Eco-housing Guidelines for Tropical Regions





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Bangkok, Thailand

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EXECUTIVE SUMMARY

The building and construction sector is a major source of environmental degradation. Its geographical spread, rapid growth rate and the long lives of the structures being built, leads to widespread impacts affecting several generations. This makes this sector a hot spot requiring careful analysis and benign intervention. The dynamics of current socio-economic systems ensure that the sector will continue to grow at a rapid rate. The development pathways of most Asian countries are symptomatic of these trends.

The application of eco-housing has the potential to reverse these trends. A central goal of this evolving concept is to achieve comfortable and healthy habitats at affordable costs, through low impact methods, consuming less resource than a standard habitat and using environmental friendly materials and products. It also sets out to be a net producer of environmental and social goods by imitating the self sustaining, cyclic processes of nature. In practice, this will involve minimising resource intensity leading to "dematerialisation" and to "rematerialise" by using the bio-climatic features of the site to create environmental and social goods. Bio-climatic design principles and life cycle approaches aids in this process. Eco-housing re-visits sustainable traditional architectural practices, explores the possibilities of modern technology and advocates the use of renewable resources.

This wide spectrum of objectives needs to be integrated across several mature disciplines and design objectives. Environment friendly site planning, appropriate choices of materials and products, sustainable use of energy and water, provision of clean water, indoor environment quality and sanitation, waste water and solid waste management, and proper operation and maintenance, are key areas of application of the concept. This calls for an effective inter-disciplinary team with good project management skills. Integrated design and project management software's could help in this process.

Eco-housing has caught the attention of decision makers in Asia, but a lack of real examples has prevented its adoption on a larger scale. To meet this need, UNEP and UN-HABITAT joined hands in 2004, to promote and demonstrate eco-housing as a key preventive measure in the Asia-Pacific region. They facilitated the establishment of a Regional Expert Group on eco-housing, which recommended that the concept be taken forward through a project addressing four key areas: knowledge building, educational initiatives, networking and demonstration projects. Design Guidelines were prepared to facilitate the demonstration projects and for dissemination. This publication is a compilation of these guidelines and the experience in implementing it.

The guidelines are expected to build awareness and capacity in the Asia Pacific region. It also would challenge practitioners to take up more ambitious targets. Apart from the guidelines, this publication also introduces the readers to key concepts, technologies and other useful resources.

1

Introduction

1.1 The need for eco-housing

Civilisations are often known by their architectural legacy. We discover in them the accumulated wisdom of thousands of years, based on a deep understanding of sustainable patterns of living. These priceless legacies are vanishing under the assault of the technologies and fashions let loose by the Industrial Revolution. The rapid growth of the global economy and the rising trends in population and urbanization has raised concrete jungles over once verdant landscapes, threatening flora and fauna. Social changes that accompany affluence such as the splitting up of the extended families into nuclear families and the demand for larger houses, have added momentum to the increasing demand for housing. Built up land[1] increased from 0.23 billion global[2] ha in 1961 to 0.44 billion global ha in 2001; an increase of 91.3%. (WWF, 2004) The informal sector is playing a major part in supplying the huge demand for housing. This often includes self built houses, many of them illegal and mostly lacking infrastructure (UNEP DTIE, 2003. p.5) A combination of increasing quantities and decreasing qualities is straining the carrying capacity of the global ecosystem. Taking into account its entire lifespan, the built environment worldwide is currently responsible for up to 25 to 40% of energy use, 30 to 40% of solid waste generation, and 30 to 40% of global greenhouse gas emissions. (UNEP DTIE, 2006)

On the positive side, the building and construction sector have become the engines of economic growth in the modern era. On an average, the sector provides 5 to 10% of employment, mostly to unskilled workers, and accounts for 5 to 15% of the national GDP (UNEP DTIE, 2006)

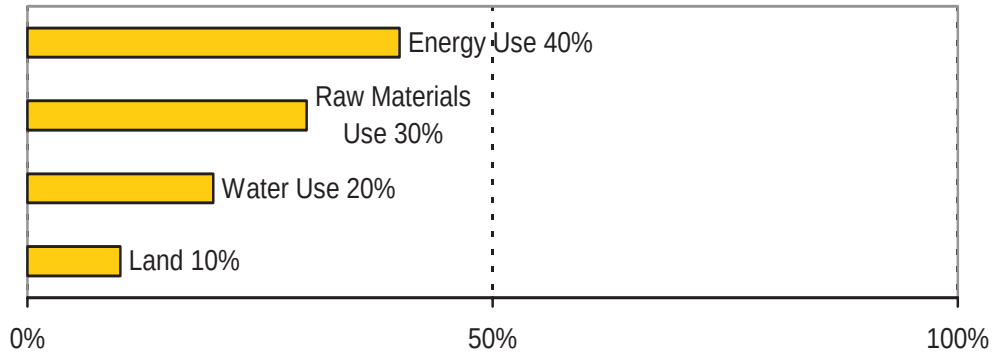


Fig 3.1 : Share of the built environment in resource use (UNEP DTIE, 2006)

[1] The area required to accommodate infrastructure for housing, transport, industrial production, and hydropower (WWF, 2004)

[2] Global hectare is a hectare whose biological productivity equals the global average (WWF, 2004)

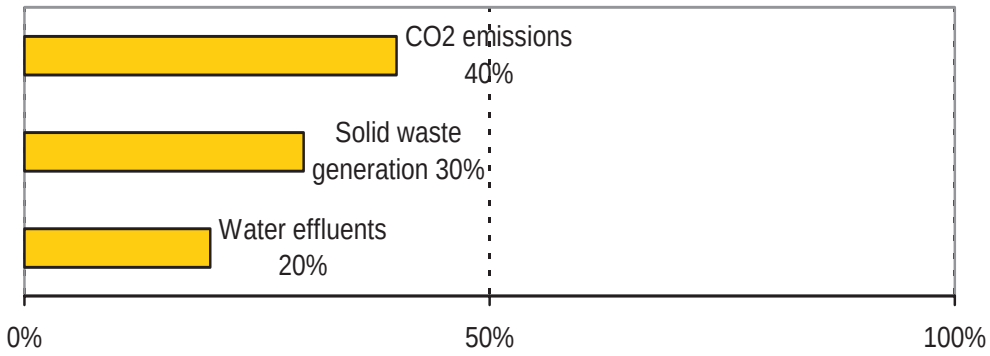


Fig 1.4: Share of the built environment in pollution emission (UNEP DTIE, 2006)

The poor and marginalised takes the brunt of the negative impacts. Pressures on urban services such as piped water, sanitation, drainage, transport, health care and education, affect the poor disproportionately since they do not have the resources or capacity to adapt. Many architectural traditions are also getting extinct due to over-emphasis of techno-commercial aspects.

The negative trends are most apparent in Asia. Asia has the fastest growing economies, the most populous countries, a burgeoning middle class, and a majority of the global poor.

Clean air is a major issue in the Asia Pacific region. Of the 15 cities in the world with the highest levels of particulate matter, 12 are located in Asia. Urban air pollution contributes to the death of nearly 0.5 million people annually in Asia.

In most Asian cities, waste generation has far outstripped the available infrastructure and technology. The urban areas of Asia produce about 0.8 million tons of municipal solid waste a day and this is expected to reach 1.8 million tons by 2025. Between one third and one half of solid waste generated within the cities in developing countries is not collected. Only few cities have adequate waste disposal facilities. Open dumping is the most prevalent mode of municipal solid waste disposal in most countries. In addition, emerging issues like electronic wastes have laid siege on the region. Toxic substances like cadmium, mercury and lead are commonly used in electronic products. The batteries from the forecasted 800 million mobile phones in Asia by 2007 have the potential to pollute 480 trillion litres of water.

Asia has also been at the epicentre of natural disasters, necessitating massive reconstruction efforts. There is a huge demand for building materials in these areas. The conventional methods of reconstruction and resource use, could lead to additional environmental impacts such as soil erosion, flooding, land slides and a loss in biodiversity.

Modern habitats and construction practices create and intensify many of these impacts. The long lives of the structures being built extend their impacts over several generations. Any policy to mitigate the impacts of the building and construction sector will reap

widespread and long-lasting benefits. Decisions makers are trying to solve these issues, even as they continue to balance the supply of buildings with the spiralling demand. It is more than apparent that a paradigm shift in approach is required in the design, construction and operation of buildings, to take care of environmental and social concerns.

The Agenda 21 formulated in the 1992 Earth Summit in Rio, spawned a soul search by different actors and stakeholders on its relevance to their specific contexts and how it could be translated into action for sustainable development. The role of human settlements in sustainable development is specifically mentioned in Chapter 7 of Agenda 21.(CIB & UNEP-IETC, 2002, p.iii) In 1996, the UN convened the United Nations Conference on Human Settlements (Habitat II) in Istanbul to formulate the Habitat Agenda, an international action plan specific to human settlements. 171 Governments agreed to adopt the Habitat Agenda and the Istanbul Declaration, thereby agreeing for developing sustainable human settlements, along with the target of ensuring adequate housing for all.

The concept of eco-housing is a most potent tool to achieve these goals. The concept has found wide acceptance from the political leadership in the Asia Pacific region, but they cite the need to see working models to take policy decisions.

1.2 About the Guidelines

UNEP and UN-HABITAT joined hands in 2004 to promote and demonstrate eco-housing as a key preventive measure in the Asia-Pacific region. A Regional Expert Group on eco-housing was established, which recommended that the concept be taken forward through four key areas: knowledge building, educational initiatives, networking and demonstration projects. The demonstration project is currently being implemented in select countries in Asia.

Design guidelines were prepared to guide the design of the demonstration projects and for dissemination. This report is a compilation of these guidelines and the experience so far in implementing it.

The guidelines presented here are not exhaustive and cannot replace more comprehensive texts, scientific documents and guides on this subject. Its objective is to introduce the concept of eco-housing to a wide audience. It will help the novice to build awareness and an interest in eco-housing. It would also help experienced professionals to refresh their ideas on eco-housing. This publication also helps in guiding them to resources available elsewhere. To build a house/building, fundamental understanding of building materials, building components and technologies is essential. These fundamentals were beyond the scope of this publication. Essential concepts and technologies have been introduced, to enhance the understanding of the guidelines. Chapter 2 presents the concept of eco-housing. Chapter 3 presents the guidelines, under the following sections:

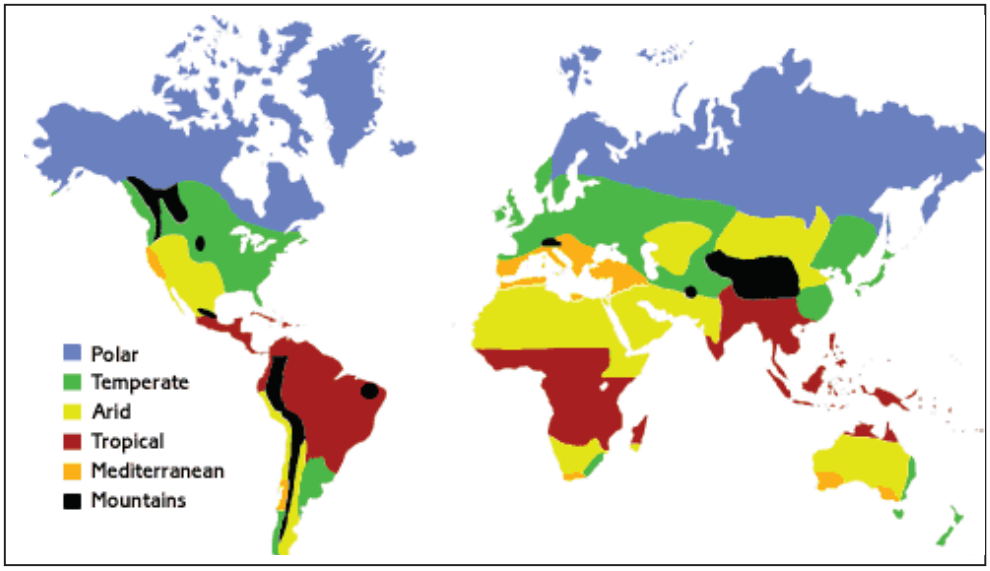
- Pre-design guidelines

- Site planning
- Material and product selection
- Sustainable use of energy
- Water and sanitation
- Solid waste management
- Indoor environment quality
- Construction administration
- Building commissioning, operation and maintenance

The application of the design guidelines in the demonstration project in Sri Lanka is elaborated in Chapter 4. Relevant concepts have been highlighted in text boxes, while technologies have been briefly explained in Annexure 1. A list of internet based resources has been given in Annexure 2.

These guidelines are mostly applicable for the warm and humid climate of the tropics, but some of it is generic. The tropical climate, including the monsoon climate, is mostly found near the equator. In the Asia Pacific region it is mostly found in South and South East Asia, and in North Australia.

Fig 1.3: World Climate Averages



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2

The concept of eco-housing

2.1 What is eco-housing?

No precise definition of eco-housing is available. An attempt to define its boundaries at this point of time might risk the premature delivery of an evolving concept. Eco-housing enthusiasts use it to refer to an all-encompassing concept of sustainability of the built environment, achieved through different methods. The most common definitions talk of a comfortable and healthy habitat, achieved by low impact methods, consuming less resource than a standard habitat and using environmental friendly materials and products. Another definition considers eco-housing as a bio-mimicry by the built environment, imitating the self sustaining and cyclic processes in an ecosystem. While eco-housing affirms that the basic purpose of buildings is to ensure human comfort, health and survival at an affordable cost, it reminds us that this is best achieved by being in harmony with the ecosystem and the socio-economic system. The use of resources for ensuring human comfort and survival would be done efficiently and effectively, without crossing any thresholds. Similarly the use of nature as a waste sink would be done prudently, without crossing any limits. The usual linear process of extraction-use-disposal would be converted to a self sustaining cyclic process.

Box 2.1: Biomemetics
(Makower, J., 2001, p.20)

Biomemetics is a new science that studies the processes in nature, in order to imitate it and design solutions for human problems. An example is studying a leaf to invent a better solar cell. Nature and its constituents have been solving problems for millions of years, out of necessity. Humans could learn a lot by studying it.

The definition, criteria and priorities will vary according to site specific factors. Something that is viable in one place may not be viable elsewhere. Several other terms like green buildings, ecological housing, sustainable housing/communities, high performance buildings, environmental architecture etc., are also used in place of eco-housing. There is also a big overlap between the concepts of eco-housing and Permaculture. Permaculture practitioners study and follow the patterns of nature to develop sustainable patterns of agriculture, land use and habitats, in order to avoid the negative impacts of industrialised agriculture.

2.2 What are the approaches for achieving eco-housing objectives?

Many specialised tools and techniques could be used for achieving the objectives of eco-housing. Some of the cross-cutting approaches that underlies many of these tools and techniques are: Integrated Design Process; Life Cycle approaches; decreasing resource intensity; bio-climatic design; adopting traditional and local architectural practices; and the use of renewable resources.

2.2.1 Integrated Design Process

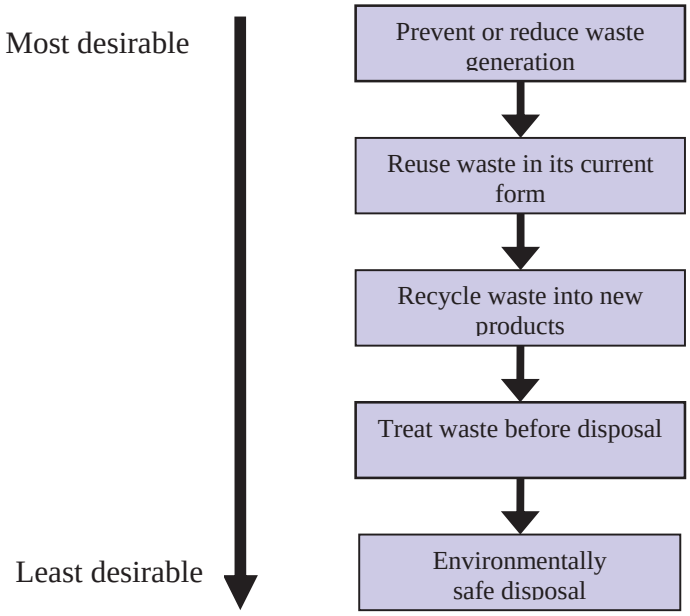
In a conventional design process, each one works within his area of expertise with minimum interaction. The Integrated Design Process is based on inter-disciplinary research and design. Rather than studying the individual building components, systems, or functions in isolation, experts from different disciplines collaborate to analyse the interrelated impacts on the economy, environment, society, building components and materials and find common solutions. Through their collaborative effort they try to integrate different objectives like economic efficiency, environment friendly site planning, appropriate choices of materials and products, sustainable use of energy and water, provision of clean water, indoor environment quality and sanitation, waste water and solid waste management, and proper operation and maintenance.

2.2.2 Life Cycle approaches

The traditional compartmentalised approach considered each stage of a product's life cycle, separately. For example, the manufacturer was not much concerned much with what happened to the product after sales. The environmental manager was unaware of the design and manufacturing issues and used to be preoccupied with "end of pipe" solutions after the waste or pollution was generated. Eco-housing encourages the consideration of the entire life-cycle of the house: from design, through construction, use, maintenance and to end of life activities. Life Cycle thinking takes into account all stages of a buildings existence and considers all stakeholders.

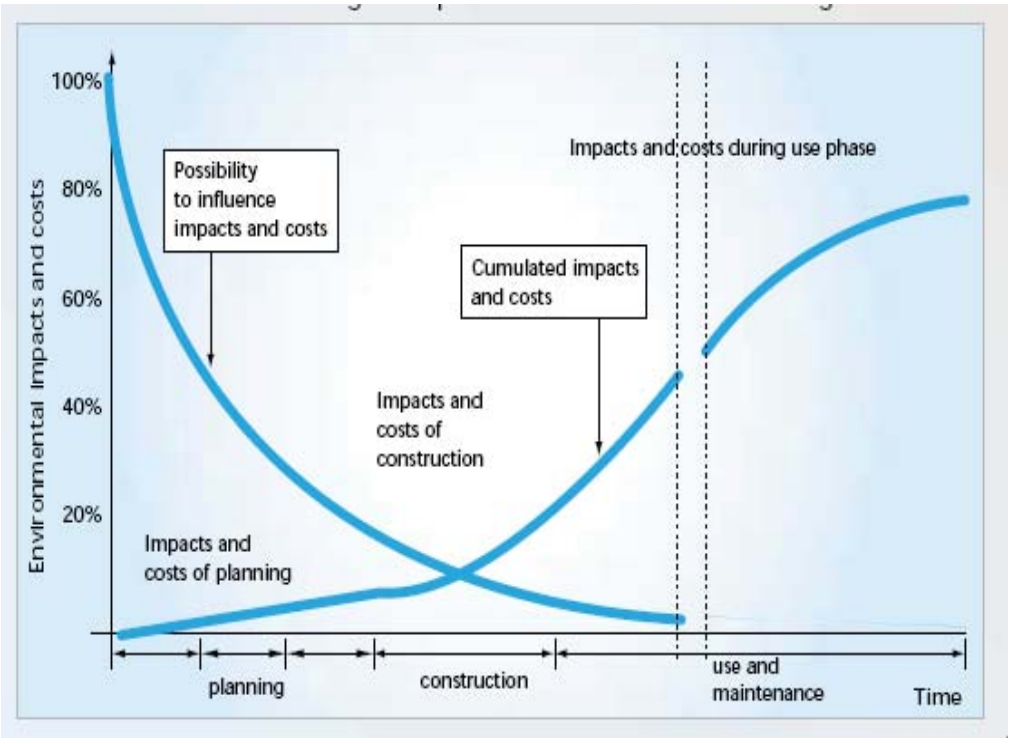
The waste management hierarchy, based on the life cycle thinking, is an important part of the eco-housing concept. The hierarchy reminds us to act early on in the life cycle of the product to prevent waste generation. The highest priority is for preventing waste generation and the least is for disposal activities. The same concept is applied in the 3 R (Reduce, Reuse and Recycle) approach.

Fig 2.1: The waste management hierarchy



Each stage has different characteristics and need different approaches. Eco-housing interventions are more effective during the early phases of the project, as illustrated in figure 2.2 given below.

Fig 2.2: Influence of design decisions on life-cycle impacts and costs of an average European and North American building (Kohler,N. & Moffatt, S., 2003, p.14).



Life Cycle Assessment or Analysis (LCA) and Life Cycle Costing (LCC) are two of the methodologies used to apply Life Cycle thinking. Among these two, the application of LCA has mostly been limited to research projects due to the large effort and data required. More than the methodologies, the emphasis should be on the contribution of Life Cycle thinking to the Integrated Design Process to take into account all inputs, impacts and stakeholders. In few cases Life Cycle thinking may not be appropriate. For example, a project for providing clean water and sanitation for disaster affected people may have the objective of immediate delivery. (Kohler,N. & Moffatt, S., 2003).

2.2.3 Decreasing resource intensity

Experts say that a reduction in resource use by a factor of four is necessary and practical with current levels of technology and knowledge. (Gertsakis. J & Lewis. H, 2003) A bevy of approaches have been promoted in different parts of the world to reduce the flow of primary resources and thereby "dematerialize" the economy. An example is Japan's promotion of the 3R's- Reduce, Reuse, and Recycle.

Eco-housing emphasises the rational use of materials, energy and water. To reduce resource use, the approach discourages use of materials with high resource intensity like concrete and steel. It encourages the use of materials and products with longer lives and needing lesser maintenance. The concept of multifunctional design helps in extending the lifetime of a building, by converting or modifying it. Recycling is enabled by deconstruction friendly design and manufacturing. Energy efficiency and load management helps in reducing the energy intensity. Technologies and techniques are available for reducing water use.

But more ambitious proponents of eco-housing propose a move from "dematerialization" to "rematerialisation". They try to not just reduce resource use and the negative impacts, but imitate natural cycles to create more and more positive impacts such as : "buildings that make oxygen, sequester carbon, fix nitrogen, distill water, provide habitat for thousands of species, accrue solar energy as fuel, build soil, create microclimate, change with the seasons, and are beautiful". They propose a system for continuous tracking of materials and correct recycling and design practices, so that the material can be recycled again and again, unlike current recycling practices, where some material are "downcycled" or recycled few times only. (McDonough,W. & Braungart, M., 2003, p.15)

2.2.4 Bioclimatic design

2.2.4.1 What is Bioclimatic design

A building provides a passive control over the climate, by separating the interior from the exterior. Additional controls, called active controls, can be provided by energy consuming heating, cooling and humidity control systems. One of the aims in eco-housing is to optimise the passive control strategies to achieve comfort conditions and use active controls only if essential. This approach is emphasised in bioclimatic

architecture. The main elements in a bioclimatic design are passive. In contrast, in conventional design the designers do not give much consideration to freely available environmental resources. Instead they rely on active controls to create comfort conditions. The factors affecting human comfort is discussed in the next section.

The following simplified illustration for a warm climate helps to explain bioclimatic design, by contrasting it with the conventional design process. In the bioclimatic design process, the site elements (vegetation and landscape) are used to modify the microclimate. Proper placement and orientation of the building helps to protect itself from sun, wind and rain. It also helps in the optimum use of the sun and wind for ventilation and daylighting. Improvements in the building envelope and emphasis on an improved indoor environment make the interior more comfortable. If the conditions are still short of comfort conditions, a much reduced amount of space conditioning is used. In the conventional design, most of these factors are neglected making the interior hotter and uncomfortable, compared to the outside. The designer then relies on energy intensive space conditioning to make the interior reach comfort conditions.

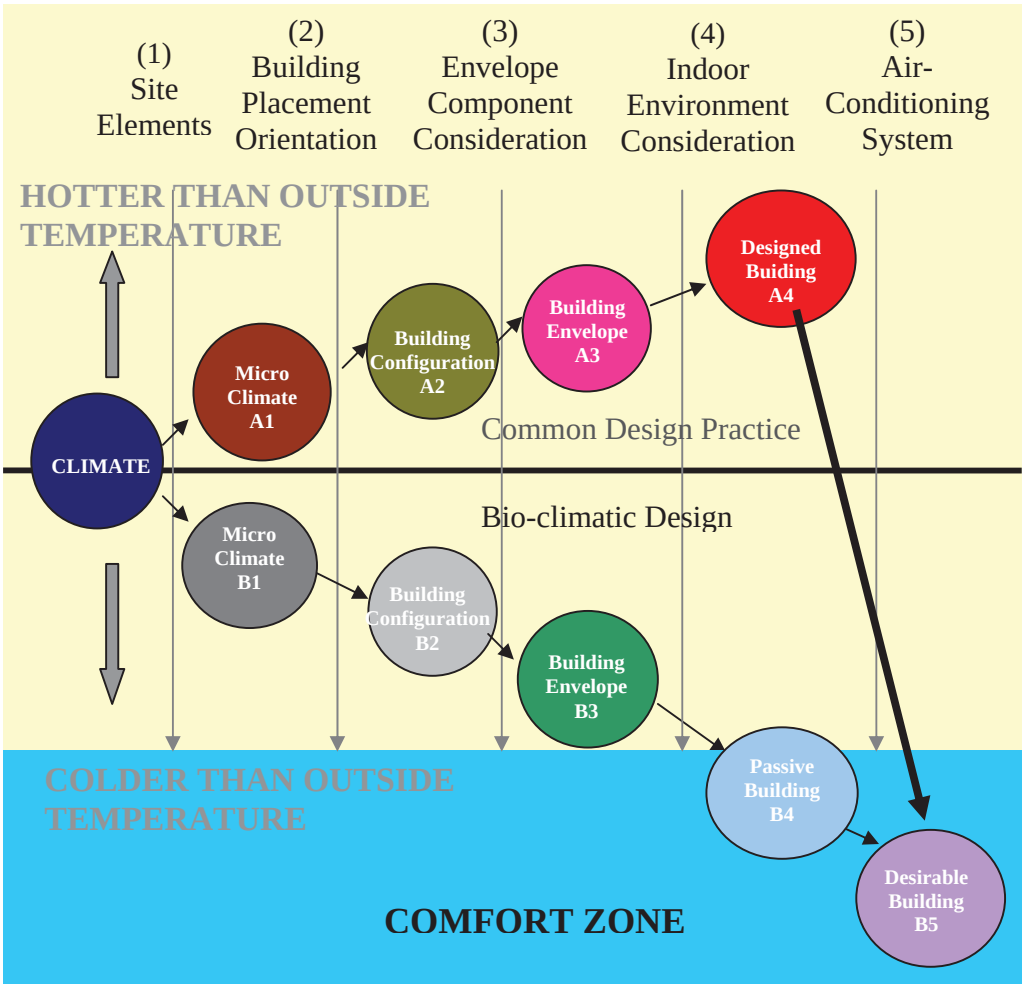


Fig 2.3: Bio-climatic design vs conventional design
(Boonyatikarn, S. & Buranakarn, V., 2006)

Figure 2.4 shows the different climatic zone and the comfort zone. As shown in Table 2.1, the basic design consideration for the construction of climate responsive buildings in hot and humid climate zones is the use of airflow to promote heat dissipation by perspiration. In addition the following are important (UNEP-IETC, 2004):

- Protection from direct solar radiation and preventing undesired heat storage
- Proper rainwater drainage and ventilation to prevent damage from moisture penetration

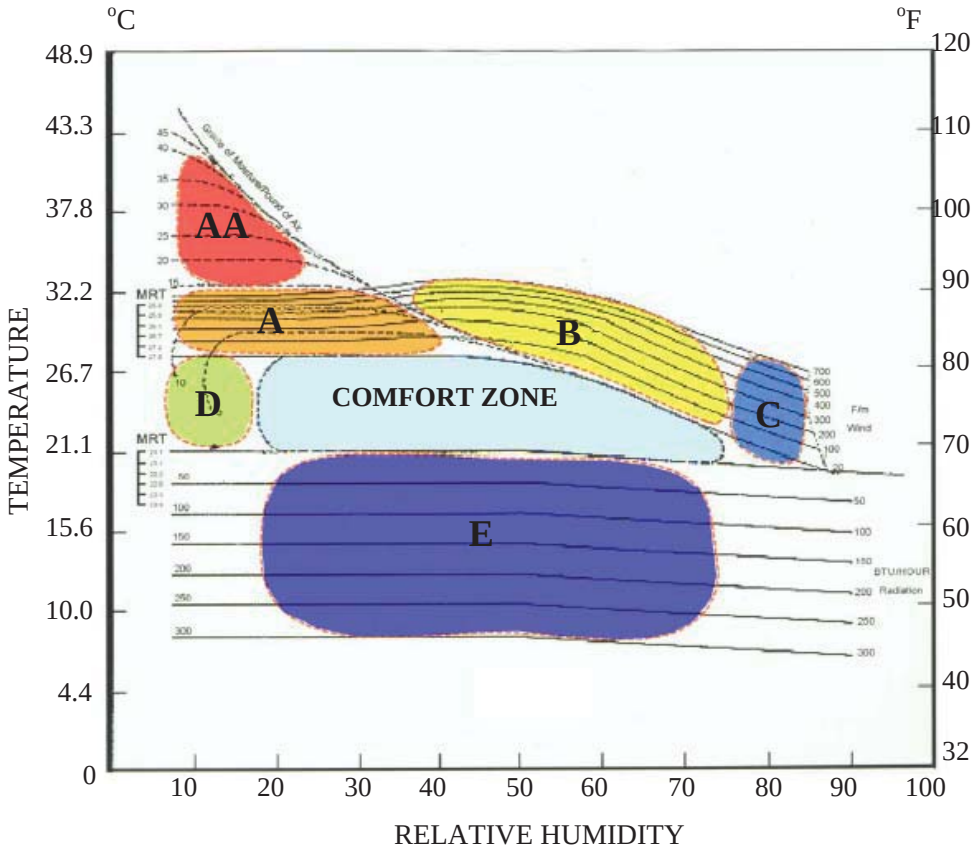


Fig 2.4: Climate and the comfort zone
(Boonyatikarn, S. & Buranakarn, V., 2006)

Table 2.1: Bio-climatic design options
(Boonyatikarn, S. & Buranakarn, V., 2006)

Zone	Type	Solution
AA	Very hot	Evaporative cooling
A	Hot	Evaporative cooling & wind velocity
B	Hot and humid	Wind velocity
C	High humidity	Dehumidifying
D	Very dry	Humidifying
E	Very cold	Solar radiation

Bioclimatic design varies from one climatic zone to the other. A building designed for a hot climate would have measures to reduce the solar gain such as, smaller window sizes; shaded walls; minimum exposure to the west and east; external wall and roof insulation; or use of design elements like solar chimneys, wind towers, etc., to maximize ventilation. The humidity levels of a climatic zone govern the use of water-based measures for cooling of buildings. While measures like water bodies, fountains, and roof gardens are conducive for a hot-dry climate, these should be used with caution in a humid climatic zone. Even within the same climatic zone, there needs to be distinctions in the design. Each building site would have distinct topography, vegetation, wind-flow pattern, solar and daylight access. The design should be able to address these site conditions and requirements.

2.2.4.2 What are the factors affecting human comfort?

(Szokolay, S V., 2001, p.97-98)

The basic function of a building is to ensure human survival, health and comfort, by protecting it from the external environment. It can be considered as the third skin, the second being our clothes. Humans require thermal, visual and acoustic comfort conditions. Thermal comfort depends on six environmental and physiological factors

- Air temperature
- Relative Humidity
- Temperature of surrounding surfaces
- Air velocity
- Clothing
- Metabolic rate

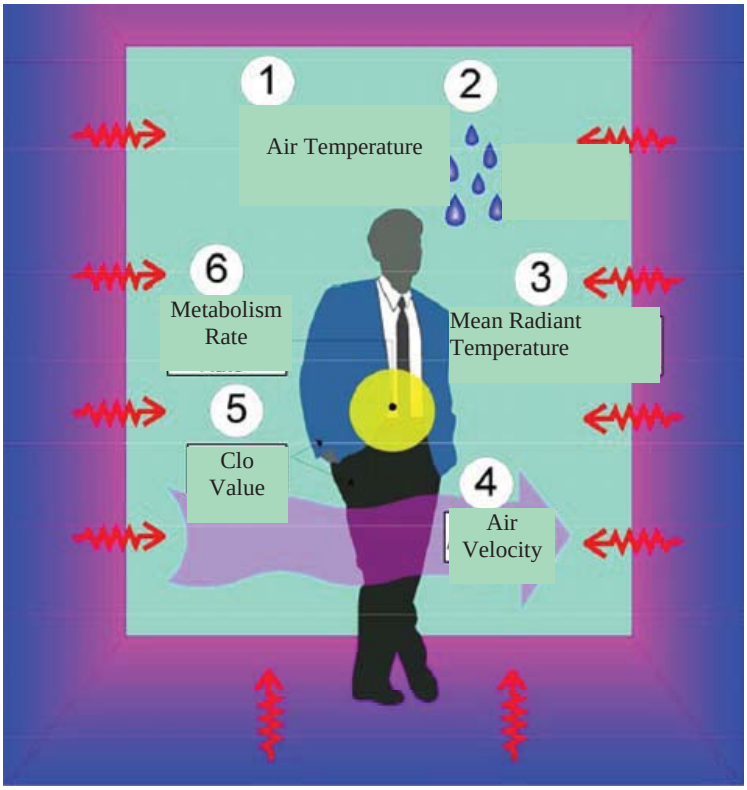


Fig 2.1: Environmental and physiological factors affecting human comfort (Boonyatikarn, S. & Buranakarn, V., 2006)

These factors are influenced by several other factors:

- Topography: It affects wind movement

- Water bodies: They have high heat storage capacity and this helps to balance the day and night temperature variation.

- Altitude: Air temperature decreases with increasing altitude, by approximately $2^{o}C$ for every 300 m.

- Vegetation: Affects all aspects of the micro climate.

- Level of urbanization: The more the built surfaces, the more the heat island effect.'

- Ground surface: Different surfaces have different heat storing and reflecting capacity and water content and hence affect the surrounding temperature differently. Light coloured surfaces reflect most of the heat. Rocks absorb heat during day time and release it during the night. Vegetations absorb heat, but remain cool, due to the evaporation from the leaves.

- Age and Sex: Metabolic activity of older people, women and children are generally lesser.

- Level of Activity: It affects the metabolic rate.

Box 2.2: The body's thermo-regulation mechanism

(Szokolay, S V., 2001, p.97-98)

For survival, human deep body temperature should be around 35-40^{o}C, and the skin temperature should be 31-34^{o}C. When outside temperature is too low, heat loss takes place from our body. If outside temperature is too high, then our body gains heat from outside. The bodies internal thermo-regulation mechanism, maintains the body temperature for all normal variations in climate. Further protection is provided by the clothing and building envelope. If the body has to retain heat(if the outside is too cold), the blood vessels contract (vascular contraction) and less blood flows towards the skin and less heat loss takes place from the body to the outside. In extreme cold conditions, we also shiver, which is a heat generating mechanism, supplementing the normal thermo-regulation mechanism. If the body needs to loose heat (if outside is too warm), then the blood vessels dilate (vascular dilation) and more blood flows towards the skin and more heat loss takes place to the outside. Sweating is a supplementary mechanism to loose heat.

2.2.5 Adopting traditional and local architectural practices

Many ancient architectural traditions promoted habitats that were sustainable. Examples are the Chinese “Feng Shui” and the Indian “Vastu Vidya”. They were based on a proper understanding of bio-climatic conditions, and sustainable patterns of living. Educated people look at these traditions with suspicion, due to their association with religion. We could gain much by rediscovering and demystifying these traditions. (CIB & UNEP-IETC, 2002) Traditional wisdom is partly reflected in the practices in use in many local communities. Traditional building methods cannot be simply copied, but needs to be adapted to make it relevant to modern realities. They could also form the basis for developing more sustainable technologies.

2.2.6 Using renewable resources

The use of renewable materials and energy helps in reducing the use of non-renewable resources. This is sustainable as long as the rate of extraction of the renewable resource does not exceed its rate of regeneration and does not cause adverse effects, such as environmental impacts or shortages in food production.

3

Guidelines for eco-housing

3.1 Pre-design guidelines



- Select an effective, multi-disciplinary design team. The team could include the owner, architects, engineers and subject-specific experts.
- Make an assessment of the existing socio-cultural, environmental and economic condition of the locality. The project needs to use and maximise the existing potential.
- Develop a vision statement. The vision statement should clearly set out the goals, objectives, and processes. It should be based on the site assessment, resource availability, available best practices and technologies, and cost-effectiveness. The project must also identify if the design goals intend to achieve improvements over the conventional standards, e.g., better envelope standards than minimum energy codes, better water efficiency than the national codes. The goals needs to be prioritized based on the needs and project constraints, e.g., water quality and conservation may be a priority in tsunami-affected regions.
- Develop an action plan, budget and time schedule.
- Finalise appropriate procedures for contracting and contractor selection. Appropriate guidelines, specifications and procedures should be laid within the contract document to meet eco-design objectives.
- Try to ensure that all stakeholders are involved in different aspects of the project planning and implementation, to ensure that all factors are considered and to increase the acceptability of the project.
- Develop simple indicators for regular monitoring and evaluation of the project progress and for social and environmental impacts of the project.
- Develop a strategy to mitigate risks due to any possible disruptions to the achievement of the project goals.

3.2 Site planning



Sustainable site planning involves proper site selection, site assessment and site development.

3.2.1 Site selection

- Avoid using sites having special value like agricultural land, cultural sites, wetlands, habitats of endangered species etc.
- Reuse land that has already been developed or a more ambitious target could be to reuse land that is polluted.
- Give special considerations for disaster prone areas. For example in a tsunami prone area, the site should be out of the safety buffer zone, at an elevated place, preferably not on slopes or near other steep slopes and should avoid different floor levels.

3.2.2 Site assessment

An assessment should be made of the site's potential to provide natural resources such as solar energy, light, water etc and the possible impacts of the project on these features. It would result in the modification of the site layout and the building design, to maximise the use of these natural resources and to protect them from deterioration. It would ensure minimum site disruption; maximum usage of bio-climatic features; minimum requirement for intra/inter-site transportation; appropriate erosion and sedimentation control plans; and appropriate landscaping. The guidelines for achieving these are as follows:

- Collect data of the geographic coordinates, topography and bio-climatic features of the site. Test air, soil and ground water quality, to ensure that no deterioration occurs to the quality as a result of the project.
- Check water quality to assess the need for accessing other cleaner sources or for establishing water treatment facilities.
- Check the depth of the ground water table. This would help to decide the depth and size of the foundation, and the depth and distance between the septic and water tanks.
- Assess soil quality, which is an important information for deciding the shape of foundation, constructing septic tanks and for accessing ground water.

Box 3.1: Data & analytical tools to be used
(UNEP-IETC, 2004, p.69)

Data

- Meteorological data: Macro and Micro Climate including detailed information about solar path analysis, sky conditions and radiation, temperature range (seasonal minimum and maximum temperatures during night and day), humidity, precipitation, air movement etc.
- Building site: topography, ventilation, orientation, vegetation, neighbouring structures, soil, water and air quality, natural disaster history.
- Building usage and cultural background: type of usage, period of usage, clothing, traditions and aesthetic values of occupants, traditional techniques and building materials.
- Economic aspects: financial resources, available labour, materials and technologies.

Analysis

- Analogue diagrams: solar diagrams, shading diagrams, comfort diagrams and tables.

- Study the existing pattern of native vegetation. Ensure that the design and construction does not result in any damage to the vegetation or their ability to survive.

- Identify the traditional style of architecture and the existing form of the city or village. The new construction should as much as possible, blend with the existing situation and use their positive features.
- Study the history of natural disasters in the locality and the design could factor in such possibilities.
- Identify the damage reversals that need to be addressed prior to implementation of the eco-housing project, e.g., measures for tackling salt contamination and groundwater contamination in tsunami affected areas. List out the actions that are required to address these issues.
- Assess the accessibility to infrastructure and conveniences such as power supply, water supply, sanitation, waste management, roads, shops, schools, hospitals, markets and employment opportunities.
- Make an assessment of the costs of construction at the locality, including the land price, cost of land filling, costs for providing basic infrastructure, cost of building material etc.
- Decide on which kind of infrastructure system to apply at the site: centralised or decentralised.
- Prepare a list of laws, codes, standards, best practices and incentives/penalties. These could include :
  - ✓ Building codes, laws and regulations such as minimum distance between houses, minimum size of plots, minimum plot density, purpose and use of building, street width, height of building and number of storeys etc.
  - ✓ Codes, laws and regulations related to water and waste management and use of renewable energy, etc.
  - ✓ Environmental clearances required, if any.
  - ✓ Disaster mitigation measures.
  - ✓ Energy codes/standards.
  - ✓ Relevant building codes.
  - ✓ Applicable international and national best practices as identified in project goal.
  - ✓ Financial incentives for eco-measures, e.g., subsidies for renewable energy systems and energy-efficient equipment.

3.2.3 Site Development

3.2.3.1 Site Layout

- Ensure that basic amenities such as bank, child care, post office, park, library, convenience grocery, primary school, clinic and community hall are near to or within the site premises.
- Make a comprehensive transportation plan for the site, taking into consideration cleaner transportation options, parking capacity and conveniences for pedestrians and cyclists. All external traffic and pollution should end at the entrance of the site or the parking space. Discourage use of fossil fuel-based vehicles, on site. Plan pedestrian access ways and bicycle tracks within site premises.
- Analyse the existing roads and pathways on site, to reduce the length of roads and utility lines.

- The site layout should allow for wind protection and solar access in winter and adequate sun protection and ventilation in summer. Having a mix of building types could help achieve this.
- Row buildings can be used as wind breakers. High-rise can increase ventilation in a dense development. Low-rise buildings should be sited so that they avoid excessive heat exchange with the environment and utilize their link with open spaces. Wherever possible, open spaces and the funnel effect should be used to increase airflow within buildings.
- The ratio of street width to building height determines the altitude up to which solar radiation can be cut off. Similarly, street orientation determines the azimuth up to which solar radiation can be cut off. These two factors should be optimized on large sites. But for warm humid climates, the main aim is to have air movement. Hence the streets should be oriented to utilise the natural wind patterns.
- Site should be properly planned to mitigate the 'heat island effect' by reducing the total paved area allowed on site. The paved areas should be made pervious or open grid. Shading should be provided for the paved surfaces.
- Use gravity systems for water supply and sewerage, wherever possible, to avoid pumping.
- Try to locate all utility lines near already disturbed areas, like roads. Use concealed or shielded conduits for utility lines.
- Optimise the layout, to save land and natural resources, without affecting the quality of life.
- The layout should be flexible to accommodate future changes that could arise from the users needs or from other perspectives.
- The layout should use innovative ways to facilitate social networks among the residents. These could include the provision of parks, recreational areas, community halls etc.

3.2.3.2 Landscaping

- For projects larger than one hectare, remove topsoil and preserve for reuse on site. For tsunami affected areas, ensure that the topsoil has not been rendered unusable. A pH of 6.0 to 7.5 and organic content of not less than 1.5% by mass, needs to be maintained. Add lime where pH is less than 6.0. Use organic compost and mychorrizal biofertilizer for remediation of alkaline soil, as is the case with soil affected by sea water intrusion. Any soil having soluble salt content greater than 500 ppm should not be used for the purpose of landscaping.
- The most effective way to prevent soil erosion, sedimentation, and to stabilize soil is through the provision of vegetative cover by effective planting practices The foliage and roots of plants provides dust control and a reduction in soil erosion by increasing infiltration, trapping sediments, stabilizing soil, and dissipating the energy of hard rain. Temporary seeding can be used in areas disturbed after rough grading to provide soil protection until the final cover is established. Permanent seeding/ planting is used in buffer areas, vegetated swales, and steep slopes. The vegetative cover also increases the percolation of rainwater thereby increasing the groundwater recharge.

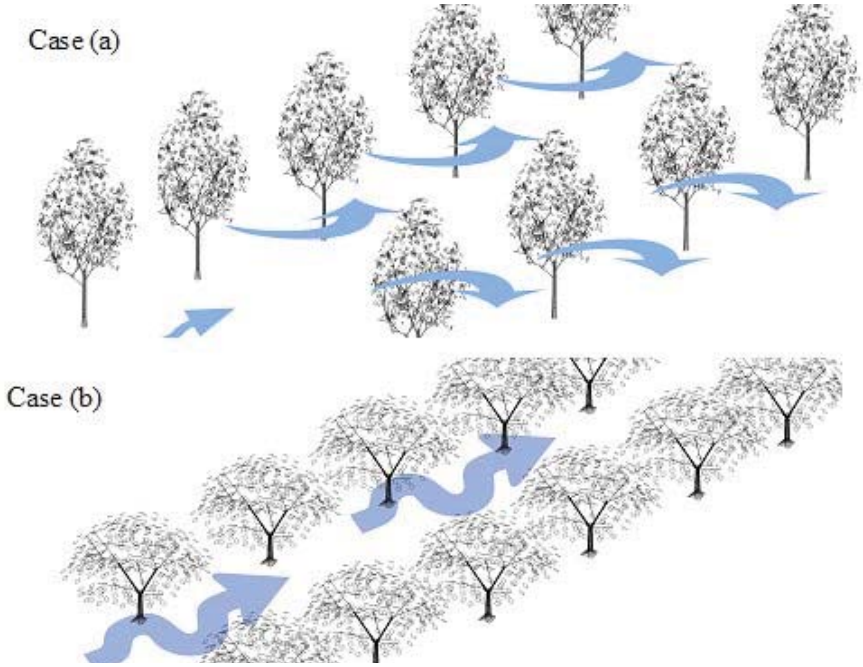


Fig 3.1: Case (a), tall trees might result in loss of wind as it gets deflected.
Case (b), small dense trees would guide the wind towards houses.

- Selection of plant species should be based on its water requirements and the micro climatic benefits that would result from it. Deciduous trees provide shade in summer and allow sunlight in summers. Evergreen trees provide shade and wind control throughout the year.
- Preserve existing vegetation on site. Mark all the existing vegetation in a tree survey plan. Evolve tree preservation guidelines. Replant within the site premises any mature trees that have been removed, in the ratio of 1:5. At the same time, care needs to be taken to avoid undesirable increase in humidity levels, by excessive plantations.
- Composting and plant wastes should be preferred to chemical fertilisers. They would also reduce the need for pesticides.
- Do not alter the existing drainage pattern on site. Existing grades should be maintained around existing vegetation. Ensure that the vegetation remains healthy.
- Use of organic mulches has to be done to enhance soil stabilization. Organic mulches include shredded bark, wood chips, straw, composted leaves, etc. Inorganic mulches such as pea gravel, crushed granite, or pebbles can be used in unplanted areas. Stone mulches should not be used adjacent to the building as they can easily get heated and cause glare. Mulching is good for stabilizing soil temperature also. The coarser the material, the deeper should it be applied.
- Sedimentation basins, and contour trenching, also helps top reduce soil erosion.
- Some methods for altering the air flow patterns by landscaping are shown in the figures 3.1 and 3.2 below

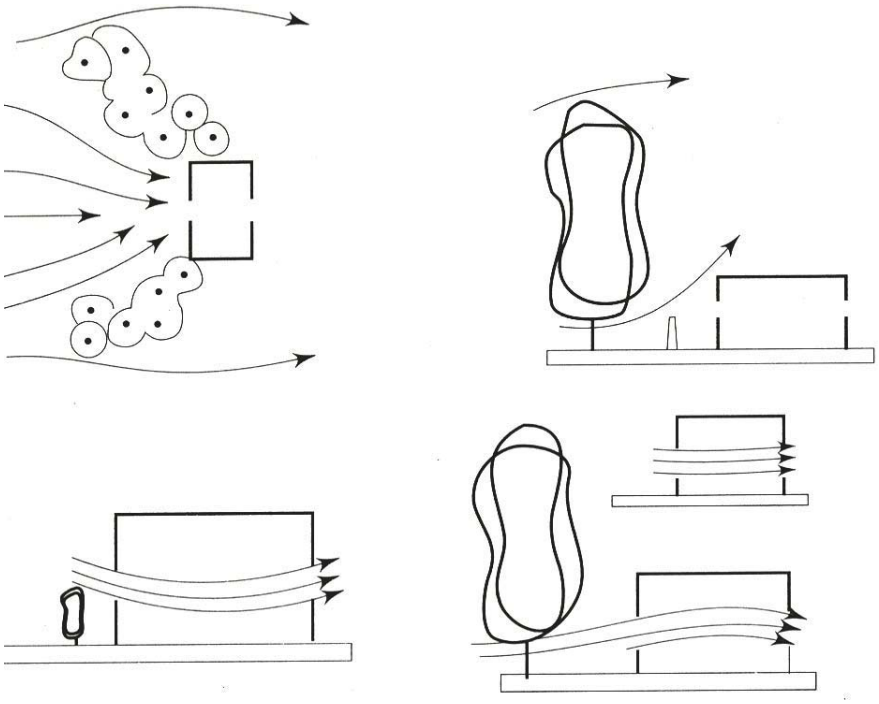


Fig 3.2 : Vegetation increasing, decreasing and directing airflow (Krishan, A. et al., 2001).

3.3 Building material and products



Eco-friendly materials are characterized by low-embodied energies, low emissions and are convenient for recycling and reuse. Building materials are mostly made from naturally available materials like clay, stone, sand or biomass. Proper selection of building materials would help to conserve these natural resources. Wastes and by-products generated from various manufacturing processes could form secondary resources for production of building materials. This would allow savings in consumption of primary grade raw materials, energy, labour, and capital investments in plants. Using local materials could minimise emissions from transport, strengthen the local industries, increases employment for locals, helps avoid taxes on imported material and help in preserving the culture. The selection of appropriate materials is driven by local/ regional considerations. A material that is suitable for one place may not be suitable elsewhere. We also need to understand that the building styles and design are heavily influenced by prevailing fashions, especially the fashions in the developed world. This was one of the reasons why many modern construction materials could ease out more durable, climate responsive traditional building materials in the developing world. (UNEP-IETC, 2004, p.27-29) The points to be noted for material and product selection are:

- Use naturally available materials, especially organic renewable materials like timber, trees, straw, grass, bamboo etc. Even non-renewable inorganic materials like stone and clay are useful, since they can be reused or recycled**.** (UNEP-IETC, 2004, p.27-29)

- Use certified timber. Check the reliability of the certificates, as forgery is possible.
- Do not use sand quarried from coral reefs.
- Check origin of soil for land filling.
- Check whether quarry sites are rehabilitated.
- Use materials with low-embodied energy content for all structural work in fill systems.
- Use locally available materials and technologies, employing local work force.
- Use materials amenable for reuse and recycling. Pure material like bricks, wood, concrete, stone, metal sheets are most suitable for this purpose. Composite materials like prefabricated solid foam-metal or foam-plaster elements are difficult to separate and to recycle.
- Use industrial waste-based bricks / blocks for non-structural or infill wall system.
- Reuse/ recycle construction debris.
- Minimise use of wood for interior works and use any of the following in place of wood.
  - ✓ Composite wood products such as hardboards, block boards, lumber-core plywood, veneered panels, particle boards, medium/ low-density fibreboards made from recycled wood scrap from sawmill dusts or furniture industry and bonded with glue or resin under heat and pressure.
  - ✓ Materials/ products made from rapidly renewable small-diameter trees and fast-growing, low-utilized species harvested within a ten-year cycle or shorter, such as bamboo, rubber, eucrasia, eucalyptus, poplar, jute/cotton stalks, etc. The products include engineered products, bamboo ply boards, rubber, jute stalk boards, etc.
  - ✓ Products made from wastes. These could be wood waste, agricultural wastes, and natural fibres, such as sisal, coir, and glass fibre in inorganic combination with gypsum, cement, and other binders, such as fibrous gypsum plaster boards, etc.
  - ✓ Salvaged timber and reused wood products such as antique furniture.
- Use water-based acrylics for paints.
- Use acrylics, silicones, and siliconized acrylic sealants for interior use.
- Use adhesives with no/ low Volatile Organic Compound (VOC) emissions for indoor use. It could be acrylics or phenolic resins such as phenol formaldehydes.
- Use water-based urethane finishes on wooden floors.
- Use particleboard made with phenol-formaldehyde resin rather than urea formaldehyde, to control indoor VOC emissions.
- Avoid the use of products using asbestos and CFC.
- In corrosive atmospheres, metallic surfaces, and foundation reinforcements should be treated with suitable anti-corrosive treatments, such as epoxy, polyurethane coatings, etc.
- Minimise the use of metallic surfaces and metallic pipes, fitting, and fixtures.
- Use products and materials with reduced packaging and/ or encourage manufacturers to reuse or recycle their original packaging materials.
- Wherever possible, use permeable wall structures made of palm leaves, reed, grass or bamboo to promote aeration and low heat storage **(**UNEP-IETC, 2004, p.53)

3.4 Sustainable use of energy

The primary function of a building envelope is to protect its occupants from heat, cold, rain, and to provide thermal and visual comfort for work and leisure. In order to achieve comfort conditions, it is almost always essential to provide energy-consuming space conditioning and lighting devices. Due to the long lives of the structures being built, the operating phase will consume the largest proportion of the energy resources compared to the overall life cycle. (UNEP-IETC, 2004). Therefore optimising the use of energy is crucial to reach the goal of a sustainable building. An eco-building should have an optimum energy performance and yet provide the desirable thermal and visual comfort. The energy usage of a building can be improved by: a) energy demand reduction; b) energy efficiency; c) use of renewable sources of energy.

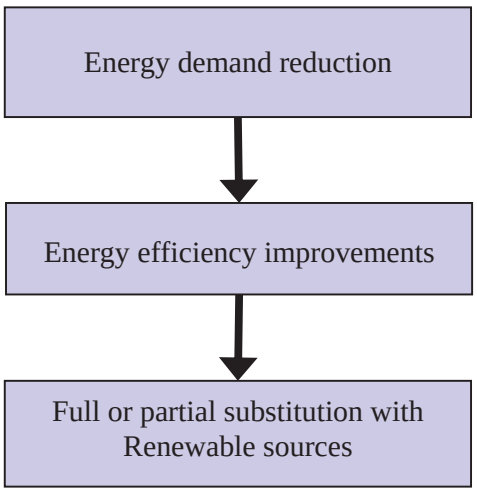
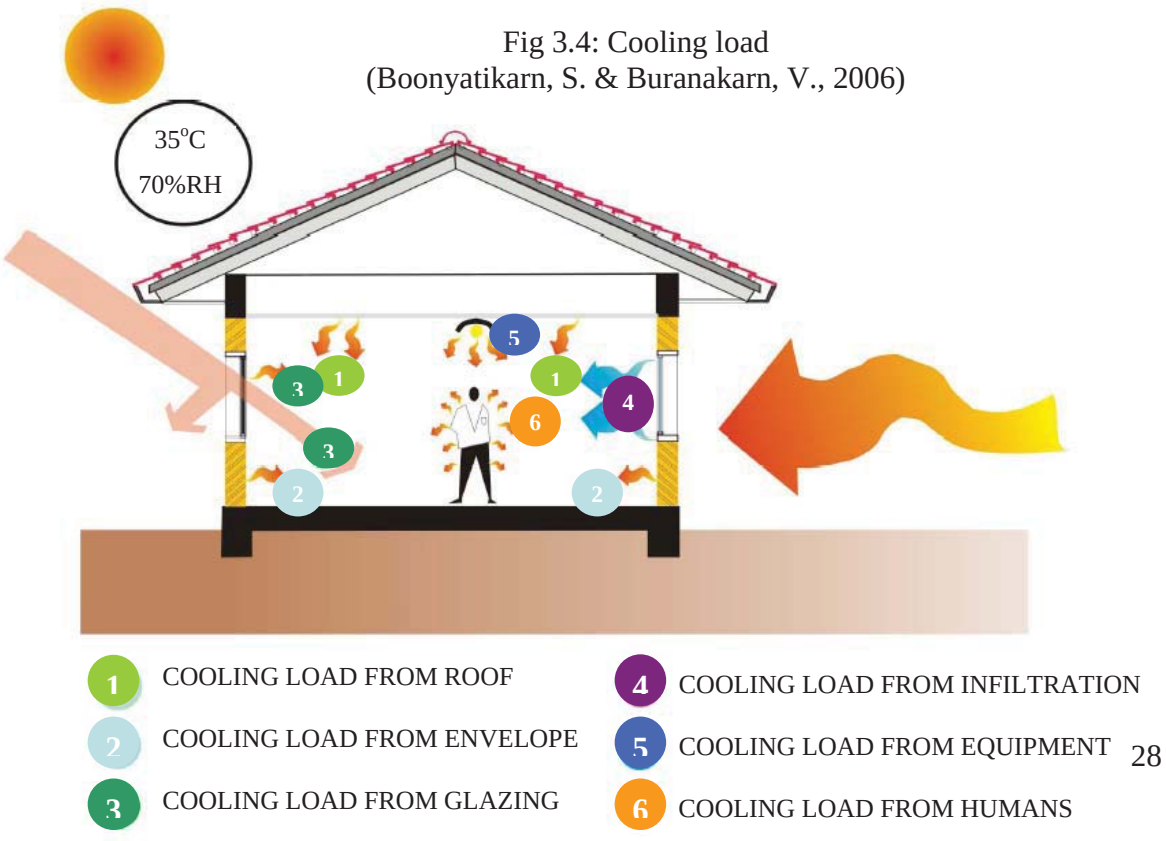


Fig 3.3: Strategy for sustainable use of energy

3.4.1 Reduction in energy demand

In tropical climates energy is mainly needed for cooling and lighting. Hence to reduce energy demand, we need to reduce cooling load and lighting load. The cooling loads of a building are from various sources as shown in figure 3.4.

Fig 3.4: Cooling load
(Boonyatikarn, S. & Buranakarn, V., 2006)



3.4.1.1 Building form

- The compactness of a building could be measured by the ratio of surface area to volume(S/V ratio). The S/V ratio should be as low as possible in hot-dry and cold-dry climates, to minimise the rate of heat transfer. For hot, humid, tropical climate, the main aim should be to have a higher air flow inside the building, for which a low S/V ratio is not essential. (Krishan, A. et al., 2001).
- The perimeter to area ratio should be kept to the minimum, to reduce heat gains.
- The roof gets the maximum amount of direct solar radiation and hence its shape is important. As shown below, the higher the roof angle, the lesser the amount of direct radiation.

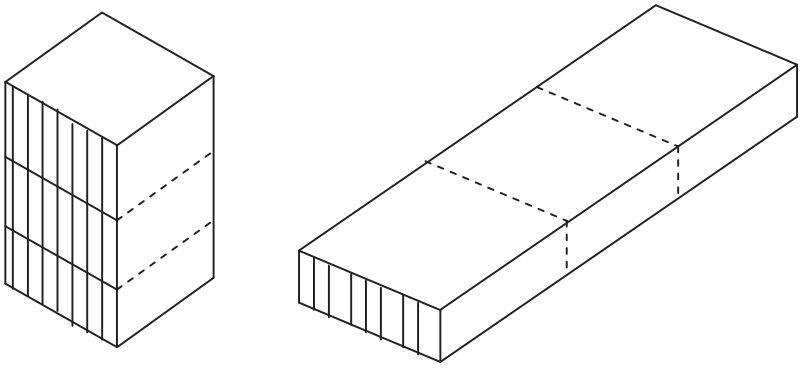
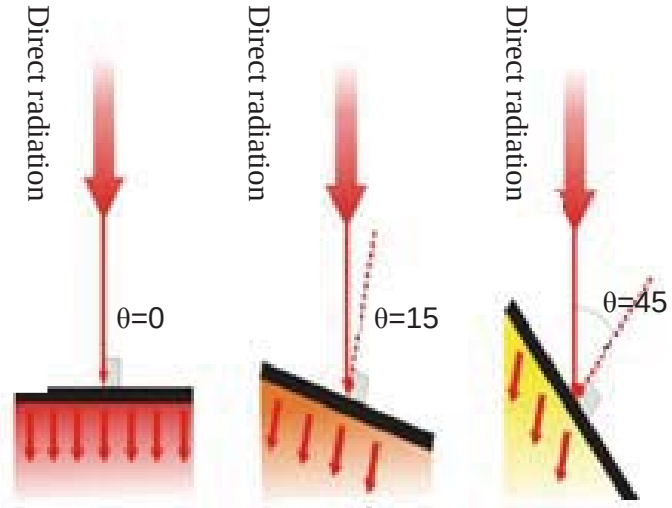


Fig 3.5: Increase in surface area, increases heat gain and heat loss (Krishan, A. et al., 2001).



Q=direct radiation× α

Q=direct radiation× Cos15× α

Q=direct radiation× Cos45× α

Q1>Q2>Q3

Fig 3.6 a: The impact of roof angle
(Boonyatikarn, S. & Buranakarn, V., 2006)

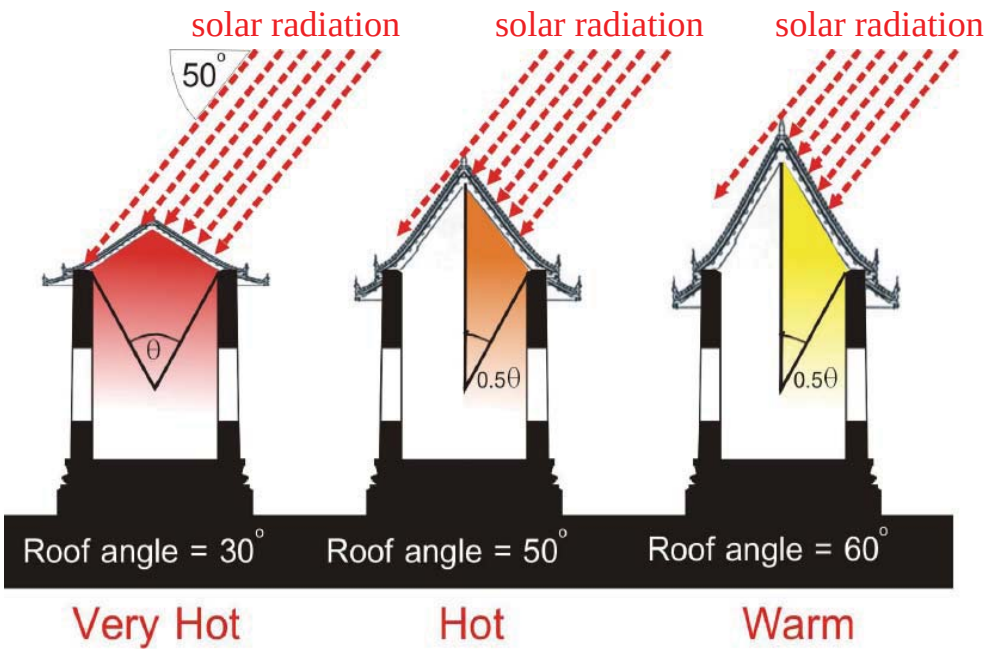


Fig 3.6 b: The impact of roof angle
(Boonyatikarn, S. & Buranakarn, V., 2006)

3.4.1.2 Landscaping

The figures below shows how proper landscaping, could reduce the ambient temperature and thereby the cooling load of the house. The first figure shows the conventional design and the second one, the design that has made use of landscaping.

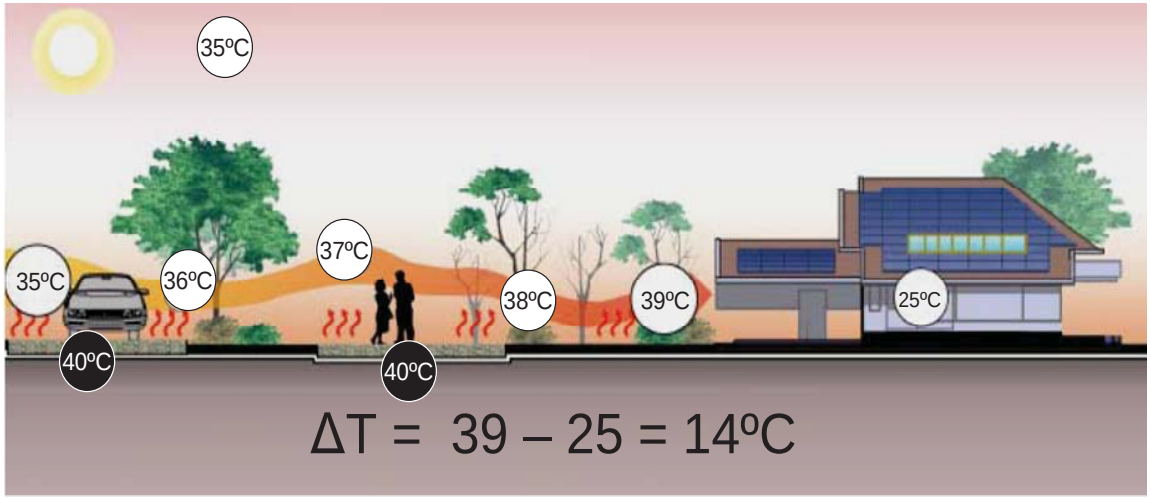


Fig 3.7 a: Effect of climate and micro-climate on cooling load
(Boonyatikarn, S. & Buranakarn, V., 2006)

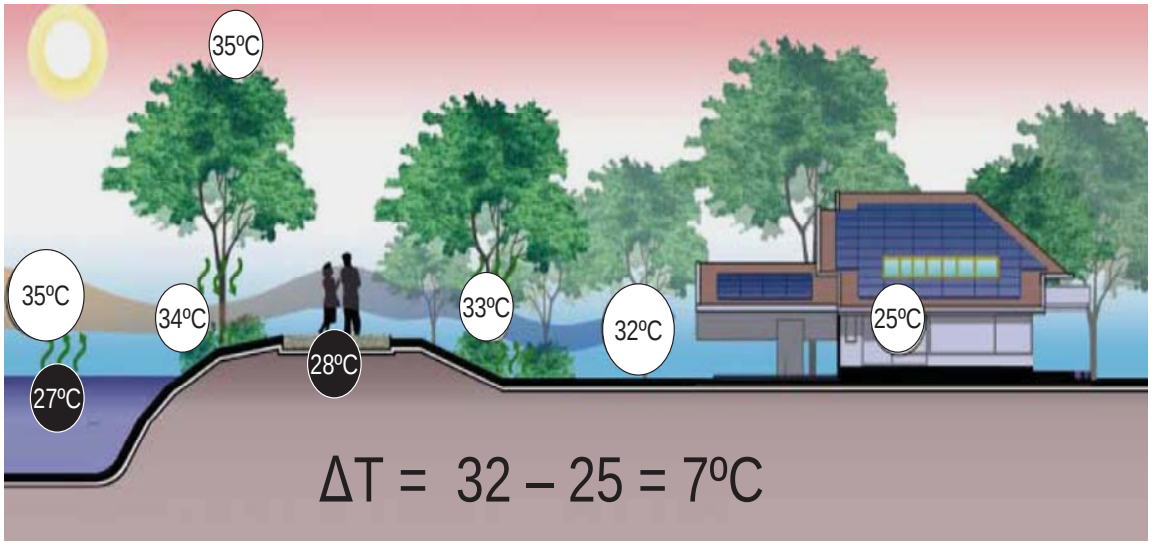


Fig 3.7 b: Effect of micro-climate modification on cooling load
(Boonyatikarn, S. & Buranakarn, V., 2006)

3.4.1.3 Insulation

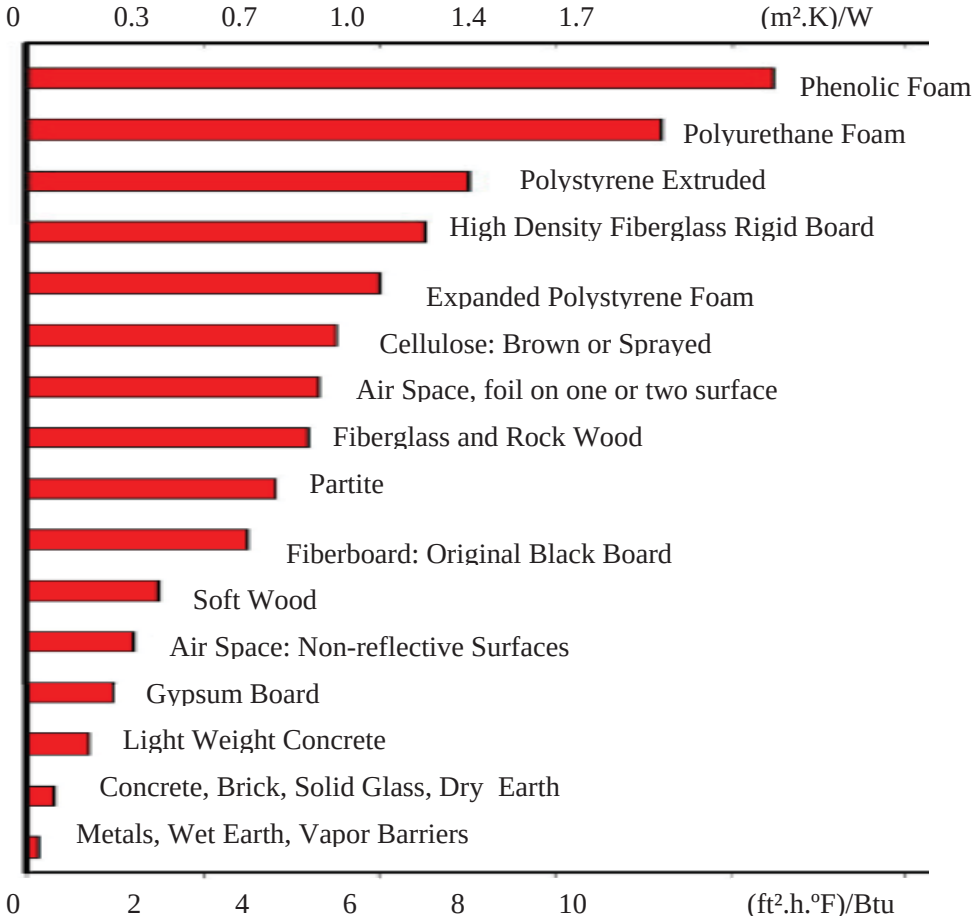
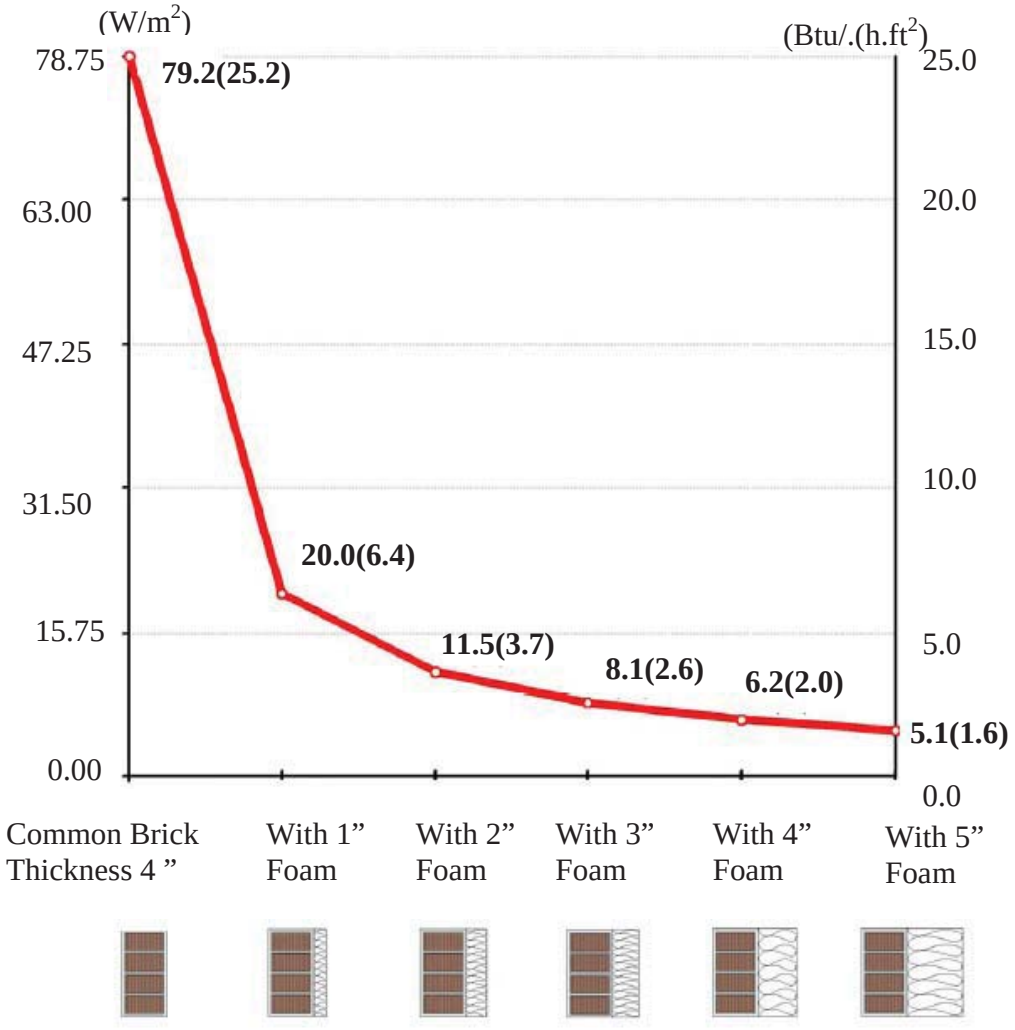


Fig 3.8: Thermal Resistance value (R) for Insulation materials
(Boonyatikarn, S. & Buranakarn, V., 2006)

- Proper insulation is essential for avoiding heat gain (for interior cooling) and heat loss (for interior heating). For air conditioned buildings, apply insulation of high insulating capacity (low U-value) throughout the building. The insulation has to be on the hotter side, i.e., on the outside for interiors being cooled and on the inside for interiors being heated up.
- For buildings that are not air conditioned, do not use thermal insulation on the walls. This would trap heat inside the building. Use insulation only for the roofs exposed to direct solar radiation (UNEP-IETC, 2004, p.53)
- External wall with high thermal resistance is recommended to minimize the heat flow from external surfaces warmed by the sun.
- Wall insulation should be considered in the event of a building being air-conditioned. Some commonly used wall insulation types like mineral wool slabs, expanded/extruded polystyrene, aerated concrete blocks, etc. could be used for this purpose.
- The roof should be protected against excessive heat gain by appropriate insulation. Bonded mineral wool could be used for under deck roof insulation. Resin-bonded

Fig 3.9: Heat Flow through Insulation (Boonyatikarn, S. & Buranakarn, V., 2006)



mineral wool is available in the form of slabs and rolls. These materials are available with or without lamination of aluminium foil. The typical thermal conductivity is about 0.029 W/mK at 10 °C mean temperature. Aluminium foil lamination is recommended for this application. In India, the cost of mineral wool insulation (material only, for 50 mm thick and 48 kg/m^3) is approximately 3 USD/ m^2 (excluding taxes). The cost of application with accessories is extra.

- Instead of roof insulation, a roof garden on the exposed roof area or a shaded roof would help to reduce heat ingress.

3.4.1.4 Thermal Mass

- Due to the climate characteristics of warm-wet region, with small diurnal temperature range, the heat capacity of buildings should be as low as possible. This will avoid accumulation of heat in the day time and its subsequent release in the night time.
- Light-weight tiles with low heat capacity are preferred for the roofs, but it might cause heat stress during daytime.
- Furniture's should be as light as possible, to reduce their potential to store heat.

3.4.1.5 Natural Ventilation

Ventilation is required for fresh air, cooling for comfort conditions and for taking away the heat stored in the building structure. Fresh air is required for providing sufficient oxygen, diluting odours and to dilute CO2 and pollutants inside the building. For the successful design of a naturally ventilated building the wind characteristics and air flow patterns around a building, influenced by climate, neighbouring topography, plants and buildings has to be taken into account. Furthermore the fulfilment of natural ventilation depends on the location of vents (e.g.: windows and roof lights) and the interior design (e.g. walls, openings and courtyards).

In warm and wet climate high-air velocities are needed to increase the efficiency of sweat evaporation and to avoid as far as possible, discomfort due to moisture on skin and clothes. Thermal comfort could be achieved at different temperatures and relative humidity levels, with certain minimum desirable wind speeds. Such wind speeds are given in Table 3.1, available from the Indian Standards for Ventilation requirements (BIS, 1987).

Box 3.2: Natural ventilation
(Roaf, S C., 2003)

Natural ventilation can be of two types. One is caused by wind pressure and the impact would depend on wind direction, speed and building shape. Using this we can provide single sided or cross ventilation. The other is caused by the density difference of air, caused by the difference in temperature between inside (warmer) and outside air. This is also called the "stack effect". If the inside air is colder, then a reverse stack effect can also be produced, which will bring in warm air from outside.

Table 3.1: Desirable wind speeds for thermal comfort conditions (BIS, 1987)

Dry bulb temperature	Relative humidity (%)						
	30	40	50	60	70	80	90
^{0}C	(wind speed, m/s)						
28	*	*	*	*	*	*	*
29	*	*	*	*	*	0.06	0.19
30	*	*	*	0.06	0.24	0.53	0.85
31	*	0.06	0.24	0.53	1.04	1.47	2.10
32	0.20	0.46	0.94	1.59	2.26	3.04	+
33	0.77	1.36	2.12	3.00	+	+	+
34	1.85	2.72	+	+	+	+	+
35	3.20	+	+	+	+	+	+

* None
+ Higher than those acceptable in practice.

- A building need not necessarily be oriented perpendicular to the prevailing outdoor wind. It may be oriented at any convenient angle between 0– 30 degrees without losing any beneficial aspect of the breeze. If the prevailing wind is from east or west, the building can be oriented at 35 degrees to the incident wind so as to diminish the solar heat sacrificing slightly the reduction in air motion indoors.
- Large openings, doors, and windows are of advantage in a warm-wet climate provided they are effectively protected from penetration of solar radiation, rain, and intrusion of insects.
- Inlet openings in buildings should be well-distributed and should be located on the wind-ward side at a low level. Outlet openings should be located on the leeward side. Inlet and outlet openings at a high level would only clear the air at that level without producing air movement at the level of occupancy.
- Maximum air movement at a particular plane is achieved by keeping the sill height of the opening at 85% of the critical height (such as head level). The following levels are recommended according to the type of occupancy.
  - ✓ For sitting on chair = 0.75 m
  - ✓ For sitting on bed = 0.60 m
  - ✓ For sitting on floor = 0.40 m
- Inlet openings should not be obstructed by adjoining buildings, trees, signboards or other obstructions, or by partitions in the path of air flow.
- To maximise air flows, the inlet and outlet should not be in a straight line.
- For rooms having identical windows on opposite walls, the average indoor air speed increases rapidly by increasing the width of window by up to two-thirds of the wall width. Beyond that the increase in indoor air speed is in much smaller proportion, compared to the increase in window width. The air motion in the working zone is highest when the window height is 1.1 m. A further increase in window height

promotes air motion at a higher level of the window but does not contribute additional benefits as regards air motion in the occupancy zones in buildings.

- Greatest flow per unit area of openings is obtained by using the inlet and outlet openings of nearly equal areas at the same level.
- For a total area of openings (inlet and outlet) of 20 – 30 % of floor area, the average indoor wind velocity is about 30% of the outdoor velocity. Further increase in the window size, increases the available velocity but not in the same proportion. In fact, even under most favourable conditions, the maximum average indoor wind speed does not exceed 40% of the outdoor velocity.
- Where the direction of wind is quite constant and dependable and the size of the inlet should be kept within 30–50 % of the total area of openings. Where the direction of the wind is quite variable, the openings may be arranged equally on all sides, to the extent possible. Thus, no matter what the wind direction may be, effective air movement through the building would be assured.
- Windows of living rooms should open directly to an open space. In places where this is not possible, open space could be created in buildings by providing adequate courtyards.
- In case of rooms with only one wall exposed to the outside, provision of two windows on that wall is preferred to that of a single window.
- Windows located diagonally opposite each other with the wind-ward window near the upstream corner gives better performance than other window arrangements for most building orientations.
- A single-side window opening can ventilate a space up to a depth of 6-7 m. With cross-ventilation, a depth up to 15 m may be naturally ventilated. Integration with an atrium or chimney to increase the ‘stack effect’ can also ventilate deeper plan spaces.
- Horizontal louver, a sunshade atop a window, deflects the incident wind upwards and reduces air motion in the zone of occupancy. A horizontal slot between the wall and horizontal louver prevents upwards deflection of air in the interior of rooms. Provision of an inverted L-type louver increases the room air motion provided that the vertical projection does not obstruct the incident wind.
- Provision of horizontal sashes, inclined at an angle of 45 degrees in an appropriate direction, helps promote indoor air motion. Sashes projecting outwards are more effective than those projecting inwards.
- Air motion at working plane, 0.4 m above the floor, can be enhanced by 30 % by using a pelmet-type wind deflector.
- Roof overhangs help promote air motion in the working zone inside buildings.
- A veranda open on three sides is to be preferred as it increases room air motion with respect to the outdoor wind, for most orientations of the building.
- A partition placed parallel to the incident wind has little influence on the pattern of air flow, but when it is located perpendicular to the main flow, the same partition creates a wind shadow. In such cases, a partition with a gap of 0.3 m underneath helps augment air motion near the floor level in the leeward compartment of the building.
- In a building unit having windows tangential to the incident wind, air movement increases when another unit is located at an end-on position on the downstream side.
- Air motion in two wings oriented parallel to the prevailing breeze is promoted by connecting them with a block in the downstream side.

- Air motion in a building is not affected by constructing another building of equal or smaller height on the leeward side, but it is slightly reduced if the building on the leeward side is taller than the windward block.
- Air motion in a shielded building is less than that in an unobstructed building. To minimize the shielding effect, the distance between the two rows should be 8 H (8 times the height) for semi-detached houses and 10 H for long row houses. However, for smaller spacing, the shielding effect is diminished by raising the height of the shielded building.
- The ventilation indoors can be improved by constructing buildings on earth mound, having a slant surface with a slope of 10 degrees on the upstream side.
- Roof overhangs and pitch should be as high as possible, to increase pressure difference and thereby the air flow.
- Provide openings in roof tiles, this would enhance stack effect and enable hot air to escape outside (Figure 7a). One such example is the kindergarten for Sri Aurobindo International Institute of Educational Research in the warm and humid climate of Pondicherry, India, which has used specially designed roof tiles for escape of hot air (Figure 7b).
- Provision should be made for forced ventilation strategies by use of ceiling/wall-mounted fans, exhaust fans.
- Provide buffer spaces like staircases, lifts, store, toilets, double-wall without opening etc., on at least 50% of the west wall
- Hedges and shrubs deflect air away from the inlet openings and cause a reduction in the indoor air motion. These elements should not be planted up to a distance of about 8 m from the building because the induced air motion is reduced to a minimum in that case. However, air motion in the leeward part of the building can be enhanced by planting low hedges at a distance of 2 m from the building.
- Raising the building on stilts, at least 30 cm above ground, has three main advantages in warm and wet climates. First, it enables better ventilation by locating windows above the surrounding zone comprising lower buildings. Second, it enables cooling of the floor from below. Third, it helps to prevent moisture problems. It also gives flood protection, in flood prone areas.



Figure 3.10: Recessed windows & ventilated roof

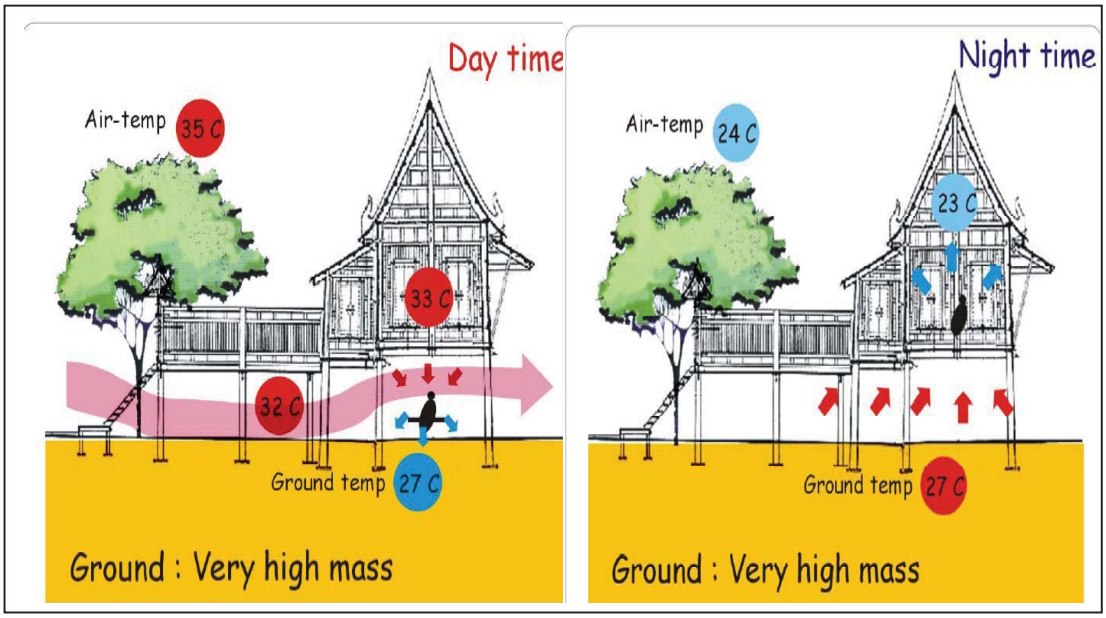
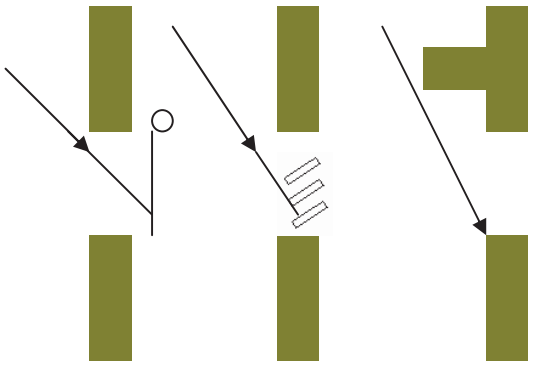


Fig 3.11: House on stilts
(Boonyatikarn, S. & Buranakarn, V., 2006)

- Trees with large foliage mass having trunks bare of branches up to the top level of the window, deflect the outdoor wind downwards and promote air motion in the leeward portion of buildings.

3.4.1.6 Shading and Glazing

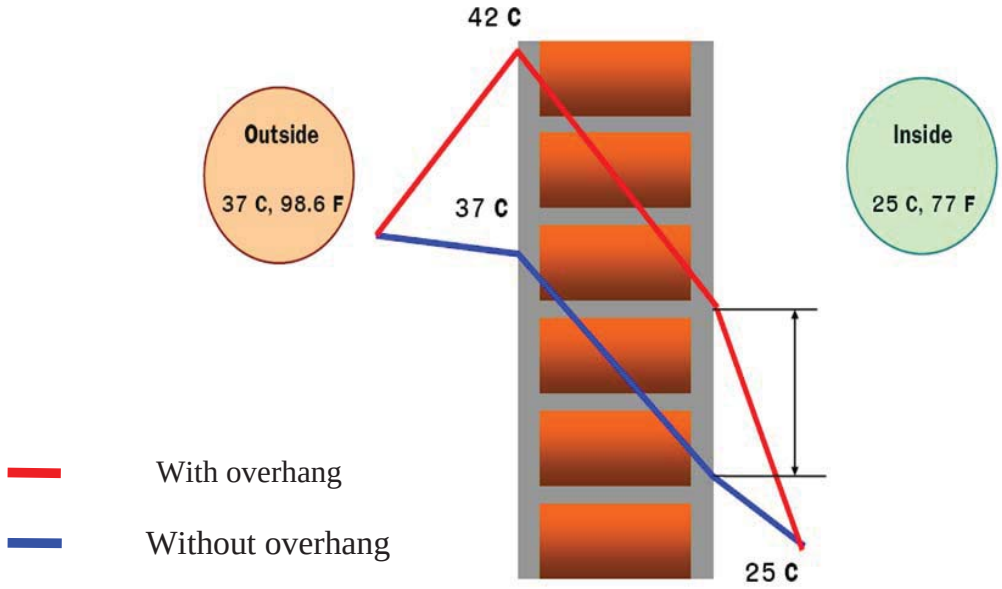


Movable blind Louvers Fixed Overhang

Fig 3.12: Shading Types (Baker,N., 2001)

- In hot climates, shading should be provided for the east and west façade, to reduce solar heat gains especially during the morning and afternoon hours. Moveable blinds or curtains needs to be used carefully, since they impede ventilation, which is desirable in warm, humid climates. Overhangs and louvers provide effective shading. Similar shading can be provided by porticos. An example of the difference made to the heat gain, by providing a fixed overhang is shown in the figure below.

Fig 3.13: Difference in cooling loads, with and without fixed overhangs
(Boonyatikarn, S. & Buranakarn, V., 2006)



- Minimize use of glass in buildings. Glass should not cover more than 50% of the wall area.
- Efficient glazing systems that maximize day-lighting and providing sun control should be adopted. The different types of glazing materials are: transparent glass, double glazing, absorbing glass, dark glass, reflective glass, polycarbonate, double poly carbonate with air space, corrugated fibre glass and acrylic sheets. The properties of these glazing materials are given below (Etzion, Y., 2001, p.119-120)

Table 3.2 : Properties of glazing materials
(Etzion, Y., 2001, based on Watson, D. & Labs, K., 1983. *Climatic Design-Energy Efficient Building Principles and Practices.* McGraw-Hill Book Company, New York, p.188)

	Glass Thickness (mm)	Light penetration (%)	Total solar radiation (%)
Glass			
Single, transparent	3	90	83
	5	88	77
Double, transparent	3	82	71
	5	78	60
Absorbent	3	84	65
	5	76	48
Dark	3	62	63
	5	42	44
Reflective/mirror	-	8-34	11-37
Polycarbonates			
Single	3	86	89
	5	82	86
Double	-	73-80	21-60
Corrugated fibre glass			
Absolutely transparent		93	82
Translucent		87	81
White		32-66	21-60
Acrylic sheets			
Transparent		83	83
White		23-70	19-67

3.4.1.7 External colours and textures

- For warm humid climates, light colours and rough textures are preferred. Light colours are more reflective. Rough textures cause self shading and also increase the surface area for re-radiation. Both these factors help reduce heat gain.

- Thermal barrier paints could be used for the roof: These coatings form a seamless membrane that bridges hairline cracks. They have high reflectance, high emittance as well as a very low conductivity value. The approximate cost of application of thermal barrier paint in India is about USD 24/m2.

3.4.1.8 Lighting

- The roof could be used as a day light source, along with some shading to reduce the heat gain.
- High windows provide the best distribution of light, but they should have baffles to avoid glare. Low windows allow in ground reflected light. From the point of view of light distribution, windows in the middle are least preferred.
- The penetration of daylight deep into the rooms can be increased by using light directing elements such as light shelves, reflective blinds, adjustable or fixed louvers or prismatic components in the window area, especially in the higher part. This could direct sufficient natural lighting up to 7m away from the windows. They act as shading elements and help to redirect the incoming light to the rooms´ ceiling. Their surfaces and that of the interior ceilings should have highly reflective surfaces(UNEP-IETC, 2004, p.73-74)
- The right type of glazing need to be chosen, for maximising day lighting and minimising solar heat gain, as mentioned earlier.
- The reflectance of internal finishes should be as per the desired daylight conditions.
- Avoid excessive illumination levels inside, which will add to the cooling load inside the building.
- Hard, smooth paving reflect light, causing glare. So they should be minimised. In case they are necessary, the surface could be made rough.

3.4.2 Energy efficiency

Maximizing the energy efficiency of the building system offers further opportunity for energy savings. Use of efficient energy consuming equipments for lighting, air-conditioning, heating etc., can reduce the energy use in a building by at least 10-20 %. The main energy consuming equipments in buildings are the HVAC, and lighting systems. The efficiencies of these systems could vary depending on the technology used and the way they are operated and maintained. While implementing energy efficiency, care should be taken that it does not lead to a decrease in the quality of life. For example, it should not lead to reduced ventilation and higher concentrations of pollutants inside the house. Care should also be to avoid the rebound effect: for example, a tendency to increase the hours of usage of energy efficient equipment. This would cancel out the benefits from energy efficiency. Energy efficiency measures would also fail due to shortcomings in design, commissioning or use. Following are some guidelines for minimising energy consumption in buildings and homes.

- Use high efficiency window air conditioners. Window air-conditioning systems are now available with some energy-saving features, such as sleep mode and filter-clean reminder. The sleep mode feature helps to save electric energy by increasing the set

temperature, when the occupants are sleeping. The single-biggest reason for inefficiency in window air conditioners is a dirty filter. A clogged filter results in increased power consumption and poor cooling. The filter-clean reminder feature reminds the user, when the filter is to be cleaned.

- Water cooled AC systems should be preferred over air cooled systems. Water-cooled units are of higher capacity and more energy-efficient compared to air-cooled units. Air-cooled units are more suitable for places where water is scarce or of hard quality or where there is no space for installing a cooling tower.
- In all HVAC systems the, scaling or soiling of the heat transfer surfaces (condenser, cooling tower and evaporator) would reduce the system efficiency. Hence it is important to have proper maintenance practices.
- Shading the exposed part of the AC system would help to reduce up to 10 % of the power consumed by the compressor.
- Use fluorescent/ compact fluorescent lamps operating on electronic or low-loss ballast, for indoor lighting.
- Use HID (high-intensity discharge) lamps with minimum circuit efficacy of 80 lm/W for outdoor lighting, e.g., high-pressure sodium vapour lamps.
- Apply control devices judiciously, such as timers, photocells or occupancy sensors, to turn lights on and off.
- Provide fixed/ pre-wired luminaires with sockets that will only accept lamps with high efficacy.
- Use energy efficient cooking stoves. They reduce energy consumption and indoor air pollution.
- Microwave ovens reduce energy use considerably, especially when cooking small quantities.
- In general, try to use the smallest size utensil for cooking. Cooking small quantities in a large utensil is inefficient.
- A pressure-cooker reduces cooking time and energy use considerably.
- If possible, the size of the utensil on a stove should be larger than the size of the burner or the electric element. Otherwise there will be energy loss.
- An efficient burner will give a blue flame, instead of a yellow flame. This would depend on the cleanliness of the burner and the correct fuel to air ratio. Check for the efficiency of the gas burner, periodically.
- Electric stoves will continue radiating heat for a short period, even after it is turned off. Use this feature to save energy.
- Defrost frozen foods before cooking.

Box 3.3: Improved wood stoves

The following is a comparison between some of the improved wood stoves in India with the traditional stove.

Criteria/ stove type	*Traditional*	*Vishal*	*Pawan*	*Sugam*
Thermal efficiency (%)	13.8	19.1	6.5	14.6
Emission factor-CO (gm/kg)	21.2	20.6	6.7	6.0
E_{TSP} (gm/kg)	8.2	7.9	26.8	3.9

- Apart from spoiling the taste and reducing nutritional value, overcooking wastes energy.
- Certain foods that take long time to cook, like lentils, could be soaked in water, prior to cooking.
- Wherever it is feasible, substitute solid fuels with gaseous fuels, both for cooking and heating. Gaseous fuels are more efficient and cleaner than solid fuels. Replace electricity with gaseous fuels, wherever electricity is costly and/or is generated from polluting fuels.

3.4.3 Renewable Energy

Fossil fuels supply 80 percent of the world's primary energy at present, but resource depletion and long term environmental impacts might curb their use in future. Use of renewable forms of energy, based on solar, wind, and biomass energy helps in reducing demand for polluting, conventional fossil fuel based energy. The most likely application of renewable energy in the residential sector would be based on solar, wind or biomass energy. Before installing renewable technologies, check for all possibilities for energy demand reduction and energy efficiency. This would reduce the initial investment considerably.

3.5 Water and sanitation



Detailed guidelines and resources on water and sanitation are available from WHO at http://www.who.int/water_sanitation_health. A brief overview of some aspects is given below.

3.5.1 Water supply and use

Considering the increasing demand and limited availability of water, it is important that it be used and managed efficiently. In efficiently managing its water resources, most countries in Asia lag behind the developed countries and a lot could be done to improve the situation. To illustrate the potential, we could compare the water usage in India and in the US. In India, conventional toilets use 13.5 litres water per flush. The Energy Policy Act of USA, 1992, established standards that require new toilets to have a flow rate of 6.2 litres/ flush, urinals with a flow rate of 3.8 litres/ flush, and showerheads and lavatory and kitchen faucets with a flow rate of 9.5 litres/ flush. Some guidelines for the effective management of water are:

- Prepare a water balance for the site.
- Fix norms for water quality from various sources as per the specified local standards for different applications.
- Supplement surface water and ground water sources with rain water, by rain water harvesting.
- Use efficient fixtures that distribute of water at the desired pressure and avoid wastage and losses.
- Ensure regular monitoring of both consumption patterns and quality.

- Perform regular checks on plumbing systems to check for leakages, wastages, and system degradation.
- Adopt planting of native species and trees with minimal water requirement.
- Use mulches and compost for improving moisture retention in soil.
- Encourage rainwater harvesting and storage/ recharge for capturing good quality water. This is particularly important for coastal areas where groundwater is saline and intrusion of sea water has occurred.
- When water is sprayed on concrete structures for curing, free flow of water should not be allowed. Concrete structures should be covered with thick clothe/gunny bags and water should be sprayed on them, which would avoid water rebound and will ensure sustained and complete curing. Ponds should be made using cement and sand mortar to avoid water flowing away from the flat surface while curing
- Concrete building blocks should be cured in shade.

Box 3.4: Sources of Water

Rain water *could be collected by rain water harvesting. It provides good quality water and is a good way to supplement other sources of water.*

Surface water *refers to the water from lakes, rivers and similar sources. They are easy to access, but are susceptible to pollution and hence needs to be treated and protected.*

Groundwater *refers to the water available underground in aquifers, accessed by wells or boreholes. They could become polluted due to higher levels of chemicals such as arsenic, chlorides, fluorides etc.*

In humid regions, there is the possibility to extract ***water vapour in the atmosphere.*** *For example, Prof.Soontorn Boonyatikarn and his group at the Department of Architecture, Chulalongkorn University, Thailand has demonstrated a simple technique to collect around 40 litres of water per day from the atmosphere on a 125 m^2roof. It is based on the fact that a sloped roof is cooler than a flat roof and coating it with a low emissivity material could help to further reduce its temperature. At night time, the low temperature around the roof helps in condensing the water vapour in the atmosphere.*

3.5.2 Sustainable drainage

Conventional drainage methods usually involve transporting water as fast as possible to a drainage point, either by storm water drainage or a sewer. Sustainable drainage systems work to slow down the accumulation and flow of water into these drainage points and increases on-site infiltrations. This results in a more stable ecosystem as the water level and the water flow speed in the watercourse is more stable, and hence less erosion will take place. The best strategy should be to slow down the drainage and then clean it by a natural system, before discharging it to a water course.

- Drainage can be slowed down using swales, soak-ways, holding ponds and by having more pervious surfaces.

- Pervious surfaces needs to be encouraged on site in the form of pavements and parking, which allow rainwater to seep through them. Table 1 gives the typical values for the run-off coefficients for different types of surfaces.

Box 3.5: Calculation for run-off coefficient on site

Gross site area	=	**A** m^2
Ground coverage	=	**p** %
Built-up area on site (A_b)	=	**(p / 100) x A** m^2
Total open area on site (A_O)	=	**(A - Ab)** m^2
Open area on site planned for pervious surface (A_p)	=	$\sum A_1 \times C_1 + A_2 \times C_2 +$ ---

A_1, A_2 – Area of surfaces such as pavements/roads/vegetation, etc. with different run-off coefficients C_1, C_2, etc.

Average run-off coefficient = A_p / A_O

Pervious surfaces such as gravel or other open-textured material are only suitable for pedestrian or low-volume, light-weight traffic, such as walkways and personal driveways, but they are very easy to implement and inexpensive compared to the other methods. A combination of different types of pervious surfaces such as large or small paving blocks should be used. Large blocks have large holes that are filled with soil, and allow grass to grow in them. The surface is only suitable for foot traffic or occasional cars but has an aesthetic benefit due to the mostly grassy surface. Small blocks are impervious blocks that fit together in such a way so as to leave small openings in the joints between the blocks, allowing water to flow through. These blocks can take more and heavier traffic than large element blocks.

Table 3.3: Run-off coefficient for various surfaces

Surface type	***Run-off coefficient***
Roofs conventional	0.7–0.95
Concrete/ kota paving	0.95
Gravel	0.75
Brick paving	0.85
Vegetation	
1%–3%	0.2
3%–10%	0.25
> 10%	0.3
Turf slopes	
0%–1%	0.25
1%–3%	0.35
3%–10%	0.4
> 10%	0.45

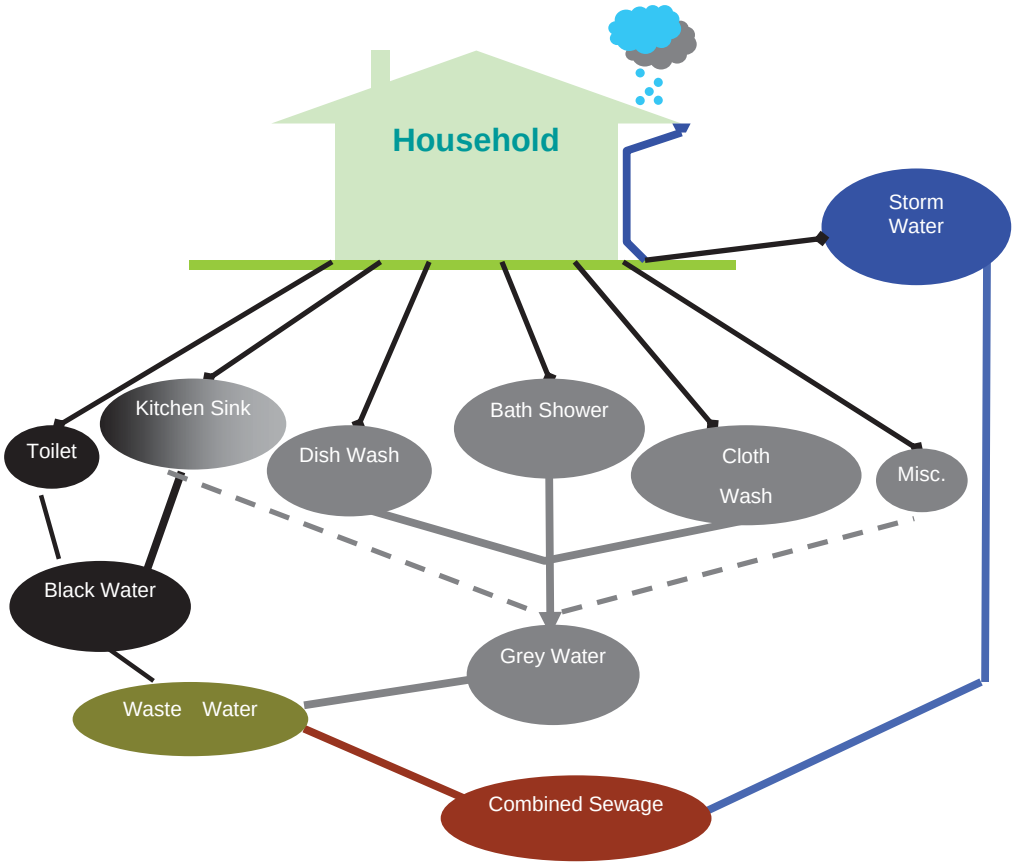
- Well planned roadways, parking lots, or walkways, with compact circulation patterns, could minimize pavement costs, centralize run-off, and improve efficiency of movement. This would help to reduce the ratio of impermeable surfaces to the gross site area.
- Restrict the net run-off from a site to a maximum of 60 %. In case the

site hydrogeology does not allow the run-off factor to be 0.6, measures are to be taken to allow the collection of run-off into soak pits or collection pits so that the net run-off from the site is not more than 60 %.

- Make spill prevention and control plan that clearly states measures to stop the source of the spill, contain the spill, dispose the contaminated material, and provide training of personnel. Some of the hazardous wastes to be cautious about are pesticides, paints, cleaners, and petroleum products.
- The run-off from construction areas and material storage sites should be collected or diverted so that pollutants do not mix with storm water runoff from undisturbed areas. Temporary drainage channels, perimeter dike/swale, etc. should be constructed to carry the polluted water directly to municipal drains. The plan should indicate how the above is accomplished on site well in advance of the commencement of construction activity.

3.5.3 Waste Water treatment and Sanitation

Fig 3.13: Sources of household wastewater
(UNEP-IETC, 2000).



Wastewater can be divided into greywater and blackwater. Greywater consists of the wastewater from washing/bathing, washing of clothes and from the kitchen. The

wastewater from the toilet is called blackwater. Storm water also contains solids and pollutants, picked up from the surfaces it flows on. So it too requires treatment. Stormwater collection is important from the point of view of flood control. If wastewater is combined with storm water, we call it a combined sewage. The main aim of waste water treatment is to reduce the Biological Oxygen Demand (BOD) and Suspended Solids (SS) to acceptable levels. Normally BOD is reduced to less than 20 mg/L, and SS to less than 30 mg/L. SS is removed by filtration and sedimentation. BOD is mainly removed by aerating the water, but nowadays anaerobic treatment is also being done, mainly to recover energy.If the waste water is discharged to water bodies that are sensitive to nutrients, then nutrients also should be removed. (UNEP-IETC, 2000) Pathogenic and faecal indicator micro-organisms needs to be reduced to acceptable levels, to ensure that this will not pose any threat to human health, Different types of treatment techniques can be adopted depending on land availability and on the quantity, and characteristics of waste water. Removing BOD and SS produces sludge. The sludge has to be further treated, before reuse or disposal. Treatment plants, which are used for treating sewage, are usually based on the biological process. The process is dependent on natural micro-organisms that utilize oxygen and organic contaminants in waste water to generate CO_2, sludge, and treated water.

The guidelines that could be followed are:

- Do not mix up different kinds of wastes. Collect solid wastes, waste water and storm water separately, but have an integrated plan to deal with them.
- Promote low-cost decentralized waste water treatment system.
- Develop norms based on existing standards for reuse of treated water for non-potable applications.
- Water under or near a pit or septic tank can get polluted. To prevent this, septic tanks should be located 15-20 m away from the nearest water supply point and 3 m from the nearest house.
- The kitchen should be separated from animals and the toilet, to ensure hygiene.

3.6 Solid waste management



Solid waste generated from buildings consists of a mix of biodegradable, non-biodegradable, and inert waste. Municipal solid waste is usually dumped in landfill sites or open dump sites, leading to air and water pollution. Through efficient waste management methods, a significant amount of solid waste could be reduced, recycled or reused. (SKAT, 2001,2002).

Traditionally urban solid wastes are managed in a hierarchy that looks like an inverted pyramid as shown below. Innovative solutions have been applied for each level of this hierarchy, for reducing environmental impacts, such as material and energy recovery, waste water management etc. The technical inputs required increases towards the top of the pyramid. The degree of partnership required decreases towards the upper level. (UNEP-IETC, 2003b)

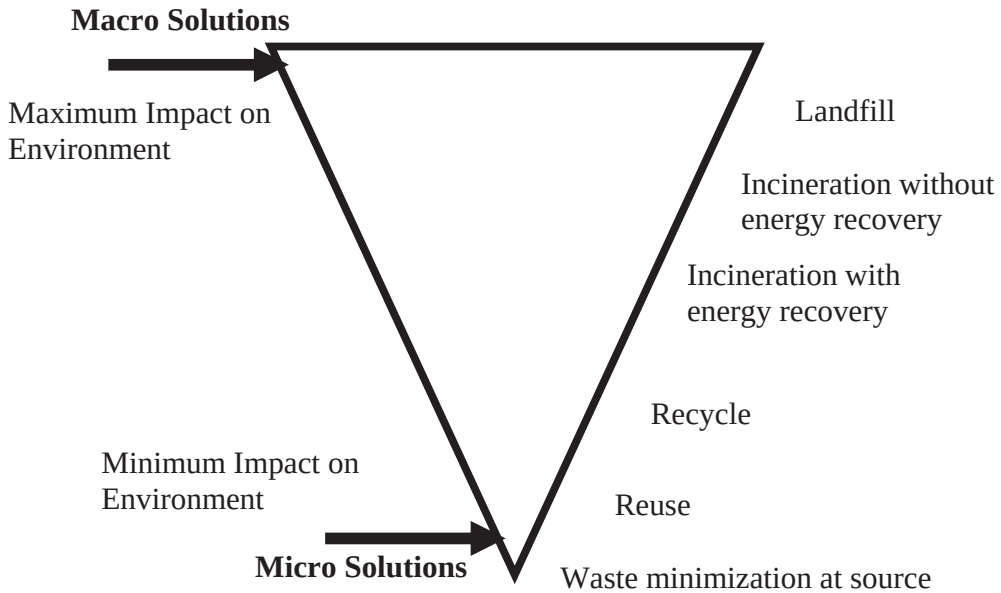


Fig 3.16: The Inverted Waste Pyramid (UNEP-IETC, 2003b).

The guidelines are as follows:

- Provide facilities for collection of segregated waste at the household and colony levels.
- Identify facilities for recycling of non-biodegradable wastes such as plastics, glass, and paper.
- Develop decentralized treatment and resource recovery systems at site based on composting or anaerobic digestion process for segregated organic waste. Identify appropriate options for the use of biogas and manure.
- For good performance, resource recovery processes like bio-methanation and composting should be given proper care, like in any production process. Marketing and the quality of the product, should be given due importance.
- In most countries in Asia, open dumping is practiced. Develop norms for disposal of non-degradable and inert waste in landfills based on local standards, to ensure safe environment in the surrounding areas. Sanitary landfills needs to be designed and people need to be trained in managing and maintaining it.
- A common mistake is to provide the infrastructure, but neglect the managerial aspects. It usually involves managing a large workforce, working together closely with the public and handling teething financial and maintenance problems.
- Establish an efficient waste reduction, recycling, and reuse (3R) programme.
- Avoid or reduce toxic and hazardous materials. Recycle items such as ballasts, mercury-based lighting products, used oil, unusable batteries, etc.
- Reuse construction debris. In isolated areas that do not have indigenous manufacturing units for building materials, like the islands in Maldives, building materials have to be imported. Optimization of building materials becomes a priority in these areas. In such

cases, the use of construction debris after segregation and crushing could be considered. This is also true for many of the disaster affected areas.

- Recycling and reuse can be enabled if easy disassembling of the building and its components is possible. The following are principles of design for disassembly (DfD) as applied to buildings (Kibert, C J., 2003)
  - ✓ Minimize the number of types of materials & components
  - ✓ Avoid composite materials and make inseparable products from the same material
  - ✓ Avoid secondary finishes to materials
  - ✓ Provide standard and permanent identification of material types and components
  - ✓ Use mechanical rather than chemical connections.
  - ✓ Minimize numbers of fasteners and connectors. Minimize types of connectors
  - ✓ Use an open building system with interchangeable parts
  - ✓ Use modular design
  - ✓ Separate the structure from the cladding
  - ✓ Provide access to all building components
  - ✓ Design components sized to suit handling at all stages
  - ✓ Provide adequate tolerance to allow for disassembly
  - ✓ Design joints and connectors to withstand repeated assembly and disassembly
  - ✓ Allow for parallel disassembly
  - ✓ Use prefabricated sub-assemblies
  - ✓ Use lightweight materials and components

Box 3.5: Site specific factors to be considered for solid waste management

Composition of the waste*: This would impact handling and transportation options as well as options for recycling, reusing, recovering energy or incineration. For example, if the moisture content of the waste is high, incineration would not be possible.*

Accessibility to waste collection points.*.*

Costs of storage and transport.

Social attitudes to waste collection services *such as willingness to segregate waste to assist recycling; willingness to pay for waste management services; opposition to siting of waste treatment and disposal facilities etc.*

3.7 Indoor environment quality



People spend 80%–90% of their time indoors, at home, school, and work. Hence indoor environmental quality is an important parameter in a sustainable habitat. Poor indoor air quality causes headaches, tiredness, shortness of breath, and allergic reactions such as sinus congestion, irritation of the eyes and throat, sneezing, coughing, and wheezing. In

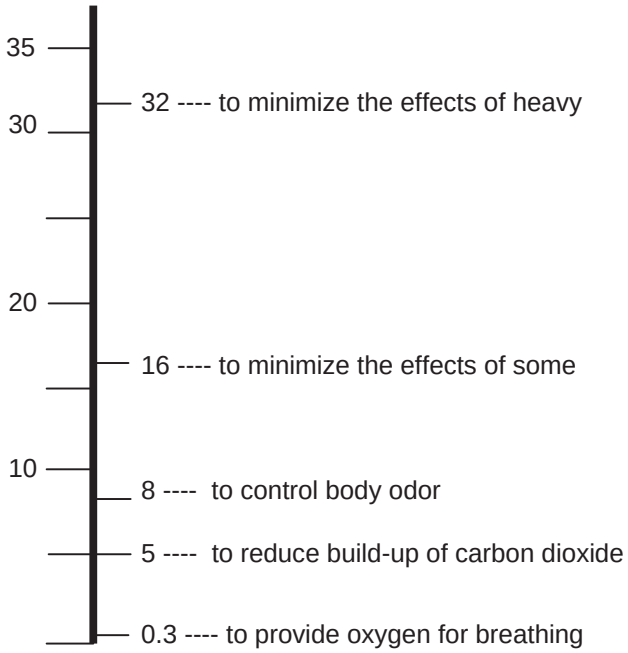
some cases, an allergic reaction of the lungs (hypersensitivity pneumonitis) has also been reported. Indoor air quality is affected by ventilation rates, temperature and humidity, building materials, kind of devices used indoor and outdoor air pollution entering into the home.

Biological contaminants also contribute to the poor indoor air quality. In coastal regions, warm, humid conditions provide an excellent environment for breeding of dust mites, moulds, and fungi. The contaminants include animal dander, water-borne microbes, moulds, etc., all of which can cause an allergic reaction. Some organisms can contaminate water sources and become air-borne through humidifiers.

Combustion by-products due to incomplete burning of fuels (oil, gas, kerosene, wood, coal, etc.) generate gases and tiny particles like carbon monoxide and respirable suspended particulate matter, nitrogen dioxide, formaldehyde, ammonia, etc, which are known to cause adverse health impacts.

Radon is a naturally occurring radioactive gas given off by traces of uranium in soil and rock. Some buildings could have high levels of radon in its structure, leading to an increase in the long-term risk of lung cancer. The guidelines for maintaining indoor environmental quality are as follows:

Fig 3.17: Fresh air requirements for a sedentary person in an office from UK data (Roaf, S C., 2003). (litres per second of fresh air per person)



- Use interior finishes and products with zero VOC (volatile organic compound) or low VOC content.
- Indoor ventilation rate should be maintained as per ASHRAE 62.2-2004.

(ASHRAE, 2006) or national standards.

- Design for indoor thermal comfort level as per ASHRAE 55-2004.
- Avoid use of hazardous materials e.g., asbestos.
- Keep the house clean and dust-free to reduce allergens such as house dust mites, pollen, and animal dander.
- Avoid leaving any material that could degrade/rot inside house.
- To prevent growth of mould, lower the humidity by venting moist areas or by installing dehumidifiers or humidistats.
- Disinfect the house regularly, especially whenever mould is seen to be growing.
- Separate cooking area from living area.
- Use high-efficiency combustion devices with outside vents (chimney).
- Implement no-smoking rules.
- Design for day lighting as per the local code.
- Provide views from all living spaces.
- Adopt measures to tackle noise pollution inside building, if there are high noise sources, such as airport in the vicinity. Use appropriate constructed or natural screens to reduce the impact of noise from external sources.
- Ensure proper slab construction between floors to deter structure-borne noise.
- Choose internal surface finishes based on acoustic performance.
- Consider acoustic lining for noise-producing equipment e.g., diesel-generating sets.
- Give sufficient ventilation to the kitchen.
- Use stoves that have chimney.

3.8 Construction administration



Environmentally conscious construction practices can minimise site disturbance, construction waste and the use of natural resources. It also reduces the overall project cost. The guidelines are as follows:

- Incorporate environmental guidelines into the construction contract.
- Develop construction safety norms and include the same in contractor’s document.
- Identify potential health hazards and formulate measures to address the same.
- Isolate construction sites from occupied areas.
- Adopt good practices for air pollution management on site.
- Optimize water use in construction by adopting water-efficient technologies e.g., use of ready mix concrete.
- Use recycled water for construction.
- Recycle and re-use construction debris

3.9 Building commissioning, operation and maintenance



Commissioning involves examining, approving or withholding approval of the building and its sub-systems to ensure that it is constructed in accordance with the contract documents, and is performing as intended. Commissioning enables the integration and organization of design, construction, operation, and maintenance of a building and its sub-systems. The O&M (operation and maintenance) costs throughout the building life cycle are considerable and could exceed the buildings' initial investment. The design intent of a building and systems is not met unless it is maintained properly. Appropriate maintenance procedures also help to keep the building and its sub-systems in order, so that they give the same output as during the initial stages. The guidelines are:

- Prepare a detailed commissioning plan. Prepare the criteria for processes and systems to be commissioned.
- Involve the design team in monitoring the commissioning process.
- Ensure commissioning is in accordance with the contract document.
- Ensure that qualified professionals are engaged in operation and maintenance.
- Train facility staff for proper maintenance of facilities.
- Prepare a detailed O&M plan with written policies and procedures for inspection, preventive maintenance, repairs, and cleaning. Material safety data sheets and information on cleaning chemicals to be used for cleaning, frequencies of cleaning, and pest-control methods, should be properly documented and followed.
- Monitor the performance parameters of the buildings and compare it with established benchmarks.
- Monitor thermal and visual comfort parameters.

4

Case study: Application of design guidelines in Sri Lanka

4.1 Background

This chapter describes the application of the Design Guidelines and the implementation of the demonstration project in Sri Lanka. The project was part of the tsunami reconstruction project in Sri Lanka. The tsunami reconstruction project involved the construction of 55 residences and associated community facilities. The eco-housing demonstration was undertaken in this tsunami reconstruction project. The project was initiated through the National Inception Workshop held in Colombo during May, 2005, where the Generic Design Guidelines, the action plan and site selection was discussed with stakeholders. After the site was finalised, a Site Specific Design Guideline was prepared.



Fig 4.1: Map of Sri Lanka with location of Kalutara



Fig 4.2: The site, before construction began

The project was executed by the Sarvodaya Shramadana Movement, the largest local peoples movement in Sri Lanka. The National Focal Point for the project was the Ministry of Environment and Natural Resources. The design team from Sarvodaya underwent a weeks training in Bangkok. The preliminary site plans and house designs were then revised. The "Damniyangama" eco-village was inaugurated on 28th March, 2006 by the President of Sri Lanka, H.E.Mahinda Rajapaksa. Figure 4.3 shows the site layout. All the houses constructed are of the same design and the plan view is shown in Figure 4.7.

4.2 About the site

The project area, Lagoswatte, is located in Kalutara district, approximately 40 km south of Colombo, Sri Lanka's capital. It lies between latitude 6°41'34" and 6°43'10" and longitude 80°02'53" and 80°05'03". The site for the project has an area of 5 acres. One main road and two arterial roads subdivide the site into four strips. The site does not fall under the disaster control zone. The surroundings are lush green and covered with dense vegetation (Figure 4.2). The soil on site is stabilized and is covered with grass. The soil type is red yellow podsolic soil. The allotted plot for development is connected to the city through a main road, which runs across the site. There is a high-tension wire crossing the site.

Temperatures are high and follow a very constant diurnal pattern throughout the year. The annual mean temperature is about 27 ºC and the range of average monthly temperature is very small, about 1–3 ºC. The diurnal range, on the other hand, may vary from 8–15 ºC. Humidity and rainfall are high throughout the year. The vapour content of the atmosphere is high, with vapour pressures of about 25 mm, and relative humidity being 75% and above. Wind speed is 1.5–3.0 m/s. From April—August, the predominant wind direction is south-west to north-east, while from October to March, the direction reverses. Table 3 gives the key climatic data of the site.

Table 4.1: Climatic data of the site (monthly average values)

Month	DBT °C	WBT °C	DPT °C	RH %	V.P hpa	Wind Speed (Knots)	Pressure Hpa	Rainfall mm	Cloud cover Octas	Visiblitiy Km
2002										
May	28.9	26.5	25.5	82	32.6	-	1008.4	11.7	5.7	22.5
June	28.7	26.1	25	81	31.7	-	1008.1	2.07	5.3	25
July	28.5	25.7	24.5	79	30.7	-	1009.5	1.34	5.4	24
Aug	28.3	25.3	24	77	29.8	-	1009.6	1.00	5.5	22
Sep	29.3	25.5	23.8	73	29.5	-	1010.45	4.35	5.3	24
Oct	27.4	25	23.9	81	29.6	4	1009.7	18.23	6.2	17.5
Nov	27.2	24.9	23.9	83	29.6	3	1009.9	9.0	6	16.5
Dec	26.6	24.1	22.9	81	27.9	-	1010.7	9.59	6	15.5
Jan	26.9	23.9	22.5	77	27.2	-	1011.6	4.72	5.5	17
Feb	27.7	24.9	23.6	79	29.1	6.2	1010.2	3.65	4.2	18
March	28.5	25.1	23.6	75	29.1	5	1009.6	8.25	5.2	19.6
April	29.1	25.5	24.5	76	30.7	-	1008.5	4.5	6	18
2003										
May	29.4	26.5	25.3	79	32.2	-	1009.3	6.19	5.6	19.5
June	29.0	26.1	24.9	79	31.5	-	1007.9	5.92	5.4	19.5
July	28.8	25.7	24.3	77	30.4	-	1008.1	7.15	6.1	19.5
Aug	28.7	25.7	24.4	78	30.6	-	1010	2.8	5.9	20
Sep	28.5	25.6	24.3	79	30.4	-	1011	9.34	5.8	19

Oct	28.3	25.2	23.9	77	29.6		1010.9	7.87	5.5	17
Nov	26.5	24.5	23.6	84	29.1	-	1010.6	13.43	7.1	13.4
Dec	27.7	24.3	22.7	75	27.6	-	1010.6	1.07	4.1	17.5
Jan	27.7	24.3	22.7	74	27.6	-	1010	1.07	4.5	18
Feb	28.0	24.2	22.4	72	27.1	-	1010.1	1.43	4.8	17
March	29.1	25.4	23.7	73	29.4	-	1009.2	.06	4.8	16
April	29.5	26.3	24.9	77	31.5	-	1008.7	2.63	5.9	15.5

DBT – Dry Bulb Temperature, WBT – Wet Bulb Temperature, V.P – Vapour Pressure

4.3 Analysis and site specific guidelines

4.3.1 Site and its microclimate

Thermal analysis was carried out using a software,TRNSYS 16. The internal temperatures that were observed inside a typical house near the site of the project was 30–35 ºC and the relative humidity outside was 75–90 %. With these internal environment parameters, according to SP41 (BIS, 1987), to achieve thermal comfort conditions, wind speed between 1.5–2.5 m/s is desirable. To achieve this wind speed, continuous ventilation is essential and will affect all aspects of building design, such as orientation, the size and location of windows, and layout of the surroundings.

Another software, Ecotect_v 5.20 was used to understand the relationship between predominant winds and the proposed site, and to study the annual and daily sun path for latitude 6 degrees. A sun path study helps to determine the favourable orientations and to design shading devices for critical facades.

The climate data indicates that the predominant wind direction is the South West. Wind speeds are 1.5–3.0 m/s. When the wind direction is SW, optimum ventilation conditions are achieved when the long facades are oriented towards the north or south, a direction which may also be preferable from the solar radiation viewpoint.
.

An analysis was done to optimise the window design to enhance natural ventilation inside the house. For example, in bedroom 1 (figure 4.7), the optimum window area is equal to 35% of the floor area. SP41 gives a relationship between the effects of area of opening on average indoor wind velocity. For fenestration area = 35% of floor area, available wind velocity inside the room would be 35% of the outdoor wind velocity. For example, when the outdoor wind velocity is 6 knots (3.08m/s), the indoor wind speeds achieved = 1.06 m/s. Referring to Table 2, when inside air speed = 1.06 m/s, thermal comfort is achievable inside the room without any fans or mechanical means given the condition that internal air temperature does not rise above 30 ºC and relative humidity is up to 90%.

The large area of openings required in warm and wet climates necessitates adequate shading. Otherwise, indoor temperature might rise above the outdoor level.

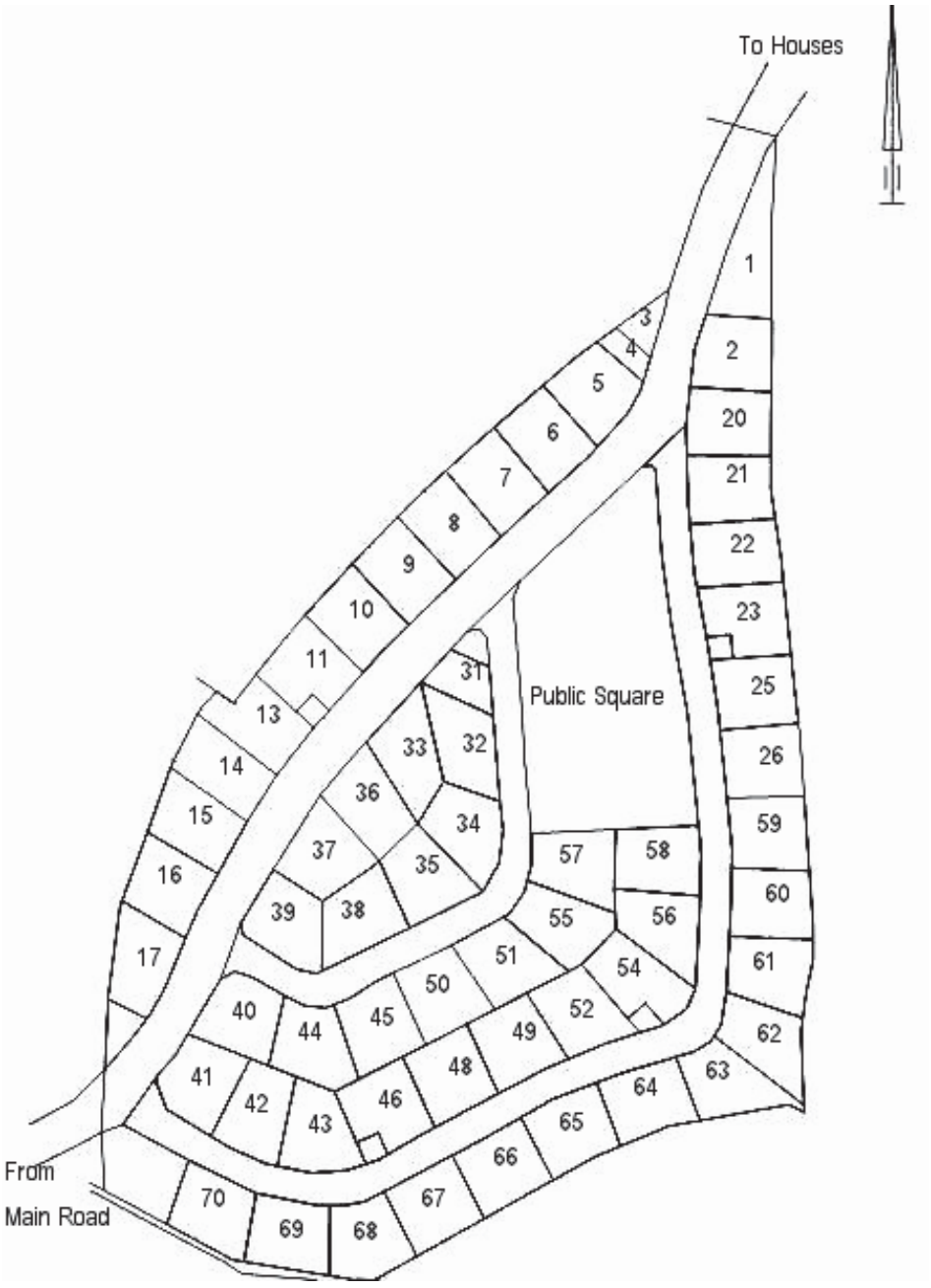
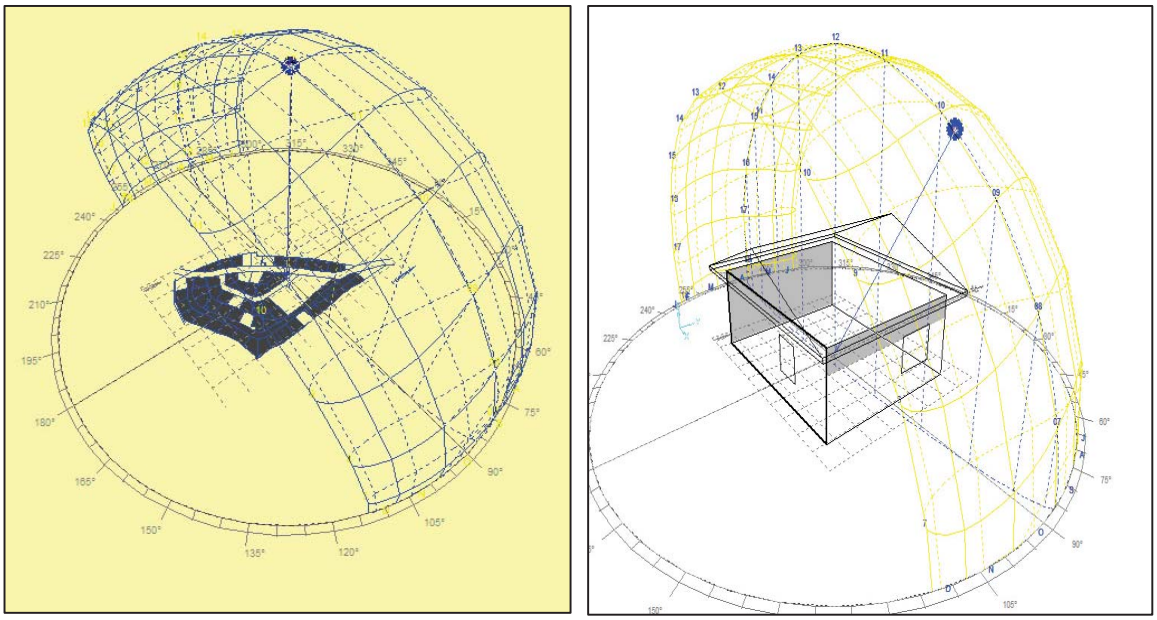


Fig 4.3: Preliminary layout of the site, before review

Figure 4.4 predicts the movement of Sun at 6 degrees north latitude. The east facade, west façade and roof are the crucial parts of the building envelope that require shade. It is also observed that being located near the equator in the Northern Hemisphere the sun does not come towards the Southern Hemisphere or south orientation during the summer months (April–September). It does cross the north orientation at low angles early morning and late evenings. The stereographic figures 4.5 and 4.6 show south orientation wall would always be under shade and be protected due to roof overhangs from 8:00 to 17:00 h in the months March–October. It can also be observed that from April–September, the South façade does not get direct sunlight from sunrise till sunset. Hence, all the houses are proposed to be oriented with long facades facing North–South, as shown in Figure 4.8. Smaller openings are recommended on east and west orientations. In the east, 4’10”-wide overhang projection extending outside the window for both W1 and W2 is recommended. The projection would cast a shadow on the window from 9:00 hrs onwards. The eaves of the pitched roof 2’6” overhang are enough to provide shade to the proposed apertures on north and south orientations. No extra shading device is required for north and south orientations.

Fig 4.4: Sun path diagram for Kalutara district and the ecohouse



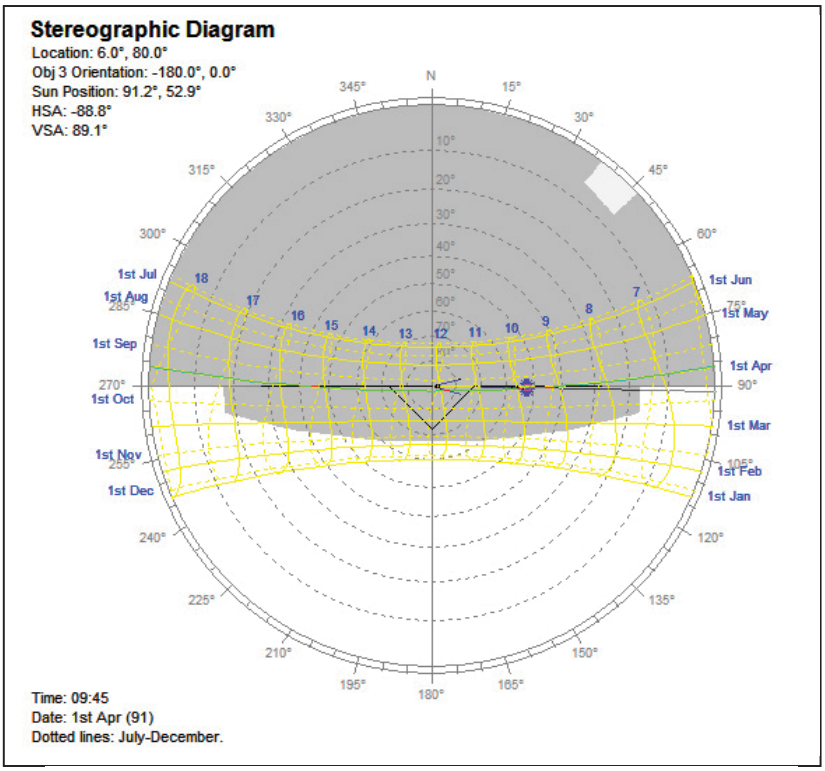


Fig 4.5: Stereographic projection showing shading mask projected by roof eaves on south facade of the house

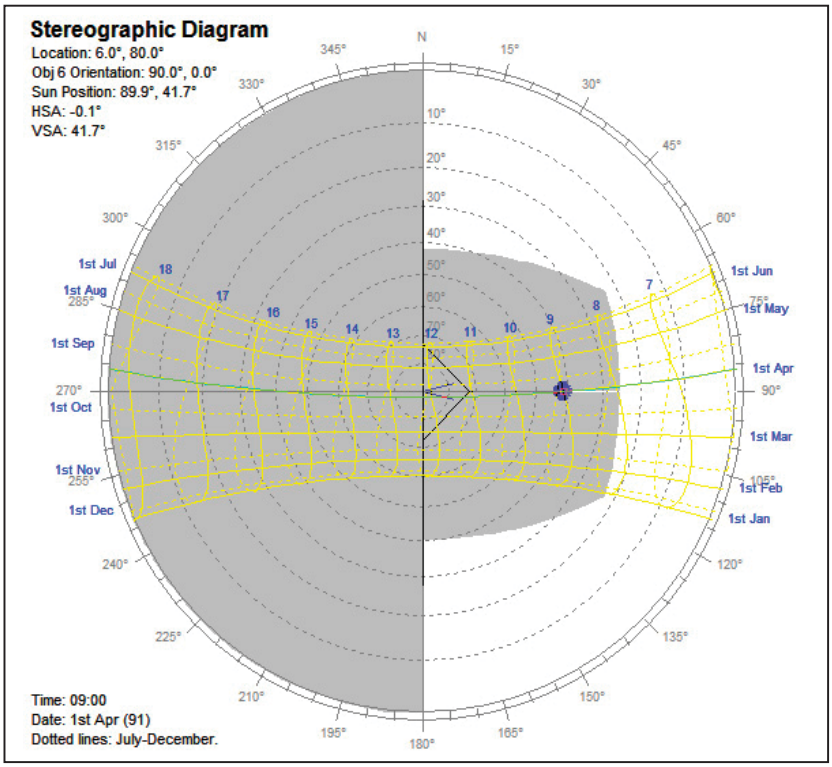


Fig 4.6: Stereographic projection showing shading mask projected by 4'10" shading devices on aperture W1, east façade of the house

Box 4.1: Stereographic chart or the sun-path chart

Stereographic chart or the sun-path chart is one of the many ways we can display solar geometry. For each latitude there is a specific stereographic diagram. It is a plot of the angular position of the sun from the building's geographic latitude, as it traverses the sky on a given day. It can be done by either projecting the sun path on to a horizontal surface (cartesian coordinates) or by projecting it on a vertical plane(rectangular coordinates). If it is projected on to a horizontal plane, the following applies:

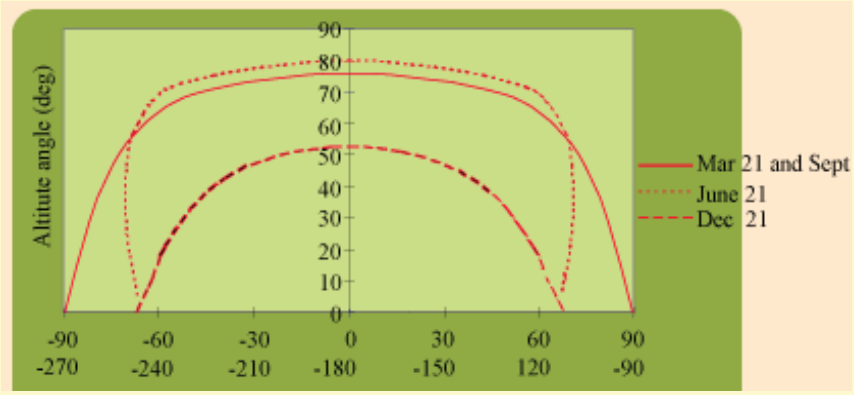
- *Radial lines represent the solar azimuth.*
- *The altitude angle of the sun is read on the various concentric circles, from 0 to 90 degrees. The horizon is represented by the outermost circle.*
- *Elliptical lines represent the months of the year and the hours of the day.*

The trajectories of the sun's movement in the sky are plotted, for the 21st day (equinox) of each month from June to December. The other months are obtained using the equivalence: July is same as May, similar correspondence is there between August-April; September-March; October-February; and November-January. The lines perpendicular to the sun's trajectories shows the position of the sun for a given time. (ESRU)

If it is projected on a vertical plane, the following applies:

- *The x axis represents the solar azimuth angle*
- *The y axis represents the solar altitude angle*
- *The curved lines represents months and hours*

The following diagram shows a sun-path diagram for Bangkok, projected on the vertical plane. (Chirarattananon, S., 2003)



4.3.2 Orientation and layout

Based on the analysis, the existing layout shown in figure 4.3 was revised as shown in Figure 4.8 to optimize ventilation and provide maximum protection from solar radiation. Following were the criteria considered while laying out the proposed arrangement.

- Minimum site disruption
- Maximum usage of microclimatic features
- Erosion-control measures
- Appropriate landscaping to be achieved through the control of paved areas and use of local plant species that consume less water.
- Positioning of plants to enhance natural ventilation around and inside houses.

Following were the proposed site layout features.

- All houses arranged with long facades facing the north and south orientation and short facade facing east–west orientation (Figures 4.7 and 4.8).
- The houses need to be oriented to achieve best-possible ventilation. Contrary to common belief, this does not mean that the wall with the inlet windows should face the prevailing winds. In fact, it is beneficial to orient the façade within 35 ^{0} of the wind direction.
- Open planning and wide, free spaces between buildings help to achieve good ventilation. The wind-flow pattern depends upon the geometry of the array, especially height-to-width ratio. The recommended H/W ratio is <0.7, under which condition, the flow pattern would be the same as if they were isolated houses. This has been mostly followed in the proposed layout.
- Tree planting could be used to guide air flow inside houses
- To enhance cross ventilation, windows on the windward side should be given access through large openings to rooms on the opposite pressure side region. Hence two more windows, W1 and W2 are recommended in the existing house design (Figure 4.7)

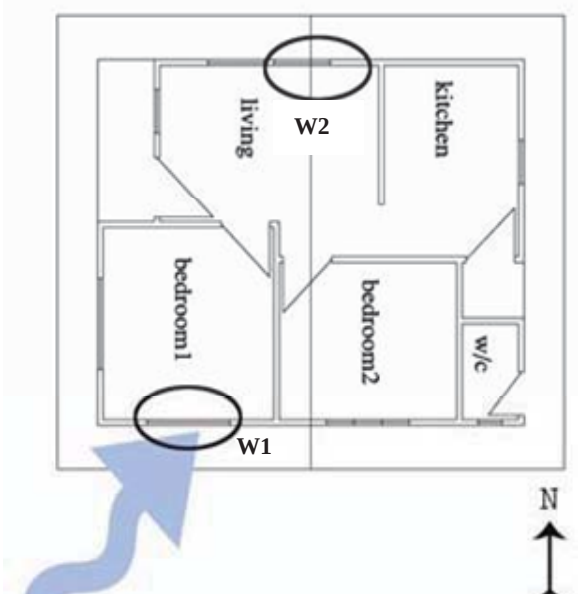


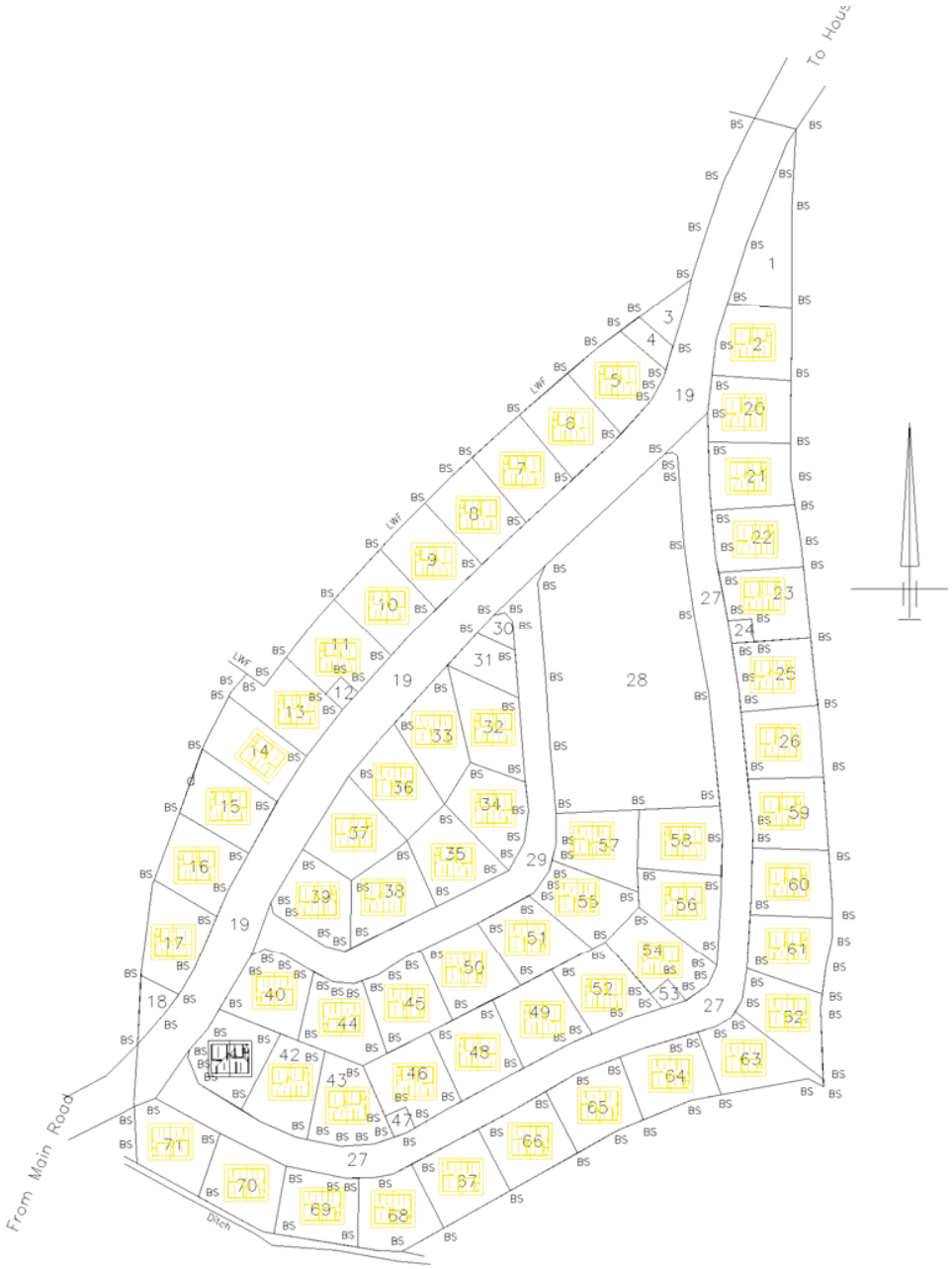
Fig 4.7: House oriented with long facades on North-South orientation

It is recommended to plant trees parallel to the wind stream. This would aid to streamline the air movement, which is desirable to increase air movement in and around the houses. Placement of vegetation perpendicular to the

predominant wind direction should be avoided as this would block the air movement around the houses. Keeping this guideline in mind, an indicative landscape layout is proposed in accordance with property lines in the site and at the same time to enhance natural ventilation inside the houses. This is illustrated in Figures 4.9 and 4.10.

The houses as seen have been oriented with long facades facing N–S. Depending upon the street layout, plot orientation, and its relation with wind direction, trees have been positioned parallel to wind direction. The number of trees to be planted would depend on the plant characteristics and site specific factors.

Fig 4.8: Proposed site layout, all houses oriented with long facades North-South



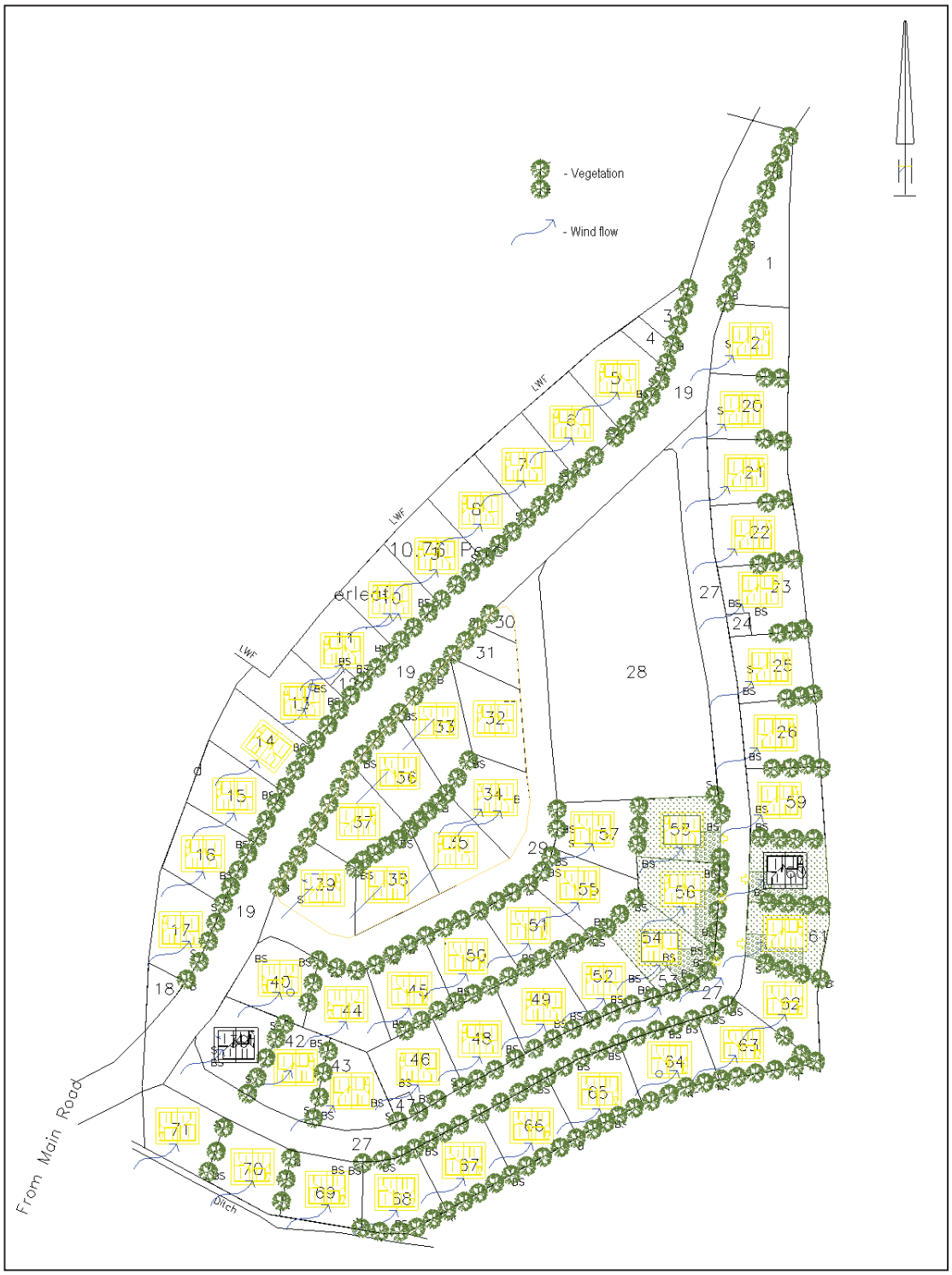


Fig 4.9: Wind flow patterns in proposed landscape layout

4.3.3 Soil stabilization

Landscape activities and design could help retain the soil in its place and will have a significant effect on erosion. It would be beneficial to grow native plants to reduce watering and maintenance cost. It is also recommended to grow low-height deciduous trees (5–7 m high) with a wide diameter (4–5 m wide). However, it should be noted that landscaping that is designed for soil erosion mitigation might sometimes affect passive solar gains or obstruct the wind currents. The proposed layout plan has been optimized to achieve erosion control without affecting the wind currents or passive solar gains. Small-height trees would streamline the air movement at human scale around the houses (Figure 4.10). The landscape architect should consider these aspects while selecting plant species. On the remaining soft ground, grass, flowers, crops, vegetables, and other small plants could be grown around the house which would not affect the air currents but at the same time, hold the soil together and prevent soil erosion.

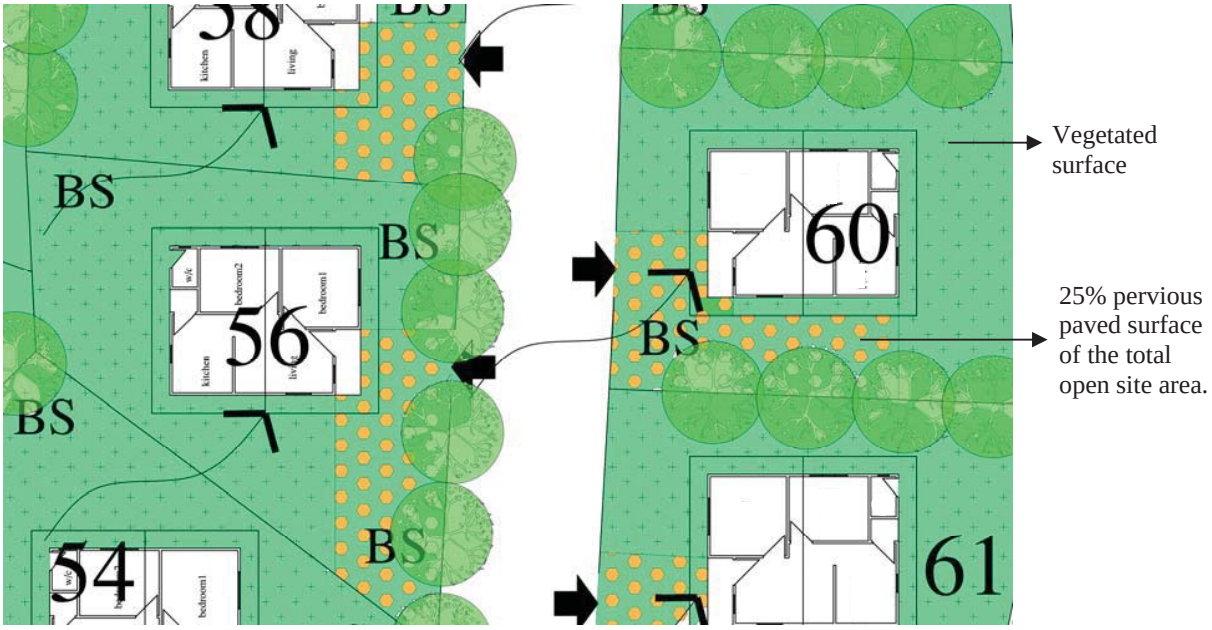


Fig 4.10: Landscape design around an eco-house for soil stabilisation

4.3.4 Drainage

The proposed layout plan minimizes storm water run-off and increases on site infiltration around the house. This has been achieved by reducing the paved surface to 25% of the total open area on site (Figure 4.10). The remaining open site has vegetation cover. The proposed paving is made of a permeable system of block- latches that permits drainage, grass growth in the lattices, as well as to give strength and stability. This surface is only suitable for pedestrians or light-weight traffic like occasional cars or personnel driveways.

4.3.5 Landscape design to reduce heat island effect

Use of dark, non-reflective surfaces for parking, roofs, and pathways contribute towards the heat island effect created when heat from the sun is absorbed and radiated back to the surrounding areas. The heat island effect causes the ambient temperature to rise in comparison to the undeveloped areas. This can be mitigated by reducing the use of hard paving on site, by shading hard surfaces, and by using light colours that reflect heat instead of absorbing it.

By planting trees and bushes, a properly planned landscape can help reduce the heat island effect by reducing the ambient temperature through evapo-transpiration. For example in plot 60, trees are planted so that they provide shade and do not obstruct the wind currents. The pervious pavements are placed such that they are shaded by trees and provide access to the house (Figure 4.10). Other guidelines that could be followed are:

- Use light coloured, reflective roofs having SRI (solar reflectance index) of 50% or more. The dark coloured, traditional roofing finishes have an SRI varying from 5%-20%. Light-coloured roof finishes helps to reflect the heat off the surface because of high solar reflectivity and infrared emittance. High solar reflective (albedo) roof coatings or heat-reflective paints on roofs could also be used.
- Use light-coloured aggregates or 'white top' the pavements with 50-mm-thick layer of cement concrete. Stabilize pavements with porous materials such as sand.

4.3.6 Daylighting

Day lighting reduces the need for electric lighting of building interiors, resulting in decreased energy use. In addition, day-lit spaces provide a connection between indoor spaces and the outdoor environments. Figure 4.11 is an illustration, which shows that more than 90% of the room areas have access to the outside views. As discussed earlier, well designed windows would also aid cross-ventilation and enhance natural ventilation.

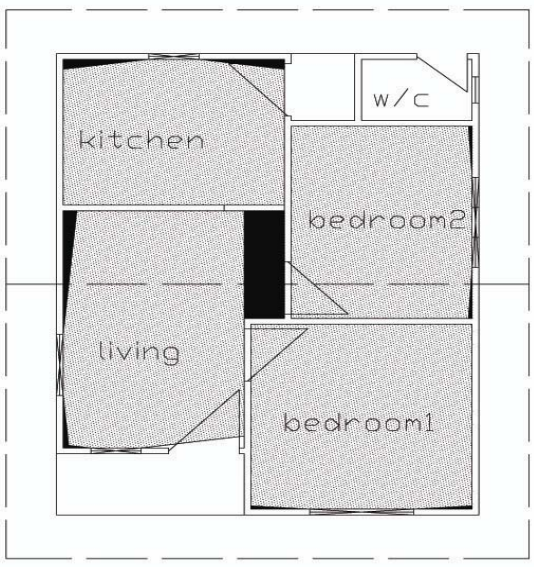


Fig 4.11: Window placement: rooms in an eco-house should have good access to outside views

4.4 Implementation

The design team used the site specific guidelines mentioned above to guide the design and construction. They also underwent a one week training in Bangkok, prior to doing the design. The following is an adaptation of the implementation report of the demonstration project (Sarvodaya, 2006).

4.4.1 Pre-design planning

Visions, goals and objectives were set out by the design team for the eco-village.

Vision: Demonstrate healthy living through a self sufficient ecological way of life, respecting all life and sharing resources.
Goals: Integrate human activities into the natural world in a sustainable way. Some of the methods used include use of renewable energy sources, recycling of material resources, composting of organic waste and rain water harvesting.
Objectives:

- Quick resettlement of the tsunami affected families in a secure and productive atmosphere
- Provide a good quality of life to the residents
- Promote environmental awareness among residents and encourage public participation in environmental initiatives
- Use the project to demonstrate and disseminate the concept of eco-housing

The following principles guided the design process:

Construction

- Minimum housing space should be 500 square ft.
- Locally available materials such as earth bricks and roof tiles should be prioritized for construction.

Waste management

- Each house should have compost bins.
- Waste water will be used for watering of plants which are tolerant to low quality water.
- The solid wastes which are not used for composting must be put in to separate ferro cement bins and delivered to recycling plants.

Water management

- Rain water harvesting tanks will be constructed for a group of houses. Cleaning of the tank should be done by the families.
- Water quality in the wells would be monitored by the Water committee. The wells should be cleaned in time with community participation.

Energy

- Solar panels will be provided for each of the houses.
- A Memorandum of Understanding (MOU) will be signed between Sarvodaya and the beneficiaries to prevent unauthorized selling and transfer of solar panels.

Disaster mitigation methods

- The site is not located in a disaster zone and is thus considered to be safe from natural disasters. Since the site was not affected by the tsunami there are no issues related to the impact of the tsunami.
- Wind breakers will be established for protecting the site.

Financial incentives/penalties

- House holds who practise more eco friendly measures will be identified and presented am award by the Sarvodaya Shramadana Society.
- The households that are not practicing recycling should be levied an amount, payable to the Sarvodaya Shramadana Society. The amount will be decided by the community.

4.4.2 Site planning

The site layout has been done to minimize destruction of land. The drainage was designed according to the slope of the land. All the buildings were designed to take maximum benefit of sun, wind and day light. The ratio of street width to building height would be suitable for good access of daylight inside the building. The village has been designed to be pedestrian and bicycle friendly and the project team is working on creating income opportunities that do not require commuting by motorized vehicles.

A main priority was to re-establish vegetation cover which had largely been destroyed earlier. Landscaping was planned to maximize indoor ventilation, provide shading and promote evaporative cooling. Plants were also used as wind breakers. Other considerations included reduction of soil erosion and the provision for subsistence farming. Multipurpose tree species were selected, that had economic value also. The trees were selected in cooperation with the community to avoid potential conflicts.

Drainage canals were constructed according to the existing drainage pattern to prevent soil erosion. The existing drainage pattern was not disturbed. Run-off from the construction area was diverted through drainage canals with a minor negative impact on the environment.

4.4.3 Materials and product selection

The original plan was to use locally available materials with low embodied energy, such as earth bricks. But due to the low availability of earth bricks in the local market and the urgent need for reconstruction, cement bricks were used for the construction of houses. The cement bricks also proved to be cheaper than earth bricks. In general, locally available materials, technologies and labour were used in the construction process. Earth bricks would be used for the construction of the multipurpose community hall. For example, the members of the Sarvodaya Shramadana Society made cement bricks for the

construction and the beneficiaries of the project worked as skilled and unskilled labourers. Other precautions taken include:

- Water based acrylics were used for paints.
- Acrylics, silicones and siliconized acrylics sealants were used for inside use.
- Water based urethane finishes were used as wooden finishes.
- Particle board made with phenol-formaldehyde resin was used to control indoor VOC emission.
- Minimum use of wood was made for interior works.
- Asbestos has been avoided in the construction.

4.4.4 Sustainable use of energy

Demand management and energy efficiency
Since the project area belongs to the low country wet zone, it was not crucial to implement measures such as water bodies, roof gardens, etc. to minimize the heat effect. However, the following passive cooling measures have been implemented to reduce the energy demand:

- Buildings were planned according to the wind pattern to ensure adequate natural ventilation inside the house.
- Inlet openings in the buildings were located on the windward side and outlet openings were located on the leeward side.
- Inlet openings are not obstructed by adjoining buildings or trees.
- Inlet and outlet openings have nearly equal areas at the same level.
- Windows in living rooms open directly to an open space.
- All the rooms have two windows.
- Roof tiles were used as roofing material as it was most suitable for protection of the house against excessive heat gain.
- Trees and vegetation was used to increase humidity levels, improve shading and thereby cool the environment.
- Efficient lightening systems were installed for energy conservation.

Renewable energy sources
Each house was provided with solar PV panels for lighting.

4.4.5 Water and Sanitation

Rainwater harvesting tanks were constructed, each tank shared by a group of houses. Five drinking wells and two bathing wells were also constructed. Wastewater is being used for watering plants which tolerate low quality water. A sub terra system will be installed for recycling of waste water. The quality of the drinking water was tested by the Water Board and was confirmed to be within the range of national standards. A water sub-committee will be formed to monitor both consumption patterns and quality of the water.

4.4.6 Solid Waste management

For recycling of biodegradable solid waste, compost bins have been provided to each house. Awareness programmes are being planned to sensitise people on the efficient management of waste. Separate bins have been constructed in two corners of the site to collect non biodegradable solid waste (glass, paper, metal, plastic, polythene, etc.) which will be transported to recycling plants. Construction debris has been reused for various purposes. For example, bamboo used in the construction has been reused for making compost bins.

4.4.7 Indoor environment quality

All the buildings were designed to take maximum benefit of sun, wind and day light. The day light and air flow inside the house has improved the indoor environment quality. As mentioned earlier, toxic and hazardous materials have been avoided in the construction. The site is located away from the main road and is not much affected by noise.

4.4.8 Construction administration

The construction was managed by technical staff from Sarvodaya and no contractor was employed. The team employed environmentally conscious construction practices to the extent possible. Recycling of construction waste was also done.

4.4.9 Operation and maintenance

Sub committees have been established for the operation and maintenance of the different components of the eco-village. Capacity building was also carried out. Some of the committees that have been formed are:

- Environmental Sub Committee to establish standards to protect and enhance the environmental quality, visual beauty and property investment value of the eco-village. They also promote energy independence and process requests for design changes related to specific architectural/ environmental considerations.
- Operation and Maintenance Committee for the solar panels
- Water Committee for monitoring consumption and the maintenance of drinking and bathing wells
- Facility Maintenance Committee to take inventory, and for preventive maintenance, repair, and security of buildings and equipment held in common. They will also facilitate community trash pick-up and promote well-maintained residential exteriors.
- Social Committee to foster a spirit of community and enhance residents' knowledge on ecological living. The committee will also organise regular social events like tree planting events, concerts etc.

4.5 Conclusion

The project underscored the importance of social and educational programmes for effective implementation of such projects. A majority of the residents, initially unaware of these issues have now understood their relevance. The project execution proved to be a success because of appropriate interventions for capacity building, leadership development and conflict resolution. The involvement of the community was particularly important during site planning. Through the various sub committees established, many of the eco-housing concepts and practices have now been integrated into the daily routines of the residents. By living out the visions and goals of the community, the "Damniyangama" eco-village is expected to provide valuable inputs to the Government of Sri Lanka and other Governments in the region, for further establishment of sustainable communities.

References

ASHRAE, 2006. *Standards & Guidelines*. The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, USA.
http://www.ashrae.org/technology/page/548

Baker,N. et.al., 2001. *Climate Responsive Architecture: A Design Handbook for Energy Efficient Buildings*. Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

Baker,N., 2001. *Daylighting and Shading* in Baker,N. et.al., 2001. Climate Responsive Architecture: A Design Handbook for Energy Efficient Buildings. Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

Boonyatikarn, S. & Buranakarn, V., 2006. Presentations made for the training programme for architects on "Design of eco-houses" as part of the UNEP- UN HABITAT regional initiative on eco-housing. Department of Architecture, Chulalongkorn University, Thailand.

BIS, 1988. *SP41- Handbook on Functional Requirements of Buildings other than industrial buildings.* Bureau of Indian Standards, New Delhi, India.

Chirarattananon, S., 2003. *Solar radiation and Sunshading*. Development of Media for Transfer of Technology for Energy Conservation for Buildings, Energy Field of Study, School of Environment, Resources and Development, Asian Institute of Technology, Thailand. http://www.serd.ait.ac.th/ep/mtec/selfstudy/Chapter1/position.html

© Crown copyright, 2000. *World Climate Averages*. Met Office, Devon, UK.
http://www.metoffice.com/education/data/climate/index.html

CSE, 2003. *A water harvesting manual for urban areas: Case studies from Delhi and Mumbai.* Centre for Science and Environment, New Delhi, India.

CIB & UNEP-IETC, 2002. *Agenda 21 for Sustainable Construction in Developing Countries.* The International Council for Research and Innovation in Building and Construction, Rotterdam, Netherlands and United Nations Environment Programme International Environmental Technology Centre, Osaka, Japan.
http://www.cibworld.nl/website/priority_themes/agenda21book.pdf

ESRU. *Single Issue Tools - Simple - Sun Charts*. Energy Systems Research Unit, Department of Mechanical Engineering, University of Strathclyde, Glasgow, UK.
http://www.esru.strath.ac.uk/Courseware/Design_tools/Sun_chart/sun-chart.htm.

Etzion, Y., 2001. *Openings in Hot Climates – Wind, Sun and Shading* in Baker,N., et.al, 2001. Climate Responsive Architecture: A Design Handbook for Energy Efficient Buildings. Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

Gertsakis. J & Lewis. H, 2003. *Sustainability and the Waste Management Hierarchy.*Discussion paper for EcoRecycle Victoria, Australia

http://www.cfd.rmit.edu.au/content/download/189/1390/file/Sustainability%20and%20the%20Waste%20Hierarchy.pdf

Givoni, B., 1969. *Man, Climate and Architecture.* Elsevier Publishing Co. Ltd, England

IEA, 2001. *Types of Tools.* Annex 31 Energy-Related Environmental Impact of Buildings. International Energy Agency, Paris, France.
http://annex31.wiwi.uni-karlsruhe.de/pdf/Microsoft%20Word%20-%20Annex%2031%20Types%20of%20Tools.pdf

Ingersoll T G.et al., 1975. *Climatic Design in Manual of Tropical Housing and Buildings.* Orient Longman, New Delhi, India.

Kibert, C J., 2003. *Deconstruction: the start of a sustainable materials strategy for the built environment* in UNEP DTIE, 2003. Sustainable Building and Construction. Industry and Environment Review, Vol 26 No 2-3. United Nations Environment Programme Division of Technology, Industry and Economics, Paris, France.
http://www.unep.fr/media/review/vol26no2-3/voL26_no2-3.htm

Kohler,N. & Moffatt, S., 2003. *Life-cycle analysis of the built environment* in UNEP DTIE, 2003. Sustainable Building and Construction. Industry and Environment Review, Vol 26 No 2-3. United Nations Environment Programme Division of Technology, Industry and Economics, Paris, France. http://www.unep.fr/media/review/vol26no2-3/voL26_no2-3.htm

Krishan, A. et al., 2001. *Shelter of Form* in Baker,N., et.al, 2001. Climate Responsive Architecture: A Design Handbook for Energy Efficient Buildings. Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

Kyocera, 2004. *Understanding Solar: Modules.* Kyocera International, Inc, USA
http://www.kyocerasolar.com/learn/modules.html

Majumdar M., 2004. *Development of eco housing base line principles for Pune.*
Report submitted to United States Asia Environmental Partnership

Makower, J., 2001. *The Clean Revolution: Technologies from the Leading Edge*. Global Business Network and Clean Edge, Inc., USA. http://www.cleanedge.com/reports/gbn.pdf

McDonough,W. & Braungart, M., 2003. *Towards a sustaining architecture for the 21st century: the promise of cradle-to-cradle design* in UNEP DTIE, 2003. Sustainable Building and Construction. Industry and Environment Review, Vol 26 No 2-3. United Nations Environment Programme Division of Technology, Industry and Economics, Paris, France. http://www.unep.fr/media/review/vol26no2-3/voL26_no2-3.htm

Roaf, S C., 2003. *Natural Ventilation of Buildings in India* in Baker,N., et.al, 2001. Climate Responsive Architecture: A Design Handbook for Energy Efficient Buildings. Tata McGraw-Hill Publishing Company Limited, New Delhi, India.
Santa Monica Green Building Programme. *Incorporate Occupancy Controls in Zones with Intermittent Use.* City of Santa Monica, USA
http://greenbuildings.santa-monica.org/controlsys/sensorcontrols.html

Sarvodaya, 2006. *Implementation report of the demonstration project in Sri Lanka,* report submitted as part of the UNEP-UN HABITAT lead regional initiative on eco-housing. Sarvodaya Shramadana Movement, Moratuwa, Sri Lanka.

SKAT, 2001,2002. *Introduction to Solid Waste Management* in Sanitation Connection. SKAT, St.Gallen, Switzerland
http://www.sanicon.net/titles/topicintro.php3?topicId=4

Szokolay, S V., 2001. *The Building Envelope* in Baker,N., et.al, 2001. Climate Responsive Architecture: A Design Handbook for Energy Efficient Buildings. Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

UNEP DTIE, 2003. *Sustainable Building and Construction*. Industry and Environment Review, Vol 26 No 2-3. United Nations Environment Programme Division of Technology, Industry and Economics, Paris, France.
http://www.unep.fr/media/review/vol26no2-3/voL26_no2-3.htm

UNEP DTIE, 2006. *Sustainable Building and Construction Initiative – Information Note.* UNEP, Division of Technology, Industry and Economics, Paris.
http://www.uneptie.org/pc/pc/SBCI/SBCI_2006_InformationNote.pdf

UNEP-IETC, 2000. *International Source Book On Environmentally Sound Technologies for Wastewater and Stormwater Management* . United Nations Environment Programme International Environmental Technology Centre, Osaka, Japan
http://www.unep.or.jp/Ietc/Publications/TechPublications/TechPub-15/main_index.asp

UNEP-IETC, 2003a. *Phytotechnologies: A Technical Approach in Environmental Management*. United Nations Environment Programme International Environmental Technology Centre, Osaka, Japan.
http://www.unep.or.jp/ietc/Publications/Freshwater/FMS7/index.asp

UNEP-IETC, 2003b. *Urban Waste Management Strategy*. United Nations Environment Programme International Environmental Technology Centre, Osaka, Japan.
http://www.unep.or.jp/ietc/focus/waste-strategy.doc

UNEP-IETC, 2004. *Basic Principles and Guidelines in Design and Construction to Reduce Greenhouse Gases in Buildings.* United Nations Environment Programme International Environmental Technology Centre, Osaka, Japan
http://www.unep.or.jp/ietc/kms/data/2842.pdf

WHO & Leeds University, 2001,2002. *Wastewater Reuse* in Sanitation Connection. World Health Organisation, Geneva and University of Leeds, UK. http://www.sanicon.net/titles/topicintro.php3?topicId=3

WWF, 2004. *Living Planet Report 2004*. World Wide Fund for Nature, Gland, Switzerland. http:www.wwf.be/eco-footprint/docs/LPR2004_en.pdf

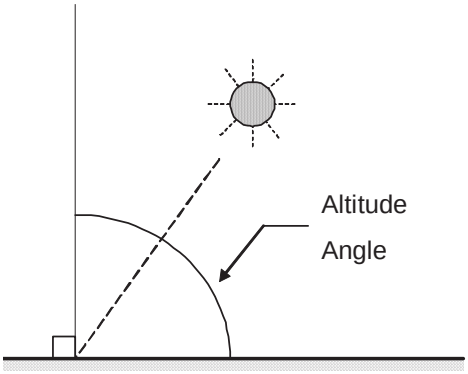
Yannas, S., 2003. *Passive Heating and Cooling Design Strategies* in Baker,N., et.al, 2001. Climate Responsive Architecture: A Design Handbook for Energy Efficient Buildings. Tata McGraw-Hill Publishing Company Limited, New Delhi, India.

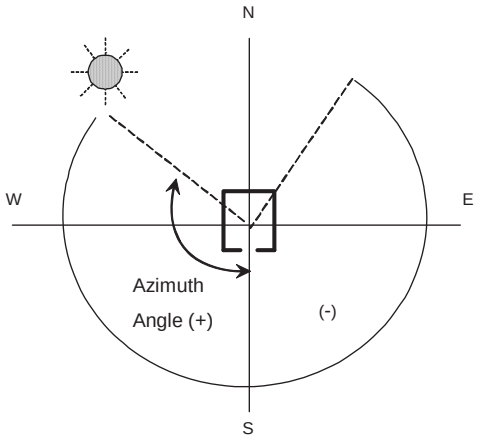
Glossary

ASHRAE(American Society of Heating, Refrigerating, and Air-conditioning Engineers): ASHRAE is an international organization involved in research, standards writing, publishing and continuing education in the field of HVAC.

Azimuth and Altitude angle:
The angular position of the sun as seen from a particular place on the surface of the earth varies from hour to hour and from season to season. The basic position of the sun at any instant can be described by two angles: the solar altitude and azimuth.

The solar altitude angle is the angle measured between the line drawn towards the sun from a point on earth and the horizontal surface. When the sun is on the horizon, the solar altitude is 0° and when directly overhead, it is 90°.





The solar azimuth angle is the angle the projection of the line to the sun makes with the southern direction. The azimuth is normally referenced to due south in the Northern hemisphere. By convention, it is negative before noon (towards east of south) and positive after noon (towards west of south). (ESRU)

Ballast: A device used in conjunction with an electric discharge lamp to cause the lamp to start and operate under the proper circuit conditions of voltage, current, wave form, electrode heat, etc.

Biological Oxygen Demand (BOD) : An indicator of the concentration of organic matter present in a sample of water. It measures the rate at which micro-organisms take in oxygen at a fixed temperature for a given period of time. Well treated municipal sewage would have a 5 day BOD value of about 20 mg/l. Very clean rivers water will have less than 1 mg/l. Moderately polluted rivers may have values between 2 to 8 mg/l.

Building commissioning: The start-up phase of a new or remodelled building. This phase includes testing and fine-tuning of the equipments and their systems to assure the proper functioning and adherence to design criteria. Commissioning also includes preparation of the system operation manuals and instructions for the building maintenance personnel.

Caoutchouc : Natural rubber obtained as a latex from various tropical plants.

Contour trenching: An earth embankment or ridge and channel arrangement constructed parallel to the contours along the face of a slope at regular intervals, on long and steep slopes (in sloping areas with slopes >10%). The area is used for reducing run-off velocity, increasing distance of overland run-off flow, holding moisture and minimising sediment loading of surface run-off.

Embodied energy: It is the energy expended on a material or product to make it available to the users. It may include the energy used for transporting the material/product.

Fenestration: Any opening or arrangement of openings in a building (normally filled with glazing) that admits daylight and any devices in the immediate proximity of the opening that affect light distribution (baffles, louvers, etc.)

Formaldehyde: A gas used widely in production of adhesives, plastics, preservatives, and fabric treatments and commonly emitted by indoor materials that are made with its compounds. It is highly irritating if inhaled and is now listed as a probable human carcinogen.

Heat island effect: An area, such as a city or industrial site, having consistently higher temperatures than the surrounding areas because of a greater retention of heat, due to buildings, concrete, and asphalt.

HVAC (Heating, Ventilation, and Air Conditioning) system: The equipment, distribution systems, and terminals that provide either collectively or individually, the process of heating, ventilating, or air-conditioning to a building or portion of a building.

Life-cycle: The consecutive, interlinked stages of a product, beginning with raw materials acquisition and continuing with manufacture, use and concluding with end of life activities such as recovery, recycling, or waste-management options.

Light pollution: Illumination of the night sky by electric lights as in an urban area.

Lumen (Lm): The SI unit of luminous flux. Radiometrically, it is the radiant power, as in luminous flux. Photometrically, it is the luminous flux emitted within a unit solid angle (1 steradian) by a point source having a uniform luminous intensity of 1 candela.

Micro climate: The climate of a small, specific place within an area, as contrasted with the climate of the entire area.

Sedimentation basin: A dam or basin for collecting, trapping, and storing the sediment produced by construction activities, to allow sediments to settle before the run-off is directed away.

U-value (thermal conductivity value): A measure of a material's ability to conduct heat. The lower the U-Value, the better the material's insulating capacity. The heat loss rate of a building is the product of U-value, surface area, and temperature difference between indoors and outdoors.

VOCs (Volatile Organic Compounds): Chemical compounds based on carbon and hydrogen structures that are vaporized at room temperatures. VOCs are a type of indoor pollutant.

Annexures

1

A scan of eco-housing technologies and techniques

A brief scan of some of the technologies and techniques that could be useful for implementing the eco-housing guidelines is given below. More comprehensive reviews can be obtained from the list of internet based resources given in Annexure 2.

1.0 Site preparation



1.1 Mulching

Mulching is one of the simplest and most-beneficial practices used in landscaping. Mulch is simply a protective layer of a material that is spread on top of soil. Mulches can either be organic, such as grass-clippings, straw, bark chips, and similar materials, or inorganic, such as stones, brick chips, and plastic. Both, organic and inorganic mulches have numerous benefits, such as: protect soil from erosion; reduce compaction from impact of heavy rains; conserve moisture, reducing the need for frequent waterings; maintain a more even soil temperature; prevent weed growth; keep fruits and vegetables clean; keep feet clean, allowing access to the garden even when damp; and provide a 'finished' look to the garden.

1.2 Phytoremediation

Phytoremediation involves the use of plants to remediate contaminated soils, sludge, sediments and water. It supplements, and in some cases replaces conventional mechanical clean-up technologies. It is mostly used for sites with low to medium contaminant concentrations, and contamination in shallow soils.(UNEP-IETC, 2003a)

2.0 Building Materials and Technologies



2.1 Prefabrication

Prefabrication of building components in factories is possible, like that of walls, floors, roofs, windows, doors etc. This helps to save time, labour costs and ensures better quality. Even if onsite construction is done, some prefabricated components like windows and doors could be used.

2.2 Compressed Earth Blocks(CEB)

CEB's are earthen bricks compressed with hand-operated or motorized hydraulic machines. To produce them, soil (raw or stabilised) is slightly moistened, poured into a steel press, and then compressed. The soil should be of good quality, and should not contain any organic material that can decompose. Stabilisers like cement, lime, or gypsum, ensure better compressive strength and water resistance. The advantages of

CEB's are: uniform sizes and shapes, use of locally-available materials and reduction of transportation; avoidance of wood in manufacturing; lower production cost and energy input compared with fired bricks.

2.3 Concrete Hollow Blocks

Concrete block construction are available in various sizes and shapes. Compared to fire clay bricks, their advantages are: better insulation properties; no fuel or wood required for production; voids can be used for filling with steel bars and concrete or with electrical installation and plumbing ; lighter in weight; easy to use.

2.4 Vertical Shaft Brick Kiln technology (VSBK) for brick production

It is an energy efficient and cleaner method of producing bricks, with 30 to 50 percent savings when compared with conventional methods. It consists of one or more rectangular, vertical shafts within a kiln structure. At a time, one batch of dried green bricks is loaded at the top of the shaft, followed by the next batch. A weighed quantity of powdered coal is spread on each layer uniformly to fill the gaps. The layers of green bricks gradually pass through the shaft encountering pre-heating, firing and cooling zones before they reach the exit at the bottom. The brick unloading is done from the bottom using a trolley on rails. The kiln can be operated year long and the investment is low. Suspended Particulate Matter can be reduced up to 90 %, while carbon dioxide emissions could be lowered by 30 to 50 %. The bricks are 95 % uniform and of high quality, unlike in conventional technologies where maintaining quality is difficult.

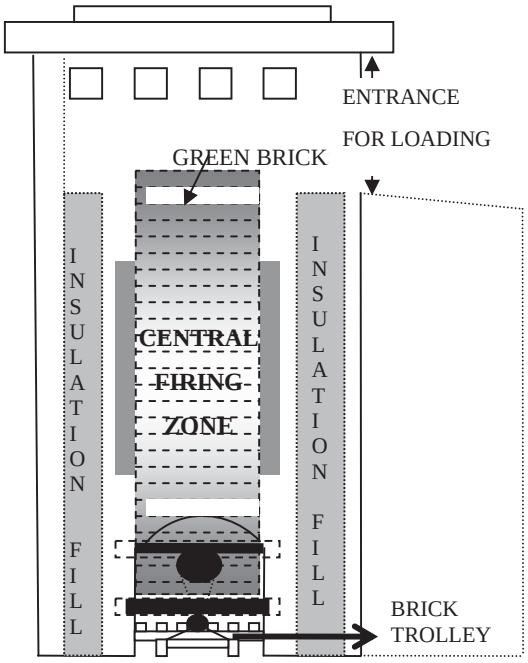


Fig A1.1: Vertical Shaft Brick Kiln

2.5 Habitech Self-Contained Housing Delivery System

The Habitech building system has been developed by the Habitech Centre in the Asian Institute of Technology, Thailand. The components of the building system are prefabricated modular interlocking concrete-based elements that can be put in place easily without the need for heavy equipment. Because the components are self-aligning, unskilled workers can take part in the building process. The production facility can be set up locally, creating jobs that generate income for local populations. A typical production facility will employ 30 to 40 workers in production and in construction for the project it

supplies. Production facilities can become permanent and address local construction markets. The scale of the production process could range between 2 houses a week to 10 houses a day. By using this system, construction costs could be lowered by 30 to 50 %.

3.0 Energy management



3.1 Cogeneration

Cogeneration or combined heat and power (CHP) refers to the use of a single source of energy (fuel), to produce both power and heat. In contrast, a normal thermal power plant produces electricity only. This is normally a decentralized system, implemented at the end user side. A large improvement in efficiency of the overall system is possible due to the usage of the waste heat and the avoidance of the transmission and distribution losses, as compared to using grid power from a thermal power plant. The heart of the system is the equipment producing power and heat. This could be based on gas turbines, steam turbines, IC engines, fuel cells or a combination of them.

3.2 Energy recovery heat exchangers

Indoor air can be 2 to 5 times more polluted than outdoor air. One of the reasons is that modern buildings have less ventilation and are much more sealed up for space conditioning and energy conservation objectives. For such spaces it is essential that there be a provision for leaking out the pollutant build up and the addition of fresh air. On the other hand, better ventilation will result in energy loss in air conditioned spaces. To avoid energy loss, an energy recovery heat exchanger is used. These heat exchangers allow the recovery of the cooling in the exhaust air, by transferring it to the incoming warmer fresh air and thus saving energy. The main modification required in the existing system is to re-route the fresh air and the exhaust air through the energy recovery heat exchanger. They also have the dual purpose of humidity control, due to condensation in the heat exchanger and/or by having desiccants that absorbs moisture from the incoming air. Once these desiccant materials are saturated with moisture, they could be regenerated by the incoming fresh air. By recovering energy, the heat exchanger adds to the cooling capacity of the HVAC system. Thus they reduce the need for a bigger air conditioning system, resulting in savings in the initial investment of new systems. The savings from such a system can be realised only in well insulated, air tight buildings.

3.3 Ground Cooling

At about 10-14 metres below the surface the soil has a constant temperature throughout the year, close to the mean annual outdoor air temperature. (Yannas, S., 2003) Hence during summers, it could be cooler than the outside air temperature and during winters it could be warmer. Ground cooling can be done by direct contact, by constructing the house partially or completely underground. The other method is by using earth to air heat exchanger pipes. For earth to air heat exchangers, outside air is taken through pipes buried in the ground. The air is indirectly cooled by the surrounding soil. The air at the

outlet of the exchanger is cooler than the outside temperature. Dehumidification could also occur, if the air is cooled below its dew point. (UNEP-IETC, 2004).

3.4 Movable insulation

A movable insulation can protect the roof from the sun during the day but can be retracted at night to allow radiant cooling of the roof surface to the cool night sky. The cooling effect can be enhanced by the exposure and insulation of a large thermal storage mass, like a roof pond. The roof pond has to be covered with an insulating layer during the day and opened up for radiative cooling at night. (UNEP-IETC, 2004, p.90)

3.5 Vapour absorption refrigeration system

The vapour absorption refrigeration system uses heat as the main energy input, unlike the conventional vapour compression refrigeration systems using electricity for the compressors. The heat could be any form of waste heat or solar radiation. It runs on the principle that certain liquids (absorbent) have a strong tendency to absorb specific vapours(refrigerant). The refrigerant liquid which evaporates at low temperature absorbs heat from surrounding when it evaporates and thereby cools the surrounding. For air-conditioning temperatures, pure water is used as the refrigerant and lithium bromide solution is used as the absorbent. Apart from reducing the use of electricity, it also helps to avoid ozone depleting refrigerants used in conventional systems. (UNEP-IETC, 2004, p.91)

3.6 High Efficiency Cooking stoves

Higher efficiency cooking stoves use several techniques to reduce the fuel input and emissions. These include: fine tuning the air-fuel ratio to ensure complete combustion without loosing much heat in the flue gas; improved insulation; increasing the length of travel of the flue gas to improve the heat transfer ; pre-heating the air before combustion ; and sometimes using catalytic converters for ensuring complete combustion.

3.7 Electronic Ballasts

Chokes or ballasts are required for starting and stabilizing the illumination of Fluorescent lights . Conventional ballasts are electromagnetic and have a higher loss of around 12 Watts. Electronic ballasts have a loss of 3 watts or less. Electronic ballasts also supply power to the lamp at a much higher frequency and this increases the efficiency and output from the lamp.

3.8 Compact Fluorescent Lamp(CFL)

They are smaller diameter, low power fluorescent lamps that are often used as an alternative to incandescent bulbs. They are much more efficient than incandescent lamps. For example, a 9 watt CFL can replace a 60 watt incandescent bulb. They also could last around 8 to 10 times longer.

3.9 High Intensity Discharge(HID) lamp

The HID lamps have a longer life and provide more light (lumens) per watt than most other light sources. They are available as mercury vapour, metal-halide, high-pressure sodium, and low-pressure sodium types. They are mostly used outdoors.

3.10 Occupancy sensors

It is a control device that senses the presence of a person in a given space, in order to control lighting and sometimes HVAC. They are mainly of three types: infrared, ultrasonic and acoustic sensors. Infrared sensors detect motion when someone (heat source) moves from one place to another. The sensor needs a direct line of sight to the occupants to detect motion; hence they are not ideal for spaces with partitions or with irregular shapes. They are comparatively less sensitive and hence chance for false triggering from small movements is less. Ultrasonic sensors emit high-frequency waves which bounce off objects in the room and return to the sensors. Objects moving in the space shift the frequency of the returning signals and this shift is detected by the sensors. They are very sensitive and do not require a direct line of sight to occupants. Hence there are chances for false signals like wind-blown curtains or papers. Acoustic sensors rely on voices, machinery sounds, keyboard tapping and other typical daily noises. This technology works well in areas with partitions or obstructions. Nowadays a combination of these technologies is used, to avoid false signals. For example, while an ultrasonic sensor would sense a wind blown paper and would tend to turn the lights on, the infrared sensor would not sense a movement of heat and would override the ultrasonic signal. Installation, commissioning and fine tuning of the system is critical to realize energy savings. (Santa Monica Green Building Programme)

3.11 Timers and Photosensors

Timers can be used to automatically turn on and off lights at specific times. For outdoor lighting, if we use a simple timer, then we have to reset it for the different seasons. In such case, it would be more convenient to use it in combination with other controls, like a photosensor. Photosensors senses the ambient lighting levels and accordingly controls the light output.

3.12 Dimmers

Dimmers are control devices used to reduce the lighting output.

3.13 Day lighting techniques

There are several methods by which artificial lighting can be reduced through enhancing day lighting. The techniques in vogue make use of specially designed openings, the optical properties of glazing materials, use of reflectors and the photometric characteristics of surfaces (texture, colour and transmissivity). The techniques can be

classified into: openings on vertical walls; openings in the roof; atria; and light ducts. (UNEP-IETC, 2004)

4.0 Renewable energy technologies



4.1 Solar Photovoltaic (PV) technologies

The solar PV (photovoltaic) technology comprises photovoltaic modules, which collect and convert solar energy into electrical energy and the balance of systems (BOS) designed to store, and deliver the generated electricity. Balance of systems includes the

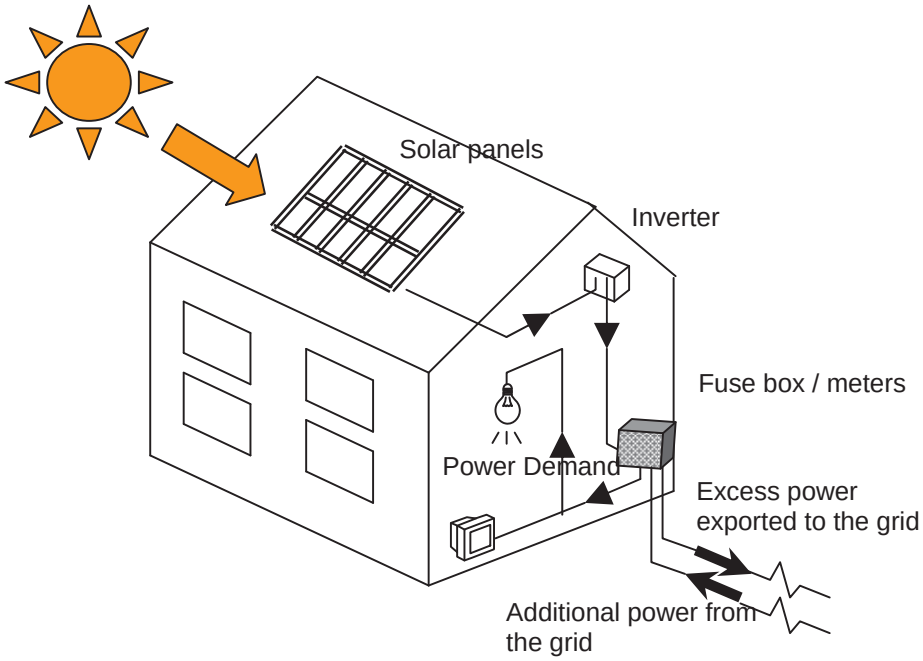


Fig A1.2: A grid connected solar PV system

support structure; wiring; batteries; power electronics and controls. The material commonly used for solar cell production is silicon – either crystalline (mono and poly) or amorphous silicon. Out of it, crystalline silicon cells are the most popular, though more expensive. Thin film solar modules are cheaper because less material is used and it has a relatively easier manufacturing process. In spite of this, it still has a smaller market, mainly due to its relatively lower efficiency. Generation is possible only when the sun is shining, so a battery is needed to store electricity and use it at night or during periods of insufficient sunshine. In places where sale to the grid is possible and attractive, the user could avoid the use of batteries, by using the grid as the storage medium. An inverter is used to convert the DC current into AC current. The amount of sunlight and hence the output from the PV module varies according to the angle of the module relative to the position of the sun in the sky. At present, PV based power is more costly compared to that of grid electricity in most cases. However, in places with no access to the electric

grid or with a high electricity cost, PV system is an attractive option. The PV module would have a life of 20 years or more, the inverter around 12 years and the battery around 3 to 5 years.

Building Integrated PV systems (BIPV)

PV arrays are normally mounted on special-support structures. However, they can also be made an integral part of the building envelope. There are several building elements that can readily accommodate PV, such as curtain walls, atria, and roofs. In addition, new products are being developed with PV as an integral component, such as active shading elements, building glazing, or roof tiles. It can thus replace conventional building materials, in addition to being a power generation option

Solar Home System (SHS)

It consists of a single PV module of 18–75 W capacity; a deep discharge-type lead acid battery; charge controller; 1, 2 or 3 CFLs (compact fluorescent lamps); and a DC power point for another appliance such as radio, tape recorder. The module generates energy that is stored in the battery and can be used at any time of the day.

PV-based mini-grids

A mini-grid refers to small power plants that supply three-phase AC electricity through low-tension distribution networks to households for domestic power, commercial (for example, shops, cycle repair shops, and flour mills) activities, and community requirements such as drinking water supply and street lighting. State-of-the-art batteries and inverters are used to ensure long life and reliable field performance. An appropriately designed mini-grid can easily supply power for 8–10 hours daily. Though there is no limit on the capacity of the mini-grid, PV-based mini-grids are typically of 25–100 kW. Installation, operation and maintenance of these mini-grids are normally contracted on a turnkey basis to the PV supplier. At the local level, the village community is expected to play a critical role in facilitating payment collection, monitoring of theft, complaint redress, etc.

Solar street lighting system

Street lighting is another application, which could utilize PV technology. A typical system could have the following configuration:

- 74 W solar PV module
- 12 V, 75 Ah tubular plate battery with battery box
- Charge controller cum inverter
- 11-watt CFL lamp with fixtures
- 4 m mild steel lamp post above ground level

Solar water pumps

Pumping of water is an application, which does not require battery storage. In this system, PV modules are directly coupled to the motor-pump unit and water is pumped as long as the sun shines. There are several system designs based on various types of motor and pump sets. For example, the most commonly used ones in India are 900 or 1800 W

DC surface and AC submersible motor-pump sets. These pumps are suitable for both drinking and irrigational requirement.

4.2 Solar water heating system

Solar energy could be used to heat water by using a solar water heating system, usually placed on the roof top. Water is passed through pipes in an absorber, which is placed in a glazed and well insulated collector. The water gets heated up and is then passed to an insulated storage tank. Thermo-siphon systems do not use pumps. The water flows by gravity and is based on thermodynamic principles. In forced circulation systems, a pump is used for water circulation. In most places, solar thermal systems are cost competitive with other modes of water heating. (UNEP-IETC, 2004, p.94)

4.3 Solar cookers

Several designs of solar cookers are available in the market. In India, the MNES (Ministry of Non-conventional Energy Sources), Government of India, is promoting solar box-type cookers, since the 1980's. These are available in different sizes, suitable for cooking for a family or a group of 6–8 persons. The approximate cost is USD 50-70 depending on models and size. Each cooker can save the use of 40 to 60 Kg of LPG (liquefied petroleum gas) per year. Solar dish cookers are used for community cooking. A dish cooker of 4 m^2 collector area can serve for 10-15 people per day. The approximate cost is USD 95-120/m^2 of the collector area of the cooker. Solar cookers need south-facing gallery or open space free from shadow. The place should be free from shadow for at least four hours during the day around noon time. Kitchens having south-facing wall can be provided with a retractable /sliding platform on the outside to keep the solar box cooker. This will reduce the work of going to the terrace or open-ground and solar cooking can be monitored from the kitchen.

4.4 Solar stills

They use direct solar energy for desalting saline water. These devices generally imitate a part of the natural hydrological cycle in that the saline water is heated by the sun's rays so that production of water vapour increases. The water vapour is then condensed on a cool surface, and the condensate is collected as water. In a solar still plant, the only moving part is the pump, used to pump saline water from the well. The solar still can de-salt saline water having a wide range of salinity, including sea water. In addition, it also removes toxic ions and bacteriological contamination. Thus, solar stills are ideal to provide safe drinking water to isolated communities of small villages, islands, lighthouses, and salt works. The average yield of a 1 m^2 single slope, single basin, solar still is about 2 litres per day. The capital cost of a commercial solar still of 1 m2 area is about USD 120. Some preconditions for setting up solar stills of relatively larger sizes are as follows:

- Uninterrupted supply of saline water preferably over 10,000 ppm and sunny weather throughout the year.

- The quality of the glass sealing plays a very crucial role as far as performance of still is concerned as vapour-leakage through the joints appreciably reduce the output.

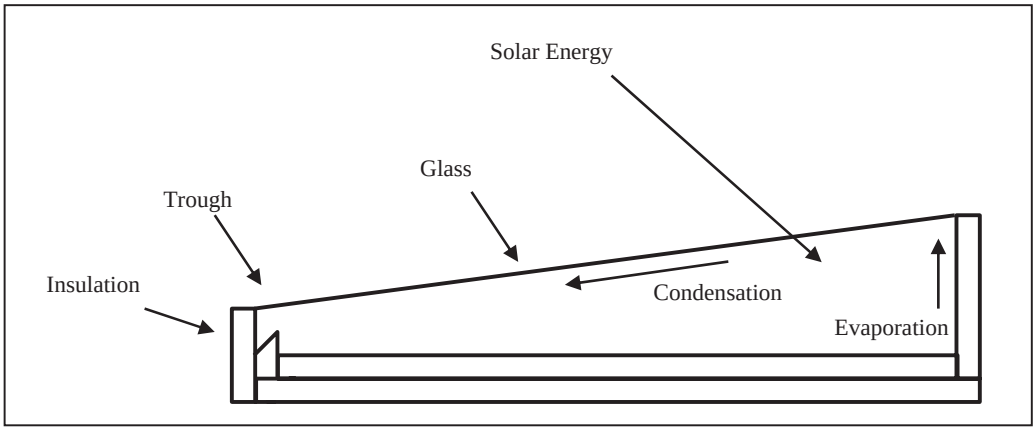


Fig A1.3: Solar still

4.5 Wind energy

A wind turbine transforms the energy in the wind into mechanical power, which can then be used directly for work(pumping, grinding etc.) or for further conversion to electric power. The key factors that decide the suitability of a site for wind power and the kind of equipments are: how often the wind blows and at what speeds; how turbulent the wind is; and the wind direction.

4.6 Biomass

The use of biomass for energy is considered a carbon neutral activity, since it absorbs the same amount of carbon in growing as it releases when consumed as a fuel. Another advantage is that it can be used to generate heat or electricity with the same equipments that are now used with fossil fuels. Instead of burning the loose biomass fuel directly, it could also be used conveniently in a compacted form as briquettes. Biomass energy can also be used as bio-gas by an anaerobic digestion process. This is being widely promoted in rural areas as a source of energy for cooking, though it could have other applications like small scale power generation. The residue could be used as manure.

4.7 Mini or Micro Hydel power

Hydro power is one of the cheapest, and cleanest sources of energy, though big dams result in many environmental and social problems. Smaller dams (mini or micro hydro power) are free from these problems and could be used for power generation in remote areas that have no access to the grid.

5.0 Water supply and use



Rainwater harvesting is traditionally practised in many parts of Asia, e.g., in Maldives this is the only source of drinking water in many islands. PVC tanks are predominantly used for storing rainwater. The decision whether to store or recharge water depends on the rainfall pattern of a particular region. Maldives being a high rainfall zone, rain falls throughout the year, barring a few dry periods. In such a case, one can depend on storage tank as the period between two spells of rain is short. Rainwater drainage pipes collect rainwater from roof to storage container. Appropriate precautions should be taken to prevent contamination of stored water. Mesh filters provided at mouth of drain pipe prevent leaves and debris from entering the system. If stored water is to be used for drinking, a sand filter should also be provided. Underground masonry/ reinforced cement concrete tanks, or over ground PVC tanks could be used for storage of rainwater. Each tank must have an overflow system connected to the drainage/ recharge system.

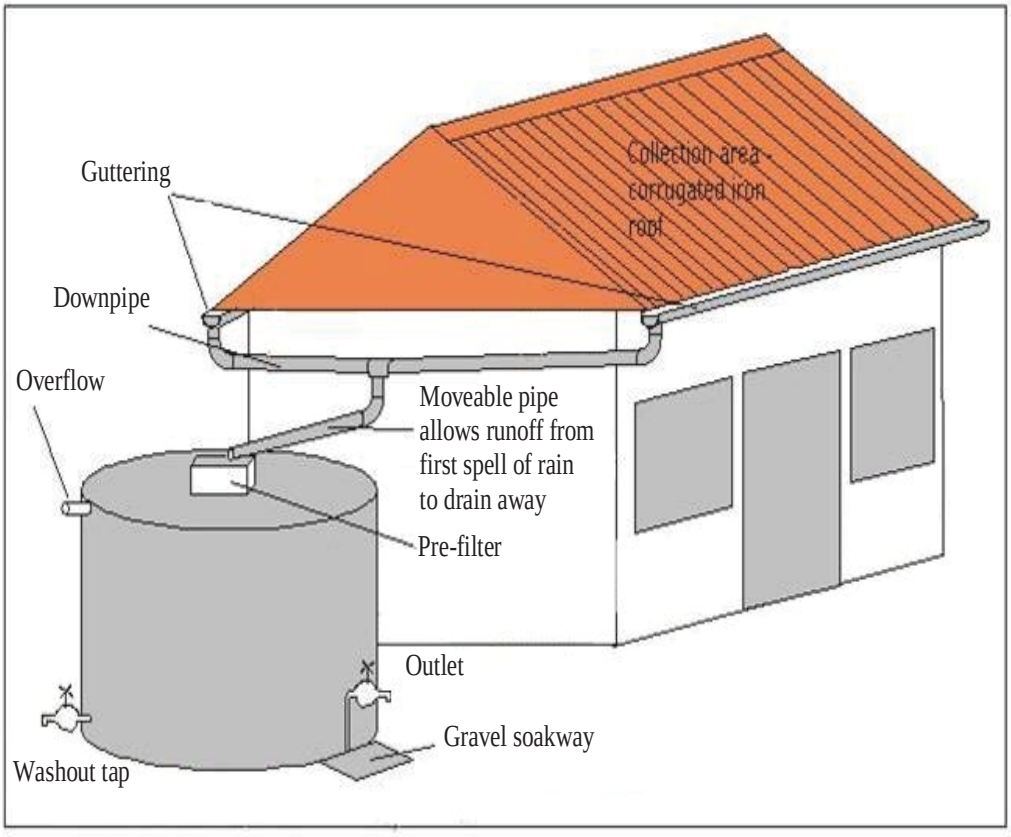


Fig A 1.4: Rainwater harvesting system

Rainwater collected from rooftops is free of mineral pollutants like fluoride and calcium salt but is likely to be contaminated by air and surface pollutants. All these contaminations can be prevented largely by flushing off the first 10-20 minutes of rainfall. Water quality improves over time during storage in tank as impurities settle in the tank if water is not disturbed. Even pathogenic organisms gradually die out due to storage. Additionally, biological contamination can be removed by other means.

5.2 Plumbing Fixtures

- Low-flow flush toilets: Low-flush toilets have a flow rate of 6 litres/flush, while ultra-low-flush toilets are available with a flow of 3.8 litres/flush.

- Low-Flow Urinals: Low-flow urinals consume water at the flow rate of 3.8 litres/flush. Use of an electronic flushing system or magic eye sensor can further reduce the flow of water to 0.4 litres per flush.

- Waterless urinals: Waterless urinals use no water but a biodegradable liquid for cleaning. These functions by allowing the urine to pass though the biodegradable liquid using a funnel system called cartridge thus preventing any odour and maintains a hygienic surrounding. The advantage of using such a system is not only saving water but also reducing the load in the sewer system. The average life of the cartridge is 7000 uses.

- Water taps: The use of conventional faucets results in flow rates as high as 20 lpm (litres per minute). Low-flow faucets are available which can result in withdrawal of water at a flow rate of 9.5 lpm. In addition to this, further reduction of water consumption is possible by using auto control valves, pressure-reducing device, aerators and pressure inhibitors for constant flow and magic eye solenoid valve self-operating valves.

- Showerheads: Showers of different diameters at different pressures result in different flow rates. The conventional showerheads have a range of flow rates of 10–25 lpm. Fixtures are available with flow rates of 9.5 lpm.

5.3 Water Treatment Technologies

Water-borne diseases can be caused by microbiological contamination. Excessive levels of fluoride, nitrates, iron, and arsenic can cause severe health disorders. Water needs to be stored properly and treated to national or WHO (World Health Organisation) standards, before being used for drinking purpose.

5.3.1 Household level treatment

Some means of disinfecting water at household level are enumerated below:

- Boiling: Boiling is a very effective method of purification and very simple to carry out. Boiling water for 10 to 20 minutes is enough to remove all biological contaminants.
- Chemical disinfection using chlorine: Chlorination is done with stabilised bleaching powder (calcium hypo chlorite, CaOCl2), which is a mixture of chlorine and lime. Chlorination can kill all types of bacteria and make water safe for drinking purposes. About 1 gm (approximately ¼ tea spoon) of bleaching powder is sufficient to treat 200 litres of water. Sometimes chlorine tablets are used. They are easily available commercially. One tablet of 0.5 g is enough to disinfect 20 litres of water.
- Filtration
  - ✓ *Charcoal water filter*. A simple charcoal filter can be made in a drum or an earthen pot. The filter is made of gravel, sand and charcoal, all of which are easily available .
  - ✓ *Sand filter*. Sand filters have commonly available sand as filter media. They are easy and cheap to construct. These filters can be employed for treatment of water to effectively remove turbidity (suspended particles like silt and clay), colour, and micro-organisms.
  - ✓ *Ceramic filter*. These filters are manufactured commercially on a wide scale. Most water purifiers available in the market are of this type.

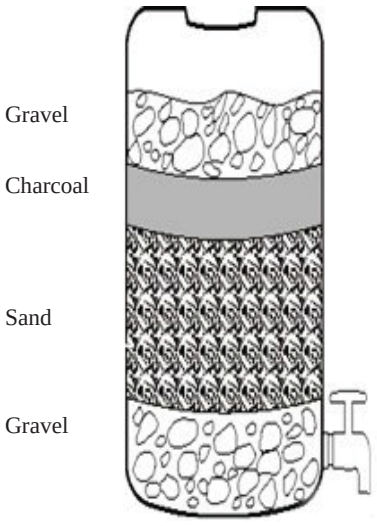


Fig A 1.5: Charcoal water filter

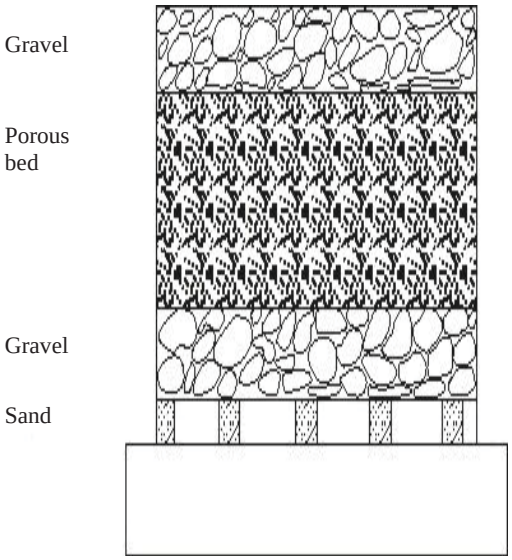


Fig A 1.6: Sand filter

5.3.2 Community level water treatment

Other systems are available for various kinds of community applications. For example, an on-line dosing coagulant system could be used to prevent microbial growth in treated, stored water. Systems have been developed to treat brackish water, fluorides, arsenic, and iron. These are also available as hand pump attachments. The particles are either adsorbed on a resin or onto a catalytic media. Another option for providing quality water at low cost is to use 'package plants.' Package plants consist of various components of the treatment process, such as chemical feeders, mixers, flocculators, sedimentation basins, and filters in a compact assembly. As these units are assembled based on standard designs, they are cheaper as compared to those that are built on site.



Fig A 1.7: Arsenic removal kit with hand pump

6.0 Waste water treatment and sanitation



6.1 Wastewater treatment

Wastewater can be treated onsite or off-site. The common on-site treatment is done by

- Pit latrines and Pour flush latrines
- Composting toilets
- Septic tanks and Imhoff tanks

The common off-site treatment systems are

- Activated sludge treatment
- Trickling filtration
- Constructed wetlands
- Simple anaerobic systems
- Upflow Anaerobic Sludge Blanket (UASB)
- Lagoons or ponds
- DEWATS (Decentralised WastewaterTreatment Systems)

There are several variations and improvements of these systems. There are also several land based treatments, which are more suitable for arid and semi-arid regions.

6.1.1 On-site treatment systems

6.1.1.1 Pit latrine and Pour flush toilet

In pit latrines, the excreta is collected in a pit in the ground. The main treatment is by the anaerobic decomposition by bacteria. The sludge has to be emptied. (UNEP-IETC, 2000).

The pour flush toilet is similar to the pit latrine in terms of collection and treatment. The main difference is that water is used to flush the excreta and a water seal is used to avoid insects and odour. (UNEP-IETC, 2000).

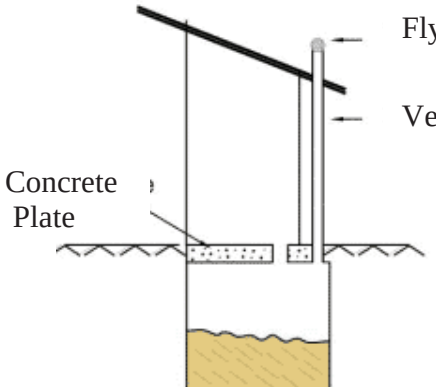


Fig A 1.8: Pit latrine

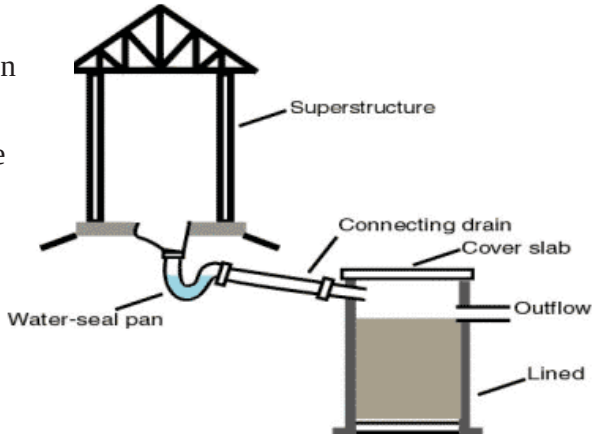


Fig A 1.9: Pour and flush latrine

6.1.1.2 Composting toilet

The toilet is above ground with opening for air to come in, to enable aerobic decomposition. Household organic waste can be added. To adjust the carbon to nitrogen ratio and moisture, saw dust and other materials can also be added. Like ordinary composting, the full process would take several months. A six months storage volume is recommended. (UNEP-IETC, 2000).

6.1.1.3 Septic tanks and Imhoff tank

In areas not connected to the central sewerage, **septic tanks** are used on site. It is a small scale system providing the most elementary sewage treatment. It can be used with pour flush toilet or cistern flush toilet and can receive both blackwater and greywater. It consists of a sedimentation tank where the settled sludge is treated by anaerobic digestion and the suspended matter leaves the tank untreated to a leach drain. It is simple, durable, requires little space. Though its efficiency is low and the effluent has an odour., it is popular since it is cost-effective. (UNEP-IETC, 2000).

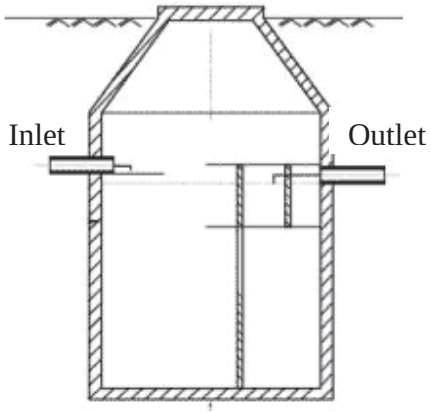


Fig A 1.9: Septic tank

An improvement over the septic tank is the **imhoff tank**, which has baffles in it to separate the fresh influent from the bottom sludge. The settling compartment is above the digestion chamber. The baffles prevent the up-flowing foul sludge particles from getting mixed with the effluent and thus the effluent remains fresh and odourless. Like the septic tank , it takes less space , but it needs regular de-sludging.

6.1.1.4 Simple Anaerobic treatment systems

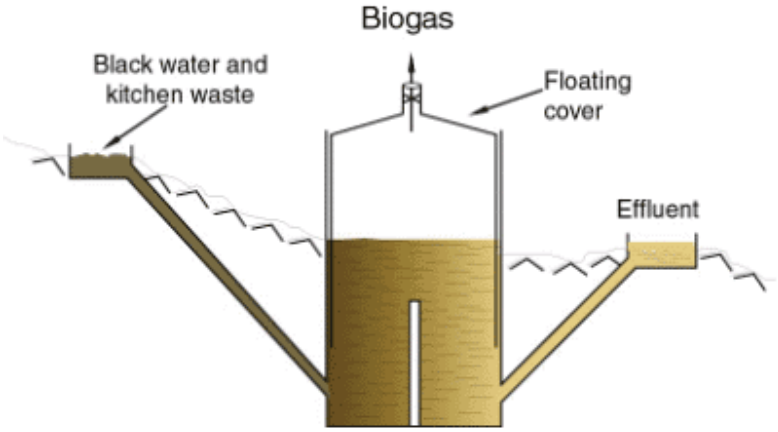


Fig A 1.10: Simple system for anaerobic treatment of wastewater

Anaerobic treatment is suited for wastewater high in BOD. The figure shows a simple method used to treat blackwater and kitchen waste. Anaerobic treatment results in the production of carbondioxide and methane (biogas), which is collected. (UNEP-IETC, 2000).

6.1.2 Off-site treatment systems

Off-site treatment is for waste water that is conveyed using a sewerage system

6.1.2.1 Activated sludge treatment

It consists of a primary treatment, which consists of mechanical screening to remove the suspended solids. This includes: removal of light weight, gross materials; removal of heavier, finer materials like sand; sedimentation in tank to remove finer solids. This is followed by the secondary treatment. Here aeration is provided by mechanical means to the primary treated wastewater in an aeration chamber. The chamber contains activated sludge. Aerobic bacteria attached to the sludge consume the organic matter in the waste water. The waste water resides in the chamber for a few hours. The sludge formed as a result of the action of the bacteria is carried over to a sedimentation tank, where the sludge settles down. The sludge is pumped back to the aeration chamber. Depending on the flow rate of wastewater, several parallel trains of primary and secondary stages can be

employed. It can also be operated in batches, rather than continuously. (UNEP-IETC, 2000)

6.1.2.2 Trickling filtration

It also has a primary treatment, where mechanical screening of solids is done. The secondary treatment is done by passing the waste water through the trickling or biological filter. The filter is a bed of solid media, such as stones or special plastics etc. Its purpose is to provide a surface for the aerobic bacteria to attach and to allow flow of air. The bacteria attached to the solid media consume the organic matter in the waste water. Aeration is by natural means, hence lesser energy is consumed. The sludge formed as a result of the action of the bacteria is carried over to a sedimentation tank, where the sludge settles down. The sludge is not pumped back. Compared to activated sludge process, the energy requirement is less, but the area required is higher. It can also be operated in batches, rather than continuously. (UNEP-IETC, 2000)

6.1.2.3 Constructed wetlands

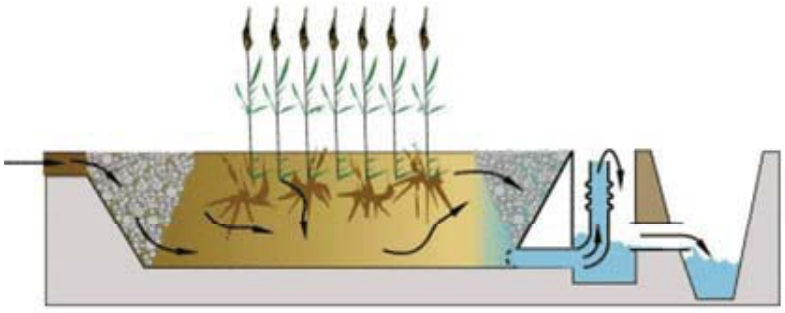


Fig A 1.11: Constructed wetlands

Natural wetlands help protect water quality, by transforming many of the common pollutants in wastewater into harmless by-products or essential nutrients. This idea has led to the development of constructed wetlands that can be used for the treatment of pre-treated domestic or industrial waste water. Different wetland systems types and alternative plant species can be considered in constructed wetlands. It can be made on the surface like natural wetlands (Free Water Surface Systems) or the waste water can flow below the surface (Subsurface Flow Systems). It has a high treatment efficiency. The disadvantages are that of high cost, high space requirement, and that good care needs to be taken during the first 2 years. The Root Zone treatment system, is one such system developed in Germany. The land area required for a treatment plant is around 30-35 m^2/m^3 of waste water treated per day. According to Indian standards for residential communities with population up to 20000, the quantity of water consumed and therefore waste water generated (litres per head per day) is equal to 70–100 litres. In India, the cost of a root zone treatment plant that could treat 1000 LPD of sewage is about USD 2,380.

6.1.2.4 Upflow Anaerobic Sludge Blanket (UASB)

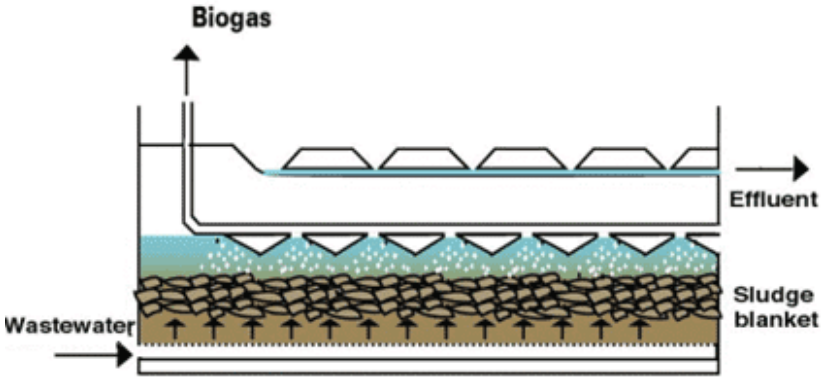


Fig A 1.12: UASB reactor

The UASB reactor contains a sludge blanket of anaerobic bacteria, which have developed into granules. Settled wastewater is passed upward through the reactor. The anaerobic action of the bacteria on the waste water produces carbondioxide and methane. The gases also helps in better mixing between the wastewater and the granules of bacteria. The granules are not carried over with the upflowing wastewater and hence a high concentration of bacteria is maintained in the tank. The treated effluent needs further aerobic treatment to reduce its BOD and odour. (UNEP-IETC, 2000).

6.1.2.5 Lagoons or Ponds

A lagoon is a shallow excavation in the ground (1 to 2 m deep), into which the wastewater is collected. It is generally unlined and percolation of wastewater into the soil and groundwater takes place. They are effective in reducing BOD, and SS. Due to the longer residence time, in the order of days, pathogenic bacteria and viruses also die off compared to an activated sludge treatment plant. Most of the solids are removed by sedimentation. The aeration occurs naturally by diffusion and wind movement. The oxygen is supplemented by algae, which produces it photosynthetically in the presence of sunlight.Three conditions could occur in the pond:

- Anaerobic: In this case anaerobic bacteria acts and methane gas is produced.
- Facultative: Whenever sunlight is present, algae produces oxygen and conditions are aerobic. Otherwise it is anaerobic. In such conditions, facultative bacteria acts, which can survive in both aerobic and anaerobic conditions.
- Aerobic: In this case aerobic bacteria acts.

There could be a series of lagoons, the first one or two being anaerobic, the middle ones being facultative and the final ones aerobic. The sedimentation is mostly is the initial anaerobic ponds. They are simple to construct, have high pathogen removal rate, little maintenance, and high treatment efficiency. But they require large permanent space requirement.

6.1.2.6 DEWATS (Decentralised Wastewater Treatment Systems)

DEWATS is a concept that encourages the use of a combination of appropriate, low-cost, easy to operate and low maintenance sewage treatment technologies. It is based on the following treatment systems:

- Sedimentation and primary treatment in sedimentation ponds, septic tanks,or Imhoff tanks.
- Secondary anaerobic treatment in fixed bed filters or baffled septic tanks.
- Secondary and tertiary aerobic/anaerobic treatment in constructed wetlands or ponds

These systems are combined in accordance with the wastewater influent and the required effluent quality.

6.2 Sludge treatment

Sludge is mainly from 2 sources

- Sludge produced from waste water treatment. They consist of:
  - ✓ Suspended solids
  - ✓ Soluble solids converted to bacterial cells
- Faecal Sludge

For safe use or disposal, they have to be stabilized aerobically or anaerobically, to reduce the BOD further. Two common methods are anaerobic digestion and composting: (UNEP-IETC, 2000).

6.2.1 Anaerobic digestion or bio-methanation

Bio-methanation is the process of conversion of organic matter in the waste (liquid or solid) to biogas and manure by microbial action in the absence of air (anaerobic digestion). The process has two benefits: it yields biogas, which can replace conventional fuels and it provides digested sludge, which can be used as a high nutrient fertilizer.
The bacteria decompose the organic wastes to produces a mixture of methane and carbon dioxide gas (biogas). The process is maintained at around 35°C. After digestion, the sludge is passed to a sedimentation tank where it is thickened. The thickened sludge needs to be treated further prior to reuse or disposal. If needed, the gas can be used to heat the tank to maintain the temperature. (UNEP-IETC, 2000).

6.2.2 Composting

It is an aerobic process, where bacteria act on the sludge to produce more stable organic material (humus). The humus is very good as a soil conditioner. The optimum conditions are a moisture content of about 50 % and a carbon to nitrogen ratio of about 25 to 30 and a temperature of 55 °C . The carbon to nitrogen ratio is low (5 to 10) for wastewater sludge, since it is rich in nutrients. It is also high in moisture. Materials like dry saw dust, mulched garden wastes, forest wastes and shredded newspaper have a higher carbon to nitrogen ratio. They should be added to adjust both the moisture and carbon to nitrogen ratio. To destroy the pathogens, the temperature of 55 °C has to be maintained for 2

weeks. During this period, the material has to be turned every 2 to 3 days to ensure that the temperature is maintained throughout the compost and for proper aeration. This immature compost then should be allowed to mature for around 12 weeks, before it could be used. (UNEP-IETC, 2000).

6.3 Stormwater treatment

Stormwater collects pollutants and solids along the path it moves. Separately collected stormwater can be treated by the following methods(UNEP-IETC, 2000).

- Filter strips: gently sloping vegetated area, where water is drained.
- Swales: long shallow channels, where water is drained.
- Filter drains and permeable surface: Water permeates through permeable surfaces and through permeable materials below the soil.
- Infiltration devices: Water is directed to soakways and infiltration trenches, located below the ground. Water is stored there and allowed to infiltrate into the soil.
- Basins and ponds: Storm water is directed into basins and ponds from where it infiltrates into the soil. Basins are storage area that is dry during dry weather. Ponds have water throughout the year.

7.0 Solid waste management



7.1 3 R's- Reduce, Reuse and Recycling

The priority is in the order of reduce, reuse and recyle. Preventing or reducing the generation of waste is the best option. Wherever possible, the waste could be reused as it is. Recycling refers to the reprocessing of materials recovered from wastes, into a new product. This could also include processes such as composting and anaerobic digestion. It helps to reduce the use of virgin raw material and reduces energy use. Some materials like glass and metal can be recycled for any number of times. Other materials like paper can be recycled a few times only, due to the shortening of the fibres. Often, a certain amount of virgin material needs to be added for such materials and this is termed as downcycling.

7.2 Anaerobic digestion and Composting, explained in the section on sludge treatment, could be used for treating the organic solid waste.

7.3 Materials Recovery Facility(MRF)

The MRF is a facility that receives, separates and prepares recyclable materials from the waste, before sending them to potential users.

7.4 Mechanical Biological Treatment (MBT)

These are a flexible mix of mechanical and biological treatment methods, used to recover all type of resources from a mixed waste stream. The recovered materials could then be recycled. The mechanical part is similar to the MRF and the biological treatment normally consists of anaerobic digestion or composting. The process also may produce a fuel from the waste, termed as Refuse Derived Fuel (RDF).

7.5 Incineration

Incineration involves burning the wastes at high temperatures. It could be done with energy recovery or without energy recovery. In modern incinerators, hazardous and recyclable materials are removed, prior to combustion. It is considered useful for destroying pathogens and toxins at high temperatures, especially from clinical wastes. It is also attractive in countries having a shortage of land. A main concern in incineration is the emission of harmful pollutants like dioxin and furan.

7.6 Sanitary landfills

Sanitary landfills are carefully designed landfills that prevent pollution of air, water and soil, and other risks to man and animals. Most of them have expensive and carefully constructed impermeable layers to contain leachates and drainage systems to take the leachate to a treatment plant or a storage tank. Aesthetic considerations are also taken into account.

2

Information resources

Building Technologies, Materials and Components

1. Advanced Buildings Technologies and Practices
   http://www.advancedbuildings.org
2. Air infiltration and ventilation centre (AIVC)
   http://www.aivc.org
3. Basin - Building advisory service and information network
   http://www.gtz.de/basin/
4. Dachverband Lehm e.V.
   http://www.dachverband-lehm.de/index_gb.html
5. Efficient Windows Collaborative
   http://www.efficientwindows.org
6. IEA - ECBCS Annex 35, HybVent
   http://hybvent.civil.auc.dk
7. Illuminating Engineering Society North America (IES)
   http://www.iesna.org
8. James & James database of Energy Efficient and Sustainable Building Suppliers and Services
   http://jxj.base10.ws/suppands/edseeb/index.html
9. Selector.com
   http://www.selector.com.au/
10. Valorisation of building demolition Materials and Products
    http://www.regione.emilia-romagna.it/vamp/index_e.htm

Case Studies

11. Aga Khan Award for Architecture
    http://www.akdn.org/agency/aktc_akaa.html
12. CEPHEUS project
    http://www.cepheus.de/eng/index.html
13. EASE, Education of Architects On Solar Energy And Ecology, Case Studies:
    http://www-cenerg.ensmp.fr/ease/sustain_main.html
14. Energy Comfort 2000 (EC2000)
    http://erg.ucd.ie/EC2000/ec2000_about.html
15. Eco-buildings
    http://ec.europa.eu/energy/res/fp6_projects/ecobuildings_en.htm
16. Green File of the European Green Building Forum
    http://www.egbf.org
17. European Solar Building Exhibition
    http://www.eu-exhibition.org/en.htm

18. Gaia Group
    http://www.gaiagroup.org/
19. Green Buildings BC
    http://www.greenbuildingsbc.com/
20. National Renewable Energy Laboratory, Center for Buildings and Thermal Systems
    http://www.nrel.gov/buildings_thermal/
21. IEA Task 23 International Energy Agency Solar Heating and Cooling Programme
    http://www.iea-shc.org/task23/index.html
22. Sustainable Building Information System (SBIS)
    http://www.sbis.info
23. GATE International e.V.
    http://www.gate-international.org/publications.htm
24. Solar Energy in European Office Buildings, Altener Mid-Career Education
    http://erg.ucd.ie/mid_career/mid_career.html
25. Energy Research Group (ERG), University College Dublin
    http://erg.ucd.ie/erg_downloads.html
26. Solarbau Monitor Programme
    http://www.solarbau.de
27. Sustainable Architecture and Building Design (SABD) Hong Kong, China,
    http://www.arch.hku.hk/research/BEER/index.html
28. Sustainable Refurbishment Europe (SUREURO)
    http://www.sureuro.com/

Education and research

1. Advanced Buildings and Technologies
   http://www.advancedbuildings.org/
2. Ecole des Mines de Paris, Centre for Energy and Process
   http://www.cenerg.ensmp.fr/english/index.html
3. Massachusetts Institute of Technology (MIT)
   http://web.mit.edu/bt/www/
4. Royal Melbourne Institute of Technology.
   http://www.rmit.edu.au/
5. University of Hong Kong, Department of Architecture, Building Energy Efficiency Research
   http://arch.hku.hk/research/BEER/
6. UK Government Sustainable Development discussion forum website.
   http://www.sustainable-development.gov.uk/index.asp
7. Uni Konstanz, Prof. Dr. E. Bucher (PV):
   http://www.unikonstanz.de/FuF/Physik/Bucher/Ishome.htm

8. Uppsala University Sweden, Ångström Solar Center (ÅSC)
   http://www.asc.angstrom.uu.se
9. Displays and Solar Cells, for Smart Transparent PV:
   http://www.msk.ne.jp

Energy Efficiency

1. Absorption cooling, Health-Get Link Directory
   http://www.healthget.com/info/absorption_cooling.html
2. Alliance to Save Energy
   http://www.ase.org
3. CLIMATE 1 - The Global Climate Data Atlas
   http://www.climate1.com/
4. Fraunhofer Institute for Solar Energy Systems
   http://www.ise.fhg.de/english/sitemap/index.html
5. World Energy Efficiency Association (WEEA)
   http://www.weea.org/

General resources on sustainable buildings

1. Archnet
   http://crisp.cstb.fr/links.htm
2. Building Advisory Service and Information Network, BASIN
   http://www.gtz.de/basin/
3. Building Services Research and Information Association
   http://www.bsria.co.uk/
4. BuildingGreen.com
   http://www.buildinggreen.com
5. CEVE, Experimental Center of Low Cost Housing.
   http://www.ceve.org.ar/ingles.htm
6. e3building
   http://www.e3building.net/en/index.php
7. Eco-housing mainstreaming partnership
   http://www.ecohousingindia.org/
8. Eco-portal
   http://www.environmentalsustainability.info/
9. Ecosustainable
   http://www.ecosustainable.com.au/links.htm
10. Energy Research Group (ERG), University College Dublin
    http://erg.ucd.ie/down_thermie.html

11. Environment co-housing in Europe
    http://www.eco-housing.org/
12. European Data Bank Sustainable
    http://www.sd-eudb.net/
13. European Green Building Forum
    http://www.egbf.org
14. Global Ecovillage Network (GEN)
    http://gen.ecovillage.org/
15. GREENTIE
    http://www.greentie.org
16. Hybvent
    http://hybvent.civil.auc.dk/puplications/research_papers.htm
17. IDEA, Interactive Database for Energy-efficient Architecture
    http://nesa1.uni-siegen.de/wwwextern/idea/main.htm
18. International Council for Research and Innovation in Building and Construction (CIB)
    http://www.cibworld.nl/
19. International Federation for Housing and Planning (IFHP)
    http://www.ifhp.org/
20. International Network of Engineers and Scientists for Global Responsibility
    http://www.inesglobal.org/
21. Practical Recommendations for Sustainable Construction (PRESCO)
    http://www.etn-presco.net/links/index.html
22. Skat Foundation and Skat Consulting
    http://www.skat.ch/
23. Social Science Information Gateway (SOSIG)
    http://www.sosig.ac.uk/
24. Sustainable Architecture, Building and Culture
    http://www.sustainableabc.com/
25. Sustainable Building Information System (SBIS)
    http://www.sbis.info/
26. Sustainable Cities Development System,
    http://www.sustainable-cities.org/about.html
27. Sustainable Refurbishment in Europe – SUREURO
    http://www.sureuro.com/
28. Sustainable Sources
    http://www.greenbuilder.com/sourcebook/
29. Technologies for Sustainable Development
    http://www.nachhaltigwirtschaften.at/english/index.html
30. TRIALOG
    http://www.tu-darmstadt.de/fb/arch/trialog/

31. Wuppertal Institute for Climate, Environment, Energy GmbH Working Group on Eco-Efficiency and Sustainable Enterprise,
http://www.oekoeffizienz.de/

Life Cycle Assessment LCA

1. Building Science at the University of California Berkeley
http://arch.ced.berkeley.edu/resources/bldgsci/index.htm
2. Europe Commission, Comparative study of national schemes
http://europa.eu.int/comm/enterprise/construction/internal/essreq/environ/lcarep/lcafinrep.htm
3. UNEP, Comparisons between Environmental Technology Assessment (EnTA) and selected other environmental tools (e.g. LCA):
http://www.unep.or.jp/ietc/publications/integrative/enta/aeet/3.asp
4. GDRC, Defining Life Cycle Assessment:
http://www.gdrc.org/uem/eia/lca-define.html
5. Green Building Challenge (GBC)
http://www.buildingsgroup.nrcan.gc.ca/projects/gbc_e.html
6. International Council for Local Environmental Initiatives (ICLEI)
http://www.iclei.org
7. International Initiative for Sustainable Built Environment (iiSBE)
http://iisbe.org
8. Society of Environmental Toxicology and Chemistry (SETAC)
http://www.setac.org
9. Stakeholder Forum for Our Common Future
http://www.stakeholderforum.org

Renewable Resources

1. Agency of Renewable Resources (FNR)
http://www.fnr-server.de/cms35/index.php?id=139
2. Austrian Strawbale Network
http://www.baubiologie.at/asbn/linkseu.html
3. Biomatnet, Biological Materials for Non-Food
http://www.nf-2000.org/home.html.
4. Brazilian Institute of Environment and Renewable Natural Resources
http://www.ibama.gov.br/
5. European Strawbale Discussion Forum
http://amper.ped.muni.cz/mailman/listinfo/strawbale

6. Strawbale projects worldwide
   http://www.bestofweb.at/sb_world.html
7. World Resource Institute (WRI)
   http://www.wri.org/

Renewable Energy

1. ASEAN Center for Energy
   http://www.aseanenergy.org/
2. CADDET, Centre for Analysis and Dissemination of Demonstrated Energy Technologies
   http://www.caddet.org/
3. Danish Wind Industry Association
   http://www.windpower.org/
4. Erneuerbare Energien Kommunikations- und Informationsservice
   http://www.energie-server.de/
5. EUFORES
   http://www.eufores.org/
6. EUREC
   http://www.eurec.be/
7. European Association for Renewable Energies (EUROSOLAR)
   http://www.eurosolar.org/new/en/home.html
8. Fraunhofer Institute for Solar Energy Systems
   http://www.ise.fhg.de
9. Independent World Council for Renewable Energy (WCRE)
   http://www.wcre.de/en/index.php
10. Intergovernmental Authority on Development (IGAD), Regional Household Energy Programme
    http://igadrhep.energyprojects.net/
11. International Energy Agency (IEA) Solar Heating and Cooling Programme
    http://www.iea-shc.org/
12. Lior-International
    http://www.lior-int.com/
13. Lior International, AGORES – A Global Overview of Renewable Energies
    http://www.agores.org/
14. Momentum Technologies LLC, the Source for Renewable Energy online business directory
    http://energy.sourceguides.com/index.shtml
15. National Renewable Energy Laboratory (NREL)
    http://www.nrel.gov/
16. Renewable Energy Policy Project (REPP)
    http://www.crest.org/

17. Solar Buildings Library
    http://wire0.ises.org/wire/doclibs/SolArchLib.nsf!OpenDatabase
18. Solar Energy links
    http://people.linux-gull.ch/rossen/solar/solarbookmarks.html
19. Solarserver, Forum for Solar Energy
    http://www.solarserver.de/index-e.html
20. Soltherm
    http://www.soltherm.org/
21. The Department of Energy, Utilities and Sustainability
    http://www.deus.nsw.gov.au/
22. World-wide Information System for Renewable Energy (WIRE)
    http://wire0.ises.org

Softwares

1. FirstRate house energy rating software
   http://www.seav.vic.gov.au/buildings/firstrate/
2. SUNCODE (SERI-RES)
   http://www.ecotope.com/
3. EQUEST;DOE-2 PowerDOE
   http://www.doe2.com/
4. EnergyPlus
   http://www.eere.energy.gov/buildings/energyplus/
5. TRNSYS
   http://sel.me.wisc.edu/trnsys/default.htm
6. LISA (LCA in Sustainable Architecture), also available case studies.
   http://www.lisa.au.com/
7. The Environmental Impact Estimator
   http://www.athenasmi.ca
8. ESP-r, integrated modelling tool, designed for the Unix operating system, with supported implementations for Solaris and Linux, made available at no cost
   http://www.esru.strath.ac.uk/Programs/ESP-r.htm
9. BEAT 2002, Building Environmental Assessment Tool 2002
   http://www.sbi.dk/en/publications/programs_models/beat-2002
10. Escale
    http://www.cstb.fr/http://crisp.cstb.fr/view_rdworks.asp?id_rdworks=11
11. Ecquer
    http://www.cenerg.ensmp.fr/english/index.html
12. Eco-Quantum,
    http://www.sbr.nl/default.aspx?ctid=2322

13. Greencalc
http://www.dgmr.nl/new/software/software_gc.html
14. Eco-effect
http://www.infra.kth.se/bba/bbasvenska/forsning/miljoweb/miljovardering/nysammanft.pdf
15. Envest2: environmental impact estimating software for the early planning phase
http://www.bre.co.uk/sustainable/envest.html
http://envestv2.bre.co.uk/
16. BREEAM environmental impact estimating software
http://products.bre.co.uk/breeam/index.html
17. LEED (Leadership in Energy and environmental Design), Credit based Green building estimating and certification system
http://www.usgbc.org/
18. GBToolTM (Green Building Tool)
http://www.iisbe.org/
19. CASBEE (in development)
http://www.taisei.co.jp/english/environment/05_repo_img/05_report.pdf

3

Tools and assessment methods for energy-related impact of buildings

The International Energy Agency had examined how tools and assessment methods can be developed and used to improve the energy-related impact of buildings on interior, local and global environments. (IEA, 2001) Guidelines are one of the many possible methods for facilitating a sustainable building. The whole list is being summarised here.

Table A1.1: Tools and assessment methods for energy-related impact of buildings (IEA, 2001)

TYPE OF TOOLS	DESCRIPTION	EXAMPLES (mostly from Europe and USA)
1. Life cycle assessment tools	analyses relationships between building specifications and potential environmental impacts, during one or more stages in the life cycle.	http://www.eere.energy.gov/buildings/tools_directory/subjects_sub.cfm
2. Energy and ventilation modeling software	Used to optimise building performance. Could be embedded into LCA tools.	
3. Passive tools		
Laws, Regulations and Conventions	Legally binding requirements.	• European building product guidelines • thermal performance regulations • air pollution regulations • noise regulations
Guidelines	declaration of intent and basic approaches to achieve it	• Environmental handbook for architects – Germany, Ecological building handbook Ministry for the Environment - Germany
Checklists	help structure activities and decision-making processes	• Checklists for energy efficient, ecological planning & building – Switzerland • Dutch packages of sustainable building measures – Netherlands
Ecological and quality assessment for buildings	Evaluation of the documentation. Usually a label or certificate is provided.	• GBC'98 assessment manual – international • BREEAM assessment method – Great Britain • AKÖH-Building certificate – Germany
Case-studies / Best practice / Example buildings	highlights positive examples	• GBC'98 – Example building – international • Best Practice Programme – Great Britain • SEV/ Novem examplar projects green building - Netherlands
Building passport / documentation	Complete description (and possibly evaluation) of the building and its properties	• The BM Bau building passport concept - Germany
Energy passport	Documentation that makes explicit the energy efficiency of the building	• Energy Demand Pass according to WSVO'95 - Germany • EC SAVE-Guidelines

		• Energy performance advice for existing buildings by energy companies - Netherlands
Element catalogue	evaluated information about functional elements in a building	• SIA D0123 Building construction according to ecological principles - Swiss • F 2249 Primary energy content in building – Germany • Element Catalogue – Editions AUM to LEGOE – Germany
Ecologically oriented specification aids	To introduce energy and environment related requirements	Ecological submission documentation – Switzerland
Product labelling – ecological and quality grading	To show that a product is ecologically superior to other comparable products	• Environment mark “Blauer Engel” (Blue Angel) - Germany • EC Environment mark - European Community • Wood with FSC mark (Forest Stewardship Council) – worldwide
Product descriptions	Unevaluated information of the product	• Criteria for product declaration SIA 493 - Switzerland • Product declaration - Bavarian Architectural Institute - Germany • Dutch MRPI-page –Netherlands
Recommendations and exclusion criteria	Impartial recommendations to reduce the health and environmental risk of building products and processes	• Schwarz: Ecology in Building (handbook)- Switzerland • Dutch instructions for environmentally sound do-it-yourself builders - The Netherlands
Plus and minus lists	Easy to understand lists, with specific recommendations on products to be avoided.	Test results in magazines such as “Öko-Test”, Germany