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Optimization of Organizational Energy using Linear Programming

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ABSTRACT: Linear programming (L.P) method is applied to optimize energy consumption within an organization. Three parameters are chosen for energy conservation, namely changing of normal window to double glazed or triple glazed window, installation of Solar Panels, replacing of Fluorescent tube lights with LED tube lights. Optimize use of these parameters will results in saving of good amount of energy which will save our money. The cost for various equipment such as compact fluorescent light bulbs, LED bulbs, double glazed and triple glazed window and solar panels are taken from manufacturer website. The project provides the optimized solution for three ranges of budgets viz. Low, Medium and high. The project also provides the recovery period or payback period for the investment being done.

Keywords: Linear programming, double glazed windows, solar panels, payback period

I. INTRODUCTION

Energy can be defined as one of the most basic and the most important part of our universe. We require energy to do work, energy lights our cities and surrounding's. Energy powers our transportation modes like vehicles, trains, airplanes and rockets etc. Energy gives us pictures on television, warms our houses, plays our music, and cooks our food. Energy is the basic entity which powers up machineries in factories. Energy is defined as "the ability to do work." When we eat food, our body transforms this food into energy which is used to do work. When we run or walk, we "burn" this energy which we get from food. Even when we think, read or write, we are also doing work. Cars, planes, boats, trolleys and various machinery also transforms the energy into useful work. Work is said to be done when something moved or lifted, some temperature is raised, or in lighting. All these are some of the various form of work. But do we know that where does this energy come from? There are various sources of energy. Energy is a fundamental part of our day to day lives. The various forms of energy we use daily are Fossil Fuels like Coal, Oil and Natural Gas Hydro Power and Ocean Energy, Nuclear Energy, Solar Energy, Wind Energy. Some of the forms of energy we can use are called renewable energy. The renewable energy may include wind, solar, geothermal or hydro energies as these types of energies are constantly renewed or regenerated. But there are many other forms of energy that we use in our homes and cars which are not being restored. Fossil fuels takes millions of years to form, they cannot be made in short time and therefore are finite. Once they are gone we are not able to use then again. So, we must all do our part in saving as much energy as we can. Mostly all these form of energies are converted in to electricity and then sent to users for commercial and residential applications. In our homes, we can save this electrical energy by turning off the appliances that are not in use. We can turn off lights when they are not in use. By putting insulation in walls and windows, we can restrict the heat entering the amount of energy consumed can be reduced.

Energy saving refers to a decrease in the amount of energy used by some method or technology, while achieving a very similar outcome of end use. Saving energy has many advantages like we can save money and protect our environment from further degradation. Generation of electric energy requires exploitation of viable natural resources, for instance coal, oil or natural gas. Therefore, by using less amount energy and by preserving these resources we can make them last longer in the future.

Problems that we have to focus on, regarding to the context of Energy saving are-

1. How to make the optimum uses of energy that we are extracting from non- renewable sources and that too at maximum efficiency.
2. Along with optimum utilization of non-renewable resources, How to utilize renewable sources or alternative sources of energy.

3. Also get the investment back in doing the above two point i.e. calculating the payback or recovery period.

Solution to second problem will lead to the energy alternatives that emphasize on energy quality and that too in a renewable, flexible and more environmental friendly way. In conjunction to finding alternative sources to energy requirements there is a strong need to move forward to energy management. Concept of energy management shows that no single energy source can possibly fulfill all the energy requirements. Thus, the basic goal of the energy management is to obtain sustainable energy and to lay down various combinations of measures for the conservation of energy. Energy conservation or saving is regarded as a fast and much economical way to solve the energy shortage and also as a means of conserving the finite energy source. Energy conservation methods are cost effective and economical because of less initial investment and usually tend to have short pay back periods. As per the study conducted by Energy Management Centre, New Delhi, it has been indicated that there is almost 25% potential of energy conservation or saving in the commercial/ industrial sector.

II. EXPERIMENTAL SETUP AND PROCEDURE

Building specifications: We are considering a single story building having 10 rooms of dimension 5.5m X 5.5m, total area of 300m^2. Further specifications are as follows:

Table 1: Building Specifications.

Building Specification	Quantity
Total base area,m^2	300m^2(11mx27.5m)
Total floor area for solar panel installation, m^2	150m^2
No of Windows in the building (size-1.52mX1.83m)	30 (2.8m^2 each)
Rooms in the building (size- 5.5mX5.5m)	10 (30m^2 each)
Light required	40 x 28W fluorescent tube lights(T5)

The project is working on the following parameters:

- Changing of normal window to double glazed or triple glazed window.
- Installation of Solar Panels.
- Replacing of Fluorescent tube lights with LED tube lights.

Energy saving in double glazed window

Heat flux via double glazed window can be calculated as [25]:

$$Qd = \frac{\Delta Ta}{\frac{1}{As}\left(\frac{1}{ha}+\frac{dg}{kg}+\frac{da}{ka}+\frac{dg}{kg}+\frac{1}{ha}\right)}$$

……..…….....*eq.1*

Table 2: Energy saving values in double glaze window.

ΔT_a (°c)	h_a w/(m^2-°c)	d_g (m)	k_g w/(m-°c)	d_a (m)	k_a w/(m-°c)
15	50	0.006	0.78	0.012	0.026
Q_r (w/m^2)	Q_d (w/m^2)	Q_{sd1} (w/m^2)	Q_{sd} (w/2.8m^2)	C_d (₹)	
272.7	29.01	243.7	682.4	36120	

Where,

$Q_{d,}$ heat transfer by double glazed window, W

$\Delta T_{a,}$ temperature difference of inner and outer side during winter, °C

$A_{s,}$ surface area of double glaze window, m^2

$h_{a,}$ heat factor of air, W/(m^2-°c)

$d_{g,}$ width of glass layer, m

$k_{g,}$ temperature conductivity of glass, W/ (m- °C)

$d_{a,}$ layer thickness of air, m

$k_{a,}$ temperature conductivity of air, W/ (m- °C)

$Q_{r,}$ heat dissipation by regular window

$Q_{sd1,}$ Energy savings after installation of double glaze window per m^2, Q_{rg}-Q_d

$Q_{sd,}$ Energy savings after installation of one double glaze window (size 2.8m^2)

$C_{d,}$ Complete cost of double glaze window of standard size.

Table 3: Summarized Energy saving and installation cost of various parameters.

Parameter	Energy Saving(watts)	Installation cost
LED tube light	10W	₹550/-
Double Glazed Window	682.4W	₹36120/-
Triple Glazed Window	721.2W	₹42168/-
Solar panel	100W	₹8500/-

Table 4: Various variables used in the LP model.

Parameter	Decision Variables	Cost	Energy saving
LED tube light	X_l	C_l	Q_{sl}
Double Glazed Window	X_d	C_d	Q_{sd}
Triple Glazed Window	X_t	C_t	Q_{st}
Solar panel (Type A)	X_s	C_s	Q_{ss}

Formulation of LP problem

Parameter to be maximized is Energy Saving, *S*

$MAX\ S = (Q_{sl} \times X_l) + (Q_{sd} \times X_d) + (Q_{st} \times X_t) + (Q_{ss} \times X_s)$

……..…….. *eq 2*

Constraints:

1) Budget, B : $(C_l \times X_l) + (C_d \times X_d) + (C_t \times X_t) + (C_s \times X_s) < B$ *.....eq 3*
2) No of LED tube lights, X_l: $X_l < 40$ *……..eq 4*
3) No. of windows , $X_d + X_t$: $X_d + X_t < 30$ *……..eq 5*
4) Solar Panel Area, A : $0.75X_s$ <150 *...……...eq 6*

Payback period

Payback period is the time required to get the investment back as profit or saving. Power saving is converted into cost saved in rupees in one year. Payback period is calculated in years

- For converting kW to W we have multiplied by 1000.
- B is the budget in ₹
- 365 and 24 indicates the number of days in a year and hour in a day.
- S represents energy saving in W, and
- ₹ 4.4 is price of one unit of power in ₹ /kWh, as per UPCL

$$P = \frac{1000 \times B}{365 \times 24 \times S \times ₹4.4/kwh}$$

…….....*eq. 7*

III. RESULT AND DISCUSSION

Table 5: Optimized results for medium budgets (₹00000 to ₹200000).

Budget (₹)	LED lights (no.)	Double glazed window (no.)	Triple glazed window (no.)	Solar panel	Energy saving (W)
B	X_l	X_d	X_t	X_s	S
700000	24	19	0	0	13198
800000	9	22	0	0	15094
900000	40	24	0	1	16868
1000000	40	27	0	0	18814
1100000	29	30	0	0	20750
1200000	40	30	0	11	21960

Optimized result can be found by installing the following parameters:

1) Installing 40 LED tube lights.
2) Installing 30 double glazed windows.
3) Installing 11 Solar panels i.e 1100W of solar panels.
4) Saving - 21960W
5) Budget - ₹ 1200000

Table 6: Optimized results for high budgets (₹ 1300000 to ₹ 1800000).

Budget (₹)	LED lights (no.)	Double glazed window (no.)	Triple glazed window (no.)	Solar panel	Energy saving (W)
B	X_l	X_d	X_t	X_s	S
1300000	38	30	0	23	23140
1400000	34	30	0	35	24300
1500000	30	30	0	47	25460
1600000	40	30	0	58	26660
1700000	38	30	0	70	27840
1800000	35	30	0	82	29010

Optimized result can be found by installing the following parameters:

1) Installing 35 LED tube lights.
2) Installing 30 double glazed windows.
3) Installing 82 Solar panels i.e. 8200W of solar panels.
4) Saving – 29010W
5) Budget - ₹ 1800000

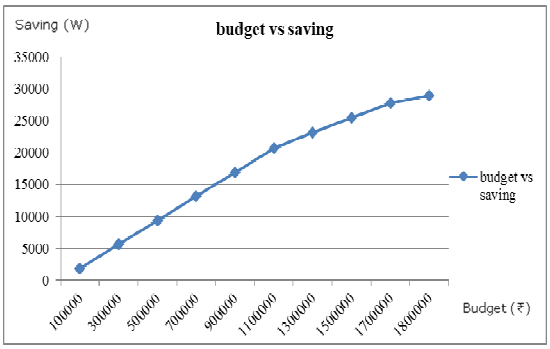

Fig. 1. Graph between Budget and Energy Savings.

Table 7: Payback Period for different ranges of Budgets.

BUDGETS, B (₹)	ENERGY SAVING,S (W)	PAYBACK PERIOD, P(YEARS)
100000	1814	1.43
300000	5656	1.38
500000	9356	1.39
700000	13198	1.38
900000	16868	1.38
1100000	20750	1.38
1300000	23140	1.46
1500000	25460	1.53
1700000	27840	1.58
1800000	29010	1.61

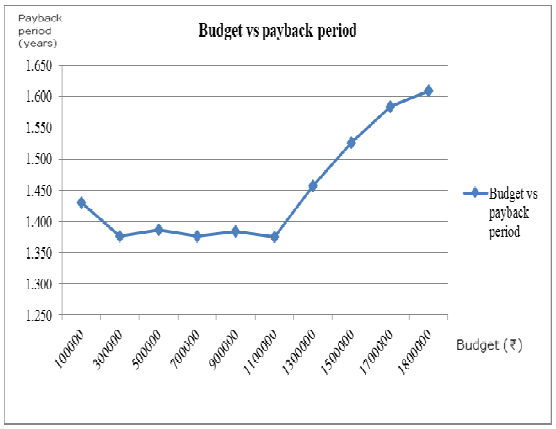

Fig. 2 Graph between Budget and Payback Period

IV. CONCLUSION

- Purchasing double glaze window and replacing CFL lights to LED lights is an optimum choice for low budget, as they have low cost as compared to other techniques.
- In the results we see that double glazed window is better option than triple glazed window when price and energy saving is considered, therefore we are not getting optimize result with triple glazed window in any of the budget range.
- Installation of solar panels along with double glazed window is an optimum choice for medium and high budget range as they are costly.
- In the given problem we are getting the maximum energy savings as 11312W, 21960W and 29010W for low, medium and high budget respectively.
- As we see the graph between budget and saving, we can say that as the budgets is increased saving also increases and we get maximum saving for highest budget.
- Payback period is almost same ie. 1.38 years for the budgets ranges from 300000 to 1100000 and payback period increases as the budget is increased above this.
- We can modify this project by taking another building or different climatic condition. In that case final results will vary due to different value of constraints.
- We can also apply the concept of double glaze window for the insulation purpose of vehicles. As we see that our car got heated when it is in contact with direct sunlight. By using double glazed window in place of normal window in cars we can restrict the heat entering in it which will result less consumption of air conditioning as hence the fuel economy can be improved.

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