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Techno-Economic Evaluation for Re-Designing Existing Hospital Building to a Sustainable Structure

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***Abstract*— A green building is an environmentally sustainable building, designed, constructed and operated to minimise the total environmental impacts. Green buildings have gained quite a lot of momentum recently. To further increase this momentum, conventional buildings need to be converted into Green (or sustainable) buildings. Even though this may mean an additional cost burden to improve and standardize the existing parameters to satisfy the Leadership in Energy and Environmental Design (LEED) certificate program, green buildings offer numerous benefits in the long run.**

This study focusses on converting a conventional building in Mumbai into a Green building, which should then satisfy the prerequisites of the LEED's certification program and earn points to achieve different levels of certification. An existing building is re-designed, and a feasibility, economic and environmental analysis is done. The parameters to be re-designed are discussed, and the overall sustainability of the project is determined.

***Keywords*— LEED, sustainability, feasibility, green building**

I. Introduction

Green Building (also known as Sustainable Building or Green Construction) refers to a structure which involves processes which are environment friendly and resource-efficient in its entire life-span right from site selection, design phase, construction phase, serviceability phase, maintenance and renovation phase, until dismantling phase even after its useful life is over. This practice of construction adds positive attributes to the conventional construction in regards of economy, utility, sustainability, life-span and serviceability. Also Sustainability refers to meeting the needs of present generations without compromising the ability of future generations to meet their needs. There is continuous research conducted all around the globe to enhance the technology applied to green structures, the common objective being to reduce the overall impact of the built-up environment on human health and particularly on our biological surroundings.

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This study aims in converting a non-sustainable building into a sustainable building. This project deals with what is required to make an existing conventional building into a green building. The parameters on which a green building is compared to environmental standards are energy efficiency, lighting, ventilation, use of sustainable construction materials, biomedical waste and water management. On basis of this, enhancement of these parameters of existing building project (Guru Nanak Hospital, Bandra-E, Mumbai) will be done by suitable measures which shall prove to be fit in environmental standards criteria, be economical and practically feasible. Techno-Economic Evaluation for the Re-Design of an Existing Building to a Sustainable Structure shall be done as per the methodology adopted. [1] [11]

II. Case Description

The Guru Nanak Quinn Centenary Memorial Hospital Project comprises of a hospital which contains 223 beds. The Hospital consists of a Y-shaped seven storey tower block for in-patients and three numbers hexagonal, two storied blocks for out-patient department which are placed symmetrically on the central axis of each axis of each wing of the in-patient block in order to achieve a unified character of the complex.
The entries to different buildings have been segmented to avoid cross traffic and confusion. The central hall consists of stair cases and lifts for passengers, stretchers and goods. All three wings of the hospital are approachable through the central core.

- *Materials*: The hospital is built using White Reinforced Cement Concrete, brown anodized aluminum and glass.
- *Main Technical Installations:* Throughout the building, pipes installation are carved out through shafts engineering channels and service spaces. The arrangement gives easy access to installations for maintenance and offers the possibility of carrying out alterations in any department with minimum inconvenience to adjoining departments.
- *Heating & Ventilation*: The building is partly air conditioned with a system that will be individually thermostatically controlled.

- *Supervision Centre*: A supervision center has been set up in the basement from which will all technical installations could be looked over.
- *Lighting*: The lighting installation for general lighting is predominantly carried out using built in fluorescent light fittings while the special lighting for work purposes was candescent.
- *Fire Prevention:* The hospital will be protected by fire alarms.

Considering these initial parameters, we will be analyzing the existing structure with a view point of assessing it's sustainability by making the required changes. The main aim is to improve material, energy and water efficiency so as to attain the highest possible LEED rating for the reformed structure.

III. Materials Considered

A. *Lighting:*

Three of the most common energy-efficient lighting types include energy-saving incandescent, CFLs, and LEDs. They are all more energy-efficient than traditional incandescent bulbs. In addition, CFLs (about 75% energy savings) and LEDs (about 75%-80% energy savings) are better at energy saving than the energy-saving incandescent.

The light emitting diode (LED) uses the same technology as the little indicator light on your cell phone, but designed to light your home. It is one of today's most energy-efficient and rapidly developing technologies. ENERGY STAR-qualified LEDs use only 20% – 25% of the energy and last up to 25 times longer than the traditional incandescent bulbs they replace. While LEDs are more expensive at this early stage, they still save money because they last a long time and have very low energy use. [10]

B. *Heating, Ventilation, and Air condition (HVAC)*

Hospital Healthcare HVAC System [7] [9]: -

• Ozone has been successfully used to reduce smell, bacteria, mould, mildew and other microorganisms from the HVAC system.

• Controlled quantity of ozone introduces in the AC Ducts Eliminates Toxic gasses, odors smoke by oxidation and microbes & virus.

• It is very important to maintain good indoor air quality (IAQ) in hospital Operation theatre. A significant consideration in Operation Theatre is the control of aerosols, anesthesia gases and smoke. The concentration of gases in the Operation Theatre is critical and needs to be controlled.

• A significant consideration in Operation Theatre is the control of aerosols, anesthesia gases and smoke. In Operation Theatre, however, the main sources have an indoor origin are the patient, the surgical team and the equipment. The anesthesia gases disperse in ORs are also considered as pollutants. The anesthesia gases are disposed in the environment through problems in the equipment and from the exhalations of the patient. Some gases used in the surgery, for example, NO_2 will continue to be exhaled by the patient for up to one hour after the surgery is finished. During surgery, the highest concentration of gases is on the floor. However, with the movements of the people, these gases can be mixed with room air and inhaled by the surgical team.

• The concentration of gases in the Operation Theatre is critical and needs to be controlled; otherwise the productivity and the quality of the work of the surgical team can decrease, and in the medium and long term health problems may occur.

• Food hygiene in hospital poses peculiar problems, particularly given the presence of patients who could be more vulnerable than healthy subjects to microbiological and nutritional risks.

• Ozone oxidizes any bacteria, viruses, fungus, moulds and fungi thus; using it in the kitchen creates a totally sanitary environment in which to prepare food, free of germs and diseases.

• By neutralizing bacteria, ozone also kills odors, leaving the kitchen totally free of any unpleasant odors from stale cooking smells, dustbins or drains, or clears the air of chemical pollution like glue or paint.

C. *Solar Energy*

Residential solar thermal installations fall into two groups: passive (sometimes called "compact") and active (sometimes called "pumped") systems. Both typically include an auxiliary energy source (electric heating element or connection to a gas or fuel oil central heating system) which is activated when the water in the tank falls below a minimum temperature setting such as 55 °C. Hence, hot water is always available. The amount of heat delivered by a solar water heating system depends primarily on the amount of heat delivered by the sun at a particular place (the insolation). In tropical places the insolation can be relatively high, e.g. 7 $kW.h/m^2$ per day, whereas the insolation can be much lower in temperate areas where the days are shorter in winter, e.g. 3.2 kW.h/m2 per day. Even at the same latitude the average insolation can vary a great deal from location to location due to differences in local weather patterns and the amount of overcast. Useful calculators for estimating insolation at a site can be found with the Joint Research Laboratory of the European Commission and the American National Renewable Energy Laboratory. [8][9]

D. Carbon energy Footprint

The carbon footprint of such household systems varies substantially, depending on whether electricity or other fuels such as natural gas are being displaced by the use of solar. Except where a high proportion of electricity is already generated by non-fossil fuel means, natural gas, common water heating fuel, in many countries, has typically only about 40% of the carbon intensity of mains electricity per unit of energy delivered. Therefore the 3% or 8% energy clawback in a gas home referred to above could therefore be considered 8% to 20% energy clawback, a very low figure compared to technologies such as heat pumps.

However, PV-powered active solar thermal systems typically use a 5-30 W PV panel which faces in the same direction as the main solar heating panel and a small, low power diaphragm pump or centrifugal pump to circulate the water. This reduces the operational carbon and energy footprint: a growing design goal for solar thermal systems. [2] [13]

E. Life Cycle Carbon

Recognized standards can be used to deliver a quantitative life cycle assessment (LCA) [2] [11]. LCA takes into account the total environmental cost of acquisition of raw materials, manufacture, transport, use, service and disposal. There are several aspects of this assessment, including:

- The financial costs and gains incurred during the life of the equipment.
- The energy used during each of the different stages.
- The CO_2 emissions due to each of the different stages.

F. Financial Assessment

In summary, the energy and emissions cost of a SWH system forms a small part of the life cycle cost and can be recovered fairly rapidly during use of the equipment. Their environmental impacts can be reduced further by sustainable materials sourcing, using non-mains circulation, by reusing existing hot water stores and, in cold climates, by eliminating antifreeze replacement visits. [11]

G. Material Efficiency:

Sustainable materials proposed to be used to construct a green building are low-calcium fly-ash based geo-polymer concrete, fly-ash brickwork, plastering, ceramic tile flooring, low-VOC paint, FSC-certified wood and sustainable glass in lieu of conventional construction materials viz. ordinary Portland cement concrete, clay-brickwork, marbonite flooring, emulsion paint, Burma teak wood and ordinary glass. The rates of some of the conventional materials are low however when observing in entirety the cost of sustainable building materials is lower than the conventional materials.

TABLE I: COMPARISON OF QUANTITIES AND RATES FOR CONVENTIONAL AND SUSTAINABLE STRUCTURE

Sr.No	Description	Quantity	Rate for		Unit	COSTING		
			Conventional	Sustainable		Conventional construction cost	Sustainable construction cost	Savings or difference
1	Concrete	6200	6500	4000	cu.m	40,300,000	24,800,000	15,500,000
2	Brickwork	3160	3750	5100	cu.m	11,850,000	16,116,000	-4,266,000
3	Plastering	57960	275	175	sq.m	15,939,000	10,143,000	5,796,000
4	Tile flooring	10352	2250	650	sq.m	23,292,000	6,728,800	16,563,200
5	Painting	115920	95	125	sq.m	11,012,400	14,490,000	-3,477,600
6	Openings (frames)	65	75000	17000	cu.m	4,860,000	1,101,600	3,758,400
7	Openings (doors)	1296	1600	1850	sq.m	2,073,600	2,397,600	-324,000
8	Glass	1080	1750	1150	sq.m	1,890,000	1,242,000	648,000
TOTAL COSTING						111,217,000	77,019,000	34,198,000
TOTAL COSTING PER BED (223 nos.)						498,731	345,377	153,354

IV. Water Savings

A. *Waste Water Treatment*

The treatment of sanitary wastewater specifically generated from hospitals without blending from other domestic sources is much more challenging as compared to municipal wastewater. [6] [13] the effluent generated from a Hospital/ Medical College should conform to the limits stated in the table. The following flow sheet depicts the water treatment process.

The treatment of effluent generated from hospital will be done in three steps. They are mainly known as Primary, Secondary and Tertiary treatment and explained as follows:

Primary Treatment - Removal of coarse particles, oil and grease and mixing co-agents in the water for removal of suspended solids through sedimentations

Secondary Treatment –Extensive aeration of the Primary treated water, bacterial growth, addition of oxygen and chemical which help in bacterial growth and lastly settlement of the biological waste as sludge.

Tertiary Treatment - Here the effluent after secondary treatment is first mixed with Sodium Hypo Chloride, and then effluent will be pass passed through (DMF) dual media filter and (ACF) activated carbon filter where sand, anthracite and activated carbon will be used as filtration media.

B. *Rainwater Harvesting System:*

Broadly there are two ways of harvesting rainwater:

(i) Surface runoff harvesting: In urban area rainwater flows away as surface runoff. This runoff could be caught and used for recharging aquifers by adopting appropriate methods.

(ii) Roof top rainwater harvesting: It is a system of catching rainwater where it falls. In rooftop harvesting, the roof becomes the catchments, and the rainwater is collected from the roof of the house/building. [4] [5]

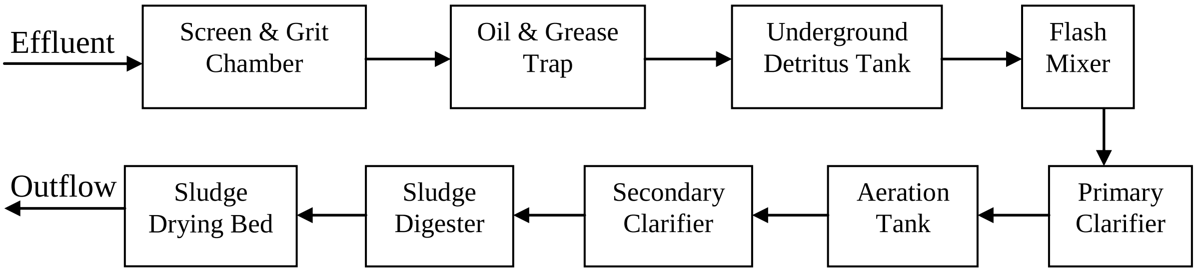

Fig 1 Flow Sheet Depicting the Treatment Process

V. Energy saving

A Biogas Plant in the Hospital premises for efficient solid waste management and to provide an alternative and cost-effective energy source. Biomass in any form is ideal for the Biomethanation concept. Based on the thermophilic microorganisms and microbial processes, the design of the biogas plant is developed. The plant is completely gravity based. [3]

VI. Conclusion

The Guru Nanak Quinn Centenary Memorial Hospital Project undertaken for implementation for a Sustainable Re-design can be certified by determining the number of parameters this hospital satisfies according to the LEED India Certification Levels.

From the studies carried out, it can be observed that the sustainable construction costs less than conventional construction right from initial stage onwards. Also with the passage of time the difference between the two increases at a constant rate indicating that the sustainable construction proves profitable from initial stage onwards and right up to the end of life-span of structure, thereby proving to be a feasible option. Hence, one should always opt for sustainable construction technologies & systems for over-all profit-earnings in the long-run and also for contribution towards the global green movement.

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