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Brunei Darussalam Energy Consumption Survey: Residential and Commercial and Public Sectors

Prepared by

Economic Research Institute for ASEAN and East Asia

and

Brunei National Energy Research Institute

Brunei Darussalam Energy Consumption Survey:
Residential and Commercial and Public Sectors

Economic Research Institute for ASEAN and East Asia (ERIA)

Sentral Senayan II 6th Floor

Jalan Asia Afrika no.8, Gelora Bung Karno

Senayan, Jakarta Pusat 10270

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Foreword

Brunei Darussalam is rich in energy resources such as oil and gas, but its total final energy consumption significantly increased by 3.4% per annum in 1990–2015, while gross domestic product (GDP) grew by 2.9% in the same period. Total final energy consumption will grow by 7.4% per annum in 2015–2040, with GDP growth rate assumed at 5.6% (Kimura and Phoumin, 2019). Energy elasticity to GDP was and will be more than 1. Brunei Darussalam, therefore, needs to promote energy efficiency and conservation (EEC) in residential and commercial activities, whose demand for electricity will continue to grow more than demand for gasoline and diesel oil as transport fuel. To set up appropriate energy efficiency policies for the residential and commercial sectors, however, policy makers must know their current energy consumption situation and level. The Economic Research Institute for ASEAN and East Asia (ERIA) supported the Ministry of Energy in conducting the Brunei Darussalam Household Energy Consumption Survey (BDHECS) in 2015 and the Commercial Buildings – Brunei Darussalam Energy Consumption Survey (C-BDECS) in 2018, in collaboration with the Brunei National Energy Research Institute (BNERI).

The ministry implemented both surveys through BNERI. ERIA provided technical support for the (i) design of the survey questionnaires, (ii) content of the questionnaire manual, (iii) training for enumerators (university students), (iv) validation check of the sampled data, (v) use of database, and (vi) analysis of the sampled data (how to produce key tables and figures).

The BDHECS results suggest that high-energy performance standards should be promoted and that a labelling system should be applied to appliances that use a significant amount of energy, such as air conditioners, refrigerators, lighting, and water heaters. The C-BDECS results suggest that applying building energy intensity labelling will be crucial.

Brunei Darussalam must implement EEC policies and action plans for households and commercial buildings to mitigate their increasing electricity consumption. ERIA would like to support the promotion of EEC continuously through policy-oriented energy research studies.

Professor Hidetoshi Nishimura

President, ERIA

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Pengiran Haji Jamra Weira bin Pengiran Haji Petra

Deputy Permanent Secretary

Ministry of Energy

Brunei Darussalam

Project Members

Mr Shigeru Kimura. Special Advisor on Energy Affairs, Economic Research Institute for ASEAN and East Asia (ERIA)

Dr Romeo Pacudan. Interim Chief Executive Officer (CEO) and Chief Researcher, Brunei National Energy Research Institute, Brunei Darussalam

Mr Muhammad Nabih Fakhri bin Matussin. Researcher, Climate Change and Renewable and Alternative Energy Department, Brunei National Energy Research Institute, Brunei Darussalam

Ir Leong Siew Meng. Managing Consultant, Green Technology Solutions PLT, Malaysia (American Society of Heating, Refrigerating and Air-Conditioning Engineers, Malaysia)

Mr Abdul Salam bin Haji Abdul Wahab. Head, Energy Efficiency and Conservation, Sustainable Energy Division (SED), Ministry of Energy (ME), Brunei Darussalam

Mr Abdul Matiin bin Haji Muhd Kasim. SED, ME, Brunei Darussalam

Mr Asrul Sany bin Haji Mohammad Ali. SED, ME, Brunei Darussalam

Mr Mohammad Abdul Muizz Faiz Hazwan bin Haji Mat Yassin. SED, ME, Brunei Darussalam

Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

ASEAN	Association of Southeast Asian Nations
BAGUS	Brunei Accredited Green Unified Seal
BCA	Building and Construction Authority, Singapore
BDHECS	Brunei Darussalam Household Energy Consumption Survey
BEI	building energy intensity (kWh/m^2/year)
BNERI	Brunei National Energy Research Institute
C-BDECS	Commercial Buildings – Brunei Darussalam Energy Consumption Survey
DES	Department of Electrical Services
EE	energy efficiency
EEC	energy efficiency and conservation
ERIA	Economic Research Institute for ASEAN and East Asia
EU	European Union
EUI	energy use intensity
ktoe	kiloton of oil equivalent
GWh	gigawatt hour
JPKE	Jabatan Perancangan dan Kemajuan Ekonomi (Department of Economic Planning and Development)
kWh	kilowatt hour
LPG	liquefied petroleum gas
MEPS	minimum energy performance standards
MOD	Ministry of Development
ME	Ministry of Energy
UBD	Universiti Brunei Darussalam

Executive Summary

The lack of baseline primary data on energy consumption in Brunei Darussalam is one of the main drivers for carrying out a national survey on energy consumption in the residential sector and assessing energy performance of commercial and public sector buildings. The study outlines policies to improve residential, commercial, and public energy efficiency.

Residential Energy Consumption

Electricity represented about 76% of total residential energy demand. Natural gas accounted for about 11% and liquefied petroleum gas (LPG) for 13%. They were mainly used for cooking and water heating. Natural gas was available mainly in Belait district because it is close to gas fields and processing plants.

Table ES 1: Share of Household Electricity Consumption by Appliance Type

Appliances	Brunei Darussalam	Districts			
		Brunei-Muara	Tutong	Kuala Belait	Temburong
Air Conditioners	59.5%	60.5%	57%	59.5%	54%
Electric Fans	3%	3%	4%	3%	3%
Refrigerators	18%	16.5%	19%	19%	25%
Lighting (Indoor)	3.5%	4%	4%	2%	3%
Lighting (Outdoor)	3.5%	3%	4%	4%	4%
Water Heaters	6%	7%	6%	6%	5%
Washing Machines	1%	1%	0.5%	1%	1%
TVs	3%	3%	3%	3%	2%
Rice Cookers	2.5%	2%	2.5%	2.5%	3%
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Source: Author (2019).

Air conditioning represented almost 60% of national average household electricity demand, with its share varying from 60.5% in Brunei-Muara district (highest income) to 54% in Temburong district (lowest income) (Table ES 1). Other major electricity-consuming services were refrigeration (18% of national household electricity demand), lighting (7%), and water heating (6%). Households in high-income districts had higher electricity demand shares of air conditioning and water heating than those in low-income ones. Conversely, the share of refrigeration tended to be higher in low-income than in high-income districts because low-income people owned more refrigerators than air conditioners.

Amongst household electrical appliances, air conditioners were used most intensively, accounting for 2,637 kWh per unit per year (Table ES 2). Other energy-intensive appliances were water heaters, consuming 1,146 kWh per unit per year, and refrigerators, 947 kWh. Rice cookers consumed about 300 kWh per unit per year, TV sets 200 kWh, and outdoor lighting 100 kWh. Washing machines and indoor lighting consumed less than 100 kWh per unit per year. These variations depended on usage time and power rating of appliances. On average, per unit electricity consumption of appliances was highest in Temburong (the lowest-income district) and lowest in Brunei-Muara. One reason was that a high-income household owned multiple appliances (e.g. more than three air conditioners) but a low-income household may have had only one or none. Low-income households used appliances longer than high-income households, resulting in higher electricity consumption per appliance.

Air conditioners, water heaters, refrigerators, and lighting consumed about 94% of total household electricity. Replacing them with more efficient versions could save about 73 gigawatt hours (GWh) per year and could be the priority of an energy-efficiency policy.

Table ES 2: Electricity Consumption per Appliance (kWh/unit/year)

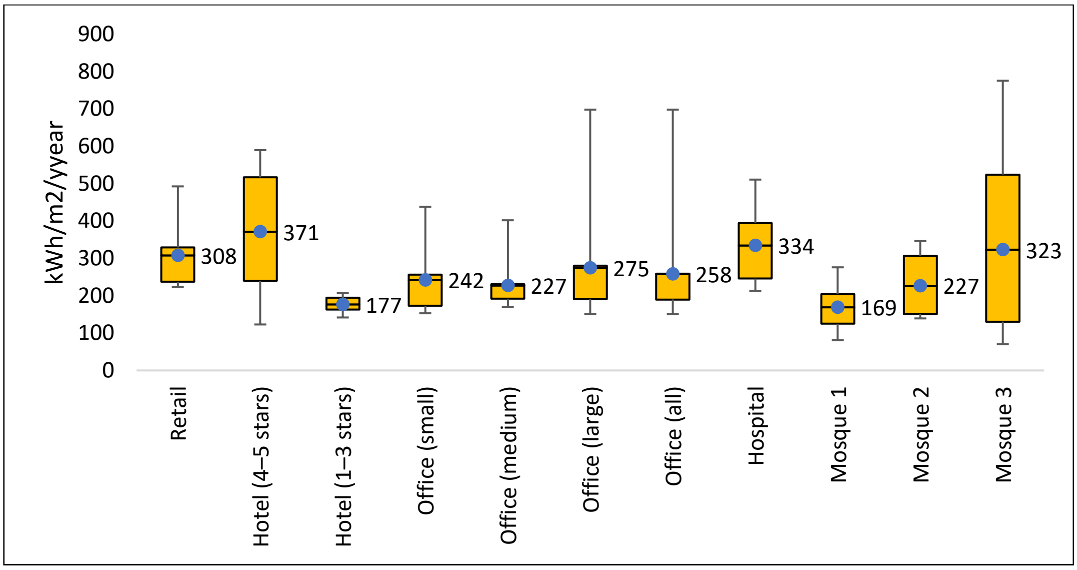
Appliance Type	Brunei Darussalam	Districts			
		Brunei-Muara	Tutong	Kuala Belait	Temburong
Air Conditioner	2,637	2,580	2,599	2,826	2,896
Electric Fan	131	125	150	128	151
Refrigerator	947	923	990	968	994
Lighting (Indoor)	41	41	43	37	53
Lighting (Outdoor)	128	115	154	140	185
Water Heater	1,146	1,069	1,187	1,424	1,507
Washing Machine	72	70	72	77	74
TV	239	253	215	223	203
Rice Cooker	357	366	312	361	385

Source: Author (2019).

Energy Performance of Commercial and Public Buildings

The building survey used building energy intensity (BEI) as the index (kWh/m^2/year) to assess the energy performance of commercial and public buildings (Figure ES 1). The 4–5-star hotels were the most energy intensive, consuming 371 kWh/m^2/year. Other energy-intensive buildings with BEI values above 300 kWh/m^2/year were hospitals (334), large mosques (323), and retail buildings (308). Buildings with BEIs of about 200 kWh/m^2/year were office buildings (average of 258) and medium-sized mosques (227). The 1–3-star hotels had a BEI of 177 kWh/m^2/year and small mosques and prayer rooms 169. Small mosques had a lower average BEI because they used much less air conditioning than other types of buildings. Because of the small sampling size, however, the explanation for the lower average BEI value of 1–3-star hotels is not conclusive.

Figure ES 1: Building Energy Intensity Survey Results



Source: Author (2019).

In general, the average BEI values derived from the Commercial Buildings – Brunei Darussalam Energy Consumption Survey were much higher than the target BEI values under the green building certification schemes in Malaysia and Singapore.[1] Savings opportunities exist since the BEIs of buildings in Brunei Darussalam were much higher than the more efficient ones in neighbouring countries, which have similar climatic conditions.

Policy Action Plans

The government's main challenge is how to exploit the savings potential identified in the residential and commercial and public sector building studies. Policy intervention measures to improve residential and building energy efficiency are proposed in Table ES 3.

[1] Singapore and Malaysia are the comparators since Brunei Darussalam has not yet implemented a national green building rating scheme.

Table ES 3: Energy Efficiency Improvement Action Plans

Time Horizon	Residential	Commercial and Public Building Sector
Short Term	• Technical guidelines for passive measures • Minimum energy performance standards • Information and awareness campaign	• Technical guidelines for passive measures • Minimum energy performance standards • Information and awareness campaign • Benchmarking study • Capacity building to increase the number of energy managers
Medium Term	• Standard and labelling system for appliances • Building energy intensity labelling for commercial and public buildings • Technical guidelines for active measures	• Technical guidelines for active measures • Expansion of the green building rating scheme • Setting up energy efficiency and conservation laws
Long Term	• Home energy management systems • Technology road mapping	• Building energy management systems • Technology road mapping

Source: Author (2019).

In the short term, the government could launch technical guidelines for passive measures and minimum energy performance standards (MEPS) for electrical appliances. Often, these schemes are accompanied with information and awareness campaigns. The measures could benefit both the residential and building sectors. The government could collect more information on buildings' energy consumption through a benchmarking study, and the scope of current training for building managers could be broadened to include the private sector.

In the medium term, the government could formulate the standard and labelling system for imported appliances, with an inspection laboratory and technical guidelines for active measures for households. Technical guidelines for active measures and the application of a green building rating system, including BEI labelling localised to Brunei Darussalam under EEC laws or regulations, are suggested for commercial and public buildings.

Energy management systems for buildings and residences could be promoted in the long term. The government could carry out a technology road-mapping study to identify the most innovative and advanced but cost-effective technologies for development and adoption.

Chapter 1

Brunei Darussalam Household Energy Consumption Survey

1. Objectives

The Brunei Darussalam Household Energy Consumption Survey (BDHECS), completed in December 2015, was the first comprehensive energy consumption survey in the country. Before 2015, data on energy consumption by end use were limited and residential electricity consumption was not broken down by end-use. Data on energy consumption, type of appliances, and their shares of energy use, as well as other data indispensable to implementing energy efficiency measures, were limited. Scenarios of energy use, energy consumption, and trending in energy demand must be understood. We, therefore, conducted the first comprehensive nation-wide household energy consumption survey, from April to December 2015.

The primary goal of BDHECS was to obtain comprehensive and reliable data that could be used to analyse end-use residential energy consumption, preferences, and trending of energy use. The survey results would be used to formulate and implement policies and programmes to improve sustainability through prudent and efficient use of electricity. Specifically, the survey was designed to accomplish the following:

(i) Determine the energy consumption profile for household and private transportation.
(ii) Establish the current efficiencies of household appliances and private vehicles.
(iii) Establish baseline end-use consumption data for energy efficiency policy analysis and future trends in energy consumption.
(iv) Improve the efficient use of residential energy.
(v) Establish national energy indicators such as, but not limited to, the following:
    (a) energy use intensity (EUI) (kWh/household/year),
    (b) end-use energy consumption per household by district,
    (c) percentage share of electricity use by appliance and establishment of priorities for MEPS for appliances,
    (d) average age of major appliances,
    (e) travel distance and fuel consumption, and
    (f) fuel economy by vehicle type.

The survey was the result of international cooperation. The Economic Research Institute for ASEAN and East Asia (ERIA) and the Institute of Energy Economics, Japan assisted with the technical aspects, including development of the survey questionnaire, its implementation, validation, and data analysis.

The Brunei National Energy Research Institute (BNERI) managed and implemented the survey, and coordinated with various higher education institutes to conduct interviews. The

Ministry of Energy of Brunei Darussalam (ME) guided and facilitated the overall survey implementation.

This report provides useful information for agencies formulating and implementing energy efficiency and conservation (EEC) policies.

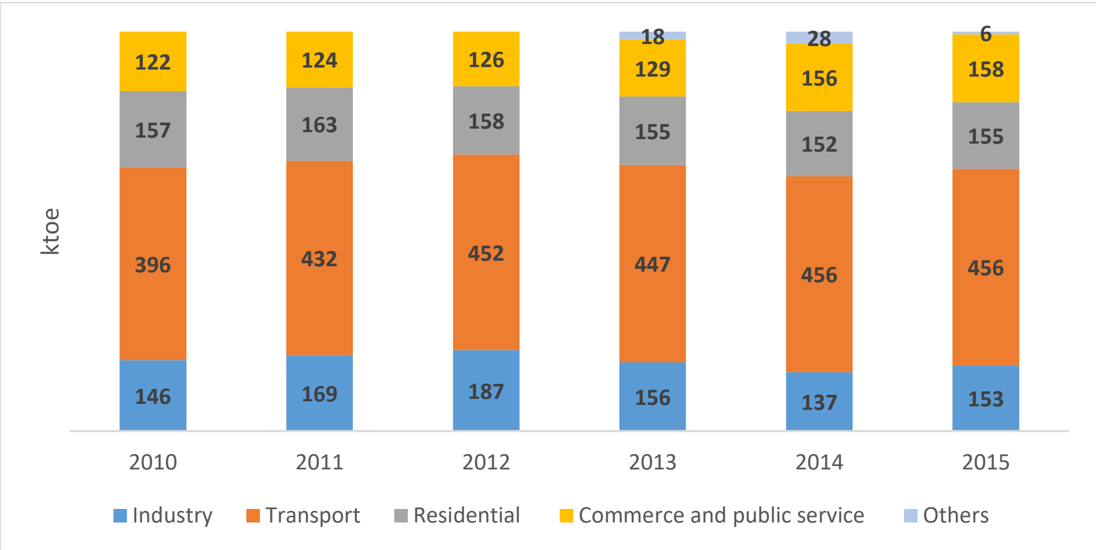
2. Energy Situation in 2015

Crude oil and natural gas were the main energy resources in Brunei Darussalam. In 2015, total primary energy was met mainly by natural gas (84%); oil's share remained at 16%. Total primary energy supply declined by 3% in 2014–2015, from 4,154 kilotons of oil equivalent (ktoe) to 4,034 ktoe.

Domestic needs are modest because the population is small. Consequently, most natural gas and crude oil produced in the country are exported. Only a small percentage of natural gas is allocated for domestic power generation and downstream petrochemical industries. About 12% of the crude oil produced is refined to manufacture petroleum products to meet domestic demand, whilst the rest is exported.

Brunei Darussalam's final energy consumption amounted to 928 ktoe in 2015, a slight decline of 0.1% from the previous year. Transport led total energy demand, with 456 ktoe or 49% of the overall amount (Figure 1). Other sectors (residential, commercial and public service, others) accounted for 34% of total final energy demand, and industry for 16%.

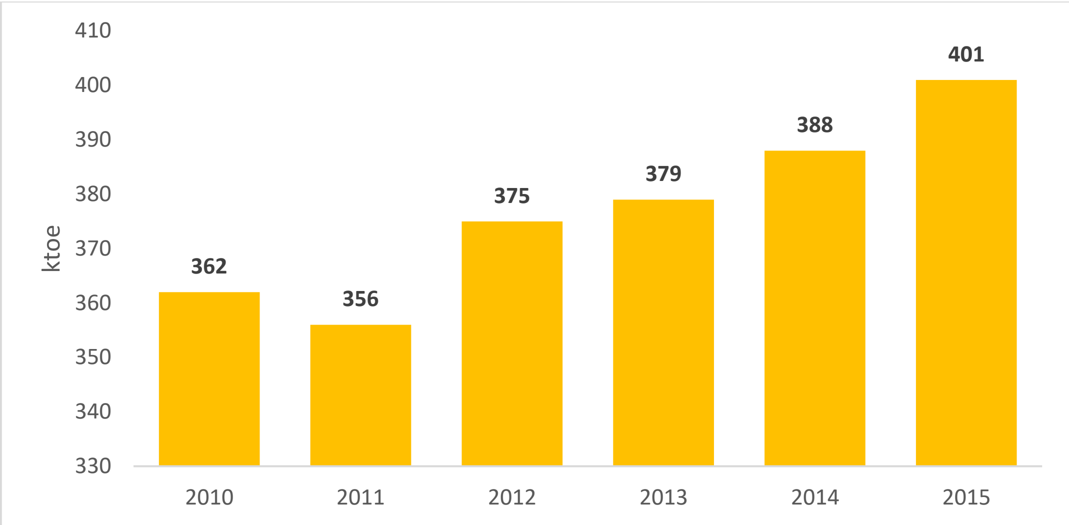
Figure 1.1: Final Energy Consumption by Sector, 2010–2015



Source: Author (2019).

In 2015, total installed power generation capacity of public utilities and autoproducers[2] reached 922 MW. Most of the electricity was generated by natural gas (4,666 GWh). Electricity grew steadily by about 11% over the previous 5 years, reaching 401 ktoe in 2015 (Figure 2).

Figure 1.2: Total Electricity Generation, 2010–2015

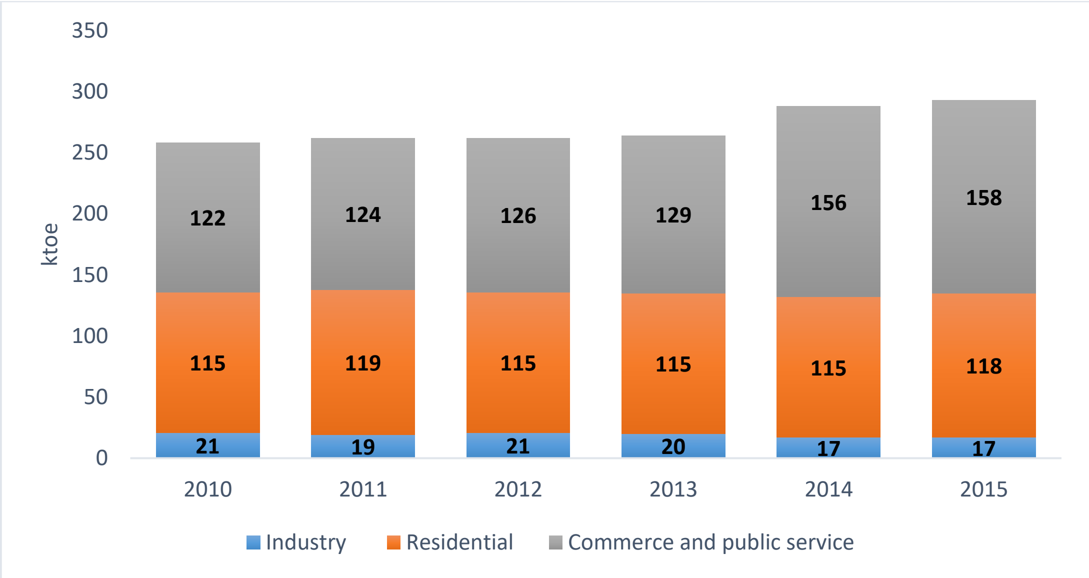


Source: Author (2019).

The residential sector was consistently the second-highest consumer of electricity since 2010, taking up 40% (118 ktoe) of total consumption in 2015. The commercial and public sector accounted for 53% (158 ktoe) and the industrial sector for 7% (17 ktoe) (Figure 3). Residential energy consumption was mainly of electricity (118 ktoe), whilst the rest was of natural gas (19 ktoe) and petroleum (18 ktoe) (Figure 4).

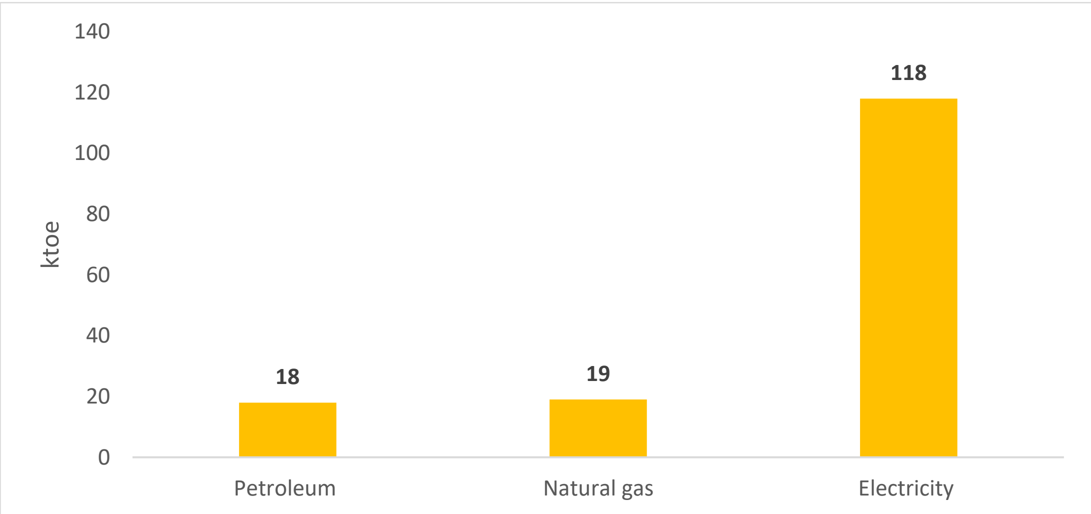
[2] Autoproducers generate electricity and/or heat, wholly or partly for their own use as an activity that supports their primary activity.

Figure 1.3: Final Electricity Consumption by Sector, 2010–2015



Source: Author (2019).

Figure 1.4: Residential Energy Consumption by Fuel Type



Source: Author (2019).

3. Survey Overview

3.1. Electricity Consumers in the Brunei Darussalam Household Energy Consumption Survey

The survey covered dwellings occupied as a primary residence. For random sampling purposes, an address list, obtained from the Department of Electrical Services (DES) and comprising households subscribed to DES Prepaid Electricity was used. The full list contained 67,306 addresses, according to DES's Prepaid Accounts in March 2015.

3.2. Household Energy Use Survey Method

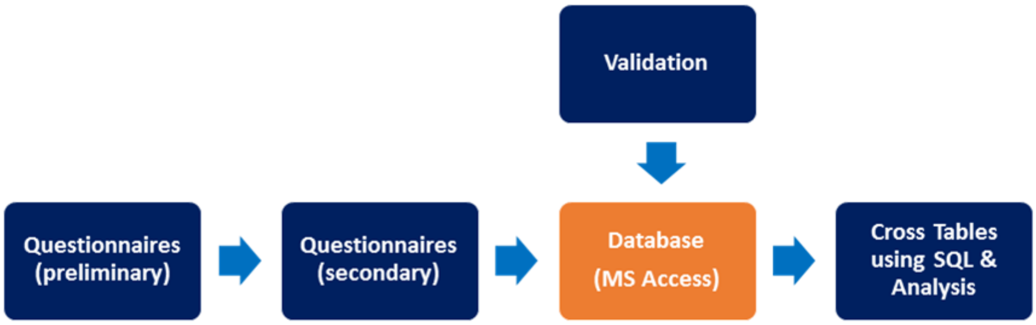
The BDHECS was based on random (probability) sampling. The survey was conducted with randomly selected households in four districts: Brunei-Muara, Belait, Tutong, and Temburong (Table 1.1). Data was collected using the questionnaire, which was designed to capture data to understand actual scenarios of energy use, with breakdowns of consumption by appliance. Trained interviewers, mainly ME officers, conducted face-to-face interviews, and ME interns recorded the data. The hardcopy questionnaire had pre-encoded data for certain standardised items to facilitate the interpretation of data. Interviewers were given a guidebook as a reference on common household appliances and familiarised with the various types and the type of data expected to be extracted from appliance nameplates.

One household member, usually the one responsible for the household, answered on behalf of the whole household. Several households living in the same housing unit were considered one household if electricity was not billed separately.

Questionnaire data was processed (Figure 5). Both preliminary and secondary questionnaires were gathered in a database (Microsoft Access) for validation. After validation, cross tables were produced using Structured Query Language (SQL) and analysed.

Potential savings were expected to be derived using information about household energy consumption and conservation and the pattern of electricity consumption of household appliances and equipment.

Figure 1.5: Data Process Flow



Source: Author (2019).

4. Survey Results

4.1. Response Rate

Based on the survey information, sample units were divided into three groups: respondents, non-respondents, and ineligible units or rejected samples. The initial quality indicator, i.e. the response rate, was found by considering the groups' sizes.

The survey sample target was set at 1,000 respondents. Of the 1,000 survey samples conducted, 608 responded, 15 of which were rejected, resulting in 593 validated samples. Measurement and processing errors were deemed one reason for the rejected samples. Difficulties in conducting the survey included reluctance to provide certain personal information because of privacy concerns and respondents' lack of knowledge about household appliances and technical information.

The number of validated samples were distributed as follows: about 55% in Brunei-Muara; 22% in Belait, the second-most populated district; 17% in Tutong; and 6% in Temburong, the least-populated district (Table 1.1).

The validated survey samples represented 1% sample coverage of the number of households based on DES Prepaid Account as of March 2015. Whilst the sample coverage was small, it was significant for observing household energy consumption patterns.

Table 1.1: Number of Validated Survey Samples by District

Districts	Number of Validated Survey Samples
Brunei Muara	324
Belait	132
Tutong	100
Temburong	37

Source: Author (2019).

4.2. Survey Items

The survey was divided into 11 categories (Table 1.2). The first part consisted of general background information on the household, household characteristics, and energy consumption and bills. Parts two to nine included selected home appliances and electronics that are common to an average household. Part 10 consisted of fuels other than those used for private transportation, i.e. natural gas, LPG, and others. Part 11 contained consumption profiles for private transportation.

Table 1.2: Brunei Darussalam Household Energy Consumption Survey Items

Districts	Number of Validated Survey Samples
Part 1: Identification of Household	Number of primary household members, monthly household income, household-based income-generating activity
Household Characteristics	Gross floor area, number of rooms
Energy Consumption and Energy Bills	Approximate spending for electricity per month (prepaid or post-paid), frequency of outages in a month, average duration of outages in a month
Part 2: Home Appliance: Air Conditioner	Type of air conditioner, number of years in use, manufacturer or brand, model, cooling capacity, power rating (watts), hours of daily usage, location of unit
Part 3: Home Appliance: Fan	Type of fan, number of years in use, manufacturer or brand, model, power rating, hours of daily usage
Part 4: Home Appliance: Lighting	Type of lamp, number of units, average hours of daily usage, average power rating (watts)
Part 5: Home Appliance: Refrigerator	Type of refrigerator and/or freezer, number of years in use, manufacturer or brand, model, rated current (amps), power rating (watts), volume of capacity, unit
Part 6: Home Appliance: Water Heater	Type of electrical water heater, number of units, number of years in use, manufacturer or brand, model, size for boiler, power rating (watts), hours of daily usage, average usage days per week
Part 7:	Type of washing machine and/or dryer, number of units,

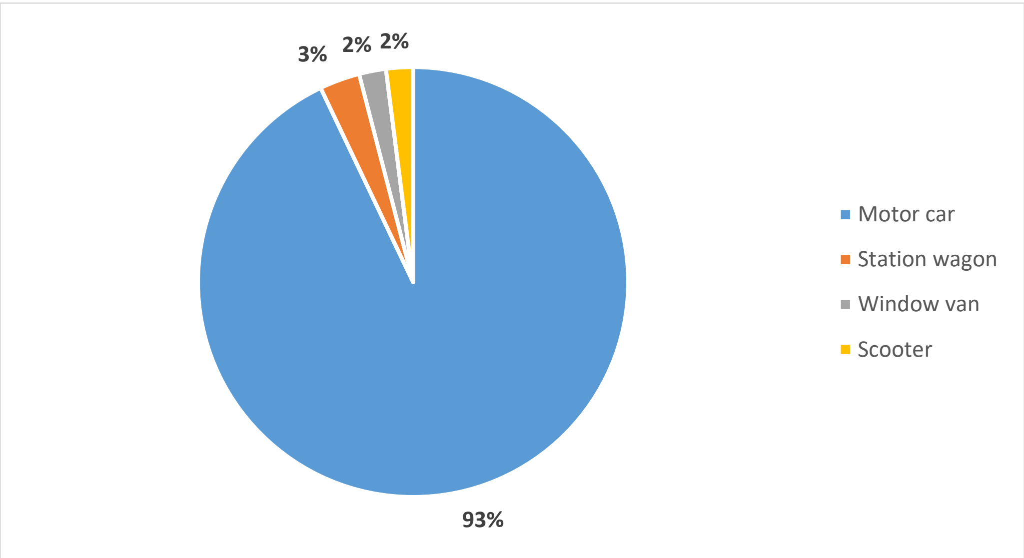
Home Appliance: Washing Machine	number of years in use, capacity (kg), manufacturer or brand, model, power rating (watts), frequency of usage per day, number of days per week the equipment is used for washing and/or drying
Part 8: Electronic: TV	Type of TV, number of years in use, manufacturer or brand, model, size, power rating (watts), hours of daily usage,
Part 9: Home Appliance: Rice Cooker	Type of rice cooker, number of years in use, manufacturer or brand, model, power rating (watts), frequency of cooking per day
Part 10: Other Fuels	Type of fuel, use of fuel, consumption of fuel per month
Part 11: Private Transportation	Number of motor vehicles owned, type of vehicle, year of registration, engine capacity, type of fuel, average distance travel per weekday, average distance travel per weekend, average distance travel per week (km), average fuel expenses per week (Brunei dollar [BND])

Source: Author (2019).

4.3. Basic Characteristics of Households

Households had an average of five people. About 34% of households had 1–5 members, 54% 6–10, and 12% more than 10. Most households lived in detached houses, most (93%) owned motor cars, and the rest owned station wagons (3%), window vans (2%), and scooters (2%) (Figure 6). On average, every household owned about three cars.

Figure 1.6: Share of Vehicle Type



Source: Author (2019).

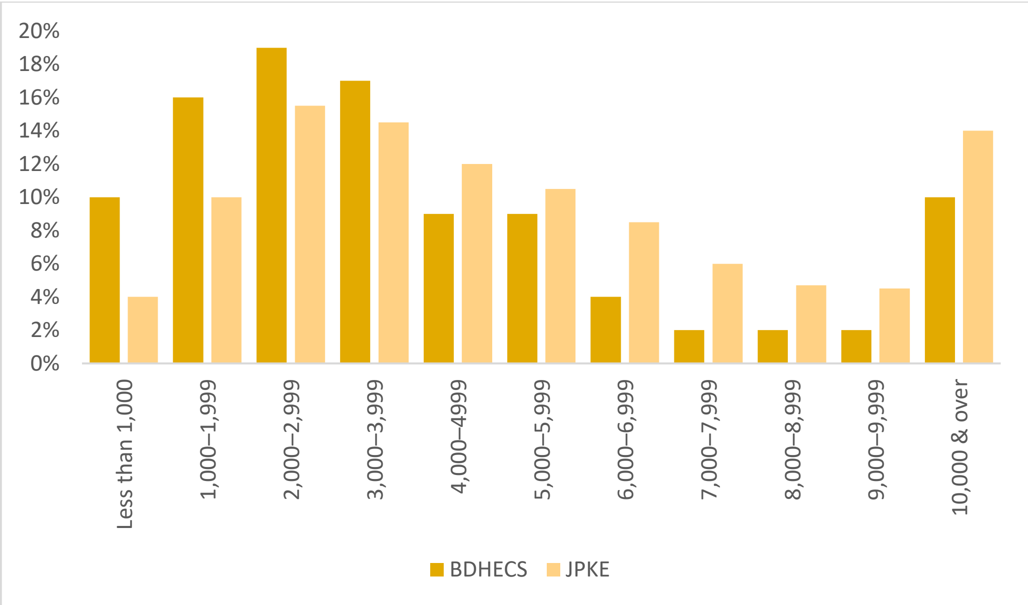
Dual wage-earning families were not uncommon and work from home was not unusual (some people ran their business from home whilst doing housework and rearing children).

The distribution of households by income varied, with about 80% earning BND1,000–BND10,000 (equivalent to US$742.75–US$7,427.52) monthly and the largest proportion (20%) earning BND2,000–BND2,999 (equivalent to US$1,485.60–US$2,227.51) monthly. Brunei Muara had the highest earning capacity.

Unlike the results of the Department of Economic Planning and Development (JPKE) Household Expenditure Survey, on the number of households by income level in 2015 (Figure 7), the BDHECS results include income bias, which shows that the proportion of lower-income households was higher by 6.7% and the proportion of higher-income households lower by 3.2%. Consequently, the BDHECS results on energy consumption were expected to be underestimated because the energy consumption survey greatly concentrated on households with low incomes.

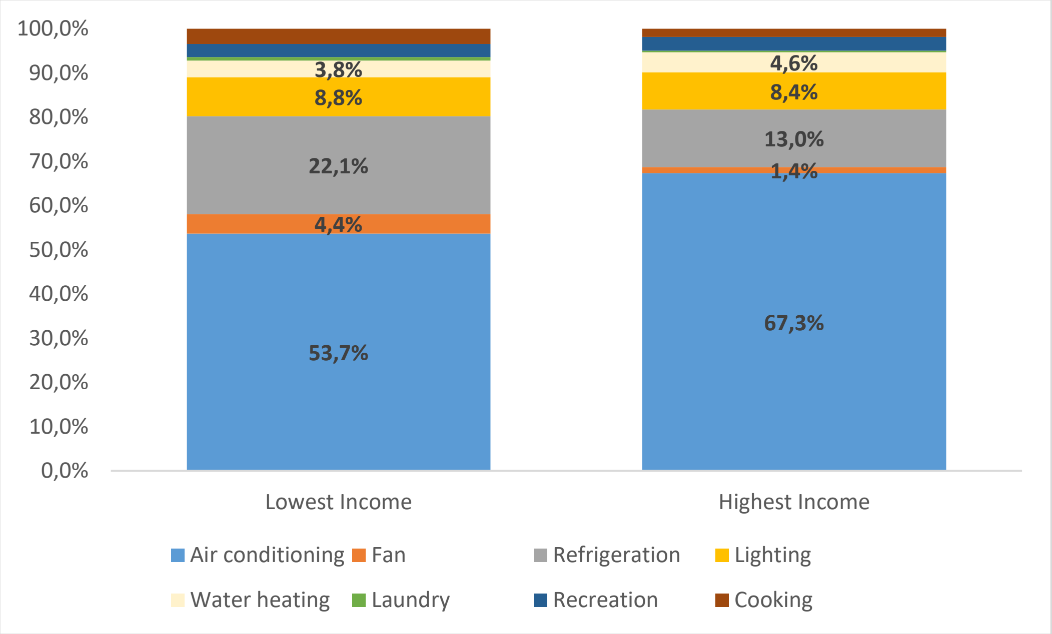
As shown in Figure 8, high-income households (BND10,000 and over) had higher shares of electricity demand for air conditioning and water heating than low-income households (less than BND1,000). In contrast, shares of electricity demand for refrigerators and fans were higher amongst low-income than in high-income households.

Figure 1.7: Comparison of Survey Results and National Statistics on Number of Households by Income Level



BDHECS = Brunei Darussalam Household Energy Consumption Survey, JPKE = Department of Economic Planning and Development.
Source: Author (2019).

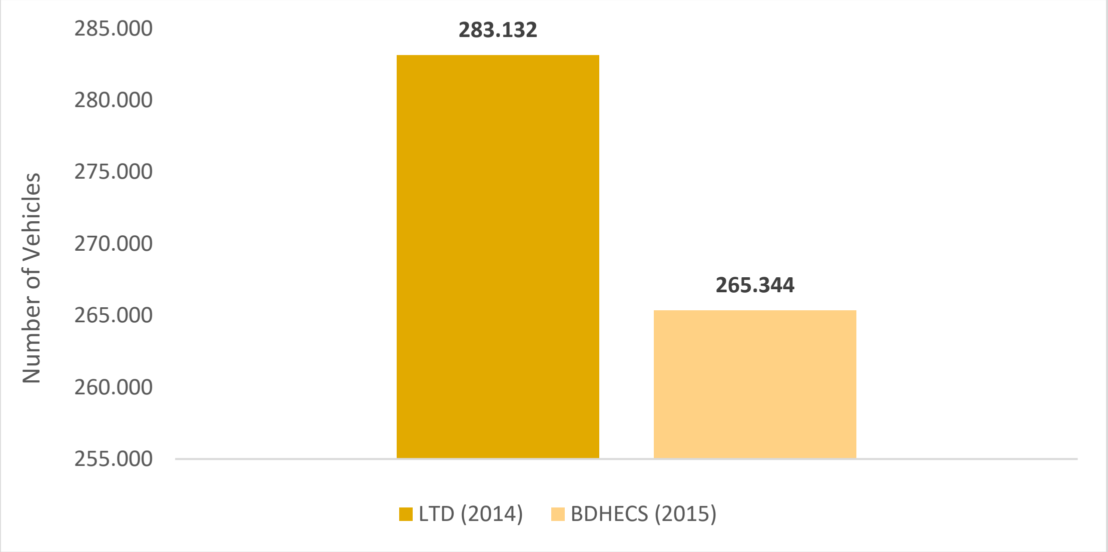
Figure 1.8: Comparison of Lowest-Income and Highest-Income Household Shares of Appliances



Source: Author (2019).

As for transportation (Figure 9), Land Transport Department statistics show that the number of vehicles (motor cars only, excluding government and commercial vehicles) was higher than that in BDHECS by 6.3%, which suggests the need for further investigation to verify this discrepancy.

Figure 1.9: Comparison of Survey Results and National Statistics on Number of Vehicles



BDHECS = Brunei Darussalam Household Energy Consumption Survey, LTD = Land Transport Department.
Source: Author (2019).

4.4. Energy Use by Households

The analysis of energy and fuel types consumed (by number of households) indicated that electricity represented about 76% of total residential sector demand. Total consumption of electricity per household was about 15,785 kWh per year (or 1,315 kWh per month per household), which made it the highest amongst Association of Southeast Asian Nations (ASEAN) members (Figure 11 and Figure 12). Brunei-Muara recorded the highest average consumption at about 18,019 kWh per year (or 1,502 kWh per month per household), followed by Tutong at 14,067 kWh per year (or 1,172 kWh per month per household), Temburong at 13,288 kWh per year (or 1,107 kWh per month per household), and Belait with 12,303 kWh per year (or 1,025 kWh per month per household).

APEC Energy Statistics shows that electricity consumption was 23% higher than the BDHECS results. Table 1.3 shows that projected national electricity consumption was about 21.8% higher than national energy statistics. Electricity consumption derived from this survey seems to have been underestimated. This validation check suggests that (i) the survey results might have been influenced by the sampling concentration on low-income households, and (ii) the sample size and spread of households in the survey might have been insufficient to establish greater accuracy of the survey data. Nevertheless, the survey's analyses and trending should be useful for formulating plans to improve energy efficiency.

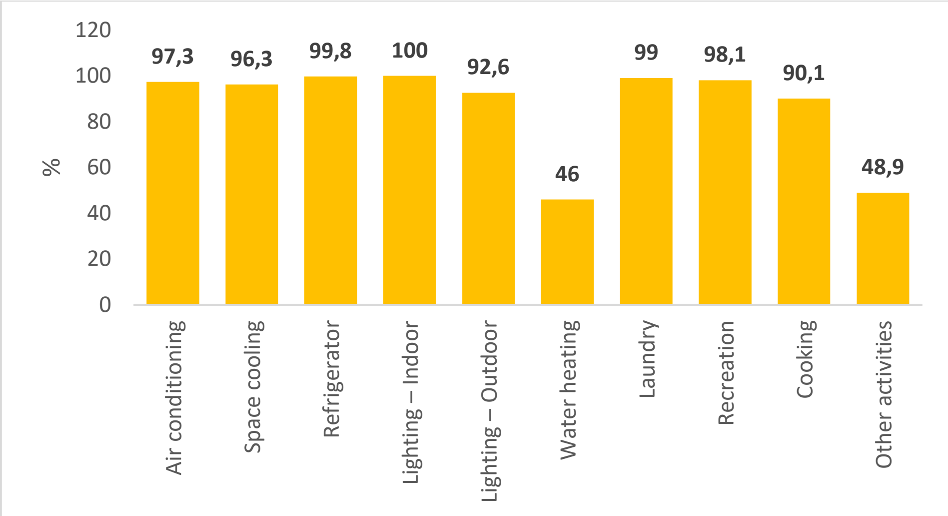
Table 1.3: Comparison Between Projected National Residential Electricity Consumption and National Energy Statistics

	Data Derived from BDHECS	National Energy Statistics	Remarks
No. of households in Brunei Darussalam	–	67,966	National statistics
Average electricity consumption per household from BDHECS	15,785 kWh/year	–	National average electricity consumption per household derived from the survey data.
National residential electricity consumption	1,073 GWh/year (92.25 ktoe/year)	118 ktoe/year	The difference between the projected electricity consumption based on BDHECS and the national energy statistics is 21.8%.

BDHECS = Brunei Darussalam Household Energy Consumption Survey.
Source: Author (2019).

As to the extent of electricity usage by appliance, Figure 10 shows the appliances commonly used, such as air conditioners, refrigerators, indoor lighting, laundry, and recreational appliances. Nearly all energy demand was met by electricity, except for cooking (90% from electricity and 10% from LPG) and water heating (50% from electricity and 50% from other energy sources).

Figure 1.10: Share of Appliances Utilising Electricity (%)



Source: Author (2019).

LPG provided 11% of residential demand for cooking and water heating. The national average consumption of LPG per household was 0.23 m^3. Belait recorded the highest average consumption of LPG per household at 0.3039 m^3, followed by Tutong at 0.2119 m^3, Brunei-Muara at 0.2109 m^3, and Temburong at 0.1867 m^3. The survey showed that total household LPG consumption in 2015 reached 121.30 m^3.

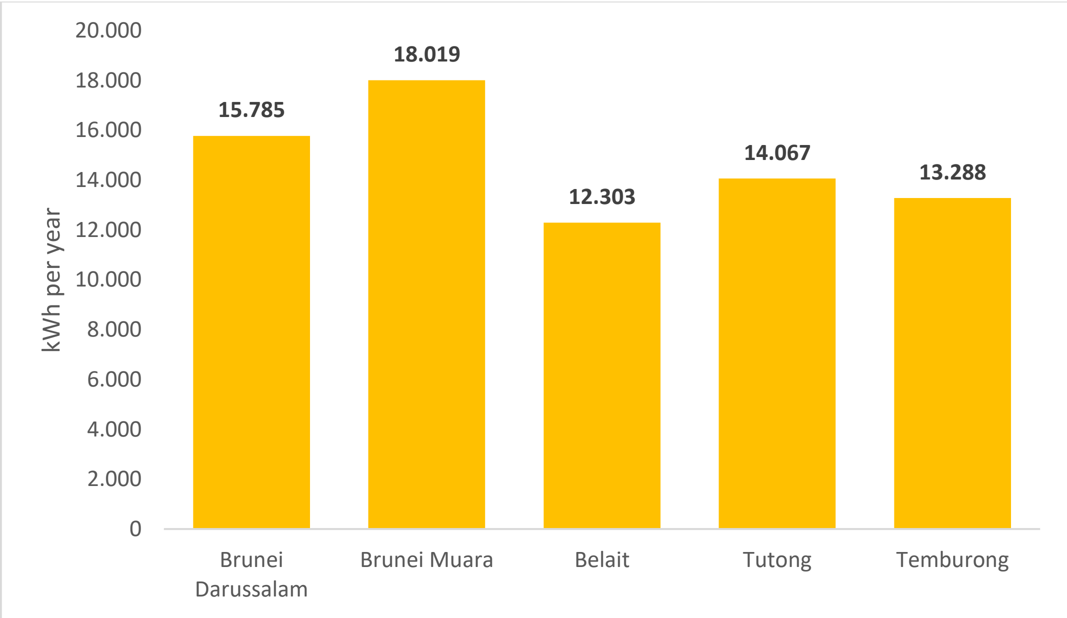
Of residential energy demand, 13% was met by natural gas, which was consumed only in Belait, for cooking, water heating, and electricity generation. Since natural gas consumption in Belait was fixed at BND5.00 per month per household, total natural gas consumption could not be calculated for the purpose of this survey. The households' data on consumption of fuels based on the survey results are in Table 1.4, covering energy consumption in all households, excluding energy utilised for domestic business activities.

Table 1.4: Number of Households Using Other Fuels, Percentage Share of Households Using Other Fuels, and Household Consumption by Type of Fuel by District

Other Fuels	No. of Households	Total Consumption (m^3)	Share (%)	Average Consumption per Household (m^3)
Brunei Darussalam	584	121.30		
Natural Gas	43	NA*		
Liquefied Petroleum Gas	540	121.30	100%	0.2246
Others	1		0%	
Brunei-Muara	317	66.86		
Natural Gas		NA		
Liquefied Petroleum Gas	317	66.86	55%	0.2109
Others			0%	
Belait	132	26.74		
Natural Gas	43	NA*		
Liquefied Petroleum Gas	88	26.74	22%	0.3039
Others	1		0%	
Tutong	99	20.98		
Natural Gas		NA		
Liquefied Petroleum Gas	99	20.98	17%	0.2119
Others			0%	
Temburong	37	6.72		
Natural Gas		NA		
Liquefied Petroleum Gas	36	6.72	6%	0.1867
Others	317	66.86		

Source: Author (2019).

Figure 1.11: Average Yearly Electricity Consumption per Household by District, and National Average

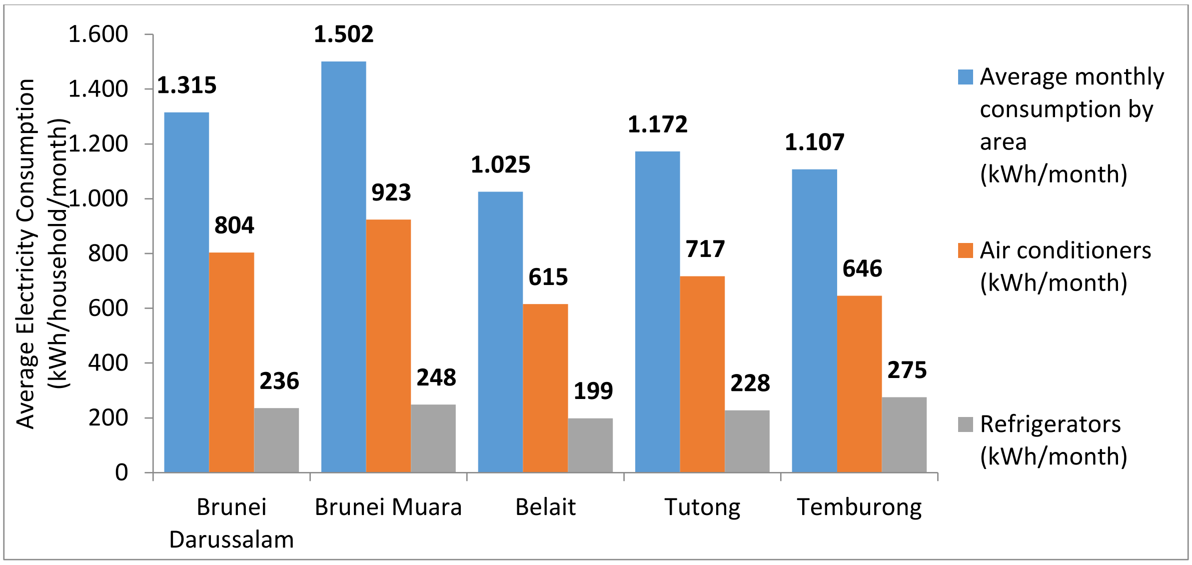


Source: Author (2019).

Figure 11 shows average yearly electricity consumption per household for the four districts; the national average was 15,785 kWh per year. Brunei Muara recorded the highest at 18,019 kWh per year. Surprisingly, sparsely populated and remote Temburong recorded fairly high electricity consumption at 13,288 kWh per year, which was almost as much as in urban districts.

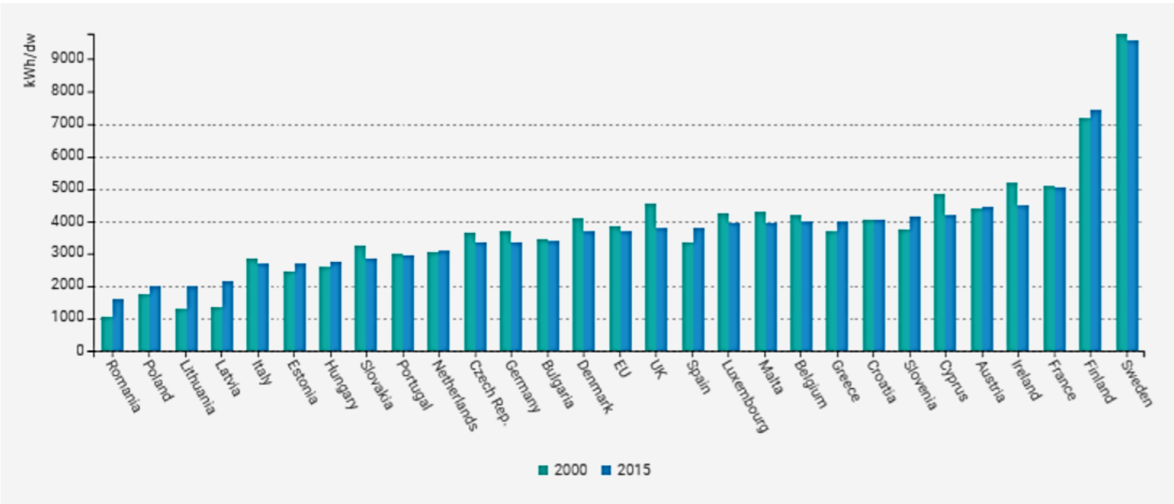
Figure 12 shows the average monthly electricity consumption per household for the four districts; the national average was 1,315 kWh per month. As expected, Brunei Muara recorded the highest at 1,502 kWh per month and, correspondingly, electricity consumption for air conditioning was the highest at 923 kWh per month or 61.45% of the average monthly consumption for the district. Interestingly, monthly electricity consumption of refrigerators was highest in Temburong at 275 kWh per month. The average monthly electricity consumption of air conditioners in Temburong was also fairly high at 646 kWh per month, which was almost as much as in Tutong at 717 kWh per month. This suggests that there was no distinct difference in electricity consumption between urban areas and remote areas such as Temburong.

Figure 1.12: Average Monthly Electricity Consumption per Household and Corresponding Electricity Consumption of Two Major Appliances



Source: Author (2019).

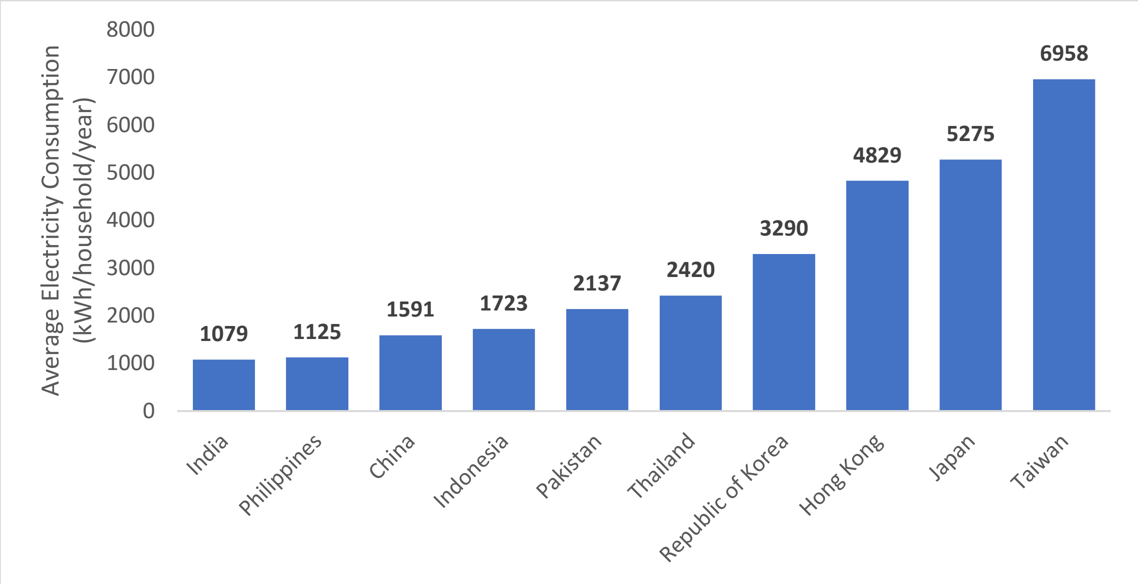
Figure 1.13: Electricity Consumption per Dwelling in European Union Countries



Source: Odysseemure (2015).

The average electricity consumption per household in the European Union (EU) was lower at around 4,000 kWh per year in 2015, although Finland and Sweden consumed 8,000–10,000 kWh per year (Figure 1.13). The publication on household energy consumption in the EU (2015) reported that Norway recorded the highest at 16,000 kWh per year. Based on the World Energy Council data for Asia in 2014 (Figure 1.14), average electricity consumption per household in Asia was lower at about 1,800 kWh per year, although Taiwan recorded the highest average consumption of 6,958 kWh/year. Therefore, the survey result for Brunei Darussalam of average electricity consumption per household of 15,785 kWh per year is considered high.

Figure 1.14: Average Electricity Consumption per Household in Asia



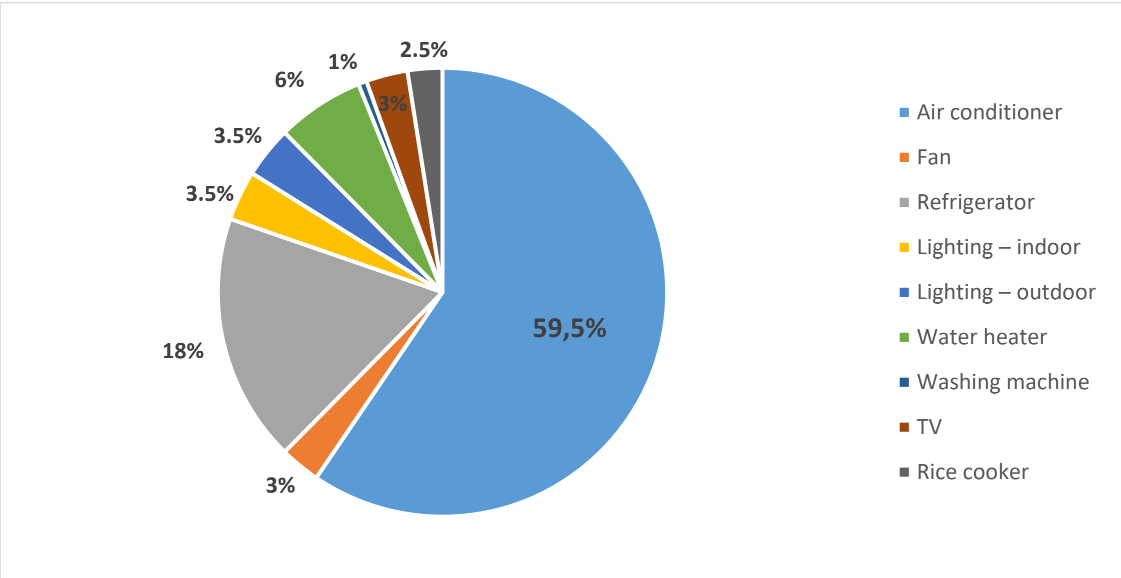
Source: World Energy Council (2014).

5. Key Findings

5.1. End-Use Energy Consumption Pattern

Electricity consumption has grown over recent years. The survey results show all households commonly used a large number of electrical appliances, accounting for significant residential electricity consumption.

Figure 1.15: Share of Electricity Consumption by Appliance



Source: Author (2019).

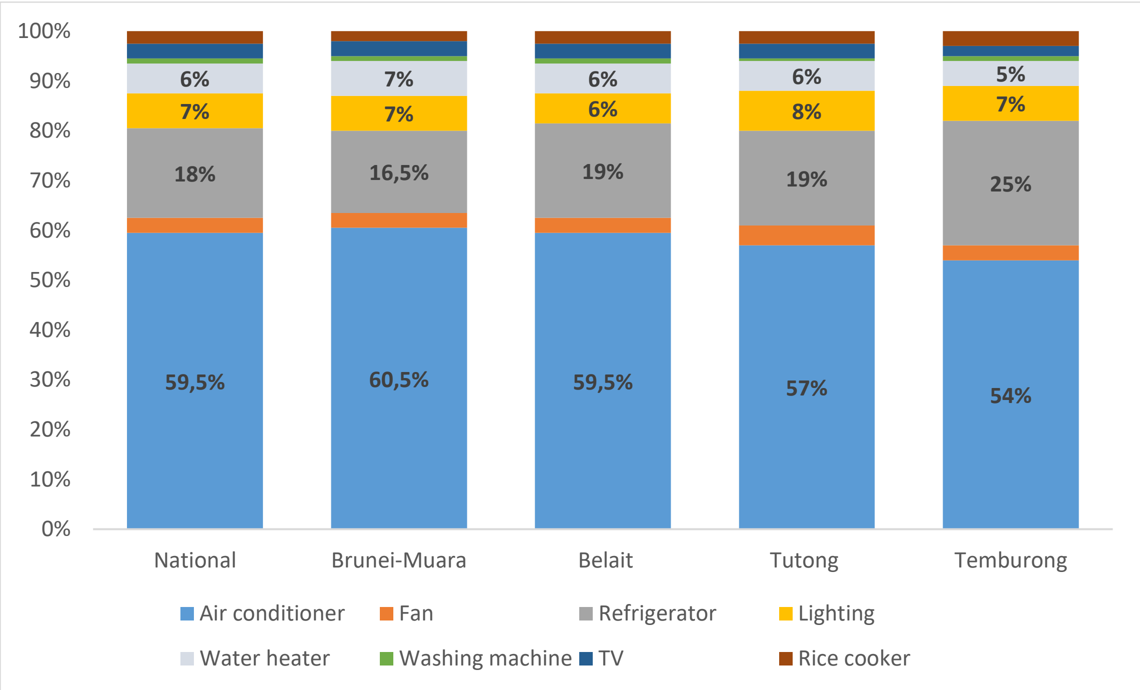
Figure 1.12 and Figure 1.15 show the results from the survey of electricity consumption by household appliance and by district. Generally, the electricity consumption trend by appliance for all four districts was consistent. In total, air conditioners consumed the largest proportion of energy, almost 60%. Combined fan and space cooling accounted for 62.5% of residential electricity consumption.

Refrigerators came in second at about 18%, and lighting (outdoor and indoor) third at 7%. Water heaters accounted for about 6%.

The combined share of these appliances accounted for almost 94% of end-use electricity consumption. Priority should be given to them in energy efficiency action plans to target energy saving. Other appliances that accounted for the rest of electricity consumption were washing machines, TVs, and rice cookers.

Figure 16 shows the share of electricity consumption of appliances by district compared with the national average values. The analysis of end-use household energy consumption patterns provides useful information on the use of energy by common household appliances. Considering the volume of these appliances in households, any plan to educate the public and change to more energy-efficient appliances will contribute significantly to energy savings. One such possible measure is to prioritize energy efficiency labelling of appliances that have larger shares of residential load demand, which will result in quick energy savings.

Figure 1.16: Share of Electricity Consumption by Appliance by District



Source: Author (2019).

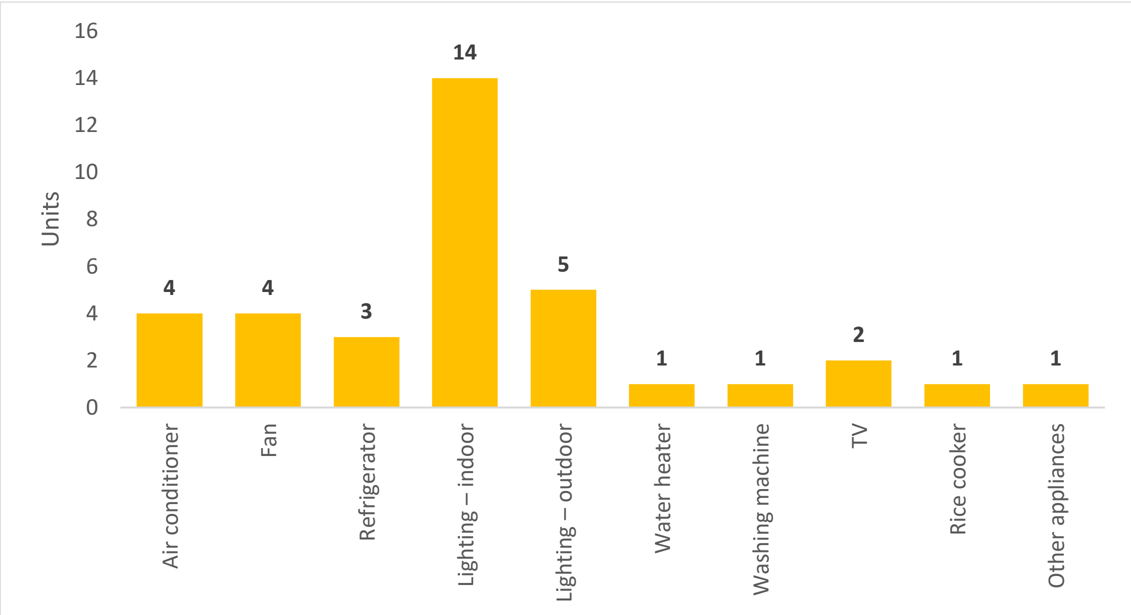
5.2. Average Number of Appliances per Household

The survey results show that electricity use was growing primarily because of the increase in number and usage of household appliances (Figure 17).

Indoor lighting has universal coverage and accounted for the highest number (14) of appliances per household. Air conditioning was the largest consumer of electricity in the survey. The findings show that every household had up to four air conditioners on average, demonstrating that each air conditioner contributed to the largest share of energy consumption.

Another widely used appliance was the refrigerator; 99.8% of households owned at least three on average. Each household had at least two TV sets. Since information technology is developing rapidly, the usage rate of recreational appliances such as TVs, desktop computers, laptops, amongst others, is growing rapidly. The number of appliances and electronics is expected to grow as the number of households increases.

Figure 1.17: Average Number of Appliances per Household



Source: Author (2019).

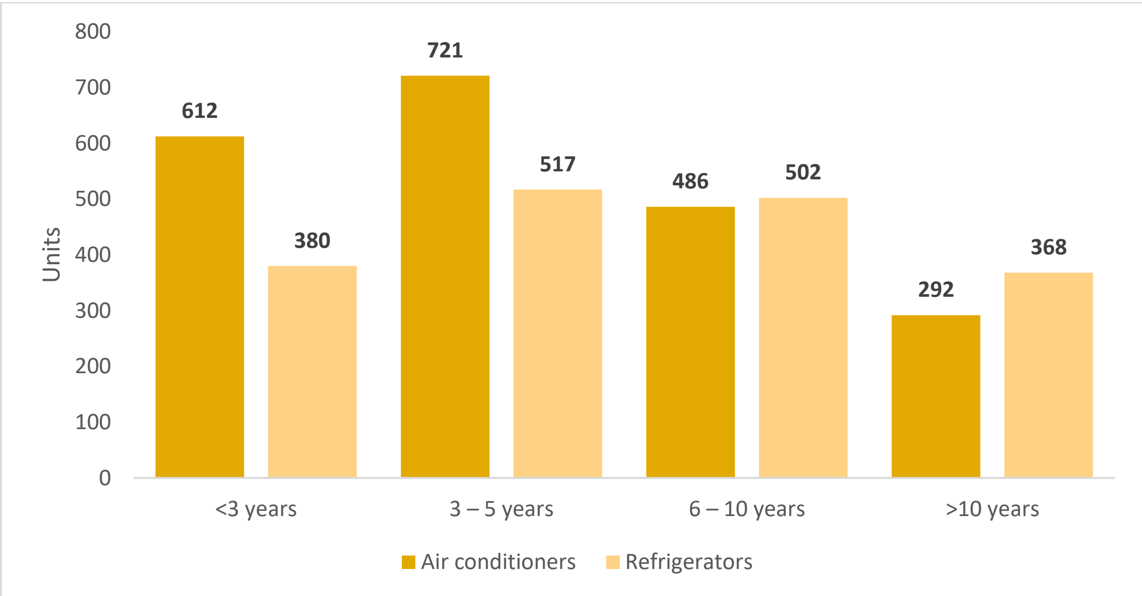
5.3. Age of Critical Household Appliances

Based on appliances' end-use energy consumption patterns (section 1.5.1), air conditioners and refrigerators accounted for 77% electricity consumption. This section reviews their usage in less than 3 years, 3–5 years, 6–10 years, and more than 10 years. The age of a household appliance can affect its energy efficiency. The survey results show that a significant number of household appliances were 10 years old or more, which were likely to be less energy efficient than newer units. A significant number of air conditioners (292 units constituting almost 14% of the existing stock) and refrigerators (368, almost 21%) were more than 10 years old (Table 1.4). The number of air conditioners more than 6 years old was about half the number of air conditioners 5 years old or under. Similarly, the number of refrigerators more than 6 years old was almost equal to the number of refrigerators that are 5 years old or under.

In other words, the proportion of older household refrigerators (the number of those 6 years old or more was almost the same as that of refrigerators 5 years old or less) seemed to be larger than the proportion of older air conditioners (6 years old or constitute about half as many as those 5 years old or less). Since the newer refrigerator models use inverter technology and are more efficient, it makes sense to promote them to replace old refrigerators, especially because they operate non-stop.

Survey respondents were asked about the frequency of air conditioner usage. Typically, an air conditioner was used mainly at night, for an average of 9.17 hours per day. On average, new models are more efficient than old models by 3%. Since air conditioners account for almost 60% of total household consumption, an energy efficiency campaign to increase awareness of substantial energy saving potential would benefit consumers.

Figure 1.18: Number of Units by Age Group



Source: Author (2019).

Table 1.5: Number of Units and Electricity Consumption per Unit by Number of Usage Years

Type of Equipment	Quantity (units)	Electricity Consumption (kWh)	Average Consumption per Unit (kWh/unit)
Air Conditioners			
< 3 years	612	1,546,945	2,528
3–5 years	721	2,008,826	2,786
6–10years	486	1,252,525	2,577
>10 years	292	757,521	2,594
Total	2,111	5,565,816	
Refrigerators			
<3 years	380	323,448	851
3–5 years	517	457,235	884
6–10 years	502	515,791	1,027
>10 years	368	376,547	1,023
Total	1,767	1,673,021	

Source: Author (2019).

5.4. Electricity Saving Potential of Appliances

The residential sector would have significant potential for energy saving if energy consumption habits changed. A sizeable portion of households were unaware of EEC and have not, therefore, done anything to use electricity more efficiently. Air conditioners, refrigerators, lighting, and water heaters consumed the most electricity in the residential sector (Figure 16). The proportion of refrigerators 6 years or older was significant at 49.3%. The proportion of air conditioners over 6 years old was only about 37% of all air conditioners. Newer refrigerators and inverter-type air conditioners are more energy efficient.

Households were asked about the use of energy-efficient lights such as compact fluorescent and other types of low-energy light bulbs instead of incandescent ones. About 95% of households said they had installed at least some low-energy light bulbs for indoor and outdoor lighting. Only 5% of households used LED.

As for water heating, most households (67.4%) had instantaneous water heating: 32.6% of households had a boiler and no households had solar water heating.

An estimated total of 73 GWh or 5.3% of residential electricity consumption (in 2015) could be saved if users of the four appliances were to engage in energy-saving practices.

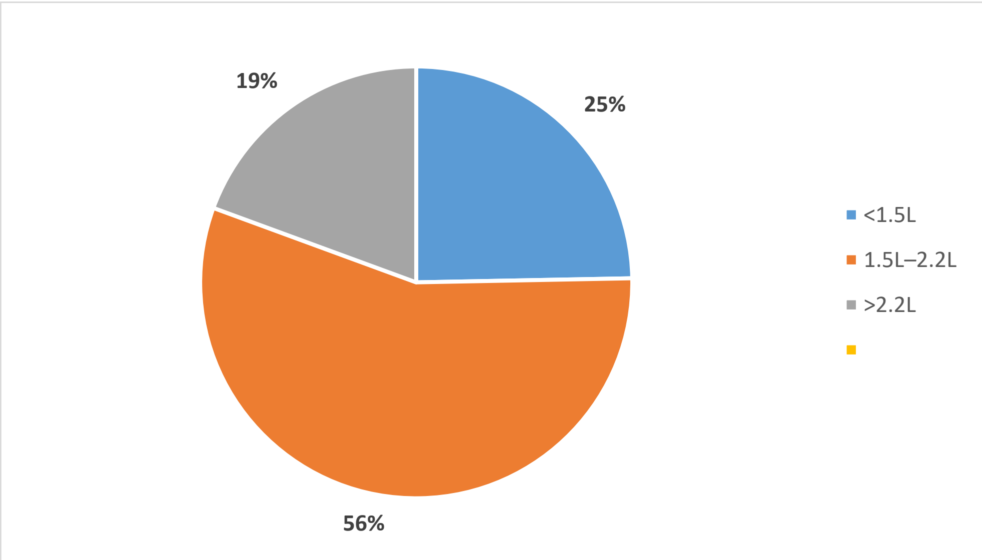
5.5. Analysis of Vehicle Ownership

The questionnaire included several questions about households' ownership of vehicles and use of motor fuels. Most households (92%) owned motorcars and the rest (8%) had some form of transportation such as station and dual-purpose wagons, window vans, scooters, microbuses, and motorcycles.

The indicator was higher for households living in Brunei-Muara and lowest in Temburong. Car-owning households owned an average of three. Households with incomes of BND3,000– BND10,000 and above had the highest rate of car ownership (16%).

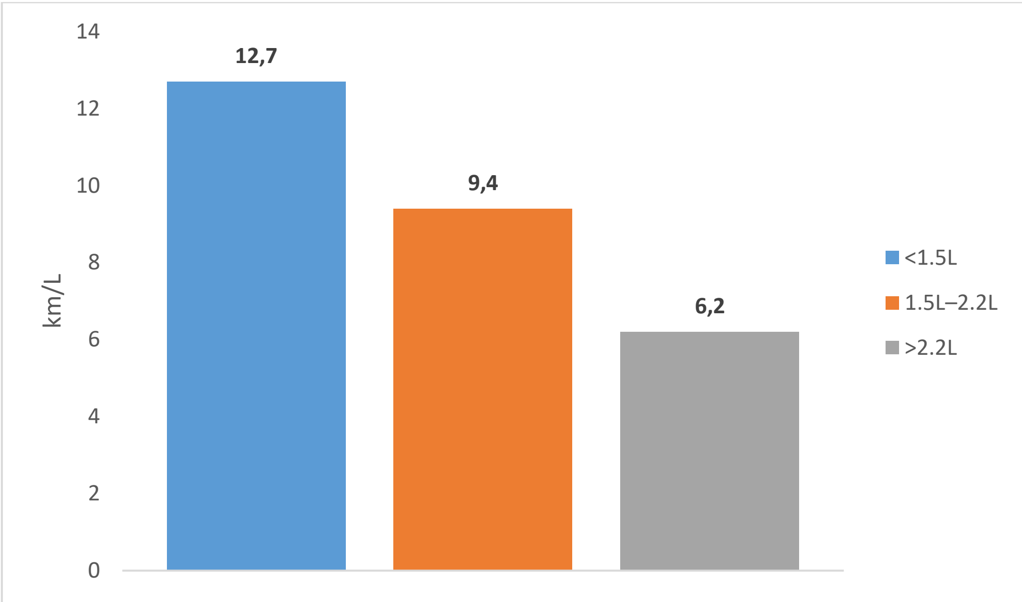
Half of households (56%) owned vehicles with an engine capacity of 1.5L–2.2L and about 19% of households owned vehicles with an engine capacity more than 2.2L (Figure 19). About 25% of households owned vehicles with an engine capacity of less than 1.5L. Vehicles with an engine capacity of less than 1.5L had the highest fuel economy of 12.7 km/L, followed by those with an engine capacity of 1.5L–2.2L at 9.4 km/L, and those with an engine capacity of more than 2.2L at 6.2 km/L (Figure 20). The overall average fuel economy was about 8.10 km/L.

Figure 1.19: Share of Vehicles by Engine Capacity



Source: Author (2019).

Figure 1.20: Share of Fuel Economy by Vehicle Engine Capacity

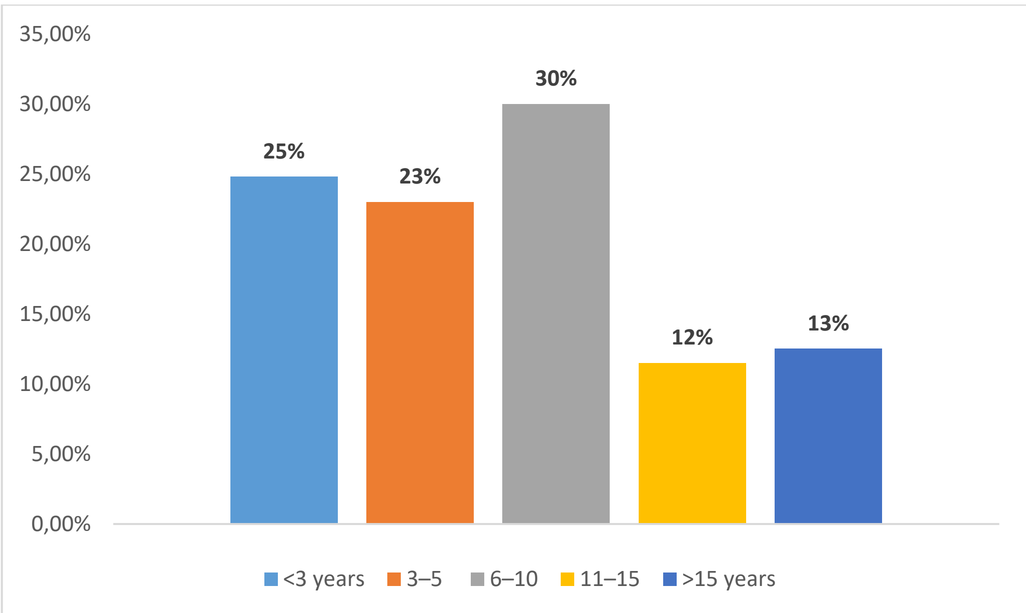


Source: Author (2019).

The analysis of the car stock (Figure 21) revealed that 30% of vehicles were 6–10 years old and 13% 15 years. The average age of cars was about 7.6 years.

Motorcars using petrol dominated with a share of 81%. Motorcars using diesel accounted for 18% and those using other fuels for 1%. Hybrid motorcars had no records. However, more detailed data is needed to establish a clear overview of energy consumption in transport.

Figure 1.21: Age of Vehicles (Years)



Source: Author (2019).

6. Summary of Key Findings on Household Energy Consumption

(i) Electricity was the main energy source, followed by LPG and, to a lesser extent, natural gas.

(ii) Average electricity consumption per household was 15,785 kWh/year (or 1,315 kWh per month), which was significantly higher than the average values of EU and Asian household electricity consumption. However, actual electricity consumption per household could be higher because the survey results were lower than national energy statistics (Table 1.3).

(iii) Average household electricity consumption in the four districts showed consistent trends:

(a) Average electricity consumption per household was consistently high, exceeding 1,000 kWh per month in each district. The lowest monthly average was 1,025 kWh per month in Belait and the highest 1,502 kWh per month in Brunei-Muara (Figure 12).

(b) All four districts showed substantial use of air conditioners and refrigerators.

(iv) Air conditioners, refrigerators, lighting, and water heaters used a significant amount of energy. Their combined share was about 91% of total household electricity consumption (94%, including fans). Air conditioners used the most electricity, with an average share of 59.5% (Figure 15).

(v) The influence of household income on electricity consumption is summarised in Figure 8. The highest-income group consumed more electricity for air conditioning (65.6%) whilst the lowest-income group consumed less (53.1%).

(vi) A significant proportion of refrigerators in use that were 6 years or older was almost 50% whilst that of air conditioners in use that were 6 years or older is 37%. Savings could be significant if old refrigerators were replaced with newer and energy-efficient models. (Appendix A compares refrigerators' unit electricity consumption by years used.) Because air conditioners are on for long hours, energy savings could be significant if old units were replaced with newer and energy-efficient models equipped with inverter technology.

(vii) Air conditioners were on for several hours (average 9.17 hours per day) because electricity tariff was low, which is why they accounted for about 60% total residential electricity demand. Electricity consumption data from the BDHECS were lower than national energy statistics. Air conditioners could be used longer than suggested by the survey, which means the share of electricity consumption by air-conditioners should be more than 60%.

7. Policy Recommendations

Analyses from the survey results show that appliances and electronics drive much of the household energy consumption in Brunei Darussalam. Most households had limited understanding of appliance and equipment efficiency. To achieve significant residential energy savings, the following are recommended:

7.1. Implement mandatory standards and a labelling system

(i) Develop regulations and legislation for standards and labelling of lighting, appliances, and equipment and ensure that these measures are enforced and regularly updated. Standards and labelling should focus on products that will deliver the greatest energy savings as well as offer economic and environmental benefits by helping reduce energy intensity and the carbon footprint.

(ii) Establish minimum energy performance standards (MEPS) for building components and systems such as glazing, wall and roof materials, insulation, windows, water heating, and cooling systems.

(iii) Establish an energy labelling scheme to help consumers compare the energy efficiency of domestic appliances and make informed choices based on reliable and certified information.

(iv) Establish laboratories to test and evaluate the efficiency of household appliances and equipment, and to make sure that they comply with regulations and MEPS.

7.2. Develop information and awareness campaigns and educational programmes

Short term

(i) Develop and implement continuous and sustainable communication outreach programmes such as roadshows and exhibitions, as well as media information and education campaigns, to highlight energy efficiency opportunities of stakeholders in the energy business and of end-use consumers.

(ii) Publish energy efficiency guideline booklets and distribute them to households (applicable to all appliances). The booklets would be made available on the ME website to help consumers make informed decisions based on energy savings and quality of life rather than only on initial costs. Since space cooling accounted for the largest proportion of residential electricity use, the guidelines should promote optimising cooling through passive measures before considering energy saving through appliances.

(iii) Encourage replacement of appliances with efficient units, especially old units exceeding 10 years.

Long term

(i) Incorporate EEC in primary and secondary school curriculums, and train teachers so they can instil in students EEC as an integral part of living habits and decision making.

(ii) Introduce national energy awards to give public and professional recognition for excellent work in energy efficiency and to help encourage best practices.

(iii) Appoint an energy efficiency body or champion in government, business, and the public to save energy.

7.3. Implement incentives and tariff reform

(i) Encourage consumers to choose energy-efficient appliances and vehicles, including by reducing duties or sales tax on them.
(ii) Provide soft loans for efficient appliances and low-emission vehicles.
(iii) Restrict the importation of inefficient appliances based on MEPS and labelling.
(iv) Complement efforts to reform electricity tariffs and transport fuel assistance. Any increases in government expenses as a result of these measures could be balanced by a decrease in spending on energy subsidies.

7.4. Promote residential building energy efficiency technology

Adopt passive design strategies:

(i) Install insulation on roofs and/or walls to minimise solar thermal heat gain.
(ii) Install window shading devices to minimise solar thermal heat gain.
(iii) Improve building design and construction, e.g. doors, windows, and ceilings, to minimise air leakage.
(iv) Use roof turbine ventilators to vent out hot air.
(v) Use building materials suitable for a hot and humid climate.

Adopt active design strategies:

(i) Develop guidelines for selecting energy-efficient appliances.
    (a) Select suitable appliance capacity for household usage to avoid over-sizing.
    (b) Select appropriate technology, e.g. inverter type for air conditioning and refrigeration, CFL and LED lighting, solar water heating, outdoor photo sensors or timers and security lighting, amongst others.
(ii) Develop guidelines for the efficient use and maintenance of appliances.
    (a) Avoid ineffective usage (energy conservation).
    (b) Encourage regular servicing and maintenance.

8. Conclusion

The BDHECS was successful despite the small sampling size and some inaccuracies that resulted in electricity consumption results lower than national energy statistics. However, the discrepancy between the survey results and the national energy statistics is within a reasonable range.

The BDHECS analyses provide useful information for policy planning (section 1.6). The dominant consumer of household electricity was clearly air conditioners, contributing 59.5% of average residential electricity consumption. Air conditioners, refrigerators, lighting, and water heaters consumed about 91% of electricity. Therefore, by adopting the four key EEC policy measures recommended in section 1.7, Brunei Darussalam could potentially reduce its electricity consumption by up to 5.3% annually. Implementing these recommendations would require active participation of all stakeholders nationwide. If a residential EEC road map were to be established, the BDHECS would be a useful reference and guide.

Chapter 2

Brunei Darussalam Commercial and Public Buildings Energy Consumption Survey

1. Introduction

Commercial and public buildings accounted for 53% of total electricity consumption in 2015 – higher than in the residential and industrial sectors. Following the completion of the BDHECS, a similar survey was conducted for commercial and public buildings. The survey's primary objective was to understand the energy consumption patterns through building energy intensity (BEI), which is basically energy consumed per square metre of a building in 1 year.

The survey was carried out under an international cooperation framework similar to the BDHECS'. Experts from ERIA provided technical guidelines to develop the survey questionnaire and to validate and analyse data. BNERI and ME primarily managed the survey, including coordination with survey target respondents and data collation and analyses.

2. Survey Methodology

2.1. Sampling and Sampling Size

A total of 116 samples were collected throughout the 1-month field survey in Brunei-Muara, Tutong, and Belait, but not in Temburong because of logistical and budget constraints. Offices made up most of the samples at about 54%, followed by mosques at 23%, retail stores at 13%, hotels at 6%, and hospitals at 3%. Table 2.1 shows the distribution of samples by building type.

The evaluation of the energy performance of commercial and public buildings uses BEI, which is typically determined by the following formula (based on Malaysia's Green Building Index BEI computation):

$$BEI = \frac{TBEC - CPEC - DCEC}{GFA - CPA - DCA - (GLA\ X\ FVR)}\ X\ \frac{AWH}{WOH}$$

where

BEI is the Building Energy Intensity (kWh/m^2/year),

TBEC is the annual total building energy consumption (kWh/year),

CPEC is the annual car park energy consumption (kWh/year),

DCEC is the data centre energy consumption (kWh/year), GFA is the gross floor area (m^2),

CPA is the car park area (m^2),

DCA is the data centre area (m^2),

GLA is the gross lettable area (m^2),

FVR is the floor vacancy rate (%),

AWH is the average weekly operating hours (hours/week), and

WOH is the weighted weekly operating hours (hours/week).

Table 2.1: Number of Samples by Building Type

Type of Equipment	Number of Samples	Share of Samples
Office	63	54.3%
Retail	15	12.9%
Hospital	4	3.4%
Hotel	10	6.0%
Mosque	27	23.3%
Total	**119**	**100%**

BEI has been widely used in many countries. Most ASEAN members have already developed their own green building rating systems to promote green and energy-efficient buildings. Indonesia has GREENSHIP, Malaysia has the Green Building Index, Singapore has Green Mark, whilst the Philippines has Building for Ecological Responsive Design Excellence. Different building categories have different BEI values depending on the function of the buildings and, therefore, their energy requirements. Each green building rating tool sets a minimum BEI value requirement for green building entry level.

Table 2.2 illustrates typical benchmark values used in Malaysia and Singapore for various building types, which can be used to compare BEI values for Brunei Darussalam in this study.

Table 2.2: Comparison of Building Energy Intensity Values in Malaysia and Singapore

Building Type	EUI for Green Mark, Singapore ($kWh/m^2/y$)		BEI for Green Building Index, Malaysia ($kWh/m^2/y$)	
	Conventional (Based on average 2008 EUI)	***Green Building Entry Level***	***Conventional***	***Green Building Entry Level***
Office Buildings	274	160	250	150
Hotels	274	260	330 (1–3-star) 480 (4–5-star)	200 (3-star and below) 290 (4-star and above)
Retail Buildings	389	360	400 (low-end outlets) 580 (high-end outlets)	240 (low-end outlets) 350 (high-end outlets)
Hospitals	354 (private) 341 (public)	N/A	330 (small/medium sized) 480 (large)	200 (small/medium sized) 290 (large)

BEI = Building Energy Intensity, EUI = energy use intensity.

Source: BCA (2018)

2.2. Questionnaire Preparation

A questionnaire was developed in consultation with study team members comprising staff from the Sustainable Energy Division (SED) of ME and BNERI, as well as experts from ERIA. For all sample types except for mosques, the questionnaire consisted of sections shown in Table 2.3.

Table 2.3: Questionnaire Sections and Details

Section	Details
A1	Name of Building
A2	Address
A3	Building Information • Building Age • Total Floor Area • Total Air-Conditioned Area • Total Non-Air-Conditioned Area • Maximum Number of People • Building Footprint Sketch
A4	Building Utilisation • Building Operating Hours per Day • Air-Conditioning System Operating Hours per Day • Building Operating Days per Week
A5	Data Centre or Server Room • Area • Total Electricity Consumption per Year (for the last 3 years)
A6	Electricity Consumption • Total Electricity Consumption per Year (for the last 3 years)

2.3. Distribution and Collection of Questionnaires

The questionnaires were distributed by the survey enumerators according to their assigned locations. Target respondents, through their focal persons, who were available during the survey, were interviewed face-to-face, and then given the questionnaires together with an official letter of information and request from ME. Focal persons who were unavailable for interviews were requested to respond to the questionnaire at their convenience. In such instances, the documents (questionnaires and official letters) were emailed or left with administration officers. After a period agreed on by enumerators and focal persons, completed questionnaires were collected and checked thoroughly by the enumerators.

For quality assurance, the following steps were undertaken: (i) training of enumerators to understand and interpret survey questionnaires, including simulated survey sessions; (ii) checking by individual enumerators; (iii) second checking by supervisors; and (iv) call back or revisit (random and spot checks) by the team leader or supervisor.

3. Data Validation

Out of 119 samples (Table 2.4), only 78 were deemed valid and complete, corresponding to about 65% of the total survey samples; 35% of the samples were not considered as most of the key data (electricity consumption or floor areas) were missing.

Table 2.4: Validated Samples with Respect to Total Samples

Type of Equipment	Number of Samples	Share of Samples	Number of Validated Samples
Office	63	52.9%	37
Retail	15	12.6%	4
Hospital	4	3.3%	3
Hotel	10	8.4%	9
Mosque	27	22.6%	25
Total	119	100%	78

Source: Author (2019).

3.1. Office Buildings

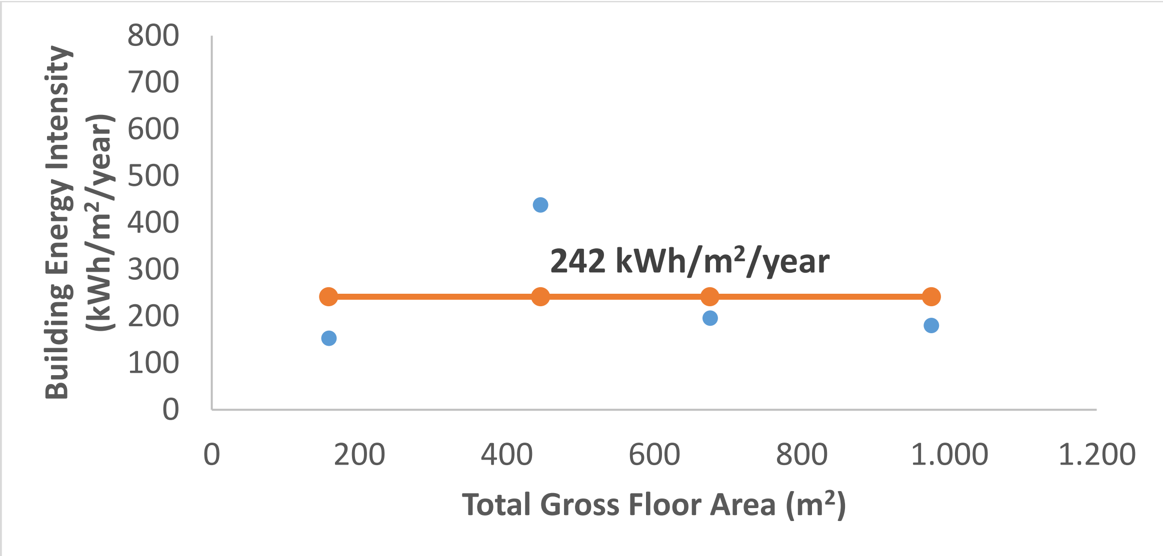
Electricity was the main source of energy in offices. Offices had varying operating hours and the average operational hours amongst the buildings surveyed worked out to be 2,028 hours per year, corresponding to an average of 39 operating hours per week. The surveyed data included working hours beyond the average official operational hours where the air-conditioning systems were still in operation. Nonetheless, total energy consumption was adjusted to reflect the same operational hours of 2,028 hours per year to rationalise energy consumption for comparison purposes.

Offices were grouped according to their size:

(i) small offices with gross floor area of less than 1,000 m^2,
(ii) medium-sized offices with gross floor area of 1,000 m^2 to 2,000 m^2, and
(iii) large offices with gross floor area exceeding 2,000 m^2.

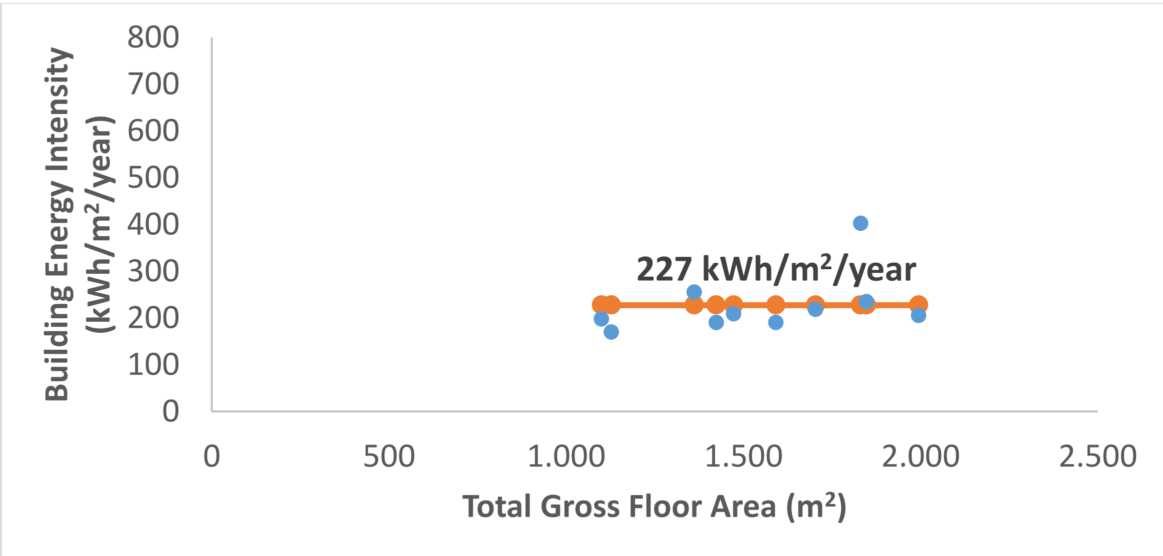
In general, the average BEI values were distinct from each other in accordance with office size. However, the average BEI value for medium-sized offices at 227 kWh/m^2/year (Figure 2.2) was slightly less than that for small offices at 242 kWh/m^2/year (Figure 2.1). This is comparable to offices in Singapore, where small and large offices have conventional BEI values of 268 and 212 kWh/m^2/year, respectively. For large offices in Brunei Darussalam, the average BEI value was about 275 kWh/m^2/year (Figure 2.3). Taking into account offices of all sizes, the average BEI was calculated as 258 kWh/m^2/year (Figure 2.4), which is higher than Singapore's and Malaysia's BEI values for conventional office buildings but in similar order of values (i.e. comparable values).

Figure 2.1: Building Energy Intensity Against Total Gross Floor Area for Small Offices



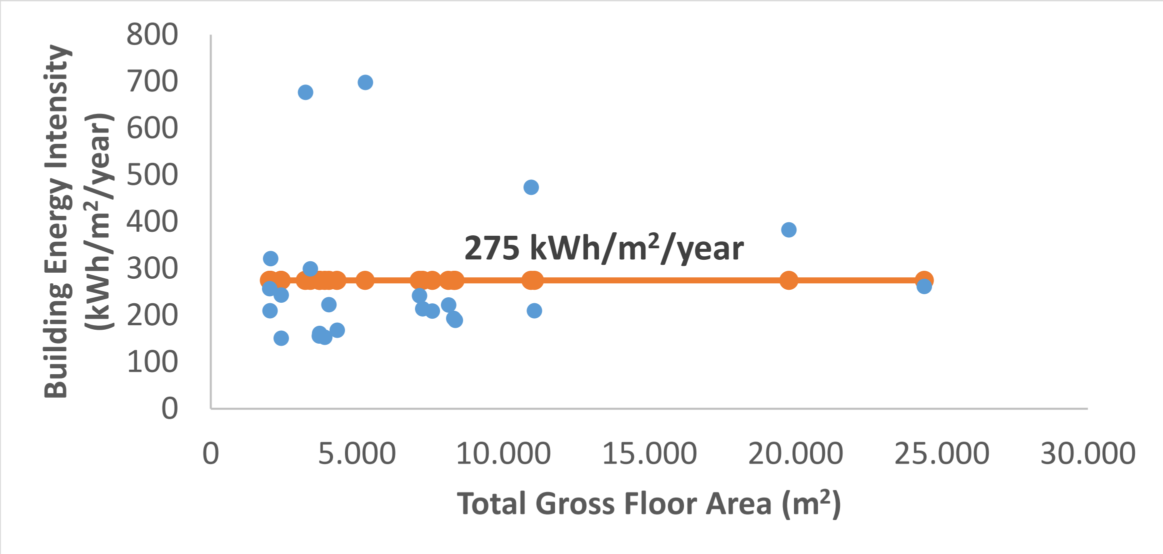
Source: Author (2019).

Figure 2.2: Building Energy Intensity Against Total Gross Floor Area for Medium-sized Offices



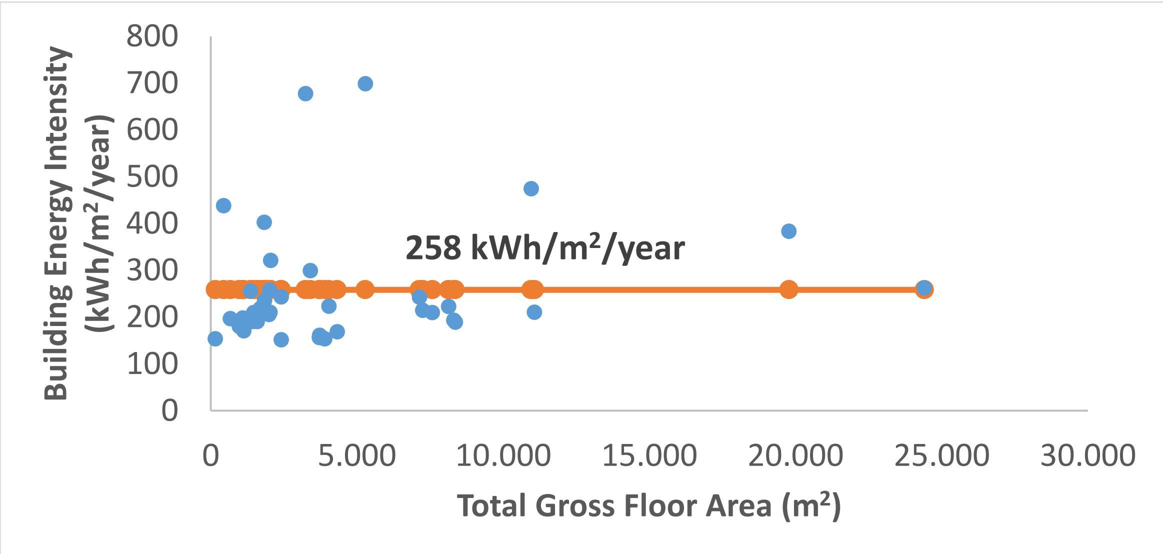
Source: Author (2019).

Figure 2.3: Building Energy Intensity Against Total Gross Floor Area for Large Offices



Source: Author (2019).

Figure 2.4: Building Energy Intensity Against Total Gross Floor Area for All Offices



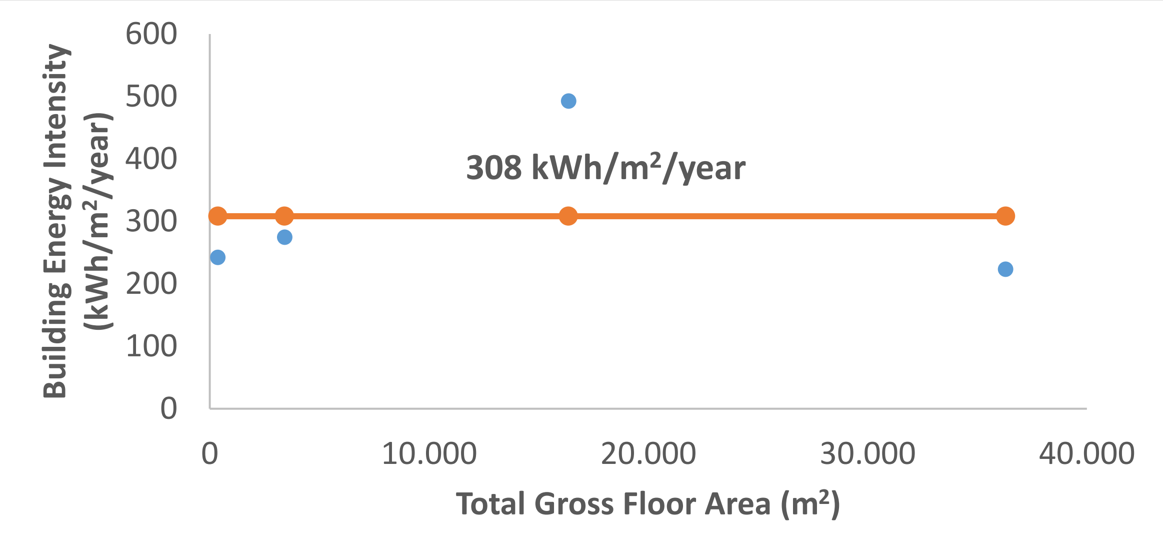
Source: Author (2019).

3.2. Retail Buildings

Retail buildings surveyed consumed mainly electricity, although a few large shopping malls also utilised LPG, primarily in their food and beverage section, and diesel, as fuel for back-up generators. Like offices, these buildings had different operating hours but averaged 81 hours weekly, which corresponded to 4,212 hours annually. Therefore, total energy consumption was adjusted to reflect the same operational hours of 4,212 hours per year to rationalise energy consumption for comparison purposes.

Figure 2.5 illustrates that the average BEI value was about 308 kWh/m^2/year, based on a very small sampling size. The rest of the samples were found to have exceptionally low BEI values (less than 100 kWh/m^2/year) and deemed outliers and therefore omitted from data analysis.

Figure 2.5: Building Energy Intensity Against Total Gross Floor Area for Retail Buildings

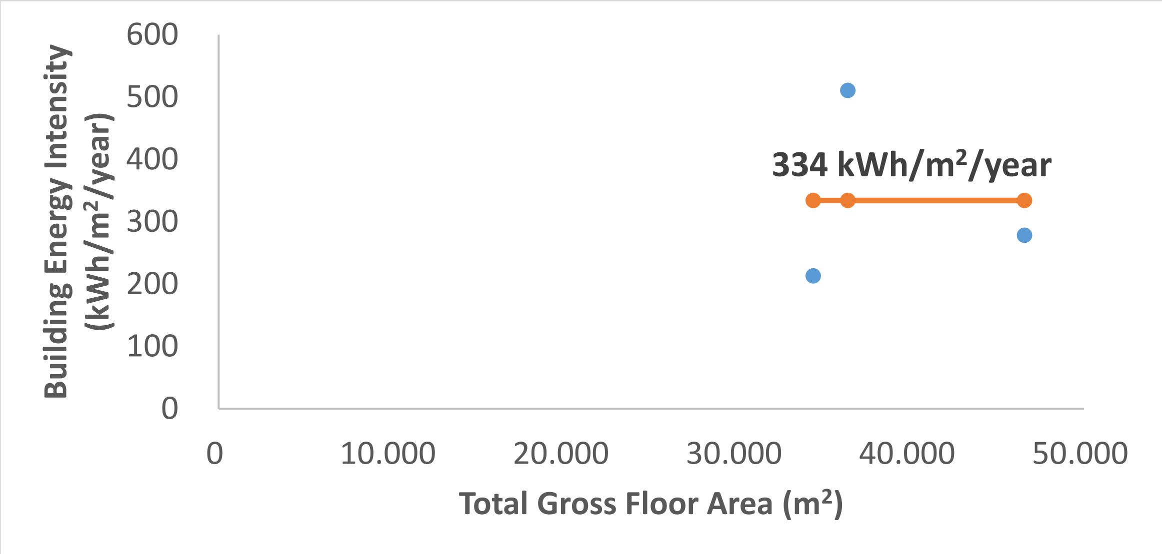


Source: Author (2019).

3.3. Hospital Buildings

Because of the limited number of samples, all the hospitals surveyed were large, with floor areas from 30,000 m^2 to 80,000 m^2. Most hospitals recorded BEI values from 213 to 511 kWh/m^2/year, except for one with an exceptionally low value of 80 kWh/m^2/year. Therefore, the computation of average BEI value for hospitals did not include this hospital as the value was considered an outlier. The average value worked out to be 334 kWh/m^2/year (Figure 2.6). Electricity was the main source of energy for hospitals, with diesel as a secondary fuel for standby generators.

Figure 2.6: Building Energy Intensity Against Total Gross Floor Area for Hospital Buildings



Source: Author (2019).

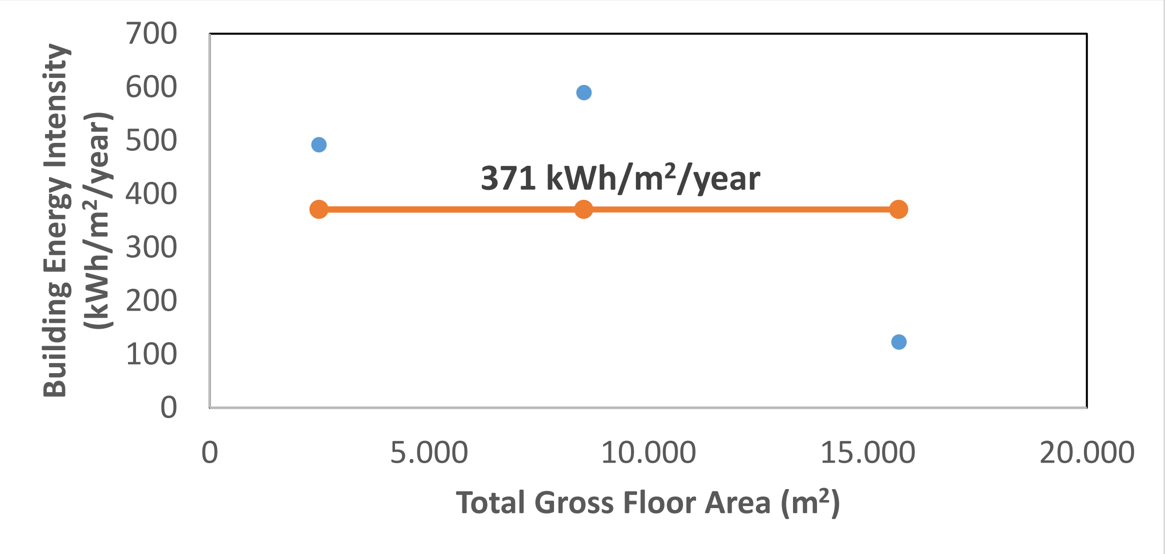
3.4. Hotels

Half of the 10 hotels surveyed were 3-star rated, whilst one was 4-star rated, two 4.5-star rated, and the rest 5-star rated. Electricity was the main source of electricity, followed by diesel for standby diesel generators and LPG for cooking.

Figure 2.7 and Figure 2.8 illustrate the vast difference in BEI values of 1–3-star and 4–5-star hotels. The average BEI value of 1–3-star hotels at 177 kWh/m^2/year was much lower than that of 4–5-star hotels at 371 kWh/m^2/year. The BEI value of 371 kWh/m^2/year for the 4–5-star hotels was much higher than for corresponding hotels in Singapore and Malaysia. This could mean that hotels in Brunei Darussalam have the potential to save energy if this BEI value could be accepted as the benchmark for conventional 4–5-star hotels.

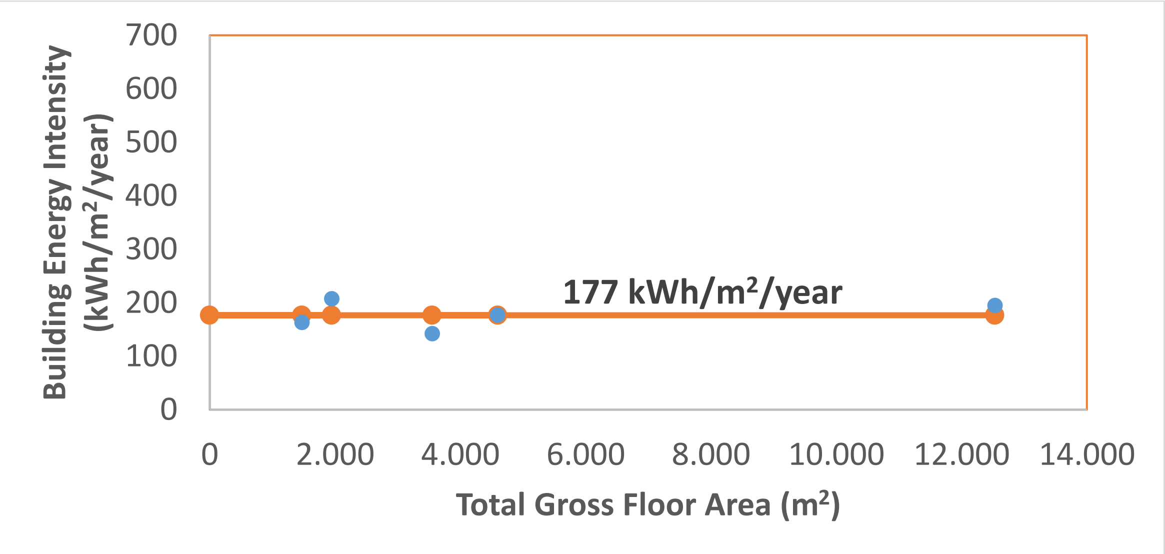
The 1–3-star BEI value of 177 kWh/m^2/year, however, seems low compared with Singapore's 274 kWh/m^2/year and Malaysia's 330 kWh/m^2/year for conventional hotels of the same class. The survey did not ascertain whether the difference might be due to low occupancy rates, fewer hotel facilities, or inadequate record keeping by 1–3-star hotels in Brunei Darussalam. Therefore, the average BEI value of 177 kWh/m^2/year for 1–3-star hotels needs to be further verified before it is adopted as the baseline BEI value for 1–3-star hotels in Brunei Darussalam.

Figure 2.7: Building Energy Intensity Against Total Gross Floor Area for 4–5-Star Hotels



Source: Author (2019).

Figure 2.8: Building Energy Intensity Against Total Gross Floor Area for 1–3-Star Hotels



Source: Author (2019).

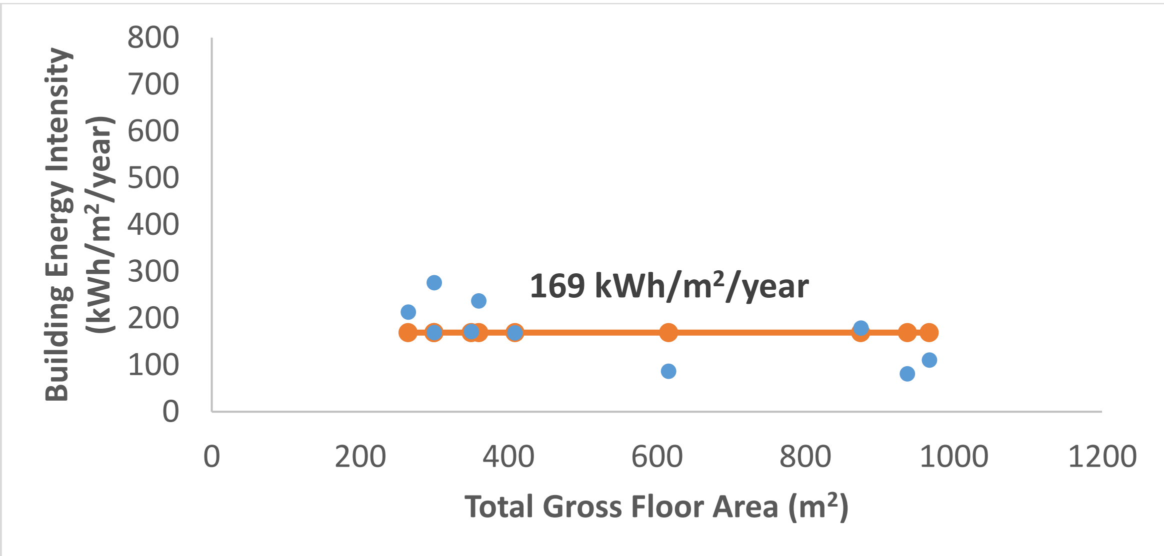
3.5. Mosques

Like offices and retail buildings, mosques surveyed were grouped by size:

(i) small mosques or prayer halls with gross floor area of less than 1,000 m^2,
(ii) medium-sized mosques with gross floor area from 1,000 m^2 to 2,000 m^2, and
(iii) large mosques with gross floor area exceeding 2,000 m^2.

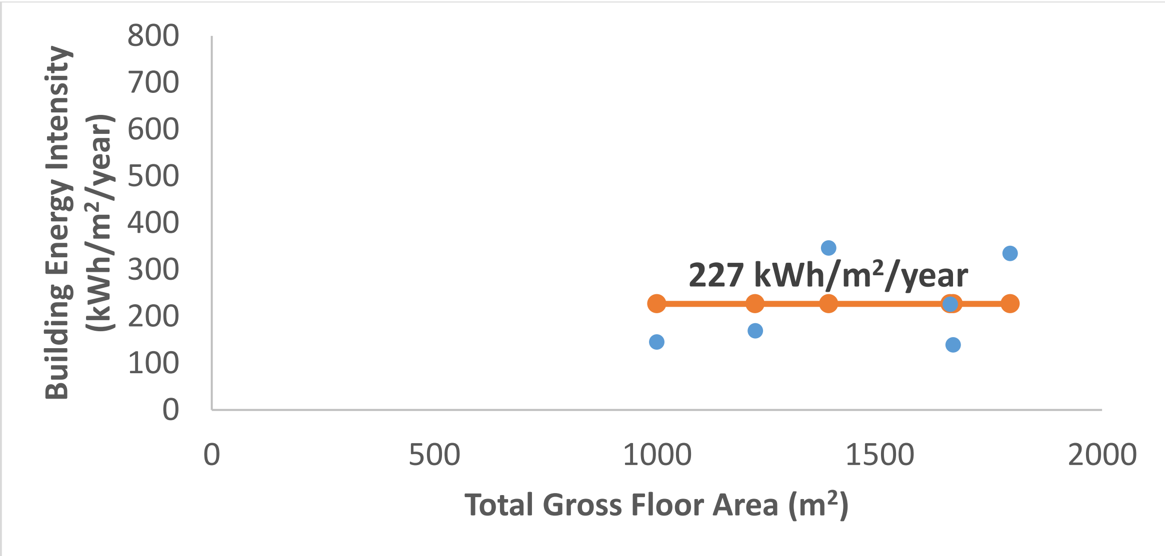
Electricity was the main source of energy for mosques. It was primarily used for air conditioning and lighting. As expected, the BEI value was influenced by the size of mosques (Figure 2.9, Figure 2.10, and Figure 2.11). Small mosques or prayer halls had an average BEI value of 169 kWh/m^2/year, followed by medium-sized mosques with 227 kWh/m^2/year, and large mosques with 323 kWh/m^2/year. The difference in BEI values was likely due to the extent of air-conditioning installations and usage. Small mosques were likely to have fewer air-conditioning installations and less usage, and smaller-capacity air-conditioning systems, whilst larger mosques were likely to have more air-conditioning installations and usage and larger-capacity air-conditioning systems. This is why large mosques had higher BEI baseline values.

Figure 2.9: Building Energy Intensity Against Total Gross Floor Area for Small Mosques or Prayer Halls



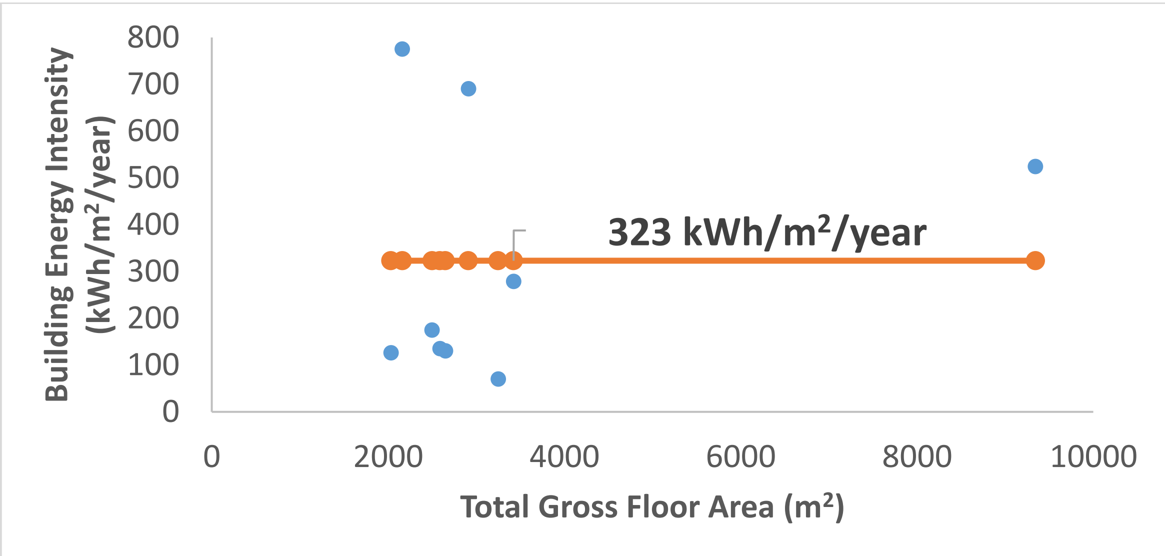
Source: Author (2019).

Figure 2.10: Building Energy Intensity Against Total Gross Floor Area for Medium-sized Mosques



Source: Author (2019).

Figure 2.11: Building Energy Intensity Against Total Gross Floor Area for Large Mosques



Source: Author (2019).

4. Summary of Key Findings

The key findings from the commercial energy consumption survey can be summarised as follows:

(i) The average BEI values derived from the survey are summarised in Table 10. Because of the limited number of survey samples, these BEI values were indicative baseline average values only for conventional buildings without energy efficiency measures. However, it appears that the BEI values for office buildings and mosques were more acceptable because of their more substantial number of samples. The BEI values for conventional retail buildings, hospitals, and hotels were not conclusive and should be analysed further using more samples.

Table 2.5: Summary of Average Building Energy Intensity Values for Conventional Buildings Derived from the Survey

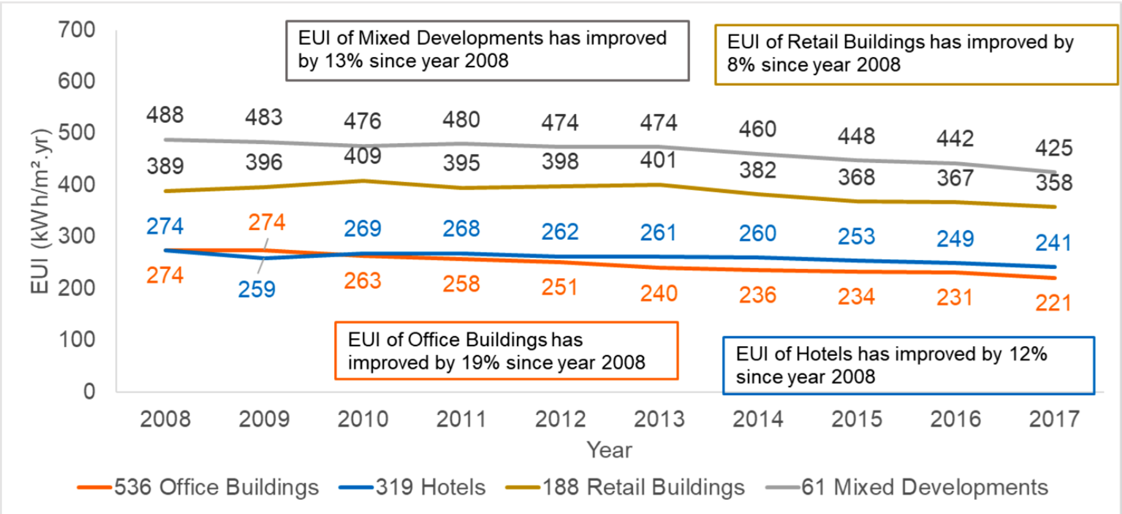
Building Type	Average BEI Derived from the Survey (kWh/m^2/year)	Remarks
Offices	Small: 242 Medium sized: 227 Large: 275 Overall: 258	The overall BEI value is similar to that Singapore (274 kWh/m^2/year) and Malaysia (250 kWh/m^2/year).
Retail Buildings	Overall: 308	This BEI value appears to be better than that of Singapore and Malaysia. However, the comparison may not be accurate as the sample was small and the extent of facilities maybe different.
Hospitals	Overall: 334	This BEI value is comparable with Malaysia's small and medium-sized hospitals' BEI.
Hotels	4–5 star: 371 1–3 star: 177	Because the sample is small, comparisons with Singapore and Malaysia's BEI values may not be meaningful.
Mosques	Small: 169 Medium sized: 227 Large: 323	Data to make a comparison is lacking. However, the trend of these BEI values shows that less usage of air conditioning (in the small mosques) indicates lower BEI value.

BEI = Building Energy Intensity.
Source: Author (2019).

(ii) Average BEI values by building type can help in monitoring national trends in building energy efficiency. Figure 33 shows average EUI (or BEI) against years, illustrating the trend of energy performance of Singapore office buildings, hotels, retail buildings, and mixed developments that have attained Green Mark certification since 2008. The EUI of office buildings has improved by 19% since 2008, hotels by 12%, retail buildings by 8%, and mixed developments by 13%.

If BEI labelling were adopted in Brunei Darussalam, however, energy savings would be greater because they would be compared with Brunei's BEI baseline values, which are higher than Singapore's EUI values in 2008 (Figure 2.12).

Figure 2.12: Average Energy Use Intensity Trend by Commercial Building Type in Singapore



EUI = energy use intensity.
Source: BCA (2018).

(iii) BEI labelling and benchmarking could be useful in driving the energy efficiency agenda in the commercial sector. Once the baseline BEI values are established for conventional buildings and minimum 'entry level' BEI values for energy-efficient buildings for the various building categories, energy savings can be easily quantified. Commercial viability can then be analysed and justified.

(iv) Despite the limited number of survey samples and the physical and financial constraints in conducting the survey, indicative BEI values for existing building stocks showed that energy savings could be made if BEI were used to drive the energy efficiency agenda and make the operation of buildings more energy efficient. In other words, if there were BEI labelling and BEI targets for energy-efficient buildings, which adopt energy efficiency measures, energy consumption in the commercial sector and, therefore, carbon dioxide emission intensity could be reduced.

5. Issues and Challenges

The survey faced challenges and limitations:

(i) **Sampling size.** Because of field survey time and budget constraints, the number of samples across some building types was low, especially hotels (nine validated samples), hospitals (three), and retail buildings (four). The number of samples was higher for offices and mosques, so the results for these buildings should be better.

(ii) **Data collection.** The answered questionnaires had missing items such as gross floor area and energy (electricity) consumption of buildings. The issue of missing data on electricity consumption in some buildings was resolved through DES, which checked the yearly and monthly electricity consumption through buildings' account numbers. The issue of missing gross floor area was far more complex as most of the buildings, especially the old ones, did not have accurate plans and drawings. Google Maps was used to measure area and results were not accurate, which resulted in questionable BEI values.

(iii) **Resources.** Most of the significant number of discrepancies discovered during data collection were difficult to rectify because of limited resources and time.

(iv) **Survey questionnaire.** It was designed with assistance from ERIA. Before the survey, the questionnaire was pilot tested to gauge field enumerators' understanding of it. Whilst no major changes were needed, enumerators took some time to understand the questionnaire, especially the sections on building information and building utilisation.

(v) **BEI.** BEI is relatively new and not well understood amongst building owners and management personnel in Brunei Darussalam. No regulatory frameworks are dedicated to BEI and energy management in general, so building managers are not obliged to record, monitor, or report regularly on BEI.

(vi) **Results.** The survey results were indicative as this was the first survey of its kind to be conducted in Brunei Darussalam and was not comprehensive. It is recommended that similar surveys be conducted separately, i.e. one survey per building type.

6. Green Buildings Action Plan

6.1. Background

The study's objective was to carry out a baseline survey to establish the current energy performance of commercial and public sector buildings in Brunei Darussalam. The study results provide first-hand information about current energy consumption of buildings in the country. While the information is useful, however, it is not sufficient to set national green building targets because the number of survey samples was limited. This section provides an outline of the next steps to increase the sustainability of the building sector and to promote the development of green buildings.

6.2. National Benchmarking Study

The study established baseline information on the energy performance of public sector and commercial buildings. The results are useful inputs to develop a national policy that promotes the development of green buildings. Following international standards, the study used BEI to measure energy performance and estimated the average BEI for each building category.

Because the number of samples was limited, the study results were insufficient to establish BEI target values for policy making. More samples are needed to establish a reliable database to develop policies on green buildings. The next step is to establish more accurate BEI values through a comprehensive building benchmarking study that will collect and analyse information and energy consumption data of all buildings.

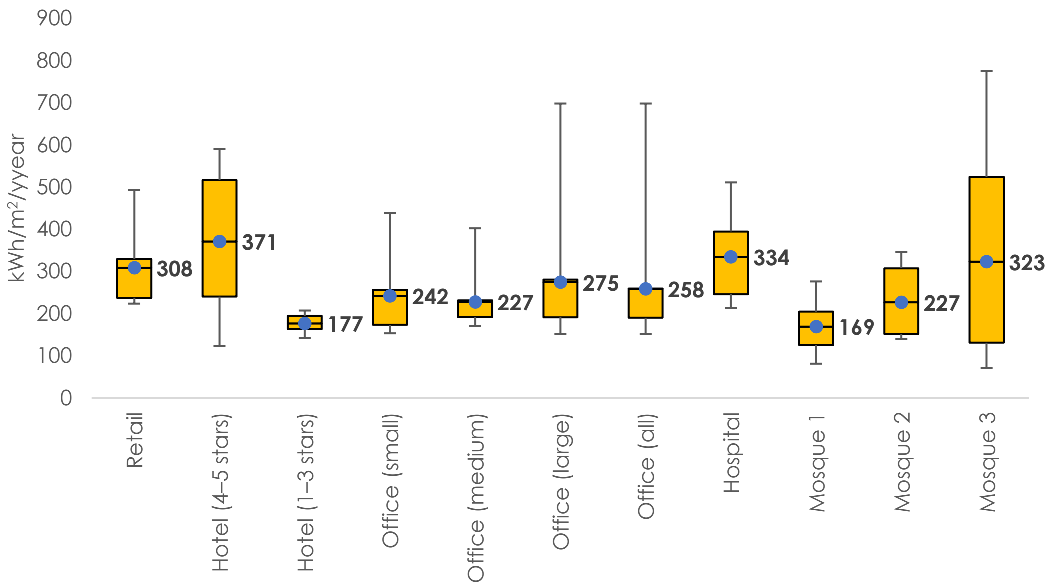
A detailed benchmarking study will enable (i) the government to more accurately assess buildings' energy consumption and efficiency and provide a more concrete basis to formulate policy measures to reduce the impact of buildings on the environment; (ii) building owners, facilities managers, and tenants to know the energy performance of their buildings and improve their energy efficiency; (iii) consultants and designers to have more effective guidelines and adopt best practices in designing or retrofitting energy-efficient buildings; and (iv) research and education communities to carry out research and studies using shared data to further advance green building technologies and solutions (BCA, 2014b).

6.3. Green Building Certification Scheme

The survey results are summarised in Figure 2.13. The box plot diagram shows the average values of the samples as well as maximum and minimum values of BEI by building category. Amongst the buildings covered in the survey, 4–5-star hotel buildings had the highest BEI, followed by hospitals, large mosques, and retail buildings. The results are an important input to the development of energy efficiency indicators under a national green building certification system.

The Ministry of Development (MOD) has introduced a rating scheme for government buildings called Brunei Accredited Green Unified Seal (BAGUS) (Kimura, Pacudan, Leong, and Phoumin, 2017). Three government buildings were awarded the BAGUS and required to reduce electricity consumption by more than 15% per year and to meet the government-mandated energy efficiency indicator of 175 kWh/m^2 per year.

Figure 2.13: Survey Results



Source: Author (2019).

The existing scheme could be further expanded to cover the private sector and other building types in addition to government office buildings. This expanded scheme should be hosted by a dedicated agency to be identified by MOD since a green building certification scheme covers much broader criteria. In Singapore, for example, the criteria include climatic responsive design (passive measures), energy efficiency, water efficiency, smart and healthy buildings, and other advanced green efforts. Malaysia's Green Building Index criteria include energy efficiency, indoor environmental quality, sustainable site planning and management, materials and resources, water efficiency, and innovation. A new set of criteria and procedures that are suitable for the country needs to be developed when introducing a more comprehensive green building certification system to cover both the public and private building sectors in Brunei Darussalam.

Under the energy efficiency criterion, BEI for different building types will be established for existing and new buildings. The target BEI values must be set based on specific studies and in consultation with various experts, industry practitioners, and other stakeholders. However, the full implementation of a green building certification scheme will take time as it will involve greater efforts and more stakeholders. As an interim measure, ME can look into establishing BEI labelling under the MEPS, which will be an easier and effective route to achieve energy-efficient buildings.

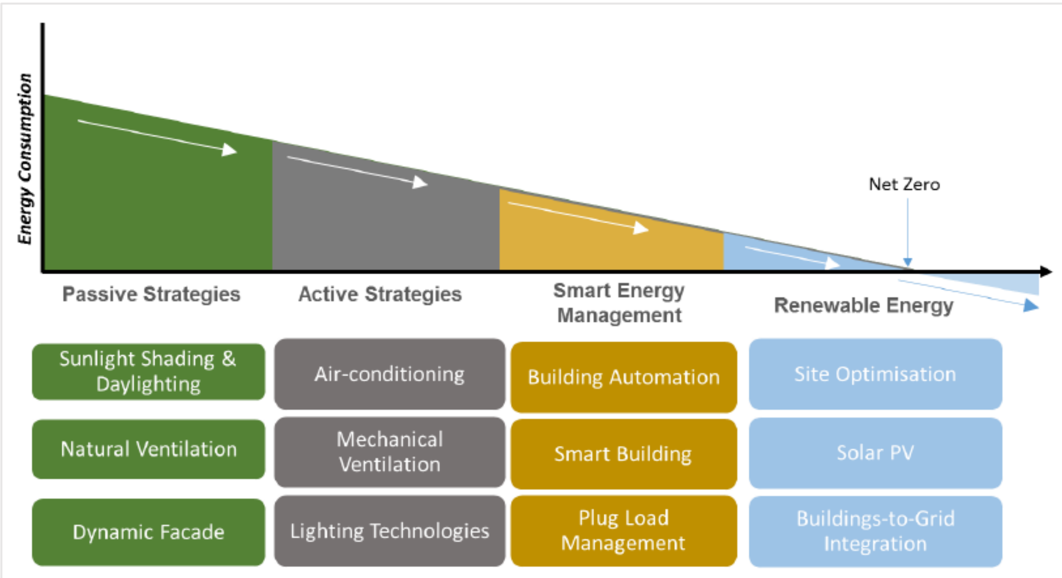
6.4. Technology Road Mapping

Kimura, Pacudan, Leong, and Phoumin (2017) identify technologies and strategies that could be applied in Brunei Darussalam, including passive design strategies, active design strategies, and the use of smart and green technologies. Singapore's BCA (2018) emphasises renewable energy technologies as the fourth area for energy efficiency in buildings (Figure 2.14). For a holistic approach to energy efficiency in buildings, passive design must be adopted before an active design strategy is considered (BCA, 2018; BCA, 2014a; Kimura et al., 2017).

Building energy efficiency studies have focused mostly on active strategies because the analysis has been centred on electricity demand and direct measures to reduce demand. The Mitsubishi Research Institute (MRI) (2012) found that about 80% of electricity demand in private buildings was mainly used for air conditioning, about 75% in government buildings, and about 70% in hotels and other buildings. Lighting constituted the second-largest end-use demand in the building sector with demand share of 10%–15%. Water heating is important in hotels and hospitals.

In technology road mapping, strategies and technical measures are identified and feasibility studies (technical and economic) carried out. The measures are ranked based on their cost-effectiveness. Cost-effective measures are then considered for policy interventions.

Figure 2.14: Energy Reduction Strategies Towards Low-energy Buildings



Source: BCA (2018).

Based on studies carried out in Singapore, strategic and technical options that could be adopted in Brunei Darussalam are outlined in Table 2.6. The list focuses mainly on existing technologies that could be readily adopted. The impacts of these measures were estimated for Singapore, but the results could provide a good reference for Brunei Darussalam. Most of the measures under passive strategies and plug load reduction technologies and strategies have medium impacts on BEI (5–10 kWh/m^2/year) whilst most measures under active strategies and smart energy management systems have high impacts on BEI (higher than 10 kWh/m^2/year).

Further studies need to be carried out and experts and industry stakeholders consulted when adopting these measures for technology road mapping. Some measures may be relevant only to some building categories and some may not be relevant at all. The measures' cost-effectiveness needs to be further assessed.

Technology road mapping could project the potential reduction of a green BEI in the medium (5 years) and long (10 years) terms. Aggressive but realistic green BEI targets could then be established.

Table 2.6: Existing Technologies and Strategies

Strategies	Technologies	Impacts
PASSIVE STRATEGIES		
Temperature control through insulation	Thermal insulation	L-M
	Insulated glazing	L-M
Temperature control through shading	Double skin façade	M
	Façade greenery	M
	Cool paints	M
Temperature control through natural ventilation	Wind-driven natural ventilation	M-H
Daylight redirecting technologies	Light shelves	L-M
	Tubular daylight	L-M
Building envelope	Insulation materials	M
	Solar heat shielding film	M
ACTIVE STRATEGIES		
Air conditioning and mechanical ventilation	Demand-controlled ventilation	H
	Dedicated outdoor air system	H
	Radiant cooling panels	H
	Active chilled beam	H
	Displacement ventilation	H
	Hybrid system: elevated temperature + increased air movement	H
	Advanced direct expansion type AC system	H
	VAV fan speed's optimisation system	M
	Energy efficient, oil less chiller	H
	Evaporative cooler	M-H
	Energy valve	M
	Solar air conditioner	M

	High-volume low-speed fan	M
Lighting technologies	Direct DC LED lighting with smart control	H
	Ambient + task lighting	L-M
	DALI smart lighting control system	H
SMART ENERGY MANAGEMENT SYSTEM		
Smart energy management system	ACMV optimisation	H
	Continuous commissioning	M
	Retro-commissioning	M
	Building energy management system	H
	Fault detection and diagnosis system	H
	Demand ventilation controls	M
	Weather sensing and adaptive controls	L-M
Solar PV	Integrate PV into architectural	H
	Co-location of solar PV and greenery	H
	Innovative lightweight structures	M
	Anti-degradation system	H
PLUG LOAD REDUCTION TECHNOLOGIES AND STRATEGIES		
Technologies impacting user behaviour	Individual technological control	M
	Centralised control systems	M
Reduce energy waste	Smart power strips	L-M
	Timers	L-M
	Computing and printing equipment	M
	Eliminate redundant equipment	M
Plug load reduction – change user behaviour	Smart WiFi timer plug with remote control	M
	Personal electricity consumption monitoring and benchmarking	L-M

Note: Impact on building energy efficiency indicators: low (L): < 5 kWh/m^2/year; medium (M): 5–10 kWh/m^2/year; high (H): >10 kWh/m^2/year.
Source: BCA (2018).

6.5. Building Energy Policies and Regulatory Frameworks

One challenge in improving the energy performance of the building sector and in deploying green buildings is the lack of or limited policy and regulatory frameworks. Most initiatives have been directed to public sector buildings.

Building Regulation

The legal frameworks for buildings are the Building Control Order (2014) and Building Control Regulations (APERC, 2015). MOD recently released the fourth edition of the mandatory Building Guidelines and Requirements (PBD 12: 2017). PBD 12 stipulates regulations related to space, light, and ventilation; structural, construction, and fire requirements; electrical installations; earthworks, roads, and water; and drainage and sewerage.

MOD issued the Energy Efficiency and Conservation Guidelines for Non-Residential Buildings in 2015, which is mandatory for public buildings. MOD and ME could, however, collaborate to make this guideline mandatory for the private sector as well to achieve greater energy savings.

Standards and Labelling Regulation

ME has conducted several preparatory studies and created implementation plans to introduce MEPS and labelling programmes. The plan is to focus initially on air conditioners and later cover refrigerators, lighting equipment, and others.

Various regulatory hurdles face the introduction of a mandatory standard and labelling programme. Perhaps ME could introduce a voluntary programme as a transitory phase and make it mandatory (with supporting legal frameworks) later.

6.6. Capacity Building and Awareness Raising

The lack of technical capacity is a limiting factor in the development of green buildings. ME is gradually building the capacity of energy managers in government buildings through training and a certification scheme for energy auditing and management. This programme could be expanded to the private sector.

Initiatives to increase awareness of energy efficiency have focused on the public sector. Since energy efficiency activities are limited, efforts related to energy efficiency information campaigns and awareness raising have also been minimal.

Aggressive capacity building and awareness raising are associated with implementing energy efficiency regulatory frameworks and programmes such as standards and labelling, building energy certification, benchmarking policy, amongst others. These activities must, therefore, be packaged together, with new initiatives related to building energy efficiency.

7. Conclusion

The commercial sector survey shows that more samples would produce more credible results. The results for office and mosque buildings are considered acceptable but show that energy savings could be made in the commercial and public building sector if BEI labelling and benchmarking were established. Baseline or benchmark indicators are needed so that building owners and management are well informed and able to monitor and assess the building energy performance of their buildings. Therefore, establishing BEI labelling and benchmarking within the MEPS framework should be explored and considered to attain energy efficiency in a shorter time.

Chapter 3

Conclusions

This report presented the results of the energy consumption survey of the residential and commercial and public sectors in Brunei Darussalam, and outlined policy options to improve energy efficiency in the residential sector and energy performance of commercial and public sector buildings. Despite the survey limitations, the study provides baseline information on the level of energy consumption in these sectors.

The key results of the residential survey are the establishment and determination of (i) the breakdown of energy consumption by end use, (ii) the average consumption per end-use appliance or equipment, and (iii) the savings potential.

Amongst residential energy end uses, air conditioning accounted for the highest share at about 60% of household electricity consumption, followed by refrigeration (18%), lighting (7%), and water heating (6%). Air conditioners were the most energy-intensive equipment, with average consumption of about 2,600 kWh per unit per year, followed by water heaters (1,149 kWh), refrigerators (947 kWh), rice cookers (357 kWh), and TV sets (239 kWh). Energy consumption by outdoor lighting equipment amounted to 128 kWh per unit per year whilst washing machines consumed 72 kWh per unit per year. Indoor lighting equipment was the least energy intensive, with 41 kWh per unit per year. Electricity savings could be achieved by replacing technologies with the most efficient ones. About 73 GWh or 5.3% of household electricity consumption could be saved if the four appliances were replaced with more efficient ones.

The building survey established indicative energy performance of the various categories of commercial and public buildings using BEI (kWh/m^2/year) as the assessment criteria. Amongst the building types included in the survey, 4–5-star hotels had the highest average intensity at about 371 kWh/m^2/year, followed by large hospitals with 334, large mosques with 323, and retail buildings with 308. Large office buildings had a BEI value of 275 kWh/m^2/year, medium-sized offices 227, and small ones 242.

In general, these BEI values are much higher than the target BEI values under the green building certification schemes in Malaysia and Singapore. (The comparison is made with Singapore and Malaysia since Brunei Darussalam does not have a national green building rating scheme yet.) The survey showed that savings opportunities exist since the current BEIs of buildings in the country are much higher than the more efficient ones in neighbouring countries. The comparison is considered valid since Brunei Darussalam and its neighbours have similar climatic conditions.

The main challenge for Brunei Darussalam is how to realise and reap the benefits of energy-saving potential in the residential and commercial sectors. This study identified measures arranged in three timeframes that could be pursued by the government to improve energy efficiency (Table 3.1).

The action plans in Table 3.1 could simultaneously target the residential and commercial and public sectors. The government has already carried out studies and implementation plans for energy efficiency labelling and MEPS for electrical appliances. The launching of a MEPS programme would benefit the residential and commercial sectors since household and office electrical appliances are mostly identical. But energy efficiency labelling takes time to become mandatory; regulations must be applied, and an inspection laboratory set up to test the power rating of appliances. The introduction of the above measures must be accompanied with information and awareness campaigns to increase the programme recipient coverage and reach. These measures could be implemented in the short term.

Other measures that could be introduced in the short term for the building sector are the benchmarking study and capacity building. The benchmarking study (chapter 2) is data collection and could be launched as soon as possible to create the basis for further policy measures. ME has already initiated capacity building for building energy auditors and an energy management system. These could be gradually increased in the short term and sustained in the long term.

Table 3.1: Energy Efficiency Improvement Action Plans

Time Horizon	Residential	Commercial and Public Sector Buildings
Short Term	• Technical guidelines for passive measures • Minimum energy performance standards • Information and awareness campaign	• Technical guidelines for passive measures • Minimum energy performance standards • Information and awareness campaign • Benchmarking study • Capacity building to increase the number of energy managers
Medium Term	• Standards and labelling system for appliances • Building energy intensity labelling for commercial and public buildings • Technical guidelines for active measures	• Technical guidelines for active measures • Expansion and implementation of the green building ratings scheme • Setting up energy efficiency and conservation laws
Long Term	• Home energy management systems • Technology road mapping	• Building energy management systems • Technology road mapping

Source: Author (2019).

In the medium term, the government could introduce technical guidelines for active measures for building energy efficiency. These guidelines could focus on the residential and commercial sectors. The government has introduced a voluntary green building ratings scheme for the public sector. This could be further enlarged to cover the private sector but would need to be made mandatory under EEC laws. However, such policy measures may take time. Therefore, as an interim measure, BEI labelling for commercial and public buildings should be introduced under the MEPS to achieve energy savings in these sectors sooner.

In the long term, energy management systems could be promoted for the commercial and residential sectors (including public buildings). A technology road-mapping study could be undertaken to identify which innovative and advanced but cost-effective technologies could be supported to further improve energy efficiency in the residential sector and building energy performance in the commercial and public sector.

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Annex

Workshop: Brunei Darussalam's Transition to Green Buildings

A. Background

Brunei Darussalam has high primary energy intensity. Improving energy efficiency is a national priority, marked by the country's commitment to the Association of Southeast Asian Nations (ASEAN) and Asia-Pacific Economic Cooperation targets of reducing primary energy intensity to 45% below 2005 levels by 2035. The government has introduced various programmes and frameworks to improve energy efficiency in the public sector and to promote private sector investments in energy efficiency technologies. Despite this, barriers to improving energy efficiency remain significant.

A survey on building energy efficiency was undertaken by the Brunei National Energy Research Institute (BNERI) and Economic Research Institute for ASEAN and East Asia (ERIA) with support from the Ministry of Energy (ME). The study carried out an energy consumption survey to establish baseline information as basis for policy making.

B. Objectives

The Institute of Policy Studies, BNERI, and ERIA organised the workshop to present the study's preliminary results and facilitate discussion amongst stakeholders on building energy efficiency policies. The workshop highlighted the preliminary project results to elicit inputs from stakeholders on an action plan.

C. Participants

The workshop had 126 participants whilst it expected only 80. They included representatives from government agencies and key stakeholders in the energy and building sector. Officiating the seminar was ME Permanent Secretary Honourable Mr Awang Haji Azhar bin Haji Yahya. Also present at the opening ceremony was His Excellency, Motohiko Kato;[i] Honourable Mrs Dayang Hajah Siti Aidah binti Haji Mohammad, Deputy Permanent Secretary at the Ministry of Development; and Dr Abby Tan, Assistant Vice Chancellor of Universiti Brunei Darussalam (UBD) for research.

[i] Mr Kato served as the Ambassador Extraordinary and Plenipotentiary of Japan to Brunei Darussalam from 2017 to 2019.

Figure A 1: Speakers and Guests

Front row: His Excellency Ambassador Motohiko Kato, then Japanese Ambassador to Brunei Darussalam (fifth from left); Honourable Mr Awang Haji Azhar Haji Yahya, Permanent Secretary at ME (sixth from left); Dr Abby Tan Chee Hong, Assistant Vice Chancellor (Research) of UBD (seventh from left); Hjh Siti Aidah Mohammad, Deputy Permanent Secretary, MOD (eight from left); Pg Dr Mohd Iskandar Petra, Assistant Vice Chancellor (Academic) of UBD (ninth from left); Dr Mahani Hamdan, Director, Institute of Policy Studies, UBD (tenth from left); Mr Shigeru Kimura, Senior Adviser to the President of ERIA (fourth from left); Dr Romeo Pacudan, Interim CEO, BNERI (second from left).
Back row: Prof Wongkot Wongsapai (fifth from left), Ir Leong Siew Meng (third from left), Dr Rohaniyati Salleh (seventh from left), Dr Gao Chun-Ping (fourth from left), Mr Abdul Salam Haji Abdul Wahab (sixth from left), Mr Muhammad Zafri Rusli (ninth from left).
Not in photo: Mr Muhammad Nabih Fakhri Matussin.

The four sessions were moderated by Dr Lim Chee Ming, Director, Centre of Advanced Materials and Energy Sciences (CAMES) (session 1); Dr Hanif Mahadi, Professor, CAMES (session 2); Dr Hong Wan, Professor, Faculty of Integrated Technologies (session 3); and Dr Romeo Pacudan, Interim CEO of BNERI and Associate Professor at the Institute for Policy Studies (session 4).

D. Session 1: Patterns of Residential and Commercial Energy Consumption

Mr Shigeru Kimura presented the results of the Brunei Darussalam Household Energy Consumption Survey, covering its approach, methodology, results, and policy recommendations. The results show that space coolers accounted for the highest share of household electricity demand (about 60%), followed by refrigerators, lighting, and water heaters. The four appliances accounted for 94% of total household electricity demand. The survey estimated the electricity-saving potential of these appliances at 73 GWh or 5% of household electricity consumption in 2015 if they were replaced by new and more efficient ones. The presentation highlighted the key pillars of residential energy efficiency improvement: (i) minimum energy performance standards and labelling programmes, (ii) incentives and tariff reforms, (iii) residential building energy efficiency technologies, and (iv) information and awareness campaigns.

Mr Nabih Matussin presented the preliminary results of the energy consumption survey in the commercial sector. The presentation showed the building energy intensity (BEI) values for different commercial building types and compared them with those of Singapore's Green Mark and Malaysia's Green Building Index. Relative to the size and functionality of buildings, the BEI for retail buildings was the highest in Brunei Darussalam, followed by hospitals and offices. The survey results are only indicative and a more comprehensive survey should be conducted. Survey limitations include lack of understanding of the survey questionnaire and record keeping of the building data (electricity consumption and floor area). The sampling size was small and the concept of BEI new.

Mr Wongkot Wongsapai shared the results of the energy consumption survey in residential and building sectors in Thailand. The data showed the top 10 household appliances (similar to those in Brunei) with the highest electricity consumption. They have a combined share of almost half of electricity consumption in urban and rural households. Savings potential was estimated at 13.98% of total energy consumption if existing appliances were to be replaced with the most efficient appliances available. The study presented energy consumption patterns of commercial buildings. Energy efficiency policies for commercial buildings have been focused on designated buildings. Energy demand in these buildings is mainly for cooling (chillers and air conditioners) and lighting.

Key points were the following:

i. Brunei Darussalam could implement standards and labelling, intensify campaigns and awareness, incentivise tariff reform, and promote residential building energy efficiency technology (passive and active design).
ii. Brunei Darussalam has the highest energy consumption per household or per capita in ASEAN. Data comparing household and commercial buildings energy consumption in Asia can be found on the Building Energy Structure and Lifestyle Database of Asia website (http://www.belda.asia/wp/). This project carries out household energy consumption surveys and compares energy consumption in Asia.
iii. Since electricity demand and residential energy consumption will eventually increase

with the connectivity of Temburong Bridge, experts recommend exploring the potential of hydro power in Temburong to generate electricity. The increase in demand would make an important case to promote energy efficiency.

iv. As legal and regulatory frameworks take time to be developed and implemented, the government could engage in voluntary energy-saving agreements with commercial and industrial clusters and business associations.

E. Session 2: Building Energy Efficiency Practices, Strategies and Policies in Southeast Asia

Dr Rohaniyati Salleh of MOD highlighted the benefits and challenges of saving energy in Brunei Darussalam. As an energy-exporting country, Brunei Darussalam must 'save more and sell more energy'. The benefits of saving energy are endless: boosting the economy, reducing carbon emissions, and creating jobs, amongst others. Challenges include lack of knowledge and awareness of energy efficiency, and lack of baseline data for new and existing residential and commercial buildings. Policies and initiatives in place include MOD's Building Code Order; Building Guidelines and Requirements, which encourage energy efficiency and conservation practices for buildings; and Brunei Accredited Green Unified Seal (BAGUS), which aims to reduce energy usage in government-run buildings by 15%. MOD has introduced the BAGUS checklist as a guideline for energy efficiency practices in the building sector. Although compliance with this checklist is voluntary, the ministry hopes to make it compulsory.

Ir Leong Siew Meng of the American Society of Heating, Refrigerating and Air-Conditioning Engineers in Malaysia presented, as background, the evolution of national plans, policies, and legal frameworks to promote energy efficiency in buildings in Malaysia. Key local issues that drive energy efficiency promotion in buildings include rapid urbanisation, acceleration of energy demand in the residential and commercial sectors, and the lack of an official BEI. Amongst the energy end uses in typical office buildings, air conditioning accounts for the highest share at 64%, followed by lighting at 12%; the rest of office equipment represents about 24%. The overall strategy pursued by the Malaysian Standards on Energy Efficiency and Use of Renewable Energy for Non-Residential Building (MS 1525, 2014) is to pursue both passive and active energy efficiency practices in promoting energy efficiency in buildings. Passive practices include architectural and passive design strategies and building envelope whilst active ones cover lighting, power and distribution systems, air conditioning and mechanical ventilation systems, and energy management control systems. Key success factors in energy efficiency promotion are the (i) introduction of legal frameworks and formulation of master plans; (ii) establishment of technical standards (building codes, green building rating tools, standards and labelling, and guidelines); and (iii) public–private partnerships in policy implementation.

Dr Gao Chun Ping of the Building and Construction Authority of Singapore presented the rationale for promoting building energy efficiency in Singapore, the evolution of building efficiency regulations, key milestones and progress in greening the environment, and the progress of the country's Green Mark schemes. Climate change concerns are a driving force pushing energy efficiency improvement in buildings. In 2005, when the country launched Green Mark, less than 0.1% of all buildings were considered green. The share of green buildings increased to 37% in 2018 and is projected to go over 80% in 2030. The key success factors for the green building programme in Singapore are the following: (i) the government actively led the initiative, (ii) incentives were provided to the private sector, (iii) performance standards were introduced, and (iv) support to strengthen the technical capacity was provided. The government aims to further develop super-low-energy buildings through technology road mapping and investment in research and development of advanced technologies.

Key messages emerged during the question and answer session:

- Measures that can minimise costs and increase benefits include the following:
  - Inter-ministerial cooperation in the implementation of the greening strategy could potentially reduce administrative and transaction costs.
  - Economies of scale of energy-efficient building materials could be achieved by a large-scale programme. As demand increases, costs are expected to decrease.
  - Transformation of the industry could also lead to cost reductions. In Singapore, this was achieved by developing the green building industry and digitalisation. Brunei Darussalam needs to develop its business sector to invest in the green economy and to develop the required skills. This can be supported by international cooperation.
  - There are also hidden benefits of green buildings, such as improvement of air quality, which could be quantified and monetised, increasing project benefits and reducing net costs.

F. Session 3: Selected Programmes and Case Studies

Mr Abdul Salam Wahab, head of the Sustainable Energy Division, ME, highlighted the importance of behavioural insights in helping reduce electricity consumption and providing benefits. ME's continuous visits in 2016–2017 to ministries and government departments to deliver energy-saving seminars and walk-in energy auditing contributed energy savings of BND22 million in 2016–2017. To further curb energy consumption in buildings, certified energy managers and auditors from ME will provide training courses for professionals such as energy inspectors, auditors, energy efficiency consultants, and energy managers.

Mr Muhammad Azri Rusli presented the services and energy efficiency solutions for lighting and heating, ventilation and air conditioning systems of TNB Energy Services through performance contracting in Malaysia. Two case studies were presented to demonstrate the stages in performance contracting: energy auditing, contract signing, measurement, and verification. Energy performance contracting is one of TNB Energy Services' initiatives to increase the awareness and enhancement of energy efficiency. The company is interested in collaborating with the government on implementing its energy efficiency programme.

Mr Wongkot Wongsapai shared Thailand’s experience in energy reporting and database systems for designated facilities that can be adopted in Brunei Darussalam. All government buildings in Thailand had a minimum target of 2% reduction in spending as a key performance indicator. Now, Thailand uses energy utilisation intensity (EUI) as a benchmark and has set energy targets for all buildings. It has created an award system to increase innovation and spread awareness amongst consumers and energy users of the importance of energy conservation. The data collected for EUI will be reviewed every 5 years and the baseline adjusted. This method has proved highly effective in reducing energy consumption in buildings.

Key messages emerged during the question and answer session:

- Encourage people to select more efficient appliances and equipment and replace old with efficient ones.
- Encourage energy service company services to increase investments in energy efficiency and conservation.
- Explore the benefits of using EUI as a benchmarking tool.

G. Session 4: Building an Energy Efficiency Action Plan

Dr Romeo Pacudan presented the project objectives and an outline of action points for Brunei Darussalam to promote energy efficiency in buildings. Key action points included setting of targets; a benchmarking study; and short-, medium-, and long-term measures to transition to green buildings.

Key experts made some recommendations:

i. Introduce policies, regulatory frameworks, and targets on building energy efficiency, such as a green building certification scheme, minimum energy performance standards, and an appliance labelling scheme, and define a clear policy direction for green buildings. A labelling programme should include the establishment of testing laboratories. Building code elaboration needs partnership with all stakeholders.

ii. Identify challenges in adopting energy efficiency. Conduct a regular needs assessment (in terms of institutional framework, transport, factory, technology, finance, and capacity building). Elaborate on and implement action plans (short, medium, and long term) and assess the impacts of programmes.

iii. Ensure data quality by increasing the level of data disaggregation and by involving the government in data collection. A benchmarking study must consider the timeframe whilst dealing with data quality. Information and data obtained from reporting should be used to produce a performance ranking in terms of building energy efficiency.

iv. Conduct an awareness campaign. It will also support the development of energy service companies.

Workshop Programme

7.45–8.30 am	**Registration**	
8.30 am	**Arrival of Guest of Honor** Recital of Surah Al-Fatihah	
	Welcome Remarks	Dr. Mahani binti Haji Hamdan (Director, Institute of Policy Studies)
	Opening Remarks	His Excellency Mr. Motohiko Kato (then Ambassador of Japan to Brunei Darussalam)
9.00 am	Keynote Speech by the Guest of Honour	Haji Azhar bin Haji Yahya (Permanent Secretary at the Ministry of Energy)
9.20 am	Photo Session	
9.30-10.00	**Coffee Break**	
10.00-11.15	**Session 1. Patterns of Residential and Commercial Energy Consumption** Moderator: Dr Lim Chee Ming, Director, Centre for Advanced Materials and Energy Sciences	
	Residential Energy Consumption in Brunei Darussalam	Mr Shigeru Kimura (Special Adviser to the President, ERIA, Indonesia)
	Commercial Energy Consumption in Brunei Darussalam	Mr Muhammad Nabih Fakhri Matussin (BNERI)
	Residential Energy Consumption in Thailand	Prof Wongkot Wongsapai (Chiang Mai University, Thailand)
	Q&A	
11.15-12.30	**Session 2. Building Energy Efficiency Practices, Strategies and Policies in Southeast Asia** Moderator: Dr Abdul Hanif Mahadi, Centre for Advanced Materials and Energy Sciences	
	Brunei Darussalam	Dr Rohaniyati Salleh (Ministry of Development)
	Malaysia	Ir Leong Siew Meng (American Society of Heating, Refrigerating and Air-Conditioning Engineers Malaysia)
	Singapore	Dr Gao Chun Ping (Building and Construction Authority – Singapore)
	Q&A	
12.30-14.00	**Lunch Break**	

14.00-15.15	**Session 3. Selected Programmes and Project Case Studies** Moderator: Dr Hong Wan, Faculty of Integrated Technologies	
	Energy Efficiency Improvement in Government Buildings through Behavioural Insights	Mr Abdul Salam Haji Abdul Wahab (Ministry of Energy)
	Energy Efficiency through Energy Performance Contracting	Mr Muhammad Zafri Rusli (Tenaga National Berhard Energy Services, Malaysia)
	Energy Efficiency and Conservation Database in Thailand	Prof Wongkot Wongsapai (Chiang Mai University, Thailand)
	Q&A	
15.15-15.30	**Coffee Break**	
15.30-17.00	**Session 4. Building Energy Efficiency Action Points for Brunei Darussalam** Moderator: Dr Romeo Pacudan, Interim CEO, BNERI, and Associate Professor, Institute of Policy Studies	
	Panel Discussion	All speakers and participants
17.00	**Closing Session**	
	Wrap Up	Dr Romeo Pacudan (BNERI/Institute of Policy Studies)
	Closing Remarks	Mr Shigeru Kimura (Special Adviser to the President, ERIA)