DESIGN CONSIDERATIONS FOR SUSTAINABLE NEIGHBORHOODS

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF ARCHITECTURE

By

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JUNE, 2006

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in this dissertation entitled **"DESIGN CONSIDERATIONS FOR SUSTAINABLE NEIGHBORHOODS"** in partial fulfillment of the requirement for the award of the Degree of Master of Architecture [M.Arch] submitted in the Department of Architecture and Planning, Indian Institute of Technology, Roorkee, India is an authentic record of my own work carried out from July 2005 to June 2006 under the supervision of **Prof.S.Y.Kulkarni**.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

MOHAMMED ALI SHARIEFF

This is to certify that the above statement made by the candidate is true and correct to the best of my knowledge.

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ACKNOWLEDGEMENTS

By the grace of Almighty **ALLAH** the most knowledgeable, the most wise.
I take this opportunity to remember, acknowledge and thank the people who helped me and gave valuable suggestions in the course of this dissertation.

To my guide and mentor **Prof.S.Y.Kulkarni** for his constant guidance, support and valuable help during the period of this program. His wisdom and advice have helped complete this thesis through the several stages of its formation.

To **Prof.R.Shankar**, Head of the Department for his constant support, guidance, motivation and help through the entire period of this program.
To **Prof.P.K.Patel**, M.Arch Coordinator for the constant encouragement and help to the fullest of his capacities through the entire period of this program.
To **Prof.R.Sahu**, **Prof.B.K.Tyagi**, **Prof.Najmuddin**, **Prof.Rita Ahuja** and **Prof.Pushpalata** for their valuable comments and guidance in this dissertation.

To the **Ministry of HRD** and **IIT Roorkee** for the Assistantship/Contingency I received during the entire period of this course.
To all other faculty members, non-teaching staff, library staff, administrative staff and canteen staff, especially **Dinesh** of this Department for their undue help.
To all my classmates, friends and juniors especially **Gopal**, **Nachiketa**, **Javed** and **Tony** (who left us) for their friendship, patient hearing, late night hang-outs and time.

To my **mother** with love and affection, for her blessings and prayers, whose ambition and hard work has single handedly led me to this knowledge level.
To all my **family** members and my **in-laws** for their unconditional support since the day I decided to join master's program at an advanced stage of my life.
To my **wife** and **son** for their love, affection, sacrifice and being there for me.
To my innocent **daughter** (of eight weeks), I **dedicate** this dissertation.

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1.0 INTRODUCTION

The following study is an attempt to understand the broad scope of sustainable design through the research and distillation of existing sustainable design theories, technologies and strategies for a holistic development thorough design of the neighborhood. From this, a series of design considerations (sustainable guidelines and principles), covering practical and real life design measures is proposed.

Existing knowledge on this topic is generally limited to the separate disciplines, without much inter-coordination. A complete holistic perspective of achieving sustainability in a neighborhood with the backbone of architectural design is a topic that has not been explored greatly. This is the reason for this study. A holistic perspective on this topic results in a much clearer understanding of the concept of sustainability, as well as a better grasp of how to steer the design industry towards more sustainable practices.

It is important to note here, that this study derives its focus from traditional and modern sustainable design practices. Hence, much of the gathered literature and information comes from different sources and backgrounds. This study is not representative of the global field of sustainability, other cultures and regions have different perspectives and approaches to sustainable design. The area under study is an emerging area as regards sustainable development; and relatively new with vast scope and potential for further research and understanding of the sustainable design of neighborhoods.

2.0 OBJECTIVES AND METHODOLOGY

"It's the action, not the fruit of the action that is important.
You have to do the right thing.
It may not be in your power, may not be in your time,
That there will be any fruit.
But that doesn't mean you stop doing the right thing.
You may never know what results come from your action.
But if you do nothing, there will be no result."
Mahatma Gandhi

2.1 Need for the study

A complete holistic perspective of achieving sustainability in neighborhoods through architectural design is a topic that has not been explored greatly. Thus the reason for this study is based on a vision incorporating sustainability and architectural design with the following outlines:

2.1.1 Environmental Quality

A clean healthy and enjoyable neighborhood where the total environment is valued and there is clean air, clean water, and clean soil; streets are clean; a toxin-free city - both within and outside buildings; and a noise free neighborhood.

2.1.2 A Living Caring Neighborhood

A place where people want to live, work and visit with activity 24 hours a day; a thriving viable economic community; attraction for people of all ages; a strong sense of caring, safety and community; and people of all ages being valued.

2.1.3 Opportunity, Choice and Responsibility

A neighborhood with a variety of options for living, working, moving and recreating, besides providing ample opportunities for people to contribute towards sustainable practices; people actively participate to the neighborhood's future; people to act on their own behalf in community ventures and where the community recognizes that the common good may curtail individual freedoms and require individual responsibilities.

2.1.4 Resource Use

A neighborhood where land and resources are used efficiently and where buildings are of energy efficient design and are ecologically responsible; energy resources are used wisely; the potential for use of renewable energy is maximized; development is not at the expense of scarce resources; water is managed efficiently; storm water is harvested for re-use; resource recovery is maximized and waste sent to landfill is minimized.

2.1.5 Natural Environment

A neighborhood where the natural environment provides opportunities for peaceful activity, where natural amenity is protected and where park, land, terrestrial and aquatic environments are restored; there is an ecological balance of uses; green areas are continuous - providing corridors for people and fauna.

2.1.6 Movement and Access

A neighborhood with a diverse mix of compatible land uses, where people can have access (preferably walking) to all their work, living and recreation needs and have real alternatives to car use. Transport decisions are made in an integrated way to promote priority to pedestrians and cyclists; elimination of unnecessary vehicular traffic; unrestricted access to people with disabilities; provision of an effective public transport service which is clean, comfortable, frequent, flexible and compatible with pedestrians and the neighborhood form.

2.1.7 Balance

A neighborhood where people are in balance with the environment and where there is adequate natural light, access to sunlight, protection from sun; summer shade from street trees and access to fresh air; diverse communities, individuals and businesses live in harmony; the parks and lands have an appropriate and sustainable balance between recreation and environmental uses; resource use and waste management does not cause imbalance with adjacent local communities.

2.1.8 Management

A neighborhood where all are responsible and take the best of social, economic and environmental decisions in order to manage and sustain the neighborhood.

2.2 Aims and Objectives

This study is to be carried out with the following goals in mind:

a. to provide an ecological approach to neighborhood design strategies;

b. enhance neighborhood life through sustainable development;

c. to facilitate and achieve active, vibrant, attractive, safe and user-friendly neighborhoods;

d. to create an interesting and cohesive neighborhood scape;

e. to understand and analyze the old and new practices in the design and functioning of our neighborhoods;

f. suggest sustainable design measures that can enhance the total environment of the neighborhood

2.3 Scope of the study

For most urban dwellers, daily life is framed by the neighborhood in which they live. The scale of the neighborhood is the most appropriate one at which to apply design strategies. This study intends to address the following issues:

a. study of "how to make a neighborhood sustainable?"
b. study and analyze neighborhoods for sustainable design principles
c. familiarize with the latest developments in sustainable design
d. extend the concept of sustainability to the physical design of the neighborhood
e. suggest practical sustainable design strategies for neighborhoods

2.4 Methodology / Plan of study

1. literature study: data collection from books, internet, other sources
2. outline the need, aims and objectives, and scope of the study
3. case studies: analysis of existing/proposed neighborhoods
4. analysis and inferences from literature study and case studies
5. evaluation and assessment of neighborhoods for sustainable principles
6. synthesis of sustainable principles with design principles/elements
7. outline design strategies and measures for sustainable neighborhoods
8. conclusions and recommendations

3.0 SUSTAINABILITY

"Future generation is the most important" -- **Confucius.**

3.1 Man amidst nature – An ecological relationship

Global warming, ozone layer depletion, rampant species extinction, overflowing landfills, air pollution, overpopulation, and acid rain, these are just a few of the environmental dilemmas we have created in our modern technocratic society. As our man-made cities expand throughout the globe, the ever-shrinking natural world becomes altered toward a new definition of nature.

A society which does not understand the principles and ecological processes of nature cannot function in harmony with the natural world. Society has forgotten that despite our technological advances we are still a part of nature, not above it, and therefore must function as a piece of the whole. How did our society stray so far from ecological reality? The reasons are plentiful and complex. In short, it began with a basic philosophical mistake which, derived from the western belief that man was separate from nature. This was interpreted to emphasize man's divine right to subjugate and exploit nature. When combined with the industrial revolution and the discovery of fossil fuels, this created a perfect recipe for ecological disaster.

The 20th century brought about Modernism and its blind faith in technology, which added further ammunition to man's war on nature. Following World War II, Modernism became the dominant force on the urban design scene in many planners to start from scratch. Cities became modelled after machines. They were designed to become mega-factories for the efficient of goods and services.

An ideal which was best demonstrated by Le Corbusier "city as machine" theory, and Frank Lloyd Wright's, Broad acre City design. The automobile was the primary physical design determinant. How to get a car from point A to point B in the most efficient way possible became valued over the quality of the environment for the pedestrian. Quality of life in cities became ranked by economic wealth and material goods. Criteria such as community and environmental health were not a consideration in the modern city.

Regardless of who or what is to blame, there is a need to re-evaluate our relationship to nature. However, all is not doom and gloom; the ecological crisis we have created have also caused strong reactions throughout society to halt our carelessness and restore the environment. Environmental issues now rank as the greatest concern in the world. To achieve a lasting and growing impact on urban development, time, effort and resources need to be invested in the systems that support sustainability. Failing to do so can lead to the waste of scarce resources for short-term gains, without lasting benefits.

3.2 Sustainable development

"Being sustainable means intelligently following the principles of nature"

Sustainability (refer fig.1) requires that the processes set in place by an urban development initiative continue indefinitely after the initial external inputs have been withdrawn and can be replicable in similar circumstances elsewhere.

The sustainable approach to site planning and design goes beyond combining and comparing site inventories. A sustainable process attempts to determine the relationships between site factors and how those factors will adapt to change. Understanding these relationships also clarifies how development impacts from one area of the site will affect other areas. An evaluation of potential development impacts requires that a predevelopment baseline or environmental model be produced. The major steps in a sustainable approach to site planning and design are as follows:

a. Model the ecosystem to establish an environmental understanding;
b. Assess social-economic context;
c. Establish acceptable limits of change;
d. Design facility within social and environmental thresholds;
e. Monitor site factors throughout construction;
f. Reevaluate design solutions between development phases.

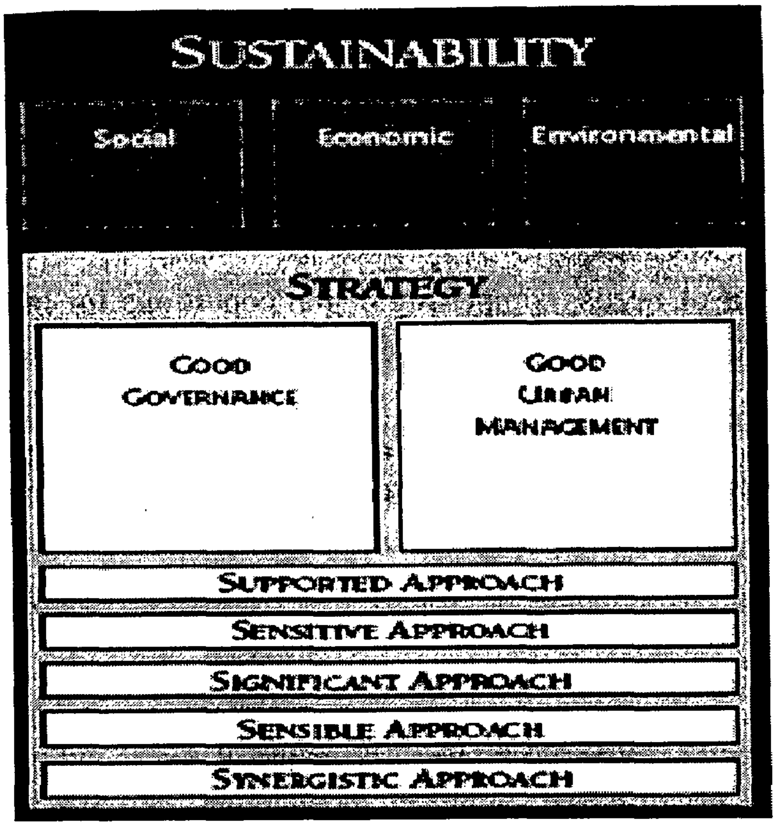


Figure 1. **The Seven 'S's of Sustainability**

Technological sustainability is the belief that we may find sustainability within the current economic, socio-political system. Within this approach, there is no need for fundamental changes in the current system. Ecological sustainability, asserts the belief that the current structure and mindset of our society is unsustainable, and in order to approach sustainability a new mode of thinking must take place. The current economic and socio-political system must be re-structured. It is finding alternatives to the practices that got us into trouble in the first place; it is necessary to rethink agriculture, shelter, energy use, urban design, transportation, economics, neighborhood patterns, resource use, forestry, the importance of wilderness, and our central values.

"Sustainable development is development which meets the needs of the present without compromising the ability of future generation to meet their own needs." -- World Commission on Environment and Development, pp. 4, Oxford University Press, New York, 1987.

The word development in this definition implicates two important aspects of the concept: It is omni- disciplinary, it cannot be limited to a number of disciplines or areas, but it is applicable to the whole world and everyone and everything on it, now and in the future. Secondly, there is no set aim, but the continuation of development is the aim.

The definition is based on two concepts:

a. the concept of needs, comprising of the conditions for maintaining an acceptable life standard for all people, and
b. the concept of limits of the capacity of the environment to fulfill the needs of the present and the future, determined by the state of technology and social organization.

The needs consist firstly of basic needs such as food, clothing, housing and employment. Secondly, every individual, in every part of the world should have the opportunity to try and raise his or her life standard above this absolute minimum. The limits consist of natural limitations like finite resources, but also of declining productivity caused by overexploitation of resources, declining quality of water and shrinking of biodiversity. For our common future, it would therefore be best if needs are best fulfilled while limits are not increased, but preferably decreased. This would lead to the quite simple conclusion that all political, technical and social developments can easily be evaluated in the light of sustainability (refer fig.2) development by these two arguments. Any development should help fulfill needs and should not increase limitations.

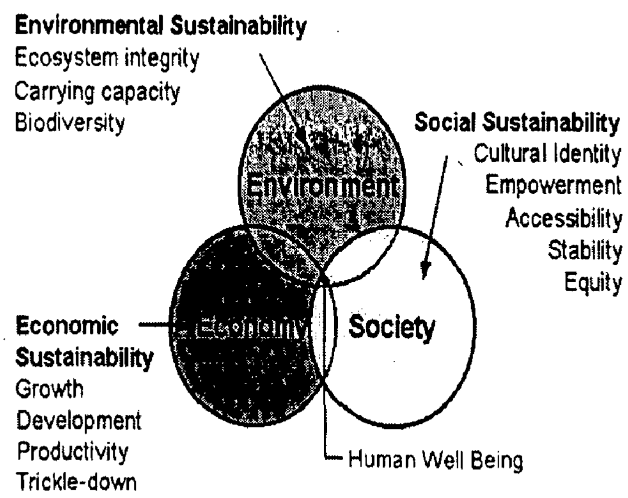


Figure 2. **The Three dimensions of Sustainability**

3.3 Sustainable architecture

"Architecture presents a unique challenge in the field of sustainability. Construction projects typically consume large amounts of materials, produce tons of waste, and often involve weighing the preservation of buildings that have historical significance against the desire for the development of newer, more modern designs." -- The Earth Pledge (http://www.earthpledge.org/)

3.3.1 Sustainable construction

Sustainable construction is defined as "the creation and responsible management of a healthy built environment based on resource efficient and ecological principles". Sustainably designed buildings aim to lessen their impact on our environment through energy and resource efficiency. It includes minimizing non-renewable resource consumption; enhancing the natural environment and eliminating or the use of toxins.

"Sustainable building" can be defined as those buildings that have minimum adverse impacts on the built and natural environment, in terms of the buildings themselves, their immediate surroundings and the broader regional and global setting. Sustainable building involves considering the entire life cycle of buildings, taking environmental quality, functional quality and future values into account. There are five objectives for the sustainable design of buildings:

a. Efficient utilization of all resources
b. Energy Efficiency (including Greenhouse Gas Emissions Reduction)
c. Prevention, treatment and control of all types of pollution (including Indoor Air Quality and Noise Abatement)
d. Harmonization with Environment (including Environmental Assessment)
e. Integrated Approaches towards an Environmental Management System

3.3.2 Green code for architecture

Based on the objectives of the Building Research Establishment's Environmental Assessment Method (BREEAM) the principles are:

a. demolish and rebuild only when it is not economical or practicable to reuse, adapt or extend an existing structure;
b. reduce the need for transport during demolition, refurbishment and construction and control all processes to reduce noise, dust, vibration, pollution and waste;
c. make the most of the site, e.g. by studying its history and purpose, local micro-climates and the prevailing winds and weather patterns, solar orientation, provision of public transport and the form of surrounding buildings;
d. design the building to minimize the cost of ownership and its impact on the environment over its life span by making it easily maintainable and by incorporating techniques and technologies for conserving energy and water and reducing emissions to land, water and air;
e. wherever feasible, use the construction techniques which are indigenous to the area, learning from local traditions in materials and design;
f. put the function of the building and the comfort of its occupants well before any statement it is intended to make about the owner or its designer. That is, make it secure, flexible and adaptable (to meet future requirements) and able to facilitate and promote communications between staff;
g. build to the appropriate quality and to last. Longevity depends much on form, finishes and the method of assembly employed as on the material used;
h. avoid using materials from non renewable sources or which cannot be reused or recycled, especially in structures which have a short life.

3.3.3 Environmental architecture

Principles of an environmental architecture (Thomas A. Fisher, AIA, Nov 1992):

a. *Healthful Interior Environment.* All possible measures are to be taken to ensure that materials and building systems do not emit toxic substances and gasses into the interior atmosphere. Additional measures are to be taken to clean and revitalize interior air with filtration and plantings.
b. *Energy Efficiency.* All possible measures are to be taken to ensure that the building's use of energy is minimal. Cooling, heating and lighting systems are to use methods and products that conserve or eliminate energy use.

c. *Ecologically Benign Materials.* All possible measures are to be taken to use building materials and products that minimize destruction of the global environment. Wood is to be selected based on non destructive forestry practices. Other materials and products are to be considered based on the toxic waste out put of production.

d. *Environmental Form.* All possible measures are to be taken to relate the form and plan of the design to the site, the region and the climate. Measures are to be taken to "heal" and augment the ecology of the site. Accommodations are to be made for recycling and energy efficiency. Measures are to be taken to relate the form of building to a harmonious relationship between the inhabitants and nature.

e. *Good Design.* All possible measures are to be taken to achieve an efficient, long lasting and elegant relationship of use areas, circulation, building form, mechanical systems and construction technology. Symbolic relationships with appropriate history, the Earth and spiritual principles are to be searched for and expressed. Finished buildings shall be well built, easy to use and beautiful.

3.3.4 The Hannover principles - William McDonough

a. Insist on rights of humanity and nature to co-exist in a healthy, supportive, diverse and sustainable condition.

b. Recognize interdependence. The elements of human design interact with and depend upon the natural world, with broad and diverse implications at every scale. Expand design considerations to recognizing even distant effects.

c. Respect relationships between spirit and matter. Consider all aspects of human settlement including community, dwelling, industry and trade in terms of existing and evolving connections between spiritual and material consciousness.

d. Accept responsibility for the consequences of design decisions upon human well-being, the viability of natural systems, and their right to co-exist.

e. Create safe objects of long-term value. Do not burden future generations with requirements for maintenance of vigilant administration of potential danger due to the careless creation of products, processes or standards.

f. Eliminate the concept of waste. Evaluate and optimize the full life-cycle of products and processes, to approach the state of natural systems, in which there is no waste.

g. Rely on natural energy flows. Human designs should, like the living world, derive their creative forces from perpetual solar income. Incorporate the energy efficiently and safely for responsible use.
h. Understand the limitations of design. No human creation lasts forever and design does not solve all problems. Those who create and plan should practice humility in the face of nature. Treat nature as a model and mentor, not and inconvenience to be evaded or controlled.
i. Seek constant improvement by the sharing of knowledge. Encourage direct and open communication between colleagues, patrons, manufacturers and users to link long term sustainable considerations with ethical responsibility, and re-establish the integral relationship between natural processes and human activity.

3.3.5 Green building

A green approach to the built environment involves a holistic approach to the design of buildings. All the resources that go into a building be they materials, fuels or the contribution of the users need to be considered if a sustainable architecture is to be produced. Measures for green buildings include reducing energy in use; minimizing external pollution and environmental damage; reducing embodied energy and resource depletion; and minimizing internal pollution and damage to health.

A "Green" building places a high priority on health, environmental and resource conservation performance over its life-cycle. Green design emphasizes a number of new environmental, resource and occupant health concerns such as:

a. Reduce human exposure to noxious materials;
b. Conserve non-renewable energy and scarce materials;
c. Minimize life-cycle ecological impact of energy and materials used;
d. Use renewable energy and materials that are sustainably harvested;
e. Protect and restore local air, water, soils, flora and fauna;
f. Support pedestrians, bicycles, mass transit and other alternatives to fossil-fueled vehicles.

3.3.6 Sustainable design

The major elements of sustainable design (refer table 1) are:

a. Sustainable design is "front loaded" compared with traditional design.

b. Sustainable design is more of a philosophy of building than a building style.

c. Sustainable buildings don't have to cost more, nor are they more complex.

d. Integrated design is critical to successful sustainable design.

ENVIRONMENT	BUILDING FABRIC	BUILDING TECHNOLOGY
Air Free air - Natural ventilation - Wind force - Energy content Stack effect - Solar energy, diffuse radiation - Solar energy, direct radiation Soil Aquifer - Heat storage - Cool storage Groundwater - Cold energy - Heat energy Earth/rock - Geothermal cooling - Heat energy Water surfaces Lake - Pump water or greywater - Heat energy - Cold energy River - Pump water or greywater - Heat energy - Cold energy Sea - Pump water or greywater - Heat energy - Cold energy	Facade and roof Transparent insulating material Photovoltaic Absorber surface Storage masses Planted surfaces Rainwater Daylight elements Collectors Construction Storage masses Passive solar absorber Heat exchanger elements Night cooling Atria Green zones Evaporative cooling Passive solar energy Heat buffer	Cooling energy Direct - Electrically driven chiller - Absorption chiller - Gas-motor driven chiller - Cooling towers Indirect - Cold storage in building - Cold storage in terrain Heat energy Direct - District heating - Boiler (gas, oil, coal, biogas, condensing) - Electric boiler (with storage) Indirect - Solar thermal system - Combined heat and power (CHP) - Heat pumps Electrical energy Mains supply - Commercial power supply utilities Self supply - Combined heat and power (CHP) - Emergency generator - Photovoltaics - Wind energy generator Water Pure water - Public supply (drinking, cooking) Greywater - Waste water Rainwater - Flushing, cleaning, cooling

Table 1. **The Sustainable design components**

3.3.7 Ecological building

Creating environmentally friendly, energy-efficient buildings and developments by effectively managing natural resources; by passively and actively harnessing solar energy and using materials which, in their manufacture, application, and disposal, do the least possible damage to the so-called 'free resources' water, ground, and air.

3.3.8 Principles of Sustainable Design

Understanding Place - Sustainable design begins with an intimate understanding of place. If we are sensitive to the nuances of place, we can inhabit without destroying it. Understanding place helps determine design practices of a building on the site, preservation of the natural environment, and access to public transportation.

Connecting with Nature - Whether the design site is a building in the inner city or in a more natural setting, connecting with nature brings the designed environment back to life. Effective design helps inform us of our place within nature.

Understanding Natural Processes - In nature there is not waste. The byproduct of one organism becomes the food for another. In other words, natural systems are made of closed loops. By working with living processes, we respect the needs of all species. Engaging processes that regenerate rather than deplete, we become more alive. Making natural cycles and processes visible bring the designed environment back to life.

Understanding Environmental Impact - Sustainable design attempts to have an understanding of the environmental impact of the design by evaluating the site, the embodied energy and toxicity of the materials, and the energy efficiency of design, materials and construction techniques. Negative environmental impact can be mitigated through use of sustainably harvested building materials and finishes, materials with low toxicity in manufacturing and installation, and recycling building materials while on the job site.

Embracing Co-creative Design Processes - Sustainable designers are finding it is important to listen to every voice. Collaboration with systems consultants, engineers and other experts happens early in the design process, instead of an afterthought. Designers are also listening to the voices of local communities. Design charettes for the end user (residents or office employers) are becoming a standard practice.

Understanding People - Sustainable design must take into consideration the wide range of cultures, races, religions and habits of the people who are going to be using and inhabiting the built environment. This requires sensitivity and empathy on the needs of the people and the community.

"Sustainable architecture involves a combination of values: aesthetic, environmental, social, political, and moral. It's about using one's imagination and technical knowledge to engage in a central aspect of the practice -- designing and building in harmony with our environment. The smart architect thinks rationally about a combination of issues including sustainability, durability, longevity, appropriate materials, and sense of place. The challenge is finding the balance between environmental considerations and economic constraints. Consideration must be given to the needs of our communities and the ecosystem that supports them." -- Samuel Mock bee, Auburn University

3.4 Sustainability: Issues (refer table 2)

SITE	ENERGY	WATER
MATERIALS	WASTE	COMMUNITY

Table 2. **Major issues**

3.4.1 Site

Sustainable design principles: These are concerned with increasing local self-sufficiency; human needs; structure development around energy-efficient movement networks; the open space network; linear concentration; an energy and water strategy.

Landform/Microclimate: Here the major concerns are those of topography; light-colored surfacing; vegetative cooling; wind buffering/channeling and evaporative cooling.

Land-Use: Factors here include use density, use mix and activity concentration.

Site Design: Considering solar orientation; pedestrian orientation; transit orientation and the micro climatic building/siting are important from design point of view.

Built Environment: The major issues here are indoor air quality; visual quality; acoustic quality; noise control; and controllability of systems.

Transportation: The issues involve integrated, multimodal street network; pedestrian; bicycle; transit; high-occupancy vehicles; pavement minimization; and parking minimization/siting.

Infrastructure Efficiency: This depends on water supply and use; wastewater collection; storm drainage; street lighting; traffic signalization and recycling facilities.

On-Site Energy: Resources than can be effectively utilized are geothermal/groundwater; surface water; wind; solar; thermal storage; fuel cell power

3.4.2 Sustainable Transportation

Integrating land-use, transport and environmental planning is important to minimize the need for travel and to promote efficient and effective mode of transport, including walking. There are four ways to influence transport efficiency and energy consumption:

a. urban and land-use planning;
b. modal mix (cars, trucks, rail, air, etc.);
c. behavioural and operational aspects; and
d. vehicle efficiency and fuel choice.

Pedestrianisation is to restrict vehicle access to a street or area for the exclusive use of pedestrians. It provides a pleasant and safe environment for pedestrians, and is ideal venues for shopping, social and cultural activities such as street markets and fairs.

3.4.3 Energy - Efficiency / Renewable

The benefits from the energy-efficient siting and design of buildings are economic (saving money), social (reducing fuel poverty); and ecological (reducing resource exploitation and emissions). Every new development ideally should have an explicit energy strategy, setting out how these benefits are to be achieved.

Computer energy simulations can be used to assess energy conservation measures early and throughout the design process. The expanded design team collaborates early in conceptual design to generate many alternative concepts for building form, envelope and landscaping, focusing on minimizing peak energy loads, demand and consumption. Typically, heating and cooling load reductions from better glazing, insulation, efficient lighting, day lighting and other measures allows smaller and less expensive HVAC equipment and systems, resulting in little increase in construction cost.

3.4.4 Water

Some of the common water conservation methods are:

A. Toilets:-

i. Low flush toilets

a. Dual flush toilets (3/6 litres)

b. Vacuum or compressed air toilets

ii. Cistern displacement devices

iii. Waterless toilets

a. Composting toilets (heated or unheated)

b. Incinerating toilets

B. Urinals:-

i. Urinal controls (infrared, radar, auto flush)

ii. Waterless urinals

C. Wash hand basins:-

i. Push taps

ii. Flow control, self closing

iii. Tap flow regulators

D. Shower:-

i. Shower mixers

ii. Water saving showerheads

iii. Self closing shower system

E. Outside and garden:-

i. Water control

F. Clothes Washers:-

i. Water saving washers

ii. Control & usage

G. Water supply:-

i. Auto shut off and pressure regulators

H. Rain water and grey water:-

i. Rain water recycling systems

ii. Grey water recycling systems

3.4.5 Materials - Embodied Energy

The quantity of energy required by all the activities associated with a green (refer fig. 3) process, including the relative proportions consumed in all activities upstream to the acquisition of natural resources and the share of energy used in making equipment and other supporting functions. To reduce embodied energy, for efficiency:

a. re-use existing buildings and structures wherever possible
b. design buildings for long life, with ease of maintenance and adaptability
c. construct out of local and low- energy materials where possible
d. reduce the proportion of high rise, detached or single-storey developments
e. design layouts which minimize the extent to roadway and utility work per dwelling

Green Features

Manufacturing Process (MP)	Building Operations (BO)	Waste Mgmt. (WM)
Waste Reduction (WR)	Energy Efficiency (EE)	Biodegradable (B)
Pollution Prevention (P2)	Water Treatment & Conservation (WTC)	Recyclable (R)
Recycled (RC)	Nontoxic (NT)	Reusable (RU)
Embodied Energy Reduction (EER)	Renewable Energy Source (RES)	Others (O)
Natural Materials (NM)	Longer Life (LL)	

Figure 3. **Green Features**

3.4.6 WASTE

"Waste - a resource in the wrong place" **-- An old Chinese proverb.**

Humans are the only species on Earth that produce waste which is not a raw material or nutrient for another species. We are the only species to produce wastes that can be broadly toxic and build up for long periods of time. Waste is not simply an unwanted and sometimes harmful by-product of life; it is a raw material out of place. Waste and pollution demonstrate gross inefficiency in the economic system since they represent resources that are no longer available for use. Waste Management Strategies include waste prevention; recycling construction and demolition materials; architectural reuse (include adaptive reuse, reusing old materials); and design for material recovery (durability, disassembly, adaptive reuse).

3.4.7 Community

A growing number of communities are developing reporting systems that involve sustainability issues. Some systems produce environment reports, others are quality of life reports and some are called sustainability reports. Communities must decide for themselves which measures are most appropriate for them, meaning that these will differ from one community to the next. Traditional community reporting systems measure changes in economic, social and environmental progress as if they were independent of each other. Community sustainability indicators show the connections among these three areas, helping to assess how society, economy and environment are interacting in a sustainable manner.

3.5 Sustainability: Strategies

3.5.1 Design Guides - The "Whole Building" Design Guide

The goal of 'Whole Building' Design is to create a successful high-performance building. To achieve that goal, we must apply the integrated design approach to the project during the planning and programming phases.

The owner, building occupants, and operation and maintenance personnel should be involved to capture their understanding of how the building and its systems will work for them once they occupy it. The fundamental challenge of 'whole buildings' is to understand that building systems are interdependent.

3.5.2 Processes

Planning and Design Process (refer fig. 4) deals with site selection and planning, budget planning, capital planning; programme planning, client awareness; goal setting (green vision, project goals & green design criteria); team development of a well-integrated design; resource management and performance goals.

Operation & Maintenance process deals with commissioning of building systems; building operation; maintenance practices; renovation and demolition.

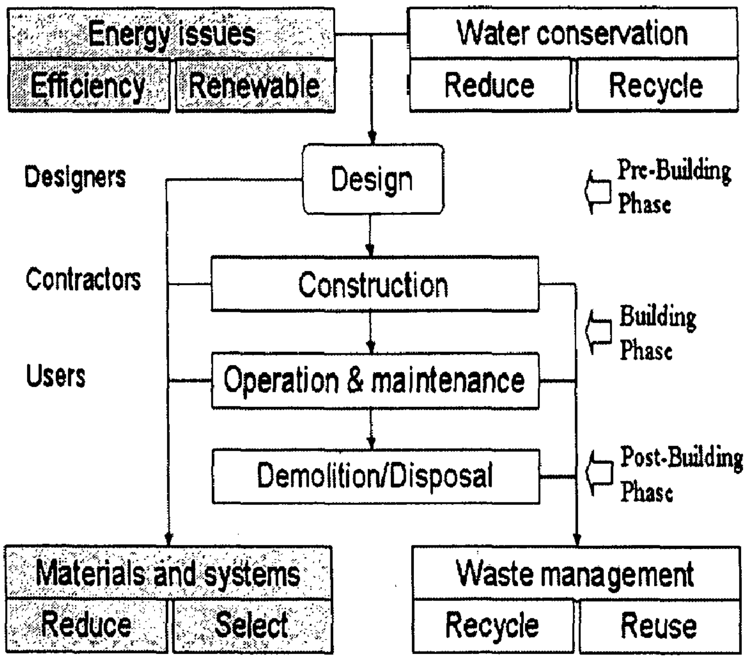


Figure 4. **The Green Process**

4.0 EVALUATION AND ASSESSMENT

4.1 Assessment methodologies

Some of the common and widely used assessment methods include:

1. Indoor air quality audit
2. Life cycle energy audit
    a. Initial embodied energy
    b. Recurring embodied energy
    c. Operational energy
    d. Benchmarking
    e. Greenhouse gas assessment
3. Lighting, thermal and ventilation (LTV) audit
4. Life cycle costing audit
5. Post occupancy evaluation

Diversity criteria: Three forms of biodiversity namely, genetic; species and ecosystems need to be preserved for species richness, abundance, diversity; ecological diversity; high number of endemic species; high number of important gene pools; and wildlife habitat. The natural environment to protect includes grassland; shrub land; forest; wetland; water stream; mangrove; marshes and swamps.

4.2 LEED-Neighborhood Development

The U.S. Green Building Council (USGBC), the Congress for the New Urbanism (CNU), and the Natural Resources Defense Council (NRDC)—three organizations that represent some of the nation's leaders among progressive design professionals, builders, developers, and the environmental community—have come together to develop a national set of standards for neighborhood location and design based on the combined principles of smart growth, urbanism, and green building. The goal of this partnership is to establish these standards for assessing and rewarding environmentally superior development practices within the rating framework of the LEED® (Leadership in Energy and Environmental Design) Green Building Rating System.

Unlike other LEED products that focus primarily on green building practices, with relatively few credits regarding site selection, LEED for Neighborhood Development (LEED-ND) places emphasis on the elements that bring the buildings together into a neighborhood, and relate the neighborhood to its larger region and landscape. It is guided by sources such as the Smart Growth Network's ten principles of smart growth, the Charter of the New Urbanism, other LEED rating systems, and other pertinent criteria. In short, LEED-ND will create a label, as well as guidelines for design and decision-making, to serve as an incentive for better location, design, and construction of new residential, commercial, and mixed developments.

The existing LEED rating system for new commercial construction has a proven track record of encouraging builders to utilize green building practices such as increasing energy and water efficiency and improving indoor air quality in buildings. It is our hope that LEED-ND will have a similarly positive effect to encourage developers and community leaders to revitalize existing urban areas, reduce land consumption, reduce automobile dependence, promote pedestrian activity, improve air quality, decrease polluted storm water runoff, and build more livable, sustainable, enduring communities for people of all income levels.

4.2.1 Neighborhood Development

The LEED-ND Core Committee intends for LEED-ND to be used to certify exemplary development projects that perform well in terms of smart growth, urbanism, and green building, and may constitute whole neighborhoods, fractions of neighborhoods, or multiple neighborhoods. Smaller, infill projects that may be just a single use, but complement existing neighboring uses, for instance, should be able to earn certification as well as larger mixed use developments. For the time being, the LEED-ND Core Committee has put no restrictions as to the minimum or maximum size a project would have to be in order to certify under LEED-ND.

As for the more qualitative aspects of what makes a neighborhood, the LEED-ND Core Committee has refrained from defining the term precisely, but has been guided by the principles of smart growth and New Urbanism in writing credits that will recognize aspects of neighborhood that have proven most successful. The qualities of an ideal neighborhood include that it has a legible center and edge; is limited in size, typically five minutes average walk from center to edge; has a mix of land uses, to allow for some basic daily needs to be satisfied within the neighborhood; accommodates a diversity of household types; has an integrated network of walk able streets; and has special sites reserved for public spaces and civic buildings.

4.2.2 Format and Vocabulary of the Draft

The "Point Overview" at 4.2.3 of this chapter shows the overall list of credits with the number of points attached to each credit in one place, along with the estimated levels of points needed to achieve the different levels (Certified, Silver, Gold, Platinum) of LEED-ND certification. The rating system itself is divided into "Credits" and "Prerequisites." LEED rating systems typically consist of a few prerequisites and many credits. In order to be certified, a project has to meet all of the prerequisites. Each credit is optional, but contributes to the project's point total. A certain point total is required for certification, and higher point scores are required for silver, gold, or platinum LEED certification. Each prerequisite and credit is organized in a format for simplicity and quick reference.

- The "Intent" identifies the main goal(s) of the prerequisite or credit.
- "Requirements" specify the criteria to satisfy the prerequisite or credit.
- "Submittals" specify the documentation required for the LEED application.
- The "Rationale" section may include other reasons for the development of the prerequisite or credit.
- "Sources & Resources" may list some of the sources for development of the credit, although the sources used are not always listed, and were often drawn from the collective expertise of committee members. This section may also include sources for more information on the topic.
- The "Notes" section contains any other comments or explanatory information.

- The "Definitions" section at the end of document contains definitions of potentially unfamiliar terms or acronyms, as well as familiar terms that are defined more precisely for the purposes of the LEED-ND Rating System.

Finally, "letter templates" are referenced in the submittals sections throughout the rating system. They outline the specific project data needed to demonstrate achievement of the LEED performance requirements and include calculation formulas where applicable.

4.2.3 Point Overview

A. Location Efficiency (2 Prerequisites / 7 Credits / 28 Points / 25%)

B. Environmental Preservation (5 Prerequisites / 11 Credits / 13 Points / 11%)

C. Compact, Complete, & Connected Neighborhoods (3 Prerequisites / 22 Credits / 42 Points / 37%)

D. Resource Efficiency (0 Prerequisites / 17 Credits / 25 Points / 22%)

E. Other (0 Prerequisites / 2 Credits / 6 Points / 5%)

4.2.4 Anticipated Certification Levels

Certified:	46 – 56 points	(40% of total points)
Silver:	57 – 67 points	(50% of total points)
Gold:	68 – 90 points	(60% of total points)
Platinum:	91 – 114 points	(80% of total points)

(Above percentages are taken from the "LEED Product Development and Maintenance Manual")

4.3 TERI-GRIHA (green rating for integrated habitat assessment)

4.3.1 Introduction

The context: Internationally, voluntary building rating systems have been instrumental in raising awareness and popularizing green design. However, most of the internationally devised rating systems have been tailored to suit the building industry of the country where they were developed. TERI, being deeply committed to every aspect of sustainable development, took upon itself the responsibility of acting as a driving force to popularize green building by developing a tool for measuring and rating a building's environmental performance in the context of India's varied climate and building practices. This tool, by its qualitative and quantitative assessment criteria, would be able to 'rate' a building on the degree of its 'greenness'. The rating would be applied to new and existing building stock of varied functions – commercial, institutional, and residential.

The challenges: The Indian building industry is highly decentralized, involving diverse stakeholders engaged in design, construction, equipment provision, installation, and renovation of buildings. Each group may be organized to some extent, but there is limited interaction among the groups, thus disabling the integrated green design and application process. Hence, it is very important to define and quantify sustainable building practices and their benefits.

The benefits: TERI's green building rating will evaluate the environmental performance of a building holistically over its entire life cycle, thereby providing a definitive standard for what constitutes a 'green building'. The rating system, based on accepted energy and environmental principles, will seek to strike a balance between the established practices and emerging concepts, both national and international. The guidelines/criteria appraisal may be revised every three years to take into account the latest scientific developments during this period.

Some of the benefits of a green design to a building owner, user, and the society as a whole are as follows:

a. Reduced energy consumption without sacrificing the comfort levels

b. Reduced destruction of natural areas, habitats, and biodiversity, and reduced soil loss from erosion etc.
c. Reduced air and water pollution (with direct health benefits)
d. Reduced water consumption
e. Limited waste generation due to recycling and reuse
f. Reduced pollution loads
g. Increased user productivity
h. Enhanced image and marketability

The development process: TERI's green building rating system (TERI–GRIHA) has been developed after a thorough study and understanding of the current internationally accepted green building rating systems and the prevailing building practices in India.

The primary objective of the rating system is to help design green buildings and, in turn, help evaluate the 'greenness' of the buildings. The rating system follows best practices along with national/international codes that are applicable to achieving the intent of green design.

The green building rating system devised by TERI is a voluntary scheme. It has derived useful inputs from the upcoming mandatory voluntary building codes/guidelines being developed by the Bureau of Energy Efficiency, and the Bureau of Indian Standards.

The basic features: Currently the system has been developed to help 'design and evaluate' new buildings (buildings that are still at the inception stages). A building is assessed based on its predicted performance over its entire life cycle – inception through operation. The stages of the life cycle that have been identified are the pre-construction, building design and construction, and building operation and maintenance stages.

The detailed evaluation criterion is given in **Appendix A.**

4.3.2 Scoring points for TERI–GRIHA

TERI–GRIHA is a guiding and performance-oriented system where points are earned for meeting the design and performance intent of the criteria. Each criterion has a number of points assigned to it. It means that a project intending to meet the criterion would qualify for the points. The points related to these criteria (specified under the relevant sections) are awarded provisionally while certifying and are converted to firm points through monitoring, validation, and documents/photographs to support the award.

TERI-GRIHA has a 100 point system where different levels of certification (refer table 3 and 4) are awarded based on the number of points earned. The minimum points required for certification is 50. Buildings scoring 50 to 60 points, 61 to 70 points, 71 to 80 points, and 81 to 90 points will get one star, 'two stars', 'three stars' and 'four stars respectively. A building scoring 91 to 100 points will get the maximum rating five stars.

Points scored	Rating
50–60	One star
61-70	Two star
71-80	Three star
81-90	Four star
91-100	Five star

Table 3. **TERI-GRIHA Points and Rating**

4.3.4 Evaluation procedure of criterion of TERI-GRIHA

List of criteria	Points	Remarks
Criteria 1: Preserve and protect landscape during construction /compensatory depository forestation.	5	Partly mandatory
Criteria 2: Soil conservation (post construction)	4	
Criteria 3: Design to include existing site features	2	Mandatory
Criteria 4: Reduce hard paving on site	2	Partly mandatory
Criteria 5: Enhance outdoor lighting system efficiency	4	
Criteria 6: Plan utilities efficiently and optimize on site circulation efficiency	3	
Criteria 7: Provide, at least, minimum level of sanitation/safety facilities for construction workers	2	Mandatory

Criteria 8: Reduce air pollution during construction	2	Mandatory
Criteria 9: Reduce landscape water requirement	3	
Criteria 10: Reduce building water use	2	
Criteria 11: Efficient water use during construction	1	
Criteria 12: Optimize building design to reduce conventional energy demand	6	Mandatory
Criteria 13: Optimize energy performance of building within specified comfort	12	
Criteria 14: Utilization of flyash in building structure	6	
Criteria 15: Reduce volume, weight and time of construction by adopting efficient technology (e.g. pre-cast systems, ready-mix concrete, etc.)	4	
Criteria 16: Use low-energy material in interiors	4	
Criteria 17: Renewable energy utilization	3	
Criteria 18: Renewable energy based hot-water system	2	
Criteria 19: Waste water treatment	2	
Criteria 20: Water recycle and reuse (including rainwater)	5	
Criteria 21: Reduction in waste during construction	2	
Criteria 22: Efficient waste segregation	2	
Criteria 23: Storage and disposal of waste	2	
Criteria 24: Resource recovery from waste	2	
Criteria 25: Use of low - VOC paints/ adhesives/ sealants.	4	
Criteria 26: Minimize ozone depleting substances	3	Mandatory
Criteria 27: Ensure water quality	2	Mandatory
Criteria 28: Acceptable outdoor and indoor noise levels	2	
Criteria 29: Tobacco and smoke control	1	
Criteria 30: Energy audit and validation		Mandatory
Criteria 31: Operations and maintenance protocol for electrical and mechanical equipment	2	Mandatory
Criteria 32: Bonus	4	
TOTAL POINTS	100	

Table 4. **TERI-GRIHA Evaluation Criteria and Weightage**

5.0 LITERATURE STUDY- ECO VILLAGE NEIGHBORHOOD IIII

Location : New York, U.S.A

Architect : Delton Jackson

Project Coordinator : Ralph Maust

Neighborhood IIII is the fourth cohousing neighborhood to be built at EcoVillage at Ithaca in New York. The Neighborhood IIII Project has been an effort to design a sustainable Cohousing community of between 30 and 50 residences, a central Common House and associated community buildings.

Neighborhood IIII is envisioned as the fourth neighborhood to be built at EcoVillage at Ithaca, the first neighborhood having been completed in 1997. EVI is located on a 176 acre site two miles west of Ithaca, New York, in a hilltop area comprised of fields and woodlands.

5.1 Conceptual strategies

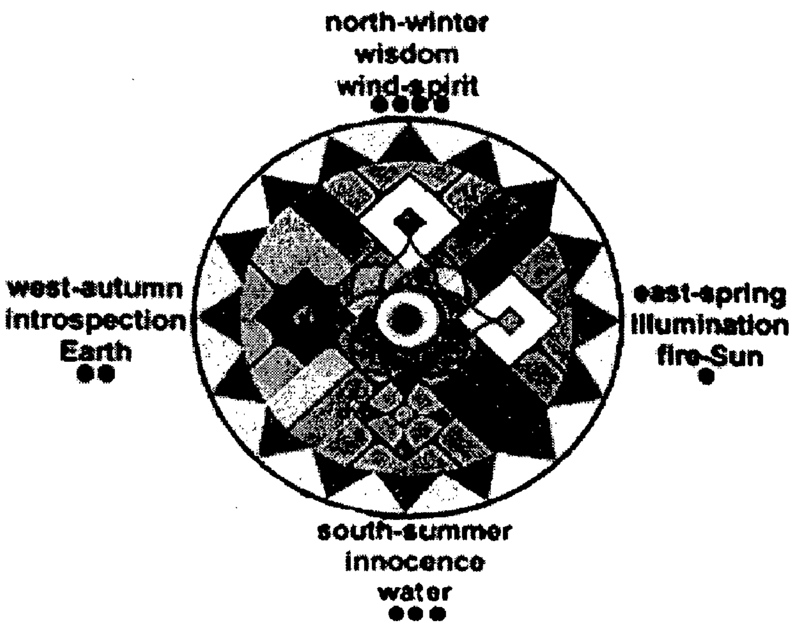


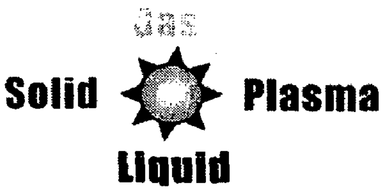
Fig. 5. **The Four Directions**

5.1.1 The Four Directions, (refer fig. 5)
as articulated in the spirituality of the American Plains Indians and other indigenous groups, serve as one of the major inspirations for the Neighborhood IIII design, including the use of 'IIII' (rather than '4' or 'IV') in keeping with their numeration of, as illustrated in the 'Medicine Shield' above. It is this spirit that underlies and inspires the layout of Neighborhood IIII, reflecting in its very structure an acknowledgment, an understanding and an appreciation of a larger universe.

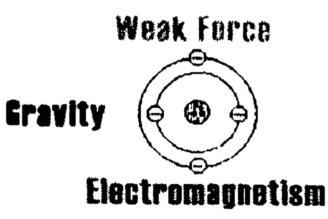
The design attempts to facilitate a holistic environment for the telling of the Universe Story, and our active participation in that story through art, education and ritual. A place to honor the artist, mystic and prophet in each person and enhance the experiences of awe, amazement, gratitude as well as suffering, silence and mystery. And, ultimately, to inspire celebration through imagination, creativity, renewal, justice-making, and compassion.

And four can also represent:

The four ancient essences



and their modern chemical equivalents



or the four physical forces of nature.

In each, a harmony of the whole is obtained by balancing opposing and complementary forces within the repeating cycles of nature as symbolized by the circle. The design incorporates these themes in the overall layout of the development and in particular, within the main gathering room of the Common House.

5.1.2 Sacred Geometries & Celestial Alignments

An examination of history's greatest buildings reveals an understanding of life's hidden geometries and reveals the beauty of their proportions and harmonies. The knowledge and science of the modern era has revealed that these patterns exist not only at the human scale, but as archetypes that span from the microcosm to the macrocosm. Reaching further into history the research of authors Graham Hancock (Heavens Mirror) and Robert Bauval (The Orion Mystery) into the monuments of prehistory reveals an understanding of advanced mathematics and of astronomy, including knowledge of the Earth itself.

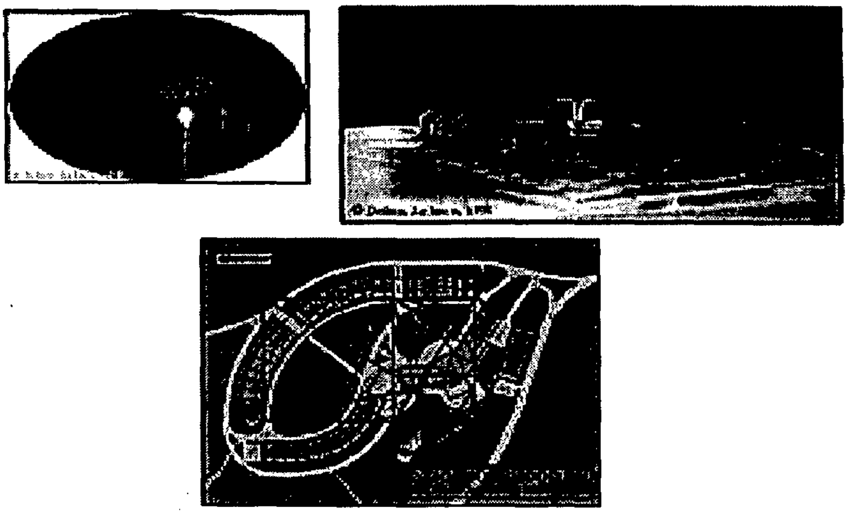


Fig. 6. **The Use of Golden Spiral**

5.1.3 Features:

Neighborhood IIII possesses five gateway points, the alignments of which celebrate and mark the noon sun and the rising and setting sun of both the winter and summer solstices. The Layout also incorporates Euclidean geometries of the Golden Mean and Section, a formula defined by the Greek mathematician Euclid in the 3rd century BC. Modern science has discovered the Golden Spiral (refer fig. 6) to be a common pattern in nature, "in the spirals of sunflower heads and snail shells, the coiled fern frond, the arrangement of leaves on a stem..... and so on", revealing the Golden Section and the phi ratio as innate patterns of nature. (p.59, The Healthy House, Sydney & Joan Baggs, Thames & Hudson Ltd., London, 1996)

5.1.4 Symbol & Myth (Poetical)

Inspiration for Neighborhood IIII has also been drawn from the name of its chosen site, the EcoVillage at Ithaca. Within this context the following features have been conceived: The Northwest terrace describes an arc, oriented toward the sun and the views. If interpreted as the bow of Odysseus, the Sunrise of the Winter Solstice can been seen as the arrow which sets winter to flight, marking this celestial event with a further layer of meaning as the sun streams up the tree-lined path from the Amphitheater Steps and through the glazed Northwest Gateway.

The Pond is another feature, a circle ringed by a path and punctuated by an "outdoor room", a gazebo or open sided structure. The symbolism (refer fig. 7) here is with the path representing Ouroboros a symbol from the mystical tradition of the eternal and cyclical nature of the universe; the body of water symbolically marking the direction of the South in relation to Neighborhood IIII. The stark geometry softened with perimeter plantings, with the pond acting as a focus and a feature within the composition of the development.

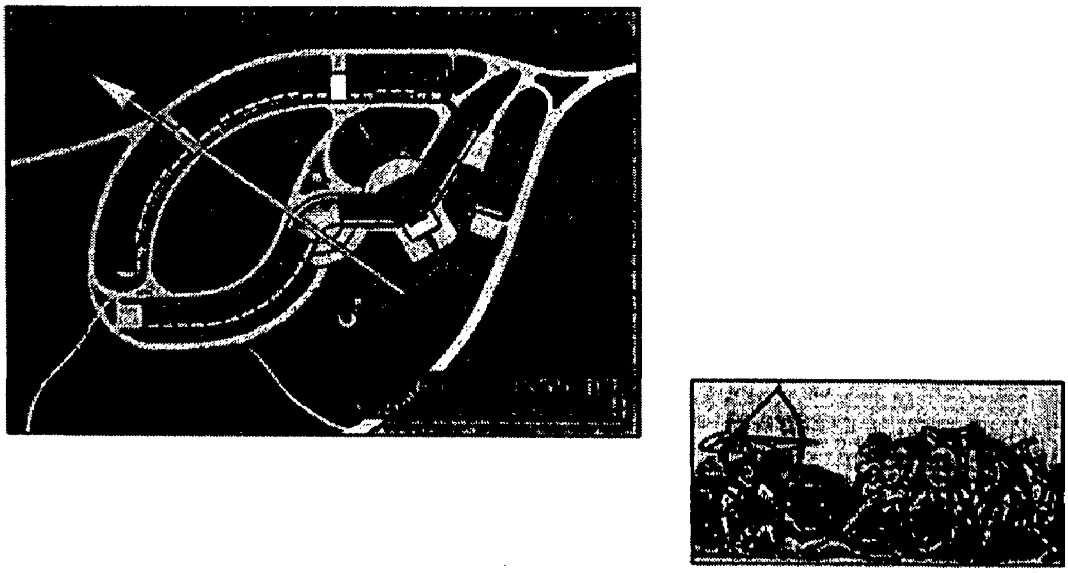


Fig. 7 **Symbol and Myth**

5.2 Precedents and inspirations

These are just a few of the many places (refer fig. 8) from which inspiration was drawn:

1. Pueblo Bonito, found in Chaco Canyon in New Mexico.

   A Native American precedent of a connected, curvilinear, solar oriented village form.

2. The medieval town of Eguishein in Alsace.

   The medieval towns of Europe demonstrate that an organic morphology can provide further basis for urban form, with a visual and functional logic that lends itself to future growth in the absence of a grid pattern.

3. Hockerton Shaker Village, USA.

   The village green is an archetypal pattern of community and village development, providing a positive environment and a common focus and tie for the community.

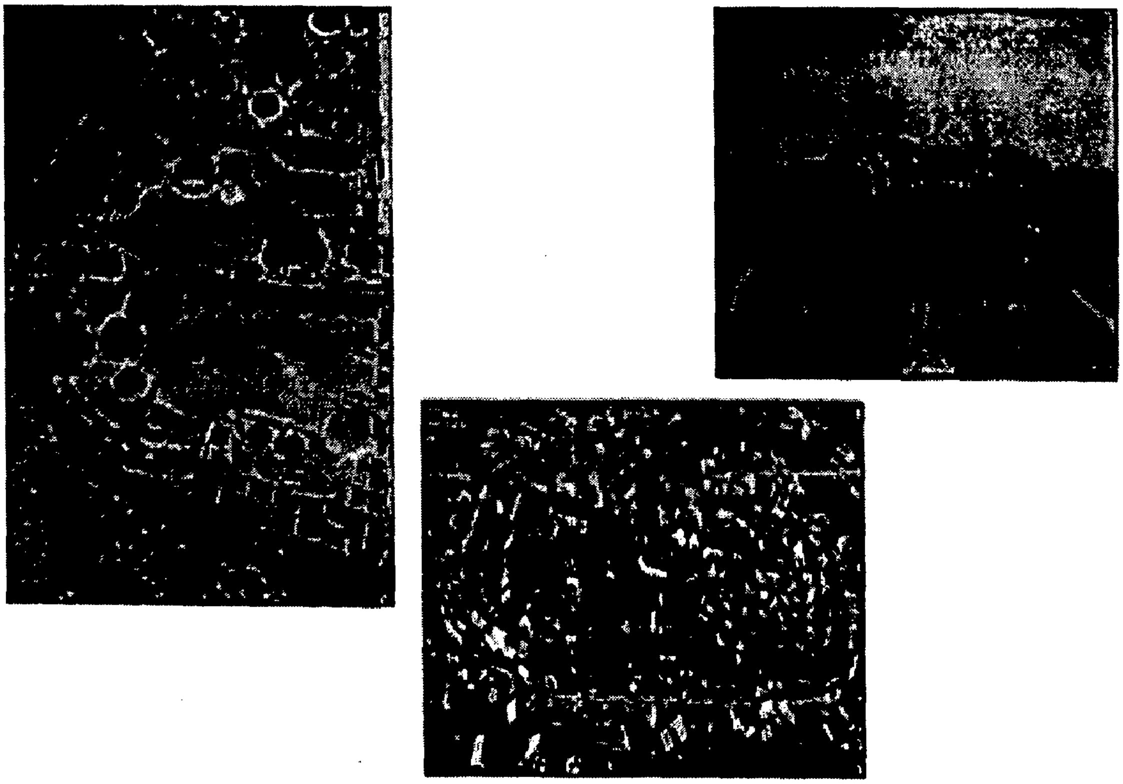


Fig. 8 **Traditional Village Forms**

Numbered from Left to Right

5.3 Response to site and master plan

5.3.1 General criteria

All facilities to be wheelchair accessible and have separate "gray water" and sewerage waste piping, and include Residence Space; and Earth sheltered design (if feasible).

Dwelling units connected by sunspace-enclosed walkways with
a. provision for aquaculture/intensive gardening*
b. provision for "gray water" recycling*
c. passive solar heat storage*
d. provision for future wind-generated electric heating or wind-driven heat pumps
e. aesthetic "lounge"/indoor park-like setting*
f. access to outside at each dwelling unit
* reference: The ARKS of New Alchemy Institute

About 50 dwelling units in multiples of about 600 square feet (20'x30') each with provision for bath and kitchen. Dwelling units easily connectable or detachable (via doors) to reform into combinations of 1,2,3 or 4 units to accommodate changes in 'family' size. Compact overall structure to maximize heating efficiency. Provide scenic vistas, through sunspace/walkways, from each dwelling. Balcony into sunspace from each second floor dwelling unit. Covered (enclosed) access to covered car park (underground). Provision for future electric power supplied by photovoltaic/hydrogen storage fuel cell system. Connected to residence units via sunspace/walkways

Main Room (Dining/Assembly/Ritual Space) Hemispherical Dome (for125 persons) (Usable as planetarium) with storage for portable tables and chairs; and good vistas.

Kitchen adjacent to main room to serve for 125 persons

a. walk-in cooler (and walk-in freezer)
b. easily accessible "root cellar"/pantry
c. easily accessible for deliveries - waste/compost removal

Other spaces are

a. Men's and Woman's Lavatories (3 stalls)
b. Laundry Room with space for sorting/folding and ironing
c. Small child/infant care/playroom with access to enclosed outside play area
d. Library/Reading/Quiet Study Space
e. "Commissary"/General Store (400-600 sq. ft.)
f. Shop/Project space with large door outside access

"Health Spa" (Wellness Center) comprising the following spaces: an exercise Room (400-600 sq. ft.); a sauna (for 10-20 persons); massage rooms (2 or 3); hot tub/whirlpool (for 10-20 persons) (Site built of Ferro cement or Gunnite) located in "tropical garden" sunspace setting; and (200-300 sq. ft.) men's and women's locker/shower rooms.

5.3.2 Rationale underlying design criteria

Dwelling Unit Size and Flexibility of Combination: As persons go through various stages of life development, the amount and complexity of required living space changes. The design should provide the option of combining adjacent units (in 600 square foot increments) to accommodate these changes in "family" structure. An overriding consideration is that older persons may forever remain integrated into the community.

Connected, Enclosed Sunspace Walkways: These features should provide protected movement between dwelling units and the common space; space for enclosed aquaculture and passive solar heat storage*; and a pleasant indoor "park-like setting for gathering, socializing, relaxing and spiritual renewal (particularly in winter).*

*Reference the ARKs of New Alchemy Institute

Hemispherical Dining/Assembly/Ritual Space: A lofty, esthetically pleasing space for gathering, meals and rituals with the ability to serve as a planetarium/theater for multimedia presentations; a health spa / wellness center with space for group relaxation, exercise and body conditioning.

5.3.3 The Master Plan (refer fig. 9)

Key elements specified by the design criteria: 30-50 Residential Units (Approx. 600 sq.ft. ea, 'studio' sized, but connectable and detachable to form residences of various sizes.) Common House providing for assembly/dining/planetarium/ritual; Kitchen Health Spa / Wellness Center; Library/Study Space; Commissary General Store; Shop & Project Space; Laundry Facilities (in visual contact with,); Childcare Facilities and Connected, Enclosed linking all the buildings.

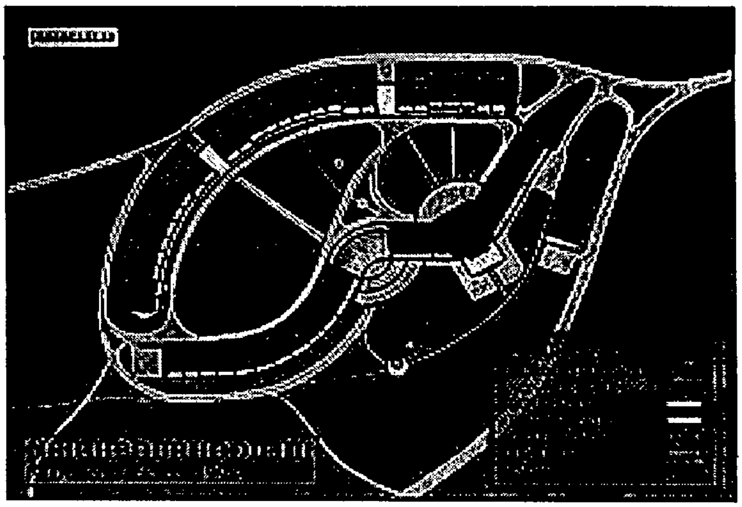


Fig. 9. **Master Plan**

The general design criteria applied here includes:

a. Wheelchair Accessible throughout
b. Provision for alternative and soft technologies
c. Maximize Views & Solar Exposure
d. Minimize Visual & Physical Impacts of Cars onsite

5.3.4 Additional Features

Village Green: This has been taken as an archetypal village and community pattern, providing positive space and a clear identity.

Private Space: Each residence is also provided with private outdoor space, with dual access to both the inside and outside of the community development.

Common House as Focus for Village: The Common House is a focus for Neighborhood IIII both visually and socially, with a clear and logical design.

Amphitheaters: The design features two amphitheater spaces, the first a grassy hollow which focuses on the north facade of the Common House. The second amphitheater space is formed by the steps which connect the village green with the lower elevation to the south, the steps doubling as seating for people to pause and appreciate the views beyond.

5.3.5 Response to site

The design of Neighborhood IIII has been created in response to the possibilities and potentials offered by the landscape and features of the site, (refer fig. 10) attempting to work as a part of that landscape as opposed to being imposed upon it. The importance of creating a clear identity for the community has also been recognized, and thus it is these two factors which will establish the genius loci, of the finished development.

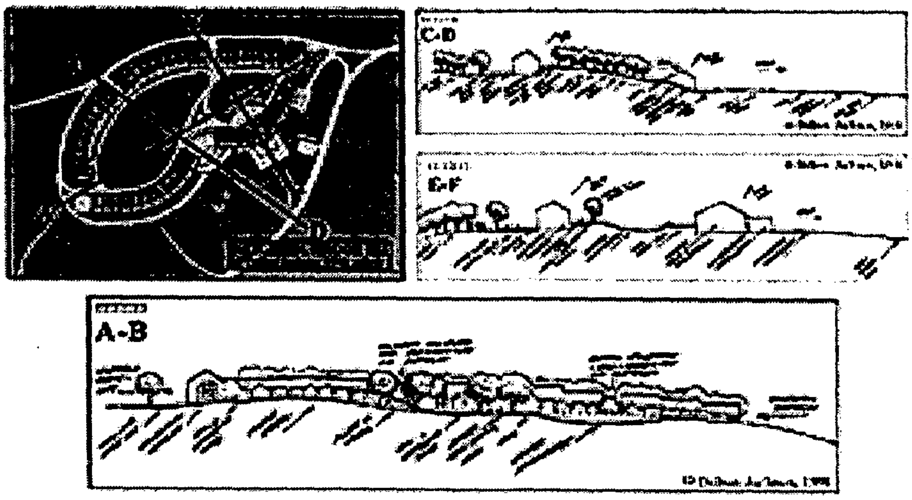
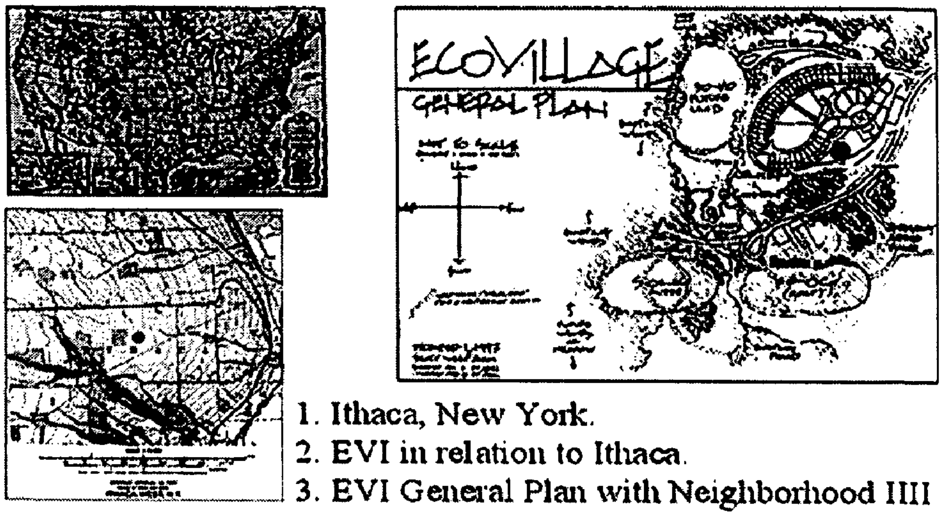


Fig. 10. **Site sections**

The following factors have influenced the finished design:

a. Orientation
b.. Climate
c. Solar Exposure
d. Views
e. Existing & Planned Developments Site Topography

The proposed development (refer fig. 11) has been designed to work with the existing topography by creating four main terraces, spaces whose character and use is defined by the surrounding buildings. This has been done in order to ensure lines of site over the southernmost buildings, providing the majority of residences with access to views; and to create a layered composition of buildings with clear identities of purpose, i.e. Residential Terraces, and an architecturally significant Common House. Paths lead down to the Common House encouraging a natural 'gravitation' to this area.



1. Ithaca, New York.
2. EVI in relation to Ithaca.
3. EVI General Plan with Neighborhood IIII

Fig. 11 **Location and General Plan**

The town of Ithaca lies in New York's Finger Lakes District, an area which features sites of outstanding natural beauty such as the Ithaca Falls. Ithaca supports various cultural amenities and a clear civic identity centered on its downtown Commons.

5.4 Built infrastructure - Residential units

30-50 Dwelling Units (refer fig. 12) of approximately 600 square feet each with Bath & Kitchen. Dwelling Units connected by Enclosed Walkways. Dwelling Units easily connectable or detachable to accommodate change in size.

The residential units are designed with:

a. Compact overall structure to maximize heat efficiency.
b. Separate "gray water" and sewerage waste piping.
c. Provide scenic vistas from each dwelling.
d. Covered access to parking.

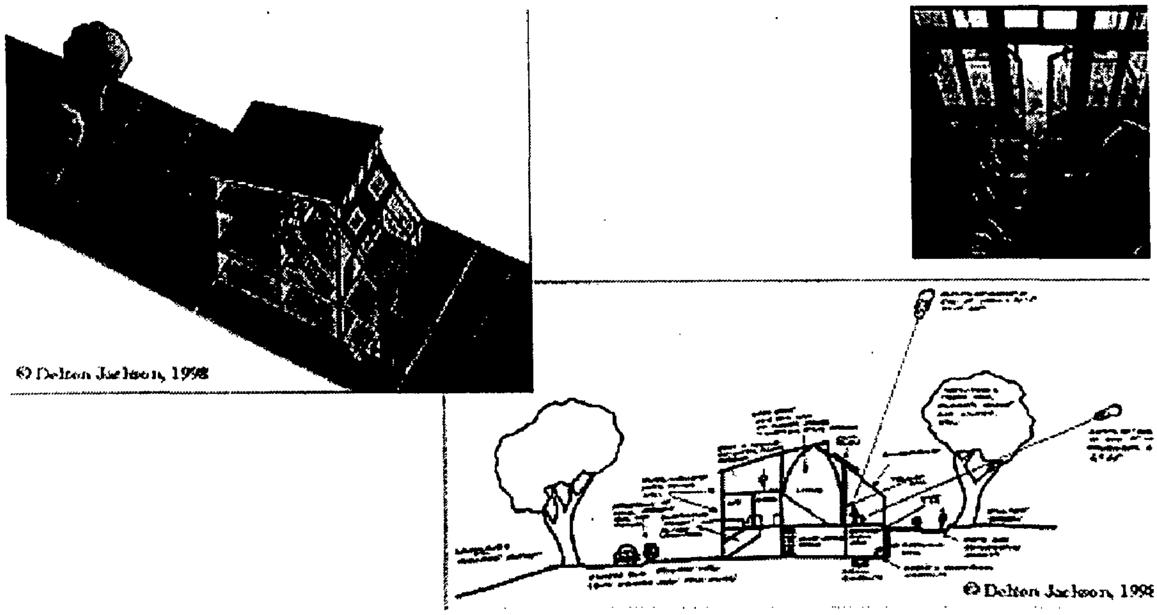


Fig. 12. **Residential Units Type I**

5.4.1 Features

Town House form has been adopted for maximum efficiency and to meet requirements of the design criteria. Party walls are removable in order to adapt and alter available residential space. Units are oriented to take advantage of Solar Gain (for heating) and the Scenic Views.

Two types of residential unit are proposed for variety. Type One includes the addition of a conservatory sunspace of approximately 200 square feet. Type Two (refer fig. 13) incorporates passive solar heating into a more vertical facade, with increased interior floor space. Type Two is also adaptable for apartment units. Both types are constructed so as to allow maximum adaptability of interior spaces and for change of use.

5.4.2 Built Infrastructure

This design created by Enertia Building Systems Inc. provides a starting point for the design of another standardized building type for Neighborhood IIII. However, such buildings should retain the same adaptability that characterizes the Type 1 units in the Neighborhood development. Standardization of these units is intended to contribute to the visual harmony of the project while at the same time reducing the overall cost.

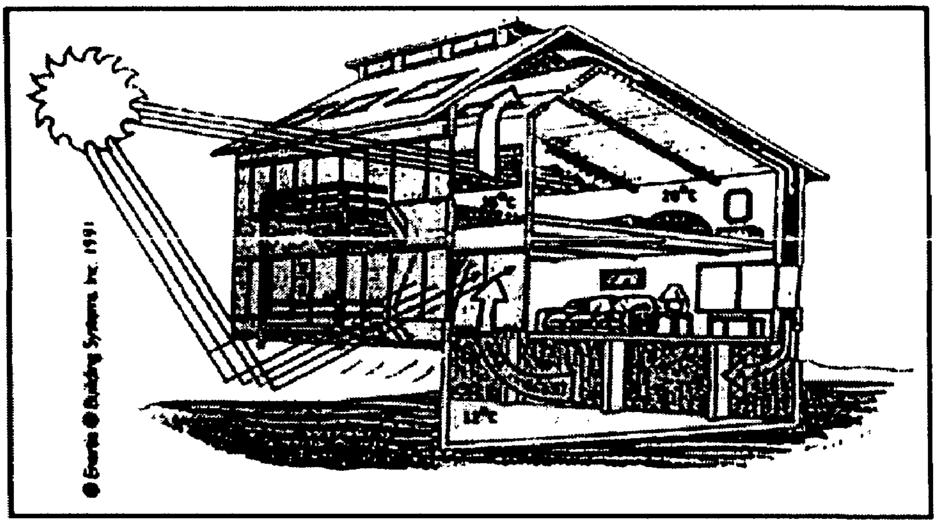


Fig. 13 **Residential Units Type II**

5.4.3 The Common House:

As a Co housing community, Neighborhood IIII will possess a Common House (refer fig. 14) for the shared life of the community. As such it must provide adequate space and facilities for communal dining and meetings for all residents.

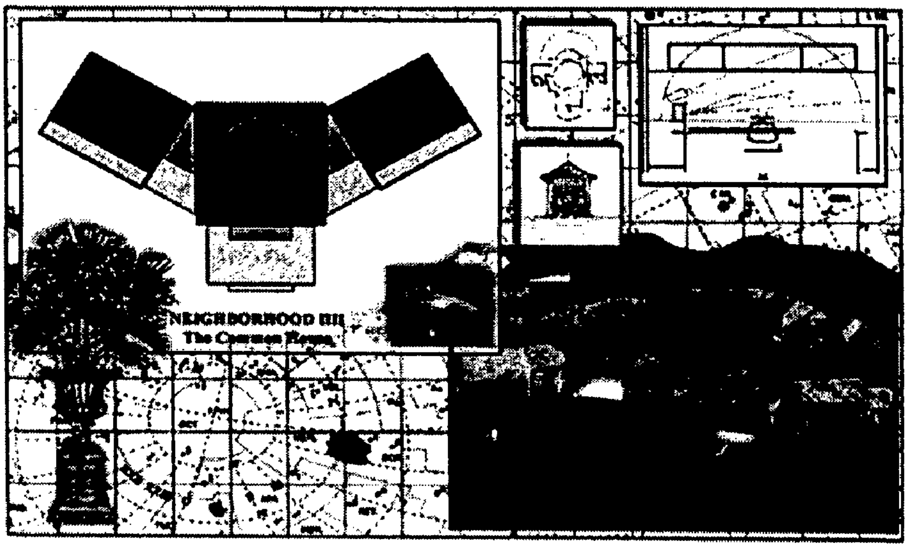


Fig. 14. **The Common House (+ Adjacent Buildings)**

Oriented toward the sun and South-eastern views it is the social heart of Neighborhood IIII, and the hub around which the life of community revolves, defining and generating the activities which will take place in adjacent areas. The various functions of the Common House are met by provision of three connected structures, allowing construction to be phased and providing long-term flexibility and adaptability.

Sun Space features include: Balcony terrace for dining, etc. at height of tree tops, Stained glass panels to celebrate and mark solar events, as viewed from a fixed and prominent position within the Sun Space itself.

Common House to house Neighborhood IIII's administration and reception offices, as well as Kitchen to prepare food and serve 125 persons with the following facilities:

a) walk-in cooler (and walk-in freezer?)
b) easily accessible "root cellar"/pantry
c) easily accessible for deliveries - waste/compost removal

Laundry Room space for sorting/folding and ironing; Small child/infant care/play with access to enclosed play area; "Commissary"/Store of 400-600 square feet; Shop/Project space with large door outside access; Common House (West Wing-low noise).

"Health Spa" (Wellness Center)

a. Exercise Room (400-600 sq. ft.)
b. Sauna (for 10-20 persons)
c. Massage Rooms (2 or 3)
d. Hot tub/Whirlpool (20) located in "tropical garden" setting
e. small (200-300 sq. ft.) men's and women's locker/shower rooms

5.4.4 Transport Issues Onsite

a. To minimize the impact of cars onsite; physically and visually.
b. To provide full access for emergency vehicles.
c. To provide child-safe paths and streets.
d. To provide enclosed walkways connecting to the Common House.

The site road infrastructure (refer fig. 15) will be kept to a minimum, consistent with safety and minimum convenience requirements. A network of pedestrian and bicycle paths will be designed and built to provide a primary circulation system.

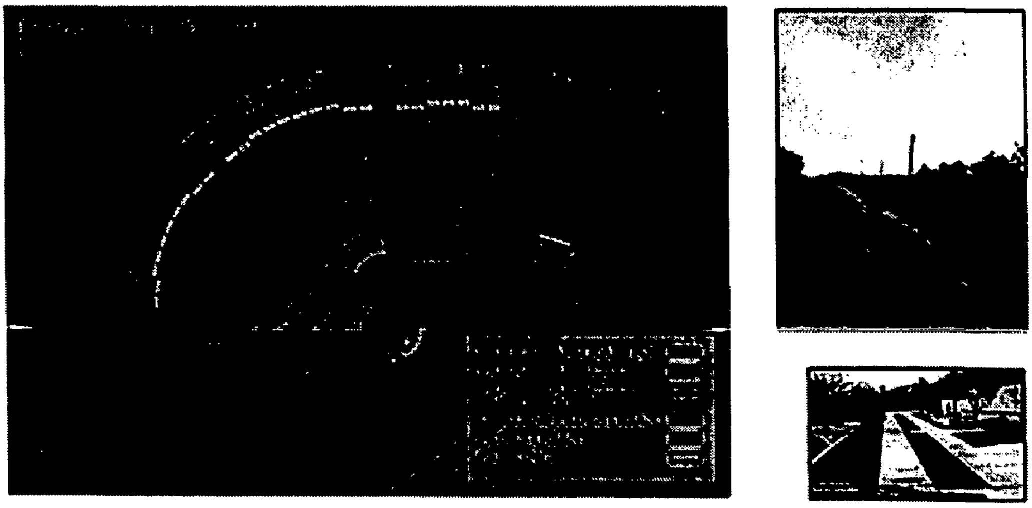


Fig. 15. **Transport Plan**

A pedestrian loop will circle through and tie together the neighborhoods. The pedestrian loop will provide primary emergency vehicle access to the residential neighborhoods. Reduce vehicle impact through mass transit, a computerized ride-sharing system, vehicle sharing, bicycle support, an initiative for high-efficiency, renewably fueled vehicles, and a policy that encourages on-site work, shopping, and recreation.

Neighborhood vehicle access will be restricted to the periphery of the residential area. The peripheral roads will be low-speed, low-cost, designed to handle trucks delivering food to the common houses as well as emergency vehicles.

6.0 CASE STUDY – ARANYA HOUSING, INDORE

6.1 Introduction about the Architect

Influenced by Le Corbusier and Louis Kahn; he continually attempted a synthesis of Western influences with his own culture; studied the relationship between indoor and outdoor space; Doshi mentions the need to 'express a cosmic relationship' and insists that aesthetic considerations in design include 'local symbolism and associations'.

His major design principles include: 'Mythical sense' of space; 'Transformation' between a building and the people that transcends functional use; Importance of 'human institutions'; 'Flexible rather than ridged approach to structure'; Incorporating symbolism; Amorphous, rather than finite forms; Ensure minimum standards of health and hygiene in each project; and Timelessness in architecture.

6.2 Aranya community housing

Architect	:	Vastu-Shilpa Foundation, Bal Krishna V. Doshi, Ahmedabad
Client	:	Indore Development Authority, Indore, India
Completed	:	1989

Aranya, 6 kilometres from Indore, was designed to house a total population of 60,000 in 6500 dwellings, on a net planning area of 85 hectares. The master plan, prepared by the Vastu-Shilpa Foundation in 1983, is designed around a central spine comprising the business district. Six sectors, each with populations of 7000-12,000, lie to the east and west of the spine and are diagonally bisected by linear parks. Ten houses, each with a courtyard at the back, form a cluster that opens onto a street. Internal streets and squares are paved. Septic tanks are provided for each group of twenty houses, and electricity and water are available throughout.

The site plan accommodates and integrates a variety of income groups. The poorest are located in the middle of each of the six sectors, while the better off obtain plots along the peripheries of each sector and the central spine. Eighty demonstration houses, by the architect B. V. Doshi, display a wide variety of possibilities, ranging from one room shelters to relatively spacious houses.

Most of the income groups buy only a house plot. Available to the poorest, in addition to the plot itself, are a concrete plinth, a service core, and a room. The down payment is based on the average income of the family, the loan balance being paid in monthly instalments. Brick, stone, and concrete are available locally, but owners are free to choose any material for house construction and decoration.

6.2.1 Objectives

1. To create a township where a sense of continuity and fundamental values of security exist in a good living environment
2. To achieve a community character by establishing harmony between the built environment and the people
3. To create a balanced community of various socio-economic groups, encouraging co-operation, tolerance and self help generated through a physical planning process
4. To evolve a framework through design, where incremental physical development can take place within legal, economic and organizational guidelines

6.2.2 Design methodology

The main street, at the centre of the plan (refer fig. 17), zigzags from top to bottom, breaking the asymmetrical irregular grid. Zoned housing (refer fig. 16) is arranged in clusters around the main service cores.


Fig. 16. **Demonstration Houses**

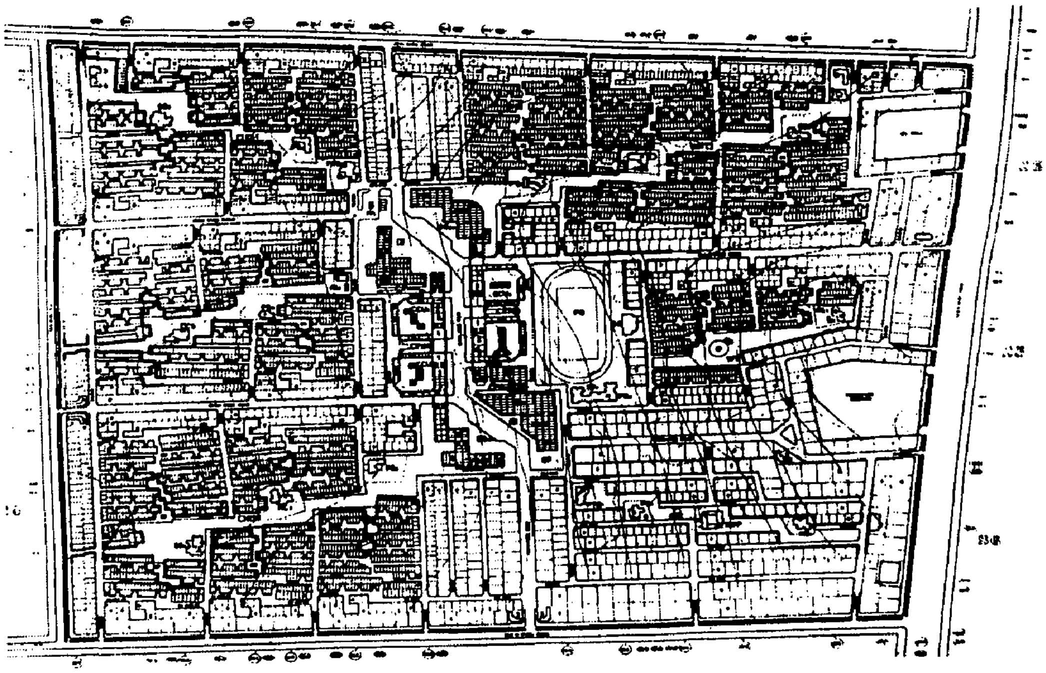


Fig. 17. **Site Plan**

There is a natural growth with rooms, possibility of new rooms, and protection of court/shade. It is a growing home of tenements/extended families having terraces/courtyards and catering to the social -economic –cultural needs. Doshi's 6th principle: *amorphous, rather than finite forms* is applied here. (refer fig. 18 a/b/c)

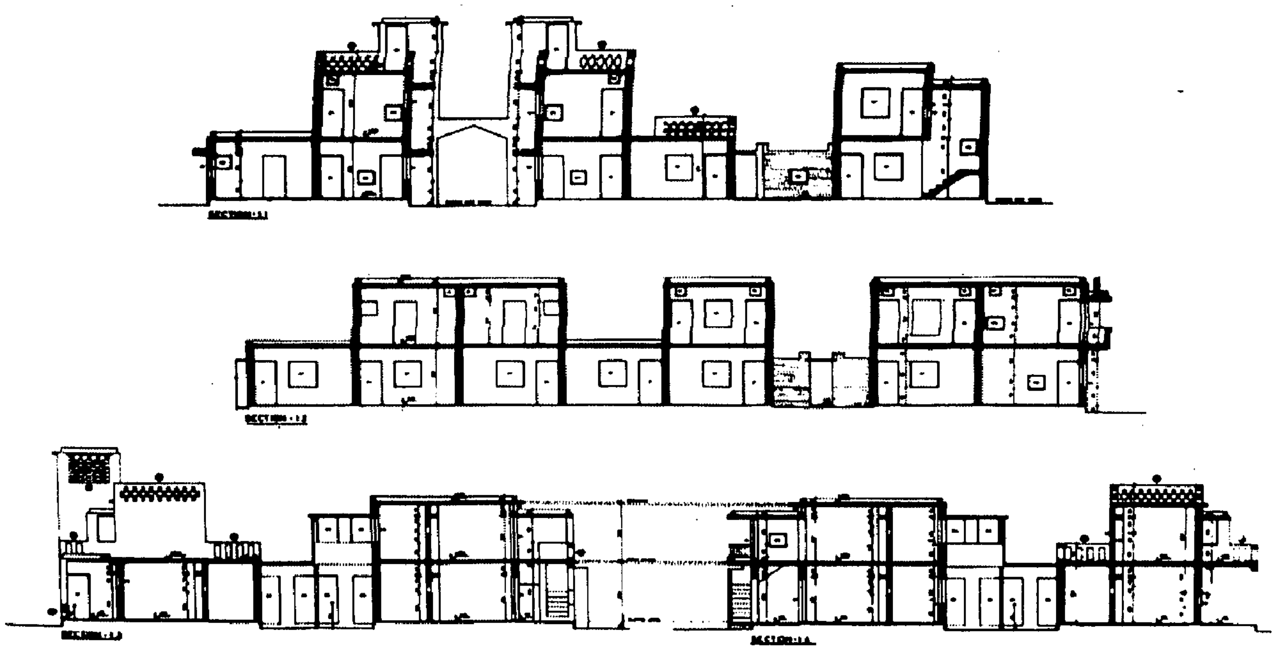


Fig. 18.a **Sections**

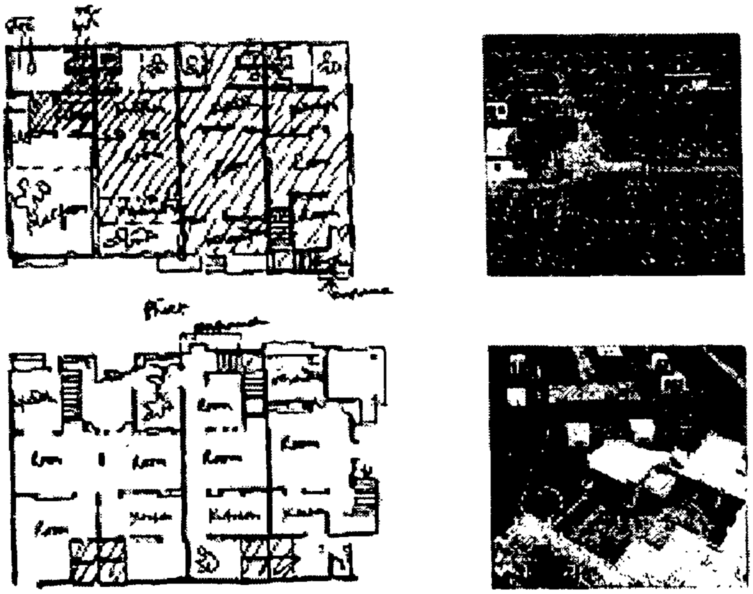


Fig. 18.b **Plans and views**

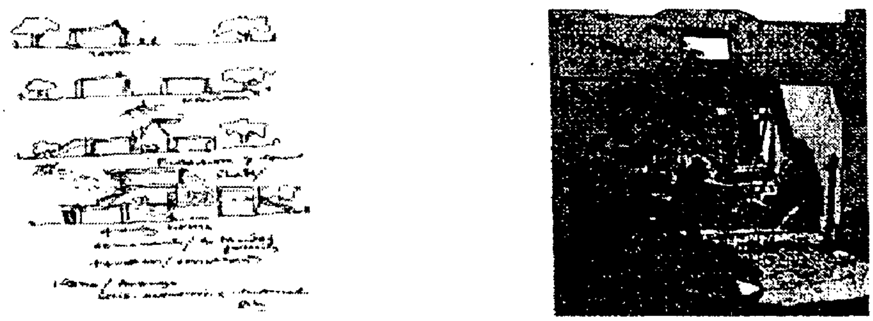


Fig. 18.c **Doshi's Sketches and Real views**

The basic framework allows buildings to be extended in a legal, economical planned way. Doshi's preliminary sketches show sensitivity to the need for outside space within a limited area. The town is informal, imitating that of the slum settlements (refer fig. 19): the centre consists of clusters of shopping, residential and office complexes, at the end of the central spine, two mixed use clusters.

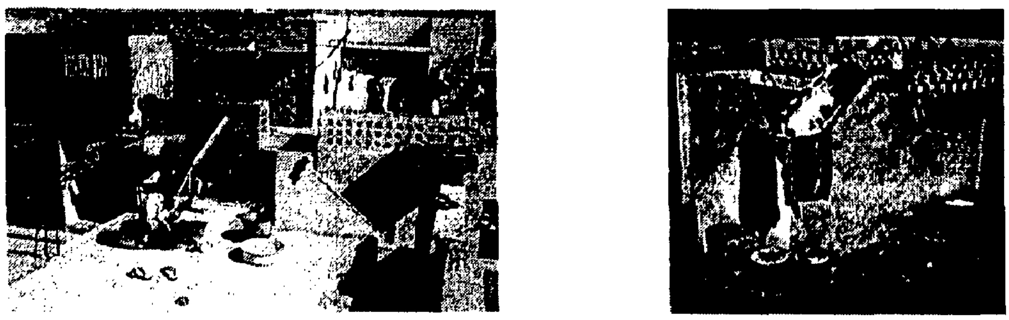


Fig. 19 **Views of Demonstration Houses**

6.2.3 Award for Aranya

This community housing project was awarded Aga Khan Award for Architecture.

a. Award seeks to identify and encourage building concepts that successfully address the needs and aspirations of societies in which Muslims have a significant presence.

b. Selection process emphasizes architecture that not only provides for people's physical, social and economic needs, but that also stimulates and responds to their cultural and spiritual expectations.

c. Particular attention is given to building schemes that use local resources and appropriate technology in an innovative way and to projects likely to inspire similar efforts elsewhere.

"The jury found Aranya to be an innovative sites-and services project (refer fig. 20) that is particularly noteworthy for its effort to integrate families within a range of poor-to-modest incomes"

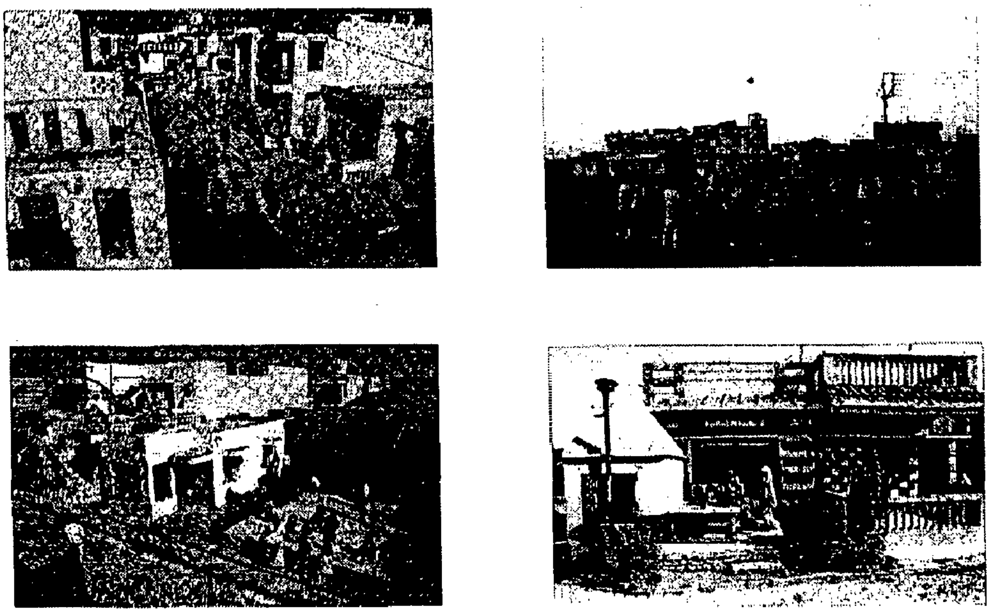


Fig. 20. **Views of Aranya Neighborhood**

An innovative site planning approach has resulted in a balanced vehicular and pedestrian access systems to each plot and the sizes and pattern of open spaces which fully integrates itself with pedestrian network. More than that, the infrastructure planning from the scale of the entire network layout to the scale of individual plot has achieved significant economy which has been widely acclaimed by national and international agencies.

6.3 Post-occupancy study of aranya housing

A study was conducted of such initiatives, in particular, a case in India: the Aranya Township completed in 1988 and considered a model project. To help determine the project's success, analysis of the consolidation of homes, the use of open spaces and compared the appropriateness of design to occupants' lifestyles, using video, photographs and drawings was done.

6.3.1 Land as a Development Tool

In a site and services approach, each family is provided with a small plot and some services such as: a water tap, storm water drainage, a sewer connection, paved access, street lightening, and so on. The level of servicing varies with the beneficiary's ability to pay; so the plot may be supplemented with core housing, comprising a latrine and a kitchen or a minimum house and plinth as an additional built-up area.

6.3.2 Aranya Township

In post-occupancy evaluation of Aranya, selected design elements were examined by looking at how they have matured, and by studying how well they function from the user's point of view. The elements chosen are the following: plot layout and dwelling units, cluster level open spaces, neighborhood level open spaces, street layouts, community level open spaces and landscaping.

6.3.3 Consolidation of homes

Starting with only service cores and the basic infrastructure, people have built their houses in stages, according to their economic resources and the available materials.

Houses are built gradually but successfully as homeowners continue to undertake incremental housing construction that matches their own needs and ability to generate resources. In initial stages of development, people used inexpensive materials, but in later stages, people mainly use bricks and reinforced concrete as construction materials, resulting in more solid and permanent structures.

6.3.4 Use of open spaces

Small open spaces play a vital role, especially in a low-income neighborhood. Such places are used differently, such as: small temple, festival gathering and resting platforms, planting trees, drying clothes, storage place. For large open spaces, people have used some of them as temples, beautiful landscapes, and large gathering site. But a lot of large open spaces have been left empty, and some are even full of waste.

6.3.5 Appropriateness of design to occupants' lifestyles

The design of the demonstration homes is very much a reflection of the local character and is reflective of their culture and lifestyle. It seems very appropriate and contextual, fitting and blending very well within itself and the surroundings.

6.3.6 Design Considerations

1. Promote person-to-person contact through cluster of human scale.
2. Provide an individual character to each other.
3. Create functionally sympathetic and aesthetically pleasing street environments.
4. Provide spaces for social and religious activities.
5. Promote income generation at cluster level.
6. Provide all essential amenities and utilities to every street.
7. Define clearly each cluster's territory and the sense of entry.
8. Have regard for pedestrian.
9. Optimize cluster patterns for economic activities and easy access.

7.0 SUSTAINABLE DESIGN GUIDELINES

The following guidelines are intended to help everyone concerned with the design of neighborhoods. These guidelines are intentionally general and refrain from prescriptive, narrow, interpretations of what is right and wrong. Understanding what constitutes good neighborhood design is more central to the purpose of these guidelines than requirements dependent on specific tastes or styles. Importantly it is hoped that these guides will demand for good design practices in the neighborhoods of the city. It is encouraged to extract from, apply and interpret what is appropriate for a particular neighborhood.

Developers and architects are encouraged in these guidelines to consider design models that are urban and contemporary yet sensitive to historic fabric. It is hoped that all concerned agencies will find these guidelines useful in the development of requests and in the review of proposals. While the difficult realities of financial feasibility must frame all development, good design will only help to make neighborhoods better places to live.

7.1 General design guidelines

1. The design character of any area should be enhanced by new development. The building design should consider the distinctive qualities and character of the surrounding context and, as appropriate, incorporate those qualities in its design. Also, the building design should be sensitive to the context of an area over time.

2. Development, through appropriate siting and orientation of buildings, should recognize and preserve established major vistas, as well as protect natural features such as scenic views of the available physical features and archaeological and historical resources.

3. Development should be sensitive to existing topography and landscaping. A design should respond to the unique terrain of the site by blending with the natural shape and texture of the land while minimizing disturbances to the natural environment.

4. Development should protect the character of the place by preserving and restoring natural habitats and ecological processes.

5. The design of the public realm, including streetscapes, parks, plazas and civic amenities, is an opportunity to provide identity to the community and to convey its design expectations. Streetscapes should provide continuity among adjacent uses through use of cohesive landscaping, decorative paving, street furniture, public art and integrated infrastructure elements.

6. Developments should integrate alternative modes of transportation, including bicycles and bus access, within the pedestrian network that encourage social contact and interaction within the community.

7. Development should show consideration for the pedestrian by providing landscaping and shading elements as well as inviting access connections to adjacent developments. Design elements should be included to reflect a human scale, such as the use of shelter and shade for the pedestrian and a variety of building masses.

8. Buildings should be designed with a logical hierarchy of masses to control the visual impact of a building's height and size and to highlight important building volumes and features, such as the building entry.

9. The design of the built environment should respond to the local environment; interior spaces should be extended into the outdoors when appropriate; materials with colors and coarse textures associated with this region should be utilized. A variety of textures and natural materials should be used to provide visual interest and richness, particularly at the pedestrian level. Materials should be used honestly and reflect their inherent qualities. Features such as deep roof overhangs and recessed windows should be incorporated.

10. Developments should strive to incorporate sustainable and healthy building practices and products. Design strategies and building techniques, which minimize environmental impact, reduce energy consumption, and endure over time, should be utilized.

11. Landscape design should respond to the environment by utilizing a variety of mature landscape materials indigenous to the region. The character of the area should be emphasized through the careful selection of planting materials in terms of scale, density,

and arrangement. The landscaping should compliment the built environment while relating to the various uses.

12. Site design should incorporate techniques for efficient water use by providing desert adapted landscaping and preserving native plants. Water, as a landscape element, should be used judiciously. Water features should be placed in locations with high activity.

13. The extent and quality of lighting should be integrally designed as part of the built environment. A balance should occur between the ambient light levels and designated focal lighting needs. Lighting should be designed to minimize glare and invasive overflow, to conserve energy, and to reflect the character of the area.

14. Signage should consider the distinctive qualities and character of the surrounding context in terms of size, color, location and illumination. Signage should be designed to be complementary to the architecture, landscaping and design theme for the site, with due consideration for visibility and legibility.

7.2 Guidelines for sustainable environment

Following are the major guidelines:

a. use an ecologically responsive approach by using resources efficiently
b. establish a sense of community within the new development and promote strong links with the existing community
c. create a socially equitable environment
d. contribute to the regeneration of town commercial centre
e. balance pedestrian safety, environmental quality, and convenience for motorists
f. promote safety, security and privacy
g. respect heritage attributes
h. offer a wide range of housing choice and diversity to attract mixed population
i. support an energy conscious approach
j. increase residential density near the town centre
k. create extensive reserves and open space linkages beyond the development.

7.3 Guidelines for sustainable infrastructure

a. use of environmental form relating to the site, region and climate
b. use locally available materials and environmental friendly materials for a healthful interior environment
c. All possible measures are to be taken to achieve an efficient, long lasting and elegant relationship of use areas, circulation, building form, mechanical systems and construction technology.
d. Symbolic relationships with appropriate history, the Earth and spiritual principles are to be searched for and expressed. Finished buildings shall be well built, easy to use and beautiful.
e. All possible measures are to be taken to ensure that the building's use of energy is minimal. Cooling, heating and lighting systems are to use methods and products that conserve or eliminate energy use.
f. Building Design must incorporate solar orientation, pedestrian orientation, transit orientation and micro climatic building/siting.
g. Infrastructure Efficiency depends on water supply and use, wastewater collection and storm drainage
h. Street lighting
i. Traffic signalization
j. Recycling facilities
k. Transportation system can be an integrated, multimodal street network comprising pedestrian, bicycle, and transit, high-occupancy vehicles, with pavement minimization and with parking minimization /siting.
l. Preferable maximum use of on-site energy-resources such as geothermal/groundwater; surface water; wind; solar; cogeneration; thermal storage and fuel cell power

7.4 The Sustainable Design Product:

7.4.1 Features of sustainability

While Chapter 3.0 focused on how sustainable design impacts the project management process, this chapter now turns to the question of what physically will be different about the design product. That is, what features will characterize sustainable neighborhoods, and serve as good design measures. Each of these features is developed in more detail in the remaining sections of this chapter. As noted earlier, these guidelines do not necessarily reflect requirements for neighborhoods. Rather they illustrate possible features that need to be developed in detail during the design phases of specific projects.

7.4.2 Site Planning and Landscape Design

Site planning is critical to the success of a sustainable neighborhood. Careful planning, building orientation, and landscaping can cut energy consumption levels and monthly utility expenses considerably. Analysis of the site should consider all existing features both natural and human made, to determine the inherent qualities that give a site its personality. A topographical analysis of existing features is advised. Emphasis should be placed on the site's relationship to the larger environment and its special values. This analysis includes natural, cultural, and aesthetic factors that affect it. The site should also be viewed as a valuable resource for education, not just a building site.

At least eight features characterize a sustainable neighborhood site:

a. Bio-diversity
b. Low input after establishment (e.g., water, mowing, labor, fertilizers, etc.)
c. Relates to and is connected to the area's natural systems
d. Uses green materials where possible
e. Relate to the bio-climatic region (automatically met if 1-4 are true)
f. Visible from the indoors
g. Modulates heating and cooling of the building (e.g., wind buffers, shading)
h. Reinforces the health and welfare of the local community and economy and engages the community in its construction and use

7.4.3 Renewable Energy Sources

Currently, a large part of the energy produced and used is from fossil fuels -- coal, oil, and natural gas. Predictions vary widely, but fossil fuel supply is finite, and fossil fuel combustion produces air pollutants and contributes to global warming. In contrast, renewable energy sources are constantly replenished and don't have the environmental consequences associated with combustion.

Renewable energy also provides an educational opportunity for communities to understand the earth's natural processes and how to put them to work for humans. For these reasons, there is wisdom in investigating the potential for using renewable energy sources in neighborhoods.

Using solar energy: The sun serves as a pollution-free source of energy. The technologies to capture the sun's energy range from inexpensive options that can easily be incorporated into new buildings, such as daylighting, to more expensive options, such as photovoltaic systems. Passive solar heating relies on the design of the building to capture and hold the sun's heat. Passive solar often go hand-in-hand with daylighting, which uses natural sunlight to supplement or replace indoor electric light. A problem can be too much solar heat; solar gains must be controlled.

Using wind energy: Wind energy employs a turbine for converting wind into either electric power or mechanical power, such as for pumping water. In neighborhoods, the primary interest is in electric power generation. Except in remote locations, this involves pumping power into the power grid. One of the first steps in assessing the possibility of using a wind turbine in a neighborhood district is to examine the wind resource. Wind classes of 3 or higher are considered viable for wind turbines. However the wind profile for any project is extremely site specific.

Environmental and aesthetic issues may also be significant concerns for a project in an urban/suburban area. Another consideration for wind turbine owners is the ability to sell excess power back to its utility, preferably at the same price they pay for electricity. This concept is often referred to as "net metering".

Geothermal heating and cooling systems: Today, many are exploring the possibility and enjoy the benefits of geothermal heating and cooling systems, and the number is growing almost daily. A comprehensive engineering study is required to evaluate soils, water table, and other factors before this type of system can be selected. Below the frost line, the earth maintains a relatively constant temperature that is warmer than surface temperatures during winter months and cooler than surface temperatures during summer months. Geothermal heating and cooling systems take advantage of this temperature differential by pumping heat from or to the earth.

In most residential installations, this requires one heat pump for every one or two rooms. The earth connection is either a series of buried pipes (closed loop) or water wells (open loop), often buried beneath parking lots or playing fields.

7.4.3 High Quality, Energy-Efficient Lighting

Lighting is a critical aspect for both a high-quality living environment and an environmentally sustainable building. There are numerous opportunities to improve the quality of light, while significantly reducing the energy used by lighting. Lighting approaches should rely primarily on well-designed daylighting systems, complemented as needed by energy-efficient electric lighting systems.

For both daylighting and electric lighting, the design should begin by carefully assessing the tasks to be performed. Controls may be needed to provide different lighting for different tasks in the same space. Daylighting and electric lighting should be designed only in the context of a whole-building design approach, starting with decisions on orientation and shape of the building.

Daylighting: It is defined as the use of natural light for illumination. Well-designed daylighting provides a superior quality of light, contributes to productivity, reduces energy costs, and improves the health of the occupants. Daylighting is more than simply installing a few skylights; it must be designed within the context of a whole building approach. In this regard, it can be an organizing principle for design. Daylighting involves consideration of heat gain, glare, and variations in light availability, and sunlight penetration into a building.

A successful design must address details such as shading devices, aperture size and spacing, glazing materials, and surface reflectance characteristics. The art and science of daylighting is not so much how to provide enough daylight, as how to do so without undesirable effects such as excessive heat gain, brightness and glare. Daylighting can also contribute to "transparency", increasing the connection between occupants and the outdoor environment. Daylighting is not easy to do well. To be successful, daylighting needs to use a systems approach to design. There are many examples of buildings where good intentions, but limited expertise or lack of communication, resulted in less than desirable outcomes.

Some of the main strategies in improving daylighting are to work with diffuse light from the sky rather than direct sunlight; design for all seasons and times of day. This requires understanding the sun's path and how the energy puzzle varies throughout the year; bring light deep into the building; provide multiple sources of daylight, preferably from at least two sides of every space, to reduce glare and shadowing problems; distribute the daylight by directing it toward ceilings, walls, and floors for gentler and more diffuse light with fewer shadows; use light-colored interior surfaces to reflect daylight and brighten the space; use vertical glass, facing north or south, for best results with daylighting and keeping solar heat out of the building.

Electric lighting: This directly accounts for a large share of the total electrical energy used in the world. Lighting also has an indirect impact on the total energy use because the heat generated by electric fixtures alters the loads imposed on mechanical equipment. During the cooling season, reduced electric lighting loads also lower air conditioning energy usage.

More importantly, electric lighting affects the quality of the building spaces and the productivity of its occupants. It has the potential to enhance or detract from the goal of a superior living environment. Lighting design is the starting point; skillfully done it can enhance quality while reducing lighting power density. Energy efficient lighting equipment is the second, companion strategy that can lower connected load and energy use still further.

Implementation of these strategies requires up-to-date lighting design skills and knowledge of available energy efficient lighting equipment and their performance. There are numerous resources available to assist with equipment selection. Sustainable lighting should also include careful consideration of outdoor lighting from the standpoint of visibility, energy use, and light trespass and pollution. Finally, it is important to emphasize that commissioning of lighting systems, as well as occupant education, become very important towards obtaining the maximum energy benefits.

7.4.4 Energy Efficient Building Shell

A building's shell consists of exterior walls, roof, foundation, doors, windows, skylights, dampers, and other openings. The objectives for a well-designed building shell are to minimize infiltration (both outside air leaking in and conditioned air leaking out) to reduce convective heat transfer through the building shell; minimize conductive heat transfer; control humidity by maintaining proper movement of water vapor in and out of the building; and to control sunlight to reduce HVAC loads and electric lighting needs.

Design aspects related to glazing -- placement, area, shading, type of glass -- provide huge opportunities to enhance architecture, daylighting, view, heating and cooling, and comfort. Good choices in these areas are critical to a successful building. There have been great advances in high performance glass options over the past two decades that should be investigated during design. Glass with specific properties (u-value, solar-heat gain coefficient, visible transmittance) should be selected for specific applications (e.g., conductive heat transfer, solar gains, daylighting, and radiant comfort). This may mean selecting different glazing for different faces of the building to account for solar orientation. This becomes very important in our climate because unwanted solar gains can significantly contribute to cooling loads.

High performance glass, on a standalone basis, may not look like a good investment compared with standard insulated glass. But when looked at from a systems standpoint in a well-integrated design, it often becomes the least expensive glazing choice.

Buildings may use unconditioned ceiling plenum space as the return air path to the heating or cooling system. Routing of return air leads to substantial air infiltration since return air plenums are depressurized and will draw in surrounding outside air if not sealed. In these situations, plenum surfaces that have connection paths to the outdoors should be sealed to prevent unnecessary air infiltration. For flat, unventilated roof spaces, add rigid insulation (most cost-effective during new design or a major re-roofing) to maintain return air temperatures, thus saving energy.

7.4.5 Energy Efficient HVAC Systems

The sustainable design goal for Heating Ventilation and Air Conditioning (HVAC) Systems is to meet the occupant comfort needs through the most energy efficient and environmentally sensitive means possible. Although this may sound simple, the HVAC system proves to be a pivotal aspect in the design of a sustainable building. The reason is that heating and cooling needs are affected by virtually every other sustainable (or non-sustainable) characteristic of the building. In essence, if everything else is done sustainably, the HVAC system should be able to be significantly down-sized. This is termed "tunneling through the cost barrier".

With significant downsizing, due to good whole-building design and responsible safety factors, efficiency of the equipment becomes somewhat less critical. The appropriate HVAC system should therefore be selected only after the entire design team has reviewed the contributing thermal loads of these interrelated systems. Sustainable design goals for HVAC systems include simple design; easy to maintain; minimize number of components; energy efficient; best life cycle cost (including energy, maintenance, and replacement); for comfort, configure system for optimum air distribution and pay attention to how surfaces affect radiant comfort; low noise; system is flexible for after-hour usage.

7.4.6 Environmentally Preferable Building Materials

Environmentally preferable materials (refer table 5) are defined as those that have a lesser impact on human health and the environment when compared to products serving the same purpose. Not only do environmentally preferable materials improve environmental quality, but they are more ecologically sensitive when analyzed over their entire life cycle. This analysis is the tracing of a material from its initial source availability and extraction, through refinement, fabrication, treatment, transportation, use, and eventual reuse or disposal. As part of this sustainable design philosophy, it is wise to use environmentally preferable building materials to the maximum extent possible. However, this can be a complex aspect of sustainable design considering:

A. the vast number of products available claiming to be "green",

B. the numerous factors for comparing products on an environmental basis. Uses of environmentally preferable products requires both a prioritization scheme, as well as shear time to research specific products, their function, cost, and local availability.

Energy Efficiency	• Energy efficient production methods • Use of renewable energy sources
Resource Responsibility	• Minimal need for other materials • Low maintenance • Durability • Efficient use of material • Recycled content • Recyclable
Social/Public Health	• Avoidance of harmful chemicals in production • Reduction of off-gassing • Avoidance of harmful chemicals in disposal and reuse
Economics/Functionality	• Initial cost • Cost savings and payback • Availability • Acceptability
Supplier or Manufacturer	• Local supplier • Local economic benefit • Suppliers with in-house environmental programs

Table 5. **Considerations for eco-friendly products**

It is also helpful to prioritize products by origin, taking care to avoid materials from nonrenewable sources:

a. *Primary Materials* - those found in nature such as stone, earth, flora (hemp, jute, reed, wool), cotton, and wood. Ensure new lumber is from certified sustainably managed forests or certified naturally felled trees. Use caution that treatments, additives, or adhesives don't contain toxins or off-gas volatile organic compounds (VOCs).

b. *Secondary Materials* - those made from recycled products such as wood, aluminum, cellulose, and plastics. Verify that production does not involve high levels of energy, pollution, or waste. Verify functional efficiency and safety of salvaged materials. Consider cellulose insulation. Specify aluminum from recycled material; it uses 80 percent less energy to produce over initial production. Keep alert for new developments; new recycled goods are coming on the market every week.

c. *Tertiary Materials* - manufactured materials (artificial, synthetic, nonrenewable) having varying degrees of environmental impact. Avoid use of materials containing or produced with chlorofluorocarbons or hydro chlorofluorocarbons that deteriorate the ozone layer. - Avoid materials that off-gas VOCs. Minimize use of products made from new aluminum or other materials that are resource disruptive during extraction and a high energy consumer during refinement.

7.4.7 Indoor Air Quality

Environmental Protection Agency (EPA) studies of human exposure to air pollutants indicate that indoor levels of pollutants may be 2 to 5 times, and occasionally more than 100 times, higher than outdoor levels. These levels of indoor air pollutants are of particular concern because it is estimated that most people spend about 90 percent of their time indoors. Comparative risk studies have consistently ranked indoor air pollution among the top four environmental risks to the public.

Indoor air problems can be subtle and do not always produce easily recognized impacts on health, well being, or the physical plant. Children are especially susceptible to air pollution. For this, and the reasons noted, air quality is of particular concern. Proper maintenance of indoor air is more than a "quality" issue; it includes safety and good management of our investment. Chemicals, sources to avoid, and their reactions:

a. Benzene found in synthetic fibers and plastics: highly toxic to red blood cells

b. Acetone found in masonry, caulking, wall coverings, strippers, adhesives, polyurethane, stains and sealers

c. Toluene found in adhesives, paint remover, paint: may cause lung damage: flammable

d. Dichloromethane found in solvent in paint remover, adhesive paint aerosols: may cause cancer, heart attacks: a known water pollutant

e. Ethylene glycol found in solvent in latex paint: may cause damage to blood & bone morrow

f. DEHP found in plasticizer used in wall covering, floor cover, to keep vinyl flexible: known carcinogen

g. Terpene found in natural pine and cedar wood furniture, and linoleum: may cause allergic reactions

h. Formaldehyde found in plywood, particleboard, adhesives, fabric finishes, carpet padding

i. 4-PC natural result of binding latex to carpet: may cause allergic reaction

7.4.8 Water Conservation

Water is a precious resource that should be used efficiently. Conserving water not only saves money, but the ramifications of water efficiency go far beyond lower water bills. For example, at the community level it can help to eliminate or defer the need for more dams, treatment facilities, and expensive water rights. Water treatment consumes a great amount of energy. A large percent of the treated water ends up being flushed in toilets and used to water landscaping. Whenever water can be saved, so can energy, and the energy savings often financially dwarf the water savings. Installing water-efficient appliances and fixtures, using drought resistant plants in landscaping, and changing irrigation practices can reduce water consumption.

In order to conserve both water and energy to the extent possible, the following steps are applied to the sustainable design process:

a. Minimize the amount of water required to operate the neighborhood.

b. Evaluate the various water uses, distinguishing those that can be performed using raw (untreated) water, versus functions requiring treated water.

c. Evaluate methods for providing the required raw water supply using on-site resources.

Therefore, the emphasis should be on water conservation through landscape design and efficient fixtures.

7.4.9 Recycling and Waste Management

Sustainable neighborhoods should not only consider the building itself, but they should be designed to foster sustainable practices within the building. For example, one requirement for all LEED certified sustainable buildings is that the building be designed for storage and collection of recyclables. There is room for improving upon these systems and to expand them to possibly include additional materials. There may be special solid waste and recycling requirements for residential, shops and other commercial establishments. Finally, the design should take into account provisions needed for recycling in areas where public events occur during off-hours. The most common spaces used are cafeterias, gymnasiums, athletic fields, and community centers.

Construction Waste Reduction and Recycling: The intention is to apply sustainability to the design, construction, operation, and ultimate dismantling of its buildings. This section describes sustainable construction methods and how to incorporate them into the design/build process. Utilizing construction methods that minimize waste generation is critical, for it is estimated construction-related waste accounts for about one-fourth of total landfill waste. It is estimated that 50 to 80 percent of construction and demolition (C&D) waste is potentially reusable or recyclable, depending on the type of project and local markets for waste materials.

Strategies for applying sustainability to construction practices include: use of waste reduction techniques during construction; reuse of construction waste material on the construction site; salvage of construction and demolition waste material from the construction; site for resale or reuse by others; return of unused construction material to vendors for credit; and recycling of construction and demolition waste for remanufacture into new products.

8.0 RECOMMENDATIONS AND CONCLUSION

The Sustainable Neighborhoods Initiative is a new approach to design and develop neighborhood areas. It combines physical development and infrastructure improvements with human service support and community-based economic development for a comprehensive neighborhood plan.

8.1 General considerations

8.1.1 Land use and zoning

a. *Neighborhood of mixed use rather than segregating uses.* Mixed land uses help create community and vitality for the neighborhood. Commercial/market activity besides promoting income generation also helps in self-sufficiency of the neighborhood for a majority of the residents needs.

b. Diversify *housing types in the neighborhood.* Provide housing at all levels and scales, including affordable housing, rather than limiting the housing to one segment. This discourages segregation and promotes population mixing and social equality besides ensuring affordability and choice.

c. *Organize cluster patterns for all types of activities.* Sense of human scale and sense of belonging can be achieved. Also this helps in creating specific character and identity, and person to person contact within the cluster.

d. *Provide necessary physical infrastructure to all plots.* Basic services such as electricity, water connection, sewer connection, drainage system, street lighting, access paths and roads must be provided for every plot. Sharing of utilities is efficient economically and from the resource utilization point of view. This increases the land value, ensures the availability of developed land, thereby ensuring faster sale of plots.

8.1.2 Site planning

a. *Plan according to and for the site topography.* Whenever possible design and construct with minimum cut and fill, and with the least disturbance to the land.

b. *Preservation of wildlife habitat and nature.* Ensure that all development is in harmony with the environment and not detrimental to the natural habitat. On the contrary, natural habitats must be harnessed and preserved.

c. *Effective access to common facilities.* Within and outside the clusters, people must have easy and quick access to essential community, recreation facilities and shopping for daily needs. The best access to the common facilities would be from the common outdoor space such as a street plaza etc.

8.1.3 Transportation

a. *Maintain hierarchy in the road network.* While it is good to provide road access to all plots in a neighborhood, it is not necessary. Wherever possible, areas can be linked by walkways and pedestrian pathways. This would encourage the use of foot or bicycle, relieving the need for the automobile.

b. *Promote multi-modal transport system.* This ensure diversity and minimum dependency on a particular type of transport.

c. *Minimize visual and physical impacts of vehicles.* As far as possible, vehicles must be kept away from the housing units and tot-lots. Besides reducing pollution, it solves conflict problems between pedestrian and vehicle.

d. *Give utmost priority for the pedestrian user.* The neighborhood should be designed primarily for the pedestrian. His access to all areas should be of prime priority.

8.1.4 Park and green areas

a. *Fence off naturally green areas.* Areas rich in flora and fauna are better if left undisturbed. In such cases, it is wise to provide low access to these areas in order to preserve and protect the environment.

b. *Distribute open spaces and play areas.* All clusters must have their own open spaces for recreation, socializing and pastime.

8.2 Architectural considerations

8.2.1 Cultural and regional identity

a. *Appropriateness and local character.* Use architectural elements and features that are distinctive and characteristic of the region. Local design features besides being ideal responses to the climate and environment help preserve the local culture and identity. It also helps to create a sense of place and belonging.

b. *Use local labour and local techniques.* Beyond the obvious economic advantages for the local economy, it creates pride and ownership for the community. It also helps preserve local construction practices and techniques.

c. *Use local materials whenever possible.* Materials available or produced locally result in economic advantages reduces transportation needs and helps the environment. This reduces dependency and increases self-sufficiency.

8.2.2 Streetscape

a. *Provide variety of open informal spaces at all levels.* Small and large open and informal spaces to cater for various needs from the cluster to the neighborhood level must be planned. There could be sharing of open and community spaces by people from more than one cluster.

b. *Provide vistas and views from maximum possible locations.* The buildings and open spaces must be planned in a way so as to obtain maximum views to and from the neighborhood. Vistas along walkways and community spaces work very well in creating a feeling of curiosity, interest and beauty.

c. *Provide streetscape landscaping.* Landscaping of road medians, planting trees along either side of the road and judicious use of water in landscape can be provided. Whenever possible, native species of trees and plants must be planted. The possibility of community farming can also be explored.

d. *Provide durable street furniture and signage.* Street furniture along pedestrian walkways lets a person rest temporarily, and to enjoy the street activity. Clear and visible signage showing locations makes easy movement; and well lit streets make a neighborhood safe and secure.

8.2.3 Climate

a. *Consider solar orientation when laying out buildings.* In general, orient the longer side of buildings on a north-south axis to minimize solar heat gain. Consider the year-round altitude and azimuth of the sun when designing exterior wall space, window sizing and placement, overhangs, and interior layout. Overhangs, windows and shading devices can be designed to provide shading during the summer months while admitting sunlight during the winter months when the sun's path is lower.

b. *Shape buildings to be conscious of wind.* Buildings can be shaped to divert wind in cold climates. In hot climates, buildings can be shaped to catch summer breezes, while the interior could be laid out to efficiently circulate these breezes.

c. *Use landscape to provide desired micro-climate for buildings.* Landscape elements such as trees, plants and berms can protect buildings from solar gains and harsh winds. Earth-sheltering techniques such as recessing the building below grade can also provide beneficial climatic protection for buildings.

8.2.4 Building Envelope

a. *Thermal mass/Building materials.* In general, the greater the mass of the exterior wall and roof, the more the thermal transfer time between the exterior and the interior. Storing solar heat gain in the daytime and using this heat during night hours can be achieved by utilizing high thermal mass construction and materials.

b. *Color:* The color of the building's exterior surfaces is also an important factor for heat gain. Light colored, reflective materials are preferable in hot climates, while dark colored, absorptive materials are preferable in cold climates.

c. *Windows:* Windows are an extremely influential factor in climatic design. Window type, size, and placement, have tremendous effects on solar heat gains, passive cooling, breeze and natural lighting. As the weakest climatic element of the building envelope, windows are an extremely poor insulator, allowing too much heat gain in the summer and too much heat loss in the winter.

d. *Shading devices.* Roof overhangs, awnings, porches, and blinds are just some examples of shading devices that could be used to prevent unwanted solar heat gains. These devices could be placed and used strategically according to the sun's altitude and azimuth.

8.2.5 Building shape and layout

a. *Minimize the surface to volume ratio (SVR).* As a general rule, the more compact the shape, the greater the heating and cooling efficiency of the building. This is accomplished by minimizing the exterior wall and roof areas.

b. *Layout interior spaces to take advantage of passive cooling.* Strategies for passive cooling include orienting the building to allow for maximum exposure to summer breezes. Use walls, overhangs and built elements to assist in channeling breezes through the building. Providing vertical air shafts also serve to efficiently remove hot air through stack-effect ventilation.

c. *Layout interior spaces for solar heat gain.* Heat can be trapped and stored in many ways. Some examples include: using high thermal mass materials to absorb and store heat; using vertical shafts as an outlet for excess heat in the summer while providing heat recovery and storage in the winter; and using large areas of southern exposed walls with large window surface areas to maximize solar heat gain. The desired times of heat gain can also be controlled using strategic use and placement of the above examples.

d. *Layout building to take advantage of natural daylighting.* Much energy can be saved through provision of natural lighting as an alternative to electrical lighting. Skylights, light shelves, light wells, and windows can be used to provide natural lighting in buildings. This could be direct or indirect depending on the desired effect and/or function of the space.

8.2.6 Building Materials

The factors and strategies to be considered in the materials selection process include:

a. *Recycling buildings.* Methods of recycling, retrofitting, and re-using buildings rather than demolition and new construction should be explored.

b. *Recycling materials.* Choosing materials which are either recyclable or re-usable is an obvious sustainable practice. Recycling programs on the construction site however is a less obvious practice with equally important environmental benefits. Rather than incinerating all the waste from a construction site, the designer should establish a recycling program to reduce the amount of solid waste accrued from construction.

c. *Origin of materials.* The proximity of the source and the product to the building site is also an important consideration. Using sustainably harvested wood from a source 3000 miles away would negate any environmental benefits. Using sources closer to the building site not only reduces transportation impacts and costs but also helps the regional economy, addressing another aspect of sustainable design.

d. *Embodied energy (emergy).* The term, embodied energy, is a method of factoring in all the hidden energy costs of producing a material. This gives an accurate cost of the building material. Some general estimates of emergy for various materials include: lumber = 1; brick = 2; glass = 3; steel=8; plastic = 30; and aluminum = 80 (5).

e. *Production of materials.* The production of building materials is a major factor in the environmental impact of a building project.

f. *Toxicity of materials.* The recent "sick" buildings phenomena has increased awareness for indoor air quality among designers. As a general rule, avoid materials which emit formaldehyde, organic solvents, VOCs, and chlorofluorocarbons.

g. *Select natural materials when possible.* Natural materials such as stone, lumber, and earth are generally less energy-intensive to produce, have lower toxicity levels, and contribute less pollution to the environment.

h. *Consider the durability and life cycle of the product.* The constant production, maintenance and disposal of materials in our "throw away" society is an unsustainable practice which must be stopped. Sustainable materials include materials which do not need high maintenance or constant replacing.

8.3 Conclusion

Effective low cost and sustainable building design works well with an integration of historic principles and new technologies and methods. These are some of the benefits:

a. Conservation of natural and building resources
b. Increased building durability
c. Increased user comfort and satisfaction
d. Energy and material savings
e. Elimination of waste and pollution
f. Savings from recycling.

Set environmental/energy use goals
Use an integrated design approach
Specify Earth-friendly materials
Think about the impact of decisions
Assure design intent is maintained
Involve users in design decisions
Never forget the goals

Minimizing energy consumption and promoting human health should be the organizing principles of sustainable design. The other elements of design can be organized: energy saving architectural features, energy conserving building envelope, and energy-efficient mechanical, electrical, and plumbing systems.

Finally it can be concluded with the following comments that:

A. Planning and design should be thorough. Sustainable design is "front loaded" compared with traditional design. Early decisions have the greatest impact on energy efficiency, passive solar design, daylighting, and natural cooling.
B. Sustainable design is more of a philosophy of building than a prescriptive building style. Sustainable buildings do not have any particular style.
C. Sustainable buildings don't have to cost more, nor are they more complicated than traditional construction.
D. Integrated design, that is design where each component is considered part of a greater whole, is critical to successful sustainable design.

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APPENDIX - A

TERI-GRIHA Evaluation Criteria

A. Site planning- Conservation and efficient utilization of resource: To maximize the conservation and utilization of resources (land, water, natural habitat, avid fauna, and energy) conservation and enhance efficiency of the systems and operations.

›Criterion 1: Preserve and protect the landscape during construction.

Commitment: Proper timing of construction, preserve top soil and existing vegetation, staging and spill prevention and erosion and sedimentation control. Replant, on-site, trees in the ratio 1:3 to those removed during construction.

›Criterion 2: Soil conservation (till post-construction).

Commitment: Proper top soil laying and stabilization of the soil and maintenance of adequate fertility of the soil to support vegetative growth.

›Criterion 3: Design to include existing site features.

Commitment: Minimize the disruption of natural ecosystem and design to harness maximum benefits of the prevailing micro-climate.

›Criterion 4: Reduce hard paving on-site and /or provide shaded hard - paved surfaces.

Commitment: Minimize storm water run-off from site by reducing hard paving on- site.

›Criterion 5: Enhance outdoor lighting system efficiency.

Commitment: Meet minimum allowable luminous efficacy (as per lamp type) and make progressive use of a renewable energy- based lighting system.

›Criterion 6: Plan utilities efficiently and optimize on-site circulation efficiency

Commitment: Minimize road and pedestrian walkway length by appropriate planning and provide aggregate corridors for utility lines.

B. Site planning-Health and well being: To protect the health of construction workers and prevent pollution.

›Criterion 7 Provide at least, the minimum level of sanitation/safety facilities for construction workers.

Commitment: Ensure cleanliness of workplace with regard to the disposal of waste and effluent; provide clean drinking water and latrines and urinals as per applicable standard.

›Criterion 8 Reduce air pollution during construction.

Commitment: Ensure proper screening, covering stockpiles, covering bricks and loads of dusty materials, wheel-washing facility, and water spraying.

C. Building planning and construction stage- *utilization of resources*: To maximize resource (water, energy, and materials) conservation and enhance efficiency.

D. Building planning and construction stage-water:

›Criterion 9 Reduce landscape water requirement.

Commitment: Landscape using native species and reduce lawn areas while enhancing the irrigation efficiency, reduction in water requirement for landscaping purposes.

›Criterion 10 Reduce building water use.

Commitment: Reduce building water use by applying low-flow fixtures, etc.

›Criterion 11 Efficient water use during construction.

Commitment: Use materials such as pre-mixed concrete for preventing loss during mixing. Use recycled treated water and controls the waste of curing water.

***E. Building planning and construction stage-Energy end use*:**

›Criterion 12 Optimize building design to reduce the conventional energy demand.

Commitment: Plan appropriately to reflect climate responsiveness, adopt an adequate comfort range, less air-conditioned areas, daylighting, and avoid over-design of the lighting and air-conditioning systems.

›Criterion 13 Optimize the energy performance of the building within comfort limits.

Commitment: Ensure that energy consumption in building under a specified category is 10%–40% less than that benchmarked through a simulation exercise.

F. Building planning and construction stage-energy *(embodied and construction)*:

›Criterion 14 Utilization of fly ash in the building structure.

Commitment: Use of fly ash for RCC (reinforced cement concrete) structures with in-fill walls and load bearing structures, mortar, and binders.

›Criterion 15 Reduce volume, weight, and time of construction by adopting an efficient technology (e.g. pre-cast systems, ready-mix concrete, etc.).

Commitment: Replace a part of the energy-intensive materials with less energy-intensive materials and/or utilize regionally available materials, which use low-energy/energy-efficient technologies.

› Criterion 16 Use low-energy material in the interiors.

Commitment: Minimum 70% in each of the three categories of interiors (internal partitions, panelling/false ceiling/interior wood finishes/ in-built furniture door/window frames, flooring) from low-energy materials/finishes to minimize the usage of wood.

G. Building planning and construction stage-Energy (renewable):

› Criterion 17 Renewable energy utilization.

Commitment: Meet energy requirements for a minimum of 10% of the internal lighting load (for general lighting) or its equivalent from renewable energy sources (solar, wind, biomass, fuel cells, etc). Energy requirements will be calculated based on realistic assumptions which will be subject to verification during appraisal.

› Criterion 18 Renewable energy - based hot- water system.

Commitment: Meet 70% or more of the annual energy required for heating water through renewable energy based water-heating systems.

H. Building planning and construction stage-Recycle, recharge, and reuse of water:

Objective– To promote the recycle and reuse of water.

› Criterion 19 Wastewater treatment

Commitment: Provide necessary treatment of water for achieving the desired concentration of effluents.

› Criterion 20 Water recycle and reuse (including rainwater).

Commitment: Provide wastewater treatment on-site for achieving prescribed concentration, rainwater harvesting, reuse of treated waste water and rainwater for meeting the building's water and irrigation demand.

I. Waste management:

Objective –To minimize waste generation, streamline waste segregation, storage, and disposal, and promote resource recovery from waste.

› Criterion 21 Reduction in waste during construction.

Commitment: Ensure maximum resource recovery and safe disposal of wastes generated during construction and reduce the burden on landfill.

› Criterion 22 Efficient waste segregation.

Commitment: Use different coloured bins for collecting different categories of waste from the building.

› Criterion 23 Storage and disposal of waste.

Commitment: Allocate separate space for the collected waste before transferring it to the recycling/disposal stations.

› Criterion 24 Resource recovery from waste.

Commitment: Employ resource recovery systems for biodegradable waste as per the Solid Waste Management and handling Rules, 2000 of the MoEF. Make arrangements for recycling of waste through local dealers.

J. Health and well-being:

Objective –To ensure healthy indoor air quality, water quality, and noise levels, and reduce the global warming potential.

› Criterion 25 Use of low-VOC (volatile organic compounds) paints/ adhesives / sealants.

Commitment: Use only low VOC paints in the interior of the building. Use water –based rather than solvent based sealants and adhesives.

› Criterion 26 Minimize ozone – depleting substances

Commitment: Employ 100% zero ODP (ozone depletion potential) insulation; HCFC (hydro chlorofluorocarbon)/ and CFC (chlorofluorocarbon) free HVAC and refrigeration equipments and/Halon-free fire suppression and fire extinguishing systems.

› Criterion 27 Ensure water quality.

Commitment: Ensure groundwater and municipal water meet the water quality norms as prescribed in the Indian Standards for various applications (Indian Standards for drinking [IS 10500-1991], irrigation applications [IS 11624-1986]. In case the water quality cannot be ensured, provide necessary treatment of raw water for achieving the desired concentration for various applications.

› Criterion 28 Acceptable outdoor and indoor noise levels.

Commitment: Ensure outdoor noise level conforms to the Central Pollution Control Board–Environmental Standards–Noise (ambient standards) and indoor noise level conforms to the National Building Code of India, 2005, Bureau of Indian Standards, Part 8–Building Services; Section 4–Acoustics, sound insulation, and noise control.

› Criterion 29 Tobacco and smoke control.

Commitment: Zero exposure to tobacco smoke for non-smokers and exclusive ventilation for smoking rooms.

K. Building operation and maintenance:

Objective – Validate and maintain 'green' performance levels/adopt and propagate green practices and concepts.

› Criterion 30 Energy audit and validation.

Commitment: Energy audit report to be prepared by approved auditors of the Bureau of Energy Efficiency, Government of India.

› Criterion 31 Operation and maintenance protocol for equipment.

Commitment: Ensure the inclusion of a specific clause in the contract document for the commissioning of all electrical and mechanical systems to be maintained by the owner, supplier, or operator. Provide a core facility/service management group, if applicable, which will be responsible for the operation and maintenance of the building and the electrical and mechanical systems after the commissioning.

› Criterion 32 Bonus points.

Four bonus points are available under the rating system for adopting criteria which enhance the green intent of a project, and the applicant can apply for the bonus points. Some of the probable points, not restricted to the ones enumerated below, could be:

a. Alternative transportation
b. Environmental education
c. Company policy on green supply chain
d. Lifecycle cost analysis
e. Any other criteria proposed by applicant