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Energy Savings by Installation of Solar Panels: A Mathematical Model

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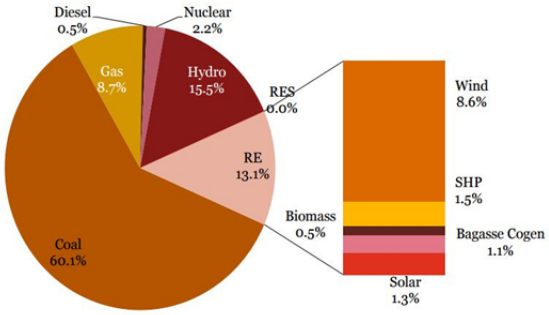
Abstract—*In this Research paper mathematical model was developed to install the Solar panels and new star rating appliances for saving of energy. For this the roof top was installed with the different types of solar panels and old appliances like Ac, Refrigerators was replaced with new technology star rated appliances. Water heater was replaced with the solar water heater, normal bulbs with led bulbs and normal glasses with Double glazed glasses for the windows and doors, the decision of installation which appliances at what cost was decided by using the linear programming. The data which was used for the calculation was collected from the dealers and some E-commerce websites. This model was applied to the two story building for analysis purpose. The budget was increased up to Rs2000000 the installation of solar panels was feasible choice. The results shows the replacing of old appliances with star rated appliances feasible when budget increases above 2000000 and in the case study of hospital the budget was feasible Rs 3500000 for long time investments.*

1. INTRODUCTION

India is the world's second most populous country after the People's Republic of China. India occupies 2.4 percent of the world's land surface area and is home to 17.5 percent of the world's population [1], for the developing countries like India the efficient use of energy is important.

After the china, USA and Russia, India is the largest Energy Consumer.[2] But Today, India is the fifth largest energy consumer in the world. While the world consumes 12000 million tonnes of oil equivalent (mtoe) of energy resources, India consumes 4.4% of the world total (524.2 mtoe). Global consumption of primary commercial energy (coal, oil & natural gas, nuclear and major hydro) has grown at a rate of 2.6%

Over the last decade. In India, the growth rate of demand is around 6.8%, while the supply is expected to increase at a compounded annual growth rate (CAGR) of only 1%.[3] The total primary energy consumption from crude oil (29.45%), natural gas (7.7%), coal (54.5%), nuclear energy (1.26%), hydroelectricity (5.0%), wind power, biomass electricity and solar power is 595 Mtoe in the year 2013[4].By the end of March 2015 as per MNRE CEA Statistics, the total installed capacity of 263.66 GW and RE capacity of 34.35 GW [5]



Source: MNRE,GoI; CEA statacics

Global solar of 177GW and india 11th with 3.3 GW.

To Reduce the Energy consumption and to save the Energy many Studies are Done by using different methods like Reduction of Energy Consumption using Modern Electronic System a study was done by Srabana (Pramanik & Tanmoy Chakraborty etl).[x] This paper has studied the role of air conditioning and lighting system in consumption of electricity of the faculty room (25‟ x 30‟) belongs to Electrical Engineering Department, Kalyani Government Engineering College and suggests the reduction of energy consumption. The reduction of energy consumption is a challenging job without curtailing the facilities. It is an endeavour to optimize the consumption utilizing the modern electronic system and similar study also done by Oum Kumari. R, Dipti [6]It has been from her Research work figured it out that most of the households are really not aware about the problems related to power and they are least bothered to conserve it.

To reduce power consumption R,Dipti was given a steps In the first step people should be primarily be Aware of regarding energy conservation techniques. Because of cheaper in cost of people are preferring the inefficient appliances than efficient one, to encounter this tax reduction and Subsidies are really help to promote the star rating appliances. And some Energy and also the Construction of green buildings have great impact in saving of energy. Similarly There have been a number of previous studies done on electricity consumptions like Fisher

and Kayson (1962) [7] from there studies the electricity consumption of USA, Residential electricity demand is direct proptional to the stock of appliances. Similar study by the Wilson [8] and Anderson [9] by using the cross sectional data between the household characteristics and price of electricity on the household consumption they concluded that price is the major determinate of electricity consumption. And a study by Parti and Parti in 1980 [10] by using regression analysis to disaggregate the total household consumption into appliance-wise consumption. In his doctoral thesis, Reddy in 1990[11] by using three different approaches on the residential electricity demand in the capital of Karnataka(Bangalore): He recognized that the appliance stock and appliance census approaches explained the end-use consumption of electricity much better than the engineering approach.

In power consumption offices and the retail sector are the most demanding energy consumers in the non-domestic building sector and it is over 50% of energy usage was for non-domestic buildings [13] the major electrical consumption in the buildings surveyed was for lighting, air-conditioning, plug loads and hot water [14].Most of the power consumed was by the office buildings for Reduce power consumption the optimal operation of office buildings is essential, this can be done by the robust energy monitoring and energy auditing systems[12].

However there have been studies that analysed electricity consumption in different buildings. However, most of the studies are done by using the monthly electricity bills because of lack of the technology development. [15]. The analysis done on the office buildings the results are different from the each other because of their different in terms of their design, construction, occupancy and activity which makes more difficult to analysis from each other. [16].

Developing and under-developed countries can either prepare their own norms or use international norms to evaluate the energy performance of buildings [17]

In the office most of energy consumption of Room was due to the glassed windows there have been several studies on the energy efficiency and cost analysis of different windows units. Sekhar et al. [18] presented a study in 1998; in his study he compared the different type of glasses for the energy performances and life cycle costs of the smart window [18].similarly a study of Bojic et al. [19] In high-rise residential buildings in Hong Kong in hot and humid climates for investigation the energy performances of multiple-glazing units And Karlsson et al. [20] published a study in 2001 in which they further developed a simple model for the annual energy balance of windows. To add this In 2004, Çetiner et al. [21] suggested an approach for evaluating energy and economic efficiency using different single- and double-glazing facade configurations in an office block. Gugliermetti et al. [22], in 2005, investigated the effect of reversible windows on the energy performance of a building. The investigated window was a double-glazing unit, where one layer is absorptive glass and the other is clear glass. Urbikain et al. [23] presented a study in 2009 in which the heating loads and energy savings of a residential building with different types of windows were obtained in three different ways. First, the energy lost through the window was evaluated, considering only the climatic conditions. Second, the window was evaluated by taking the energy used for the heating system, taking the climate and the type of building into account. Finally, different cases were simulated using TRNSYS16 and WINDOWS5.

Know a days to generate energy Renewable sources are preferring in which solar energy is the most preferred because of the from the past few years the unit cost of Renewable energy was falling down there is a feature predicting that it will decreases, because the day to day the efficiency of solar panels are increasing, the Indian government also providing a subsides on the solar panel installation.

This research paper was discuss the new approaches to save the Energy efficacy by installing the New star rated appliances for this lingo program is used to solve the set of linear Equations. By using the set of constraints like Area, Budget, and no of appliances.

For this ABC analysis was done on the used appliances and figured it out the most energy consuming appliances those are replaced with star rated appliances.

ABC analysis: ABC analysis divides an inventory into three categories- "A items" with very tight control, "B items" with less tightly controlled, and "C items" with the simplest controls.

ABC analysis was used to differentiate the appliance's which are most energy consuming , moderate and less consuming.

There is no fixed edge for each class, different percentage can be applied based on objective and criteria. ABC Analysis is similar to the Pareto principle in that the 'A' items will typically account for a large proportion of the overall value but a small percentage of number of items[24] Example of ABC class are

- 'A' items – 20% of the items accounts for 70% of the annual consumption.
- 'B' items - 30% of the items accounts for 25% of the annual consumption
- 'C' items - 50% of the items accounts for 5% of the annual consumption.

LINGO : is a comprehensive tool designed to make building and solving Linear, Nonlinear ,Quadratic, Quadratically Constrained, Second order cone, Semi-Definite, Stochastic and integer optimization models faster, easier and more efficient.[25]

2. METHODOLOGY

For the case study of the building the total no of electrical appliances used are considered and those are energy consumption was converted to the yearly and those are classified by using the ABC analysis the most energy consuming appliance's which comes under the category of A was considered for the analysis the details of the appliance's which are using in the blinding are shown in the table 1:

For the calculation of the power requirement of the washing machine and some instruments the which are not continuously used for that adjusted power requirement was calculated by using the formula as

P adjusted=

$$\frac{1000*actual\ energy\ consuption*no\ of\ times\ the\ machine\ (or)\ instrument\ was\ used\ in\ an\ year}{365*24}$$

Where the actual energy consumption was optioned from the manufacturer websites

Table 1: classification of Appliances

Appliance category	wattage	No. of Appliance	Total wattage(kw)	Classification depends on Energy consumption
AC	1500	5	3780	A
Room Heater	1000	6	3600	A
Refrigerator	1200	2	1747.2	A
100 watt incandescent bulb	100	14	1164.8	A
Air cooler	170	2	195.84	B
Water pump	750	2	821.25	B
Fan	100	6	492.48	B
Battery charger	15	12	321.93	B
Desktop Computer	120	1	249.6	B
Table lamp	40	2	35.04	C
Table fan	60	3	68.04	C
Vacuum cleaner	750	3	665.21	C
Television	100	1	78	C
Washing machine	325	1	77.74	C
Water heater	479	2	74.724	C
INSTRUMENT 1	500	1	195	C
INSTRUMENT 2	750	1	97.5	C
INSTRUMENT 3	1500	1	195	C

3. LINEAR PROGRAMMING MODEL:

The linear model which was created was solved by using the lingo program by using the constraints like as mentioned above.

$$Max\ z = (E_g * x) + (\sum_{i=1}^{n} E_{si} * si) + \sum_{i=1}^{n} (E_{ri} * ri) + \sum_{i=1}^{n} (E_{ai} * a) + \sum_{i=1}^{n} (E_{wi} * w) + (E_p * b)$$

$$(C_g * x) + (\sum_{i=1}^{n} C_{si} * si) + \sum_{i=1}^{n} (C_{ri} * ri) + \sum_{i=1}^{n} (C_{ai} * a) + \sum_{i=1}^{n} (C_{wi} * w) + (C_p * b) \leq M$$

$$\sum_{i=1}^{n} (S_i * a_i) + \sum_{i=1}^{n} (W_i * a_i) \leq f$$

$$\sum_{i=1}^{n} ri \leq e$$

$$\sum_{i=1}^{n} ai \leq j$$

$$\sum_{i=1}^{n} wi \leq k$$

$$b \leq p$$

$$g \leq s$$

E_g, Energy saved by replacing $1m^2$ normal glasses with double –glazed window. W

E_{si}, Electricity produced by installing solar panel of model i, W

E_p, Energy saved due to replacement of incandescent bulbs with led bulbs, W

E_{ri}, Energy saved by replacing old refrigerant with new Refrigerant i th star rated ac.

E_{wi}, Electricity saved by installing solar water heater panel of model i, W

C_g, Cost of $1m^2$ double –glazed windows.

C_{si}, Cost of solar panel of model i,

C_p, Cost of led bulb,

C_{ri}, Cost of refrigerator of i^{th} star rated model.

C_{wi}, Cost of solar water heater of model i,

X, y_i, z, r, p, t are non-negative

x, double-glazed window area

yi, the number of I th type photovoltaic solar panel to be purchased

z, number of incandescent light bulbs to be replaced with CFL bulbs

$$a = \begin{cases} 1 \text{ if old ac is replaced with the new star rated ac} \\ 0 \text{ otherwise} \end{cases}$$

$$r = \begin{cases} 1 \; if \; old \; refrizelator \; is \; replaced \; with \; the \; new \; star \; rated \; ac \\ 0 \; otherwise \end{cases}$$

$$w = \begin{cases} 1 \; if \; solar \; water \; want \; to \; be \; installed \\ 0 \; otherwise \end{cases}$$

This Research paper used linear programming technique for optimizing the allocation of budget to improve the energy savings in buildings in India. All the data regarding costs are collected from the local sources and from the internet. Know a days the buildings are constructed most of them are multi-storey apartments; we selected two-floor building for the case study. And it was assumed that single owner of the complete building because of it is easy to calculate energy savings for each house hold when it is compared with the multi households. And the total area of the roof top of buildings was known so that for the installation of solar plates can be done with in the available area. The windows area should be known so that the normal glass can be replaced with the double glazed windows. In our case study The building has two halls, eight rooms and four bath rooms. For lighting of rooms Sixteen100-w incandescent light bulbs are used.

Table 2: Details of a building

S. NO	Characteristics	Value
1	Total area available on roof,m^2	45m*45m
2	Total windows area,m^2	5m*6m
3	Total no of rooms(The building has two halls, eight rooms and four bath rooms)	14
4	Lighting requirement	16

Cost and energy savings:

In this case study the following methods are chosen to improve the energy conservation in a household.

- Installing solar photovoltaic modules
- Replacing normal glass with Double –glazed windows
- Replacing incandescent bulbs with led bulbs
- Replacing normal appliances with star rating appliances.

The Details of the solar photovoltaic modules & cost of the modules are optioned from the solar panel Dealer in Varanasi is shown in table2:

Table 3: Details of solar photovoltaic modules

Model	Solar Module(W)	Cost(Rs)	Area in mm2
T1	4 X 80Wp	69273	4*1060*540
T2	2 X 255Wp	1,09,349	2*1000*1667
T3	3 X 255Wp	1,59,450	3*1000*1667
T4	4 X 255Wp	1,79,254	4*1000*1667

The cost of the double-glazed window per m were obtained from the local manufacturer website [26].in Double glazed windows the thickness of the air will be changed as per Requirement and company standards of supply in this study it considered as the 10 mm and glass thick ness of 3 mm. the cost of the double glazed windows and installation cost was approximated Rs 650 per square feet. The energy calculation was done by considering the both conductive and convective heat transfer mechanism, radiation was neglected the performed calculations are given below:

$$Q = \frac{\Delta T}{\frac{1}{A}\left(\frac{1}{h} + \frac{d\ glass}{K\ glass} + \frac{d\ air}{k\ air} + \frac{d\ glass}{k\ glass} + \frac{1}{h}\right)}$$

d_{glass} , thick ness of the glass in m.

k_{glass}, thermal conductivity of glass layer, w/(m c)

d_{air}, thick ness of the air, m

k_{air} , thermal conductivity of air layer, w/(mc)

Q_{reg} : heat transfer flux through the regular window.

Q_{dg}: heat transfer flux through the double glazed window

Q_{save}: energy saved by installing double glazed window.

C_{dg} : combine cost of double glazed window & installation cost,

The average temperature of the Varanasi was considered as the 35C this data was optioned from the local websites. [27]. For the living purpose the room the temperature was considered as the 22C, the heat transfer coefficient and thermal conductivity was gathered from the available literate.[28]

The cost of the led bulbs are optioned from the online company website.[29] the power consumption by the led bulbs are 20w , where the incandescent bulbs will consume 100w the power savings was approximately equal to the 80w, the cost of the each led bulb was approximately Rs90.

The price & Energy consumed annually of the refrigerator, AC and solar water heater was optioned from the company's

websites [30][31] [32][33]. For the replacing old Ac & Refrigerator was replaced by the new star rating ac the details was mentioned in tables are shown in the table 4, Table 5& table 6.

Table 4: Star Rating and Energy consumed annually for 250 liter, frost-free refrigerator.

2014 star rating	Energy consumed annually (in kWh)	Energy saving with installed one(760.41)in in kWh	Cost of Ref	Energy savings in w
1	487.19	273.22	16333	31.18
2	389.54	370.87	22001	42.33
3	311.83	448.58	31150	51.20
4	249.27	511.14	38340	58.34
5	199.22	561.19	52364	64.06

Table 5: Star ratings and savings comparison for a 2tonne AC

2014 Star Rating	Energy Consumed in a month (in kWh)	Energy savings with installed one(672.00) (in kWh)	Energy savings with installed one for year (in kwh)	Cost of AC	Energy savings in W
1	622	49	298.68	38990	68.15068
2	579	92	556	44250	126.97
3	541	130	780.36	49999	178.08
4	509	162.	977.46	56325	221.91
5	480	192	1152	64521	263.01

Table 6: Details of the solar water heaters

Solar Water Heater	Cost	Dimensions	In mm	Kwh for year	Energy savings in W
150 Lit	25,500	10 Feet X Width 3.5 Feet	3048*1060	1107.7	126.36
250 Lit	35,000	10 Feet X Width 7.5 Feet	3048*2280	1846.16	210.74
300 Lit	45,000	Length 10 Feet X Width 12 Feet	3048*3650	2215.4	252.89
500 Liter	65,000	Length 10 F X Width 15 F	3048*4520	3692.33	421.46

By using the above technical data and price the linear program was solved by using the different budget the results was shown in the table 7& table 8

Where:

Si: solar module of type Ti.

Ri: No of normal refrigerators replaced with the star rating of refrigerator i,

Ai: No of normal Ac replaced with the Star rating of ac, i.

G: area of the normal glass replaced with double glazed glass (m).

B: No of normal bulbs replaced with LED.

Hi: No of solar water heater installed on roof top of model i

Table 7: Low budget with respective Energy savings

Budget (Rs)	S1	S2	S3	S4	R1	R2	R3	R4	R5	A1	A2	A3	A4	A5	H1	H2	H3	H4	B	G	Energy savings (W)
100000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	15	24	8447
300000	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	15	24	9586
500000	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	15	24	10724
700000	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	15	24	11862
900000	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	15	24	13000
1100000	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	15	24	14138
1300000	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	1	15	24	15276
1500000	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	1	15	24	16414
1700000	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	1	15	24	17552

Table 8: Budget with respective Energy savings

Budget	S1	S2	S3	S4	R1	R2	R3	R4	R5	A1	A2	A3	A4	A5	H1	H2	H3	H4	B	G	Energy savings(w)
2000000	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	1	0	1	15	24	19256
2500000	0	0	0	12	0	0	0	0	0	0	0	0	0	2	0	1	0	0	15	24	21773
3000000	23	0	0	5	0	0	0	0	2	0	0	0	0	4	0	1	0	0	15	24	22248
3500000	40	0	0	0	0	0	0	0	2	0	0	0	0	4	0	1	0	0	15	24	22268
4000000	40	0	0	0	0	0	0	0	2	0	0	0	0	4	0	1	0	0	15	25	22268
4500000	40	0	0	0	0	0	0	0	2	0	0	0	0	4	0	1	0	0	15	25	22268

By installing the solar plates and changing the appliance's according to the available budget the energy was saved in watts is shown above the table by using the saved energy which was convert into the yearly savings and multiple by the unit cost we will get the savings per year in this calculations the cost of unit was assumed to be Rs4, and the energy savings for a year was shown in the below tables9 for the less investment and table10 for the high investment

Table 9: Income expected to generate with years for high investment

Budget (Rs)	Revenue generated in 1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year
2000000	672881	1345763	2018645	2691527	3364408	4037290	4710172	5383053	6055935	6728817
2500000	760835	1521671	2282507	3043343	3804179	4565014	5325850	6086686	6847521	7608357
3000000	777434	1554868	2332302	3109736	3887171	4664605	5442039	6219473	6996907	7774341
3500000	778132	1556266	2334399	3112532	3890665	4668798	5446931	6225064	7003197	7781330
4000000	778132	1556266	2334399	3112532	3890665	4668798	5446931	6225064	7003197	7781330
4500000	778132	1556266	2334399	3112532	3890665	4668798	5446931	6225064	7003197	7781330

Table 10: Income expected to generate with years for less investment

Budget (Rs)	Revenue generated 1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year
100000	295171	590343	885515	1180688	1475860	1771032	2066204	2361376	2656548	2951720
300000	334973	669946	1004920	1339893	1674866	2009839	2344812	2679785	3014759	3349732
500000	374739	749478	1124218	1498958	1873697	2248437	2623176	2997916	3372655	3747395
700000	414505	829011	1243517	1658023	2072529	2487034	2901540	3316046	3730552	4145057
900000	454272	908544	1362816	1817088	2271360	2725632	3179904	3634176	4088448	4542720
1100000	494038	988076	1482115	1976153	2470191	2964230	3458268	3952306	4446344	4940383
1300000	533804	1067609	1601414	2135218	2669023	3202827	3736632	4270436	4804241	5338045
1500000	573570	1147142	1720712	2294283	2867854	3441425	4014996	4588567	5162137	5735708
1700000	613337	1226674	1840011	2453348	3066685	3680023	4293360	4906697	5520034	6133371

4. CONCLUSION

After analyzing the data the budget 3500000 was optimal decision point to investment. Because after that investment of money was not profitable the energy savings was saturated at that point. For the optimum budget we have to install s1 model solar plates 40 no's should be installed and 5 star rating refrigerators two and 5 star rating ac 4 and

Water heater of model 2 with one number, bulb 15 and complete normal glass area should be replaced with double glazed glass.

Future scope:

In this Research paper calculation of income the unit cost of electricity was fixed by making the unit cost variable the results will be accurate.

The efficiency of the appliance's assumed to be constant for all years. By considering these two new variables a set of equations can me made which gives the accurate results.

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