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Electricity Consumption in Brunei Darussalam: Challenges in Energy Conservation

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Abstract – Brunei Darussalam is considered to be one of the highest consumers of electricity per capita in the world, and the domestic households account for the highest electricity consumption in the country. Bruneian households enjoy low electricity tariff which leads to over-consumption of electricity. This paper examines the behavioural pattern of the electricity consumption among Bruneian households residing at Lambak Kanan National Housing Scheme, using two approaches including end-use metering of several common household appliances and survey questionnaire on electricity consumption behaviour and energy conservation. The paper also attempts to compare the findings of the study with the data on electricity consumption in Singapore. Findings suggest that Bruneian households consumed high amount of electricity and among the studied appliances, air-conditioning and fluorescent lighting take up a great proportion of the electricity. Energy conservation is not new within the households but implementation of it is still lacking. Challenges on energy conservation, thus were revealed as low energy-efficient technologies integrated in building systems, lack of knowledge on the benefits of energy conservation among households and the disincentive low electricity pricing system. Ultimately, rigorous methods to tackle the challenges are needed in the country in order to curb the excessive usage of electricity and to conserve energy as a whole.

Keywords – Brunei, domestic household, electricity consumption, energy conservation, energy efficiency.

1. INTRODUCTION

Electricity has become one of human's most demanded necessities. The global applications of electricity have been advanced rapidly and the industry began utilising large amounts of electricity in heating up houses, lighting up dark places and generating power to all other technologies that are needed for production. This has led to the increase in global electricity consumption. Ramage [1] stated that electricity consumption worldwide has risen by 40% during the 1980s with an average annual increase of 3.4%. The world demand for electricity is predicted to double from the year 2000 to 2030, that is, from 18% to 22% of total energy consumption [2]. Ishiguro and Akiyama [3] stated that Asian developing countries posted double-digit percentage annual growth in electricity consumption and this has been increasing rapidly. Brunei Darussalam (hereafter Brunei) too experienced an increase in electricity consumption. As reported in the 8th National Development Plan [4] and by Malik [5], the state's power demand has risen rapidly by at least 7-10% yearly, which is higher than the world's average annual increase. It is also reported by Lawrey et al. [6] that Brunei has the highest average consumption of electricity per capita in Asia.

A large proportion of Brunei's electricity consumption is used by households. According to the ASEAN Centre for Energy [7], Malik [5] and Lawrey and Pillarisetti [8], houses and residential areas account for 38% of electricity usage in Brunei (refer to Figure 1) and represent 63% of all customers. Government departments are the second highest user of electricity in

Brunei with 29% representing 6% of customers, followed by the commercial sector and small-medium enterprises which account for 18% of electricity consumption, and finally the oil and gas industry, especially Brunei Shell Petroleum (BSP) and Brunei Liquefied Natural Gas (BLNG) companies, with 15%.

Wasteful and inefficient energy policies can result in environmental externalities in the forms of acid rain and global warming, which today have become important international concerns. Brunei's power plants are all gas-fired, which contribute less carbon emission per unit of energy into the atmosphere compared to other fossil fuels. Natural gas may contain fewer impurities than either coal or oil, and is thus regarded as a relatively 'clean' fuel. However, the combustion process of whatever fuel, including natural gas, inevitably produces atmospheric pollution. The U.S. Department of Energy [9] reported that energy-related carbon dioxide emissions in developing countries increased by 82% between 1970 and 1992, compared with a much slower rate of 28% in the developed countries. Therefore, one way of reducing the negative environmental impacts, associated with energy use, is by reducing the amounts of electricity that are wasted during its use and by making electricity production more efficient. Energy conservation and efficiency is now being promoted considerably elsewhere [10], [11] and also in Brunei [5], [8], [12], [13].

In adopting an approach towards energy conservation and efficiency, it is pertinent that one understands how electricity is being used. This approach was supported by other studies including those done by Gram-Hanssen [14], Gram-Hanssen [15], Nilsson *et al.* [11], as well as by He and Kua [10]. The knowledge about how households utilise electricity could be used for directing initiatives to reduce electricity consumption. Study on household energy conservation

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in Brunei, particularly on electricity consumption, however is lacking. Most Brunei's energy studies were focused on renewable energy to generate sustainable electricity [5], [16]. Previous studies found that the use of renewable technologies as well as energy efficient buildings may not make a major implication on energy conservation if households do not have any incentive to either conserve electricity or to use it more efficiently

[5], [15], [17]. Therefore, the purpose of this paper is to look into the pattern of electricity consumption in Brunei, using households residing in the country's largest residential area, namely the Lambak Kanan National Housing Scheme, as the case study. The study focuses on residential households since they are the highest electricity consumer in the country.

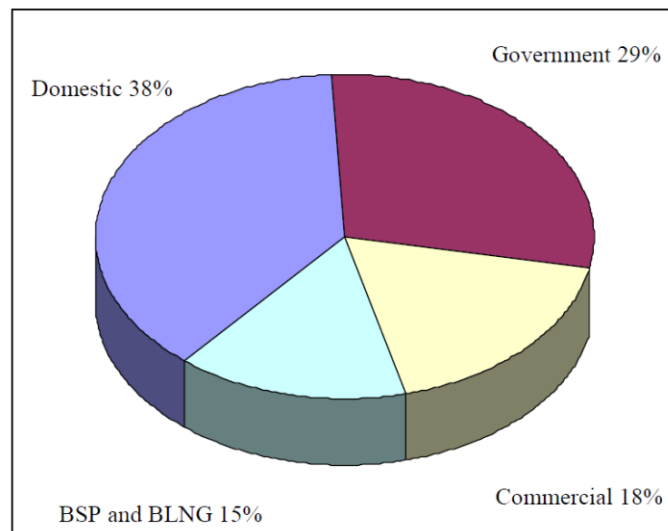


Fig. 1. Brunei Darussalam's electricity usage by consumer type [7].

2. ELECTRICITY CONSUMPTION

Brunei's electrical power system has three independent networks, namely: Network 1 which supplies power to the Brunei Muara, Tutong and Belait Districts; Network 2 which provides power in the Temburong District and Network 3 in selected load centres in the Brunei Muara District. The government's Department of Electrical Services (DES) is the operator of Networks 1 and 2, which have four generating plants with total installed capacity of 449 MW. Berakas Power Company (BPC) is a private operator of Network 3 with three generating power plants. The total installed capacity is 259 MW and it is interconnected by a triangular network which is separated from the DES grid. The three independent power generations, transmission and distribution networks are, however, not interconnected. To date, about 99.66% of the population in Brunei has been provided with electricity from the grids. About 1,000 people in remote rural villages are not enjoying the benefits of grid electricity, where small portable generator sets are used to generate electricity instead.

The electricity tariff is regressive in nature which is based on a declining block system. The residential tariffs in Brunei are charged with the first 10 kWh at B\$0.25 per kWh, the next 60 kWh at BN\$0.15 per kWh, the next 100 kWh at BN\$0.10 per kWh, and the remaining units will be charged at BN\$0.05 per kWh. As a wealthy

nation, whose per capita gross domestic product is at BN\$31,312.00 (or approximately US\$19,210.00, where US\$1.00 = BN\$1.63) which is far above most other developing countries, electricity prices are largely subsidised by the government, who pays less than the production of natural gas. When compared between Southeast Asian countries, International Energy Agency [18] reported that subsidies were the highest in Brunei when measured on a per capita basis. Subsequently, the government charges low tariffs for electricity use, with an average residential tariff bill of BN\$0.06 per kWh. According to the United Nations Economic and Social Commission for Asia and the Pacific [19], in the Southeast Asian region, Brunei was the highest consumer of electricity. It was appeared that in the year 2010, Brunei households consumed 2948 kWh per capita, which is higher than Singapore (1386 kWh per capita) and Malaysia (797 kWh per capita) (refer to Table 1) [19]. Moreover, Brunei has higher electricity demand than the other wealthy nations such as Singapore, Japan and OECD countries (refer to Figure 2) [18]. In spite of its small population of 357,800 persons, it is rather startling to learn that Brunei recorded such a high figure for its electricity consumption.

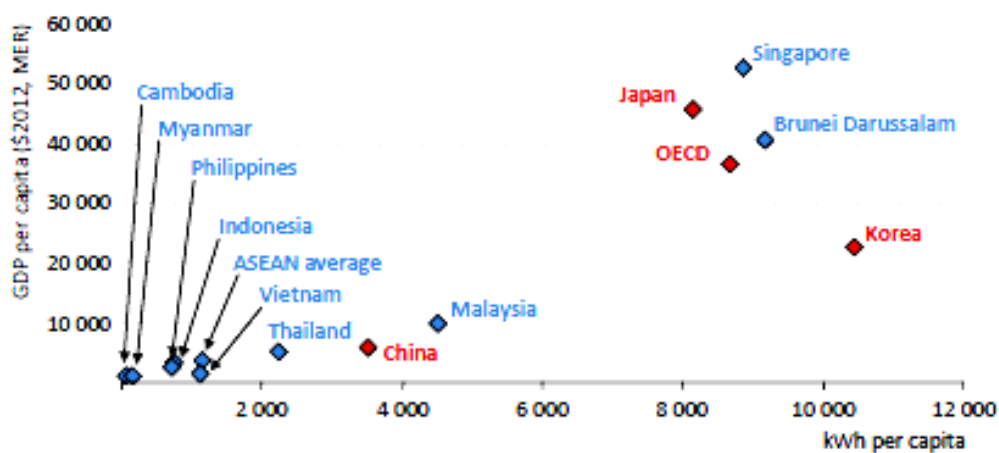


Fig. 2. Electricity demand for selected countries [18].

Table 1. Household electricity consumption for selected Southeast Asian countries [19].

Countries	kWh per capita
Brunei Darussalam	2948
Cambodia	72
Indonesia	250
Malaysia	797
Myanmar	51
Philippines	202
Singapore	1386
Thailand	502
Vietnam	354

Thus, this is one indication of Bruneian’s behavioural pattern concerning electricity consumption. Not only are Bruneian households using too much electricity, they are also paying it at a cheaper rate compared to other countries, as electricity price is mainly subsidised by the government. As a result, Bruneian tend to take electricity for granted to the extent that electricity is seen as a necessity where Bruneian heavily depend on. The low electricity prices dampen households’ incentives to conserve electricity or use it more efficiently, leading to over-consumption and eventually a loss to the society [8], [18].

In order to provide a more sustainable energy direction, it is important to understand household’s practices as well as the technologies related directly to each of the practices studied [15], [20]. As indicated by previous studies [20]-[23] there are several factors that can affect electricity consumption. Halvorsen and Nesbakken [20] analysed the changes in household electricity consumption as an impact of tax charges. They found out that as tax increases, prices also increase and this has led to the reduction of electricity consumption. Lam [21] investigated the relationship between electricity consumption with economic variable and climatic factors for Hong Kong. He concluded that electricity consumption within the studied residential sector can be estimated based on the household income,

household size, electricity price and cooling degree-days. He stated that electricity consumption increases as household income and household size increases. On the other hand, electricity consumption decreases as electricity price and cooling degree-days increases [21]. The Energy Market Authority of Singapore (EMA) also found that climate could affect electricity consumption [22]. The study conducted by EMA in 2002 on different types of households discovered that due to the hot, tropical climate of Singapore, all but one of the different types of households, have air-conditioners as taking up most of the monthly electricity consumption. Nonetheless, different type of households consume different levels of electricity. This shows that most households in Singapore prefer air-conditioners as a mode of cooling. Likewise, based on the 2001 residential energy consumption survey conducted by the U.S. Energy Information Administration (USEIA), the U.S also has air-conditioners as one of its larger portion of their residential electricity after the “other” appliances including TV, furnace fans, freezers, clothes drier and all others [23]. Although, the amount is much smaller than Singapore, it still indicates that air-conditioner is still the single-most used appliances.

Despite that Brunei is known to be a high consumer of electricity, the pattern of its electricity consumption is not well known. Therefore, the aim of

this study is to explore the consumption pattern of electricity by the highest consumer in the country, the households in particular, to determine the challenges in energy conservation in the country and to provide recommendations to overcome the challenges. The study examined the usage duration of the common electrical appliances found in the households such as television, refrigerator, and air-conditioner and examined how much of these electrical appliances make up the households monthly electricity consumption. A comparison on electricity consumption was also made between households in Brunei and Singapore, in view of the similarities between the two countries in terms of their economic status as well as the environmental conditions. The findings were used to determine how Bruneian households can reduce their electricity consumption and ultimately, reduce electricity usage for the whole nation. Hayes and Cone [24] asserted that with small reduction, if spread over many households, could have an important impact on the nation's energy resources.

3. METHODOLOGY

The methodology adopted in the study combines both methods of survey questionnaire and end-use metering of appliances. Through this approach, it was expected that information about households practices on electricity consumption and conservation as well as the technologies and cost related directly to the practices studied could be discovered. Thus, with this understanding, potential savings either by reducing electricity consumption of each appliance or using it efficiently could be proposed. End-use metering approach was conducted by previous studies such as by Sidler et al. [25]. Combining end-use metering approach with other methods such as survey and qualitative interviews was further suggested by Gram-Hanssen et al. [17] and Gram-Hanssen [14], [15]. This methodology is relevant to any study with the aim to get more information on how to assist households in reducing their energy consumption [15].

The respondents involved in the research were households at the Lambak Kanan Housing Scheme. There are approximately 2,056 houses within the housing scheme and the scheme was designed for Bruneian citizens who do not own land to build their houses. These housing units are made available at subsidised prices to be paid over a period of 20 to 30 years. The study was limited to households with conventional energy meter because these households have a systematic estimation of their electricity consumption from the Department of Electrical Services (DES). Households with prepayment energy meter were not included as records of electricity consumption were not available. This was to avoid any miscalculation or error in their electricity consumption. Using the DES estimation on monthly electricity consumption in unit of Kilowatt-hour (kWh) of seven common domestic electrical appliances in Brunei, including fluorescent lamp, refrigerator, washing machine, energy-saving lamp, air-conditioner, water heater and colour television,

the study was able to determine the monthly cost contributed by each electrical appliance to the households' electricity bills by using the equation below:

$$\text{Electricity cost of appliances} = \text{Monthly electricity consumption} \times \text{Average number of appliance in household} \times \text{BN\$0.06}$$

The electricity tariff used in the calculation was BN\$0.06 and this was based on DES estimation of electricity consumption charges for domestic appliances. The estimation on the electrical appliances was based on the lowest monthly estimated consumption. As a result, the monthly electricity cost for each electrical appliance was the minimum amount that the household would receive based on the average usage of the appliances.

In addition to the end-use metering approach, a survey questionnaire was distributed to the studied household. The survey was designed to extract data on households' behavioural pattern and methods of conservation within the households. Among the objectives of the survey were to obtain household's profile, to identify how many household electrical appliances were being utilized, to assess the usage of those electrical appliances, to determine energy conservation practices being adopted within households and to examine if selected households were willing to participate programme that could help reduce with their electricity consumption.

Findings on Bruneian households' electricity consumption were then compared to those of households in Singapore. The study utilised data on Singaporean households' electricity consumption obtained by the Energy Market Authority of Singapore (EMA) [22]. The type of Singaporean household used for the comparison was terrace houses as this particular type of private accommodation resembles mostly to the houses surveyed in Brunei, in terms of their layout and size. All data collected through the study were coded for entry into the Statistical Package for Social Sciences (SPSS). Methods of analysis employed to interpret the data include descriptive statistics, frequencies and correlation coefficients between different variables.

4. RESULTS AND DISCUSSIONS

A total of 150 questionnaires were distributed at the Lambak Kanan National Housing Scheme, with a response rate of 95% (n=142). The sample consists of different number of people per household and different levels of household income. Household size was categorised into two categories; small and large-sized household. Small-sized household was considered as having six people or below per household whereas large-sized household as having more than six people. In this research, 81.7% of the households investigated were from small-sized household and 18.2% were from large-sized households. The household has an average number of children of 2.30 while adults are 3.27 and there were more females with an average of 2.84 than males with an average of 2.71. There were three categories of

household income groups, namely low-income household (BN\$2000 and below), middle-income household (BN\$2001 - BN\$5000) and high-income household (above BN\$5000). Majority of the respondents came from middle-income households (66.9%) while 17.6% and 15.5% of the respondents were from high and low-income households respectively.

From the survey conducted, only 29.6% of the respondents admitted that their electricity consumption have increased in the past year, while 70.4% of them declared that their electricity consumption have not increased, but remained fairly constant over the past year. However, based on their electricity bills for the past three months, it was found that there is an average of 0.5% to 4% increase in their electricity bills, with an average electricity consumption of BN\$135.52. This shows that households may not be aware of the gradual increment in their bills or that they may have a different interpretation of 'increase' in their bills. Whenever there was either a small increase and/or decrease in electricity cost within a year, respondents might perceive that their electricity consumption as fairly constant.

The electricity consumption of Bruneian households for common electrical appliances is shown in Table 2 and Figure 3 shows how much each of the

electrical appliance takes up the average monthly electricity cost. Air-conditioners were recorded as having the largest portion of the monthly electricity consumption (403.2 kWh) with an average operation of 14 hours per day (refer to Table 2), and an air-conditioner takes up about 76% of Bruneian household's monthly electricity cost (refer to Figure 3). A study by APEC Peer Review on Energy Efficiency (PREE) in the country [12] also suggested that air-conditioning is the leading consumption of electricity and this is prevalent in most households, government buildings and commercial buildings. This was also reported elsewhere, such as in Singapore [22], the U.S [23] and Australia [27], where air-conditioner was the most used appliance and the primary cause of rising electricity consumption. The most plausible reasons for the highly dependence of Bruneian on air-conditioning would be due to climatic factors and building designs. Brunei is located in a tropical climate region and the average daily temperature is almost 30 degrees Celsius, hence the usage of air-conditioners is common among households. Moreover, buildings in Brunei tend to be designed with air-conditioner [8], as it is seen as a mean of cooling and to avoid heat stress due to the hot climate.

Table 2. Electricity consumption for selected households in Brunei Darussalam.

Appliances	Average operating hours/day	Wattage (kW)	Monthly Electricity Consumption (kWh) *	Average number of appliance in household	Monthly Electricity cost (\$)
Fluorescent lamp	10	0.89	8.9	22	11.75
Refrigerator	24	2.74	65.7	1	3.94
Washing Machine	3	9	27	1	1.62
Energy-saving lamp	10	0.262	2.62	1	0.16
Air-conditioner	14	28.8	403.2	4	96.77
Water Heater	3	33.77	101.3	2	12.16
Colour TV	8	2.69	21.5	2	2.58

*Source by Department of Electrical Services [26].

On average, Bruneian households use less water heater compared to fluorescent lamp with 3 hours and 10 hours per day respectively. However, water heater consumes higher electricity (101.3 kWh) than fluorescent lamp (8.9 kWh). Hot water consumption might relate with high heat utilization [15] which consequently increase electricity consumption. However, when considering the monthly electricity cost, fluorescent lamp and water heater take up the same amount of percentage (9%) in the average monthly electricity cost (refer to Figure 3). This was due to the extensive use of fluorescent lamp in a household (an average of 22 fluorescent lamps) as revealed by the survey. According to Lawrey & Pillarisetti [8], artificial lighting is used extensively in Brunei compared to natural lighting as buildings were primarily designed to

limit the use of natural light. Natural light is usually limited in buildings as sunshine will cause the air-conditioning to work less efficiently [8].

A refrigerator which operates 24 hours a day only takes up a small portion (3%) of the monthly electricity consumption of the households (refer to Figure 3). Among all the investigated appliances, energy-saving lamp has the smallest portion of the monthly electricity consumption (2.62 kWh), even though it was used regularly (an average of 10 hours per day). However, based on the survey, very few households use energy-saving lamp with an average of one lamp per household. It was found that energy-saving lamp uses more than three times lesser electricity as compared to the fluorescent lamp. This means that if households use energy-saving lamps instead of regular fluorescent

lamps, their electricity consumption under lightings can be reduced by an average of three times.

In comparing electrical appliances consumption between households of Brunei and Singapore, it was found that Bruneian households consume more electricity than Singaporean households, with an average of two times more operating hours per day, as reflected in Table 3, except for refrigerators where they were used similarly by both countries in terms of operating hours.

Although Bruneian households' electrical consumption was doubled for almost all electrical appliances, the amount of monthly electricity cost for each appliance in Brunei is far lesser than that in Singapore, in exception to air-conditioner, causing the total electricity cost of typical Bruneian household to escalate (refer to Table 4).

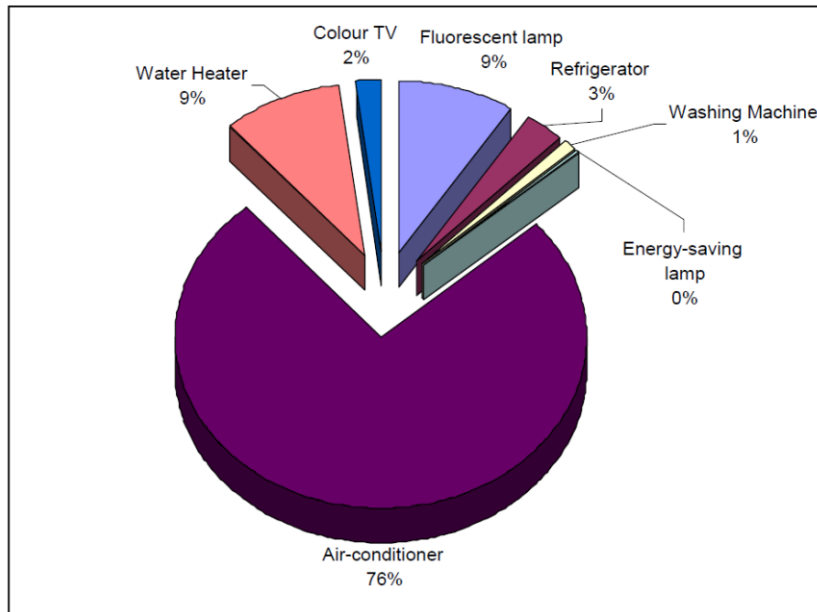


Fig. 3. Average monthly electricity cost for selected Bruneian households.

Table 3. The average operating hours per day of electrical appliances between households in Brunei Darussalam and Singapore.

	Average operating hours/day	
	Brunei Darussalam	Singapore*
Fluorescent Lamp	10	4.8
Refrigerator	24	24
Washing Machine	3	1.3
Air-conditioner	14	6.5
Water Heater	3	1.0
Colour TV	8	5.0

*Source: [22].

Table 4. Comparison of monthly electricity cost between households in Brunei Darussalam and Singapore.

Appliances	Monthly Electricity Cost			
	Singapore*		Brunei Darussalam	
	\$	%	\$	%
Air-conditioner	60.17	51.8	96.76	76.0
Refrigerator	18.64	16.0	3.94	3.1
Lighting (including energy-saving lamp)	17.33	14.9	11.81	9.2
Water Heater	11.12	9.6	12.16	9.4
TV	5.40	4.6	2.58	2.0
Washing Machine	3.60	3.1	1.62	1.3
Total	116.26	100.0	128.87	100.0

*Source: [22]

These findings indicate that Bruneian households tend to use more electricity than Singaporean households and this is mainly due to the cheaper price of electricity in Brunei. Lawrey et al. [6] stated that Brunei has an average residential tariff of only BN\$0.06 per kWh while Singapore's residential tariff is BN\$0.16 per kWh. It can be deduced that a Bruneian household who is charged with a lower tariff than that in Singapore seems to be less conscious about energy conservation. This concurs with the findings in Norway, where cheap and widely available hydro power has resulted in an extended period of high electricity consumption and has not provided much incentive for energy efficiency [28]. Lawrey and Pillariseti [8] studied the implication of subsidy and declining block tariff price structure on Brunei's electricity consumption. They suggested that both subsidy and the tariff price applied on the electricity price lead to consumer's over-consumption of electricity. This was also observed by the Energy Conservation Centre of Japan from a survey conducted in the country, where low energy prices and no tax policy weakens the public awareness on the importance of energy conservation, hence energy conservation has not been promoted [29]. The impact of this is that Bruneian tends to depend on electricity and they are not faced with the true opportunity cost of energy production [8]. Consequently, there is little economic incentive either to conserve electricity or use it wisely [5], [8], [18].

The study also examined how aware Bruneian households are in conserving electricity. It was discovered that more than 50% of the respondents admitted that they have tried to conserve electricity within their households such as switching off the lights and other electrical appliances when they are not around. The great number on household's awareness regarding electricity conservation should be applauded but by looking at the high cost of electricity consumption of the typical Bruneian's household, it was suggested that the efforts on conservation were not sufficient. More efforts are needed where the households should also be encouraged to use energy-efficient appliances. This is to ensure that even when the electrical appliances are switched on, they consume less electricity as compared to non-energy efficient appliances.

The strongest relationship associated with energy conservation is household income. This shows that as household income increases, energy conservation within the household also increases [21], [30]. Moreover, it was found that not all high-income households have high electricity consumption. This indicates that high-income households would highly likely invest their income and put effort into energy conservation measures, including energy-efficient appliances and paying more for renewable energy, which ultimately lowers their electricity consumption. On the other hand, low-income households may have high electricity consumption as they are less willing to invest their income into more energy-efficient appliances. They would rather spend much of their income on relevant expenses such as paying their utility bills.

The correlation coefficient of the variable of participation in energy conservation and electricity consumption is found to be negative (-0.277) in this research, indicating that households with high consumption in Brunei are less willing to participate in energy conservation programme. This could be explained by the lack of information concerning the benefits of energy conservation practices. Furthermore, as Brunei has low electricity price, households may still afford to pay high electricity bills even for the low-income households, thus energy conservation practices are not an incentive for reducing their electricity consumption. This corresponds with Sardonou's [31] findings among Greek households where households that are highly dependent on electricity have no intention to reduce their electricity consumption through conservation actions. This was probably due to the factors such as the lack of information on the positive effects of energy conservation, or because high energy prices are affordable and there is no economic incentive to reduce electricity cost, hence no energy efficiency investments are made.

Therefore, based on the findings on the pattern of electricity consumption of the biggest consumer in Brunei, the households, the challenges to energy conservation were revealed and these include Brunei's building system that are built with low energy-efficient technologies, lack of knowledge on the principles of energy conservation as well as being contented on the cheap electricity price. It is noteworthy that the two most leading consumption of electricity as found in this study are air-conditioner and artificial fluorescent lighting. Air-conditioner is prevalent in almost buildings in Brunei as it is seen as a mean to prevent heat stress and buildings were tend to be built with artificial fluorescent lighting. With the relatively low tariff, Bruneians have enjoyed cheap and relatively high usage of electricity. The survey revealed that household in Brunei could not be bothered to reduce electricity consumption, where even the low-income household has no concern on paying high electricity bills. Due to the low electricity tariffs, it is likely that most households are not aware of how to rationally and efficiently use electricity as there are currently no financial incentives to do so, hence energy conservation is less significance for many Bruneian. In order to curb the current pattern of electricity consumption of Bruneian household, rigorous methods need to be implemented so as to overcome these challenges.

5. RECOMMENDATIONS

There are several strategies that can be implemented in the country to reduce electricity consumption. However, from the findings and research, it was found that improving the building energy system particularly by increasing the usage of energy-saving electrical appliance is the best option within the households. In view of this, it was suggested that one of the following strategies or a combination of the following strategies could be implemented to address this issue.

One strategy is to create energy conservation policies. The reason for this is that Brunei has no

specific regulations or policies concerning energy conservation. According to the Energy Conservation Centre of Japan [29] and Tu [13], energy efficiency and conservation is not one of the primary policy concerns for the Brunei government. There are no comprehensive measures on energy management systems, incentives and subsidies for energy efficient equipment, energy labelling as well as promotion of energy service company [13]. The establishment of energy conservation policies will provide a framework or guideline that could assist in translating energy-efficient promotion approach into action. This should also include an energy efficiency standard. This is needed in order to emphasise energy efficiency measures that will save energy within a household through the installation of energy-efficient appliances and use of energy-efficient building materials within the households.

The energy efficiency standards should include the following:

- The primary agency that is responsible for the compliance and enforcement with these standards, which include giving permits to build new residential buildings or making alterations to existing buildings;
- The other agencies that are given responsibility in different areas of energy efficiency such as building, plumbing, electrical and mechanical. These agencies should be stream-lined so that their objectives are not contradicting with each other. However, each agency should be accountable in ensuring that energy-efficient materials and appliances are installed correctly and comply with the given standards; and,
- To establish minimum performance level of energy efficiency within the household. This can be achieved by using better components such as higher efficiency windows, cooling system equipment and so on. A qualified examiner or assessor can verify if a household is in compliance with the minimum performance level.

It is suggested that a better energy efficiency technology is needed, with greater emphasis on air-conditioner and lighting system. Brunei requires high cooling loads due to its hot and humid weather and as air-conditioner is the leading consumer of electricity in a household, energy-efficient air-conditioner is important in order to reduce electricity consumption and to conserve electricity. Air-conditioner with chiller and inverter technology [12] should be installed in households. Furthermore, compact fluorescent lamp and LED lamp [12] should also be introduced instead of regular fluorescent lamps. This study found that regular fluorescent lamps use more electricity by an average of three times compare to energy-saving lamps. APEC [12] estimated that energy-efficient air-conditioner and lighting could result in up to 50% reduction in energy with three quarters of this reduction coming from high efficiency air-conditioner and about 7% from high efficiency lamps.

Secondly, in the context of increasing awareness of energy-saving appliances, the government should promote awareness of energy efficiency within the

households. This can be done by educating households on how to use appliances correctly and ways to further reduce electricity consumption. A promotional activity should be done between DES and Brunei households. This is to give people the opportunity to see the different types of electrical appliances that are readily-available in the market. This also brings about a closer involvement between the government and the households in order to increase the public's confidence on the reliability, efficiency and the cost effectiveness of these appliances.

Another way to increase awareness of energy-saving appliances is by introducing energy labelling. Energy labelling provides information to the public regarding the energy efficiency of products. This is to ensure that consumers are more aware of what appliances they are using and how much they save energy. Hence, labels can educate and encourage people to go for more energy-efficient electrical appliances and products. Furthermore, with labelling regulations implemented in the country, the authority can halt the importation of non-energy efficient appliances and products into the country. As there is high usage of cooling and lighting in Brunei's residential sector, energy labelling scheme should be first imposed to air-conditioner and lighting systems, and in later phase, the scheme could be extended to cover other appliances. According to APEC [12], at least 19 APEC economies and more than 57 economies worldwide have efficiency and labelling programmes in place, which cover more than 80 different categories of appliances. An example of energy labelling is the Energy Star, created by the U.S Environmental Protection Agency and U.S Department of Energy. The aim of the Energy Star is to give energy efficient choices to households without sacrificing features, comfort and style [32]. Energy Star helps households as well as business on how to improve their homes or office buildings to make it more efficient. A similar energy labelling has also been implemented in Malaysia through its "five star" label system that provides rating and good consumer information [33]. Fundamentally, labels should be easily interpreted which can help consumers to determine their electricity cost savings and identify which appliance to opt for. It is hoped that the implementation of this regulation will assist consumers to have a better understanding of electrical appliances and products' efficiency rate, and, consequently will reduce the energy consumption nationwide.

Alternatively, buildings should be integrated with renewable energy sources. The use of renewable energy sources should be developed as Brunei has a potential for solar and wind energy development [8], [5], [16]. Brunei National Energy Research Institute (BNERI) reported that renewable energy for Brunei is still in its infancy and currently produces about 1700 MWh of solar energy annually [34].

The other strategy is to implement a programme that aims to reduce electricity consumption. The aim of the programme should be to reduce electricity consumption in households and to help change behavioural pattern in order to promote energy conservation. This programme should also encourage

individual participation in energy savings, not only within the households but also in schools and at work. Several awareness-raising programmes have been conducted by the country's Energy Division such as Energy Week, roadshows and Energy Expo [12]. These programmes need to be conducted continuously, involving all levels of the society. The younger generation is not an exception where the culture of energy conservation should be nurtured at a young age. Energy conservation could also be incorporated in the school's national curriculum.

Another example is the energy conservation programme that was implemented by Idaho Power [35]. This programme was aimed at reducing high electricity usage during peak demand during summer season, because more customers tend to use air-conditioners to cool themselves at that time. The Idaho Power programme is a voluntary programme that is offered to their customers that uses more than 300 kWh of electricity per month. Under this programme, customers are charged at a lower rate except during Energy Watch hours. During Energy Watch hours, customers are charged about four times more than the normal rates and it is only for 10 days for four hours per day during the summer season. The programme found that previous year participants have managed to reduce their electricity bill and they have also changed their electricity usage [35]. This programme encourages its participants to use as little electricity as possible especially during the Energy Watch hours. This programme can be implemented in Brunei because it is designed for those residing in hot weather condition, which is similar to Brunei. This programme has the potential to help households in Brunei to adopt energy conservation practices, not only when they are out of their homes but also when they are in them. They will learn how to be more conscious about their electricity usage, and thus, giving them an opportunity to change their behavioural pattern. However, it is important for Bruneian households to be willing to reduce their electricity consumption because if they participate in such programmes and do not change their behavioural pattern, then, their electricity bill will still increase.

Although subsidised electricity price was considered as an influential factor of over-consumption, removal of subsidy in Brunei would not be a straightforward method. Reduction or removal of subsidy may affect Bruneian's welfare, especially for the lower-income bracket. Alternatively, Brunei government should design a more effective electricity tariff system and Lawrey and Pillarisetti [8] suggested that the current tariff structure should be re-considered by replacing it with either a flat rate or increasing block tariffs. This would allow the lower-income groups to meet their basic needs of electricity while encouraging electricity conservation. Furthermore, the Bruneian society should be aware of the high opportunity cost of subsidies and the adverse environmental impact of over-consumption of energy [8]. Ultimately, as Bruneian nurture the culture of conserving energy through various means such as the adoption of energy-efficient technologies, energy conservation programme and

effective electricity pricing system, it would be expected that Bruneian will voluntarily reduce consumption of electricity in the future. The most effective strategies to be implemented in the country to reduce electricity consumption, however, need to be further analysed and this could be a direction for future research.

6. CONCLUSIONS

The study investigated the consumption pattern of electricity by household residing at Brunei's largest residential area, the Lambak Kanan National Housing Scheme, determined the challenges in energy conservation and provided potential ways to promote energy conservation in the country. It would appear that, based on these findings, Bruneian households enjoy high usage of electricity, and among the commonly used electrical appliances, air-conditioner, fluorescent lamp and water heater take up a greater proportion of the electricity consumption as well as the monthly electricity cost. However, many respondents were not aware that there was an increment in their monthly electricity cost as they claimed that their electricity bill remained constant for the past few years even though there was an actual increase in their bill. There is a potential for energy conservation in the country as Bruneians are well aware of it, but efforts are not adequate to make a change in electricity consumption. Due to the low price of electricity, high electricity bills were still affordable, even for the lower-income bracket. Hence, there is little economic incentive to reduce electricity consumption and thus energy conservation is not a priority. It was deduced that the challenges of energy conservation among households in the country would be the existing low energy-efficient technologies built in households, lack of knowledge on the principles of energy conservation and being contented on the cheap electricity price. These challenges need to be addressed in order to conserve the energy, hence Brunei's decision makers should implement comprehensive measures to curb high electricity consumption. This may involve the implementation and enforcement of energy conservation policies, where national energy efficiency standards as well as labelling could be established. As air-conditioner and lighting are the leading appliances that take up the largest portion of electricity consumption, these are the appliances that should be prioritized where a more energy-efficient air-conditioner and lighting systems need to be installed in the buildings. Alternatively, renewable energy sources should also be integrated into the building systems and developed further in the country. Moreover, the culture of energy conservation should be nurtured by all Bruneian and this is where education is needed. This could be done through various energy conservation awareness-raising programme and ultimately, Bruneian will voluntarily practice energy conservation in their daily routine.

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