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Prototype Net Zero Energy for Contemporary Residential Building of Kathmandu Valley

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Abstract

This study is an attempt to focus on way of reducing energy consumption in context of residential building of Kathmandu Valley. The strategies of Net Zero Energy Building in developed and developing nations are different. Rather they are relatively newer concepts in developing nations. This research is intended to reflect the current scenario of housing in Kathmandu, Nepal and propose energy efficient and sustainable housing.

To propose prototype Net Zero Energy Building, data of energy consumption by general building of Kathmandu Valley was collected. Those building were then compared with typical housing colony of Kathmandu. For that F-Type housing unit of Vinayak Colony, Bhaisepati was chosen. The reference building was then modified based on the recommendations drawn from passive and active design technology that is suitable for Kathmandu valley. Energy consumption was found to be reduced to 29% by replacing of energy efficient appliances through process of energy audit. Further, energy consumption especially heating and cooling system can be controlled by passive design approach up to 33% less than annual energy consumption. For remaining consuming energy which is not possible through energy auditing and passive design, active solar strategy was implemented. Solar PV systems with batteries backup were installed in net metering system. So that, excess energy produced from solar PV was proposed to sell to NEA as well as some electronics devices of the building were proposed to run through grid electricity. Thus, building was made Net Zero energy building.

Keywords

Energy Efficiency, Net Zero Energy Building, Passive Solar Strategy, Active Solar Strategy, Kathmandu Valley

1. Introduction

“Energy efficiency is an important component of the energy economy. It is often called an “energy resource”, because it helps to decrease the use of primary energy resources and achieve considerable savings.” [1].

1.1 Research objectives and questions

The main focus in this research is to construct typical Net zero energy building with best input in design, material and technology (Passive and Active design) in Kathmandu Valley. To achieve the objective of this research, following questions are to be answered:

- What is the Typical model of net zero energy contemporary building for Kathmandu valley
- How much energy is consumed in typical contemporary building of Kathmandu valley?
- How much energy can be saved through proper design and use of our natural resources?

1.2 Limitation

- The research is done for contemporary residential building for Kathmandu valley. Contemporary building (two and half storey) emphasis NRs. 25000-40,000 income group people.
- Net Zero energy though covers vast sector, this research is emphasized more to make balance to annual on grid electrical energy supply and demand. And, secondarily possible implementation to reduce environmental impact in household of Kathmandu Valley.

2. Methodology

The research is divided mainly into study, data collections, analysis, design result and evaluation. After thorough literature review, questionnaire survey is done. Following questionnaire survey, case studies of energy efficient or zero energy building was done individually. Such building provides idea on construction techniques. Site selection was then next step done for design work. Finally, proposed building was designed and its energy consumption was made to Net Zero.

3. Literature Review

3.1 Definition of NZEB

Over the decades, in many articles and research projects number of ZEB's were described and evaluated, however almost for each case the ZEB was defined different or sometimes even no exact definition was used. Recently, the lack of common understanding and common definition for ZEB became noticeable and the world wide discussion has begun. There are many studies available, in which authors tried to propose different definitions for ZEB depending on such factors:

- How the zero energy goals are achieved?
- What is the building – grid interaction?
- What are the project boundaries for the balance?

Taking into consideration all the above mentioned scenarios Torcellini, et al. (2006), distinguish and point out four most commonly used definitions [2] :

- Net Zero Site Energy: A site ZEB produces at least as much energy as it uses in a year, when accounted for at the site.
- Net Zero Source Energy: A source ZEB produces at least as much energy as it uses in year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers.
- Net Zero Energy Costs: In a net ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.
- Net Zero Energy Emissions: A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources.

3.2 Worldwide approach towards NZEB

During the last 20 years more than 200 reputable projects with the claim of a net zero energy balance have been realized all over the world. Between 2008 and 2013, researchers from Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Korea, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, United Kingdom and USA worked together in the joint research program "Towards Net Zero Energy Solar Buildings" under the umbrella of International Energy Agency (IEA) Solar Heating and Cooling Program (SHC) Task 40 / Energy in Buildings and Communities (EBC, formerly ECBCS) in order to bring the Net ZEB concept to market viability [3] [4]. The joint international research and demonstration activities are divided in subtasks. The objective is to develop a common understanding, a harmonized international applicable definition framework, design process tools and advanced building design and technology solutions and industry guidelines for Net ZEBs.

3.3 Passive and Active solar strategy in Nepal

Nepal is blessed with solar resource as it lies at 30^o Northern latitude which is ideal and there are over 300 days of sunshine annually. Further the annual average solar insolation is 5kWhe/m^2 per day. These conditions are perfect for harnessing solar energy for various conversion technologies. Therefore solar PV system is best suitable renewable energy to implement in household for energy generation. Thorough study on active and passive solar system is studied in the research. [5] [6] [7] [8]

4. Case Studies

Case studies of three building were done in this research. Two of them are from Nepal and last one from Germany.

National buildings are Center of Energy Studies building of Pulchowk Campus which is called "Zero Energy Building" and "Mato Ghar". [9] [5]

5. Contemporary Building of Kathmandu Valley and Energy Auditing of Typical Building

From the questionnaire data survey of contemporary building of Kathmandu valley was generalized and concluded as follow:

Table 1: Generalized typical contemporary residential building of Kathmandu valley

Average Number of rooms	6
Average total no. of toilet	2
Average Family members	5
Building Material	Brick
Mortar used	Cement Mortar
Windows material	Wooden
Flooring type	Marble, plaster
Exterior looks	Plaster
Natural Lights	From three sides
Kitchen garden	available
Vehicles	Motor bike
Electronic equipments	Fluorescent, CFL Fan Refrigerator Rice Cooker Vacuum Cleaner Music Player Television Laptop Desktop
Electricity Backup	Inverter
Sanitary System	Metropolitan Facility
Water supply	Tap water and Underground
Water Collection	Overhead and Underground tank
Water purification	Filter only
Water heating system (bath)	Gas boiler
Waste Management	Metropolitan Facility
Cooking System	LPG

6. Vinayak Colony F-Type

Figure 1: Vinayak colony (Schematic)

The housing unit considered as reference for analysis is a three bedroom unit with an approximate built up area of 2308.76 square feet. It is oriented towards east. The ground coverage is about 985.62 square feet which is about 49.1% of the site area. It has living, dining, kitchen and bathroom in the ground floor. The housing is constructed in reinforced concrete structure. The external and the internal partition walls are of locally available brick with cement mortar. Walls are cement plastered on both sides. The roof is constructed of reinforced concrete with cement plaster finishing and does not have any internal or external insulation. Windows are of single glazed. The roof is constructed of reinforced concrete with cement plaster finishing and does not have any internal or external insulation. Windows are of single glazed.

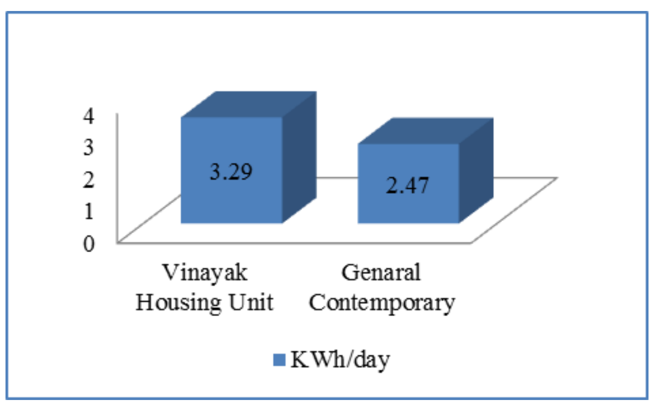

Figure 2: Comparing energy consumption of Vinayak Colony with general building

7. Energy Auditing of F-Type Vinayak Housing Colony

Table 2: Energy auditing of frequently using appliances

S.N.	Energy conservation proposal	Annual Savings Energy		Investment (NRs)	Payback Period (Year)
		(kWh_e)	Cost (NRs)		
1	LED Lighting	147.77	1403.89	10,000	7.12
2	Energy Efficient Fans	106.92	1015.74	20,000	19.69
3	LED TV	43.8	416.1	7000	16.82
	Total	298.49	2835.73	37000	13.05

Cost Benefit: The following table lists the top three energy saving opportunities identified that resemble savings worth NRs 2836 annually, against an investment of NRs 37,000 and offer an overall simple payback period of 13.5 years [9][10] [11]. The table excludes general measures which are not quantified. The total annual energy consumption of the building through NEA power supply is 1263 kWhe/Year (in average), the identified annual energy savings potential add up to 299 kWhe amounting to 23.67% of the consumption saving.

Also, some other electronics appliances which runs regularly like fridge, microven, eurogard was when replaced with energy efficient then it will reduced to 4-5% annual energy consumption i.e. electricity saving added up to 362 kWhe/year amounting to 29% over all.

8. Design of Net Zero Energy Building

8.1 Passive Design Approaches

8.1.1 Wall

Below explains the possible implementation of wall in case of Kathmandu valley:

- Full brick with insulation external
- Insulation with internal strawboard
- Cavity wall with insulation (with or without air gap)
- Rattrap bond with external insulation

Therefore recommendable solution is insulation on the walls for this design building is cavity wall without insulation. It is because, no insulation material is required and most of labor knows construction techniques as it is becoming popular in Nepal these days.

8.1.2 Flat roofs

The thermal performance of the flat roofs in the Kathmandu valley should have U -value of less than 0.79 W/m2 °C and time lag of more than 9.5 hours. Insulation on the flat roofs can be used on the top of concrete slab which increases the overall thermal capacity of the roof. Thus it raises time lag.

8.1.3 Openings

Glazing
For the Kathmandu Valley, double glazed window with wooden frame was to be used to reduce heat loss and gain which has U value of less than 3.5 W/m2 °C.

Size and position
In order to have enough air movement inside the room and proper day lighting, the size of the openings in the valley should be at least 25% of the floor area.

8.1.4 Shading device

Horizontal shading device depends upon the height of the façade to be shaded and considering sun angle of 74°, the projection of horizontal shading device should be 0.28A to protect from sun and rain. This will allow winter sun in the room. To prevent heat loss on the top of the openings as it is shaded by the projection, top of openings should be placed 30% of the height of the opening from the sill level to the shading device. This enhances horizontal air flow. Vertical shading device is used for fixed shading especially on the east and west sides, angular vertical shading device are suitable that restrict summer sun and allow winter sun **Cost benefit:** The saving, including heating and cooling, worth NRs 5757.5 annually. Therefore, annual electricity consumption will be further reduced to 845 kWhe/yr (2.3 unit/day) . The identified annual energy savings potential add up to 418.52 kWhe amounting to 33% of the consumption.

8.2 Active Design Approaches for remaining energy

a. Installation of Solar water heater:

The Valley is well-situated for the use of solar water-heaters, as it has 300 sunny days annually.

b. Installation of Solar Photovoltaic Power System:

It is the best option of renewable energy for residential building in the context of Kathmandu. The total energy consumption per year for the proposed house was 517 kWhe (considering passive design). The surveyed feasible roof area was approximately 50.37 square meters of flat type where the PV array inclination will require to be made 30° to 40° towards south direction, to collect maximum solar radiation throughout the day. The solar electricity generated during the day time could be used in the same building and at the same time the surplus electricity could be feed to the NEA grid line.

Table 3: Electricity generated by solar panel

Energy	Wh/day	kWh_e/ month
Energy Generated by 4 number of 210 Wp panel(peak sun=5)	4200	126
Energy Use by installed loads to be fed by solar Power	2837.5	85.13
Excess Energy from Solar Power	1362.5	40.87
Energy Use by installed loads to be fed by NEA Supply	400	12

Cost Benefit:
Annual electricity bill after use of energy efficient appliances= 845*9.5 = NRs. 8027.5 + NRs.4410 (gas heater)= NRs.12,438 Therefore payback period = NRs. 1, 54,000/12,438 = 12.38 year.

The life span of solar panel is 30 year. This explains feasible in installation of solar panel but cost of maintenance of battery which is supposed to be in every 4 year will make it more costlier than shows in calculation regarding in payback period.

Figure 3: Existing Building (Perspective View)

Figure 4: Proposed Building (Perspective View)

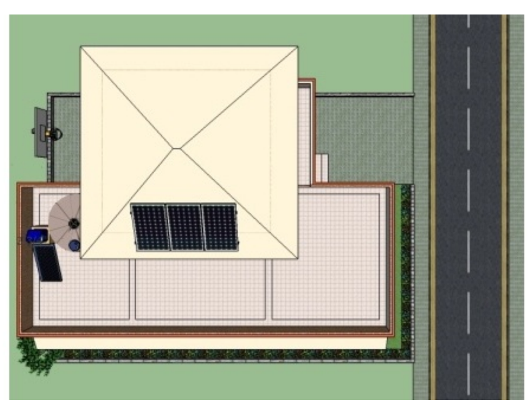

Figure 5: Proposed Building (Top View)

9. Conclusion and Recommendations

- Annual Electricity consumption in existing building is 1236 kWhe/year
- Electricity consumption in design building by use of efficient electronics appliances is 901 kWhe/year i.e. 29% of annual energy consumption
- Electricity consumption in designed building after implementation of passive building is 845 kWhe/year i.e. 33% of annual energy consumption
- Power produce by solar PV in designed building is 1512 kWhe /yr (designed for peak hour excluding some appliances)
- Annual energy consumption from NEA by designed building is 144 kWhe/yr where washing machine, vacuum cleaner runs buying NEA grid during day time and it sells solar excess electricity produced from solar i.e. 336 kWhe/yr to NEA instead.
- Assuming selling price of electricity to NEA to be lesser than buying, Net Annual energy consumption from NEA and production from Solar will be equivalent to 0 kWh_e/yr.

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