) mph	Wind speed(max) mph
1	January	9.6	13.6
2	February	7.8	12.3
3	March	9.8	14.8
4	April	12.5	17
5	May	9.4	14.8
6	June	8.7	13.9
7	July	11.2	13.2
8	August	9.8	13
9	September	9.6	11.6
10	October	8.5	11.6
11	November	10.7	14.1
12	December	10.1	13

VII.FEASIBILITY OF SOLAR ENERGY STANDALONE SYSTEM

At present, India's current installed capacity has reached 20 GW in February 2018. India has increased its solar-generation capacity by 8 times from 2014 to 2018. With the increase in population the demand for electricity is also increasing. More fossil fuels are burnt to meet this demand for electricity. The burning of fossil fuels releases 21.3 tonnes of carbon dioxide (CO2). So the best and cheapest way to produce electricity is by using solar energy which can be extracted from the Sun. It is pollution free and doesn't release any greenhouse gases like carbon dioxide, nitrogen oxide or sulphur oxide. Therefore the risk of damage to the environment is reduced. Unlike fossil fuels, solar energy is abundant in nature. Solar energy production has also created many jobs.

Chennai is one among the places which receives maximum sunlight throughout the year. VIT University has the potential to generate power from solar panels. Table 5 illustrates the average monthly Direct Normal Irradiance observed in Chennai.

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Table 5 Average Normal Irradiance for the Year in Chennai

S.No	Month	*Direct Normal Irradiance (avg) kWh/m²/day*
1	January	5.76
2	February	6.6
3	March	6.05
4	April	5.91
5	May	5.78
6	June	4.85
7	July	4.39
8	August	4.22
9	September	4.86
10	October	3.68
11	November	4.12
12	December	4.92

The annual average direct normal irradiance is 5.08 kWh/m^2/day. The above data indicates that solar standalone system it's better to use as replacement of the grid system. Approximately savings of $3, 59,087 (24712331.43 ₹) NPC and $28,442.01 (1957376.28 ₹) operating costs is possible with the replacement of a solar based system with a converter.

VIII. FEASIBILITY STUDY OF HYBRIDIZATION OF SOLAR AND WIND ENERGY SYSTEM

The uncertainties and the intermittencies involved when utilizing renewable energy sources engenders several technical and economic challenges that are to be comprehensively investigated and addressed when developing a reliable system. Especially when the world is heading towards penetration of sustainable sources in the power system, it is vital that the adequacy and the reliability is met [15]. Standalone systems despite advancements in technology is not capable of producing sufficient energy that can be used effectively for a substantial part of the year. For instance, despite the abundance of sunshine, the standalone PV system is very expensive. High cut in speeds also places a barrier on power generation from a standalone wind system[16] Hybridized RES systems consist of multiple renewable energy sources to meet the load demand. The choice of the sources depends upon numerous factors such as the economic constraints, availability of the resources, local topography, seasonal and weather variations. Site selection is especially is very crucial for PV/wind-based systems. To counteract the fluctuations in the system and improve the reliability of the system, incorporation of a hybrid seems to be the best possible option. It must be ensured that the system can satiate the load requirements at the site as well as satisfy the mentioned factors. For counterbalancing the fluctuations and time distribution mismatches between source generation and load requirements, storage system can be added [17].

The feasibility of a hybrid solar-wind energy-based system has been investigated. The employment of a solar-wind energy system enhances the overall energy output, attenuates the individual shortcomings, reduces the need of a storage system and reduces the oversizing of components [16]. It reduces the overall expense involved in the construction of the individual systems.

IX. RESULTS AND DISCUSSION

To get the optimized combination of RES system for the specified site i.e. VIT Chennai a numerous PV standalone, PV with Grid Connectivity, Wind with Grid, PV-Wind based Grid connected system and PV Wind without Grid connectivity are simulated in HOMER Software.

The system components and the assumptions for our study are as follows:

1) PV Module: The PV panel used in the simulation study is Generic flat plate PV. The per kW capital cost of PV module is $3000 and the replacement cost is $3000 and with an operation and maintenance cost of 10$/yr. These PV modules have a lifetime of 25 years and derating factor of 80%.
2) Wind Turbine: The wind turbine used in the simulation study is Generic and its rated capacity is 1 KW. The per kW capital cost of wind turbine is $7000, the replacement cost is $7000 and with an operation and maintenance cost of 70$/yr. This wind turbine has a lifetime of 20 years and hub height is 17 m.
3) Battery: Generic Lead Acid has been used for the simulation study and has a nominal capacity of 1kWh. The per Kw capital cost for battery is $300, the replacement cost is $300 and the operation and maintenance cost is 10$/ yr. The maximum and minimum storage life of the battery is 10 and 5 yrs respectively. It has maximum charge current of 16.7 A and maximum discharge current of 24.3 A. It has an efficiency of 80%
4) Converter: System converter is used for the simulation study. The per Kw capital cost for converter is $300 and the replacement cost is $300.This converter has a lifetime of 15 yrs and an efficiency of 95%.Figure 2 shows the schematic of specific loads which is considered for this study.

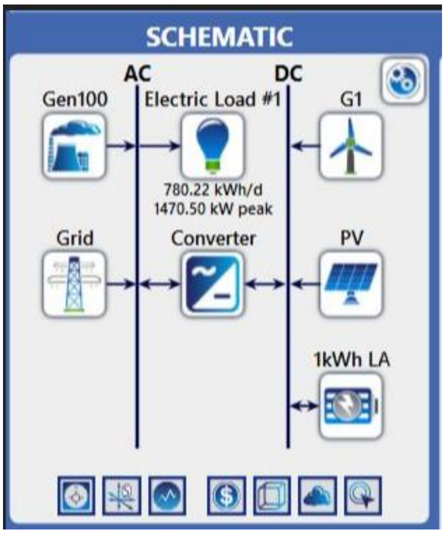

Fig. 2 The schematic of the adopted system for the specified loads

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Apart from the above-mentioned assumptions we have carried out the following presumptions as well,

1. The simulation was executed for the life period of the project taken as 25 years and an annual interest of 8%.
2. In the simulation, the grid electricity cost is taken as $0.1/kWh.
3. In the simulation for the hybrid system the capacity for:

a) PV - 2, 4, 8, 12, 16, 32 kW
b) Wind -1, 2, 3 and 5 kW
c) Battery -1, 4, 8, 16 battery bank and
d) Converter - 2, 5, 6, 100 kW.

4. The Initial cost, Operating cost, Total NPC, Levelised cost of energy and renewable fraction are used for tabulation of the result.

As shown in the Table 6, given below, the Net present cost (NPC) obtained for the PV-Wind based system without grid connectivity is $ 23211, whereas for a Hybrid PV and Wind system connected to the grid it is found to be $388952. PV system connected to the Grid has NPC equal to $380374 while for the Standalone systems, Wind and PV, their NPC's are correspondingly $ 382801 and $9065. However, the COE obtained for a Hybrid PV and Wind system not connected to the grid is 6.68 $/kWh, for a Hybrid PV and Wind system connected to the grid is seen as 0.104 $/kWh. PV system connected to the grid, Wind system connected to the grid has the COE equal to 0.102 $/kWh and 0.104 $/kWh respectively. The COE for PV in standalone configuration is equal to 3.07$/kWh. The least operating cost for the PV in standalone system with the value 35.99 $/ yr while for the Wind-Grid system the value is 28838 $/ yr. The renewable fraction is found to be the greatest for PV-Wind Hybrid without grid connectivity and standalone PV system.

Fig. 3 The daily load profile with Y axis denoting the average power in Kilowatt and X axis denoting the time in hrs.

Table 6 The cost analysis for different Renewable energy configuration in dollars

Renewable energy configuration	Initial Cost ($)	Operating Cost ($/yr)	Total Net present cost ($)	Cost of energy ($/kWh)	Renewable energy Fraction
PV-Wind- without grid connectivity	18000	403.10	23211	6.68	100
PV-Wind- with grid connectivity	15600	28473	383685	0.103	1.21
PV with grid connectivity	11000	28573	380374	0.102	1.06
Wind with grid connectivity	10000	28838	382801	0.104	0.155
Standalone PV	8600	35.99	9065	3.07	100

Table 7 The cost analysis for different Renewable energy configuration in rupees

Renewable energy configuration	Initial Cost (₹)	Operating Cost (₹/yr)	Total Net present cost (₹)	Cost of energy (₹/kWh)
PV-Wind- without grid connectivity	1238758.20	27741.30	1597378.70	459.72
PV-Wind- with grid connectivity	1073590.44	1959509.01	26405163.33	7.09
PV with grid connectivity	757018.90	1966391	26177300.64	7.02
Wind with grid connectivity	688199	1984628.28	26344326.54	7.16
Standalone PV	591851.14	2476.83	623852.39	211.28

The optimal sizing of the PV, wind, battery and converter for the various renewable energy systems have been discussed in Table 8. A PV-wind system without grid connection and a grid connected PV-Wind hybrid system both necessitate the need for 2 kW for PV, 1 kW for Wind, 8 batteries and a 2 kW converter. For a grid connected PV configuration, 8 number of batteries and a converter of 2kW with a PV source of 2kW are used. For a standalone PV system 2kW PV and a converter of 2kWw are essential. For a wind system connected to the grid a wind turbine of 1 kW, 8 batteries and a converter of 2kW are needed.

Table 8 Optimal sizing of different Renewable energy configuration

HRES configuration	PV (kW)	Wind (kW)	No. of batteries	Converter (kW)
PV-Wind- without grid connectivity	2	1	8	2
PV-Wind- with grid connectivity	2	1	8	2
PV with grid connectivity	2	0	8	2
Wind with grid connectivity	0	1	8	2
Standalone PV	2	0	0	2

The computation of the obtained results was carried out and the systems involving renewables was compared with the only-grid based system to estimate the cost savings. For a yearly basis, net Present Cost savings of approximately $344,941(2, 37, 38,805.13 ₹) and operating cost savings of

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approximately $28,074.9 (19, 32,111.81₹) are possible, for PV-Wind system not connected to the grid. For a PV–Wind hybrid system connected to the grid, NPC cost savings of approximately $4,467 (3,07,418.49₹)and $5(344.10 ₹) operating costs savings are feasible .For a PV standalone system with converter, costs savings of approximately $359,087 (2,47,12,331.43 ₹) NPC and $28,442.01 (19,57,376.28 ₹)operating costs are possible. However, for a system involving only solar panels/wind turbines with grid connectivity, the operating costs and the NPC are greater than that of the only grid system. The NPC cost savings of $12,222 (8, 41,116.82 ₹) operating cost savings of $95 (6,537.89 ₹) are obtained for an only grid system when compared to that of solar-based system with grid connectivity. Similarly, for a wind-based system with grid connectivity the approximate NPC costs and operating costs are respectively $14,649(10, 08,142.72 ₹) and $ 360(24,775.16 ₹) greater than the corresponding costs of an only grid-based system. Therefore, considering the NPC or only the operating costs, a standalone solar system has the greatest costs savings at the site among the other mentioned alternatives.

Table 9 Total NPC and Operating Cost savings of HRES configuration with respect to only grid based system

Renewable energy configuration	Total NPC ($) (savings/ surplus in comparison to Total NPC of grid)	Operating Cost ($/yr) (savings/surplus in comparison to Operating Cost of grid)
PV-Wind- without grid connectivity	Savings of 344941	Savings of 28074.9
PV-Wind- with grid connectivity	Savings of 4467	Savings of 5
PV with grid connectivity	Surplus of 12222	Surplus of 95
Wind with grid connectivity	Surplus of 14649	Surplus of 360
Standalone PV	Savings of 359087	Savings of 28442.01

Also, in order to understand the economics of the system after the initial year, comparative cost analysis of the renewable energy system with the grid was carried out. For renewables, the costs come down in the subsequent years due to the absence of the initial capital costs. From the calculations it has been observed that, for a three year period, approximately total cost savings (initial +operating)of $ 66224.7 (45,57,577.23 ₹)is observed in comparison to the grid for a hybrid solar-wind based system without grid connectivity. For a PV-Wind based system with grid connectivity, total costs savings of approximately $15,585(10,72,558.14 ₹) is obtainable. For a PV standalone system, total cost savings of approximately $ 76726.03 (52, 80,277.71 ₹) for a three-year period is possible

Table 10 Total savings/surplus cost of HRES configuration after a span of 3 years with respect to only grid-based system

Renewable energy configuration	Total savings / surplus cost with respect to grid ($)	Total savings / surplus cost with respect to grid (₹)
PV-Wind- without grid connectivity	Savings of 66224.7	Savings of 4557914.98
PV-Wind- with grid connectivity	Savings of 15585	Savings of 1072637.63
PV with grid connectivity	Surplus of 11285	Surplus of 776690.13
Wind with grid connectivity	Surplus of 11080	Surplus of 762581
Standalone PV	Savings of 76726.03	Savings of 5280669.01

However for a PV-based system connected to the grid or a wind-based system connected to the grid, the grid costs over the three years seem to be lesser than the total operating and capital costs of the solar and wind-based system with grid connectivity over the three years. Costs savings of approximately $11285 (7, 76,632.57 ₹) and $ 11080 (7, 62,524.49 ₹) are obtainable with only grid based system when compared to PV-grid and Wind-grid respectively. So, for a three year period, standalone PV based system has the highest cost savings. The hybrid wind-solar system also has significant cost savings.

X. CONCLUSION

The modelling, analysis and optimization of a renewable energy replacement system for the university, VIT Chennai has been carried out using HOMER software. For a system without grid connectivity, the COE is higher than a system with grid connectivity. A grid connected system will aid in reducing the pressure on the grid and help in the conservation of electricity from the grid. Thereby an optimal configuration for the site will be to use a renewable energy source and grid connected system at the site. PV connected to the grid is a viable solution when taking into consideration the COE (0.102).Wind energy based system connected to the grid and the hybrid energy sources connected to the grid are also viable solutions at the site, (COE 0.103 and 0.104 respectively). However, from the results, it is clear that the solar standalone system has the least initial and operating costs. At the selected site owing to more irradiance and comparatively lesser initial cost, solar energy seems as an attractive solution. From the results obtained it is found that there is an increase of nearly 97% in the Net Present cost savings by the usage of solar standalone system at the given site instead of a grid. Due to the very high initial cost of wind turbine and low wind velocities, standalone wind energy system has more economic implications and is not well suited for the given site. With the depleting resources of fossil fuels, increased usage of renewable energy sources will reduce the reliance on fossil

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fuels thereby counter balancing the high costs and deleterious effects associated with the fossil fuels. A hybrid system has helped handle the intermittencies. A hybrid system also seems a feasible option at the site with considerable savings at the site .A hybrid wind-solar system not connected to grid has a cost savings of 93% NPC compared to the only grid system. So in addition to the solar standalone system, the solar-wind hybrid system can also be a prudent one. The use of energy storage systems is also encouraged. It includes a storage medium and a conversion system and helps in developing a more reliable grid connected system. At higher efficiencies the energy can be captured and utilized during peak hours and outages using these system.

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