ENERGY EFFICIENT LANDSCAPES: A CASE STUDY IN THE NATIONAL CAPITAL REGION OF DELHI

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ABSTRACT

Landscaping gives the expression of freedom and extreme happiness in an individual's mind. This study discusses how to conserve energy in a site or a building through landscape architecture. Since the world is going through adverse climatic changes, it is important to conserve energy and do our best to make it a habitable place for our future generations.

Keywords: *Energy efficiency, landscape, open spaces*

SECTION 1: INTRODUCTION

Landscape architecture is one of the most significant form of art that has been practiced throughout ages and a basic need for humankind. Although landscaping is an important part of architecture as well as day-to-day to life, it becomes quite tedious to build up an environment with convincing energy efficient landscape designs. Energy efficiency in landscaping is important to study the extreme climate changes to provide a greener future. The objectives of this study are: *(a)* to study energy efficient landscapes and techniques; *(b)* to study the various landscaping features used in Delhi through a case study; *(c)* to study the energy efficiency in a building through landscaping; *(d)* formulate various design guidelines for landscaping in Delhi focusing on its climatic conditions; and *(e)* overall analysis of the collected data and conclusion.

Research questions in the study are as follows:

What are energy efficient landscapes and what are the factors affecting it?

Energy-efficient landscaping is the type of landscaping designed for the purpose of conserving energy. A well-designed, energy efficient landscape can reduce heating, cooling and lighting costs. In some

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circumstances, carefully positioned trees and shrubs can save up to 25 per cent of the energy in a typical household. Energy efficient landscaping has additional benefits like lower maintenance costs, a reduction in water use, a quieter home and cleaner air.

While designing an energy efficient building or even remodelling a home, much time is spent on the building envelope, electrical systems and appliances. But strategic exterior landscaping can affect the energy performance of our homes and make them more efficient. Well-placed plantings can cool the house in summer, warm it in winter, and save water year round. According to the Department of Energy, a landscape designed with conservation in mind saves enough energy to pay for itself within a span of just eight years.

- **Architectural Factors Affecting Energy Efficiency**

Following are some factors that directly and indirectly affect the microclimate of a region. These in turn, affect the thermal comfort and energy consumption of that site: Landscaping; Ratio of built form to open spaces; Location of water bodies; Orientation; Building Envelopes; and Materials used in Landscaping.

Landscaping

Landscaping refers to the activity that modifies the visible features of an area of land, including living elements, like flora or fauna; or what commonly is called as gardening; the art, craft of growing plants with an aim to create a beauty within the landscape; natural elements such as landforms; terrain shape and elevation; Water bodies; and abstract elements such as the weather and lighting conditions.

Landscaping is an extremely important element in altering the microclimate of a place. It reduces the direct sun from striking and heating up buildings surfaces. It also creates different air flow patterns and can be used to direct or divert the wind advantageously.

Open Spaces

Open spaces seen in conjunction with built forms govern air movement and heat gain and loss. In composite climate, compact planning with little or no space, would be advisable to minimize both heat gain and loss for which the ground should be soft and green.

Water Bodies

Water bodies absorb large amount of radiation and provide evaporative cooling. Areas near the water bodies are generally cooler during daytime and warmer at night time.

TABLE 1. CLASSIFICATION OF MICRO AND MACRO LEVEL

Micro Level	*Macro Level*
1. Erosion and sedimentation control	1. Urban head island effect
2. Storm water management	2. Site selection
3. Site disturbance	3. Brownfield sites
4. Water efficiency	4. Transportation
5. Innovative waster water technologies	5. Light pollution
	6. Local/regional material
	7. Rapidly renewable material
	8. Renewable energy

Orientation

Orientation of a building is significant mainly with regard to solar radiation and wind.

In cold regions, buildings should be oriented towards maximize solar radiation; the reverse is advisable for warm regions. In some regions where seasonal changes are very pronounced, both the situations may arise periodically.

The perimeter to area ratio (P/A) of a building is an important indicator of heat loss and heat gain. For greater P/A ratio, there should be more heat gain at daytime and more heat loss at night.

Building Envelope

The primary elements impacting the performance of a building envelope are: Materials and construction techniques; Roof; Walls; Fenestration and shading; and Finishes.

There are various factors affecting the energy conservation. It varies from macro level to micro level of the environment as shown in (Table 1). These can be classified as:

Elements of Landscape

The various elements of landscape are :

- Trees, planters and vegetation
- Pathways and walkways
- Softscape and hardscape
- Water bodies

Trees and Planters

Trees play a tremendous role in conditioning environment. They cut off 69 per cent of sun's heat from the ground, reduce wind velocity by 63 per cent, reduce dust pollution by 66 per cent, and reduce noise pollution by 50 per cent.

The selection of suitable plants for shading is dependent on the part of the building (example: walls, outdoor living areas, windows) to be shaded. Different types of plants like trees, shrubs and vines can be selected on the basis of their growth habitat (tall, low, dense, light permeable) to provide the desired light for various window orientation and situations.

Pathways and Walkways

Pathways in landscaping connect from one place to another, create focus and give direction to the people. Landscape architects, make a distinction between the terms *walkway* and *pathway* (See Table 2).

TABLE 2

S.No.		*Pathways*	*Walkways*
1.	Shape	A meandering route	Often straight routes
2.	Material	Casual & rustic materials Eg. Loose gravel	Hard paving materials Eg. large slabs and pavers
3.	Width	0.9 M	1.2 M

Hardscape and Softscape

Hardscape and softscape are the absolute opposites of each other, yet both are necessary to make a landscape fully functional.

Hardscape is the hard stuff used in the landscaping of a yard: concrete, bricks, and stone. Other examples of hardscape include retaining walls, pavers for paths or patios, outdoor kitchens, water features, gazebos, decks, and driveways.

Softscape is the soft, growing stuff, like perennial flowers, shrubs, succulents, and trees. Softscape is mostly living, whereas hardscape is not.

Water Bodies

Water is a great modifier of microclimate. It causes a cooling effect due to evaporation especially in hot and dry regions. On the other hand, in humid regions, water bodies should be avoided as these add to the humidity of the atmosphere.

SECTION 2: ENERGY EFFICIENT LANDSCAPING TO CONSERVE ENERGY

As urban areas develop, modifications occur in the landscape. Roads, buildings, and other infrastructure replace open land and vegetation. Surfaces that were once permeable and moist generally become impermeable and dry. This development consequently, leads to the formation of urban heat islands—the phenomenon whereby urban regions experience warmer temperatures than their rural surroundings.

1. Reduction of Urban Heat Island Effect

Many urban and suburban areas experience increased temperatures compared to their outlying rural surroundings; this difference in temperature is what constitutes an urban heat island.

Causes of Urban heat island effect:

- Reduced Vegetation in urban areas;
- Properties of urban materials; and
- Urban geometry - refers to the dimensions and spacing of buildings within a city. Urban geometry influences wind flow, energy absorption, and a given surface's ability to emit long-wave radiation back to space.

Urban heat island effect can be reduced by the following:

Trees and Vegetation

Shading trees and small plants such as shrubs, vines, grasses, and ground cover, help cool the urban environment.

Trees and vegetation cool urban climates through evapotranspiration and shading. Leaves and branches decrease the amount of solar radiation that reaches the area below the canopy of the tree or plant. The amount of sunlight transmitted through a canopy varies based on plant species. In summer time, generally 10 to 30 per cent of the sun's energy reaches the area below the tree, whereas in winters, the range of sunlight transmitted through the tree is much wider—10 to 80 per cent—because evergreen and deciduous trees don't have the same winter-time foliage, with deciduous trees losing their leaves and allowing more sunlight through.

Trees and vegetation are useful as a mitigation strategy when planted in strategic locations around buildings. Researchers have found that planting deciduous species to the west is most effective for cooling the building, especially if the trees shade windows and part of the building's roof. Shading the east side of the structure also decreases air conditioning demand.

Planting trees to the south decreases summer-time energy demand. Depending on the trees, the building's height, the distance between the trees and the building, trees maybe detrimental to an energy efficiency strategy if they block useful solar energy in the winters, when the sun is quite low in the sky, without providing much shade during summers, when the sun is high in the sky.

Shading decreases surface temperatures below the tree canopy. These cooler surfaces, decrease the heat transmitted in buildings and the atmosphere.

Evapotranspiration. Vegetation and trees absorb water through their roots and emit it through the leaves—this movement of water is called as "transpiration." A large oak tree, for e.g., can transpire 40,000 gallons of water per year; an acre of corn can transpire 3,000 to 4,000 gallons a day. Evaporation, the conversion of water from liquid to gas, i.e. water vapor, also initiates from the soil around vegetation and from trees and vegetation as they intercept rainfall on leaves and other surfaces. Together, these processes are called as evapotranspiration.

Evapotranspiration cools the air by utilising heat from the air to evaporate water. Evapotranspiration, alone or in combination with shading, can aid to decrease peak summer air temperatures. Various studies have evaluated the following reductions:

- Peak air temperatures in tree groves that are (5ºC) cooler in comparison to over open terrain.
- Air temperatures over irrigated agricultural fields that are (3ºC) cooler than air over bare ground.
- Suburban areas with mature trees that are (2 to 3ºC) cooler than new suburbs without trees.
- Temperatures over grass sports fields that are (1 to 2ºC) cooler than over bordering areas.

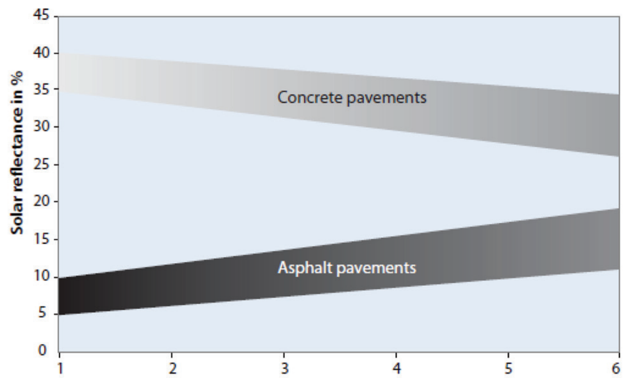
Cool pavers

These pavement technologies usually store less heat and may have lower surface temperatures in comparison to conventional products.

They can help address the issue of urban heat islands, that result in part from the increased temperatures of paved surfaces in the city or suburb.

Conventional pavements in India are *impervious concrete* and *asphalt*, which can reach peak summer-time surface temperatures of (48–67°C) (See Figure 1).

Fig. 1: Typical Solar Reflectance of Conventional Asphalt and Concrete Pavements overtime



Source: Reducing Urban Heat Islands: Compendium of Strategies

How it works : Solar energy is composed of ultraviolet (UV) rays, visible light, and infrared energy. Solar reflectance, or albedo, is a percentage of solar energy reflected by the surface. Most of the research on cool pavements has focused on this particular property, and is the main determinant of the material's maximum surface temperature. Albedo also impacts pavement temperatures below the surface, because less heat is available at the surface to be transferred into the pavement. Table 3 shows the Albedo percentages of some soils.

TABLE 3: ALBEDO PERCENTAGES OF SOME SOILS

Soil	*Albedo*
1. Moist dark cultivated	5-75%
2. Moist grey	5-15%
3. Dry sandy	10-20%
4. Wet sandy	25-35%
5. Dry sand dunes	20-30%
6. Dry soil	30-35%

Below mentioned are brief descriptions of potential cool pavements and their typical uses:

- ***Conventional asphalt pavements*** consist of the asphalt binder mixed with aggregate, can be changed with very high albedo materials or treated after installation to increase reflectance. This specific material has been applied for decades in a wide range of functions from parking lots to highways.

- ***Conventional concrete pavements*** are made by mixing Portland cement, water, aggregate, can be used in a wide range of applications like trails, roads, and parking lots.
- ***Other reflective pavements*** are made from a variety of materials, mostly used for low- traffic areas, such as sidewalks, trails and parking lots. Examples: Resin based pavements, which use clear tree resins in place of petroleum-based elements to bind an aggregate.
- ***Coloured asphalt and coloured concrete***, with added pigments or seals to increase reflectance;
  - **Resin based pavements** that use clear tree resins in place of petroleum- based elements to bind an aggregate;
  - **Coloured asphalt and coloured concrete**, with added pigments or seals to increase reflectance.
- **Non-vegetated permeable pavements** contain voids and are designed to allow water to drain through the surface into the sublayers and ground below:
  - Porous asphalt;
  - Rubberised asphalt, made by mixing shredded rubber into asphalt;
  - Pervious concrete; and
  - Brick or block pavers, are made from concrete or clay, and filled with rocks, gravel, or soil; available in the variety of colors and finishes that are designed to increase reflectance.
- **Vegetated permeable pavements**, like grass pavers and concrete grid pavers, utilize plastic, metal, or concrete lattices for support and further, allow grass or other vegetation to grow in the interstices.

SECTION 3: CASE STUDY OF TERI RETREAT CENTRE, GURUGRAM

Location: TERI Golf Course**,** Faridabad - Gurgaon Road, Gwal Pahari, Gurugram, Haryana 122102.

Project Details

RETREAT is a residential training Centre for executives, is designed to be self-sufficient, and independent of any external power supply. It consists of living quarters with 24 single-occupancy rooms and six suits complete with Conference Centre with a large hall, a dining hall, a lounge, recreational facilities and a library.

Architect – *Sanjay Prakash*

Client – Tata Energy Research Institute, New Delhi.

Area - 3000 sq m

Energy Efficiency Building Design Criteria and Factors

- Site selection, urban design, landscape planning;
- CO_2 emissions, acid rain, ozone depletion, rainforest depletion;
- Environmental policy, transport strategy, building maintenance;
- Energy performance, renewable energy, water conservation;
- Material selection, recycling of materials, waste management, disposal and reuse; and
- Air quality, thermal comfort, lighting and noise, hazardous materials.

Site Selection

- Site selection and development of site infrastructure to reduce vehicular transportation and easy access to daily facilities. Site layout with respect to wind direction and sun path;
- Appropriate erosion control mechanisms, top spoil preservation, prevent run-off from site and prevent heat island;
- Reduce site disruption by appropriate planning, preservation of natural vegetation, appropriate landscaping; and
- Energy efficient lighting on site including the use of renewable energy sources for external lighting.

Energy Efficiency in RETREAT Campus

- Use of phragmites for waste water treatment (See Figure 2).
- Use of renewable forms of energy;
- Use of solar passive strategies, use of onsite sources and sinks;
- Use of energy efficient lighting and control devices; and
- Enhance system efficiency and maximize use of renewable forms of energy.

Fig. 2: Phragmites used for treatment of sewage water

(*Source: teriin.org*)

Building Material Selection

- Best for options as per the climate suitability and specific construction requirements for that region;
- Allow significant reduction in transportation contributes to low embodied energy consumption and life cycle costs; and
- Use materials, which are manufactured from waste or recycled materials, products which can be reused.

1. Water Management

- Water quality standards and treatments required;
- Reduction of water usage by efficient fixtures and fittings;
- Reduce landscape water requirement by using indigenous species, enhancing irrigation efficiencies, restricting water consuming landscaping e.g. lawns;
- Waste water treatment/ recycling/ reuse; and
- Rainwater harvesting for storage/recharge.

2. Waste Management

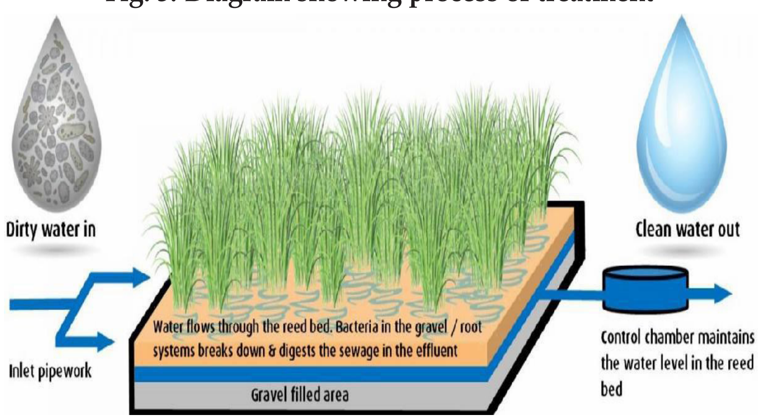
- Appropriate waste segregation and collection;
- Identity facilities for recycling of non-biodegradable wastes such as plastics, glass and paper;
- Develop decentralised treatment systems based on composting or anaerobic digestion process for segregated organic waste at the site;

- Identify appropriate options for use of products – biogas and manure from treated organic waste; and
- Develop norms for use of non-degradable and inert waste in landfills based on local standards to ensure safe environment in the surrounding areas.

Analysis and Conclusion

- The complex has harnessed both traditional and modern means of trapping renewable sources of energy to offer modern amenities such as lighting, air conditioning, cooking, laundry, and so on at substantially reduced costs.
- The complex saves 40 per cent to 50 per cent of energy costs in comparison to conventionally designed buildings at an additional investment of about 25 per cent.
- Twenty- four solar water heating panels provide up to 2000 litres of hot water every day.

Fig. 3: Diagram showing process of treatment



(*Source: threelittlebirdsresort.com*)

Fig. 4: Solar panels

(*Source: terrin.org*)

Fig. 5: ACs are not used because of EAT

(*Source: terrin.org*)

Fig. 6: Landscaping done on building facades

(*Source: Author*)

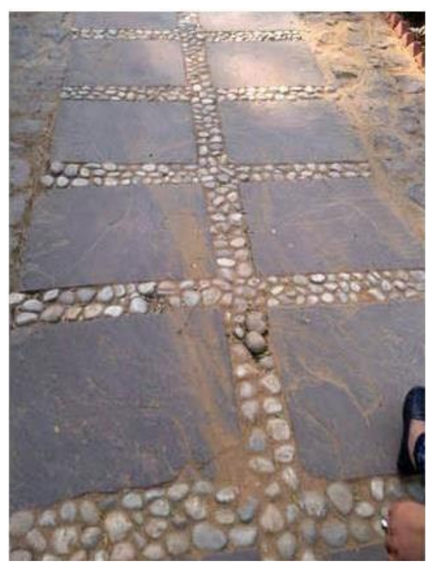
Fig. 7: Green roofs

(*Source: Author*)

Fig. 8: TERI-Deakin Nano-Biotechnology Centre

(*Source: Author*)

Fig. 9: Pebbles used in pathways to retain rainwater



(*Source: Author*)

Fig. 10: Vegetated pathways

(*Source: Author*)

Fig. 11: Natural contours of the site have not been altered

(*Source: Author*)

- The whole site runs on Solar photovoltaic system (with battery backup) and a 100kW biomass gasifier.
- Effective insulation and shade provided by trees along with a network of underground earth air tunnels circulating cool, subterranean air all around the residential block ensure that the temperature in the complex remains even all year round at 20°C in winter, 28°C in the dry summer and 30°C in the monsoon.
- The system has been augmented by the addition of chillers for dehumidification and additional cooling during the monsoon.
- A bed of reed plants (phragmites) clarifies five cubic meters of waste water from the toilets and kitchen every day, the recycled water is then used for irrigation.

The RETREAT building has deciduous trees on the south side to cut off summer heat gains. The trees shed leaves during winter so that winter sun can cause a warmer environment in winters. The wind breaks are provided in the north and north- east to protect from the winter winds. Effective roof insulation can be provided by providing vermiculite concrete. This has been used in the RETREAT building at Gual Pahari (near Delhi) and has reduced roof conduction by 60%.

Earth Air Tunnel for rooms—four tunnels of 70 m length and 70 cm diameter each laid at a depth of around four m below the ground supply conditioned air to the norms.

SECTION 4: RECOMMENDATIONS AND TECHNOLOGIES FOR COMPOSITE CLIMATE: NEW DELHI

New Delhi has a composite climate. It has a very hot, dry summer, followed by a humid season with monsoon rains. With the departure of the monsoon, it slowly becomes comfortable in autumn, followed by a short winter with the cloudy and wet as well as sunny periods. Before the summer returns there is a comfortable but short spring season.

Microclimate

The conditions for transfer of energy through the building fabric and to determine the thermal response of people are local and site-specific. The conditions are generally grouped under the term of 'microclimate', which includes wind, radiation, temperature, and humidity experienced around a building. A building by its very presence will change the microclimate by causing a bluff obstruction to the wind flow, and by casting shadows on the ground and on other buildings. A designer has to predict this variation and appropriately account for its effect in the design. The microclimate of a site is affected by the following factors:

- Landform
- Vegetation
- Water bodies
- Street width and orientation
- Open space and built form

Strategies and Techniques

1. Energy Efficient Strategies of Landform

- For hot and dry climate like Delhi's , summer requirement is heat loss and winter requirement is heat gain. If sufficient slope is available, building can be built in a slope.
- Earth contact- at the depth below 20ft, the soil temperature is stable and equal to the average annual surface temperature. Design can be of two types-
    1. *Direct contact*—where the building envelope is completely or partially buried underground.

2. *Indirect contact*—where building is cooled by buried heat exchangers such as pipes or air tubes.

- In hot climate, building in a depression can take the advantage of relatively low temperature. Leeward site is preferable which has less impact of warm breezes. The depression also helps in formation of water bodies and aids in further cooling.

2. Energy Efficient Strategies of Vegetation

Vegetation can also be used to provide shade and reduce heat gain. They can direct or deflect air movement according to design requirement. The two important factors that can be modified by vegetation are—radiation and wind. At higher temperature, more radiation is emitted.

- During winters, landscape should be designed such that it allows sun to strike fully on the building surfaces. Deciduous trees serve this purpose.
- Trees should be provided that have big canopies to provide shade, like banyan tree, peepal tress and ashoka trees.
- Installing garden roofs can capture rain water and return a portion of it to the atmosphere via Evo transpiration. Garden roofs also provide insulating benefits and aesthetic appeal.
- Vegetative paving reduces storm water runoff by allowing precipitation to infiltrate the undersurface through voids in the paving materials.
- Vegetated swales are broad, shallow channels designed to convey and infiltrate stormwater runoff. The swales are vegetated along the bottom and sides of the channel.

3. Energy Efficient Strategies for Waste Water Systems

Conventional waste water systems require significant volumes of portable water to convey water treatment facilities. However, grey water can be substituted with portable water to flush toilet and urinals. Once waste water has been conveyed to treatment facilities, extensive treatment is required to remove contaminants before discharging into receiving water body.

- The construction of artificial wet lands for waste water treatment can be incorporated on multiple scales to accommodate projects ranging from individual buildings to large developments. Aquaculture system, where contaminants in waste water become food for fish and plants.

- Phragmites can be installed in sewage treatment plants on smaller scales as they purify the water without any heavy machinery and also absorb any kind of foul smell.

4. Energy efficient strategies for Water bodies

Native landscape that have lower irrigation requirements tend to attract native wildlife, including birds, mammals and insects, creating a building that is integrated with natural surroundings.

- Perform a soil, climate analysis to determine which plant will adapt best to the site's soil and climate and specify plants that are more suitable for site conditions.
- Use techniques such as mulching, alternative ,mowing and composing to maintain plant health.
- Design the site landscape with indigenous plants.
- Water bodies should be sufficiently shaded so the water remains cool during summers.

5. Street and Orientation

In composite climates, the main concern is to minimise the heat gain. Align the street width narrow and running north-south to enable mutual shading. Avoid east-west orientation to prevent uncomfortable low sun in morning and evening.

6. Surface Character

Surface character determines whether the incident radiation is absorbed, reflected or stored and radiate later. In composite climate, surfaces should preferably be green to minimise heat gain.

Hard surface and paving should be light and rough which facilitates maximum reflection and re-radiation. During winter days, surfaces should be dark and smooth. This would ensure greater absorption and less re-radiation.

7. Open and Built form

Open spaces seen in conjunction with the built forms govern air movement and heat gain and loss. In a climate like Delhi, a little compact planning with open spaces would be advisable to minimize both heat gain and loss. The ground should be soft, preferably green. deciduous trees are preferable for permitting winter sun.

Analysis and Conclusion

Energy Consumption

- Improve the microclimate by reducing artificial heat islands through effective usage of pervious pathways, pervious parking lots, underground parking, high albedo and light colored materials, vegetative shading, roof gardening, etc. which reduces heating and cooling load of the overall site.
- Appropriate site selection leads to a plant and indigenous wild life preservation. Building on floodplains, landslide should be avoided. Properly planned environment encourages community living, the essence of life. Cost on additional or new infrastructure can be avoided.
- Develop the brownfield site which can reduce pressure on undeveloped land and expenses on additional infrastructure can be avoided.
- Use local/ regional materials which may reduce transportation costs, pollution and support local economy.
- Use of rapidly renewable material reduces major energy spent on non- renewable materials.
- Use renewable sources like wind power, geo thermal, solar power etc.
- Control of erosion and sedimentation leads to reduction of contaminated water and it reduces size, complexity and cost od storm water management.
- Reduce the building foot print. Minimal site disturbances can protect open spaces, site ecology, indigenous plant and animal species.
- Provide on site water recycling which reduces the cost on public infrastructure and energy use. Local aquifer is improved by reduction of portable water use.
- Encourage natural process of evaporation and infiltration. Storm water harvesting from roofs and hardscape can be used for non-portable uses. Install green roof, pervious paving.
- Use native plant palette which induces low irrigation requirement and less fertilizer usage. Consider species factor, density and microclimate factor while seeking plant species which ultimately reduces water consumption.

Microclimate

- Key point of microclimate landscape design is wind and radiation. Instead of spending time to alter the humidity and air temperature, it is wise to concentrate on altering the radiation and wind through landscape element.
- Consider transitivity of trees to reduce the impact of radiation.
- Select trees that cater both for summer and winter needs.
- Wind modification can improve the energy efficiency of a building.
- Properly sited water bodies in design can reduce the heat load of building.
- Use appropriate surface characteristics and color according to climate type.

Strategies for Composite Climate

- Removal of obstructions to prevailing and otherwise predictable warm season breezes.
- Use plants and landforms to funnel and accelerate warm season breezes.
- Curtail and limit plant growth between one ft and 10 ft which can limit wind flow.
- Locate outdoor activities in areas which maximises exposure to cool breezes.
- In composite climates, the main concern is to minimise the heat gain. Align the street width narrow and running north-south to enable mutual shading. Avoid east-west orientation to prevent uncomfortable low sun in morning and evening.
- Perform a soil, climate analysis to determine which plant will adapt best to the site's soil and climate and specify plants that are more suitable site conditions.
- During winters, landscape should be designed as such that it allows sun to strike fully on the building surfaces. Deciduous trees serve this purpose.
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