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Economic assessment of Operational Energy reduction options in a house using Marginal Benefit and Marginal Cost: A case in Bangi, Malaysia

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Energy Efficient (EE) appliances such as Compact Fluorescent Light (CFL) bulbs and Renewable Energy (RE), namely solar Photovoltaic (PV) can help to reduce Operational Energy (OE) in a house. In addition, a house should also incorporate Passive Architecture (PA) design strategies which in the hot and humid tropical climate, mean avoiding direct heat gain, encouraging natural cross ventilation and optimising the abundant daylight. Nevertheless, reducing OE must also mean economic gain to households to encourage their participation. Common economic gauges such as Return on Investment, Payback Period, Cost Benefit Analysis, Life Cycle Assessment and Life Cycle Cost are not suitable to validate OE options in households. These economic gauges approach economic assessment as an end-result on the cost side of the product and may result for good intention to be shelved, primarily because EE equipment and RE have high capital cost compared with the alternatives. On the other hand, reducing OE in houses is actually a continual progression from the status quo and there is always a marginal gain in doing so. The challenge is to know how much is the marginal benefit against the marginal cost of investing in EE and RE. In Economics, the ratio of Marginal Cost (MC) and Marginal Benefits (MB) measure additional benefits of every additional costs of investment at a specific level of production and consumption; and Economists suggests that effective gain and loss should be compared to the status quo, i.e., Relative Position (RP). The Economics theories of MC, MB and RP are being adapted to measure the progression of reducing OE. The living/dining area in two types of houses: with and without PA design strategies are simulated to use conventional incandescent light bulbs and CFL as well as solar PV in lieu of the mains electricity supply. The power requirement for artificial lighting in every case is translated into monetary value and the ratio of MB against MC for each case shows the gain or loss in investment to reduce OE in a 30-year period. The result suggests that the value of MB/MC is high when both houses use CFL, i.e., approximately (Ringgit Malaysia) RM2.5 gain for every RM1 cost. It is also found that investment in solar PV benefits the most in the PA case that uses superior CFL bulbs, i.e., approximately RM2 gain for every RM1 cost. Despite the high capital cost of EE equipment and RE, MB/MC approach seems to make economic sense for household to invest in reducing OE at certain stages.

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1. Introduction

1.1. Operational Energy (OE) requirement in a house

Energy consumed by a house begins during construction and it continues throughout the operational period. The latter is termed as Operational Energy (OE) and it is typically borne by the house owner or the occupant. The bulk of OE in Malaysian households is powered by mains electricity supply. As such, it is subjected to the price of natural energy resources such as coal, gas and petroleum that are used to generate electricity in Malaysia [1]. The amount of OE requirement in a house throughout its lifetime is also determined by design decisions made at the early phase of 'design and construction' stage (Fig. 1). However, the cost of OE for a house is hardly available for the buyer when committing to a purchase. House owners are only aware of building's OE when they have to pay the energy bill.

Building's OE is now a necessary element of a house because most items that fulfill occupant's modern lifestyle and indoor comfortable conditions are powered by electricity. Nonetheless, OE varies from one property to another depending on its occupants and house design; and it is via the latter where built environment can influence OE requirement in a house (Fig. 2).

1.2. Passive Architecture (PA), Energy Efficient (EE) equipment and Renewable Energy (RE)

Occupants will make personal adaptation to gain comfort whenever the personal thermal and visual comfort is being

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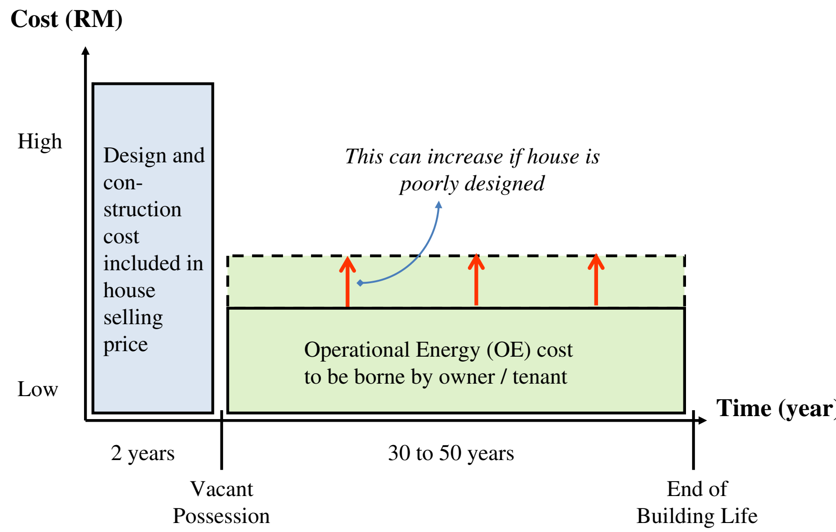

Fig. 1. OE cost happens throughout a building's lifetime upon occupancy.

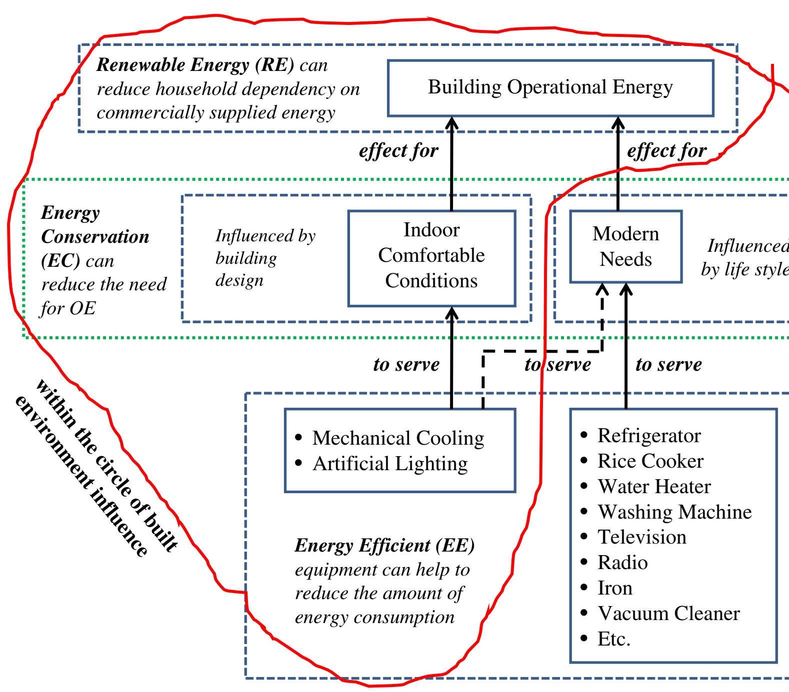

Fig. 2. Causes for OE that falls within the scope of built environment for a typical house in Malaysia.

compromised [2]. For example, to gain visual comfort in a dimmed room during daytime, occupant may seek daylight from the window and if this is still inadequate, he may switch on the artificial lightings. Similarly, if a room is hot, occupant may dress less and if he is still thermally uncomfortable, he may switch on the ceiling fan or air conditioning system. In both instances, poor building design may result for occupant to use OE for artificial lighting and mechanical cooling. As such, designing building to be naturally comfortable for occupant in the local climate conditions would help to reduce OE requirement.

Basically, Passive Architecture (PA) building addresses the local climate using basic building elements, such as openings and walls to effect for Energy Conservation (EC) and low OE. In hot and humid tropical climate, PA avoids solar radiation, promote ventilation from the prevailing wind and ensure daylight into the building without much reliance on mechanical cooling and artificial lighting. A house in Malaysia can achieve these goals by making its form slender to encourage cross ventilation; elongated east–west to avoid heat gain; and with large openings on the north to capitalise from the abundant daylight [3]. Various terminologies are used to describe buildings that are designed with climate and it is notably expressed as 'passive' to portray a 'defensive' or 'protective' attitude towards climate (Table 1). This study applies the term Passive Architecture; pointing the matter directly to the Architects who hold the primary responsibility in creating sustainable built environment.

However, all is not lost in houses that do not fully responded to climate factors, hereafter called non-Passive Architecture (non-PA). This is because action to reduce OE is a continual improvement

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