Chapter 2

Energy Consumption Survey and Energy Efficiency Indicators

1. Introduction

The Philippine Institute of Energy Management Professionals Inc. (PIEMPI) conducted the energy consumption survey for the industry sector. The Meralco Power Academy (MPA) conducted that for the commercial sector. The enumerators of both consulting companies were given training by ERIA on 6 and 7 April 2022, respectively.

The methodology was explained during the training with survey questionnaire guides prepared by ERIA. The survey questionnaire guides aimed to provide an example of the types of data to be collected in Excel files, formatted to compute the EUI for the industry sector and BEI for the commercial sector. However, during the survey and subsequent reporting, the MPA referred to BEI as EUI. Therefore, tor consistency, the EUI will also be referred to as the EEI for the commercial sector. However, the units will be different as the definitions of EUI for the industry and commercial sectors are different.

Because of the expected production interruptions due to the COVID-19 pandemic during 2020 and 2021, the PDOE and ERIA agreed that the data collection was to base on 2018 and 2019 data. The energy consumption and production output values for the industrial and commercial sectors must be consistent.

2. Survey Questionnaire for the Industry Sector

As shown in Appendix C, the survey questionnaire comprised the following tables:

1) Table C1: General information
   - General company information, industry category, etc.
   - Description of products and production processes, type of fuels used, and respective calorific values
2) Table C2: Energy consumption data, including fuels and electricity from the utility and onsite power generation, other fuel usage, and production output data.
   - Energy consumption from various sources, including utility, generator sets, and other fuel usage
   - Production outputs complete with measurement units
3) Table C3: Energy consumption breakdowns for production processes, for example:
   - Steam
   - Heating
   - Drying
   - Process heating
   - Production automated processes
4) Table C4: Energy consumption breakdowns for products with different measurement units.

3. Survey Questionnaire for the Commercial Sector

As shown in Appendix D, the survey questionnaire comprised the following tables:

1) Table D1: General information
   - General company information, building category (office or retail buildings).
   - Description of building functions, type of fuels used, and respective calorific values.
2) Table D2: Energy consumption data, including fuels and electricity from the utility and onsite power generation, other fuel usage, and the GFA.
3) Table D3: Details of air-conditioned spaces for estimating energy consumption by air-conditioning system.
4) Table D4: Lighting installations in retail buildings for estimating electricity consumption by lighting
5) Table D5: Lighting installations in office buildings for estimation of electricity consumption by lighting

4. Outcome of the Survey

The industry sector survey undertaken by PIEMPI and the commercial sector undertaken by the MPA encountered numerous challenges, such as indifferent responses, lack of cooperation, and incomplete and erroneous submissions, which were probably due to the voluntary and unfamiliar nature of the survey and the likely absence of readily available data required by the survey questionnaire. The challenges were further compounded by the COVID-19 pandemic situation, which imposed restrictions on physical or onsite surveys to be carried out. As a result, the survey reached out to the companies or respondents in the four industry sub-sectors: sugar, cement, food and beverage factories, and commercial sectors, namely office and retail buildings mainly relied on emails and telephone calls. The companies to be surveyed were primarily based on PDOE's predetermined list of companies. The scope of the survey was based on 100 samples for each of the industry and commercial sectors. The number of samples per sector was to be determined by the PDOE.

5. Industry Sector Outcome

5.1. Industry Sector Preliminary Outcome

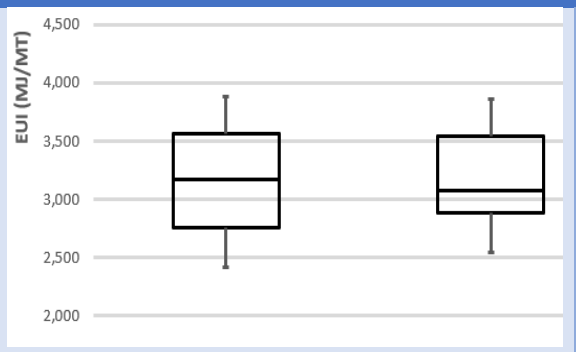
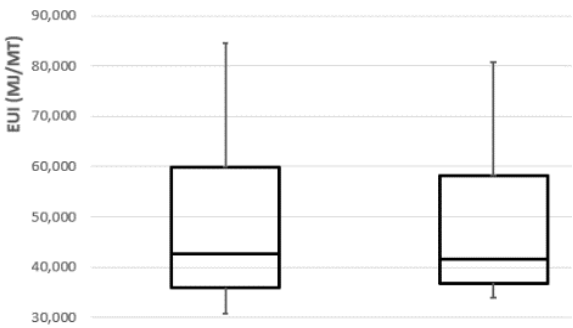
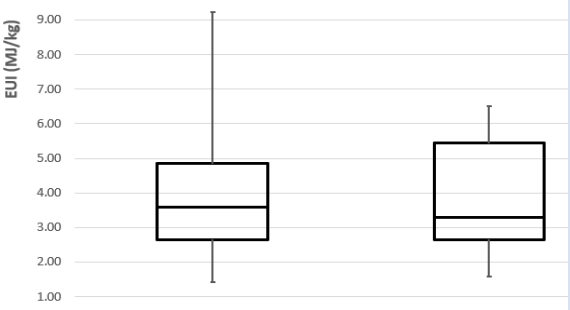
PIEMPI reported the following when they commenced the survey in May 2022:

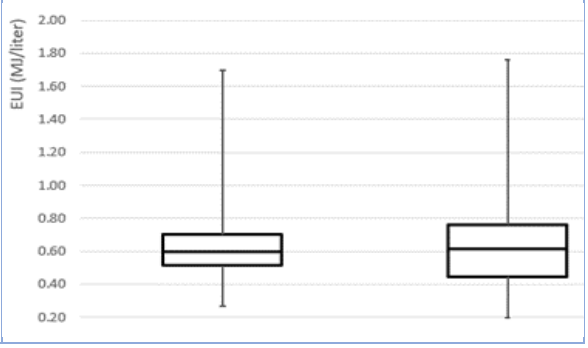
1) Five enumerators handled about 20 companies each.
2) Out of the 99 survey questionnaire emailed to companies, 18% of emails bounced, 36% without response, 27% responded but had yet to receive the completed questionnaire, and 18% responded with submissions.
3) Because of the bounced emails, PIEMPI requested 20 companies to be replaced in their original list.
4) Encountered administrative issues such as:
   - No contact telephone number in the list

- Invalid contact numbers provided
- Change of contact personnel
- Request for more time
- Approval needed from top management
- Signing of non-disclosure agreement

Following PIEMPI's submission of the first set of consolidated and validated Excel files on the survey data for the four sectors on 27 August 2022, ERIA reviewed and analysed the survey data. The following preliminary findings were shared with PIEMPI using the Box and Whisker method.

Table 2.1. Preliminary Analysis and Computation of EUI Based on PIEMPI Data Submitted on 27 August 2022

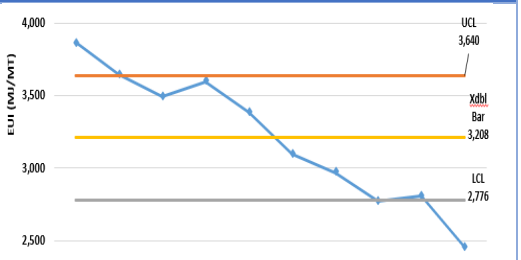
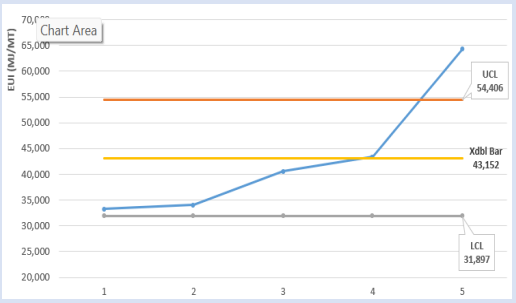
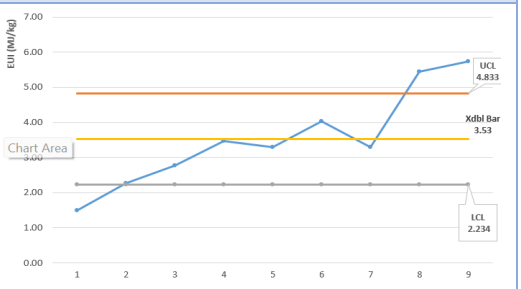
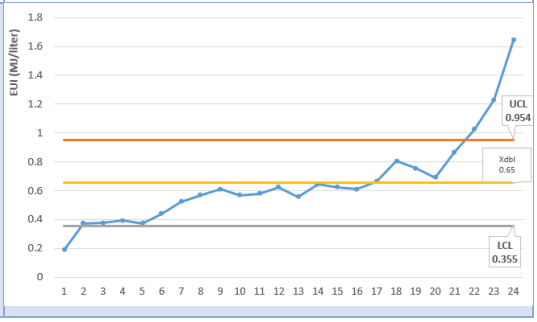
Sector	No. of Samples	Preliminary EUI		Results of Box and Whisker Analysis
		2018	2019	
Cement sector	10	3,174 MJ/MT/y	3,075 MJ/MT/y	
Sugar sector	6	42,565 MJ/MT/y	41,551 MJ/MT/y	
Food sector	9	3.59 MJ/kg/y	3.29 MJ/kg/y	

Sector	No. of Samples	Preliminary EUI		Results of Box and Whisker Analysis
		2018	2019	
Beverage sector	24	0.60 MJ/liter/y	0.62 MJ/liter/y	

Source: Authors, based on PIEMPI's survey data submitted on 27 August 2022.

PIEMPI submitted subsequently updated survey data files on 1 and 2 October 2022. ERIA made another review and analysis, but the X-bar and R-chart analytical tool was used. The results were shared and discussed with PIEMPI in a meeting held on 26 October 2022, as summarised in Table 2.2. The analysis, methodology, and various potential outliers were discussed in this meeting.

Table 2.2. Preliminary Analysis and Computation of EUI based on PIEMPI Data Submitted on 1 and 2 October 2022

	No. of Samples	Preliminary EUI			Results of X-Bar & R-Chart Analysis
		Upper EUI	Average EUI	Lower EUI	
Cement sector	14	3,640 MJ/MT/y	3,208 MJ/MT/y	2,776 MJ/MT/y	
Sugar sector	6	54,406 MJ/MT/y	43,152 MJ/MT/y	31,897 MJ/MT/y	
Food sector	9	4.833 MJ/kg/y	3.53 MJ/kg/y	2.234 MJ/kg/y	
Beverage sector	25	0.954 MJ/litre/y	0.65 MJ/litre/y	0.355 MJ/litre/y	

Source: Authors, based on PIEMPI's survey data submitted on 1 and 2 October 2022.

5.2. Industry Sector Final Outcome Reported by PIEMPI

Based on feedback given by ERIA following their reviews, , PIEMPI made further data validation and analyses. PIEMPI identified some outlier data and reported possible reasons for deviation, as follows:

- Some factories have incomplete processes (e.g. bagging only).
- Some factories have ongoing construction or facility upgrade work.
- The food and beverage sectors revealed a wide range of EUI due to differences in products and processes.

PIEMPI, which did the analyses based on the respective excel sheets, reported the following findings.

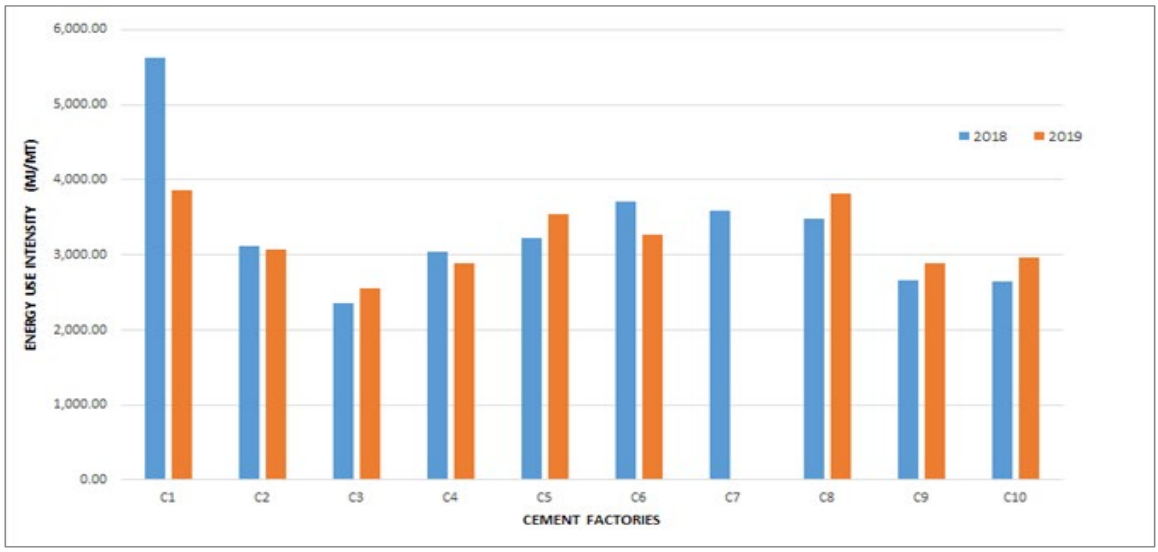
Table 2.3. Number of Survey Samples Collected and Used in the Analyses

	Target Number of Samples	Number of Samples Collected	Number of Samples Used in Analysis & Computation of EUIs
Cement Sector	15	14	10
Sugar Sector	10	7	6
Food Sector	35	16	9
Beverage Sector	40	30	24
Total	**100**	**67**	**49**

Source: PIEMPI (2023).

Cement Sector

Figure 2.1. Cement Factory EUIs Computed from Survey Data



Source: PIEMPI (2023).

Table 2.4. Range of Cement Sector EUI Computed from the Survey Data

	2018	2019	Remarks
Average EUI (MJ/MT)	3,095	3,206	Average value
Median EUI (MJ/MT)	3,118	3,075	Box and Whisker method
Lowest computed EUI (MJ/MT)	2,364	2,548	Box and Whisker method
Highest computed EUI (MJ/MT)	3,706	3,864	Box and Whisker method

Source: PIEMPI (2023).

Table 2.5. Distribution of Energy Usage in the Cement Sector

Energy Source	Percentage of Energy Usage (%)	Remarks
Coal	89	Coal is the most commonly used fuel in all cement factories.
Pet coke	53	Pet coke is the second-most commonly used fuel.
Solid fuel	42	Solid fuel is also commonly used.
Fuel oil	14	Fuel oil is relatively less commonly used.
Electricity	14	Electricity accounts for about 14% of energy usage.
Others	4-11	

Source: PIEMPI (2023).

Table 2.6. Distribution of Energy Used in Cement Production Processes

Production Process	Percentage of Energy Used	Remarks
Heating	82%–97%	Most energy is used for heating in the clinkering process, which converts the raw material into cement.
Mechanical process	3%–18%	Electricity is primarily used in mechanical processes, which account for about 3%–18% of the total energy used.

Source: PIEMPI (2023).

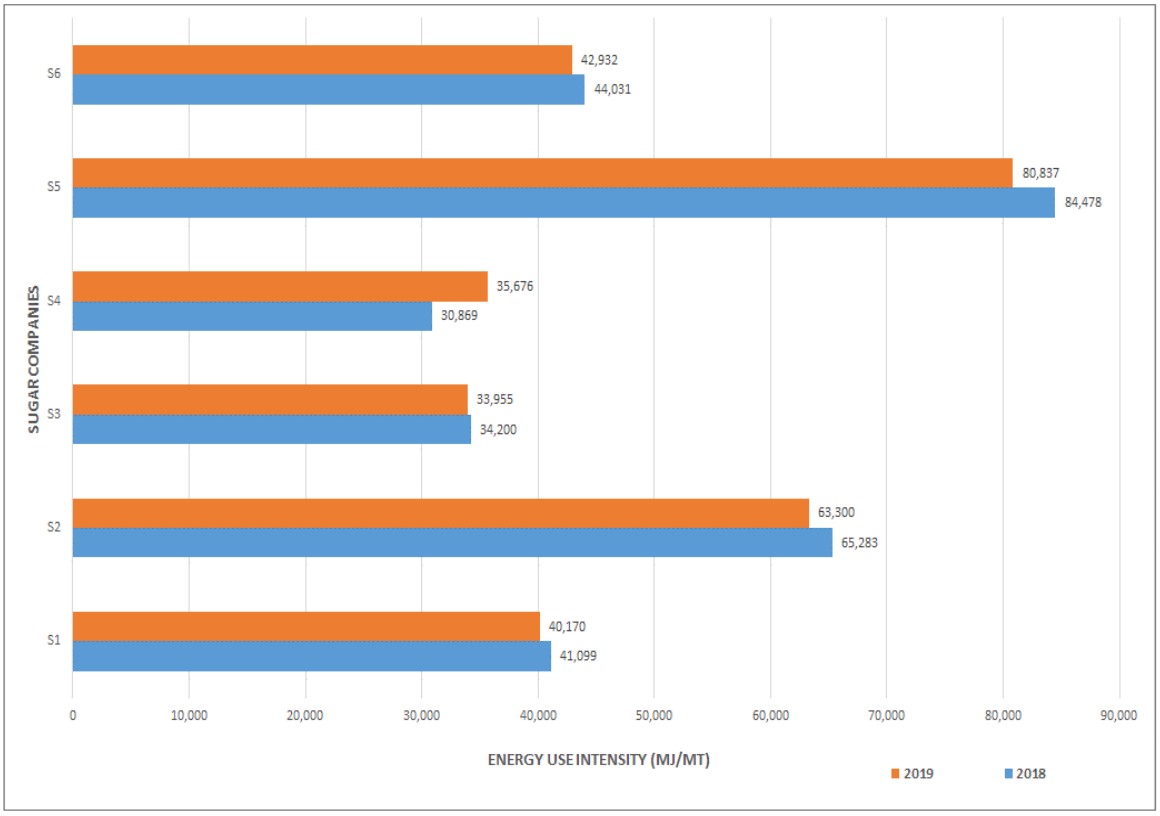
Sugar Sector

Table 2.7. Range of Sugar Sector EUI Computed from Survey Data

	2018	2019	Remarks
Average EUI (MJ/MT)	49,993	49,478	Average value
Median EUI (MJ/MT)	42,565	41,551	Box and Whisker method
Lowest computed EUI (MJ/MT)	30,869	35,676	Box and Whisker method
Highest computed EUI (MJ/MT)	84,478	80,837	Box and Whisker method

Source: PIEMPI (2023).

Figure 2.2. Sugar Factory EUIs Computed from Survey Data



Source: PIEMPI (2023).

Two sugar factories show consistently high EUIs, possibly due to the age of the factory plant equipment. In terms of fuel use, all factories use bagasse as fuel to produce electricity and steam for heating. Diesel and bunker fuel oil usage is minimal compared with other fuels consumed. The distribution of energy used in heating and mechanical processes in the sugar sub-sector is about equal (Table 2.8).

Table 2.8. Distribution of Energy Used in Sugar Production Processes

Production Process	Percentage of Energy Used
Heating	40%–56%
Mechanical	60%–44%

Source: PIEMPI (2023).

Food Sector

Table 2.9. Range of Food Sector EUI Computed from Survey Data

	2018	2019	Remarks
Average EUI (MJ/kg)	2.94	3.5	Average value
Median EUI (MJ/kg)	3.18	3.10	Box and Whisker method
Lowest computed EUI (MJ/kg)	1.42	1.58	Box and Whisker method
Highest computed EUI (MJ/kg)	4.25	5.74	Box and Whisker method

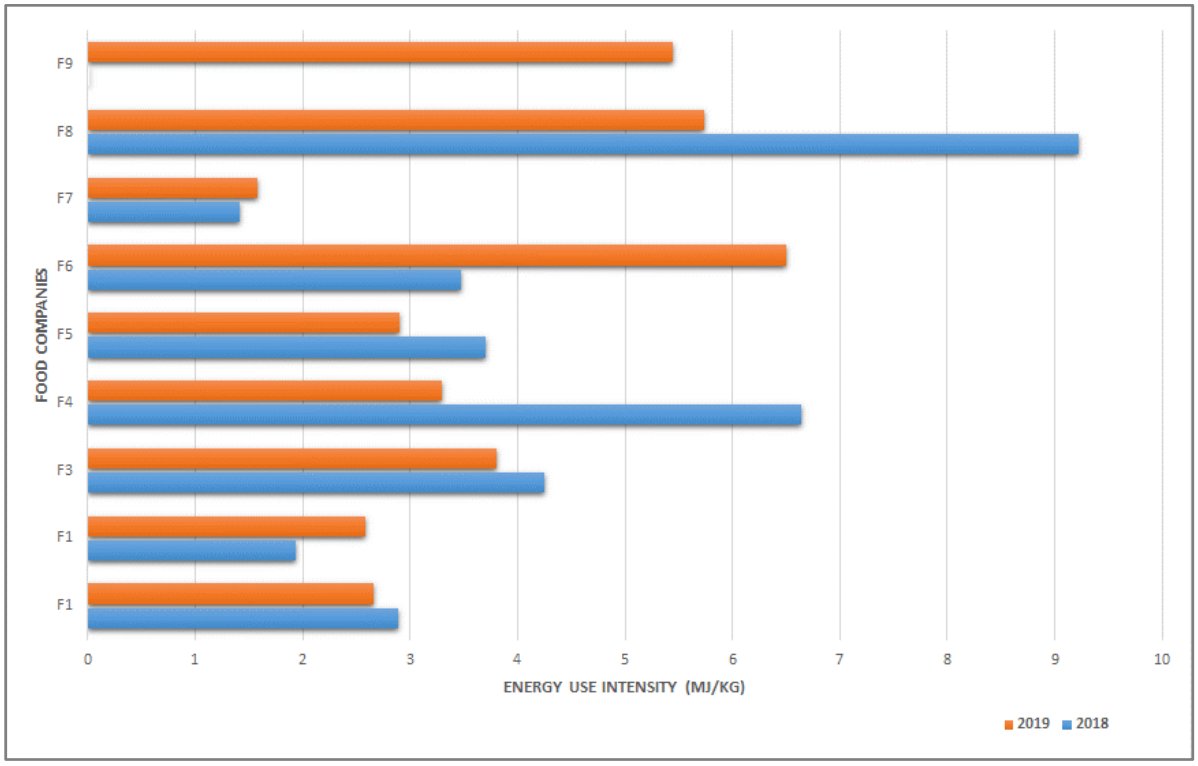
Source: PIEMPI (2023).

Table 2.10. Variations in Food Sector EUIs Due to Product Variations

Product Type	EUI (MJ/kg)	Remarks
Food snack (chips, etc.)	1.42–1.58	Consistent range
Bakery products	1.94–4.25	Wide range due to different bakery products
Varied products	5.44–5.74	Plants produce a variety of products

Source: PIEMPI (2023).

Figure 2.3. Food Sector EUIs Computed from Survey Data



Source: PIEMPI (2023).

Table 2.11. Share of Energy Usage by Percentages in Food Sector

Type of Energy Source	Range of Energy Use by Percentage (%)	Remarks
Electricity	20–72	
Fuel	80-28	Most plants used diesel, coal, and liquified petroleum gas

Source: PIEMPI (2023).

Table 2.12. Distribution of Energy Used in Production Processes of the Food Sector

Production Process	Range of Energy Use (%)	Remarks
Heating	27–81	Varied range due to products. Energy is mainly used for heating and mechanical processes.
Mechanical	73–19	Varied range due to products. Energy is mainly used for heating and mechanical processes.

Source: PIEMPI (2023).

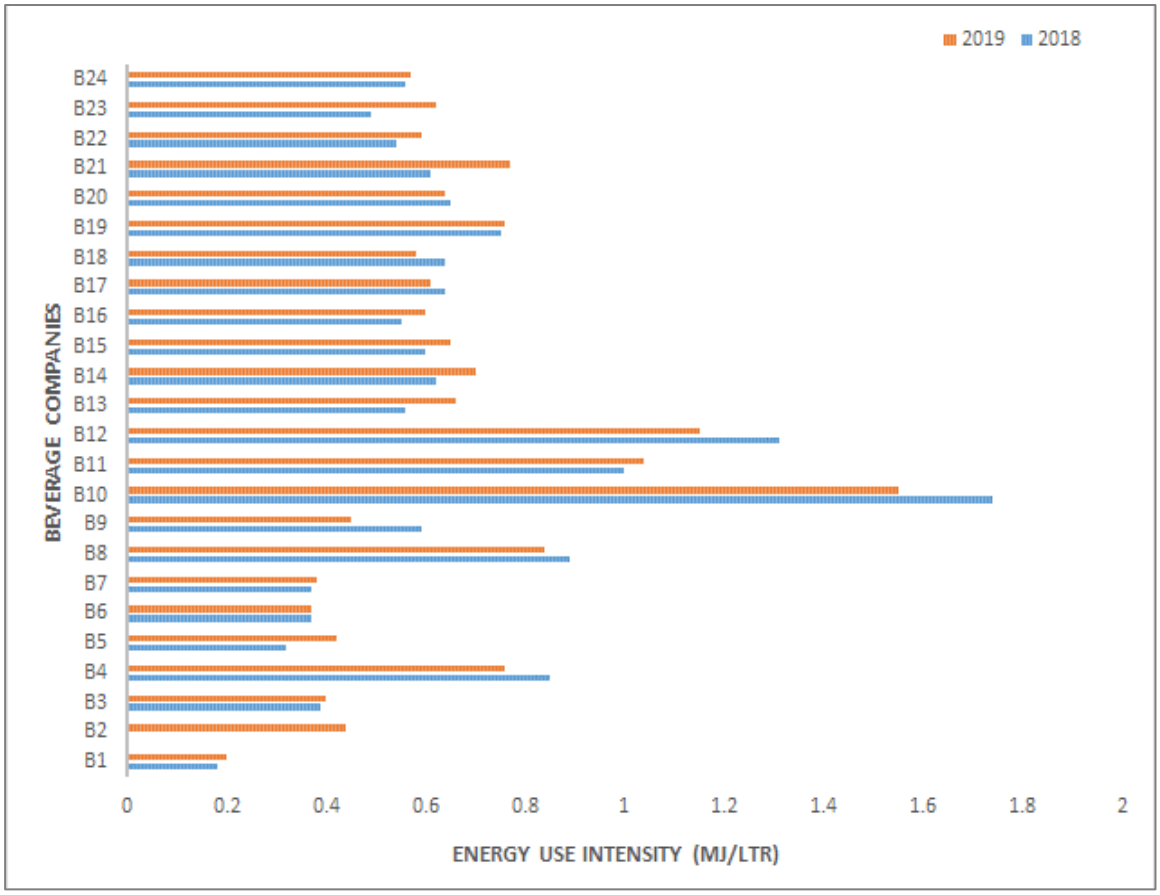
Beverage Sector

Table 2.13. Range of Beverage Sector EUIs Computed from Survey Data

	2018	2019	Remarks
Average EUI (MJ/litre)	0.66	0.66	Average value
Median EUI (MJ/litre)	0.60	0.62	Box and Whisker method
Lowest computed EUI (MJ/litre)	0.18	0.2	Box and Whisker method
Highest computed EUI (MJ/litre)	1.74	1.55	Box and Whisker method

Source: PIEMPI (2023).

Figure 2.4. Beverage Sector EUIs Computed from Survey Data



Source: PIEMPI (2023).

Table 2.14. Variations in Food Sector EUIs Due to the Nature of Products

Product Type	EUI (MJ/litre)	Remarks
Bottled water	0.18–0.44	
Soft drinks	0.49–0.77	
Beer	1.0–1.04	
Energy drinks	0.84–1.74	
Mixed beverage & food	1.15–1.31	Some plants produce mixed beverage and food, resulting in a higher EUI range.
Soya-based drinks	8.4 – 8.42	This type of product entails cooking soya beans that consume more energy than other beverage production.

Source: PIEMPI (2023).

Table 2.15. Share of Energy Usage by Percentages in Beverage Sector

Type of Energy Source	Range of Energy Use by Percentage (%)	Remarks
Electricity	25–85	Range of energy use due to process variations
Fuel	75–15	Most plants used diesel, coal, and blended fuel (diesel and bunker oil) for process heating. Companies B3 to B7 mainly use diesel, while B13 to B24 use blended fuel.

Source: PIEMPI (2023).

Table 2.16. Distribution of Energy Used in the Production Processes of the Beverage Sector

Production Process	Range of Energy Use (%)	Remarks
Heating	15–74	- Range of heating energy use due to process variations - Energy is mainly used for heating, cooling, and mechanical processes.
Cooling/Mechanical	85–26	

Source: PIEMPI (2023).

5.3. Summary of Industry Sector Final Outcome

Based on the average median values of 2018 and 2019 EUIs computed as the representative EUIs for the cement, sugar, food, and beverage sectors, Table 2.17 summarises the EUIs compared with the available target or benchmark values from other countries.

Table 2.17. Summary and Comparison of EUIs

	EUI Computed from the Survey Data	EUI Target Values of Other Countries	Source
Cement	3,097 MJ/MT/y	3,220 MJ/MT/y	ECCJ, Japan
Sugar	42,058 MJ/MT/y	37,867 MJ/MT/y	Indonesia Thinzar and Haryanto (2021)
Food	3.14 MJ/kg	N/A	—
Beverage	0.61 MJ/litre	N/A	—

Source: Compiled by the authors, based on PIEMPI and sources as quoted.

Table 2.17 shows that the EUI values computed from the survey data of the Philippines' cement and sugar sectors are within a reasonable range of values compared with the target values of Japan in the cement and sugar sectors for Indonesia. Based on the findings of the Philippine Innovation Entrepreneurship Mission, Inc. (PIEMI), it is more realistic to establish EUI values under further breakdowns in classification for the food and beverage sectors due to the wide range of products involving many variations in production processes. Therefore, PIEMI's findings show that subdividing the broad range of products in the food and beverage sectors is more meaningful, as suggested in Tables 2.10 and 2.14.

PIEMI's findings also showed that the primary energy sources are electricity and fuel, comprising mainly diesel, coal, and blended fuels. The energy sources are used primarily for heating and mechanical production processes, except for the beverage sector, where cooling is required.

PIEMI encountered the following challenges:

1) PIEMPI encountered Indifference from targeted respondent companies. Complete with a formal letter from the PDOE, many respondent companies ignored PIEMPI's efforts to establish a connection by not replying to emails or answering calls, or blocking off emails. This created so much delay in completing the survey project.

   Some company data were unclear and could not be reconciled. PIEMPI's efforts to further clarify the data submitted encountered no response.

   PIEMPI surveyed more than 200 companies in three batches to be able to complete the survey project. This project was finalised, thanks to the PDOE's assistance and the openness of ERIA to the encountered problems.

2) Some survey data submitted were unreliable because they could not be used for computation and analysis of their energy use performance. Some data or information are erroneous, incomplete, or inconsistent with what is expected of the respondents' nature of operation.

3) Not all companies in the cement sector have the complete process of producing cement, from clinkering to finished cement. A few companies undertake only one or more stage/s of the process, which hinders PIEMPI's effort to reconcile the data or information obtained.

6. Commercial Sector Outcome

6.1. Commercial Sector Preliminary Outcome

The MPA reported the following in their preliminary report dated 10 May 2022:

1) Based on a list of 100 companies received from the PDOE on 19 April 2022, an additional list of 100 companies on 22 April 2022, and an additional list of 32 companies to replace erroneous entries, the MPA reported the survey response situation as follows:

   a) Companies responded: 79 (However, out of the 79 companies responded, only 23% fully completed the survey questionnaire; 13% completed 50%; 64% completed less than 50%).
   b) Companies without response: 22
   c) Number of calls via telephone and/or mobile phone: 32

d) Additional emails after the first emails: 16

2) Issues encountered by the MPA at the initial stage of the survey:

   a) Preparation of master list and communication

      – Preparation and updating of the master list could be improved to expedite the survey implementation. On week 2 of the rollout, enumerators were still catching up on getting the correct contacts.
        - Contact details were not updated.
        - Duplication of records

   b) Several companies claimed that they did not receive emails from the PDOE.

   c) Enumerators needed to follow up with respondents on data validation due to erroneous data entries such as:
      - GFA discrepancies not matching the building footprint.
      - Operating days are given as 1 or 1.5 days/week.
      - Data for electricity and water consumption provided were incomplete.

3) Most companies selected for the survey knew about the EEC Law and practices and had submitted annual reports. Most companies were willing to contribute and participate in the survey. However, due to a lack of knowledge about the energy consumption survey, the enumerators must get buy-in or cooperation from the respondents, especially in the initial interviews. The enumerators needed to explain the objectives, scope, contents, and methods of filling in survey forms. Some companies had restrictions on accessing external websites. The MPA provided Excel format directly to these companies.

The MPA reported the following in a subsequent progress report submitted in August 2022:

1) The MPA developed a survey tool form based on the initial Excel file provided by ERIA. The survey tool form was complete with a link sent directly to the selected companies. The first draft was shown to energy practitioners for feedback before the deployment. Due to the COVID-19 restrictions, the survey was conducted through digital or online platforms.

2) The survey tool form comprised four parts for better information organisation. The form allowed respondents to review, save, exit after each part, and return to their saved work at their convenience. Additional versions of the survey tool were developed to accommodate respondents who had difficulty in accessing the form online due to company policies and security firewalls.

   Part 1 – Introduction and General Information
   Part 2 – Types of Fuels Used
   Part 3 – Air-Conditioning Section
   Part 4 – Lighting Section

3) Eight enumerators were trained and deployed to conduct the survey, including engagement with the respondents and providing technical support during the data-gathering activities.

Some strategies used in the engagement with respondents were:

- Group orientation sessions were conducted for engineers, energy managers, and building management focal persons who helped convey instructions and gather data from their subordinates.
- Enumerators guided respondents in filling out the survey tool forms.

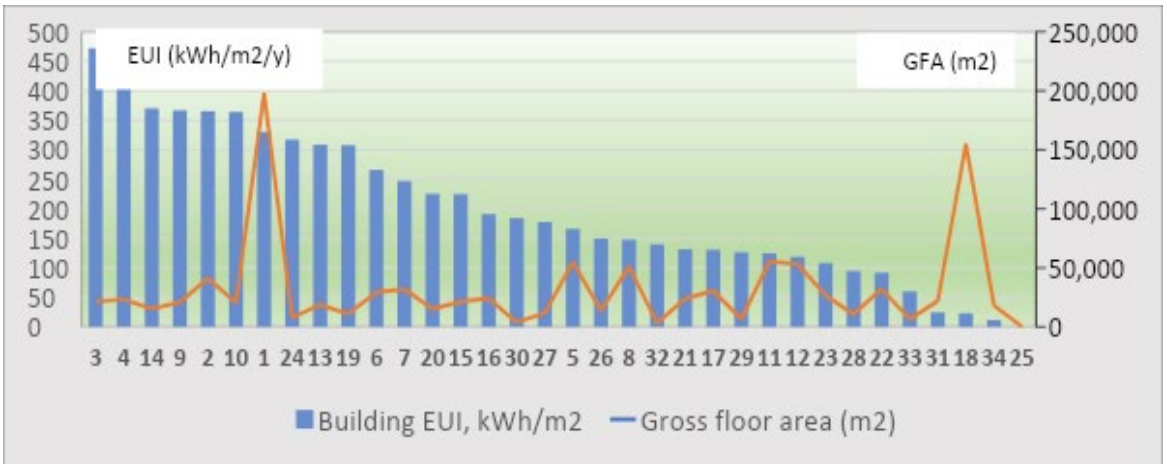
4) The MPA intended to achieve a sample size of 30 companies in retail and 30 in office buildings, and the balance in hotels and condominiums. However, the survey questionnaires were not formulated to conduct such surveys. As a result, data was insufficient to complete the survey and analyse hotels and condominiums. Hence, this part of the survey not originally planned for was aborted.

5) Out of the 200 companies in the PDOE lists, the MPA reached out to 185 companies, 92 of which were successfully contacted and responded (5 additional companies were later added to make up a total of 97 respondents). However, 93 companies (or 46.5%) were removed or excluded from the list due to the following reasons:

- Did not respond: 51 companies
- Decline to participate: 13 companies
- Double entries: 22 companies
- Disqualified: 7 companies

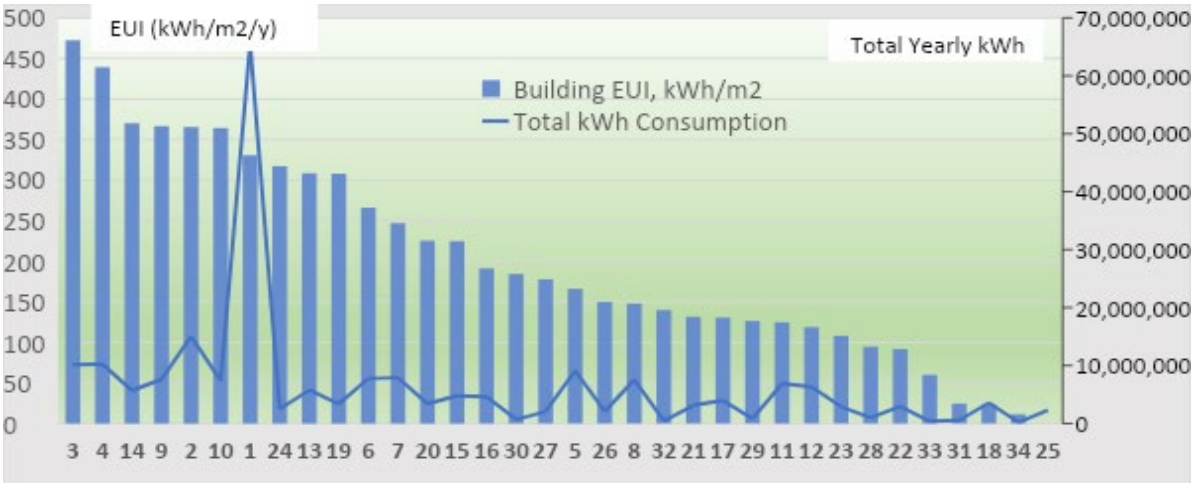
The MPA presented its survey results on office and retail buildings based on 2018 and 2019 data in a meeting held on 15 July 2022.

Figure 2.5. Computed Office Building EUI vs GFA Based on 2018 Data



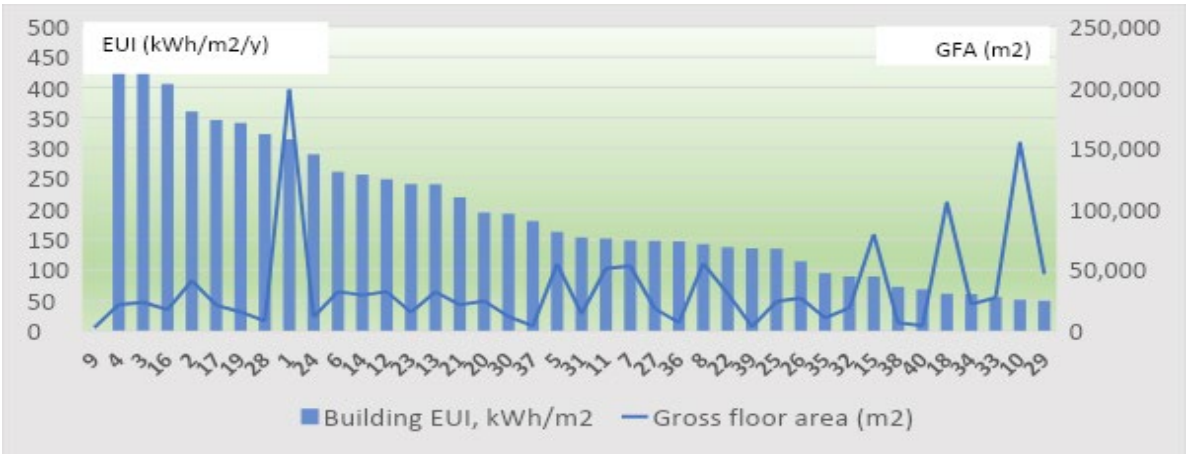
Source: MPA's PowerPoint report presented in the 15 July 2022 meeting.

Figure 2.6. Computed Office Building EUI vs Total Yearly kWh Based on 2018 Data



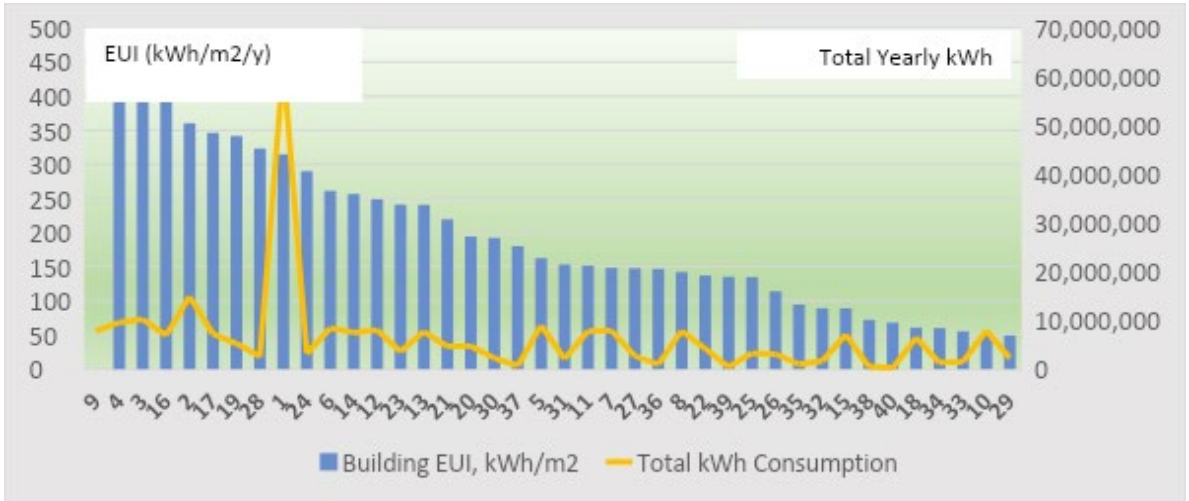
Source: MPA's PowerPoint report presented in the 15 July 2022 meeting.

Figure 2.7. Computed Office Building EUI vs GFA Based on 2019 Data



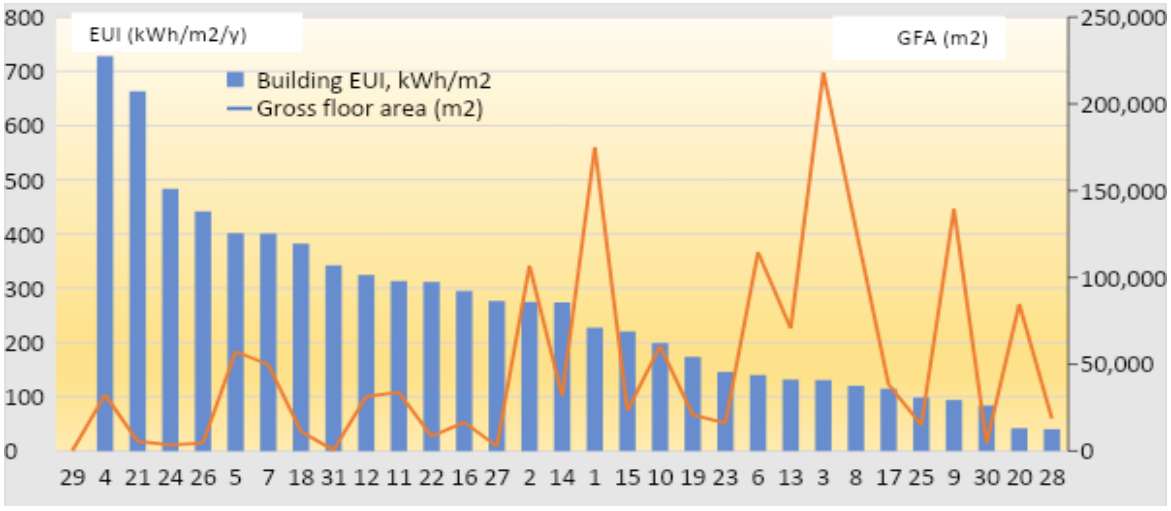
Source: MPA's PowerPoint report presented in the 15 July 2022 meeting.

Figure 2.8. Computed Office Building EUI vs Total Yearly kWh Based on 2019 Data



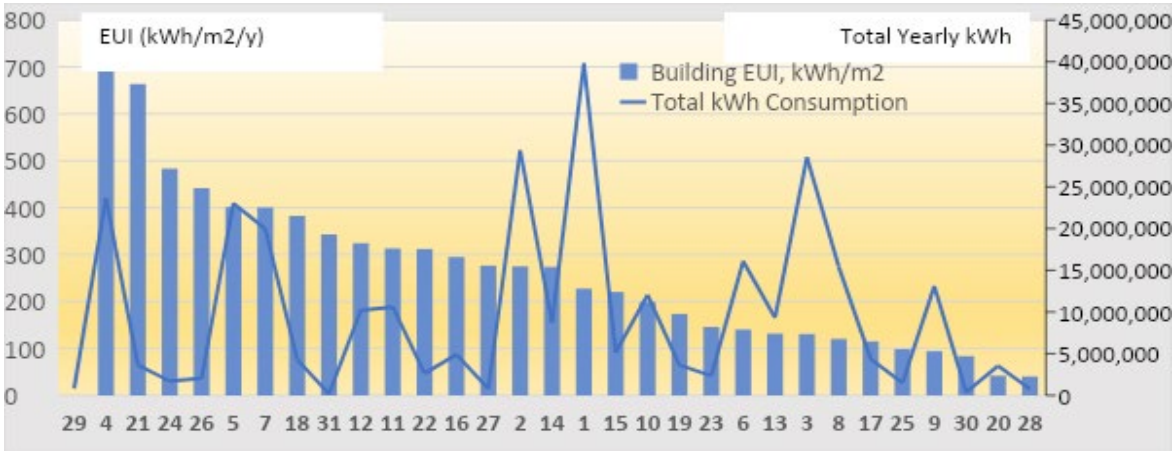
Source: MPA's PowerPoint report presented in the 15 July 2022 meeting.

Figure 2.9. Computed Retail Building EUI vs GFA Based on 2018 Data



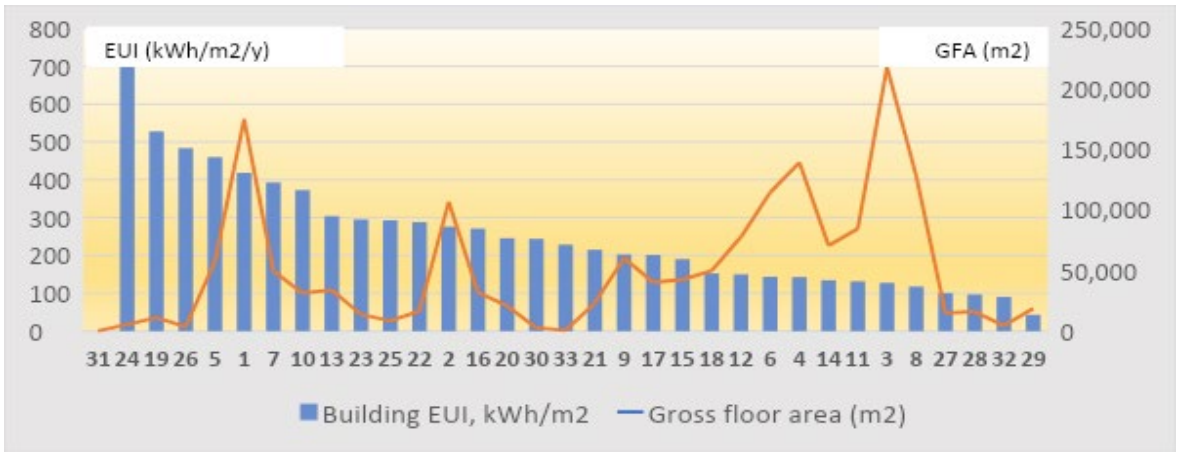
Source: MPA's PowerPoint report presented in the 15 July 2022 meeting.

Figure 2.10. Computed Retail Building EUI vs Total Yearly kWh Based on 2018 Data



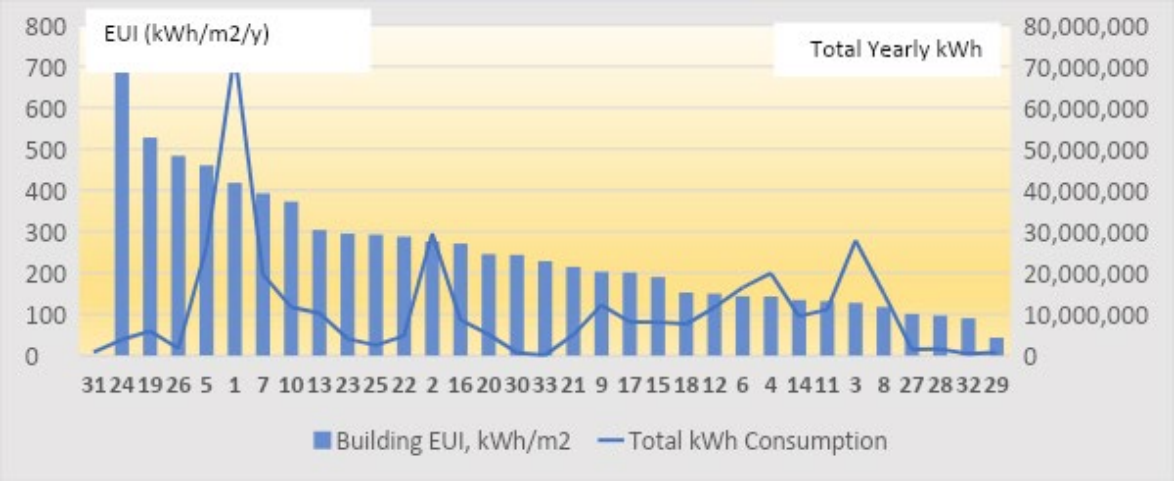
Source: MPA's PowerPoint report presented in the 15 July 2022 meeting.

Figure 2.11. Computed Retail Building EUI vs GFA Based on 2019 Data



Source: MPA's PowerPoint report presented in the 15 July 2022 meeting.

Figure 2.12. Computed Retail Building EUI vs Total Yearly kWh Based on 2019 Data



Source: MPA's PowerPoint report presented in the 15 July 2022 meeting.

The initially computed EUIs in Figures 2.5 to 2.12 show a wide range of EUI variation for both office and retail buildings. The GFA and total yearly energy consumption data were also inconsistent. The extreme values of GFA and total yearly consumption were highlighted in the meeting as potential sources of erroneous data. The MPA was advised that such extreme GFA values and total annual energy consumption would warrant further effort in reviewing and validating the data. In addition, these initially computed EUIs were not normalised to reflect the average building operating hours. For example, the range of office and retail business operating hours recorded was 40–168 hours/week was the same, but with differences in the skewed distribution of data. The average office operating hours recorded in the survey was 124 hours/week, while retail business operating hours was 94 hours/week. The standard 2,000 hours/year for office buildings aligned with the ASEAN Energy Award was also considered. The normalised EUI values could then be compared with other buildings of the same category.

The MPA explained its findings during the initial stage of the survey, as follows:

1) Some contact persons or appointed energy managers and staff appeared to need to strengthen data collection and quality control because some data on buildings, building facilities, and energy parameters were lacking or undocumented.

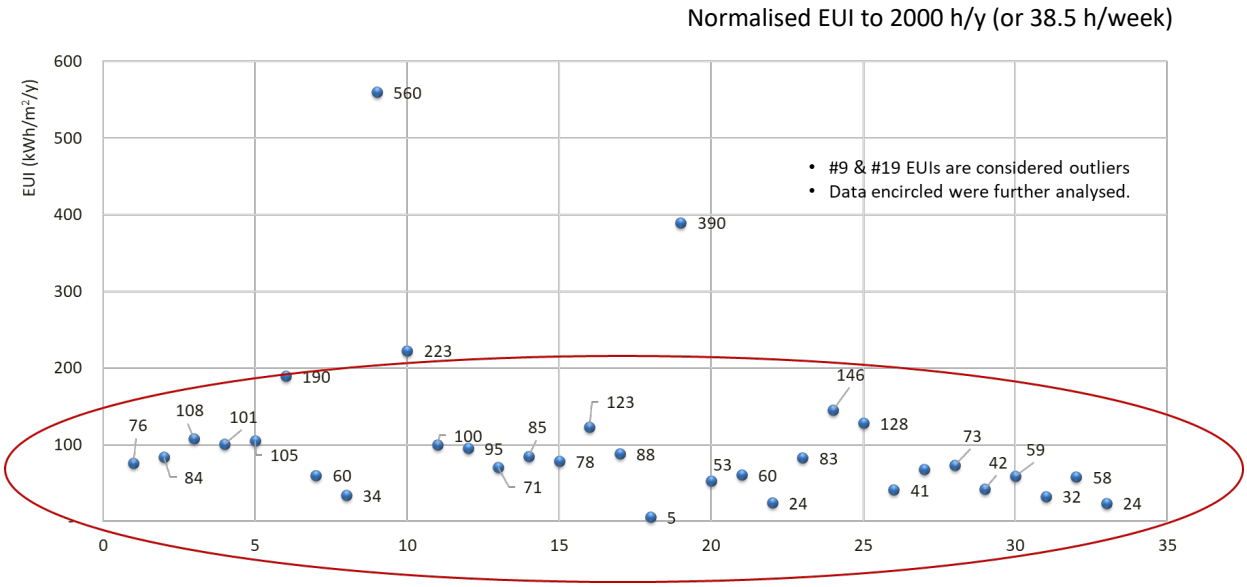
2) Most respondents needed to improve their awareness of building energy performance on energy baselining, use of energy performance indicators, and establishing benchmarking, which explained the low quality and inconsistent data provided in the survey.

3) There was a need to improve data reliability on significant energy users, energy balance, and the capability of showing or presenting energy information, including energy performance data. This showed opportunities to improve energy management processes and systems in companies.

4) The functions of some designated establishments in the Philippines' commercial sector are multi-use, multipurpose, and flexible, as they might coexist in the same building and even on the same floors. This makes the sectoral industry energy consumption survey challenging and complex.

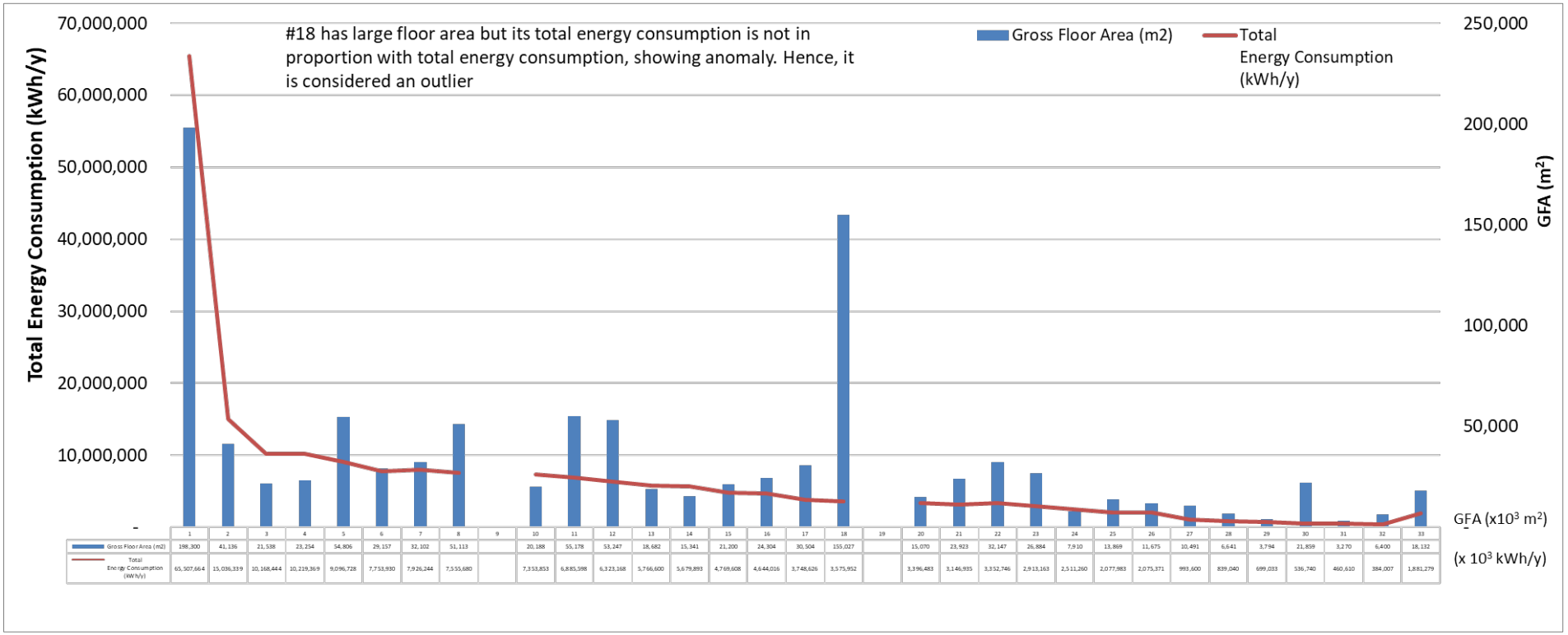
Following MPA's submission of its final report on 2 September 2022 and consolidated data on 7 September 2022, ERIA conducted a review and analysis, presented and explained in an online meeting on 4 October 2022. In addition to the anomalies in the GFA and total yearly energy consumption data highlighted above, Figures 2.13, 2.14, and 2.15 identified the outlier EUI data.

Figure 2.13. Illustration of 2018 Office Data Validation Exercise #1



Source: Author, based on MPA's submission of consolidated data in September 2022.

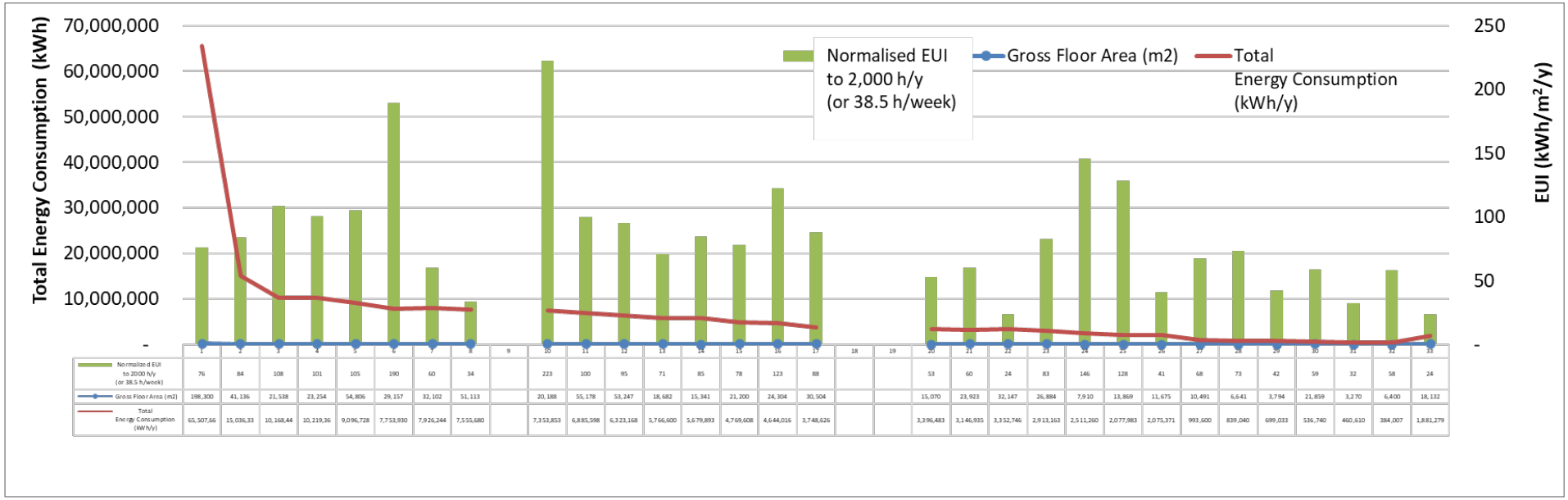
Figure 2.14. Illustration of 2018 Office Data Validation Exercise #2



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Gross Floor Area (m2)	198,300	41,136	21,538	23,254	54,806	29,157	32,102	51,113		20,188	55,178	53,247	18,682	15,341	21,200	24,304	30,504	155,027		15,070	23,923	32,147	26,884	7,910	13,869	11,675	10,491	6,641	3,794	21,859	3,270	6,400	18,132
Total Energy Consumption (kWh/y)	65,507,664	15,036,339	10,168,444	10,219,369	9,096,728	7,753,930	7,926,244	7,555,680		7,353,853	6,885,998	6,323,168	5,766,600	5,679,893	4,769,608	4,644,016	3,748,626	3,575,952		3,396,483	3,146,935	3,352,746	2,913,163	2,511,260	2,077,983	2,075,371	993,600	839,040	699,033	536,740	460,610	384,007	1,881,279

Source: Author, based on MPA's submission of consolidated data in September 2022.

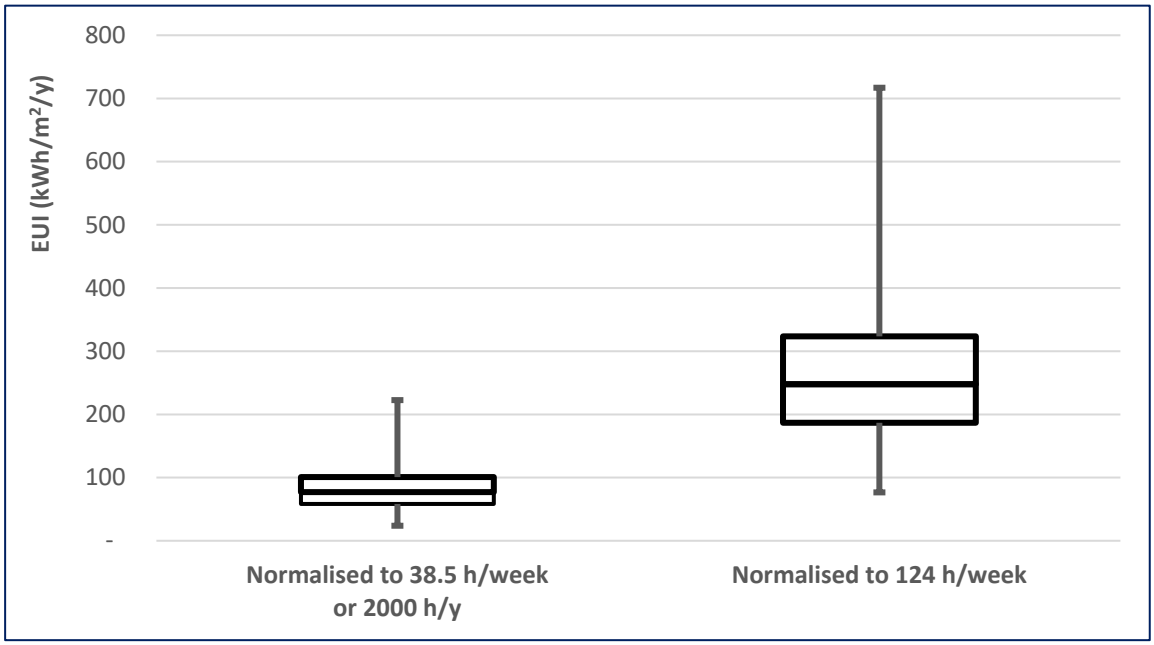
Figure 2.15. Illustration of 2018 Office Data Validation Exercise #3



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Normalized EUI to 2000 h/y (or 38.5 h/week)	76	84	108	101	105	190	60	34		223	100	95	71	85	78	123	88			53	60	24	83	146	128	41	68	73	42	59	32	58	24
Gross Floor Area (m2)	198,300	41,136	21,538	23,254	54,806	29,157	32,102	51,113		20,188	55,178	53,247	18,682	15,341	21,200	24,304	30,504			15,070	23,923	32,147	26,884	7,910	13,869	11,675	10,491	6,641	3,794	21,859	3,270	6,400	18,132
Total Energy Consumption (kWh/y)	65,507,66	15,036,33	10,168,44	10,219,36	9,096,728	7,753,930	7,926,244	7,555,680		7,353,853	6,885,598	6,323,168	5,766,600	5,679,893	4,769,608	4,644,016	3,748,626			3,396,483	3,146,935	3,352,746	2,913,163	2,511,260	2,077,983	2,075,371	993,600	839,040	699,033	536,740	460,610	384,007	1,881,279

Note: 3 sets of data (#9, 18, & 19) were excluded in the estimation of EUI.
Source: Authors, based on MPA's submission of consolidated data in September 2022.

Figure 2.16. Comparison of Average EUI from 2018 Office Data Based on the Normalisation of Average Operating Hours to 38.5 h/week and 124 h/week Using the Box and Whisker Method, Prepared by ERIA

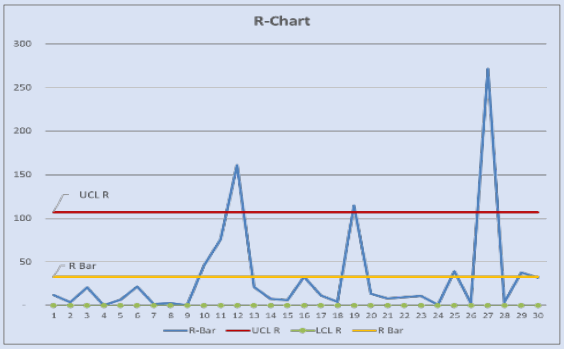
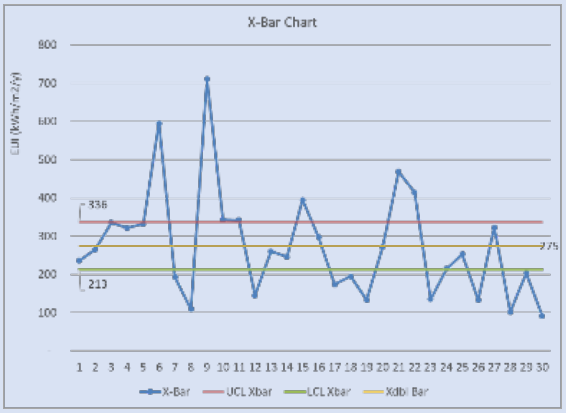
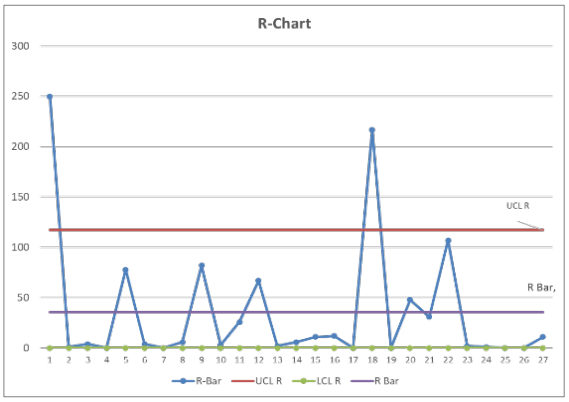
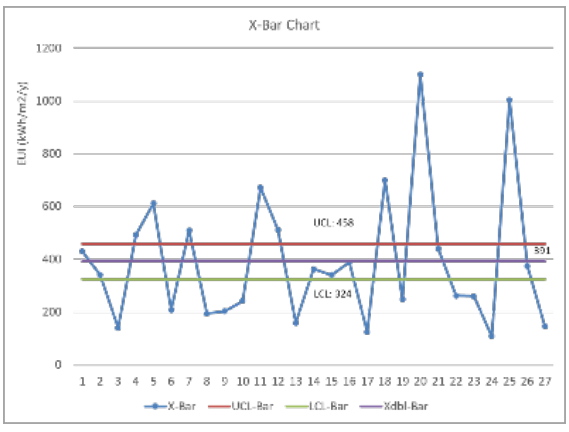


Source: Authors, based on MPA's submission of consolidated data in September 2022.

Figure 2.16 shows the results of using the Box and Whisker Plot method to estimate and compare the median values of the EUI, based on the normalisation of average operating hours of 38.5 hours/week (or 2,000 hours/y, based on the ASEAN Energy Award) and 124 hours/week, which was the average operating hours derived from respondents' survey data. Based on the average operating hours in the survey data, ERIA believed that 124 hours/week would reflect more accurately the energy consumption data obtained. Hence, the final analysis and computation of the EUIs would be based on the normalisation of operating hours of 124 hours/week derived from the survey data. The Box and Whisker method is useful if the yearly median value of the EUI is to be established. Yearly EUI data can be plotted in graphs for monitoring purposes, like Figure 1.6 on Singapore's EUI trend when sufficient yearly EUI data are established for various building categories.

In addition to the Box and Whisker Plot method, ERIA showed the MPA an alternative statistical analysis method in X-bar and R-chart for estimating EUIs during the online meeting on 4 October 2022. Table 2.18 summarises ERIA's estimation of average EUI for the office and retail buildings based on the 2018 and 2019 survey data, normalised to the respective average operating hours of 124 hours/week for office buildings, and 94 hours/week for retail buildings.

Table 2.18. Estimation of Average EUI from 2018 and 2019 Data Using X-Bar and R-Chart Method, Prepared by ERIA

	Computed EUI (kWh/m²/y)	Results of X-Bar and R-Chart Analysis
Office buildings	Based on 2018 & 2019 data and from X-Bar chart: Median EUI value = 275 kWh/m²/y Lower Control Limit (LCL) = 213 kWh/m²/y Upper Control Limit (UCL) = 336 kWh/m²/y	 
Retail buildings	Based on 2018 & 2019 data and from X-Bar chart: Median EUI value = 391 kWh/m²/y Lower Control Limit (LCL) = 324 kWh/m²/y Upper Control Limit (UCL) = 458 kWh/m²/y	 

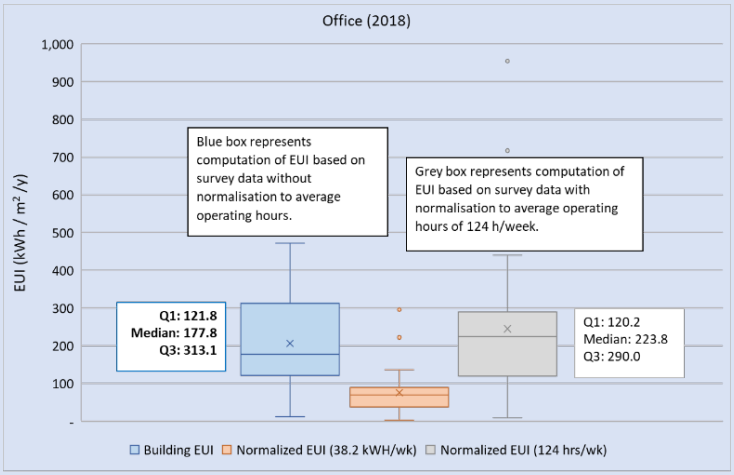
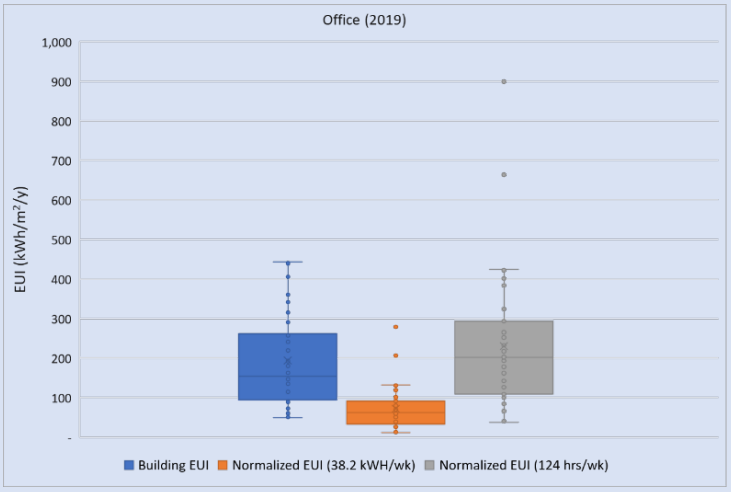
Source: Author, based on MPA's submission of consolidated data in September 2022.

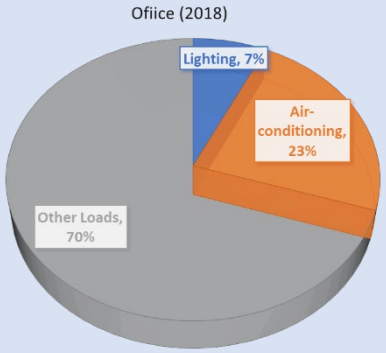
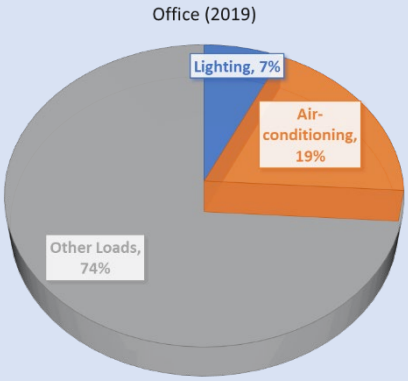
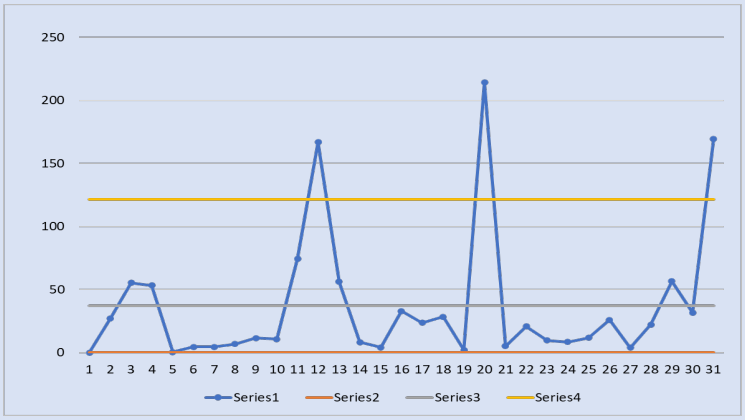
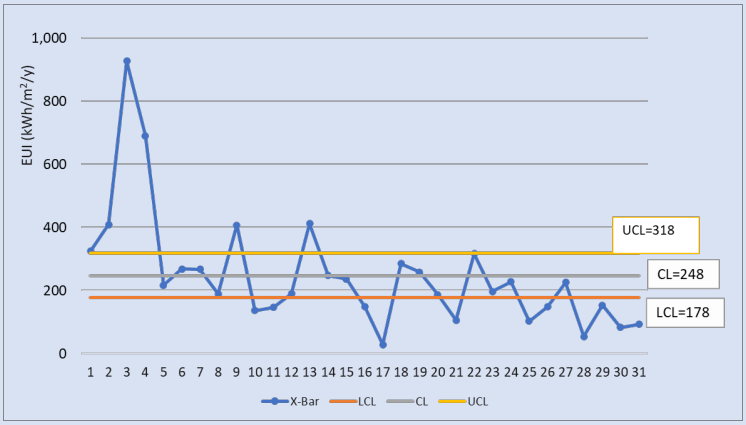
6.2. Commercial Sector Final Outcome per MPA Report

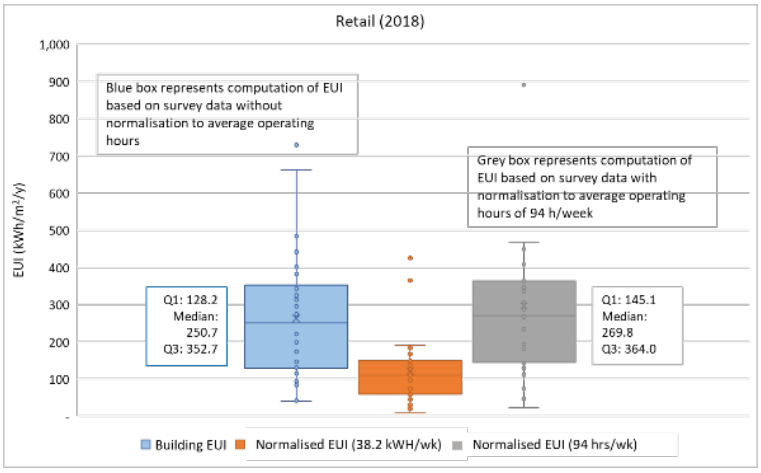
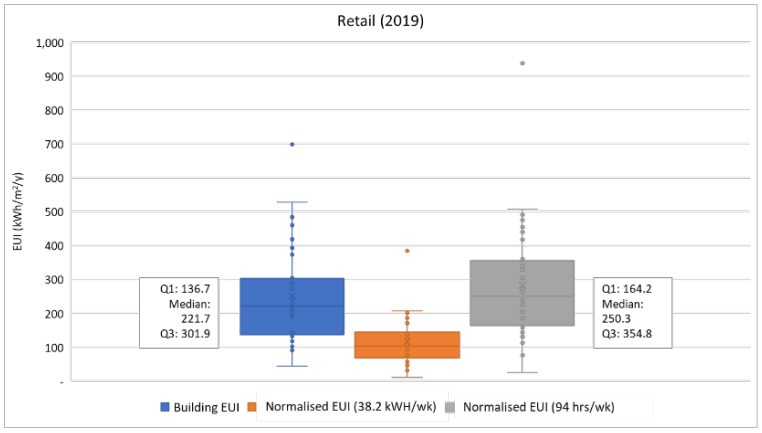
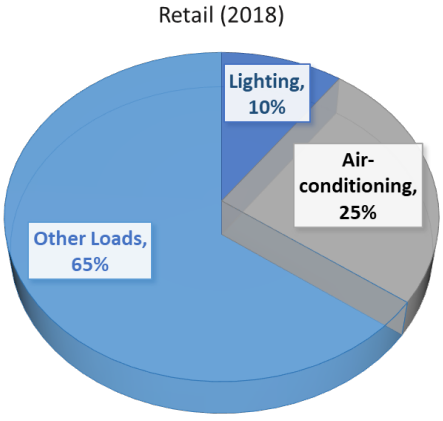
Following the review and discussion on 4 October 2022, the MPA submitted its final report on 20 December 2022. MPA's final analysis and computation of the EUIs are summarised in Table 2.19. The final computation of office building EUI is based on normalised operating hours of the average operating hours of 124 hours/week per office sector respondent, while that of retail buildings is based on the average operating hours of 94 hours/week per retail sector respondent. Table 2.19 summarises MPA's findings on estimating average EUIs with ERIA's input on the final analysis, and percentage shares of energy usage, based on the 2018 and 2019 survey data.

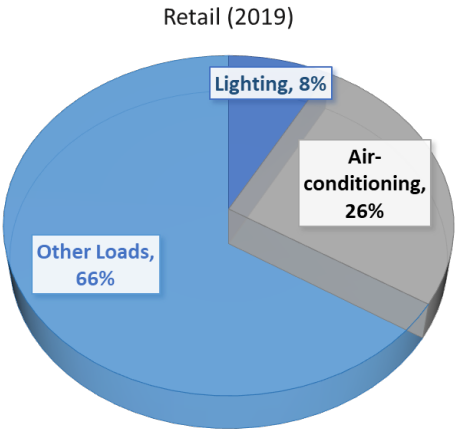
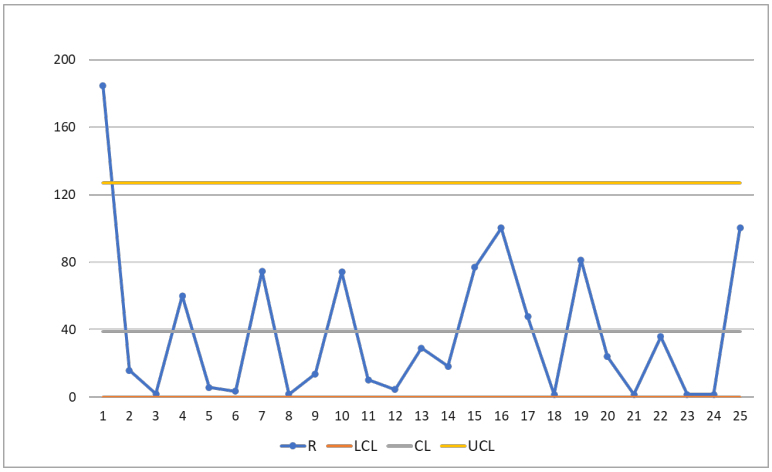
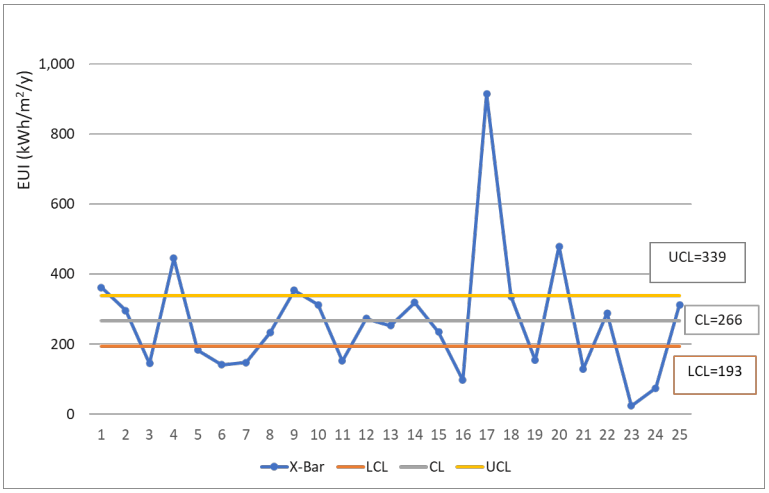
The MPA also collected data on the age and occupancy rates of office and retail buildings. However, it reported that correlations between the EUI and building age and occupancy rates for both types of buildings were weak to indiscernible.

Table 2.19. Final Analysis and Computation of EUIs Reported by the MPA

	Computed EUI (kWh/m²/y)	Results of Box & Whisker Plot Analysis
Office building	**Box and Whisker Plot Analysis:** Based on the survey data with normalization of average operating hours of 124, the median value of the 2018 office building EUI is about 224 kWh/m²/y. Based on the survey data with normalisation of operating hours, the median value of the 2019 office building EUI is about 202 kWh/m²/y.	 

	Computed EUI (kWh/m²/y)	Results of Box & Whisker Plot Analysis
	Percentage share of energy usage in office buildings in 2018: – Lighting: 7% – Air conditioning: 23% – Other loads: 70% Comment: The percentage share of air-conditioning load is unexpectedly low. Percentage share of energy usage in office buildings in 2019: – Lighting: 7% – Air conditioning: 19% Other loads: 74% Comment: The percentage share of air-conditioning load is unexpectedly low. **X-Bar and R-Chart analysis of 2018 and 2019 office data:** The median value of the office EUI data is 248 kWh/m²/y. **No. of samples used in computing for office EUIs:** **2018: 34** **2019: 40**	   

	Computed EUI (kWh/m²/y)	Results of Box & Whisker Plot Analysis
Retail building	**Box and Whisker Plot Analysis:** Based on the survey data with normalisation to average operating hours to 94 h/week, the median value of the 2018 retail building EUI is about 270 kWh/m²/y.	
	Based on the survey data with normalisation to average operating hours of 94 h/week, the median value of the 2019 retail building EUI is about 250 kWh/m²/y.	
	Percentage share of energy usage in retail buildings in 2018: – Lighting: 10% – Air conditioning: 23% Other loads: 65% Comment: The percentage share of air-conditioning load is unexpectedly low.	

	Computed EUI (kWh/m²/y)	Results of Box & Whisker Plot Analysis
	Percentage share of energy usage in retail buildings in 2019: – Lighting: 8% – Air conditioning: 26% Other loads: 66% Comment: The percentage share of air-conditioning load is unexpectedly low.	
	X-Bar and R-Chart analysis of 2018 and 2019 retail data: The median value of the retail building EUI data is 266 kWh/m²/y.	 
No. of Samples	**No. of samples used in computing for retail building EUIs:** **2018: 31** **2019: 33**	

Source: Author based on MPA's Excel file submitted on 20 December 2022.

Table 2.20. Number of Samples Collected and Used in Analysis

	Target Number of Samples	Number of Samples Collected	Number of Samples Used in Analysing and Computing EUIs
Office buildings	No breakdown was reported.	No breakdown was reported.	2018: 34 2019: 40
Retail buildings	No breakdown was reported.	No breakdown was reported.	2018: 31 2019: 33
Total	100	97 (Including condominiums)	2018: 65 2019: 73

Source: Authors, based on MPA's reports submitted in August and December 2022.

6.3. Summary of Commercial Sector Final Outcome

Since the main objective of this survey is to establish EEIs or EUIs for the commercial office and retail building sectors, this section focuses on the outcome of the analysis and computation of EUIs. Table 2.21 summarises the results based on the analyses and calculations of EUIs discussed in sections 5.1 and 5.2.

Table 2.21. Summary of EUIs Estimated by MPA and ERIA Based on the 2018–2019 Survey Data

	EUI Computed from Survey Data (Normalised to Average Operating Hours Derived from the Survey) by the MPA	EUI Computed from Survey Data (Normalised to Average Operating Hours Derived from the Survey) by ERIA	Remarks
Office buildings	Box and Whisker method: 2018: 224 kWh/m^2/y 2019: 202 kWh/m^2/y X-Bar and R-Chart method: 248 kWh/m^2/y.	X-Bar and R-Chart method: 275 kWh/m^2/y ERIA's estimation using the Box and Whisker method was 246 kWh/m^2/y (Figure 2.16).	The difference between MPA's and ERIA's EUI computations is due to the determination of outlier data. The MPA included EUI values < 100 kWh/m^2/y, which are considered unrealistic.

Retail buildings	Box and Whisker method: 2018: 270 kWh/m^2/y 2019: 250 kWh/m^2/y X-Bar and R-Chart method: 266 kWh/m^2/y.	X-Bar and R-Chart method: 391 kWh/m^2/y	Similarly, the difference between MPA's and ERIA's EUI computations is due to the determination of outlier data. The MPA included EUI values < 100 kWh/m^2/y, which are considered unrealistic.

Source: Authors.

The Building and Construction Authority (BCA), Singapore, has published the Building Energy Benchmarking Report annually since 2014. However, the program to implement improvements in building energy efficiency began in Singapore in 2005 under the Green Mark certification scheme. Given similar climatic conditions, it is appropriate to refer to Singapore's EUI benchmarking values of the same category of buildings. Since the Philippines' EEC Law was enacted in 2019, the EUIs derived from the survey in the Philippines should be compared with the respective EUI benchmarking values of 2008 in Singapore when the drive to improve energy efficiency in buildings was at the initial stage. The 2008 EUI for office buildings in Singapore was 267 kWh/m^2/y. Similarly, the 2008 EUI for retail buildings in Singapore was 401 kWh/m^2/y, (Figure 1.6).

Given the limitation of this survey due to the limited sample and the number of years and quality of data, it is impossible to identify a single benchmarking value from the analyses of this set of survey data in the commercial sector. Accordingly, a range of average EUIs derived from the survey may be considered. Using the X-Bar and R-Chart methods, the MPA computed an average EUI value of 248 kWh/m^2/y. In comparison, ERIA estimated an average EUI value of 275 kWh/m^2/y for office buildings in the Philippines for 2018–2019. Using the Box and Whisker method, the MPA estimated an average office building EUI value of 224 kWh/m^2/y for 2018 and 202 kWh/m^2/y for 2019. However, based on comparable data in Singapore and experiences in Malaysia, the range of average EUI for the office buildings in the Philippines for 2018–2019 should be based on ERIA's estimation given in Table 2.18.

Similarly, MPA's estimation of average EUI for retail buildings at an average EUI of 270 kWh/m^2/y for 2018 and 250 kWh/m^2/y for 2019 seems low when compared with the corresponding benchmarking value of 401 kWh/m^2/y in Singapore, as shown in Figure 2.17 for 2008. The Box and Whisker method used by the MPA is recognised as acceptable. However, due to the differences in data validation, MPA's computation of EUIs for the retail buildings is unacceptable. Therefore, the range of average EUI values for retail buildings in this survey should be based on ERIA's estimation (Table 2.18).

In summary, the range of average EUIs for office and retail buildings in the Philippines, based on the foregoing analyses of 2018 and 2019 survey data, is recommended to be as follows:

1) Office buildings:
    a) Median EUI value: 275 kWh/m^2/y
    b) Range of average EUIs: 213–336 kWh/m^2/y
2) Retail buildings:
    a) Median EUI value: 391 kWh/m^2/y
    b) Range of average EUIs: 324–458 kWh/m^2/y