The effects of landscaping on the residential cooling energy

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Abstract. This paper examines the effectiveness of landscaping on the air-conditioning energy saving of houses in a tropical environment. This case study involved looking at the construction and landscaping of three single-family houses in three sections of Shah Alam, Selangor, Malaysia. The houses ranged in age from 5 to 30 years old, which provided different examples of construction and maturity levels of the surrounding landscaping. Landscaping affects the thermal performance as well as on the air-conditioning energy of houses, in how it provides shade, channels wind, and evapotranspiration. While the construction of the three houses was similar, they were different in size and design, including their landscape design. These houses were chosen because they are representative of single-family tropical houses and landscaping styles in Malaysia since 30 years ago. Three houses were chosen; the 30-year-old house, the 10-year-old house, and the 5-year-old house. In a tropical country, landscaping is used to reduce the effects of the hot and humid climate. The houses spent 15-45% of the electricity cost on cooling. These results were influenced by human factors and the surrounding landscaping. Every type of vegetation, such as trees, grass, shrubs, groundcover, and turf, contributes to reducing air temperatures near the house and providing evaporative cooling.

1. Introduction

Strategically placed vegetation around a building has long been recognized as a means of cooling. However, the potential for air-conditioning energy saving has not been widely recognized and quantified. Few researchers have measured the energy reductions caused by different types of vegetation in a variety of locations and climate. Energy saving up to 55% has been measured in relation to air-conditioning, although 25–50% is more common [1-3]. Large saving was found in both dry and humid climate regions. The design of external spaces needs to be prioritized because conditions there will influence the building interior. Proper placement of trees, shrubs, vines, grass, and turf can greatly reduce the temperature around a building, and create a comfortable environment. The effects on energy use depend on general climate, building type, tree species, and tree location [4]. This study will investigate the effects of different amounts of tropical landscaping around houses on their ability to provide a cool and comfortable environment, furthermore it closely related to cooling energy use.

1.1. Air-conditioning system

Air conditioning may provide and maintain a desirable indoor atmospheric environment irrespective of outdoor conditions [5]. There are seven main processes and functions required to achieve full air-conditioning: cooling, heating, ventilating, humidifying, dehumidifying, air movement and cleaning, [6]. The requirements and importance of these seven processes of air-conditioning vary with the climate. The desired indoor atmospheric condition for human comfort applications usually involves a
temperature range of 18–22°C in winter and 21–24°C in summer and a relative humidity level of about 40–60% and a high degree of air purity [5]. The application of the particular type of air-conditioning system depends upon a few of factors such as condition and size of the area to be cooled and the total heat generated inside the enclosed area. The building designer would consider all the related factors and suggest the cooling system most suitable. Window air conditioners are one of the cheapest and the most popular and of all air conditioning systems. The window air conditioner can be used for almost all types of small spaces and commonly used for small rooms in a house. The component of this air conditioner contains the condenser, compressor, expansion valve/coil, fans, cooling coil and evaporator. All of these components were enclosed in a single box. This unit is a standard of the window frame and is fitted in a slot made in the wall of the room.

1.2. Energy use
One of the essential energy sources are used in many countries in the world is electric energy. Currently, the cost of electric energy has been drastically increased. In Malaysia, the average rate demand of electric energy is 11% per annum demand and will be increased each year, parallel to the development and standard of living in this country [7]. The consumption of electricity includes the application of electrical appliance, machinery, lighting and air conditioning system. With the development of services system, air conditioning is now widely used especially in a hot and humid climate in Malaysia. In the tropical region, the active part of air conditioning systems is the energy required to drive the cooling. There is no heating system for buildings in tropical country of Malaysia as for the climate is high in temperature and humidity throughout the year. Recently, central cities in Malaysia experienced urban heat islands effects, parallel to the increase of urban population, as well as improved living standard was contributed to the dramatic increase of air conditioner used especially for residential buildings in urban areas [7]. Ratings for air conditioning run by the number of British Thermal Units (BTU), (1-ton refrigeration = 12,000 Btu/h). The Energy Efficiency Ratio (EER) is a measure of how efficiently of air conditioning; a higher number means the system is more efficient [8]. A regular air conditioner for the home usually has a 5,500 BTU to 14,000 BTU per hour range.

1.3. The roles of vegetation
The roles of vegetation in urban microclimates are varied; directly by providing shade and channelling wind flow, and indirectly by evapotranspiration of water content, and the modification of exchange and storage of heat between urban surfaces [1,4 & 9]. Vegetation is all the plants of a place, including trees, shrubs, vines, groundcovers, grasses, and turf/lawn. Shade trees are one of the versatile components of our surrounding landscapes. The Large canopy of trees can enough to shade building envelopes include roofs and walls and to increase indoor comfort. During natural photosynthesis, solar radiation is absorbed by the tree canopy and next generating evapotranspiration that cools the leaves and comfort the surrounding air. Air movement then disperses this cool and comfort air resulting in an overall surrounding cooling effect. Trees and shrubs can be planted to funnel/deflect wind away from specific/required areas; both horizontal and vertical concentrations of foliage can modify air movement/flow patterns. In hot and humid tropical regions, the wind should be channelled for cooling and to provide relief from high temperature and humidity. A few large/shade trees with spreading branches in a strategic location can allow breezes and keep the area cool and comfortable. Groundcovers, grasses and turf/lawn also generate evapotranspiration and cool the earth surfaces and the surrounding air. Careful and strategic landscape planning around buildings can reduce the amount of solar radiation heating building surfaces and can prevent reflected sunlight from entering the indoor spaces. Hence, trees, shrubs and grass will also reduce air temperatures and humidity, while channelling wind flow near the building and provide evaporative cooling.

2. Methodology
2.1. House study
The bungalow houses sampled were randomly chosen from Shah Alam city housing development. In general, bungalow house represents around 10-15% of the mixed residential development in Malaysia. The area of study is located in Klang Valley; latitude 3°North and longitude101°east, with an
elevation range of 24 to 48 metres, about 25km from Kuala Lumpur capital city. Shah Alam is the capital of Selangor State and is also one of the well-planned cities in the tropical country of Malaysia. Three locations at three sections of low-density housing development were considered to be case study areas. The specific locations used were in Sections 6, 9 and 11. Three bungalow houses are labelled as old, ordinary and new houses respectively as can be seen in Figure 1.

![Figure 1](image)

**Figure 1.** The chosen medium size of bungalow houses surrounded by open space

2.2. Electric energy
In Malaysia domestic electricity tariff was monitored and managed by National Energy Limited–TNB (Malaysian Electric Utility Company). Data of electricity used by the residential buildings were collected for the monthly amount as the cost of electrical energy used. This total of energy costs were converted into energy used in kWh units. Electricity energy used for air-conditioning also was calculated based on current local tariff in kWh. Annual domestic electricity used in the study area, a city of Shah Alam was also analysed to validate the amount of energy used for cooling along the year.

2.3. Landscaping and energy use
The micro scale of fieldwork and site measurements was conducted at an individual residential area. The quantitative methodology to evaluate air-conditioning energy saving was done via interviews and
building and landscaping data collections in three bungalow houses. The site measurements included recording building characteristics (building orientation/location and construction, including building envelope material and surface, etc.), plant type and biomass (species, size, canopy, leave density, location, etc.), human factors/behaviour (living styles and habits), and specific/local indoor and outdoor weather conditions (temperature, humidity and wind speed/flow). All collected data were combined and analysed to estimate the effect of vegetation on thermal performance and cooling energy use in the bungalow house located in the tropical country of Malaysia.

3. Results and Discussion

3.1 Building orientation

The three medium size of bungalow houses were of similar construction but had different main façade/building orientations, wall/glass areas, and age of landscape. The main façade/building orientations for the old house were facing north/south. The majority of the glass openings were located facing the main open space/garden area. This orientation can minimize the amount of solar radiation penetrating the internal spaces. In contrast, the main façades for the ordinary landscape house and the new landscape house were facing the east and west respectively, with the majority of their glass surfaces facing the main garden area at the south side. Immature vegetation around the main garden area (west) of the new bungalow house was not sufficient to provide shade cover to walls and glass surfaces, however the amount of shade trees and at west side help to cover low wall and earth/floor surfaces; while sparse medium maturity plants around the main garden area at east side of the ordinary house had similar effects on the surrounding ambient air. Therefore, in these house studies, the best building/façade orientation to face the open space/main garden area was facing north/south where the majority of glass opening should be located to receive diffuses solar radiation in a similar way to the old house. This can provide cooler temperatures as low as 0.3–1.2°C different compared to other two houses as shown in Table 1.

| House | Building | Vegetation | Average daily microclimate data | Human factors |
|-------|----------|------------|---------------------------------|---------------|
| OL    | North & South | 51.35 | 0.12 | Moderate/Mature | Temp. outdoor (°C) | Temp. indoor (°C) | Wind speed (m/s) | RH (%) | Cooling energy (%) | Occup. number |
| OD    | East & West | 87.30 | 0.30 | Moderate/Mature | 32.08 | 29.62 | 0.40 | 77.22 | 45.00 | 6.00 |
| NE    | East & West | 94.50 | 0.33 | Moderate/Immature | 32.98 | 29.90 | 0.51 | 71.10 | 15.00 | 6.00 |

3.2. Albedo

The colour of walls at all study houses was light such as white, crème, peach and grey can provide high albedo value more than 0.3 and can reflecting well solar radiation. While roof covering is vary; in the old landscape house was brown and generated the lowest albedo value 0.12. This may affect the heat gain to the building and may increase the surrounding temperatures and directly to the indoor air temperatures. A light colour of roof covering such as light grey and light orange which were used at the new and ordinary landscape house with albedo value 0.30 and 0.33 respectively were more effective at reflecting solar radiation.

3.3. Surrounding landscaping

The three different ages of landscaping/vegetation located around the three bungalow houses create moderating effects by providing shade to the building envelopes and earth surface, channelling wind to the garden and evapotranspiration cooling to the surrounding outdoor area. In this study, the building envelope components such as roofs, walls and glass surfaces are the most exposed parts to direct solar radiation. This is due to non-strategic planning and placement of plants. Medium sized of
shade trees and around/spreading form of the canopy can potentially provide shade to walls surfaces nearby. The non-strategic location of shade trees and shrubs was for the old landscape house. Most of the trees in the old landscape house were located between 15 and 20m from the house and therefore cannot provide shade to the building envelope/surface. This suggested the need for two/three trees of medium size with heights 6–9m be planted on the west and east sides’ 3 to 5m distance from the house. This shade trees would cover part of the roofs and walls in early morning and afternoon, and shade most of the earth surfaces close to the house over a day. Furthermore can reduce heat gain to the surrounding garden and building, as well as decrease the surrounding temperature during the peak hour of the day. The result of this study clearly shows that small and low shrubs, groundcovers and turf located close to walls, only can provide shade to the nearest underground foundations and floors, while the walls and windows of the house are still too exposed to the direct sunlight during morning and afternoon. The hotter outdoor environment resulting from sparse and non-strategic landscaping can directly promote warmer interior spaces. The temperatures in the three bungalow houses gradually increased with the peak indoor temperature delayed by approximately three hours.

3.4. Human Factor

The human/behaviour factors for the three bungalow houses were similar in terms of the number of occupants but they had different total cooling energy consumption. In the evening, the average interior temperature for the three houses was up to as much as 29°C showing that the occupants need an active cooling system to achieve their comfort level. For example, the two bungalow houses with similar living habits; the ordinary and old houses used 100% air-conditioning for their master bedrooms, while the new house used the air-conditioning system for only 3 hours during early mid-night time, although the set temperature was low when it was used. The rest of the times the new house used a ceiling fan and the passive ventilation system. This reduced the total electrical energy used. The advantage of the new house is the house is located facing a large natural open space where the prevailing winds can refresh the surrounding air all the time. This cool and comfort ambient air directly flowed to the indoor spaces. The strategic position of immature vegetation around the new house provides cool ambient air by channelling wind to the surrounding garden and its indoor spaces.

Overall a strategic placement of vegetation at the east and west sides where direct solar radiation receives, close to the building is very important to provide shade/cover to the building envelope especially roofs, walls and windows. Evapotranspiration cooling during plant photosynthesis was produced by a combination of plants and water elements provide cool ambient air. The arrangement and positioning of plants in the garden and around houses should be compatible with prevailing wind directions and to channel and promote wind to the appropriate places around and through the interior of the house. The combination of shading by all types of plants, compatible moderate wind flow and evapotranspiration cooling can produce fresh, cool and comfortable environment.

3.5. Energy saving

Human factors are one of the main factors that influence the energy consumption for cooling in a tropical city. The living habits recorded for the three bungalow houses included the number of occupants and their ages, the total of time they used the active cooling systems during the day and night and the occupants’ preferred temperature. The house will release the heat is stored in its building envelope throughout the day when the outdoor temperature around a house decreases during the night. This heat in the interior spaces contributes to the discomfort of the occupants, so using an active air-conditioning system is the only way to ease this. All of the occupants of the three houses in this study used air-conditioning at slightly different times, but mainly when most of the family members were at home. In all houses the occupants closed external openings at night for security reasons, to prevent noise, insects and to protect themselves and their house interiors from any extreme climate phenomena such as heavy rain or thunderstorms during their rest time at night. As a result, they depend entirely on active cooling systems to achieve their preferred thermal comfort levels at night.

The three bungalow houses used similar window air-conditioning systems, but they had different capacities and models. The ordinary house had eight air conditioning units, with six occupants/users; five adults and a teenager. The old house had four air-conditioning units for six occupants, all adults.
Finally, the new house had three air-conditioning units for six occupants; three adults and three children. All houses used their cooling systems extensively at night, especially in the bedrooms while the occupants were sleeping. The ordinary house used the highest amount of cooling energy, followed by the old house, then the new house. The houses used the cooling system with different temperature settings and for different amounts of time. As a result, the ordinary house spent 45% of the electrical energy on air-conditioning; the old house used approximately 35%, and the new house only used 15%. This shows that the time's air-conditioners were used and different temperatures influenced the amount of cooling energy consumption for each house. Overall, the longer cooling system was used, and lower temperature settings will affect the amount of cooling energy consumption.

![Figure 2. Cooling energy use for the three bungalow houses](image)

In a tropical city, during the night, air conditioning is a basic need for the people being able to live/rest safely and comfortably. However, the new house is designed to use as much natural ventilation as possible to minimize the need for active cooling. The building configuration/orientation was perpendicular to the prevailing southerly wind during the daytime, while the prevailing wind at night was from the east. The new house was strategically located, with large, open green spaces to the south and west. The house was also surrounded by a private garden. These factors promoted convective cooling of the building. The design of the window openings meant the interior was relatively safe from rain or strong wind at night while providing ventilation. For example, the master bedroom was located on the first floor, and the windows were protected by shading devices and a veranda roof. All of these factors mean that the use of natural ventilation probably contributed to less cooling energy being used in the houses.

4. Conclusion
The construction methods materials used and of all houses were similar. They used typical styles of tropical architecture and design. The medium size of each house was built in different eras. The building orientation of the old and ordinary houses was east/west, while the new house was orientated...
north/south. The main areas to protect from direct solar radiation during morning and afternoon is the east and west sides of the houses, while the other sides; north and south areas needed protection from diffuse solar radiation. The size and amount of all types of plants, as well as their lushness and natural condition, were also important factors. These can affect the ability of the plants especially trees to provide shade and promote the evapotranspiration process. The air-conditioning used in their indoor spaces was in different temperature settings and for different amounts of time. The ordinary house spent 45% of the electricity cost on cooling; the old house used approximately 35%, and the new house only used 15%. This reveals that human factors and behaviour of occupants influence the cooling energy. The lower temperature settings and longer time especially during the peak time of the day of air conditioning used will affect the amount of cooling energy used.

References
[1] Misni A 2013 Procedia - Social and Behavioral Sciences. Modifying the Outdoor Temperature around Single-Family Residences: The Influence of Landscaping 105 664
[2] DOE 1995 Landscaping for Energy Efficiency. Energy Efficiency and Renewable Energy, (046) p. 1-8.
[3] Parker JH 1987 Landscape Journal. The use of shrubs in energy conservation plantings 6 132
[4] Misni A and Allan P 2010 Sustainable Building Conference (SB10). Sustainable Residential Building Issues in Urban Heat Islands - The Potential of Albedo and Vegetation (New Zealand: Wellington)
[5] Oughton DR and Hodkinson S 2002 Faber and Kell's Heating and Air-conditioning of Buildings. Ninth ed., Oxford Butterworth Heinemann.
[6] McDowall R 2007 Fundamental of HVAC Systems. First ed., Oxford (UK: Elsevier)
[7] Nasution H and Hassan MNW 2009 Energy Efficiency at Usage of Air Conditioning Systems In the Effort of Electrics Energy Saving Consumption, 27 September 2009; Available from: http://www.he4si.com/Artikel/Abstract_ROVISP05.PDF.
[8] Bailey O and R Alcock 2009 Home Energy Brief. 23 September 2009; Available from: http://www.p2pays.org/ref/32/31147.pdf.
[9] Akbari H et al 1992 Cooling our Communities, A Guidebook on Tree Planting and Light-Colored Surfacing, (Washington: Lawrence Berkeley Laboratory)