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INVESTIGATING THE ADAPTABILITY OF EXISTING BUILDING ENERGY RATING SYSTEMS TO SRI LANKAN RESIDENTIAL BUILDINGS

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Abstract: Energy represents a considerably higher percentage of running cost of a building and also affects the optical and thermal comfort of the occupants. Despite the fact that the investment for buildings is higher than most of those equipment, only developed countries and few developing countries have developed their own energy ratings or certifications for buildings. Nevertheless, energy efficiency in building sector is utmost important as it accounts more than one fifth of annual energy consumption worldwide. Energy efficiency rating system can be considered as a key policy instrument that will assist government to reduce the energy consumption. Energy rating includes the direct benefits such as, energy requirement and CO_2 emission reduction; increase the public awareness regarding energy issues; cost reduction for the users and improve the available data for the building. Studying the existing energy rating systems is very much important prior to the development of energy rating system for Sri Lanka. This paper examines 12 existing energy rating systems and analyses the adaptation opportunities for emerging Sri Lankan energy labelling system. The existing rating methodologies including asset and operational rating, parameters used for developing the energy rating and the comparability matrix were compared and discussed in this review.

Keywords: Insulating Energy rating; Building energy efficiency; Energy certification; Sustainability; Residential buildings

1. Introduction

The global climate change, fossil fuel depletion and the increase of CO_2 emission have created a great interest on energy efficiency in many sectors including the construction industry. Energy represents a considerably higher percentage of running cost of a building and also affects the optical and thermal comfort of the occupants. Energy efficiency is considered as a key factor to consider when purchasing many electrical and electronic equipment and the energy rating for those equipment are available for providing the accurate information. Despite the fact that the investment for buildings is higher than most of those equipment, only major developed countries and few developing countries have developed their own energy ratings or certifications for buildings [1]. Nevertheless, energy efficiency in building sector is utmost important as it accounts more than one fifth of annual energy consumption worldwide [2].

According to Stein and Meier [3], energy rating system is defined as "a method for the assessment of predicted energy use under standard conditions and its potential for improvement" and it provides an output with predicted energy use, a rating score comparing with a reference building and list of recommendations for energy efficiency improvements. Few examples of the energy rating schemes in the world are Energy Star (USA), HERS (USA), BEQ (USA), MOHURD (China) and NatHERS (Austrailia) [1].

Energy efficiency rating system can be considered as a key policy instrument that will assist government to reduce the energy consumption [4]. Energy rating includes the direct benefits such as, energy requirement and CO_2 emission reduction; increase the public awareness regarding energy issues; cost reduction for the users and improve the available data for the building [5]. The government of Sri Lanka also has identified the importance of energy performance of buildings and considers it as a strategy for the sustainable energy development of the country. Conforming to this, Sri Lanka Sustainable Energy Authority (SLSEA) has developed a "Code of practice for energy efficiency buildings in Sri Lanka" which mainly covers the building envelop, ventilation and air conditioning, lighting, electrical power and distribution and service water heating [4].

Studying the existing energy rating systems will help the future researchers to understand the most common practices in energy rating system development and identify the most suitable methods by considering the pros and cons of those systems. To support that this paper examines 12 existing energy rating systems and analyses the adaptation opportunities for emerging Sri Lankan energy labelling system.

2 Overview of the energy rating methodologies

Energy is an important element in any building as it represents a significant percentage of the running cost of the building and it has a major impact on occupants' thermal and optical comfort. The energy efficiency in building arose as an important consideration for building in early 1970's with the oil supply crisis [6] and the requirement for the building energy rating was also emerged. Over the past years many countries have developed and adopted various energy rating systems for buildings.

The current building energy rating systems fall in to two basic categories based on the assessment type as; calculated rating and measured rating [6]. The assessment method that uses the calculated or simulated energy consumptions is defined as calculated rating or asset rating. In this method the inherent energy performance properties of the building it-self is considered, rather than the dynamic process of the building operations [7]. The energy consumption measure is based on a calculation tool or a simulation model such as AccuRate (Austrailia for NatHERS) [8], BREDEM (UK for SAP) [9], HOT2000 (Canada for EnerGuide) [10], Ek-Pro (Denmark for Energimerker) [11], and EnergimerkeKalkulator (Norway for Energimerking) [12]. If the calculated assessment is conducted for a standard conditions of the building it is defined as the standard rating, and when the conditions are tailored for a specific building conditions it is known as the tailored rating [7].

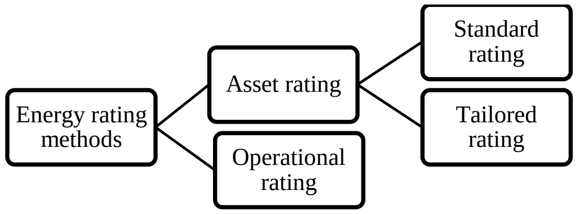

Fig 01: Energy rating methods

The rating which is based on the actual energy consumption is defined as the measured rating and it is also known as operational rating. The energy consumption is measured using the utility meters and this rating is common in existing buildings. This is widely seen in residential buildings where the figures are more sensitive to the occupant behaviour [7]. In order to minimize the impact of the occupant behaviour to the rating, the measured rating should be normalized for various conditions such as weather and floor area. BEE star rating system in India normalize the energy consumption for hours of operation, climate and the conditioned area [13].

The California HERS (USA) normalize for weather and number of billing days [14] and the Energy Star (USA) normalize energy consumption for weather [15].

Asset rating and operational rating provide different rating values and only MOHURD system in China has made some attempts to integrate the two ratings although it was not yet successful. In MOHURD system for the first year after the inspection only the asset rating should be displayed and after the first year, based on the continuous energy measurement for one year the operational rating is also given where, the energy label displays both asset rating and operational rating after the first year [16].

3. Parameters used for existing energy rating systems

3.1 Source and site energy

When measuring and calculating energy use it is important to consider at which point the energy should be measured. If the energy is obtained from different energy sources, this becomes a major requirement to be considered. Based on the point of measurement the energy is categorized in to two as site energy and source energy. The energy consumption reflected in the utility bills are normally fall in to site energy category and it may be as primary energy (raw fuel burnt onsite such as natural gas or fuel oil) or secondary energy (energy product created from a raw fuel which can be purchased from the grid) [17].

The source energy is recommended most of the cases for energy rating, as it provide more accurate determination of the energy consumption of the building. Since the source energy cannot be measured directly the energy rating systems which use source energy use conversion ratios to convert site energy to source energy (refer Table 1). Building Energy Quotient [18] and Energy Star [19] are some examples of the rating systems which use source energy and Energimerking (Norway) [20] use site energy for the energy rating calculations

Table 1: Site to source conversion in bEQ rating

Energy use by fuel type	Site energy (kBtu)	Source – site ratio	Source energy (kBtu)
Electricity	251,200	3.34	839,008
Natural gas	800,000	1.047	837,600

3.2 Fuel type and CO_2 emission

The fuel type is considered if the rating system use source energy and usage of renewable energy is considered widely, especially when the energy rating is aimed at net zero energy [18]. In Energimerking (Norway) where two grades called energy grade and heating grade is displayed in the label, the colour in the heating grade reflect the proportion of the renewable energy used in the building [20].

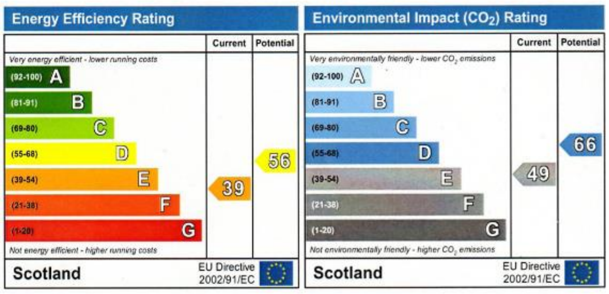

Figure 2: SAP Energy rating system [21]

The carbon dioxide emission is measured or calculated by several systems even though it has not been considered in determining the energy rating. As displayed in figure 2, the SAP system (UK) has indicated energy efficiency rating and environmental (CO_2) impact rating as two ratings in the energy label [9]. Some systems such as RESNET HERS (USA) considers the net zero energy home has zero carbon foot print and has define the scale accordingly [22].

3.3 Geographical location

Energy rating systems strongly consider the geographical location of the buildings as many conditions such as weather and climate also depend on the location. The energy consumption applicable to cold climate will be different to the hot climate due to the difference in thermal energy requirement. When the simulation models are used for energy performance estimation a weather file need to be fed [10] which include data such as dry bulb temperature, daily temperature range, humidity, wind speed and wind direction. For operational rating the energy consumption is normalized for weather. The equation used for calculating the energy score of PBE Edifica [23] clearly indicates the usage of geographic location for the calculation (equation 1).

$$PT_{UH} = (a \times EqNumEnv) + [(1-a) \times EqNumAA] \quad (1)$$

Where:

- PT_{UH} is the total score of energy efficiency level of the housing unit
- a is the coefficient adopted according to the geographic region
- $EqNumEnv$ is the numerical equivalent for the envelope characteristics
- $EqNumAA$ is the numerical equivalent for the water heating system

3.4 Physical characteristics of the building

The systems, which use asset rating (NatHERS [8], SAP [9], Energimerkng [11], bEQ [18]) usually use the physical characteristics of the building in their energy consumption calculations as the asset rating considers the inherent energy performance properties of the building. The building data such as conditioned and unconditioned space, building components (External walls, roofs, foundation, internal wall etc.), shape of the building, orientation of the building, shading, number of buildings (if an apartment complex), building dimensions, floor plan, thermal performance of the components and construction type of the components are widely considered in the calculations [24].

In addition to that the ventilation and infiltration rates, mechanical ventilation, HVAC systems and the heating or cooling system efficiencies, heating and cooling degree days are widely considered in many rating systems [25][26]. Except for few rating systems such as PBE Edifica [23], the other systems have ignored the passive houses and the natural ventilation.

3.5 Other factors

Along with the above factors there are several parameters affecting the energy consumption of the building, which heavily depend on the occupant behaviour such as plug and process loads and building specific scheduling [27][28][29]. These energy uses are heavily depend on the occupant behaviour and always considered in operational rating. Some building energy modelling software ignore the plug and process loads when calculating the energy consumption and some systems such as RESNET HERS (USA) use projected energy use for plug and process loads. Equation 2 illustrates how those energy loads are incorporated to the RESNET HERS index [7].

$$HERS\ index = \frac{PE_{frac}\times 100\times (E_{heating}+E_{cooling}+E_{wh}+E_{la})_{rated\ home}}{(E_{heating}+E_{cooling}+E_{wh}+E_{la})_{reference\ home}} \quad (2)$$

$$PE_{frac} = \frac{E_{used}-E_{produced}}{E_{used}} \quad (3)$$

Where:

- E is energy consumption
- wh is water heating
- la is light and some appliances
- PE is purchased energy

4. Comparability matrix

The scales which are commonly used in the existing energy labelling schemes are in two main categories as continuous scale and discrete scales. In the continuous scale the rating value can place anywhere in the scale and in discrete scale there are limited number of categories represent by set of letters or by number of stars [7]. Rating systems such as PBE Edifica (A – G) [23], Energimerking (A-G) [11], BEE (5 star) [13] , MOHURD (5 star) [16] and NatHERS (10 stars) [8] use discrete scales and although it provides a better illustration the assessors meet with challenges when rating the performance near the border of each category. The systems such as bEQ (0-145) [18], EnerGuide (0-100) [10], and California HERS (0-250) [14] use continuous scales and they provide a better differentiation of the best and worst energy performers although it is difficult to illustrate the comparative performance.

Reference is an important consideration in the development of scale as those scores will be compared with that reference either as absolute or relative manner [7]. The absolute standards are defined for a single value and it will provide diverse buildings a common metric to compare. Countries such as Denmark use zero kWh per square meter as the absolute reference which has been highlighted as a goal in their government policy. The relative reference requires the use of reference buildings which is developed using statistical or simulated techniques. The simulated references are compared to the building code, average or other factor. For example in Norway the scale is developed according to the relative reference based on TEK 10 (current building regulation) and TEK 69 (1969 building regulation) [20].

5. Adaptability to Sri Lankan scenario

The adaptability of the above discussed energy rating systems depends on various factors including the economic situation, climate conditions, building type, fuel types, building characteristics and the end uses. There is a positive correlation between the economic growth and the energy consumption of the countries [30]. Thus the developing countries experience higher growth rate of energy consumption when the developed countries have stable energy consumption [2]. Most of the selected systems for this review are for the developed countries and only BEE (India), MOHURD (China) and PBE Edifica (Brazil) are applicable to the developing countries.

The energy demand and the energy requirements depend on the climatic conditions as the heating or cooling requirement is governed by the climate. The countries which have a cold climate and clearly distinguishable seasons prioritise heating and cooling energy demands when calculating the energy rating. Sri Lanka has mostly a tropical monsoon climate and five countries in the sample have similar climate at least for part of the country. Brazil has a tropical climate where north part of Australia, Hawaii and Florida in USA, Southern China and South India have similar climatic conditions.

This review focuses on the energy rating in the residential sector and all of the systems in the sample except BEE (India) has energy rating systems for residential buildings. The energy rating calculation is different based on the type of energy use considered. For example several systems ignore the plug and process entirely loads (such as PBE Edifica [23]) and some use projected energy use for the simulation (eg. RESNET HERS [7]). Considering the plug loads will be important in developing energy rating in Sri Lanka as, 79% of the morning peak and the 53% of the evening peak energy consumption are for the plug loads [31].

6. Conclusions

Different systems relate to the Sri Lankan scenario in different ways and it is difficult to find one system, which is totally suitable only for Sri Lanka. However, it is possible to use the features used in those rating systems which have similar climatic conditions and economic situations while including the other aspects such as plug and process loads. The reference values that are used for developing the scale is country specific and it will be important to develop own reference building stock or an absolute reference base on country policies. Furthermore, when the energy efficiency rating systems applied inappropriately to an environmental outside its scope inadequacies arise and therefore the energy rating systems are not normally applicable across different countries or climate zones [32]. Due to this reason, the energy rating systems developed in other countries cannot be directly adopted to Sri Lanka and it is required to design a system carefully considering all the related aspects to the Sri Lankan context.

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