Chapter 2
Energy Demand Surveys

Introduction

The energy consumption survey was conducted for the industry, road transport, residential, and commercial sectors. The survey aimed to collect the necessary consumption data to enable the estimation of Myanmar's energy consumption by sector and by type of energy source. The estimated unit consumption of the different types of fuel consumed by the sectors served as the basis for estimating the total fuel consumption of Myanmar. Inflating the survey result to the whole of Myanmar was done by multiplying the specific energy consumption (intensity) with the respective sector's activity. However, in view of the voluntary nature of this survey, limited time frame, and relatively new experience of such energy consumption surveys in the country, it was understandable that some constraints and difficulties were experienced due to lack of full understanding of some items in the questionnaire and of full cooperation from the survey subjects. The data appeared to be inconsistent and some results were erratic. To eradicate the impact of outlier data, objective interpretation and judgment were made so that reasonable results, in accordance with building practices in other ASEAN countries of similar climate, could be made in analysing the survey data. The following sections discuss the assumptions and logic used in the analyses of data.

Methodology

To achieve the objective of the consumption survey, the following steps were undertaken.

Preparation of Questionnaire

The study team, consisting of the local consultant, Myanmar Survey Research (MSR), and experts from the Economic Research Institute for ASEAN and East Asia (ERIA), staff of the Oil and Gas Planning Department (OGPD), and other departments under the Ministry of Energy and Electricity (MOEE) of Myanmar, prepared the questionnaire for the survey. The questionnaire consisted of two parts: general information and energy consumption. In the case of the industry sector, the general information consisted of the general description of the manufacturing industry, such as the name of the factory, a major product, the International Standard Industrial Classification Code, the yearly production amount of the major product, and the industry's annual gross revenue.
The questionnaires were tested during the enumerator training and were adjusted and finalized with suggestions from experts.

Sampling and Sampling Size

The industry sector sampling consisted of 13 major industry sub-sectors (Table 2.1). The sample size was to be around 20 samples per sub-sector. The final coverage was 175 samples.

The transport sector sampling is for the parking lot survey. Vehicles sampled were sedans, SUVs, pickups, trucks, buses, motorcycles (private, taxi, tuk-tuk). The sample size was 200 vehicles in 10 parking lot locations (around 20 samples per location). Usually the parking lots did not have big buses. For big buses, the approach was to interview a bus company in Yangon. The residential sector survey consisted of urban and semi-urban areas. The total sample consisted of 200 residential dwellings.

The commercial sector survey consisted of four types of commercial building: (i) office, (ii) hotel, (iii) mall/shop, and (iv) hospital. The total sample numbered 151 commercial buildings.

All samples mainly came from Yangon. The sample frame was based on the available list of establishments that the survey team sought from different sources (such as hotel and restaurant association, chamber of commerce and industry, garment association, etc.), where applicable. The sampling used both

randomised and purposive techniques, as relevant. For each sector and sub-sector, certain criteria were developed, which were discussed with and suggested by the ERIA experts during the training workshop before the start of the field survey.

Distribution and collection of survey questionnaires

The questionnaires were used to collect fuel consumption data by sector. The target respondents who were available during the survey were interviewed face-to-face. In some cases, the target respondents were not available or requested to reply to the questionnaire at their convenience. In this case, the questionnaires were emailed or left with the administration officers to be filled out by their authorised officers. The enumerators would personally go back to collect and check the completion of the form. For all interviews, the letter of introduction about the survey provided by the MOEE was attached to the questionnaires.

Since quality of information was key, the following steps were undertaken for quality assurance: (i) first check by individual enumerator, (ii) second check by supervisor, and (iii) call back or revisit (random and spot check) by the team leader/supervisor.

Industry Sector

The survey was conducted to estimate the energy consumption of the sampled industry sub-sectors.

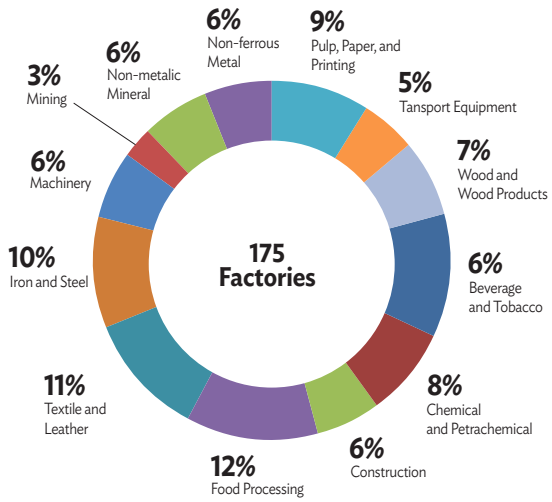
Survey results

Sampled in the survey were 175 factories under 13 industrial sub-sectors (Figure 2.1 and Table 2.1).

The survey collected the fuel consumption of the sub-sectors not only for the production process but also for other purposes such as lighting, transportation, standby power (auto generator/captive), feedstock, etc. The basis for the estimation of fuel consumption in the industry sector is the fuel consumed for the production process.

The fuel consumed by the sub-sectors was recorded in its physical unit. For coal, it is in kilogram; petroleum products except liquefied petroleum gas (LPG), in

Figure 2.1. Industry Sub-sector Samples



Source: Myanmar Survey Research (MSR) (2018).

Table 2.1. Overview Information of the Industry Sector

Industrial Sub-Sector	Sample	Total Worker	Average Worker/ facory	Main Products
Beverage and Tobacco	20	2400	120	Drinking water, fruit juice, soft drink, alcohol, energy beverage, bottling and packaging of beverages
Chemical and Petrochemical	15	2097	140	Paint, soap, liquid soap, organic fertiliser products, mosquito repellent coil, plastic bag, plastic carpet and mat, plastic basket, plastic seed products, plastic pipe products, plastic bottle, other plastic products
Construction	10	465	47	Construction work, scaffolding and construction formwork, system integrating and building solution
Food Processing	21	2329	111	Pudding bread, milk bread and cream cake, water snack, palm jam, puffed snack, milk powder, chilli sauce, edible peanut oil, canned fish, candy, sugar/mollases, instant noodle, rice paste, ice cream and ice bar, ready-made fish ball and fish bar, canned food
Textile and Leather	20	13130	657	Garment, shirt and sports shirt, uniform for office staff, female underwear, female blouse, pants and trousers, jackets, Cut-Make-Pack (CMP) garment, male jerkin production, knitting on traditional longyi, leather and PVC, leather shoes
Iron and Steel	17	1227	72	Iron sheet production, steel bar, steel rod, steel block, other steel products, elevator iron block, car rooftop tank with steel, raw iron, regulator box, iron construction material, iron ware
Machinery	10	2466	247	Agricultural machine parts production, water pump, fluorescent lamps and switch production, transformer production, electric motor, electronic, safeguard, invertor and regulator, electronic products, panel production, train jointer production

Mining	5	400	80	Lead, coal
Non-metalic mineral	10	1522	152	Cement, brick, concrete brick production, prefabricated tile, read-mixed concrete, autoclaved aerated concrete and aerial precast concrete, concrete and concrete-related product, glass and mirror
Non-ferrous metal	10	784	78	Electric wire with copper, wire production, melting of lead and aluminium, aluminium and glass, aluminium door frame, other aluminium products, car water tank with bronze
Pulp, Paper, and Printing	15	606	40	Paper, recycled paper, exercise book and ledger, poster, calendar, invitation card, paper box, other paper products, printing paper trading, carton box, printing & offset
Transport Equipment	9	769	85	Tire re-treading, battery manufacturing, car workshop, car engine air filter production, body of fibre speed boat, electric bicycle production, car production
Wood and Wood Products	13	1195	92	Wood, timbre, plywood and veneers, furniture, and other wood products
Total	175	29390	168	

Source: MSR (2018).

kilolitre; LPG, in ton; and electricity, in kilowatt-hour (kWh). The fuels must be converted into the energy unit before summation. Table 2.2 shows the density and heating values of the different fuels.

The activity of the sampled factory was represented by its sales revenue. Thus, the survey estimated the factory unit fuel consumption per sales revenue. Some sampled factories, however, consider sales revenue confidential. In this case, the samples only have consumption data. In some cases, the samples have sales revenue data, but the consumption data is only for purposes other than production. Both revenue and fuel consumption data are necessary for the production process to estimate the average unit consumption per sales revenue.

Table 2.3 shows the fuel consumption and sales revenue of the sampled factories in each sub-sector. Fuel consumption includes the fuel used for other purposes such as diesel for standby power and electricity for offices.

Table 2.2. Density and Heating Value of Fuel

Type of Fuel	Density		Heating Value	
	Unit	Value	Unit	Value
Steam Coal	-	-	kcal/kg	4,513
Lignite	-	-	kcal/kg	2,842
Wood/Blomass	-	-	kcal/kg	3,725
Sawdust	-	-	kcal/kg	2,300
Electricity	-	-	kcal/kWh	860
Natural Gas/CNG	kg/cum	0.900	kcal/cum	8,684
Liquefied Petroleum Gas	kg/ltr	0.510	kcal/kg	11,295
Diesel	kg/ltr	0.999	kcal/kg	10,268
Gasoline	kg/ltr	0.862	kcal/kg	10,579
Fuel Oil	kg/ltr	0.947	kcal/kg	9,648
Lubricant	kg/ltr	0.858	kcal/kg	9,600
Other Oil Products	kg/ltr	0.858	kcal/kg	9,600
Naptha	kg/ltr	0.740	kcal/kg	10,579

CNG = compressed natural gas, cum = cubic metre, kg = kilogram, ltr = litre, kcal = kilocalorie, kWh = kilowatt-hour.

Source: ASEAN/APEC-IEA Joint Energy Format-energy questionnaires of Myanmar.

Inflation to total consumption

In the industry survey, the unit consumption for total fuel was calculated by dividing the total fuel consumption in each sub-sector surveyed by its sales revenue and adjusted by the value-added ratio. Multiplying the unit consumption with the sector's gross domestic product (GDP) will result in total fuel consumption of the industry sector for the whole country. Thus, total consumption would be:

$$EC_i = \sum_{i=sector}^{n} IECi * (GDPi/VARi)$$

Where:

ECi is the total energy consumption for sector i

IECi is the energy consumption per revenue for sector i (intensity)

GDPi is the total GDP for sector i

VARi is the value-added ratio for sector i (assumed to be 0.5 for all sector).

Table 2.3. Sales Revenue and Fuel Consumption

Sampled Industry Sub-sectors	Sales Revenue (mil. US$)	Fuel Consumption (ktoe)	ktoe/mil. US$	Fuel Share (%)							
				Coal	CNG	Electricity	Diesel	LPG	Other Oil Products	Biomas	Total
Manufacturing/Processing	206.636	31.199	0.1510	4%	5%	42%	19%		1%	30%	100%
Iron and Steel	5.860	5.309	0.906	3%		93%	2%			3%	100%
Chemical (incl. Petrochemical)	18.601	3.174	0.171		19%	60%	5%		0.01%	16%	100%
Non-ferrous Metals	4.409	0.535	0.121	10%		61%	29%				100%
Non-metalic Mineral Products	39.190	3.860	0.098	21%	9%	19%	43%		7.20%	0.1%	100%
Transportation Equipment	44.963	1.411	0.031		37%	52%	9%	3%			100%
Machinery	17.083	0.836	0.049			48%	32%			20%	100%
Food Processing	4.364	4.450	1.020	2%		20%	17%			61%	100%
Beverage and Tobacco	21.257	7.165	0.339			24%	24%			52%	100%
Pulp, Paper, and Printing	9.601	0.955	0.099			27%	10%			63%	100%
Wood nd Wood Products	11.740	0.657	0.056			2%	50%		0.17%	29%	100%
Textiles and Leather	29.669	2.848	0.096	7%		36%	17%		0.03%	41%	100%
Construction	9.364	0.241	0.026			29%	71%		0.4%		100%
Mining and Quarrying	8.982	0.452	0.050			3%	91%		6%		100%
Total Industry	224.982	31.893	0.142	4%	5%	41%	20%	0.1%	1%	29%	100%

Note: US$1.00 = 1,100 kyat (MK).

CNG = compressed natural gas, ktoe = kiloton of oil equivalent, LPG = liquefied petroleum gas.

Source: Author's calculation.

Myanmar's GDP structure comprises the agriculture, industry, and services sectors (Table 2.4). The data was collected by the MSR from the Central Statistical Organization (CSO) for 2013–2014 to 2016–2017. The GDP from 2010–2011 to 2012–2013 was obtained directly from the 2018 Myanmar Statistic Yearbook of the CSO.

Table 2.4. Myanmar GDP (Million MK, Current Price)

Sectors	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016 (PA)	2016-2017 (End of March)
AGRICULTURE	4,658,961.3	15,048,295.7	15,680,310	17,132,994	18,162,255	19,466,837	20,300,036
Agriculture	11,108,404	11,113,043	11,349,615	12,316,082	12,780,581	13,417,668	13,736,113
Livestock and Fishery	3,392,103	3,758,635	4,141,221	4,631,984	5,243,294	5,906,519	6,505,196
Foresty	158,45	176,617	189,474	184,929	138,380	142,650	58,727
INDUSTRY	10,528,140	14,490,502	16,594,171	18,773,850	22,508,640	25,063,666	27,917,838
Energy	66,995	2,241,424	2,745,828	2,919,975	4,011,395	3,687516	2,669,961
Mining	299,433	469,269	418,324	547,645	789,099	759,982	835,280
Processing and Manufacturing	7,900,494	9,132,523	10,299,192	11,553,545	13,007,190	15,130,437	18,167,437
Electric Power	421,883	481,449	614,930	695,854	926,866	1,030,837	1,111,244
Construction	1,839,335	2,165836	2,515,898	3,056,830	3,777,091	4,454,895	5,133,917
SERVICE	14,589,664	16,769,090	18,984,779	22,104,782	24,590,995	28,183,518	31,503,024
Transportation	4,589,664	5,511,332	6,112,724	6,925,716	7,512,856	8,239,653	8,948,035
Communications	332,227	401,983	605,797	913,832	1,158,120	1,512,271	1,638,900
Financial Institution	37,715	65,318	85,346	114,385	139,681	173,402	233,833
Social and Administrative Services	915,720	989,006	1,326,077	1,683,301	2,025,534	2,686,744	2,806,427
Rental and Other Services	738,484	883,291	1,095,646	1,323,898	1,537,312	1,812,108	2,159,037
Trade	7,971,161	8,918,160	9,759,190	11,143,651	12,217,492	13,759,341	15,716,793
GROSS DOMESTIC PRODUCT	39,776,765	46,307,888	51,259,260	58,011,626	65,261,890	72,714,021	79,720,898

Source: MSR (2018); Central Statistical Organization (CSO) website.

The industry sector's contribution to total GDP reached around 35% in 2016, increasing from its share of 26% in 2010. The industry sector was separated into (i) energy, (ii) mining, (iii) processing and manufacturing, (iv) electric power, and (v) construction. In a similar table of the Asian Development Bank for

Myanmar's GDP by industrial origin (current price) (ADB, 2017), the mining and quarrying GDP is the sum of the mining and energy GDP in Table 2.4.

There was no further breakdown of processing/manufacturing into the different sub-sectors. In this regard, the share of the revenue in the sampled survey was used to break down industry sector GDP. In addition, industry GDP used to calculate the national total excludes the electricity sub-sector GDP since the energy balance table (EBT) breakdown of the industry excludes the electric power sub-sector. The calculation of total consumption was done for 2016 to be in accordance with the OGPD data representation of the Myanmar EBT (Table 2.5).

Table 2.5. Estimated Total Energy Consumption

Main Activity	Sampled Sub-sector Revenue Share, %	GDP 2016		Survey Result	Estimated Energy Consumption (Ktoe)
		mil. MK Transfers	mil. US$	ktoe/mil. US$	
Industry		2,680,655	24,370	0.11385	387
Manufacturing	100%	18,167,437	16,516	0.15099	1,247
Iron and Steel	3%	515,194	468	0.90593	212
Chemical (incl. Petrochemical)	9%	1,6353,89	1,487	0.17066	127
Non-ferrous Metals	2%	387,679	352	0.12123	21
Non-metallic equipment	19%	3,445,579	3,132	0.09849	154
Transportation equipment	22%	3,953,116	3,594	0.03138	56
Machinery	8%	1,501,906	1,365	0.04892	33
Food Processing	2%	383,650	349	1.01984	178
Beverage and Tobacco	10%	1,860,154	1,691	0.33866	286
Pulp, Paper, and Printing	5%	844,078	767	0.09945	38
Wood and Wood Products	6%	1,032,219	938	0.5598	26
Textiles and Leather	14%	2,608,473	2,371	0.09598	114
Construction		5,133,917	4,667	0.02577	60

Note: US$1.00 = 1,100 kyat (MK).

ktoe = kiloton of oil equivalent.

The estimated total energy consumption of industry based on the survey result was 1,387 ktoe. Using the fuel shares calculated from the survey as shown in Table 2.3, the estimated total energy consumption by fuel in 2016 showed that majority of the fuel consumed by the manufacturing sector was electricity followed by biomass and oil, which mainly was diesel (Table 2.6)

Table 2.6. Estimated Total Energy Consumption by Fuel (ktoe)

Main Activity	Estimated Energy Consumption (ktoe)	Coal	Gas	Electricity	Diesel	LPG	OOP	Total Oil	Biomass	CHECK total
Industry	1387	53	59	542	348	2	16	365	368	1387.23
Manufacturing/ Processing	1247	53	59	522	232	2	11	245	368	1246.83
Iron and Steel	212	6	0	196	3	0	0	3	6	212.15
Chemical (incl. Petrochemical)	127	0	24	76	7	0	0	7	20	126.86
Non-ferrous Metals	21	2	0	13	6	0	0	6	0	21.36
Non-metallic Mineral Products	154	32	14	30	67	0	11	78	0	154.25
Transportation Equipment	56	0	21	29	5	2	0	6	0	56.38
Machinery	33	0	0	16	11	0	0	11	7	33.40
Food Processing	178	4	0	36	30	0	0	30	108	177.85
Beverage and Tobacco	286	0	0	68	68	0	0	68	150	286.34
Pulp, Paper, and Printing	38	0	0	10	4	0	0	4	24	38.16
Wood and Wood Products	26	0	0	5	13	0	0	13	8	26.26
Textiles and Leather	114	8	0	41	19	0	0	19	46	113.80
Construction	60	0	0	18	43	0	0	43	0	60.14
Mining and Quarrying	80	0	0	3	73	0	5	78	0	80.27

Source: Author's calculation

The estimated total industry consumption was 73% lower than that of the EBT (Table 2.7). In addition, the shares of the fuel consumed were also different. In

Myanmar EBT 2016, majority of the fuel consumed by the industry was biomass (44%) and diesel (34%).

Also, some data was available for the sub-sector consumption, particularly natural gas consumption. Most of total consumption was entered as non-specified industry consumption because no sub-sector consumption data was available. The industrial survey was conducted to estimate the total consumption of these sub-sectors.

Table 2.7. Industry Energy Consumption by Fuel (ktoe)

INDUSTRY SECTOR	Coal	Petroleum Products	Gas/ Diesel Oil	Fuel Oil	LPG	Other Petroleum Products	Gas	Others	Electricity	Total
Total Industry	419	3,860	3,509	120	0	231	530	4,610	800	10,219
Manufacturing/ Processing	210	1,823	1,754	60	0	8	265	2,305	400	5,002
Iron and Steel	37						7			44
Chemical (incl. Petrochemical)							117			117
Non-ferrous Metals							2			2
Non-metallic Mineral Products	123						119			242
Transportation Equipment							0			0
Machinery							5			5
Food, Beverages and Tobacco							6			6
Pulp, Paper and Printing							0			0
Wood and Wood Products										
Textiles and Leather							8			8
Non-specified Industry	49	1,823	1,754	60		8	2	2,305	400	4,578
Construction		215				215				215
Mining and Quarrying										

LPG = liquefied petroleum gas.

Source: Myanmar EBT 2016.

The estimated total consumption from the current industry survey was significantly different from the OGPD data in the Myanmar EBT 2016. The differences were due to the limitation of the GDP statistics. Since no data was available on manufacturing GDP by sub-sector, shares of sub-sector revenue were used to calculate sub-sector breakdown. Multiplying the sub-sector GDP with its intensities (ktoe/million MK) will give the estimated industry consumption of the sub-sectors at the national level.

The real share of these sub-sectors' manufacturing GDP can be obtained by improving the national account statistics to include the value added for the manufacturing sub-sectors. Some surveyed samples exclude revenue data; the exact value-added ratio is also not available. These limitations of the survey and Myanmar's national account statistics affected the estimation of industry intensities.

This energy consumption survey of the industry sector is the first of its kind for the OGPD. Therefore, there will be differences between the estimated fuel consumption from the survey result compared to the EBT data collected by the OGPD. As a conclusion, the survey results can further be improved in the future, which will contribute to the breakdown of energy consumption in the industry sub-sectors.

Future improvement

The industry survey was used to estimate the unit energy consumption of each sub-sector surveyed. The sales revenue of the sub-sector surveyed was used to represent the activity of the sub-sector. Thus, the unit energy consumption is calculated per sales revenue.

Sales revenue is confidential in some factories surveyed; thus, it is not possible to calculate the unit energy consumption of these factories. In addition, the sample results of the unit energy consumption also exhibited outliers. Both missing sales revenue and outliers reduce the accuracy of the average unit energy consumption in each sub-sector.

In the future, before the survey, the OGPD will need to collect the list of manufacturing industries operating in Myanmar to understand the population of

the different sub-sectors. The number of samples is recommended to be more than 175 since some factories have missing sales revenue data and some have outliers.

At the national level, gross value added of the sub-sector indicates sub-sector activity. Therefore, inflating the industry survey result of the estimated energy consumption to the national level needs the breakdown of the Myanmar manufacturing GDP by the surveyed sub-sector. The current GDP structure of Myanmar excluded the gross value added of the manufacturing sub-sectors.

Another option to estimate the unit energy consumption is per production amount of each sub-sector surveyed. At the national level, this will also need the total production of the sub-sector to estimate its energy consumption. In conclusion, the national production or gross value added of the sub-sectors is very important in estimating the total energy consumption of Myanmar industries.

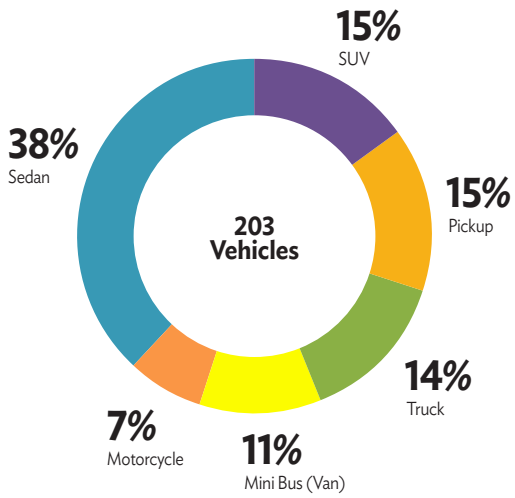
Road Transportation Sector

Survey result

The parking lot survey was conducted in several areas of Yangon. These areas were the Mahabandoola Road and Anawrahta Road (downtown areas), Junction City and Myanmar Plaza (shopping areas), Aung Mingalar Highway Bus Terminal and Dagon Ayer Highway Bus Terminal (highway bus terminals), Yangon Central Railway Station, and Yangon International Airport. Sampled vehicles totalled 203 (Figure 2.2), consisting of 77 sedans, 31 SUVs, 30 pickups, 28 trucks, 22 minibuses/vans, and 15 motorcycles.

The fuel consumed by the sampled vehicles were either gasoline, diesel, compressed natural gas (CNG), or dual. The latter was mainly consumed by taxis under the category 'sedan'. Figure 2.3 shows the fuel consumption of the sampled vehicles and their share. Overall, of the 203 vehicles sampled, 61% consumed gasoline, 33% consumed diesel, 4% CNG, and 2% dual fuel. The share of the vehicles by type and fuel share is the basis in estimating the national road transport consumption by vehicle type.

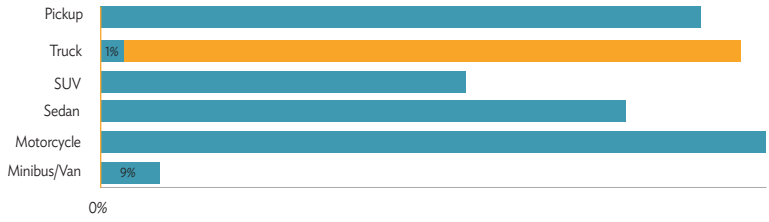
Figure 2.2. Type of Vehicles Sampled



Source: Author's calculation.

Based on the vehicles' weekly consumption and distance travelled, it is possible to calculate the average fuel economy of the vehicle and its distance travelled over the year. The fuel economy of the vehicle is the relationship between the distance travelled and the amount of fuel consumed by the vehicle.

Figure 2.3. Breakdown of Vehicles by Fuel Consumed



	Minibus/Van	Motorcycle	Sedan	SUV	Truck	Pickup
Gasoline	2	15	61	17	1	27
Diesel	19		6	14	26	2
CNG	1		6		1	1
Dual			4			

CNG = compressed natural gas, SUV = sport utility vehicle.

Source: Author's calculation.

Consumption can be expressed in terms of volume of fuel to travel a distance, or the distance travelled per unit volume of fuel consumed. In the calculation, some samples are outliers and are, thus, removed from the data. An outlier is an observation that lies at an abnormal distance from other values in a random sample from a population.

Table 2.8. Fuel Economy and Distance Travelled of Sampled Vehicles

Type of Vehicles	Average km/litre		Avergae Km/Kg	Average Km/Year			FUEL USE (Ltr)/CAR		
	Gasoline	Diesel	CNG	Gasoline	Diesel	CNG	Gasoline	Diesel	CNG
Passenger Car	9.4	7.0	17.5	12,904	9,001	29,367	1380	1278	1676
Bus	-	2.7	10.7	-	14,114	23,040	-	5186	2160
Pickup	11.5	9.7	12.3	10,159	9,570	15,288	886	990	1248
Truck	-	5.9	11.1	-	15,284	14,400	-	2571	1296
Motorcycle	23.2	-	-	3,468	-	-	150	-	-

Passenger Car includes SUV.

CNG = compressed natural gas, kg = kilogram, km = kilometre.

Source: Author's calculation.

Table 2.8 shows the calculated average fuel economy and distance travelled for the sampled vehicles according to the type of vehicle.

Inflation to national total

Based on the unit fuel consumption of the different types of vehicles obtained from the survey, total consumption of road transport was estimated as follows:

$$Fuel_i = \sum_{i=vehicle}^{n} (FEi * DISi * VEHi)$$

Where:

Fueli is the total gasoline/diesel/CNG consumption for vehicle type i

FEi is the fuel economy of vehicle type i

DISi the distance travel of vehicle type i

VEHi is the total number of gasoline/diesel/CNG vehicles for type i.

The unit fuel consumption or intensity is the consumption per vehicle over a year. This is calculated from the sample result as the product of the fuel economy (km/l) and its distance travelled (km/year).

The total number of vehicles is the activity data for the road transport sector. The CSO provided the annual transportation statistics based on vehicle registration. CSO data showed the annual number of vehicles by type of vehicle and by area (Yangon and others). No breakdown by fuel consumed was available in the annual statistical publication of the CSO.

The consultant (MSR) was able to obtain vehicle population by type of vehicle and fuel consumed as of June 2018 (Table 2.9) from the Road Transport Administration Department of the Ministry of Transport and Communication.

Table 2.9. Vehicle Population in Myanmar 2018

Type of Vehicle	Fuel						Total
	Gasoline	Diesel	CNG	LPG	EV	HV	
Passenger car	426,626	98,933	1,364	66	449	3,226	530,664
Bus Car	585	21,555	5,456	3			27,599
(Light Duty)	142,355	191,851	3,267	104	13	5	337,595
(Heavy Duty)	447	55,754	604	3			56,808
Two-wheeler	5,738,085				3,402	32	5,741,519
Three-wheeler	97,316	458			527	1	98,302
Trailer Jeep	623	42,848					43,471
Heavy Machinery		1,792					1,792
Trailer							15,821
Others	2,452	89,761	448	2	1		92,664
Total	6,408,489	502,952	11,139	178	4,392	3,264	6,946,235

Description:

1. 'Passenger car' includes saloons, station wagons, microbuses (can carry up to 15 passengers), light vans, jeeps, and double cabs.

2. 'Bus car' includes minibuses (can carry over 15 passengers) and buses.

3. 'Light truck' includes pickups, single cabs, light trucks, vans, and trucks that can carry up to 3 tons.

4. 'Heavy truck' includes vans and trucks that can carry over 3 tons.

5. 'Others' include ambulance vehicles, fire-fighting vehicles, cranes, hearses, fuel bowsers (tankers), mobile water tanks, vehicle-carrying pipes, salvage trucks, vehicle-carrying drilling machines, dump trucks, and concrete mixer trucks.

CNG = compressed natural gas, EV = electric vehicle, HV = hybrid vehicle, LPG = liquefied petroleum gas.

Source: MSR from Road Transport Administration Department, Ministry of Transport and Communication.

Not all vehicles in the statistics were surveyed. LPG, electric, and hybrid vehicles were not surveyed. In addition, three-wheelers, trailer jeeps, heavy machinery, trailers, and others were also not surveyed. As a result, only the number of vehicles for passenger cars, buses, light duty trucks, heavy duty trucks, and two-wheelers were used in estimating total consumption. In addition, the estimation was limited only to gasoline, diesel, and CNG vehicles.

MSR and CSO data was used to estimate the number of vehicles in 2016. The resulting number of vehicles to calculate the total fuel consumption for road transport in 2016 was 6.1 million (Table 2.10), where 5.3 million were two-wheelers (motorcycles). By fuel consumed, majority of the vehicles (94%) consumed gasoline. The remaining were diesel vehicles (5.3%) and CNG vehicles (0.2%). Table 2.10 shows the number of vehicles by type and fuel consumed and their intensity (consumption per vehicle per year).

Table 2.10. Number of Vehicles and Fuel intensity per Vehicle

Vehicle Types	Number of Vehicles				Fuel Use (ltr) / Car		Fuel Use (Kg) / Car
	Total	Gasoline-fuelled	Diesel-fuelled	CNG-fuelled	Gasoline-fuelled	Diesel-fuelled	CNG
Passenger Car	508,534	411,737	95,480	1,316	1,380	1,278	1,676
Bus	26,798	568	20,932	5,298	-	5,186	2,160
Pick-Up	261,292	110,220	148,542	2,530	886	990	1,248
Truck	61,144	481	60,012	650	-	2,571	1,296
Motorcycle	5,267,952	5,267,952			150	-	-
TOTAL	6,125,719.31	5,790,958.13	324,966.90	9,794.28			

CNG = compressed natural gas, kg = kilogram, ltr = litre.

Source: Author's calculation.

Applying the formula, multiplying the number of vehicles with their intensity resulted in the total consumption of vehicles at the national level. The result showed that consumption of total petroleum products for road transport in Myanmar was around 1,889 ktoe where 70% of this total was gasoline consumption, 29% was diesel consumption, and 1% was CNG (Table 2.11). In terms of its physical unit, total gasoline consumption for road transport was 1,453,916 kl while for diesel consumption, the result was 531,983 kl. The CNG consumed by the road transport sector reached 17,650,335 kg.

Table 2.11. Estimated Total Consumption of Road Transport

Vehicle Type	Gasoline	Diesel	Ttotal Oil	CNG	Gasoline	Diesel	CNG	Total
	kl			kg	Ktoe			
Passenger Car	568,132	122,064	690,196	2,206,732	518	125	2	645
Bus		108,552	108,552	11,444,209		111	9	122
Pick-up	97,699	147,057	244,756	3,156,822	89	151	2	243
Truck		154,310	154,310	842,573		158	1	159
Motorcycle	788,086		788,086		719			719
TOTAL	1,453,916	531,983	1,985,900	17,650,335	1326	546	14	1889

Source: Author's calculation.

Table 2.12 shows the Myanmar EBT 2016 only for the road transport sector. The table includes consumption of other petroleum products for the road transport sector. This is the lubricant consumed by the vehicles. The lubricant consumption was deducted from the total consumption for comparison with the estimated total consumption from the survey.

In terms of total consumption, the estimated result of the OGPD data was 1,885 ktoe, slightly lower than the OGPD data in Table 2.12 (1889 ktoe). By fuel type, gasoline consumption from the estimation was only 0.4% lower than the OGPD data. In this regard, the major study results (fuel economy and mileage) could be useful for the analysis of gasoline vehicles.

Diesel and CNG consumption, however, differ significantly. The estimated diesel consumption was 39% higher than the OGPD data while CNG was only around one-tenth of the OGPD data. Diesel is mainly consumed by buses and trucks. Buses included minibuses that can carry over 15 passengers, trucks were heavy trucks carrying over 3 tons, and light trucks were pick-ups and those carrying less than 3 tons. In the calculation, no differentiation was made on the fuel economy and mileage of buses since the statistics on registered vehicles provide only the total number. Similarly, with trucks, the differentiation is only on the type of truck, whether it is a light or heavy truck. In addition, the vehicle intensity was multiplied by the number of vehicles. Usually for bus and truck companies, the number in operation in a year will be less than the total number. Assuming operating buses and trucks were 70% of the total number, the reduction will result in a total consumption around 7% higher than the OGPD data.

In the case of CNG, the sampled vehicles were only 13 (Figure 2.3), of which 4 were dual fuel vehicles. The fuel economy and distance travelled of the surveyed CNG passenger cars as shown in Table 2.8 were 17.5 km/kg and 29,367 km, respectively. Therefore, the intensity of the CNG passenger cars was 1,674 kg per vehicle. Compared with the study on Urban Transport Scenario of Yangon, Myanmar (Win and Dhakal, 2015), the intensity of CNG vehicles was around 5,000 kg per vehicle (Table 2.12). Clarification on the number of CNG vehicles, the fuel economy, and annual mileage of the vehicles (taxi, bus, etc.) will be necessary to calculate the national CNG consumption.

Table 2.12. Survey Table: Vehicles (km) and Fuel Efficiency by Vehicle Type

	Primary Products Receipts	Inter-product Transfers
Gasoline Passenger Vehicles	29,230	9.24
Diesel Passenger Vehicles	27,892	9.26
CNG Passenger Vehicles	54,057	11.45

CNG = compressed natural gas, kg = kilogram, km = kilometre.

Source: Survey result.

Table 2.13. Road Transport Fuel Consumption, 2016 (ktoe)

	Petroleum Products	Motor Gasoline	Gas/Diesel Oil	Other Oil Products (OOP)	Gas	Total	Total - OOP
Road	1,902	1,331	394	177	164	2,066	1,889

Source: ERIA (2016).

Future improvement

The Road Transport Administration Department, Ministry of Transport and Communication (RTADMTC) provided the registered number of vehicles by type of vehicle and by the fuel it consumed. Further data on fuel consumption such as gasoline, diesel, and CNG will be necessary. In addition, fuel economy and the annual mileage of each vehicle type will be estimated. The availability of the data will result in a more accurate estimation of the fuel consumption at the national level.

For the future, the OGPD should approach the RTADMTC and collect information on the engine size of the registered vehicles. Collecting the detailed

registered number of vehicles will make possible differentiation of the vehicle population by type, engine size, and fuel consumed.

The statistics on the number of vehicles need to be clarified – whether it is all in operation or just a cumulative number from previous years. Consequently, the RTADMTC should collect every year the number of scrapped vehicles.

Lastly, estimation of the fuel consumed by the transport sector needs to be compared with the fuel sales of oil and gas companies to the pump stations and to the gas filling stations. Comparing this sales data to that of the pump and gas filling stations will provide the fuel consumption used in the road transport sector.

2.5 Commercial Sector

The commercial sector consists of five categories of buildings (Table 2.14).

Table 2.14. Categories of Commercial Buildings and Sample Size

Category of Buildings	Sample Size
Offices	44
Hotels	29
Shopping Malls	13
Restaurants	40
Hospitals	25
Total sample size	151

Source: MSR (2018).

A useful method to evaluate the energy performance of commercial buildings is to derive a benchmark value in building energy intensity (BEI) from the survey data. BEI is expressed as kWh per m2 per year and can be determined by the following formula:

$$BEI = \frac{(TBEC - CPEC - DCEC)}{(GFA - DCA - GLA \times FVR)} \text{ x } \frac{AWH}{WOH}$$

Where:

TBEC total building energy consumption (kWh/y)
CPEC car park energy consumption (kWh/y)
DCEC data centre energy consumption (kWh/y)
GFA gross floor area ($m^{2)}$
DCA data centre area (m^2)
GLA gross lettable area (m^2)
FVR floor vacancy rate *(%)*
AWH average weekly hours (hr/week) – based on nationwide practice
WOH weighted weekly operating hours (hr/week)
BEI building energy intensity (kWh/m2/y)

The analyses discussed below were compared with similar benchmark values of BEI in Malaysia and energy use intensity (EUI) in Singapore. Typical BEI and EUI values for commercial buildings in similar climatic conditions such as Singapore and Malaysia are given in Table 2.15. The information provided in this table was extracted from publications made by the Green Building Index Sdn Bhd, Malaysia and the Building Construction Authority, Singapore, and from the author's interpretation.

Office buildings

The key data obtained in the survey were the following:

1) Total electricity consumption per year (kWh/year)
2) Energy consumption per year of other energy sources (i.e., fuel energy other than electricity)
3) Daily operational hours
4) Total GFA (in m2 – excluding car park and data centre)

A total of 44 survey data sets for office buildings were analysed. It was also noted that the operational hours of office buildings varied and the average operational hours amongst the buildings surveyed turned out to be 2,453 hours per year, or an average of 47 hours per week. The average operational hours seemed low compared with those adopted by the green building practices in Malaysia, which use a value of 2,700 hours per year. This is an average of 52 hours per week. The latter included some extended working hours beyond the official operational hours in offices where air-conditioning systems were still operational.

Nevertheless, the analysis of Myanmar survey data is based on the average value of office operational hours of 47 hours per week. After adding the consumption of other energy sources, total energy consumption was adjusted to reflect the same operational hours of 2,453 per year to rationalise the energy consumption for comparison purposes on the same basis.

Table 2.15. Comparison of Building Energy Intensity Values

Building Type	EUI for Green Mark, Singapore (kWh/m²/year)		BEI for GBI, Malaysia (kWh/m²/year)	
	EUI for Green Mark, Singapore	Green Building Entry Level	Gas/ Diesel Oil	Green Building Entry Level
Office Buildings	268 (Small) 212 (Large)	160	250	150
Hotels	267	260	N/A	200 for 3-star and below 290 for 4-star and above
Retails Buildings	366	360	345	240 for malls consisting of general retail outlets and low-energy intensity outlets. 350 for malls consisting of at least 10% (of its NLA) high-energy intensity outlets such as F&B, supermarkets, and outlets operating long hours, such as cinemas, etc.
Hospitals	345	N/A	300	200 for hospitals providing limited clinical services such as day surgery, etc. 290 for hospitals providing major clinical services (requiring high energy intensity)

BEI = building energy intensity, EUI = energy use intensity, F&B = food & beverage, kWh = kilowatt-hour, NLA = net lettable area.
Source: Green Building Index Sdn Bhd, Malaysia and BCA Green Mark, Singapore.

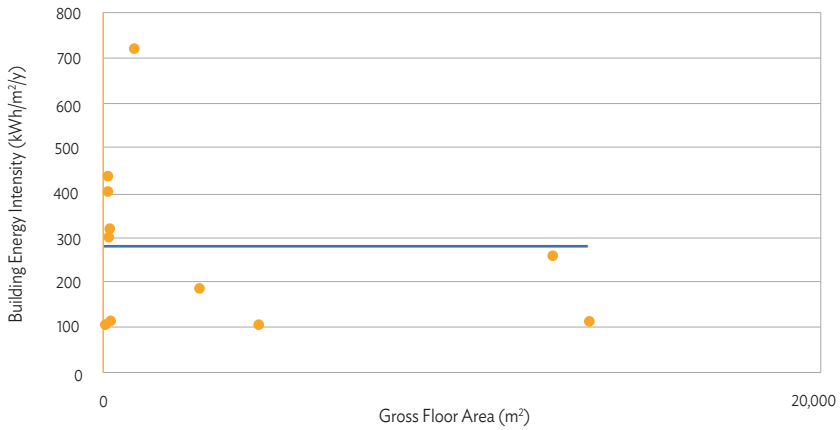
The main energy source of office buildings was electricity. However, some office buildings recorded higher consumption of diesel fuel than electricity consumption, e.g. ,3,360 litres per year of diesel fuel consumption (or 33,595 kWh per year of electricity equivalent) versus a record of 4,200 kWh of electricity consumption at the same premises. In some office buildings, the consumption of diesel fuel is almost as much as electricity consumption, e.g., 324,192 kWh yearly electricity consumption versus 24,300 litres per year of diesel fuel (or 242,960 kWh per year of electricity equivalent). Data shows that consumption of diesel fuel in office buildings is substantial at about 10% of total energy consumption.

BEI values were determined using the total energy consumption based on the rationalised operational hours and the GFA recorded in the survey. Preliminary analysis showed exceptionally low BEI value (151 kWh/m^2/year) compared with office buildings in Malaysia and Singapore, which have similar climatic conditions.

Preliminary analysis of BEI values shows an average BEI value of about 151 kWh/m2/year, which is not realistic because that of the average conventional buildings without the incorporation of energy efficiency design and installation is in the range of 250 kWh/m2/year in Malaysia and 246 kWh/m2/year in Singapore (Table 2.2). The discrepancies could be due to the accuracy of the energy consumption data and the GFAs, and the average operational hours in office buildings. It was noted that some BEI values calculated from the survey data were much less than 100 kWh/m2/year and some BEI values calculated were even near zero. Therefore, these BEI calculated values were considered outliers.

Further analysis was conducted by keeping to the range of BEI values calculated from the survey data to within 100 kWh/m2/year to 750 kWh/m2/year. The BEI values outside this range were deemed to be outliers and, hence, were excluded in the analysis. Having discarded the outliers, the final analysis was based on a small pool of 11 data sets. Figure 2.4 shows the results of this analysis.

Figure 2.4. Analysis of Building Energy Intensity for Office Buildings



Source: Author's calculation.

An average BEI value of 279 kWh/m2/year was derived from the survey data. For the purpose of this survey, the average benchmark value of energy consumption intensity for office buildings in Myanmar is 280 kWh/m2/year. This average BEI value and the national statistical information on office space are used to project national energy consumption in office buildings in the country. Table 2.16 provided by the MSR shows the government and private office spaces in and outside Yangon for 2015.

Table 2.16. Government and Private Sector Office Building Space in Myanmar

	Office Space in Yangon (m^2)	Office Space outside Yangon (m^2)	Total Office Space in Myanmar (m^2)
Government Office Buildings	5,160,726	549,192	5,709,918
Private Sector Office Buildings	1,269,314	755,608	2,024,922

Source: ADB (2015).

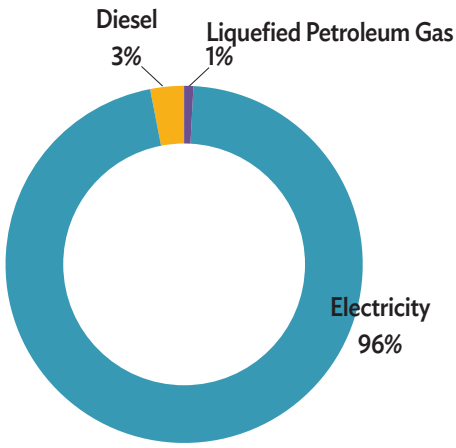
Table 2.16 shows that government office space is about four times that of private sector office space in Yangon. Comparing the total office space in the whole country, government office space is almost three times more than that of the private sector. However, the survey of energy consumption in office buildings conducted in Yangon was mainly of private sector office buildings. Therefore, the average BEI value calculated from the survey data might be biased towards private sector office buildings.

Figure 2.5 shows that the main energy source of office buildings is electricity, which takes up 96% of total energy consumption. Other energy sources are diesel and LPG.

Hotels

The key data obtained in the survey were the following:
1) Total electricity consumption per year (kWh/year)
2) Energy consumption per year of other energy sources (i.e., fuel energy other than electricity)
3) Star ratings of hotels
4) Total GFA (m2 – excluding car park and data centre)
5) Total number of hotel rooms

Figure 2.5. Average Share of Energy Sources for Office Buildings in Myanmar

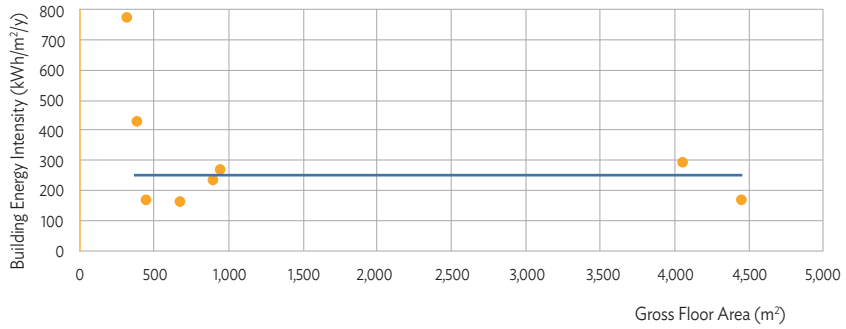


Source: Author's calculation.

The analyses of BEI values based on the survey data were conducted under two categories: 1–3 star-rated hotels and 4–5 star-rated hotels. The main energy source for both hotel categories was electricity. Total energy consumption was derived from the yearly consumption values of electricity, diesel, and LPG. Based on the GFA obtained in the survey, BEI values were calculated.

The BEI values calculated from the survey data for 1–3 star-rated hotels, whose sample size was 20, were inconsistent. Some BEI values calculated were much less than 100 kWh/m2/year; some were even almost zero, while some BEI values exceeded 700 kWh/m2/year. Some of these high BEI values calculated were in the range of 785 kWh/m2/year to 2,153 kWh/m2/year. Figure 2.5 shows the analysis of BEI values, which exclude the extreme values of low and high BEI values. The analysis of BEI values was confined to 160 kWh/m2/year to 420 kWh/m2/year. BEI values outside this range were considered outliers. This has resulted in reducing the sample size to 7 instead of 20 hotels for the analysis. The result of the analysis of 1–3 star-rated hotels is shown in Figure 2.6, which derives an average BEI value of 246 kWh/m2/year from the seven sets of data.

Figure 2.6. Analysis of Building Energy Intensity for 1–3 Star-Rated Hotels

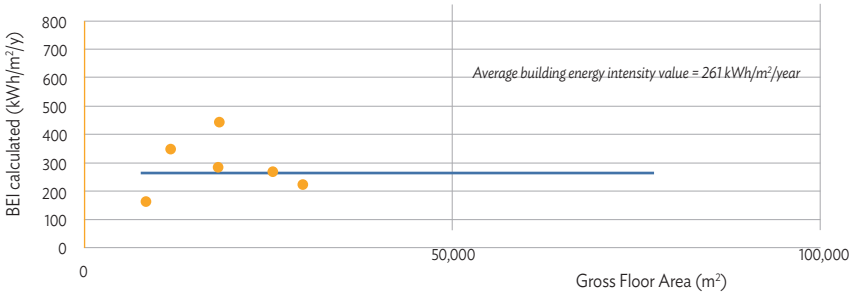


kWh = kilowatt-hour.

Source: Author's calculation.

The BEI values calculated from the survey data for 4–5 star-rated hotels were more consistent but the sample size for this category was small at six hotels only after discarding the outliers. The range of relevant BEI values calculated was kept to within 250 kWh/m2/year to 450 kWh/m2/year to enhance the derivation of more appropriate BEI values. Figure 2.7 shows that the average BEI value for 4–5 star-rated hotels is 261 kWh/m2/year.

Figure 2.7. Analysis of Building Energy Intensity for 4–5 Star–Rated Hotels



Source: Author's calculation.

Table 2.17. Statistical Information on Hotels, Motels, and Guest Houses in Myanmar

Item	States/Regions	No. of Hotels, Motels, and Guest Houses	No. of Rooms
1	Kachin State	29	856
2	Kayah State	17	368
3	Kayin State	24	880

4	Chin State	6	171
5	Sagaing Region	33	1,265
6	Tanintharyi Region	39	1,525
7	Bago Region	70	1,755
8	Magway Region	35	845
9	Mandalay Region	380	13,604
10	Mon State	52	1,683
11	Rakhine	60	1,892
12	Yangon	387	20,123
13	Shan State	314	10,259
14	Ayeyarwaddy Region	79	3,264
15	Nay Pyi Taw	65	5,488
	Union Total	1,590	63,978

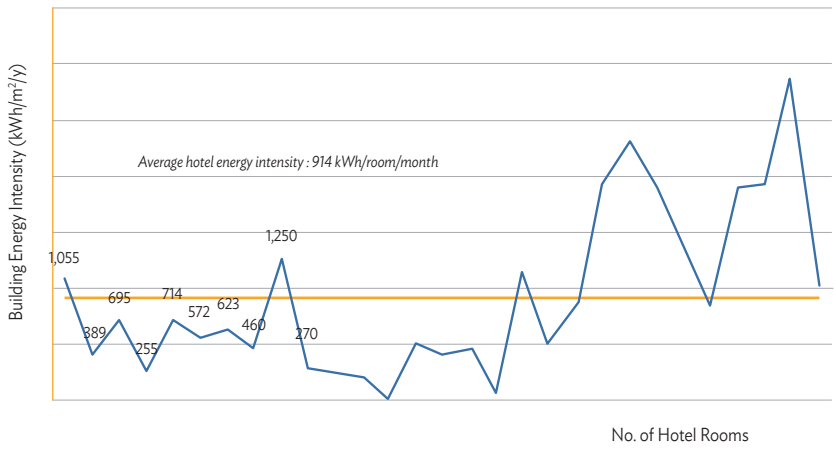
Source: MSR (2018).

Since the hotel statistical information available in Myanmar is number of hotel rooms (without being classified under hotel star rating), the use of the BEI method to estimate the projected energy consumption cannot be applied as in office buildings. Therefore, it is necessary to work out the EUI based on per room to estimate the projected energy consumption of hotels from the survey data analysis. To make a national projection of energy consumption for hotels, the total energy consumption and the corresponding number of hotel rooms were extracted and calculated based on energy consumption per hotel room per month. The monthly basis is a convenient way of assessing and comparing the level of energy consumption so it could be easily gauged. The analysis of hotel energy intensity is shown in Figure 2.8 and the average intensity value turned out to be 914 kWh/room/month, which can be used to estimate the projected national energy consumption for hotels.

Figure 2.9 shows that the main source of energy for the 1–3 star-rated hotels is electricity, which takes up 76% of total energy consumption. Diesel fuel use is substantial at about 18% and LPG is the other fuel used mainly for hotel food and beverage applications. One of the 1–3 star-rated hotels provided their energy

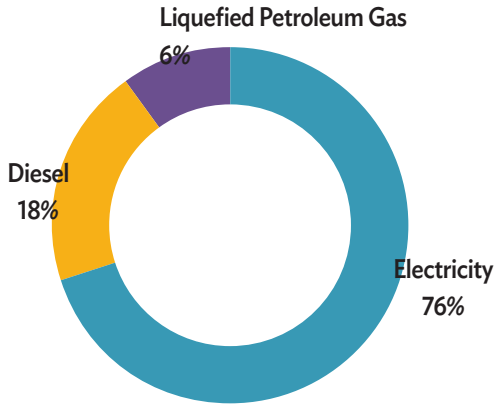
consumption data entirely on diesel without the use of electricity. This did not seem to be realistic.

Figure 2.8. Analysis of Hotel Energy Intensity



Source: Author's calculation.

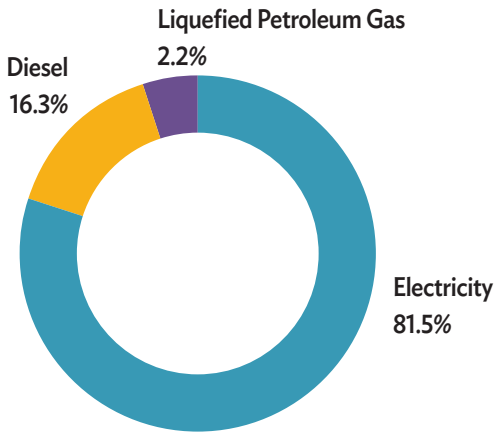
Figure 2.9. Average Share of Energy Sources for 1–3 Star-Rated Hotels in Myanmar



Source: Author's calculation.

Similarly, Figure 2.10 shows that the main energy source of the 4–5 star-rated hotels is electricity, which takes up a higher share at 81.5% of total energy consumption compared to the 1–3 star-rated hotels. Diesel fuel use is substantial at about 16.3% but LPG share is much less at 2.2% compared with the 1–3 star-rated hotels.

Figure 2.10. Average Share of Energy Sources for 4–5 Star-Rated Hotels in Myanmar



LPG = liquefied petroleum gas.
Source: Author's calculation.

Shopping malls

The key data obtained in the survey are the following:
1) Total electricity consumption per year (kWh/year)
2) Energy consumption per year of other energy sources (i.e., fuel energy other than electricity)
3) Daily operational hours
4) Total GFA (m2 – excluding car park and data centre)

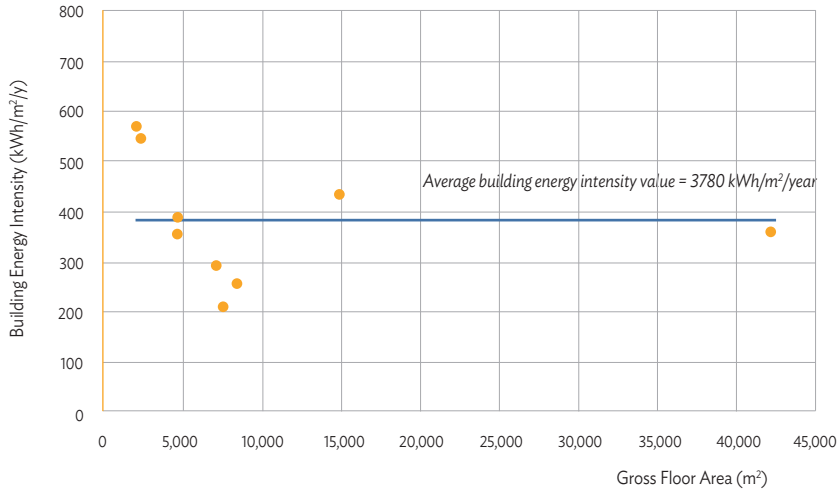
The weekly operational hours for shopping malls varied and the average operational hours amongst the shopping malls surveyed turned out to be 83 hours. This is almost 12 hours per day and is comparable to the 84 operational hours per week (or 4,368 hours per year) for green buildings (Green Building Index) in Malaysia. In other words, it is possible to directly compare the BEI

values for shopping malls in Myanmar and Malaysia as far as operational hours are concerned.

Like other commercial buildings, the main energy source for retail buildings is electricity. Other fuel recorded for consumption of shopping malls was diesel; and surprisingly, no LPG data was reported in the survey. This could be due to the method of survey adopted by the MSR, which might have targeted shopping mall owners or management without interviewing shopping mall tenants, who would likely use LPG fuel if their businesses were in the food sector.

Total energy consumption was obtained by adding up electricity and diesel fuel consumption. BEI values were calculated using the total energy consumption and the GFA recorded in the survey. In analysing the BEI values calculated, outlier values exceeding 600 kWh/m2/year and those less than 200 kWh/m2/year were discarded. As a result, the number of data sets was reduced to nine shopping malls. Figure 2.10 shows the analysis of BEI values calculated for shopping malls with BEI values of 210 kWh/m2/year to 570 kWh/m2/year. The average BEI value for shopping malls in Myanmar is 380 kWh/m2/year.

Figure 2.11. Analysis of Building Energy Intensity for Shopping Malls



Source: Author's calculation.

Figure 2.12. Average Share of Energy Sources for Shopping Malls

Source: Author's calculation.

Table 2.18. Statistical Information on Retail Space in Myanmar

Year	Modern Retail Space in Yangon	Traditional Retail Space in Yangon	Retail Space outside Yangon
2016	236,851 m^2	34,319 m^2	82,384 m^2

Source: ADB (2015).

Figure 2.12 shows that the main energy source for shopping malls in Myanmar is electricity and other fuel used is mainly diesel. It is surprising to note that besides diesel, no other fuel was recorded in the survey. Based on statistical information in Table 2.18, it is possible to use the average BEI value derived from the analysis of BEI for shopping malls as shown in Figure 2.11.

Restaurants

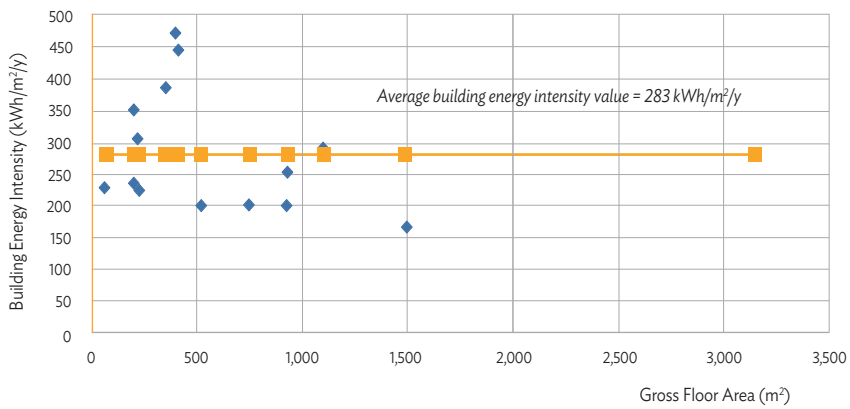
The key data obtained in the survey is the following:

1) Total electricity consumption per year (kWh/year)
2) Energy consumption per year of other energy sources (i.e., fuel energy other than electricity)
3) Daily operational hours
4) Total GFA (m2 – excluding car park and data centre)

As for shopping malls, the weekly operational hours for restaurants vary from 46 hours to 112 hours, making the average operational hours amongst the restaurants surveyed to be 81 hours or about 11.5 hours per day. Restaurants normally have rest hours. Nevertheless, the BEI values calculated were rationalised to standardise the operational hours to 81 hours so that the BEI values calculated for restaurants having different operational hours could be compared on the same operational hours.

In analysing BEI values for restaurants, the extremely low BEI value of 20 kWh/m2/year and the extremely high BEI value of 6,899 kWh/m2/year were discarded. The BEI values of two restaurants that provided energy consumption data of electricity only, with zero other fuels, including LPG, were also discarded. This is because restaurants are expected to use other fuels besides electricity. The analysis confined the range of rationalised BEI values calculated from 165 kWh/m2/year to 474 kWh/m2/year. As a result, the number of data sets was reduced to 15 restaurants. Figure 2.13 shows the result, which is an average BEI value of 283 kWh/m2/year for restaurants in Myanmar.

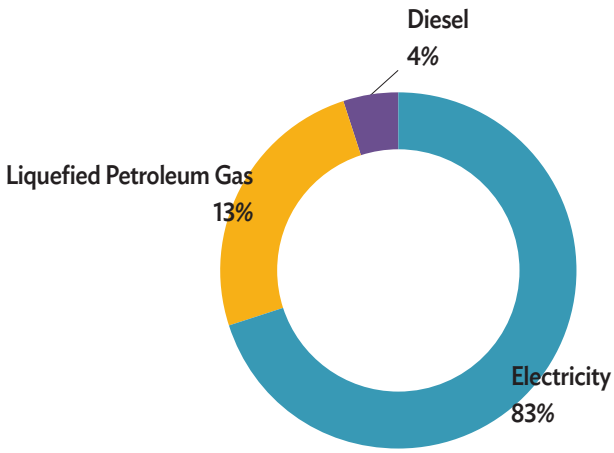
Figure 2.13. Analysis of Building Energy Intensity for Restaurants



kWh = kilowatt-hour.

Source: Author's calculation.

Figure 2.14. Average Share of Energy Sources for Restaurants



Source: Author's calculation.

Table 2.19. Statistical Information on Restaurants in Myanmar

Year	No. of Restaurants in Yangon	No. of Restaurants outside Yangon
2016	8,753	20,166

Source: ADB (2015)

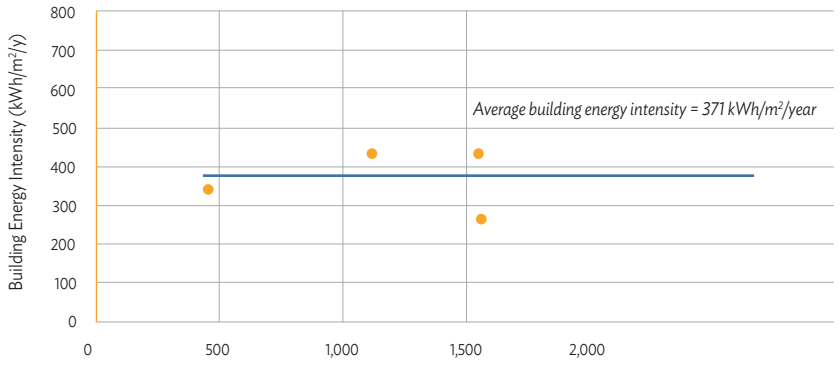
Figure 2.14 shows that the main energy source of restaurants is electricity; as expected, the consumption of LPG is substantial. LPG is mainly used for cooking purposes. There was no record of data for biomass fuel. The reason for this is probably because the energy consumption survey was conducted primarily in Yangon (Table 2.19), and that the main energy sources were electricity, LPG, and diesel (Figure 2.14).

Hospitals

The key data obtained in the survey are the following:

1) Total electricity consumption per year (kWh/year)
2) Energy consumption per year of other energy sources (i.e., fuel energy other than electricity)
3) Total GFA (m^2 – excluding car park and data centre)

Figure 2.15. Analysis of Building Energy Intensity for Hospitals



kWh = kilowatt-hour.

Source: Author's calculation.

In analysing the BEI values for hospitals, the extremely low BEI value of 1 kWh/m2/year and the extremely high BEI value of 2,452 kWh/m2/year were discarded as these values are deemed impractical and, hence, regarded as outliers. Another analysis based on energy consumption per bed per month was conducted. The result was also erratic as the range of values worked out to vary from 6 kWh/bed/month to 2,303 kWh/bed/month.

Therefore, the final analysis of hospital BEI values was confined to the range of 265 kWh/m2/year to 434 kWh/m2/year. Having discarded the outliers, the number of data sets used for the BEI analysis was reduced to 9. The result of an average BEI value of 371 kWh/m2/year is shown in Figure 2.15.

Table 2.20 was extracted from the Hospital Statistics Report 2014–2016 issued by the Ministry of Health, which provides information on number of beds and not the gross floor area of hospitals. Therefore, the BEI method to project national energy consumption of hospitals cannot be used. Since the number of hospital beds is given, it is necessary to estimate hospital energy use intensity on a per bed per month basis.

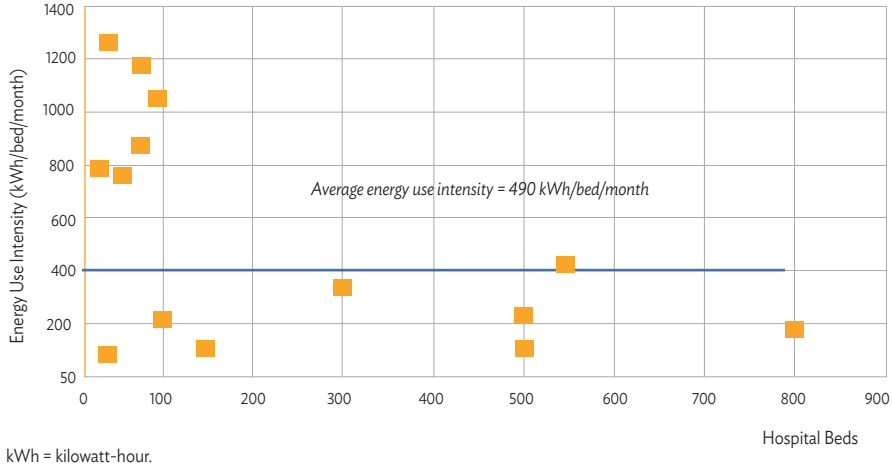
Figure 2.15 shows the analysis of hospital energy use intensity on a per bed per month basis. The per month basis is a convenient way of assessing and comparing the level of energy consumption so that it can be easily gauged. The average hospital EUI was 490 kWh/bed/month (Figure 2.16). In deriving this

Table 2.20. Government Hospital Information as of 2016

States/Region	Total No. of Government Hospitals	Available Beds
Kachin State	55	2,299
Kayah State	18	586
Kayin State	34	1,306
Chin State	28	1,072
Sagaing Region	132	4,762
Tanintharyi Region	38	1,294
Bago Region	109	3,986
Magway Region	100	3,736
Mandalay Region	108	8,456
Mon State	42	1,553
Rakhine	63	2,079
Yangon	85	12,260
Shan State	159	5,717
Ayeyarwaddy Region	121	4,675
Nay Pyi Taw	23	2,114
Union Total	1,115	55,895

Source: Ministry of Health and Sports (2018).

Figure 2.16. Analysis of Hospital Energy Use Intensity



kWh = kilowatt-hour.

Source: Author's calculation.

average EUI value, the extreme values of 4 kWh/bed/month and 2,242 kWh/bed/month were discarded and deemed to be outliers as they were impractical values. The intensity values considered to be valid for the analysis was confined to a range of 85 kWh/bed/month to 1,270 kWh/bed/month.

Residential Sector

The energy consumption survey of the residential sector was conducted in selected townships in the Yangon region. The survey questionnaire was developed by the MSR with guidance from the ERIA team. The questionnaire was designed to obtain the following data:

- Type of locality (urban, suburban, or rural)
- Type of building and occupancy details
  - -apartment or house
  - -floor area, number of bedrooms
  - -number of occupants
- Energy consumption
  - -electricity consumption per year
  - -other types of fuel consumption per year

Two hundred sets of survey data were collected from 13 townships in the Yangon area. Table 2.21 shows the breakdown in sampling areas and sample size. The sampling areas were generally classified under urban, suburban, and rural. This survey is limited as the rural areas defined in the survey might not be the same as the rural areas outside Yangon. The electricity consumption data collected was not the actual consumption over a 12-month period because yearly consumption data would have taken care of the seasonal effects. However, the actual data collection was the electricity consumption over a 1-month period, which was then converted into yearly consumption by multiplying it by 12 months. Therefore, some errors can be expected in the analysis due to the survey data.

The raw data in the 200 sets of household surveys was very scattered and needed to be treated. Treatment of the raw data is explained in the following:

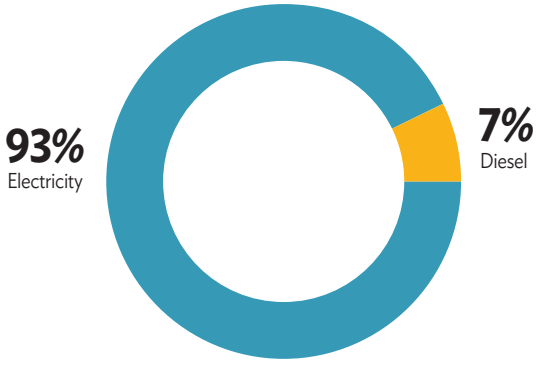
1) Total energy consumption per household was calculated by adding up the consumption of electricity and other fuels monthly.

Table 2.21. Sampling Areas and Sample Size

Districts	Locality	Township	Sample Ward	Sample Size
South Yangon	Rural	Dala	Aung Min Ga Lar Ward	15
North Yangon	Rural	Htantabin	No (1) Ward	15
North Yangon	Rural	Taikkyi	Kyan Sit Thar Ward	15
South Yangon	Rural	Hnawbi	Myo Ma (South) Ward	16
East Yangon	Suburban	Dagon Myothit (North)	No (29) Ward	15
North Yangon	Suburban	Hlinethaya	No (9) Ward	15
North Yangon	Suburban	Mingaladon	Pyi Taw Thar Ward	16
North Yangon	Suburban	Shwepyitha	No (3) Ward	15
West Yangon	Urban	Bahan	Bo Sein Hman Ward	15
West Yangon	Urban	Hline	No (7) Ward	16
West Yangon	Urban	Mayangon	No (2) Ward - Tha Maing Myo	15
East Yangon	Urban	Pazuntaung	No (7) Ward	16
East Yangon	Urban	Thingangyun	Bo Kan Nyunt Ward	16
Total number of samples				200

Source: MSR (2018)

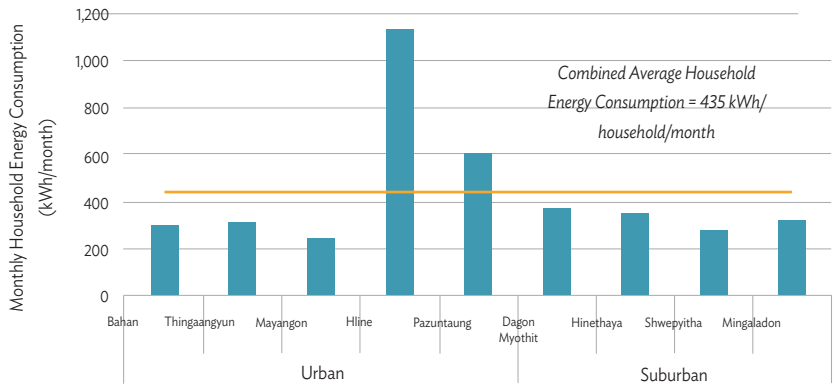
Figure 2.17. Average Share of Energy Sources for Hospitals



Source: Author's calculation.

2) Data was grouped and analysed as clusters for the respective districts under the locality categories of urban, suburban, and rural areas.

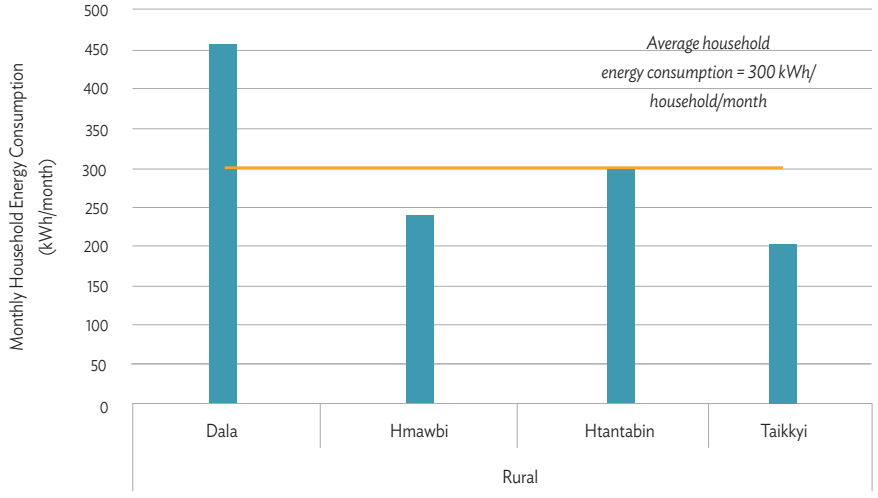
Figure 2.18. Analysis of Energy Consumption per Household per Month in Urban and Suburban Areas, including Electricity and Other Fuels



kWh = kilowatt-hour.

Source: Author's calculation.

Figure 2.19. Analysis of Energy Consumption per Household per Month in Rural Areas, including Electricity and Other Fuels



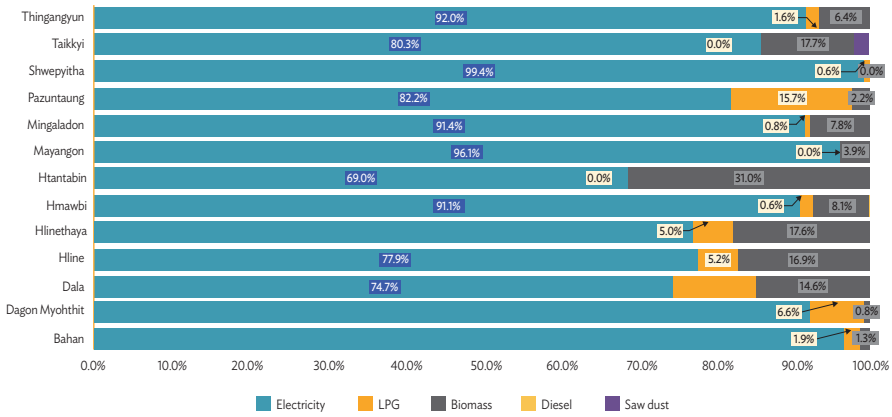
Wh = kilowatt-hour.

Source: Author's calculation.

3) Weighted average method was used to analyse the scattered data. This method considers the spread of data. It calculates the average based on the frequency of data occurred in a specific range.

Figures 2.17 and 2.18 show the results of the analysis of household energy consumption in urban, suburban, and rural areas, respectively. Combined average household consumption was calculated for the urban and suburban areas because the statistical information on the number of households is available under the urban classification only.

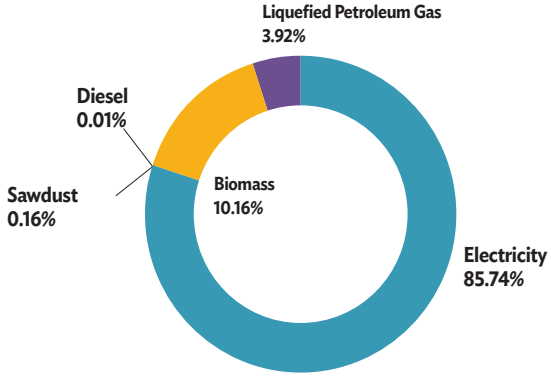
Figure 2.20. Average Share of Energy Sources for Each Township Surveyed



LPG = liquefied petroleum gas.

Source: Author's calculation.

Figure 2.21. Overall average share of energy sources for residential sector



Source: Author's calculation.

The shares of energy sources for the households that participated in the survey were analysed. Figure 2.19 shows that electricity is the main energy source for urban and rural areas in Yangon. However, as noted from the EBT, the consumption of other fuels such as fuel wood and wood waste is a much larger share than electricity. Firstly, the explanation for this discrepancy is mainly that the rural areas surveyed in Yangon are not representative of the actual rural areas in Myanmar. Secondly, there might be difficulties in keeping the consumption records of biomass fuel. Thirdly, the sampling size is small. Nevertheless, the survey results indicate that the populations are switching to the use of electricity, which is a more convenient source of energy and has become a necessity where access to electricity is available in urban, semi-urban, outer city, and some rural areas. Figure 2.20 shows the overall average share of energy sources for the residential sector in Myanmar.

Estimates of National Energy Consumption in the Commercial and Residential Sectors

Commercial sector

Based on the analyses in Sections 2.5 and 2.6, the national energy consumption in the commercial sector can be projected (Table 2.22). Subject to the availability of statistical information, the projected estimates were based on the BEI and other EUI values derived from the analysis of survey data; the total floor area obtained in the national statistical information for office and retail spaces; and the national statistics on the number of respective buildings, hotel rooms, hospital beds, and restaurants in Myanmar.

Office buildings

Based on the average BEI value estimated in Section 2.5.1 and the statistical information on office space reported for 2015, it is possible to estimate the projected energy consumption of office buildings in Myanmar (Table 2.22).

Table 2.22. Estimation of Projected Energy Consumption of Office Buildings in Myanmar

	Office space as of 2015 (m^2)	Average BEI ($kWh/m^2/y$)	Projected Total Energy Consumption (GWh)	Projected Total Energy Consumption (ktoe)
Goverment Office Buildings	5,709,918	280	1,599	137
Private Sector Office Buildings	2,024,922	280	567	49
Projected Total Consumption			2,166	186

Source: BEI = building energy intensity, GWh = gigawatt-hour, ktoe = kilo ton of oil equivalent.

Source: ADB (2015).

Hotels

The estimation of projected energy consumption of hotels is different from the method used for office buildings. The difference is due to the statistical information available for hotels regarding number of rooms, instead of floor area, without star rating classification. It is necessary to estimate the average EUI per room of 1–3 and 4–5 star-rated hotel data to project the energy consumption of hotels nationwide from the survey data analysis (Table 2.23).

Table 2.23. Estimation of Projected Energy Consumption of Hotels in Myanmar

	No. of hotel rooms[a] (as of 2016)	Average Energy Use Intensity (EUI) on per hotel room basis[b] (kWh/room/month)	Projected National Energy Consumptionb (GWh/year)	Projected National Energy Consumptionb (ktoe/year)
Yangon	20,123	914	221	19
Outside Yangon	43,855	914	481	41
Total Projected Consumption			702	60

Sources: [a] Ministry of Hotels & Tourism (2017).[b] Author's calculation.

Shopping malls

The statistical information on shopping malls is available in floor area. Therefore, the BEI method was used to estimate the projected energy consumption of shopping malls in Myanmar (Table 2.24).

Table 2.24. Estimation of Projected Energy Consumption of Shopping Malls in Myanmar

	Retail Space (m^2)	Average BEI Baseline value ($kWh/m^2/year$)	Projected National Energy Consumption (GWh/year)	Projected National Energy Consumption (ktoe/year)
Yangon	271,170	380	103	9
Outside Yangon	82,384	380	31	3
Total Projected Consumption			134	12

BEI = building energy intensity, GWh = gigawatt-hour, kWh = kilowatt-hour, ktoe = kilo ton of oil equivalent.

Sources: [a] ADB (2015). [b] Author's calculation.

Restaurants

The statistical information in number of restaurants was extracted from the Myanmar Energy Master Plan, which was made available by the MSR. However, to use the BEI method, it was necessary to assume an approximate floor area of a typical restaurant. At the third Working Group meeting, the members agreed that a typical floor area of 150 m2 would be used as basis for the estimation (Table 2.25).

Table 2.25. Estimation of Projected Energy Consumption of Restaurants in Myanmar

	Estimated Floor Area of Restaurants Assuming 150 m^2 each (as of 2016)	Average BEI Baseline value[b] ($kWh/m^2/year$)	Projected National Energy Consumption (GWh/year)	Projected National Energy Consumption (GWh/year)
Yangon	8,753x150= 1,312,950 m^2	283	372	32
Outside Yangon	20,166x150 = 3,024,900 m^2	283	600	52
Total Projected Consumption			972	84

BEI = building energy intensity, GWh = gigawatt-hour, kWh = kilowatt-hour.

Sources: [a] ADB (2015). [b] Author's calculation (the assumption of floor area of 150 m^2 per restaurant was made by the author)

Hospitals

The statistical information available for hospitals is the number of hospital beds in government hospitals. Thus, it was necessary to derive the EUI on a per hospital bed basis from the survey data. The number of private hospital beds was not available. To estimate the projected energy consumption of private hospitals, the number of beds was estimated from the number of private hospitals in the Hospital Statistics Report 2014–2016 and the number of government hospital beds.

Table 2.26. Estimation of Projected Energy Consumption of Hospitals in Myanmar

	No. of Hospital Beds (as of 2016)	Average Energy Use Intensity (kWh/bed/month)	Projected National Energy Consumption (GWh/year)	Projected National Energy Consumption (GWh/year)
Government Hospitals	55,895	490	329	28
Private Hospitals	11,179	490	66	6
Total Projected Consumption			134	12

Notes: [a] Ministry of Health and Sports (2018).[b] Information on the number of beds of private hospitals was not available. Based on the 187 private hospitals compared with 1,115 public hospitals, which is about 20% (in terms of the number of hospitals), the number of private hospital beds was assumed to be also 20% of public hospital beds.

GWh = gigawatt-hour, kWh = kilowatt-hour.

Source: Author's calculation.

Projected national energy consumption for the commercial sector

Table 2.27 summarises the projected energy consumption of each of the five sub-sectors in the commercial sector – namely, office buildings, hotels, shopping malls, restaurants, and hospitals. The projected national energy consumption from the energy consumption survey is compared with the national 2016 EBT (made available in July 2018).

Table 2.27. Projected National Energy Consumption based on Survey Data and EBT Energy Consumption for the Commercial Sector

	Projected National Energy Consumption Based on Survey Data (GWh/year)	Projected National Energy Consumption Based on Survey Data (ktoe/year	Total Energy Consumption based on 2016 Energy Balance Table (ktoe/year)
Office	2,166	186	329
Hotels	702	60	66
Shopping Malls	134	12	
Restaurants	972	84	
Hospitals	395	34	
Total	4,369	376	294

EBT = energy balance table, GWh = gigawatt-hour, ktoe = kilo ton of oil equivalent.

Sources: [a] Author's calculation. [b] ERIA (2016).

Table 2.25 shows that the total energy consumption for the commercial sector projected from the survey data is 376 ktoe, which is greater than the corresponding value of 294 ktoe from the 2016 EBT. The 294 ktoe from the 2016 EBT comprises 260 ktoe of electricity consumption and 34 ktoe of petroleum products consumption. The sources of error could be due to the following:

1) The survey sampling size was small. The actual analyses were based on an even smaller pool of data as some of the data analysed was outliers.

2) The surveys were mainly conducted in Yangon, which might not be representative of the consumption trending in Myanmar, e.g., the electricity consumption recorded in EBT is 260 ktoe (or 88.4% of the total commercial energy consumption), and the balance is 34 ktoe of petroleum product consumption (or 11.6% of the total commercial energy consumption). However, the survey data shows that in addition to electricity and diesel as energy sources, LPG is also a substantial source of energy for the commercial sector.

3) Energy consumption records and building information such as gross floor area might not have been kept properly and might not be readily available and reported during the surveys.

4) Human errors might have contributed to the discrepancies, due to the following:

a) Inexperienced enumerators who were not familiar with the technical nature and requirements of the energy consumption survey, e.g., interpretation of gross floor area, overlooking shopping mall tenants for source of LPG data, etc. The lack of direct training of the enumerators by ERIA experts might have contributed to this source of errors.
b) Respondents who were not fully cooperative might have given inaccurate data.
c) Respondents might not be familiar with the technical nature and requirements of energy consumption survey.

5) The survey coverage and the EBT for the commercial sector might have different boundaries.

6) The projected estimates rely on the accuracy of the survey data and the building statistics available from the published sources. There could be a mismatch in terms of the year for which the building statistics and the EBT data were compiled.

Nevertheless, the comparison of the projected national energy consumption (376 ktoe) for the commercial sector and the corresponding EBT value (294 ktoe) is within a discrepancy range of 28%, which is reasonable.

Residential sector

Based on the analyses in Section 2.6, the projected national energy consumption can be derived as given in Table 2.26. The projected estimates were based on the average national baseline energy consumption for household under two categories: urban–suburban and rural areas. The projected national residential energy consumption was derived from the analysis of the survey data and the national statistics on the number of households.

The number of households based on the Myanmar Population Census 2014 was 3,049,433 in urban areas and 7,828,399 in rural areas as reported by the MSR. However, to derive the updated number of households, the Working Group used the population growth rates presented at its third meeting[1] in making adjustments to tally with the population growth. The population in 2015 was

[1] Refers to the Third Working Group meeting of ERIA Research Project FY2017 held in Bangkok, 18–20 April 2018.

reported to be 52.4 million. Based on the reported 4.4 persons per household in the 2014 census, the total number of households in 2015 was derived and tabulated in Table 2.26. As a result, the total energy consumption for the residential sector projected from the survey data is 4,151 ktoe/year, which is less than the corresponding 2015 EBT value of 7,720 ktoe. The difference between these two values is substantial. The 7,720 ktoe of residential energy consumption comprises 574 ktoe of electricity (or 7.44% of the total residential energy consumption), 2 ktoe of coal products (or 0.02%), and 7,144 ktoe of biomass (or 92.54%).

Main discrepancy between 2015 EBT value and the projected value is the electricity consumption. The electricity consumption of 574 ktoe tabulated in the EBT represents 7.44% while the projected estimates of energy consumption from the survey data constitute mainly electricity consumption at 85.74% for the residential sector. The percentage share of biomass in the survey data is only 10.16% only. In other words, based on the survey results, a large part of the biomass energy consumption by the residential sector was not captured.

Table 2.28. Projected National Energy Consumption Based on Survey Data and EBT Energy Consumption for the Residential Sector

	Urban	Rural	Total
No. of households	3,338,530	8,570,561	11,909,091
Average household energy consumption (kWh/household/month)	435	300	N/A
Projected yearly energy consumption	17,427 GWh or 1,498 ktoe	30,854 GWh or 2,653 ktoe	47,187 GWh or 4,151 ktoe
Energy Balance Table			7,720 ktoe

EBT = energy balance table, GWh = gigawatt-hour, ktoe = kilo ton of oil equivalent, N/A = not applicable.

Sources: [a] MSR (2018). [b] Author's calculation. [c] ERIA (2015).

Therefore, there is discrepancy in the breakdowns of the projected energy consumption values and the EBT breakdown values. The reasons for this discrepancy could be due to the following:

1) The survey areas being confined to Yangon would reflect a much higher share of electricity use due to the relatively better infrastructures in Yangon.
2) The rural areas in Yangon referred to in the survey are not representative of the rural areas in Myanmar. Hence, the use of biomass, including firewood

and wood waste, are not reflected in the survey data. The EBT shows a much larger share of other fuels including biomass (92.54%).

3) The survey sample size was small.

4) There might be difficulties in keeping yearly records of biomass fuel, which might have caused the lack of reporting or under-reporting of the consumption of biomass fuels.

5) The survey coverage and the EBT for the commercial sector might have different boundaries.

6) Human errors due to the following:

a) Inexperienced enumerators who were not familiar with the technical nature of energy consumption surveys. The lack of direct training of the enumerators by ERIA experts might have contributed to this source of errors.

b) The yearly energy consumption data collected was based on the consumption for a particular month or months.

c) Respondents were unwilling to fully cooperate and give accurate data voluntarily.

d) Respondents might not be familiar with the technical nature and requirements of energy consumption survey.

References

Asian Development Bank (ADB) (2017), *Key Indicators for Asia and the Pacific 2017*. Myanmar, www.adb.org/statistics (accessed 24 October 2018).

Asian Development Bank (ADB) (2015), *Myanmar Energy Master Plan, December*. Manila: ADB.

Central Statistical Organization (CSO), *Myanmar Statistical Yearbook.* http://www.mmsis.gov.mm/sub_menu/statistics/fileDb.jsp (accessed 25 November 2018.)

Economic Research Institute for ASEAN and East Asia (ERIA) (2016), *Energy Balance Tables*. Jakarta: ERIA.

Economic Research Institute for ASEAN and East Asia (ERIA) (2015), *Energy Balance Tables 2015*. Jakarta: ERIA.

Ministry of Hotels & Tourism (2017), *Myanmar Tourism Statistics 2017.* Nay Pyi Taw: Ministry of Hotels and Tourism.

Ministry of Health and Sports (2018), *Hospital Statistics Report 2014–2016*. Nay Pyi Taw: Ministry of Health and Sports.

Win, Y.T. and S. Dhakal (2015), 'Urban Transport Scenario of Yangon, Myanmar. AIT', paper presented at the GCP Workshop on Sustainable cities, 15–17 January 2015, Toyota City, Aichi, Japan, p.9. www.cger.nies.go.jp/gcp/pdf/toyota-workshop-jan2015/20-ye-thu-win.pdf (accessed 25 November 2018.)