# Formulation Of Energy Efficient Design Stratergies For Retrofitting Of Hotel Building

## *Case of Orchid Hotel, Pune*

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**ABSTRACT**

*Retrofitting of existing building gives an opportunity to upgrade the energy performance of commercial building assets for their ongoing life. Often energy retrofit involves modifications to existing commercial buildings that either improve energy efficiency or decrease energy demand.*

*Energy-efficiency retrofits can reduce the operational costs, particularly in older commercial buildings. Existing commercial buildings account for most of the energy used in the building sector, as compared to new buildings that are designed as per NGT norms. Therefore, it is important to retrofit existing buildings to increase energy savings. This research is an effort to propose energy efficient retrofitting for existing hotel building with thrust on environmental and architectural aspects.*

***Keywords:*** *Retrofitting, energy consumption, energy efficiency of building, hotel building, passive and active design strategies.*

## I. INTRODUCTION

Hotel buildings are an assembly of varied functions and spaces which have significant energy usage. It is a public, commercial space which has considerable impact on site surroundings and environment. The proposal is an attempt to upgrade existing commercial building for its energy efficiency, by simple retrofitting techniques. There are no mandatory EC norms to introduce and enhance energy compliance in existing buildings. Through this research, author proposes few key retrofit techniques that can be adapted in most of the commercial, hospitality buildings and campus.

Aim of the research paper is to enhance energy efficiency of a hotel building by retrofitting techniques and propose appropriate energy efficient design strategies of retrofitting.

## Retrofitting

Retrofitting is an addition of new technologies to old structures.

To retrofit a building means to put new components or new equipment in it after it has been in use for some time, especially to improve its functionality, aesthetics or make it work better. A change in design or construction as of a building already in operation, in order to incorporate later improvements. Energy-efficiency retrofits can reduce the operational costs, particularly in older buildings, as well as help to attract tenants and gain a market edge.

Existing buildings account for most of the energy used in the building sector, as compared to new buildings use only a small percentage of energy. The energy use in commercial buildings is predicted to increase every year for at least two decades. Therefore, it is important to retrofit existing buildings to increase energy savings. Retrofit of existing buildings represents an opportunity to upgrade the energy performance of commercial building assets for their ongoing life.

Often retrofit involves modifications to existing commercial buildings that may improve energy efficiency or decrease energy demand.

In addition, retrofits are often used as opportune time to install distributed generation to a building.

## Hotel

Hotels vary in their typologies, forms and size. Design and Utility of hotel buildings is a key quotient for it to function for long time.

A hotel building must balance functional, layout, and aesthetic issues to develop a property that simultaneously meets the needs of the guests, the staff, and the owner.

For example, star properties have public areas that are heavily design oriented, with the functional aspects carefully integrated to enhance, but do not dominate the space.

Budget properties tend to favor function and layout over design, for maximum utility.

A good hotel design is one that inspires; is safe, efficient, and cost effective; and that maintain their utility and charm through time.

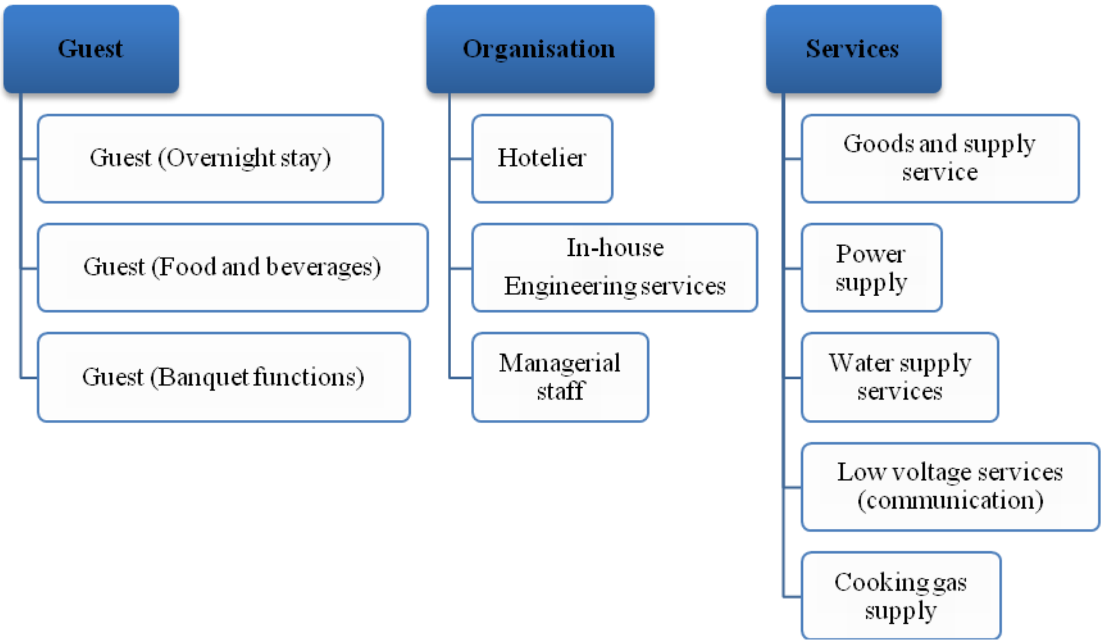
Special architectural conditions and needs are common in almost all Hotels. The main retrofit drivers are:

Reduce the energy consumption of building

Improve the indoor environmental quality and functionality, to enhance the guest experience

Optimize the building operation and relative maintenance costs.

Fig.1: Hierarchy list-Primary considerations for energy consumption in hotel




NGT guidelines, initially, were loosely followed by construction industry; resulting into low performance of building over the years. In the year 2006, NGT rules and regulation became mandatory for every building. Hence newly sanctioned buildings are compliant to NGT norms leaving aside the older buildings. There has been a strong push given to the similar researches in recent years considering the need of improving building performance by retrofitting.

The main objective of this research paper is to provide readers with a pragmatic design reference manual for the design and implementation of some of the most commercially viable alternative energy technologies. In view of the unprecedented worldwide demand for solar power cogeneration systems, this book has extensive coverage of solar physics, associated technologies, and pragmatic design guidelines for professionals who must assume responsibility for all aspects of a solar power project design. Design guidelines discussed in the book reflect my personal experiences as a consulting engineer and educator.

The project follows mixed methodology of research with conscious effort to propose design strategies under constructivist paradigms. The concept development is based on qualitative data, whereas, conclusions and recommendations are supported with quantitative analysis.

## II. OBSERVATIONS

Two hotels are located mirroring, the L shaped doubly loaded plan. The mirrored geometry allows formation of an open court at the center. The prevailing wind direction allows free wind movement through central open court, which creates the opportunity to implement passive strategies. Kitchen and service area placed at the lowermost level of building. To reduce direct heat gain, earth berming is done. Swimming pool placed at the convention at center of courtyard that provides passive cooling in courtyard spaces and also acts as a buffer between banquet hall below to the direct heat gain from sunlight above. Window - DGU glass used for resisting heat gain. Window – Frames are sandwiched with heat insulating material to reduce heat gain. Exterior of building is cladded with Argeton tiles: which is three-layer sandwich tiles reducing heat gain.

Connected load calculation and lighting power density for standard room is 30 % greater in 2007 than current practice. Pumps and motors for Plumbing, HVAC, gardening purposes are also old IE2 confrigation and no VFD (variable frequency drive) observed. Conventional methods such as AHU Chillers Pumps for HVAC systems are used. Hotel consists of no star rated fittings as it also results in more consumption than standard star rated equipment. Site includes STP installation for water recycling which supports secondary purposes like gardening, washing, etc.

## III. ANALYSIS

Reduction in energy consumption being thrust of the research, analysis of key energy requirement is targeted. The energy requirement of Hotel building comprises majorly of its lighting, HVAC and MEP services. The energy retrofitting gives the scope of up-gradation in these existing services. Basis of analysis is climatic data of the site and design standards of selected hotel building.

### 1) Argeton Tile

Hotel building demands of specific indoor climate to be maintain as per user comfort level hence cooling load in such building becomes crucial and more energy is required to maintain the indoor climate. In chosen cases design indoor temperature is 22 degrees for which HVAC loads are follows.

Table 1: Required TR load to achieve desire indoor comfort.

| **Design Criteria for HVAC calculation** | | | |
|---|---|---|---|
| The basis of design for Air-conditioning will be as follows: | | | |
| | Summer | Monsoon | Winter |
| Design Outside | 40.0° C DB | 28.3° C DB | 10.0° C DB |
| | 24.4° C WB | 26.1° C WB | 5.6° C WB |
| Design Inside | Summer 22° C DB & RH not exceeding 65% | | |

Increase in cooling load directly affects increase in energy consumption. To reduce energy consumption, reduction in heat gain is an effective strategy. Wall cladding with very low transmittance (u value) is effective solution to lower down direct heat gain. Argeton tile, cladded externally to building façade reduces direct heat gain resulting into lower cooling load on the HVAC system.

A comparison of transmittance of conventional AAC concrete wall and Argeton cladded wall is given to check the effectiveness of Argeton tile cladding. U-Value of Argeton tiles cladded Wall is 1.33 W/m.K. and U-Value of conventional AAC Wall-2.31W/m.K. For study purpose Opaque assembly maximum U-factor ecbc compliant building is 0.40 for Hot and Dry climate.

A comparative analysis of TR load is given to check the reduction in cooling load of the hotel building before and after installation of argeton tile cladding. Table 1 shows prior cooling loads whereas, Table 2 shows revised TR load to achieve desire indoor comfort for (Argeton tile) cladded wall.

Table 2.1: U-Value Calculation Of Argeton Tiles Cladded Wall

| | | | |
|---|---|---|---|
| **U-value calculation of Argeton tiles cladded wall** | | | |
| U-value = thermal transmittance | | | |
| U-value = 1 / sum of thermal resistance of each layer | | | |
| U-value = 1 / R Argeton tile+ R air space+R plaster+ R block + R plaster + Rsi | | | |
| **R -Value and U-factor Calculations for Cavity Wall Construction** | | | |
| Argeton tiles | | 35 mm | |
| Air Gap | | 100 mm | |
| External Plaster | | 15 mm | |
| Lightweight concreate block wall | | 150 mm | |
| Internal Plaster | | 15 mm | |
| | | | |
| R value = | | | R1 + R2 + R3.... |
| | | | |
| **Materials of wall** | **Thickness ( mm )** | **Conductivity (W/m.K)** | **Resistance (W/m2 k)** |
| Argeton tiles | 35 | 0.02 | 0.23 |
| Air Gap | 100 | | 0.048 |
| Lightweight concreate block wall | 150 | 0.57 | 0.38 |
| External Plaster | 15 | 0.18 | 0.026 |
| Internal Plaster | 15 | 0.18 | 0.026 |
| | | | |
| Total thickness of wall | 315 | Total resistance | 0.71 |
| | | | |
| | | | |
| 1 / sum of thermal resistance of each layer | | | |
| U-value = thermal transmittance | | | |
| **U-value = 1.33 W / m. K** | | | |
| For study purpose Opaque assembly maximum U-factor ecbc compliant building is 0.40 for Hot and Dry climate. | | | |

Table 2.2: U-Value Calculation Of conventional Wall

| | | | |
|---|---|---|---|
| **U-value calculation of wall** | | | |
| U-value = thermal transmittance | | | |
| U-value = 1 / sum of thermal resistance of each layer | | | |
| U-value = 1 / R Argeton tile+ R air space+R plaster+ R block + R plaster + Rsi | | | |
| **R -Value and U-factor Calculations for Cavity Wall Construction** | | | |
| External Plaster | | 15 mm | |
| Lightweight concreate block wall | | 150 mm | |
| Internal Plaster | | 15 mm | |
| | | | |
| R value = | | | R1 + R2 + R3.... |
| | | | |
| **Materials of wall** | **Thickness ( mm )** | **Conductivity (W/m.K)** | **Resistance (W/m2 k)** |
| Lightweight concreate block wall | 150 | 0.57 | 0.38 |
| External Plaster | 15 | 0.18 | 0.026 |
| Internal Plaster | 15 | 0.18 | 0.026 |
| | | | |
| Total thickness of wall | 180 | Total resistance | 0.432 |
| | | | |
| U-value = 2.31 W / m.K | | | |
| 1 / sum of thermal resistance of each layer | | | |
| U-value = thermal transmittance | | | |
| **U-value = 2.31 W / m. K** | | | |
| For study purpose Opaque assembly maximum U-factor ecbc compliant building is 0.40 for Hot and Dry climate. | | | |

Table 3.1: Preliminary cooling loads

| | | Orchid | Vits |
|---|---|---|---|
| 1) | Lower ground Floor | 48.4TR | 62.1TR |
| 2) | Ground Floor | 135.1TR | 46.3TR |
| 3) | First Floor | 77.0TR | 59.0TR |
| 4) | 7 Guest Floors | 341.0TR | 333.0TR |
| 5) | Terrace Floor | 16.6TR | 12.5TR |
| | Aggregate | **618.1TR** | **512.9TR** |
| | | **Total** | **1131 TR** |

Table 3.2: Revised cooling loads

| | | Orchid | Vits |
|---|---|---|---|
| 1) | Lower ground Floor | 33.52 TR | 43.47TR |
| 2) | Ground Floor | 94.47TR | 32.41TR |
| 3) | First Floor | 53.9TR | 41.3TR |
| 4) | 7 Guest Floors | 238.7TR | 233.1TR |
| 5) | Terrace Floor | 11.62TR | 8.75TR |
| | Aggregate | **432.2TR** | **359.1TR** |
| | | **Total** | **791.3 TR** |

The comparitive charts show a significant difference in cooling loads under two different cases. Reduction in cooling load causes decrease in energy required for HVAC systems.

By addition of Argeton tile cladding as a means of lowering direct heat gain, **TR load upto is reduced to 30%.**

Strategy ensures minimal retrofitting to the building and efectively serves to cater the reduction in energy consumption.

**2) Efficient Pumping**

Hotel building requires of demand of water and water cycle dependent process 24 hour in building, therefore STP,. Hence pumping is continuous process and no of pumps are used in building. In chosen cases it is observed that IE2 and IE1 specification pumps are in use.

Which need to be upgraded in maintenance.

Hotel building has an extensive network of plumbing and water supply systems. Water demand of the building includes hot water availability, HVAC chiller plant, gardening and landscape maintenance, fire ducts, swimming pools, water recycling, STP, etc. Pumping system being primary to cater all such demands, is targeted to be upgraded and revised.

In selected case of Orchid Hotel, IE1 and IE2 pumps are installed. The pumps are recommended to be upgraded with more efficient IE3 and IE3+ pumping system that is more effective and reduces the energy consumption.

**Key Features For Efficient Motors Pumping:**

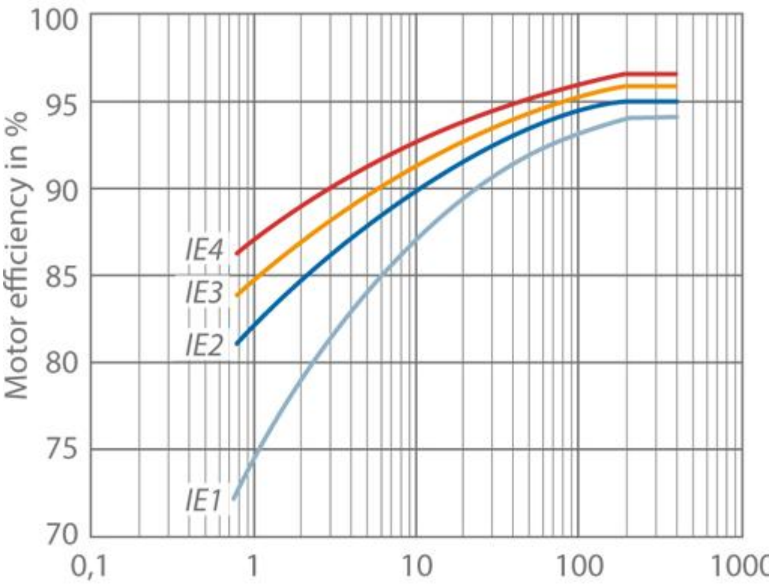
- IE2 motors: High efficiency motors
- IE3 motors: Premium efficiency motors

  (IE stands for International efficiency)

A comparative analysis of motors with IE2 and IE3 standards is given to show the efficiency of pumping system. The replacement of motors of IE2 standards by motors of IE3 standards shows **increase in efficiency upto 4-5%** which results into less consumption of energy for pumping.

*Refer chart for Comparison Of Efficiency Between IE2 And IE3 Motors.*

Fig. 2: Graphical Representation For Pumping Efficiency:




Below efficiency class motors are in accordance with the standards IEC 60034-30:2008 and IS12615: 2011. These standards defines efficiencies for Motors upto 6 Poles This standard supersedes all other previous standards in which stray losses was assumed to 0.5%, now instead they are determined by taking measurements.

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Table 4 : Comparison Of Efficiency Between IE2 And IE3 Motors

| kW | | 2-Pole | | | 4 Pole | | | 6 Pole | |
|---|---|---|---|---|---|---|---|---|---|
| | Frame | Efficiency % | | Frame | Efficiency % | | Frame | Efficiency % | |
| | | IE2 | IE3 | Size | IE2 | IE3 | Size | IE2 | IE3 |
| 0.37 | 71 | 72.2 | 75.5 | 71 | 70.1 | 73 | 80 | 69 | 71.9 |
| 0.55 | 71 | 74.8 | 78.1 | 80 | 75.1 | 78 | 80 | 72.9 | 75.9 |
| 0.75 | 80 | 77.4 | 80.7 | 80 | 79.6 | 82.5 | 90S | 75.9 | 78.9 |
| 1.1 | 80 | 79.6 | 82.7 | 90S | 81.4 | 84.1 | 90L | 78.1 | 81 |
| 1.5 | 90S | 81.3 | 84.2 | 90L | 82.8 | 85.3 | 100L | 79.8 | 82.5 |
| 2.2 | 90L | 83.2 | 85.9 | 100L | 84.3 | 86.7 | 112M | 81.8 | 84.3 |
| 3.7 | 100L | 85.5 | 87.8 | 112M | 86.3 | 88.4 | 132S | 84.3 | 86.5 |
| 5.5 | 132S | 87 | 89.2 | 132S | 87.7 | 89.6 | 132M | 86 | 88 |
| 7.5 | 132S | 88.1 | 90.1 | 132M | 88.7 | 90.4 | 160M | 87.2 | 89.1 |
| 11 | 160M | 89.4 | 91.2 | 160M | 89.8 | 91.4 | 160L | 88.7 | 90.3 |
| 15 | 160M | 90.3 | 91.9 | 160L | 90.6 | 92.1 | 180L | 89.7 | 91.2 |
| 18.5 | 160L | 90.9 | 92.4 | 180M | 91.2 | 92.6 | 200L | 90.4 | 91.7 |
| 22 | 180M | 91.3 | 92.7 | 180L | 91.6 | 93 | 200L | 90.9 | 92.2 |
| 30 | 200L | 92 | 93.3 | 200L | 92.3 | 93.6 | 225M | 91.7 | 92.9 |
| 37 | 200L | 92.5 | 93.7 | 225S | 92.7 | 93.9 | 250M | 92.2 | 93.3 |
| 45 | 225M | 92.9 | 94 | 225M | 93.1 | 94.2 | 280S | 92.7 | 93.7 |
| 55 | 250M | 93.2 | 94.3 | 250M | 93.5 | 94.6 | 280M | 93.1 | 94.1 |
| 75 | 280S | 93.8 | 94.7 | 280S | 94 | 95 | 315S | 93.7 | 94.6 |
| 90 | 280M | 94.1 | 95 | 280M | 94.2 | 95.2 | 315M | 94 | 94.9 |
| 110 | 315S | 94.3 | 95.2 | 315S | 94.5 | 95.4 | 315M | 94.3 | 95.1 |
| 125 | 315M | 94.5 | 95.3 | 315M | 94.6 | 95.5 | 315M | 94.4 | 95.2 |
| 132 | 315M | 94.6 | 95.4 | 315M | 94.7 | 95.6 | 315L | 94.6 | 95.4 |
| 160 | 315L | 94.8 | 95.6 | 315L | 94.9 | 95.8 | 355M | 94.8 | 95.6 |
| 200 | 315L | 95 | 95.8 | 315L | 95.1 | 96 | 355M | 95 | 95.8 |
| 250 | 355M | 95 | 95.8 | 355M | 95.1 | 96 | 355L | 95 | 95.8 |
| 315 | 355L | 95 | 95.8 | 355L | 95.1 | 96 | 355L | 95 | 95.8 |

### 3) Rooftop Solar Power

Since energy demand is growing at a very fast pace, the fossil fuel resources are depleting rapidly. Hence to ensure growth renewable resources has to be used to meet the energy demands. Since electricity expenses are increasing rapidly, Solar Energy is the ultimate solution.

206671 kw Jan and 196505 kw Feb are current billed readings from Orchid Hotel. Considering high demand in

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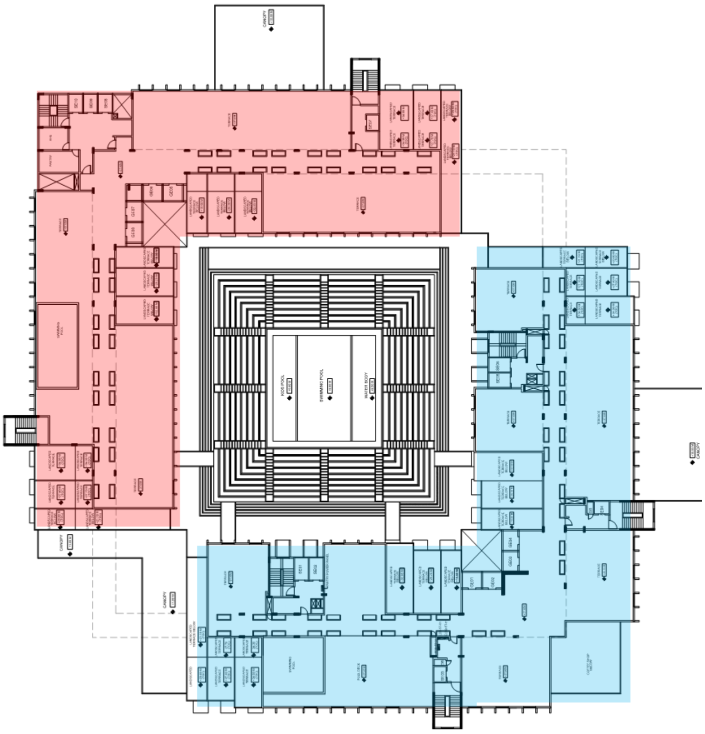
summers and gradual decrease demand in Mansoon and Winter **1950000 kw is average annual energy demand** of hotel.

Vits Hotel Wing



Orchid Hotel Wing

Fig. 3: Terrace floor Plan

Terrace area available above Vits Hotel wing is 1130 sq.m Therefore annual solar power generation possible is 129250 kw.

Terrace area available above Orchid Hotel wing is 1400 sq.m Therefore annual solar power generation possible is 159500 kw.

(Terrace area for PV cell calculation excluded for lift room water tanks and services.)

**Total 288750 kw approx.. is annual rooftop solar power generation.** Therefore **15% annual saving** is achieved on energy bill with proposed rooftop solar power plant.

The strategy enables not only energy saving but it is a very effective renewable energy resource. Building terraces are unoccupied and mundane spaces, which are not in used for any commercial purposes as a part of hotel. Therefore rooftop solar power plant proves to be a feasible and effective energy retrofit for the selected hotel building. The buildings of commercial and hospitality functions can efficiently adopt these systems with minimal disturbance to existing structure of buildings. Hence proves to be the most feasible and simple energy retrofitting strategy.

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Table 5: Rooftop Solar Enegy calculation

| **SOLAR ENERGY CALCULATION ( P.V cell ) Vits hotel building** | | | |
|---|---|---|---|
| 1 PV PANEL GENERATE ( 12 SQ.M AREA REQUIRED ) - 5 Kw ENERGY / DAY | 5 Kw / DAY | 275 DAYS | TOTAL Kw / YEAR |
| 5 HOURES FULL SUN VISIBILITY ( SUN WINDOW / DAY ) | 5 | 275 | 1375 |
| | TERRACE AREA | PANEL AREA | NO OF PANELS |
| TERRACE AREA AVAILABE FOR PV PANEL | 1130 | 12 | 94.16666667 |
| ANNUALLY IN PUNE REGION 275 DAYS HAVE GOOD AMOUNT OF SUNRAYS | | | |
| | TOTAL Kw / YEAR | NO. OF PANELS | TOTAL Kw OF ALL PANELS ( Kw ) |
| | 1375 | 94 | 129250 |
| | | | |
| | | | |
| ENERGY GENERATION POSSIBLE ABOVE VITS HOTEL BUILDING ANNUALLY ( Kw ) | 129250 | | |
| | | | |

| **SOLAR ENERGY CALCULATION ( P.V cell ) Orchid hotel building** | | | |
|---|---|---|---|
| 1 PV PANEL GENERATE ( 12 SQ.M AREA REQUIRED ) - 5 Kw ENERGY / DAY | 5 Kw / DAY | 275 DAYS | TOTAL Kw / YEAR |
| 5 HOURES FULL SUN VISIBILITY ( SUN WINDOW / DAY ) | 5 | 275 | 1375 |
| | TERRACE AREA | PANEL AREA | NO OF PANELS |
| TERRACE AREA AVAILABE FOR PV PANEL | 1400 | 12 | 116.6666667 |
| ANNUALLY IN PUNE REGION 275 DAYS HAVE GOOD AMOUNT OF SUNRAYS | | | |
| | TOTAL Kw / YEAR | NO. OF PANELS | TOTAL Kw OF ALL PANELS ( Kw ) |
| | 1375 | 116 | 159500 |
| | | | |
| | | | |
| ENERGY GENERATION POSSIBLE ABOVE ORCHID HOTEL BUILDING ANNUALLY ( Kw ) | 159500 | | |
| | | | |

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Table 6: Energy Savings calculations from Solar Project (25 years)

| | Power Generation | Tariff | Annual Savings | O&M Exp | Depreciation | Tax savings | Net Yearly Savings | Cumulative Savings |
|---|---|---|---|---|---|---|---|---|
| | A | B | C=AxB | D | Benefit | E | F=C-D+E | G |
| 1 | **288,000** | 15.15 | **4,363,200.00** | 115,200.00 | 3,840,000.00 | **1,152,000.00** | 5,400,000.00 | 5,400,000.00 |
| 2 | 285,696 | 15.45 | 4,414,860.29 | 119,808.00 | 2,304,000.00 | 691,200.00 | 4,986,252.29 | 10,386,252.29 |
| 3 | 283,410 | 15.76 | 4,467,132.23 | 124,600.32 | 1,382,400.00 | 414,720.00 | 4,757,251.91 | 15,143,504.20 |
| 4 | 281,143 | 16.08 | 4,520,023.08 | 129,584.33 | 829,440.00 | 248,832.00 | 4,639,270.75 | 19,782,774.95 |
| 5 | 278,894 | 16.40 | 4,573,540.15 | 134,767.71 | 497,664.00 | 149,299.20 | 4,588,071.65 | 24,370,846.60 |
| 6 | 276,663 | 16.73 | 4,627,690.87 | 140,158.41 | 298,598.40 | 89,579.52 | 4,577,111.97 | 28,947,958.57 |
| 7 | 274,450 | 17.06 | 4,682,482.73 | 145,764.75 | 179,159.04 | 53,747.71 | 4,590,465.69 | 33,538,424.26 |
| 8 | 272,254 | 17.40 | 4,737,923.32 | 151,595.34 | 107,495.42 | 32,248.63 | 4,618,576.61 | 38,157,000.87 |
| 9 | 270,076 | 17.75 | 4,794,020.34 | 157,659.15 | 64,497.25 | 19,349.18 | 4,655,710.36 | 42,812,711.23 |
| 10 | 267,915 | 18.11 | 4,850,781.54 | 163,965.52 | 38,698.35 | 11,609.51 | 4,698,425.52 | 47,511,136.75 |
| 11 | 265,772 | 18.47 | 4,908,214.79 | 170,524.14 | 23,219.01 | 6,965.70 | 4,744,656.35 | 52,255,793.10 |
| 12 | 263,646 | 18.84 | 4,966,328.05 | 177,345.11 | 13,931.41 | 4,179.42 | 4,793,162.37 | 57,048,955.47 |
| 13 | 261,537 | 19.21 | 5,025,129.38 | 184,438.91 | 8,358.84 | 2,507.65 | 4,843,198.12 | 61,892,153.58 |
| 14 | 259,444 | 19.60 | 5,084,626.91 | 191,816.47 | 5,015.31 | 1,504.59 | 4,894,315.03 | 66,786,468.62 |
| 15 | 257,369 | 19.99 | 5,144,828.89 | 199,489.13 | 3,009.18 | 902.76 | 4,946,242.52 | 71,732,711.14 |
| 16 | 255,310 | 20.39 | 5,205,743.67 | 207,468.69 | 1,805.51 | 541.65 | 4,998,816.63 | 76,731,527.76 |
| 17 | 253,267 | 20.80 | 5,267,379.67 | 215,767.44 | 1,083.31 | 324.99 | 5,051,937.22 | 81,783,464.99 |
| 18 | 251,241 | 21.21 | 5,329,745.45 | 224,398.14 | 649.98 | 195.00 | 5,105,542.30 | 86,889,007.29 |
| 19 | 249,231 | 21.64 | 5,392,849.63 | 233,374.06 | 389.99 | 117.00 | 5,159,592.57 | 92,048,599.86 |
| 20 | 247,237 | 22.07 | 5,456,700.97 | 242,709.03 | 233.99 | 70.20 | 5,214,062.14 | 97,262,662.00 |
| 21 | 245,260 | 22.51 | 5,521,308.31 | 252,417.39 | 140.40 | 42.12 | 5,268,933.04 | 102,531,595.05 |
| 22 | 243,297 | 22.96 | 5,586,680.60 | 262,514.08 | 84.24 | 25.27 | 5,324,191.79 | 107,855,786.84 |

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| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 23 | 241,351 | 23.42 | 5,652,826.90 | 273,014.64 | 50.54 | 15.16 | 5,379,827.42 | 113,235,614.26 |
| 24 | 239,420 | 23.89 | 5,719,756.37 | 283,935.23 | 30.33 | 9.10 | 5,435,830.24 | 118,671,444.49 |
| 25 | 237,505 | 24.37 | 5,787,478.29 | 295,292.64 | 18.20 | 5.46 | 5,492,191.10 | 124,163,635.60 |
| **Total** | **6,549,389** | | **126,081,252.42** | **4,797,608.63** | | **2,879,991.81** | **124,163,635.60** | |

## IV. CONCLUSION

Research emphasizes upon energy saving by reduction in external heat gain, addition of energy efficient pumping system and implementation of renewable energy generation techniques.

TR load is significantly **reduced up to 30%,** decreasing the electrical energy consumption on HVAC systems.

Implementation of star rated pumping systems i.e. IE3 and IE3+ (over IE2 pumping systems) **increased efficiency up to 4-5%** resulting into electrical energy savings.

Energy consumption of hotel is **reduced up to 15% annually** by implementation of solar power plant as a renewable energy resource.

As a result, electric consumption of hotel building is reduced effectively with simple retrofits for energy efficiency.

Research proposes strategies to reduce energy consumption as well as energy generation within the scope of energy retrofitting.

The findings are feasible for existing building which will be functional for a longer period of time and continue to consume energy for its functioning.

To reduce energy consumption, addition of energy efficient strategies within the scope of retrofitting is thrust area of research as it is the requirement of today's time.

## V. ACKNOWLEDGEMENTS

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