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Green Retrofitting Of Buildings – A Comprehensive Study

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Abstract
The Building construction sector is becoming one of the highest contributors to the country's carbon emissions. It alone accounts for 22 per cent of India's total carbon emissions. It is expected that this impact to increase further with the efforts to combat housing shortage affecting more than 60 million households in the country, adding to the huge resource and energy footprints of the sector.
Since an opportunity to reduce primary energy use lies within the existing building stock, retrofitting of old buildings is one such solution to answer queries about energy efficiency. To improve energy efficiency, it is a proven high-volume, low-cost strategy that can help in tackling one of the major causes of climate change.
Transformation of existing Building refers to using a process that is environmentally responsible and resource efficient in operational lifecycle to building
Keywords:- *operational lifecycle, energy efficiency, green retrofitting*

1- GENERAL

Retrofitting of existing buildings offers significant opportunities for reducing global energy consumption and greenhouse gas emissions. This is being considered as one of main approaches to achieving sustainability in the built environment at relatively low cost and high uptake rates. Although there are a wide range of retrofit technologies readily available, methods to identify the most cost-effective retrofit measures for particular projects is still a major technical challenge. This paper provides a systematic approach to proper selection and identification of the best retrofit options for existing buildings. The generic building retrofit problem and key issues that are involved in building retrofit investment decisions are presented. Major retrofit activities are also briefly discussed, such as energy auditing, building performance assessment, quantification of energy benefits, economic analysis, risk assessment, and measurement and verification (M&V) of energy savings, all of which are essential to the success of a building retrofit project. An overview of the research and development as well as application of the retrofit technologies in existing buildings is also provided. The aim of this work is to provide building researchers and practitioners with a better understanding of how to effectively conduct a building retrofit to promote energy conservation and sustainability.

2-CHALLENGES IN RETROFITTING

Retrofitting of existing buildings has many challenges and opportunities. The main challenge encountered is that there are many uncertainties, such as climate change, services change, human behaviour change, government policy change, etc., all of which directly affect the selection of retrofit technologies and hence the success of a retrofit project. The subsystems in buildings are highly interactive. Different retrofit measures may have different impacts on associated building sub-systems due to these interactions, which results that the selection of the retrofit technologies becomes very complex. Dealing with these uncertainties and system interactions is a considerable technical challenge in any sustainable building retrofit project. Other challenges may include financial limitations and barriers, perceived long payback periods, and interruptions to operations. The willingness of building owners to pay for retrofits is another challenge if there is no financial support from the government, particularly since the issue of “split incentives” is often a key factor where the cost of the retrofit generally falls to a building owner whereas the benefit often flows primarily to the tenants. On the other hand, retrofitting of a building offers great opportunities for improved energy efficiency, increased staff productivity, reduced maintenance costs and better thermal comfort. It may also help to improve a nation’s energy security and corporate social responsibility, reduce exposure to energy price volatility, create job opportunities and make buildings more liveable.

3- KEY PHASES OF RETROFITTING PROGRAMME

The overall process of a building retrofit can be divided into five major phases.

FIRST PHASE- The first phase is the project setup and pre-retrofit survey. In this phase the building owners, or their agents, need to first define the scope of the work and set project targets. The available resources to frame the budget and program of work can then be determined. A pre-retrofit survey may also be required in order to better understand building operational problems and the main concerns of occupants. It is required for building owners to select an experienced Services agency to take responsibility for planning and implementing the building retrofit.

SECOND PHASE- The second phase comprises an energy audit and performance assessment (and diagnostics). Energy auditing is used to analyse building energy data, understand building energy use, identify areas with energy wastes, and propose no cost and low cost energy conservation measures (ECMs). Performance assessment is employed to benchmark building energy use by using selected performance indicators or using green building rating systems. Diagnostics can be used to identify inefficient equipment, improper control schemes and any malfunctions happened in the building operation.

THIRD PHASE- The third phase is the identification of retrofit options. By using appropriate energy models, economic analysis tools and risk assessment methods, the performance of a range of retrofit alternatives can be assessed quantitatively. The retrofit alternatives can then be prioritised based on the relevant energy-related and non-energy-related factors. It is worthwhile to note that a range of no cost and low cost ECMs that might have been identified during the energy auditing.

FORTH PHASE- The fourth phase is site implementation and commissioning. The selected retrofit measures will be implemented on-site. Test and commissioning (T&C) is then employed to tune the retrofit measures to ensure the building and its services systems operate in an optimal manner. It is worth noting that the implementation of some retrofit measures may necessitate significant interruption to the building and occupants operations.

FINAL PHASE- The final phase is validation and verification of energy savings. Once the retrofit measures are implemented and well tuned. A post occupancy survey is also needed to understand whether the building occupants and building owners are satisfied with the overall retrofit result.

4- KEY ELEMENTS AFFECTING BUILDING RETROFITS

The success of a building retrofit program depends on many issues. The key elements that have significant impacts on building retrofits, including policies and regulations, client resources and expectations, retrofit technologies, building specific information, human factors and other uncertainty factors.

Policies and regulations are energy efficiency standards, which set minimum energy efficiency requirements for retrofitting of existing buildings. Governments may provide financial support and subsidies to assist building owners and developers in achieving the required energy performance targets through implementing energy retrofit measures. Often the range of government programs available is complex, even within a single jurisdiction.

Client resources and expectations determine the project targets and goals, and thus determine which kind of retrofit technologies should be used. Since investment decisions for energy efficiency are quite complex, it is always difficult for clients to decide whether investment in retrofits is worthwhile.

The effectiveness of a building retrofit is also dependent on building-specific information, such as geographic location, building type, size, age, occupancy schedule, operation and maintenance, energy sources, utility rate structure, building fabric, services systems, etc. For a particular project, the optimal retrofit solutions should be determined by taking into account building specific information.

Human factors are other important elements that affect the success of building retrofits. Human factors may include comfort requirements, occupancy regimes, management and maintenance, activity, and access to controls.

5- ADVANTAGES OF GREEN RETROFITTING

The advantages of green retrofitting may be sub classified as

1. Economics

Many of the old buildings are inefficient on energy use. Also, the increased costs of utilities, increasing price of energy forced building owners to search for ways to reduce energy use and waste. Green retrofit projects increasingly make good economic sense, and renovation costs will likely be recouped via energy savings. Further, real estate industry is addressing a new fact that energy efficient buildings command better rents and are increasingly desirable. More over tenants recognize the potential savings resulting from increased productivity; they demand new and upgraded green buildings. Additionally, the growing green industry is promoting green projects and is making their products and services known to the market.

2. Environmental

Retrofitting buildings provides clear environmental benefits including reducing energy consumptions, lowering demand on the power grid and decreasing greenhouse gas emission.

3. Government

Overall, the government increasingly sees the economic and environmental values of green retrofit. One of the earliest and ambitious green programs that encouraged retrofitting is the Energy Efficiency Building Retrofit Program launched in 2015 in smart city project by a Prime minister of India Shri Narendramodi.. The program explored ways to make efficiency retrofit projects In 2015, Shri Narendramodi's Smart city project incorporate "Better Buildings Initiative" proposed new efforts to improve energy efficiency in old constructed buildings. Atleast 10% of existing buildings should be retrofitted for qualifying as Smart city. The initiative aims at making old constructed buildings more energy efficient over the next decade by catalyzing private sector. Up gradation of buildings can create jobs, save money, reduce the country's dependence on foreign oil and make air cleaner.

6 - COMMON WAYS TO RETROFIT BUILDINGS

While there are many ways to retrofit a building, research identifies the most common ones as follows

6.1. LIGHTING

The most common retrofit type that building owners perform is lighting retrofits for many commercial buildings do not have energy efficient lighting, and retrofit practice informs that upgrading lighting fixtures can result in an increase in the lighting level while decreasing energy consumption up to 70%, yielding significant cost saving. Also, lighting retrofits is one of the easiest to conduct entailing little or no interruption to building's daily operation. Here are some options for a lighting retrofit project:

Change the old fluorescent lighting fixtures into Energy Star benchmarked fixtures, for example, T5 or T8 high bay fixtures;

Add a timer or occupancy sensor on the fixtures that are only used occasionally, allowing the lights to be turned off automatically when it is not in use;

Add a dimmer or photo-sensor for the fixtures so that when natural night is available, photo-sensors will adjust the brightness of the fixtures to reduce unnecessary lighting.

6.2. HEATING, VENTILATION AND AIR CONDITIONING

Through maintenance and upgrades, the efficiency of the HVAC system can be improved resulting in improving users' comfort and minimizing the negative impact on the environment. To that end, buildings' owners are encouraged to clean the air filters, ventilators, boiler tubes, *etc.* and make sure that all the HVAC equipment is sealed so that heat transfer occurs only when and where it is desired.

6.3. WATER SYSTEMS

Water conservation is important for water is essential to human continuity and many places lack water, particularly potable water. The overarching strategy is to make the building use less water whenever possible and as much as possible. The following specific strategies are helpful to conserve water:

Upgrade faucets, toilets, or showerheads fixtures that will result in significant saving on water use.

Upgrade to waterless urinal for it uses sealant liquid that has higher buoyancy than urine;

Consider adding aerators and occupancy sensors on lavatory faucets for they reduce the rate of water flowing through the faucets by mixing water with air while maintaining the pressure of the water;

Consider reducing water use by recycling it;

Rainwater can also be captured for irrigation or even to flush toilets and other uses in the building.

6.4. BUILDING AUTOMATION SYSTEM

The building automation system manages all the operation systems including the HVAC system, lighting and the appliances, *etc.* and helps to reduce utility costs and maintenance while improving user comfort. For example, the system can maintain the temperature, air quality, and lighting inside the building based on a given range and preset schedules. In addition, the system can accurately monitor and record energy usage. It also helps to identify and locate a problem if unusual energy use or system failure occurs. Further, the building automation system can be commanded remotely online and allows immediate intervention in emergency cases.

6.5. INSULATION

Building's heating and cooling systems consume significant amount of energy. Consequently, reducing the need for heating and cooling will significantly reduce demand on energy. Good insulation helps in this regard by retaining heat in winter and trapping cool air inside in summer. Well insulated windows do help in insulating the building effectively. For example, in case windows covering 15%–

25% of the building envelope, they may account for 40%–70% of the total heat loss of the building. As such, window retrofit could provide significant savings. There are various ways to enhance insulation of windows:

□□Replace existing windows with low U-factor windows and add weather-stripping on windows to prevent air leakage;

□□Replace the single pane windows with double pane windows;

□□Apply low emissivity coating on the windows to further lower heat transfer between inside and outside;

□□Pick window frames that have a low U-factor.

Well insulated walls also greatly help in reducing required energy to heat and cool a building. However, an insulation upgrade for walls is uncommon because it is costly. An affordable way to make walls less absorbent of heat is by painting them lighter colors for they reflect light effectively. Further, replacing a single door entrance with a double one (with weather-stripping) is often an affordable and effective insulation measure.

6.6.ON-SITE ENERGY GENERATION

Fossil fuel that we heavily rely on today to generate energy is a finite source and it is crucial that we seek alternative sources. Solar PV and solar thermal (more affordable than PV) are increasingly popular. Wind turbines are also becoming available and affordable; which can be incorporated in skyscrapers' retrofit. For example, in the Willis tower retrofit project, wind turbines are planned to be installed to harness wind energy. Geothermal energy could be cheaper than the solar one but are available in limited geographic areas. Ultimately, the right choice of energy renewable adoption depends on the location and climatic conditions of solar intensity, wind power, humidity, cloudiness and particles in the air each day [3].

6.7. INNOVATIONS

Technological and scientific advancement provide planners and architects new ways to improve the environmental performance and energy efficiencies of buildings. For example, lately, 3M (a global innovation company, Minneapolis, MN, USA) has introduced 3M solar film that can be placed on windows to generate energy and to reduce energy needed for cooling building by absorbing more than 90% of infrared light. This thin solar film has started to be available in the market at affordable prices. However, the downside of this film is that it provides only 3%–8% of efficiency during peak intensity, measuring 20% of what conventional solar PV can generate. Another example that highlights technological advancement is the Eco-Skin, a lightweight, transparent textile that can improve a building's insulation and generate electricity by wind or sunlight.

7-GREEN RETROFIT CHALLENGES

While energy efficiency and tax deductions do help in paying back the costs of renovations, there are still barriers to retrofitting skyscrapers. Research indicates that the greatest barriers to green retrofit include lacking financial and technical support, tenant's behavior, split-incentives problem, operation and management, and no one template to apply. Historic buildings also provide additional challenges. These challenges are detailed as follows.

7.1. COST-EFFECTIVENESS

Proving the cost-benefit equation is key to convince buildings' owners to commit to a green retrofit. To make an investment, an owner wants proven methods and technologies and demands concrete ideas of the return on investment. Often, the energy performance prediction tools are imperfect and every building responds differently. Consequently, there is a sense of lack of confidence about the cost-effectiveness of undertaking a green retrofit. Another potential barrier related to cost-effectiveness could be the amount of time it takes to obtain cost savings from renovations. In many cases, the time needed is several years. Indeed, there are instances were a retrofit is less cost-effective, and a new construction will be more effective and desirable by owners and developers.

7.2. FINANCIAL

An owner may be convinced by the presented cost-effective analysis and persuaded by the retrofit's merits but may lack resources. Therefore, securing adequate funds for green retrofit is often a barrier. Buildings' owners are looking for a quick return on investment in two to four years; and for a major retrofit, it is likely going to take longer than that. Further, in urban areas, there is a financial incentive to maximize the use of sites by adding floor spaces to achieve economies of scale and height for views, which translate in increasing rent values. However, these actions are far from being attainable in existing building in urban cores. Also, developers often perceive little economic justification for retaining existing buildings and instead look for developable land rather than retrofitting existing buildings.

Moreover, the environmental costs associated with building construction and demolition are external to developer and are excluded from value-chain analyses. Also, there is uncertainty about the continuity of financial incentives for green retrofit provided by governments and other organizations. The public has been questioning the merit of giving financial aid to retrofit privately-owned buildings. The benefits of green retrofit go directly to the owners and to renters who would pay cheaper utility bills. The direct benefit to the public seems less clear and is hard to gauge. Collectively, these issues encourage developers to favor new construction over retrofitting existing buildings. Consequently, building retrofitting programs have achieved a small market penetration of less than 1% of eligible buildings, according to a recent study by Pike Research. The commercial retrofit market continues to be small compared to its potential.

7.3. CODES AND REGULATIONS

Building policies and codes in general form a major obstacle to a building retrofit projects. For example, building codes in the United States have historically favored new construction over retrofit. In the absence of flexible land use regulations and incentives for reuse, older buildings are commonly torn down to make way for larger structures. Energy codes can also sometimes deter building reuse, as they are typically not well-adapted to the unique limitations and opportunities presented by individual buildings. When these issues are added to seismic and ADA requirements, they collectively form the "tipping point" in decisions favoring demolition. Further, bureaucracy of city planning commissions and zoning boards impose additional hurdles. For example, zoning regulations may object adding external insulation, placing solar panels or wind turbines if they exceed a certain height limit, or adding vertical or horizontal shades or screens, allowing reconfiguring building roofs into gardens, placing rooftop greenhouses and the like. Conversely, the city can amend zoning to become conducive to green retrofits. For example, the City of Boston has recently required a green building standard through municipal zoning requirements. By amending one of the articles of the municipal zoning code, the city required that all large-scale projects meet the U.S. Green Building Council's LEED certification standards .

7.4. TECHNICAL CHALLENGES

Overall, required technical expertise on the part of the project team—architects, engineers, building managers, tenants and energy service companies—continue to be lacking. Additionally, retrofit work is often regarded as riskier than constructing new buildings because the process can be less predictable, and many developers fear unforeseen technical challenges once rehabilitation is underway. This perception of risk and fear of the unknown can motivate buildings' owners and developers to demolish buildings even in instances where a retrofit may be less costly and more profitable than new construction.

7.5. TENANTS

In some cases, tenants are the most challenging factor. Once tenants reside in a building, an owner needs to obtain their permission to retrofit the building. The owner also should ensure minimum interruption and inconveniences imposed on tenants while the building goes under retrofit. Further, building's systems such as lighting and HVAC should remain functional and operational during a retrofit.

7.6. OPERATION AND MANAGEMENT

In order to guard the sustainability of a retrofit project, building's owners and managers should ensure a match between the provided systems and tenants' behavior. Research and experience confirm that building's performance degrades when there is mismatch between these two. There have been some incidences where buildings that equipped with best technologies perform the worst because of mismanagement. For example, the override feature in a system could be useful to meet temporal needs or respond to an emergency situation. However, it is important that managers reset the system back to normal. Otherwise, tenants may experience discomfort and they will likely blame the new system and equipment, not the improper management of the system.

7.7. NO ONE TEMPLATE

Due to vast variations of buildings' conditions as well as variations in geography, climate, culture and finance, it is near impossible to develop a work template that developers can use and replicate elsewhere. Developers, architects and engineers need to perform substantial studies before embarking on an effective retrofit. Also, basic familiarity with a region may shed insight on the process.

7.8. CONDUCTING RETROFIT AROUND TENANTS' OPERATIONS

As mentioned earlier, a common challenge of retrofit is conducting the work without interrupting the daily operations of staff and tenants. Though, there are strategies to address this challenge. For example, developers may not upgrade the entire HVAC system for a tenanted building at once. Instead, inefficient perimeter induction units can be replaced floor-by-floor with quieter and more efficient ones.

7.9. SECURITY

Finally, some buildings, e.g., government buildings, could require high security and conducting retrofit projects in these buildings would be challenging.

Interestingly, some buildings' retrofit projects may face a combination of the aforementioned challenges. For example, the Dirksen Federal Building completed in 1964 and 330 North Wabash completed in 1973, were recently undergone green retrofit projects that faced many challenges including "*asbestos remediation, historic preservation standards, maintenance of high security levels and, all-glass transparent facades, most of all, conducting work in and around the occupants of an operating courthouse: energy conservation is one priority among many*". Specifically, the lighting retrofit possibilities were limited because of the desire to preserve the existing historic pattern of the plaster ceiling that contains the luminaries. This issue prevented the project team from increasing lighting efficiency by redistributing light fixture and opted to increase the output of light fixtures instead. This choice has resulted in incurring higher wattages per square foot than the norm today; though, this solution still provided improvement of the existing condition.

8- CONCLUSION

A Green retrofitting of Building requires dozens of decisions by home designers and contractors. These decisions affect the initial cost of retrofitting and the cost benefit ratio. In the present work, procedure of 'Green Retrofitting' concept is studied in detail. Following are the major conclusions derived:

Green Retrofitting is very much essential and the awareness among all stakeholders is required to be created. Apart from quantitative benefits other non-quantitative and qualitative benefits also be enumerated in conclusion they are

Economical benefits:

Studies show that installing green building technologies can be cost-efficient in the long run. It can create jobs and expand the local tax base to create economically competitive communities.

Social benefits:

Improving indoor environmental quality creates a healthier environment for the occupants of a building, which may help increase their productivity. Stronger neighborhoods that create a greater sense of community.

Increase Productivity:

Increased workforce productivity in commercial buildings ultimately holds the greatest potential savings.—far greater than energy or water savings. If we can only increase 10% efficiency of work force it leads to 15% saving for employers in employee cost.

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