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Strategies to Minimize Environmental Load of a Building during Its Life Cycle

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Abstract: *Constructing a building entails not only financial costs at each stage it also requires use of energy and resources that invariably results in the discharge of a variety of substance such as CO_2 that have an impact on environment. This effect continues beyond the construction phase to include the entire life cycle of the building. It has been observed that money spent on design and construction occupies only 30% of the total life cycle cost while the rest are the post completion costs of operation, maintenance, refurbishment and eventually demolition & disposal. From environmental view point it becomes necessary to design the whole life cycle of a building instead of only paying attention on the initial costs and CO_2 emissions. It is evident that energy saving design and management are very important as measures for tackling global warming. Besides Life Cycle Cost is also one of the aspects to evaluate the economic aspects. Inadequate disposal of pollutant materials also affects life cycle cost. Chlorofluro carbon Compounds (CFC) that deplete the ozone layer have a potential to increase the "green house effect" that is several thousand times greater than that of CO_2. Although the use of CFC has been largely banned by international agreement worldwide they used to be common ingredient in building materials such as foam insulation and air conditioner coolants. Many of these material still exists in buildings and CFC's continue to be emitted from them. To solve this problem they must be carefully disposed off in order to avoid environmental degradation. This phenomenon is seemed to be largely ignored in India and result in environmental degradation. Many such theories and concepts are not followed because of lack of knowledge, concerns and ignorance of the stakeholders. Present paper discusses the process to access the whole environmental aspects and potential environmental impacts all through life style of a building. There is an effort to suggest strategies to minimize environmental load of a building during its life cycle. It is aimed to analyze the role of various parameters like technological, social systems, economic aspects during the life cycle of a building in order to stress their integration to create a sustainable environment. It highlights the importance of the role of stakeholders in creation of a better living environment for future habitat.*
Keywords: *life cycle, refurbishment, stakeholders, habitat, emissions.*

I. Introduction

Life Cycle Assessment is to assess the whole environmental aspects and potential environmental impacts all through the life cycle (i.e. from cradle to grave) *of* a product starting from the raw material extraction from the earth, followed by manufacturing, transport and use, and ending with waste management including recycling and final disposal. The areas *of* environmental impacts include use *of* resources, human health and impacts on eco-system.

II. History of LCA

It is said that the history *of* LCA goes back to the end *of* 1960's when an American Beverage Company started a research on the environmental impact *of* bottles, However, it was the latter half *of* 1990's when LCA became popular, In June 1997, ISO14040 (principle and framework *of* LCA) became an international standard as a Part *of* ISO14000 (Environmental Management). Series *of* Standards, which was

Translated into Japanese in November 1997 *to* be recognized as JIS (Japan Industrial Standards) Q14040. In Japan, the first International Conference *of* Eco-balance was held in October 1994 under the title "Life Cycle Assessment for the Development *of!* Materials and Technology", which represented the then growing interests in LCA researches in industrial sector. Also in the "Environment Basic Plan", adopted by the Cabinet in December 1994, it was clearly described to propel the research on LCA. In October 1995, under the auspice *of* the Japanese I Ministry *of* Trade and Industry (currently called the Ministry *of* Economics! and Industry), LCA Japan Forum was established. The results *of* its cross-lateral activities between industry, government and academia were compiled, into a report and opened to the public in June 1997. This was followed by a five year project starting from 1998; "Development *of* Life Cycle Assessment Technology *of* Products and Others (LCA Project)".

III. Approach to the building energy-environmental evaluation

At the beginning, the design methodology needs to define meaningful outputs that allow evaluating the performance level of the building to be analyzed. With regard to energy-environmental building evaluation, it is necessary to analyze and quantify each form of

Energy consumption, by calculating and investigating the following: embodied energy consumption and extrinsic (operative) energy consumption.

In parallel with the analysis of these two fundamental indicators, it would be appropriate to perform a cost evaluation that, as far as this research is concerned, was only roughly referred to at theoretical level. With regard to the embodied energy consumed by a building, an LCA analysis is necessary, aimed at defining a potential energy environmental impact of building materials, components and systems throughout

Their whole life cycle. The fundamental variables correlated to the building embodied energy-environmental impact are the following:

- The embodied energy comprises all the energy used for transporting and transforming rough materials into building elements, including all the energy contained in the raw materials usually employed as energy sources. Together with these energy forms, also indirect consumptions must be considered, related to use of fuel and energy for manufacturing, transporting and transforming raw materials.
- CO2 emission is the common standard indicator used to assess the earth global warming or greenhouse gases. Greenhouse gases emissions are strictly linked to energy consumption occurring during the production and transformation of raw materials. Instead, with regard to the building extrinsic energy consumption, it is necessary to calculate the energy used during the building's operation.
- The fundamental variables correlated to the analysis of the extrinsic energy consumption are:
- Power and fuel consumption, the former expressed in kWh, the latter in natural gas cube meters; they represent the basic evaluation terms to understand the use level of non-renewable resources of the investigated building and to compare these data with the consumptions of the reference buildings;
- The indoor environmental quality (IEQ), defined through several kinds of outputs, is the fundamental mandatory requirement notwithstanding the more or less energy sustainable technological and plant choices.

The astonishing growth of our civilization during the last century has been possible due to technological advancement, a seemingly limitless supply of natural resources and cheap energy derived from fossil fuels. Given the certainty of the upcoming fossil fuel shortage, our society will face tough times in the near future that will impact all aspects of our life. Most of us are so busy living our day-to-day lives that we fail to recognize these obvious facts. Conservation of all natural resources- most importantly fossil fuels- and transition to renewable energy sources will soon cross the realm of fashionable sustainability and become a matter of survival for our society.

Worldwide, buildings consume more energy than transportation, industrial or agricultural sectors. Unlike transportation, buildings are immobile and therefore present a much easier opportunity for energy conservation and for significant reduction of their dependence on energy derived from fossil fuels. All we need to do is to understand the order in which building and system parameters underpin its energy requirements and what solutions offer the most significant energy efficiency and space comfort

Improvements in its local climate setting. The correct approach does not require exclusive reliance on highly sophisticated and complex technological solutions; rather it requires proper understanding of fundamental laws of physics in the context of a building and its environment and thoughtful implementation of simple "low-tech" solutions before reaching for the "hi-tech" technologies. This logical and ordered design approach will result in a "Climate-Adapted" building design that conforms to its local environment rather than overpowers it, and requires only a fraction of energy flows consumed by conventional buildings. In fact, resource and energy efficient "Climate-Adapted" buildings were designed and built in this manner in our pre-technological past, often without the involvement of architects and engineers, relying instead on centuries tested solutions specific to each climate and resource base. We have only forgotten the traditional knowledge and have grown accustomed to heavily rely on modern energy intensive technology.

3.1 Passive Building Elements

Once a clear and measurable building energy target has been established, the design of building's passive elements must be given the highest priority. These elements directly interact with the local climate and its natural energy flows. The optimal building design will conform to its environment, with its passive elements either harnessing or protecting the building from these energy flows as needed. Depending on the local

Climate, building type and use, passive building elements can include, but are not limited to, the following:

- Shape, form, orientation, space layout, compactness
- Building skin (opaque and transparent), building mass

For example, increased building mass can provide improved energy efficiency in continental climate regions (both tempered and hot arid) with noticeable diurnal temperature variations. The passive energy storage effects of thermal mass can be further enhanced with simple operable shading devices on windows that are kept open during periods when capturing of solar gains is desirable and closed when it is not. A well insulated compact building form with low transparent to opaque wall ratio that minimizes the heat losses to its surroundings is most suited for cold regions. A light-weight, spread out, open and airy building layout, ideally raised off the ground to induce natural cross ventilation, and combined with extensive fixed overhangs to provide protection from solar radiation and rain is best suited for hot and humid climates.

These fundamental passive design options can be further enhanced by more intricate design strategies such as passive solar heating, natural wind and/or buoyancy driven ventilation, evaporative cooling, etc. But most importantly, as described earlier, the resulting passive design has to meet or exceed a specific, stringent and measurable energy performance target. An appropriate simulation tool, capable of accurately modeling the selected passive design features will have to be used to confirm the intended performance.

3.2 Active Technologies

Active HVAC system technologies must be selected on the basis of how well they can meet space thermal comfort and indoor air quality while being as energy efficient as possible. The best design solutions meeting all of these criteria can only be achieved if the selected systems are kept as simple and as integrated with the building's passive elements as possible, and if the overall design solution fully respects and works with, Rather than against, the laws of physics. To achieve this ambitious goal the ultimate active system solution must include the following three fundamental characteristics:

1. Space temperature control is independent from space ventilation;
2. Water is used as an exclusive energy carrier, and
3. System operating temperatures are very close to the desired thermal comfort range

The separation between the system's temperature control and ventilation functions achieves several positive results: it simplifies the configuration of each system, allows the exclusive use of water instead or air for energy transfer, and allows for the use of an independent ventilation system (naturally or mechanically driven) providing 100% fresh air into the occupied space. Water has more than 3,000 times the energy carrying capacity per unit volume of air. Much smaller volumetric flows of water and much less pumping energy are required to deliver the same heating or cooling capacity of an air based system. Water also transfers heat much more efficiently than air, resulting in better consumption.

IV. Conclusion

It is entirely feasible to significantly reduce their large impact on our diminishing energy resources and environment through two parallel shifts in the way buildings are currently designed and constructed around the world. The first shift is to approach the design of buildings from a more holistic viewpoint; one that considers the interaction

Between building's passive elements and the local climate first and foremost. The building design will then conform to its local environment, with its shape and orientation either harnessing or protecting the building from the natural energy flows at the site as needed. Through this approach, we can greatly reduce the building's energy requirements before any mechanical systems are even considered.

Once the passive building elements have been optimized we can then focus on the active or mechanically driven technologies. There are alternatives to the conventional forced-air HVAC system that will deliver superior thermal comfort and indoor air quality at significantly greater levels of efficiency. All that is required is careful consideration of fundamental laws of physics and thoughtful implementation of simple "low-tech"Solutions before reaching for the "hi-tech" technologies. This logical and ordered design approach will result in a "Climate-Adapted" building design that conforms to its local environment rather than overpowers it, and requires only a fraction of energy flows consumed by conventional buildings.

Building projects should be designed and their performance evaluated based on their life-cycle energy use, life-cycle cost and life-cycle carbon dioxide emissions.

The life cycle energy use (LCE) can be expressed as:

LCE = initial (or embodied) energy + n ·annual operating energy use, where n is the life duration of the building. It is relatively easy to estimate the energy consumption and the related carbon dioxide emissions associated with the building operation. Much more difficult is the estimation of embodied energy and related carbon dioxide emissions in building materials; it requires information about the energy used throughout the entire Manufacturing and installation process.

The imperative of the decade and certainly of the century is to get to understand and make substantial progress toward sustainable development. Buildings are acknowledged as the 40% sector with transport the 30% sector of impacts. Buildings and their planned co-location crucially affect the majority of our consumption of resources, air, and water and land pollution. There is a growing movement of committed

Practitioners trying to advocate and practice in a more sustainable way. In the US and a number of other countries multi-stakeholder coalitions of practitioners are coming together under the auspices of Green Building Councils to transform national markets toward sustainability. These include commercial and public sector organizations and Federal, State and Local governments. Green Building Councils and other

Organizations are recognizing the power of environmental assessment, certification and labeling (ideally third party assessed).

The second shift that is required is the revision of our current methodology used to prescribe and define building energy performance. There is a need to abandon the current methodology providing a "moveable energy performance target" and instead, adopt a more straightforward methodology that will provide a "fixed energy performance target" in clear and measurable terms. Europe has already taken the lead in developing
Such standards, although much of the developing world still looks to North America as its role model. Let's take action now to positively shape our future rather than wait until the resource and energy-starved future where we may no longer have the freedom of choice.

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