© Universiti Tun Hussein Onn Malaysia Publisher's Office

IJIE

Journal homepage: http://penerbit.uthm.edu.my/ojs/index.php/ijie

ISSN : 2229-838X e-ISSN : 2600-7916

The International Journal of Integrated Engineering

Greening Existing Buildings in Brunei Darussalam

Nurnazerah H. Julayhe[1*], Md Motiar Rahman[1]

[1]Faculty of Engineering,
Universiti Teknologi Brunei, BRUNEI DARUSSALAM

*Corresponding Author

DOI: https://doi.org/10.30880/ijie.2021.13.07.005
Received 21 October 2020; Accepted 23 March 2021; Available online 30 September 2021

Abstract: Building is the largest consumer of resources and the biggest polluter of the environment, including energy consumption and greenhouse gas emission. Greening existing buildings, an extension of green building concept to existing buildings, can potentially help to improve such issues. Greening process can considerably reduce energy consumption in buildings and thereby reduce the carbon dioxide emission. On the basis of a recent study on energy consumption in residential buildings in Brunei Darussalam, this paper demonstrates the potential savings in energy consumption and reduction of energy cost, if modern and energy-efficient electrical appliances are used in place of the existing conventional features/appliances. The results show that an average household can potentially reduce its yearly energy consumption by 32.74% and they can save annual energy cost of up to 52.20%. It is also seen that the appliances with higher energy consumption, like air conditioners and refrigerators, can offer higher savings of both energy consumption and energy cost, with relatively smaller extra initial replacement costs. A favourable awareness programme by appropriate authority is likely to motivate people to use such practices and help to reduce energy consumption and emission of greenhouse gases.

Keywords: Energy consumption pattern, energy efficiency, green building technologies, greening existing buildings, payback period

1. Introduction

Buildings in the United States account for approximately 36% of total energy consumption, 30% of greenhouse gas (GHG) emissions, 13% of water use and approximately 170 million tons of construction and demolition waste generation per year [1]. Some other sources report that the building sector is responsible for almost half of the energy consumption [2] and GHG emissions [3]. Buildings can cause 38-50% of GHG emission in the United Kingdom [4] and consume about 28% of the national energy in China [5]. Although the figures from individual studies and different countries are slightly different, they all show significant impact on the built environment in general. As a result, many countries in the world are targeting to reduce GHG emission and total energy consumption. ASEAN countries such as Brunei Darussalam, Thailand, Indonesia and Malaysia are also aiming to reduce GHG emission, although the targets of different countries are different from each other. For example, Brunei Darussalam targets 63% reduction of total energy consumption by 2035 [6], Malaysia aims 45% reduction of GHG emission by 2030 [7], Thailand intends to reduce about 20% of GHG emission by 2030 [8], and Indonesia plans to reduce 26% on its own efforts, and up to 41% with international support, against their business-as-usual scenario by 2030 [9].

The concept of green building has been introduced to address the above consequences and/or impact on the built environment. According to the United States Green Building Council (USGBC) [10], the concept of green building is generally accepted as the planning, design, construction, and operations of buildings with several central, foremost considerations: energy use, water use, indoor environmental quality, material section and the building's effects on its site [11]. However, the concept of green building is suitable and can only be applied to new buildings [12]. On the

*Corresponding author: p20181005@student.utb.edu.bn

other hand, there is a vast lot of old buildings, which are still economically viable [13]. Demolishing those old buildings and constructing new buildings instead not only requires huge capital investment, but also involves waste of many natural resources, which is grossly against the sustainability principles [9-10].

Many of the existing building stock had been constructed before the concept of green building emerged. Those buildings are not sustainable in many ways. For example, existing buildings are responsible for over 40% of the world's total final energy consumption, and accounts for 24% of world carbon dioxide (CO_2) emissions [15]. Moreover, about 95% of the existing buildings are categorized as the high-energy consumption buildings [16] and more than 80% of the life-cycle building energy consumption occurs during their operation or actual occupancy stage [17]. Therefore, the energy efficiency of the existing buildings, among other sustainability aspects, is a crucial issue related to the total energy consumption and GHG emissions [17]. Thus, the alternative way is to equip the old buildings with modern, sustainable and energy efficient devices by replacing the old devices like heating/cooling systems, door/window shutters and/or shades, roof top gardens; as and when the replacement is necessary, e.g. during maintenance or renovation works. This process is called 'greening existing buildings' (GEB) [18]. Such greening cannot turn an old building into a green building completely, but can reduce as high as 35% of GHG emissions compared to the conventional buildings [10]. There are many other benefits that can be harvested from the greening process in existing buildings [11-13]. However, despite a wide range of benefits, GEB is still not widely being implemented, especially in developing countries. This is probably due to the reason that greening projects are considered as riskier, more complex, more difficult and more uncertain than constructing new green buildings and even than general retrofit projects [22-23].

Moreover, GEB saves money from reduced energy consumption, but requires investment for energy saving equipment. This is important because money probably plays the most crucial role in deciding whether to go for such greening. With such background, this paper considers Brunei Darussalam as a case, and presents a comparison of the current expenses on energy (i.e. electricity) cost using the conventional features in Brunei Darussalam, with the potential energy and cost savings from energy efficiency through GEB. This paper uses the survey results by Kimura [24], on energy consumption in residential buildings in Brunei Darussalam. The following sections discuss the methodology used in this study and present some energy efficient features that could be replaced with the traditional/conventional features for potential saving on energy and/or cost, and simultaneously compares their energy consumption and relevant energy costs.

2. Research Methodology and the Comparison

This paper considers a recent study conducted by Kimura [24] as a source for the average energy consumption in residential buildings of each household in Brunei Darussalam, which covered all the administrative districts of Brunei Darussalam: Brunei-Muara District, Belait District, Tutong District and Temburong District. The residential buildings were typically one or two-story bungalow type individual buildings. The study covered a validated sample size of 593 households from among a total of 67,306 registered households with Department of Electrical Service's pre-paid account for payment of electricity bills. Energy (i.e. electricity) consumption per household in Brunei Darussalam was estimated about 16,000 kWh per year, or about 1333 kWh /month.

Based on the survey, the highest two energy consumption appliances in residential buildings are air conditioner (59.5%) and refrigerator (17.9%). This is followed by outdoor and indoor lighting (3.7% and 3.6%, respectively) totaling to 7.3%. Other appliances that consume electricity are water heater (6.3%), television (3.0%), electric fan (2.9%), rice cooker (2.5%) and washing machine (0.6%) [24]. The study also estimated the average number of units of each type of appliances per household. These are tabulated in Table 1, along with the computed amount of energy consumption for each type of appliances.

Table 1 - Yearly energy consumption pattern in Brunei Darussalam

Rank	Appliances	Average number of appliances per household	Total energy consumption per appliance type	Percentage of electricity consumption by appliance
1	Air conditioner	3.5 units	9520.1 kWh	59.5%
2	Refrigerator	3 units	2864.1 kWh	17.9%
3	Lighting: Outdoor	4.5 units	591.8.8 kWh	7.3%
	: Indoor	14 units	576.2 kWh	
4	Water Heater	1 unit	1008.0 kWh	6.3%
5	Television	2 units	480.0 kWh	3.0%
6	Fan	3.5 units	464.1 kWh	2.9%
7	Rice Cooker	1 unit	400.0 kWh	2.5%
8	Washing Machine	0.5 unit	96.0 kWh	0.6%

Kimura [24] focused on identifying detailed energy consumption data for the promotion of energy efficiency and conservation to curve energy consumption. On the other hand, this paper uses the energy consumption data by Kimura

[24] and examines the economic aspect of energy efficiency and conservation. A comparison has been approached between the average expenses per household with the existing traditional (or otherwise, inefficient) electrical appliances, and that with the modern and energy efficient appliances, while taking in to account of the expenses required to replace the appliances. Current residential electricity tariff structure, as shown in Table 2, was used for this exercise. The tariff structure was introduced in 2012, for all the energy consumption in residential buildings and consumed for domestic purposes. This was followed by the replacement of post-paid to pre-paid electric meters as a way of encouraging energy saving, in that the consumers need to pay the energy cost before their use, and thereby have a clear appreciation of their energy costs [25]. There is only one electricity supply company / organization in Brunei, which made it easy for all consumers to use the same tariff structure. The tariff structure also encourages less use of energy, in that the first 600 units of electricity cost $6.00 only, compared to BND 0.08/kWh for energy consumption between 601 kWh to 2000 kWh. However, this tariff structure is still considered very low compared to international prices [26] with a low monthly energy cost relevant to energy consumption of about 1333 kWh/month. Therefore, people are likely to use more energy, which causes more usage in fossil fuels and more emissions. Thus, more use of fossil fuels lead to more carbon dioxide emissions, which directly affect global warming and climate change [27]. Nevertheless, relevant comparison is tabulated in Table 3, in terms of the monthly energy consumption and energy cost, between conventional electrical appliances, and energy-efficient electrical appliances.

Table 2 - Electricity tariff structure per month

0001 kWh to 0600 kWh	$ 0.01
0601 kWh to 2000 kWh	$ 0.08
2001 kWh to 4000 kWh	$ 0.10
4001 kWh and above	$ 0.12

The annual total energy consumption per appliance type (Table 1) was divided by 12 to get the monthly energy consumption with conventional appliances (as seen in Table 3). Average monthly energy consumption using the conventional features was computed to be 1,333.37 kWh that corresponds to the energy cost of Brunei Dollar (BND) 64.64 per month. By contrast, using the energy efficient appliances/features, the estimation for monthly energy consumption is 898.78 kWh with energy cost of about BND 30.91 per month. This means that by using the conventional features, the average yearly energy consumption per household is 16,000 kWh, with relevant annual energy cost of BND 776.04. However, if high efficiency appliances or features are used, a saving of 32.74% energy consumption in a year is expected, which corresponds to the savings in energy cost of up to 52.20% annually. This is because by implementing the energy-efficient features, annual energy consumption can be reduced to 10,761 kWh (i.e. 896.78 kWh / month) and the annual energy cost per household can be reduced to approximately BND 370.92 (i.e. BND 30.91 / month) only. Hence, by implementing the energy efficient appliances, it shows that there is a saving potential both in terms of energy cost and energy consumption.

Table 3 - Comparison of energy cost and energy consumption with conventional and energy-efficient features

Appliances	Number of appliances	Conventional Features		Energy-Efficient Features	
		Monthly Energy Consumption (kWh)	Monthly Energy Cost (BND)	Monthly Energy Consumption (kWh)	Monthly Energy Cost (BND)
Air conditioner	3.5	793.35	21.47	583.20	5.83
Refrigerator	3	238.68	19.09	209.52	16.76
Lighting: Indoor	14	48.02	3.84	29.40	2.35
Lighting: Outdoor	4.5	49.32	3.95	12.60	1.01
Water Heater	1	84.00	6.72	0.00	0.00
Television	2	40.00	3.20	18.00	1.44
Fan	3.5	38.68	3.09	23.40	1.87
Rice Cooker	1	33.33	2.67	15.24	1.22
Washing Machine	0.5	8.00	0.64	5.40	0.43
Monthly energy consumption		1333.37 kWh		896.78 kWh	
Monthly electricity bill		BND 64.64		BND 30.91	

Kimura [24] made a few assumptions that a total of 73 GWh of energy could be saved in a year (equivalent to 5.3% of household energy consumption) if: (i) the air conditioners and refrigerators that exceed six years are replaced with brand-new energy-efficient appliances, (ii) replace the fluorescent lamp with light-emitting diode (LED) for both indoor and outdoor purposes, and (iii) replace the traditional/conventional water heater with the solar water heater system. Potential energy savings were stated to be: air conditioner about 8%, refrigerator about 24%, lighting about 61% and water heater about 7%. In this regard, Batih and Sorapipatana [28] summarized a range of energy-efficient features that can be suitably used in Brunei Darussalam. Those include: high-efficiency air conditioner (2.73hp), high-efficiency refrigerator (210 litres), high performance lighting e.g. LED 5W for indoor and LED 7W for outdoor, and high-efficiency television (LED-32 inch). Some other energy efficient appliances that were considered in this computation and contributed to Table 3 are solar water heater by Sae-jung et al [29], modified motor for electric fan [30], 4-litre capacity energy efficient rice cooker [31] and high-efficiency 7 kg washing machine [32].

3. Extra Cost, Saving Potential and Payback Period

This section summarizes the additional cost that is required to replace energy efficient features/appliances. The extra cost was calculated by the difference of the price of new energy efficient appliances and the price of traditional/conventional appliances. Annual cost saving is the difference between the current energy / electricity costs using traditional appliances and the expected electricity/energy costs using new energy efficient appliances (figure from Table 3) and multiple by 12 months. Saving in energy was calculated by the difference of current energy consumption using traditional appliances and the expected energy consumption using new energy efficient equipment. In order to get annual energy saving, it was multiplied by 12. Note that the price of energy efficient appliances in Table 4 are inclusive of import rate of 5% on electrical items [33].

Table 4 - Summary on extra cost and saving potential

Appliance	Price of Traditional appliances (BND)	Price of Energy Efficient appliances (BND)	Extra Cost (BND)	Annual Cost Saving (BND)	Annual Saving in Energy (kWh)
Air conditioner	289.47	472.84	183.37	187.68	2521.80
Refrigerator	355.74	415.04	59.30	27.96	349.92
Lighting: Outdoor	4.65	15.49	10.84	17.88	224.16
Lighting: Indoor	3.81	10.32	6.51	35.28	440.64
Television	402.33	472.84	70.51	80.64	0.00
Water Heater	431.55	1510.43	1078.88	21.12	264.00
Electric Fan		15.53	15.53	14.64	183.36
Rice Cooker	84.62	231.00	146.38	17.4	216.72
Washing Machine	250.00	910.35	660.35	2.52	31.20
		Total	2231.67	405.12	4231.80

Table 4 shows that a household can annually save about BND 405.12 on energy cost and roughly 4231.80 kWh of energy consumption. Moreover, if all new energy efficient appliances are implemented, an average household is required to spend an additional amount of about BND 2231.67. If simple payback period is considered, the household can cover back their additional cost within 5.51 years. However, if considered individual appliances, the payback period for air conditioner = 183.37/187.68 = 0.977 years or just about one year, refrigerator = 59.30/ 27.96 = 2.12 years, outdoor lighting = 0.60 years, indoor lighting = 2.2 months, and television = 10.5 months. Payback period for rice cooker and washing machine is 8.41 years and 263 years respectively, but their relevant energy savings are much higher.

Almost all appliances need to be replaced some time in order to achieve the saving potential in terms of cost and/or energy consumption, except the electric fan. The traditional / existing electric fans can be used with the only modification of motor inside the fan [30]. With the modified motor, the power consumption is only 0.065kW. The modification cost is BND 15.53 only, which can be recovered from the savings within 1.06 years only.

An increase in energy consumption by air conditioners and refrigerators was seen that had been used more than six years. About 700 units of air conditioners and 500 units of refrigerators had been used between three to five years; About 500 units for both appliances had been used between six to ten years; and 300 units of air conditioner and 360 units of refrigerators had been used for more than ten years. Only 600 units of air conditioners and 380 refrigerators are below three years of usage [24]. As the average number of units of air conditioners per household is 3.5 units, assume that in a year, 50% of households in Brunei Darussalam are replacing the old air conditioners that had been used more than 6 years with the new energy efficient air conditioners, it can save the energy consumption of about 84.87 GWh (33,653 households X annual saving in energy for air conditioners).

Therefore, if in a year, 10% of the total households (6730.6 households) are replacing all the old conventional appliances into new energy efficient appliances, it can save up to 28.48 GWh per year. Thus, after 10 years, assuming all the 67,306 households would be replacing all the conventional appliances into new energy efficient appliances, it is expected that Brunei Darussalam can save about 284.83 GWh of energy consumption for residential buildings.

4. Concluding Observations

Based on the mathematical calculation on the energy-efficient features/appliances, this paper showed that greening existing buildings (GEB) has a higher saving potential of energy consumption (32.74%) and energy/electricity costs (52.20%) annually. The average payback period to cover the investment is about 5.51 years. This might deter a segment of the users from undertaking GEB, as initial investment is always a main factor to decide if to implement GEB. However, higher energy consumption appliances like air conditioner and refrigerator can potentially payback within one, and about 2, years. These appliances are expected to serve for the next 5-10 years without any extra cost, but with a huge savings in energy consumption. Such observation may be considered highly favorable to a country like Brunei Darussalam, where energy tariff structure is very low compared to international prices [26], and which might have caused more emissions. While studies with much larger sample size than Kimura [24] are expected to suggest more authoritative estimates of the energy consumption patterns, the outcome of the exercise presented in this paper is clearly positive towards wider adoption of GEB. Appropriate authority may design suitable awareness programs using such outcomes to motivate people to undertake GEB, which can not only help reduction of energy consumption, but that reduction will also come with very low cost in the near future, and with no additional cost in the long run.

Acknowledgement

The authors would like to acknowledge the Faculty of Engineering, Universiti Teknologi Brunei, Brunei Darussalam.

References

[1] U. S. E. P. A. EPA. (2013). Sustainable Design and Green Building Toolkit For Local Government, no. June. United States Environmental Protection Agency

[2] U. S. E. I. A. (2012). Energy Information Administartion, Annual Energy Review 2011

[3] J. Yudelson. (2010). Greening Existing Buildings, First. New York: McGraw-Hill

[4] S. Sorrell. (2003). Making the link: Climate policy and the reform of the UK construction industry. Energy Policy, 31 (9), 865–878

[5] X. Liang, G. Q. Shen, and L. Guo. (2015). Improving Management of Green Retrofits from a Stakeholder Perspective: A Case Study in China. Int. J. Environ. Res. Public Health, (12), 13823–13842

[6] Ministry of Development. (2015). Brunei Darussalam's Intended Nationally Determined Contribution. Unfccc, no. November, p.13

[7] Malaysia. (2005). Intended Nationally Determined Contribution of the Government. p.1–6

[8] O. of N. R. and E. P. P. Bangkok (2015). Thailand ' s Intended Nationally Determined Contribution (INDC). no. 1006

[9] Republic of Indonesia. (2010). INDC_REPUBLIC OF INDONESIA.pdf

[10] USGBC (2003). Building momentum: National trends and prospects for high-performance green building. U.S. Green Build. Counc., no. November, p. 24

[11] J. Kriss. (2014). What is Green Building?. In United States Green Building Councils (USGBC). Available: https://www.usgbc.org/articles/what-green-building. [Accessed: 28-Dec-2018]

[12] S. Shams and M. M. Rahman. (2017). Green Building. in Sustainable Utilisation of Natural Resources, First., P. Mondal and A. K. Dalai, Eds. CRC Press, 539–566

[13] N. Julayhe and M. M. Rahman. (2018). A Brief Overview of Greening Existing Buildings. Brunei International Conference on Engineering and Technology, 2018, no. 12-14 November

[14] M. M. Rahman, Z. Abu-Bakar, N. Jaya, and N. Mohamad. (2017). Perceptions on Greening Existing Buildings. 1st Int. Congr. Earth Sci., no. Nov, 119–120

[15] International Energy Agency. (2010). Energy Technology Perspectives: Scenarios & Strategies To 2050. France: International Energy Agency

[16] P. Xu, E. H. W. Chan, H. J. Visscher, X. Zhang, and Z. Wu. (2015). Sustainable building energy efficiency retrofit for hotel buildings using EPC mechanism in China: Analytic Network Process (ANP) approach. J. Clean. Prod., 107, 378–388

[17] X. Liang, G. Q. Shen, and L. Guo. (2015). Improving Management of Green Retrofits from a Stakeholder Perspective : A Case Study in China. pp. 13823–13842

[18] B. C. M. Leung. (2018). Greening existing buildings [GEB] strategies. Energy Reports, 4, 159–206

[19] A. Ragheb, H. El-Shimy, and G. Ragheb. (2016). Green Architecture: A Concept of Sustainability. Procedia - Soc. Behav. Sci., 216, no. October 2015, 778–787

[20] P. A. Bullen and P. E. D. Love. (2010). The rhetoric of adaptive reuse or reality of demolition: Views from the field. Cities, 27 (4), 215–224

[21] Wilkinson, Sara J, and Jailani. (2011). User satisfaction in sustainable office buildings : a preliminary study. PRRES 2011 Proc. 17th Pacific Rim Real Estate Soc. Annu. Conf., no. January, 1–16

[22] A. S. Ali, I. Rahmat, and H. Hassan. (2008). Involvement of key design participants in refurbishment design process. Facilities. 26 (9), 389–400

[23] E. Miller and L. Buys. (2008). Retrofitting commercial office buildings for sustainability: tenants' perspectives. J. Prop. Invest. Financ., 26 (6), 552–561

[24] S. Kimura. (2018). Residential Energy Consumption in Brunei Darussalam. In Building Energy Efficiency Forum, Universiti Brunei Darussalam, 03 November 2018

[25] Electricity Tariff. *Department of Electrical Services, Brunei Darussalam*, 2012. Available: http://www.des.gov.bn/SitePages/Electricity%20Tariff.aspx [Accessed 30-May-2019]

[26] Electricity Prices around the World, June 2018. Available: https://www.globalpetrolprices.com/electricity_prices/ [Accessed 15-June-2019]

[27] Z. Pezeshki, A. Soleimani, A. Darabi, and S. M. Mazinani. (2018). Thermal transport in: Building materials. *Constr. Build. Mater.*, 181, 238–252

[28] H. Batih and C. Sorapipatana. (2016). Characteristics of urban households' electrical energy consumption in Indonesia and its saving potentials. Renew. Sustain. Energy Rev., 57, 1160–1173

[29] P. Sae-jung, T. Krittayanawach, and P. Deedom. (2015). An Experimental Study of Thermo-Syphon Solar Water Heater in Thailand. Procedia Energy, 79

[30] T. Tauqeer, M. A. Ansari, and A. Hasan. (2017). Realization for low cost and energy efficient ceiling fans in the developing countries. Renew. Sustain. Energy Rev., 76, no. March, 193–20

[31] H. Bo and Z. Feiyan. (2014). Energy efficient rice cookers, vol. 11

[32] A. Milani, C. Camarda, and L. Savoldi (2015). A simplified model for the electrical energy consumption of washing machines. J. Build. Eng., 2, 69–76

[33] Brunei Darussalam Ministry of Finance (MOF). (2017). The Customs Import and Excise Duties Effective 1st April 2017