Development of Sustainable City In Developing Countries: An Architect's Perspective

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***Abstract*—The concept of Ecocity by using the advantages of a self-contained commune with a building unit designed to cater the needs of approximately 15 to 20 families is presented in this research. The provisions will be made in these housing to enable the inhabitants to produce their own energy, grow their own agricultural produces for food, and recycle all the resources / waste. The building will be designed in such a way that it will use non-conventional & renewal energy sources totally and will not use any form of external energy source like electrical grid network or fossil fuels, etc. The main objective is to develop design strategies of suitable for self-sufficient housing units incorporating the necessary infrastructures, like equipment of energy generation, recycling, reuse.**

***Index Terms*— *Ecocity, Self Sufficient Housing, Renewable Energy*.**

I. Introduction

With its present growth rate (about 150 persons/ min.) the world population will be crossing 8.5 billion by the end of the year 2025. As per the projections made, 57% of this population will be urban, out of which 95% contribution will be due to the developing countries. As a result, the population of many cities in developing countries will cross the figure of 20 million by the year 2015. Based on projections made by UNCHS, 17 of the 21-mega cities will be in the developing countries.

LIST 1 - EXISTING MEGA CITIES (2015)

BEIJING, BUENOS AIRES, CAIRO, DACCA, DELHI, JAKARTA, KARACHI, KOLKATA, LAGOS, LOS ANGELES, MANILA, MEXICO CITY, MUMBAI, NEW YORK, OSAKA, RIO DE JANEIRO, SAO PAULO, SEOUL, SHANGHAI, TIANJIN, TOKYO.
PROJECTED LIST OF MEGA CITIES OF FUTURE (2016)
CHENNAI, HYDERABAD, ISTANBUL, KINHASA, LAHORE, LIMA, MOSCOW, PARIS, TEHERAN

Based on above projections, it is quite easy to predict the future housing needs. Already there is a global shortage of housing for 2 billion people. This shortage will be becoming more and more acute if no immediate actions/measures are taken. This definitely advocates the need of development of mass housing projects. This shortage will further increase by the year 2025, when the world population will be around 8.5 billion. But what about the tremendous impact on the field of energy usage of these future developmental projects of mass housing? A study of present processes of development with associated energy usage will help architects in designing mass housing with less energy consumption, leading ultimately to conservation of natural resources and less polluted urban environment.

Manuscript received February 22, 2016

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II. The Pressure

It is necessary here, to identify various major pressures, which are generally put on the urban areas by building more mass housing units:

Land:

As of today the land in the urban metro cities has become very dear & costly; also it is difficult to find new land suitable for mass housing. The alternative of housing in high-rise apartments is leading these urban areas towards chaotic development. They also pose greater pressure on parking and transportation system network [1].

Energy:

This is a burning problem of present era. The present unplanned and uncontrolled growth of housing cares little about energy conservation aspects. Sometimes even providing minimum energy to all households is not becoming possible by the local authorities. Studies reveal that around 18% of total energy consumption of mankind is in housing sector. It is necessary to consider energy conservation techniques before, during and after construction; as energy can be saved considerably in each stage. Over 80% of the embodied energy in mass housing is the energy required to manufacture the materials. Most of this energy usage is for manufacturing only a small number of the (high-energy) materials used in construction of housing units, principally steel products, cement, concrete products, bricks and ceramic materials. This embodied energy amounts to several times the annual energy consumption of that same housing in use. Energy is used wastefully in heat recovery processes, insulation techniques, and simple orientation concerns. Architectural lighting & space heating/ cooling are also two of the largest and most visible consumers of energy. A properly designed energy efficient housing will have a lower initial cost than one planned disregarding energy consequences. This cost advantage derives mainly from smaller building volume & lower energy demands. . The conventional centralized energy distribution network accounts for high transmission losses (ranging from 9 to 20% at times). In Indian context grid loss sometimes reach upto 35%. The energy consumption in residential structures accounts considerably high than other buildings, also it is a recurring ever cost increasing phenomena. It is very difficult to remain in the city and save energy beyond a certain limit without compromising the present day materialistic lifestyle by the city dweller households.

Utilities:

The present day big cities are growing in a faster speed; the utilities & the city of basic amenities to urban population is becoming increasingly difficult day-by-day. It is a very complex situation and a major multifaceted problem to cope up with such a huge demand. Lack of finance/ civic sense resources are further adding to this precarious condition.

Environment:

The present day pollution & lack of basic amenities are proving detrimental to future growth of residential nature in metro city areas. The polluted air and water, the toxic wastes, the dangerous fuel emissions from vehicles, are further aggravating this situation. The decreasing green areas are bringing changes in the microclimate in of these cities, making it more and more uncomfortable for living.

Transportation:

The public transport systems of almost all these urban conglomerations are running at a loss and it has become increasingly difficult to maintain their effectiveness cleanliness and punctuality, because of overcrowding and pressure of daily commuting population.

III. Energy Efficiency to Sufficiency

It had already been established in 1970 that there is no inexhaustible supply of cheap conventional energy sources, available in world & therefore serious efforts should be aimed at identifying energy conservation methods and a lot of research is being done to effectively use the available non-conventional & renewable energy sources. The future of housing design should rely on not only energy efficiency but towards energy sufficiency. For effectively using these concepts, simultaneous use of various non-conventional energy sources is necessary, which will cover the lean period of generation of energy by one source and will provide designed uninterrupted quantity of energy all the time. UNCHS recommends, "Housing should be designed with the application of bio-climatic design principle & employment of energy conservation measures will reduce 60% energy consumption in heating/ cooling of buildings."

IV. The New Concept

The concept of 'self sufficient housing' is to minimize the pressures on cities in terms of space, energy, traffic, population, etc. This housing will be in a self-contained commune with a building unit designed to cater the needs of approximately 15 to 20 families. They will produce their own energy for domestic use; grow their own agricultural produces for food, thereby limiting their visits to urban areas for such tasks and products, which are not feasible in this commune. They will be sited in economical rural spaces / natural surroundings [2]. A self sufficient home is a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. These homes are designed to meet certain objectives such as protecting health; using energy, water, and other resources more efficiently; and reducing the overall impact on the environment.

V. The Advantage

Location & Siting:

These units will be located in rural / country areas & they will be well connected with the possible work centres. The rural natural fresh & unpolluted environment and low cost of land will be the first positive aspect of siting such dwelling units. Protect and retain existing landscaping and natural features. Select plants that have low water and pesticide needs, and generate minimum plant trimmings. Use compost and mulches. This will save water and time. Recycled content paving materials, furnishings, and mulches help close the recycling loop.

Energy Sufficiency**:**

The building will be planned in such a way that it will use non-conventional & renewal energy sources totally and will not use any form of external energy source like electrical grid network or fossil fuels, etc. Here reference can be made to Nottinghamshire's Hockerton Housing Project (HHP), which is the UK's earth-sheltered, self sufficient ecological housing development [8]. Architectural strategies for energy conservation can be:-

- Develop strategies to provide natural lighting. Studies have shown that it has a positive impact well being.
- Task lighting reduces general overhead light levels.
- Use a properly sized and energy-efficient heat/cooling system in conjunction with thermally efficient walls, roofs and floors.
- Maximize light colours for roofing and wall finish materials; install high R-value wall and ceiling insulation; and use minimal glass on undesired sun exposures.
- Consider alternative and renewable energy sources.
- Passive design strategies can dramatically affect a home's energy performance. These measures include home shape and orientation, passive solar design, and the use of natural lighting.

Materials Efficiency:

Select sustainable construction materials and products by evaluating several characteristics such as reused and recycled content, zero or low off gassing of harmful air emissions, zero or low toxicity, sustainably harvested materials, high recyclables, durability, longevity, and local production. Such products promote resource conservation and efficiency. Reuse and recycle construction and demolition materials.

Recycling:

The concept of recycling of waste/ water/ garbage will be applied in such a way that it fulfils the need of dwellers without tapping any external services or utility networks. The garbage will be recycled to produce energy through non-conventional methods & end product will become manure for crops. One example of recycling can be using wastewater from washing in fishponds and from there it can be used in fields/ vegetable farms [3]. Some other measures which will definitely improve water efficiency can be:-

- Design for dual plumbing to use recycled water for toilet flushing or a gray water system that recovers rainwater or other nonpotable water for site irrigation.
- Minimize wastewater by using ultra low-flush toilets, low-flow showerheads, and other water conserving fixtures.

- Use recirculating systems for centralized hot water distribution.
- Install point-of-use tank less hot water heating systems.
- Use micro-irrigation (which excludes sprinklers and high-pressure sprayers) to supply water in non-turf areas.
- Use state-of-the-art irrigation controllers and self-closing nozzles on hoses.

Space Economy:

This building will be providing minimum adequate living space for 15 to 20 families in an economical rural/ countryside site. This number of dwellers will depend upon local conditions, extent of the problem and energy sufficiency parameters along with other factors.

Environment Friendly:

The main aim of these self sufficient housing units is to develop such a housing system in which there will be no generation of pollution by any means. Besides being sited in a rural environment these houses will be using recycling of water and all the waste materials. Thus a nature friendly & ecologically balanced surrounding will be created by these dwellers through these housing systems.

Employment Generating:

The commune development activities and maintenance of various energy generation equipments will also generate employment for the dwellers & only a handful (one person per family) may have to go to city areas for sophisticated jobs etc. As this concept provides partial food growing facility / zero energy bill along with Other economical advantages; there will be less necessity of a job, and dwellers can engage themselves in a occupation/ vocation of their own choice for better income, while living in the commune.

Minimizing Transportation:

The dwellers require minimum transportation. As only periodical shopping of merchandise & some other works may require traveling to other areas which are not possible within this commune. Though through scientific application of knowledge of farming will reduce this need to travel. This in turn will decrease the overall stress on existing transportation systems.

VI. The Process

Selection of a target group representing largest portion of such migratory population:
This selection must be made at local level considering the nearness of urban areas.

Determination of a feasible size of commune by considering local problems of Siting:
Though preliminary studies suggest about 250 families can be a manageable size for developing country social conditions, having a maximum of 5 persons per family. It is necessary to include maximum types of vocation /professionals into one commune.

Proposing living space:

For 15 to 20 families in one building, by undertaking anthropometrical studies and deciding space standards, taking along with the study of economical feasibility of the target group [5]. The minimum proposed enclosed spaces required for a family should be consisting of:

- Habitable space: bedroom / living room; utilities: kitchen / toilet / bathroom / store, etc.

In addition to these some common spaces are necessary for community living, which may be:

- Services/electric room/garbage collection room, Kitchen garden / open garden / terrace garden, farming, fishpond, poultry etc. These spaces can be created in common spaces left between the units.

Estimating space requirements:

For energy production by renewable or non-conventional energy sources: -

Biogas / biomass plant, wind energy, solar energy. Where feasible tidal energy can be also used.

Deciding Building fabric and enclosure spaces (including structural considerations):
Here due attention must be paid to achieve a structurally safe & maintenance free construction.

Earmarking Spaces for recycling plants:

For water / garbage / sewerage for energy and manure production. These spaces should be designed with optimum space utilization concept, though importance of these cannot be ignored due to their necessity in keeping the pollution level low. Care must be taken to adapt foolproof recycling systems.

Providing community spaces & common spaces for recreation and other utilities:
Park / school / primary health center / recreation center, roads / pathways, etc.

Calculating the energy demands:

of the unit and proposing energy sufficiency by tapping non-conventional energy sources. Some of such energy sources under consideration are: -

Solar (photo-voltaic), Biomass, Wind, Tidal, etc. It may be necessary to install a combination of these energy sources to get desired result all the year round.

Estimating the necessity of other resources:

like water, etc., & proposing their procurement from locally available natural sources. Rainwater must be compulsorily collected & underground water level must be allowed to charge through natural means.

Deciding the size of one building unit:

with cross checking each of the above mentioned spaces as per their feasibility and sustainability with respect to number of dwellers and self-sufficiency parameters[4].

Arriving at a suitable size as per local conditions / resources availability / willing population.

Determining the social acceptability of these relatively new housing systems, through preliminary survey of various shelter less people, or people suffering from overcrowding in conventional housing[5]. In case of crowding new commune should be planned.

VII. Architectural Design of Housing

The housing design should incorporate energy saving techniques by reducing the energy demands & some major recommendations are:-

- Proper site selection & orientation.
- Use of shady trees to control radiation reaching unwanted places of building envelope.
- Maximum window placement on the side of least sun exposure.

  Minimize exposed surface area for reducing heat transmission.

VIII. The Materials

Over 80% of the embodied energy in housing is the energy required to manufacture the building materials. It has been established that most of this energy is used in only a small number of materials, principally, iron/steel products, cement/concrete products, bricks/ceramic materials. The embodied energy in a housing unit amounts to several times the annual energy consumption of that same housing in use [7]. So, architects of self-sufficient housing have the opportunity to make a major contribution to the reduction of total energy use in built environment through some of the strategies enlisted here:

- Maximum use of low energy materials.
- Selection of lower-energy structural systems, such as load bearing masonry in place of RCC/ steel frames.
- Selection of waste/recycled materials, or manufactured materials, which incorporate these.
- Use local materials, involving less transportation.
- Use more functional windows (designed as passive solar collectors). Optionally smart windows can be also used, which use anti reflection layers, low emission coatings and switch able films.

IX. The Construction

During construction process, materials are combined in composite building components such as walls, floors and roofs. Based on the energy intensity of the materials and the quantities used, it is possible to calculate the energy insensitivity of various types of building materials and construction methods.

TABLE I: Energy Requirements Of Typical Housing Components

Components	Energy (MJ/Sq.m.)
Floors:	
Suspended Timber	733
Concrete slab on ground	1014
Walls:	
Timber frame, weatherboard cladding	198
Timber frame, brick-veneer cladding	1284
Concrete block	755
Roofs:	
Galvanized Steel	508
Concrete Tile	176

Similarly, the energy intensity of various house designs can be calculated and compared. It is notable that structures can vary up to 60% in capital energy requirement, as a result of architect's choice of materials [6].

X. Economical Considerations

A Self Sufficient home may cost more up front, but saves through lower operating costs over the life of the home. These homes require fewer trips to the doctor's office. This approach applies a life cycle cost analysis for determining the appropriate up-front cost. This analytical method calculates costs over the useful life of the home. These cost-savings can only be fully realized when they are incorporated at the project's conceptual design phase with the assistance of an integrated team of professionals. The integrated systems approach ensures that the home is designed as one system rather than a collection of stand-alone systems. Some benefits, such as improving health and comfort, reducing pollution and landfill waste are not easily quantified. Consequently, they are not adequately considered in a cost analysis. For this reason, consider setting aside a small portion of the building budget to cover differential costs associated with less tangible benefits or to cover the cost of researching and analyzing Self Sufficient housing options. This development may lead to a school of thought in the inhabitants and they will thrive to become self-sufficient.

XI. Conclusion

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

XII. Selected Examples

Though full implementation of these concepts is rare, some good examples exist in Europe, which partially use self-sufficient concept are enlisted herewith:

- The Cropthorne Autonomous Home in UK which is using renewable energy and as a result it is carbon-negative [9].
- Climate Neutral Passive House Estate in Hannover Kronsberg [10] which is using passive solar techniques along with super insulation technologies.
- Findhorn Ecovillage in UK [11] notable for low carbon and oldest community based agricultural system.

XIII. Ecocity development

If the other urban buildings/ infrastructure constructions follow the similar approach, development of eco-city will become more and more feasible. Further, it is necessary to give importance to these concepts as housing nearly covers 40% to 42% (as per Town and Country Planning norms in India), of serviced urban land area in developing countries.

References

[1] SANYAL D., *Self Sufficient Housing: Searching of parameters*, Architects India, Bombay 1995, Vol. 7, No. 6, pp.26-27.

[2] SANYAL D., *Development of Self Sufficient Housing using intelligent buildings in Indian context.* New methods and technologies in Planning and construction of Intelligent Buildings II, Proceedings of IB/IC Intelligent Buildings Congress, Tel Aviv 1997, pp.88-97.
[3] SANYAL D., *Self-sufficient housing for urban India: A study of architectural considerations.* Proceedings of National Seminar on Advances in Energy Efficient Construction Systems, Gorakhpur 1999, pp.25-35.
[4] SANYAL D., *Exploration of architectural design aspects for intelligent self sufficient housing: a study,* Proceedings of World Conference on Green Design, World Congress on Environmental Design for the New Millennium, Seoul 2000, pp.375-385.
[5] SANYAL D., *Development of Intelligent Self Sufficient Housing as Component of Ecocity in Developing Countries,* National Symposium on Sustainability and the Built Environment: Searching For Synergies, Kolkata 2014, pp.76-80.
[6] UNCHS (Habitat), Energy efficiency in housing construction and domestic use in Developing countries, Nairobi1991, (HS/218/91/E) pp.8.
[7] UNCHS (Habitat), Energy for buildings, Nairobi1991, (HS/250/91/ E) pp.88.
[8] Susan Hunt, *Self Sufficient Housing Developments: A Case Study*, (Online),3.9.2010, http://www.sustainablebuild.co.uk/self-sufficient-housing-developments.html.
[9] The Cropthorne *Autonomous Home, http://www.cropthornehouse.co.uk*.
[10] Wolfgang Feist, *Climate Neutral Passive House Estate in HannoverKronsberg: Construction and Measurement Results*, (Online), http://passiv.de/downloads/05_cepheus_kronsberg_summary_pep_en.pdf
[11] The findhorn ecovillage, (Online), http://www.ecovillagefindhorn.com.

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