Design and Analysis of a Net-Zero Energy Building

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***ABSTRACT** - Net Zero Energy Buildings satisfies energy requirements of a building through renewable energy sources on site. This paper clearly illustrates the energy consumption analysis of a typical urban residential building by considering various parameters and estimates energy production capabilities through solar and wind energies. The residential building considered is clearly designed on fathoming up various urban parameters, every morsel of energy used is calculated and an additional amount of energy through renewable energy sources can be produced by various energy capturing systems which could be used at hard times.*

Keywords: Net-zero, Renewable, Energy capture, Photovoltaic panels, Savonius turbine.

1. INTRODUCTION

Energy, an essential part in every morsel of living being, is becoming scarce and expensive with massive urbanization and increased demand for affordable housing. The colossal numbers of the population in India is making it difficult to distribute the available energy sufficiently. The household electricity consumption per capita in India as of 2016 is 206.7KWH, which accounts for 24 percent of total energy consumption. Currently, India is facing an energy crisis. It's already high time to bring awareness to people about renewable energy sources. The rural and urban population in India need to know about how energy could be saved and alternatives to energy. Due to this energy crisis, prices of electricity are experiencing an increasing trend. In the near future, the cost per unit of electricity would be at an all-time high with a great increase in the percentage. Net Zero Energy Buildings are great to encounter this crisis in the future.

In a Net-zero Energy Building, the total energy consumption is met by renewable energy by various energy collectors which is produced on-site, without any external supply of electricity. These buildings produce energy on their own, using renewable energy sources like solar and wind energies. In addition, rainwater harvesting techniques can also be employed which satisfies water needs. Although there are many techniques implemented in producing electricity using renewable energy sources, Net-zero Energy Buildings could be a great way to implement even for small-scale buildings while the construction is at the design phase.

2. ENERGY CONSUMPTION ANALYSIS:

As part of our research, we have considered a typical urban residential building and designed it accordingly with a clear plan. It consists of two levels with four 1BHK flats on each level. Lifts mentioned in the below plan can be provided optionally.

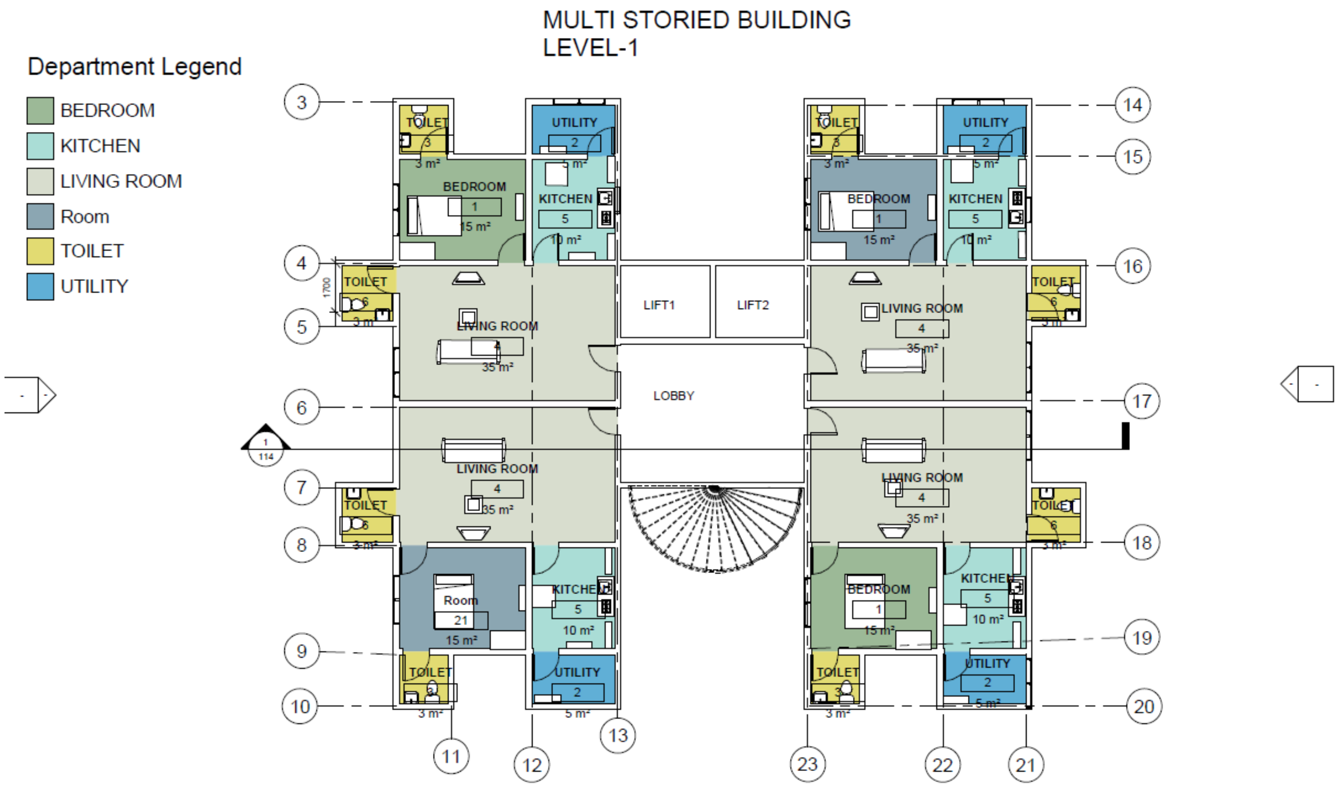

Figure 1: Level 1 floor plan (same as level 2)

Figure 2: 3D view

Below is the table which illustrates the energy consumption analysis of the provided plan for a single flat.

Room	appliances	Power Rating (W)	Consumption Time (min/day)	Total energy consumption (KWh/year)
Living room	(x2)Lights	15	420	38.325
Living room	(x4)Plugs	15	150	13.69
Living room	Fan	35	440	93.68
Living room	Television	60	270	98.5
Bedroom	(x2)Light	15	240	21.9
Bedroom	Fan	35	600	127.75
Bedroom	(x2)Plugs	15	120	10.95
Bathroom	Exhaust	30	90	16.425
Bathroom	Light bulb	15	120	10.95
Bathroom	Heater	2500	20	304.17
Kitchen	Light	15	240	21.9
Kitchen	Exhaust	30	150	27.37
Kitchen	(x2)Plugs	15	60	5
Kitchen	Refrigerator	200	1440	1752
Kitchen	Mixer	500	10	30.42

Table 1: Energy consumption analysis

Summing up, the total energy consumption per year is 2573kWh for each house. For 8 flats in the residential building, it would be 20,584kWh. For common electricity of the building like lights for each level and for other miscellaneous appliances, it would be around 400 kWh/year. So, the annual electric power requirement is around 21,000kWh.

3. DESIGN OF ENERGY CAPTURE SYSTEMS:

For this specific building, it is proposed to use Photovoltaic Solar panels for active solar energy capture, passive solar energy capture systems to capture solar thermal energy, and wind turbines for turning wind into electricity.

3.1 Photovoltaic solar panels:

They use semiconductor devices to capture solar energy and turn it into electrical energy. This electricity can be used directly by appliances like lights, refrigerators, T.V, and others. There are three different types of planes that could be used accordingly depending on the economic constraints and efficiency considerations. They are

1) Fixed panels
2) Single-axis tilt
3) Dual-axis tilt

3.1.2 Fixed panels:

They remain unchanged in terms of orientation. The energy captured by these panels vary throughout the day and also during seasonal changes of a year depending on the sun's angular position with respect to the panels. They do not require any controls and external energy supply. The efficiency of these panels is lesser than single and dual-axis tilt panels.

3.1.3 Single-axis tilt Panels:

These change orientation according to the sun's movement through the day and align themselves to maximize the sun's irradiation on the panels. But, they do not compensate for change due to seasonal changes in a year. The change in orientation can be periodic or continuous. In any case, they require manual or automatic control over the orientation and require an external energy supply for control and automation. These panels are a bit more efficient than the fixed type.

3.1.3 Dual-axis tilt panels

These are more efficient than the Fixed type and Single-axis tilt type. These panels change their orientation according to the sun's movement through the day and also comprehend the movement of the sun during a year and change the angular position accordingly. The energy required for control and automating motors for the orientation of panels can be compensated by an increase in the overall efficiency of solar energy capture.

The fixed panels would be economically viable for small-scale projects like households, small residential buildings, etc. So, considering the current plan of the 2 level residential building, fixed panels are optimal.

3.1.4 Passive solar energy capture systems:

Using electricity from Photovoltaic panels for heating applications like water or room heating implies a decrease in efficiency as the energy will be converted twice and losses can occur from device and process inefficiencies. Instead, passive energy capture systems which capture solar energy as thermal energy can be used. These devices use a single or a series of reflectors, called heliostats, to concentrate solar energy and a collector which contains water to be heated. These types of energy capture systems can be used for industrial purposes where there is a large availability of space for setting up the heliostats and collectors. But for residential purposes, normal solar heaters which heats water or heat exchanging fluid in some cases, directly without any reflectors would be apt.

Figure 3: Passive solar water heater

3.2 Wind turbines:

These systems are used to convert wind energy to electricity. These are small power output turbines that can be fitted easily on the roofs of the buildings, which could also be viable in terms of space and economy. Generally, for household purposes vertical axis wind turbines are used which can generate electricity even at low wind speeds. To choose the optimal direction for the placement of turbines, a windrose diagram should be drawn based on the wind data of the location.

A savonius vertical axis wind turbine is considered for this analysis. The general power output of these Savonius wind turbines can vary between 500W to 4kW and Voltage can vary between 12V to 150V. A small-scale transformer can be employed to step up the voltage for domestic use.

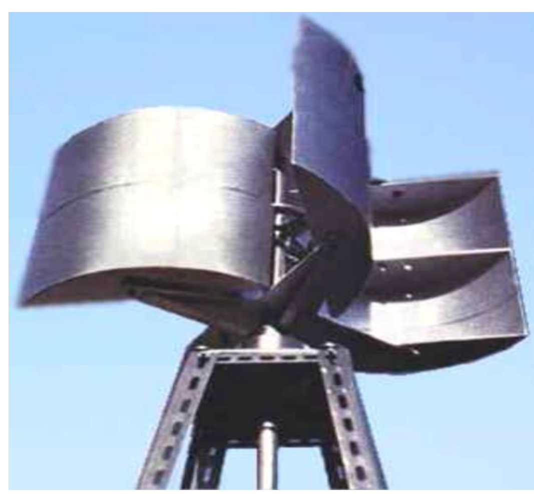

Figure 4: Savonius wind turbine

3.3 Rainwater harvesting:

The water from the rain can be used to recharge groundwater through rainwater harvesting pits that are employed around the building. Additionally, rainwater from the roof can be passed to a filtration system through drains and can be purified to be used as potable water or softened to be used for cleaning and washing purposes.

4. ENERGY PRODUCTION ANALYSIS:

4.1 Photovoltaic solar panels energy production analysis:

The requirement is to produce 21,000kWh of Energy per year. For the considered plan of the building, we have ample space to implement solar plans with proper spacing. Generally, for $10m^2$ of area, solar panels would be producing around 1kW of power. Also, a factor of 0.5 is considered to accommodate the seasonal availability of sunlight.

Total solar energy required = 21000kWh

$$\frac{21000\text{kW}}{365} = 57.53\text{kWh per day}$$

Solar energy is produced for 9hrs per day

$$\text{Power to be generated at an average} = \frac{57.53\text{kWh}}{9\text{h}} = 6.4\text{kW}$$

$8.4m^2$ area is required to produce 1kW power

Area required for solar panels $= 6.4 \times 8.4 = 54m^2$

Compensating seasonal availability, area $= 108m^2$

Total roof area available is $75 \times 4 = 300m^2$. Enough roof area is available to accommodate photovoltaic panels and also passive solar heaters. The remaining area can be used to accommodate wind turbine installations.

1kW requires 3 photovoltaic solar panels of area $8.4m^2$ each. So, we require $\frac{108}{8.4} \times 3 \cong 40$ panels.

4.2 Wind turbine energy production analysis:

Let us consider an average wind speed of 20km/hr. The average electrical energy production rate of a Savonius wind turbine is 1.144W without losses. We consider 6 wind turbines placed at the interior and exterior corners of the building. It is assumed that the turbine runs for 12 hours a day to accommodate for inconsistency of wind.

The energy production rate is 1.144W

Energy produced per day is $1.144 \times 12 = 13.728$Wh

Energy production in a year is 5kWh for one turbine

Energy produced by 6 turbines is 30kWh.

This additional energy can be used at times of energy deficit.

5. CONCLUSION:

Summing up all, considering the energy figures of consumption and production of the residential building, it is clear that the building is energy positive, which means it is more energy than it is consuming. The extra energy can be safely stored and supplied at times of emergency. Although implementing renewable energy capture systems requires a significant amount of initial investment it compensates the electricity costs and also saves a huge chunk of money in the long run. However, it is not only saving the electricity charges but also, neither fossils are burnt nor carbon emissions are produced. Net Zero Energy buildings have a huge scope in the near future. Also, many developing countries are running out of fossil fuels to generate electricity. Now the government authorities of many countries are also looking for alternatives in order to reduce carbon emissions. Net Zero Energy Buildings would be a great initiative to replace household power and to encounter these problems.

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