Int. J. Nonlinear Anal. Appl. 13 (2022) No. 1, 673-684
ISSN: 2008-6822 (electronic)
http://dx.doi.org/10.22075/ijnaa.2022.5556

Impact of movement control order implementation on electricity consumption: A case study of university buildings

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(Communicated by Madjid Eshaghi Gordji)

Abstract

The Covid-19 pandemic has first been identified in China at the end of 2019 and later has spread worldwide. In Malaysia, Covid-19 cases have increased drastically in March 2020 that caused the Government to implement a Movement Control Order (MCO) starting 18 March 2020 to curb the outbreak which has affected all sectors in the country including higher education institutions. The objective of this paper is to present the impact of MCO implementation on the electricity consumption on the university buildings particularly at Universiti Malaysia Perlis. The methodology processes involve comparing the energy usage in 2019 as baseline data with usage in 2020 as the assessed data. These data then been analyzed for every 3 months or quarterly for reporting. Based on the results, MCO implementation has shown positive impact to the energy conservation where 3,023 MWh of electrical energy has been reduced in 2020 which is 25.72% less than the same period in 2019. This condition has been extremely beneficial to the university's operations where RM 1.369 million of electricity bill has been saved. In the aspect of environmental sustainability, the amount of energy reduction is equivalent to more than 2,000 tonnes of CO_2 avoidance at rated value 0.694 tCO_2 per MWh. As a result from energy reduction, the BEI performance of the buildings has improved from 3-Star (moderately efficient) to 4-Star (efficient).

Keywords: COVID-19, Lockdown, Energy Consumption, Building Energy Intensity and Sustainability.

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Received: August 2021 *Accepted:* September 2021

1. Introduction

As of March 2021, over 114 million Covid-19 cases have been confirmed worldwide with a total death toll of 2.5 million. This Covid-19 pandemic has initially been identified in China at the end of 2019 and later has spread worldwide. The first Covid-19 case in Malaysia has been reported on 25th January, 2020 and within a year, Malaysia has ranked 29th for number of Covid-19 cases worldwide in 25th January 2021 due to the highest number of Covid-19 infections in two weeks monitoring period [35, 5, 33]. The pandemic outbreak has a major impact on Malaysian which consists of 30 million people since strict restrictions have been imposed on social and economic activities to curb the spread of Covid-19. Undoubtedly, all economy sectors such as industries and commercials are severely affected which can be reflected on the changing of load profile [3]. Moreover, Government's policy to control Covid-19 pandemic has shown significant impact on electrical energy consumption, green energy deployment, global warming and energy market [39]. In addition, there are energy security risks since conventional generation system are not flexible enough to cater significant loss of energy demand due to the implementation of lockdown to curb the pandemic health crisis [24, 25].

The first restriction that has been imposed by Malaysian Government is the Movement Control Order (MCO) starting 18 March 2020 to break the transmission of Covid-19 chains due to the number of cases that have been increased drastically in March 2020 [34, 29]. According to the Prevention and Control of Infectious Diseases (Measures Within The Infected Local Areas) Regulations 2020, it is stated by Regulation 3 that no person shall make any journey from one place to another within any infected local which has resulted in a strict nationwide lockdown [7]. Due to the enforcement of MCO, all sectors in the country have been affected including higher education institutions where face-to-face learning has been replaced by online learning [30]. University Malaysia Perlis (UniMAP) as one of the higher education institutions involved has implemented precautionary measures in ensuring the safety of on campus students by providing transportations for 1,200 students to return to their hometowns on 17th Mac 2020 in line with the MCO enforcement. This has caused noticeable impact on the energy consumption in the campus since the energy consumption is highly depend on the number of occupants, occupants' daily life activities and occupancy level [16, 6, 20]. Therefore, this research has a significant impact towards future concept of sustainable higher education sectors mainly virtual campuses in term of energy consumption and greenhouse gas emissions [13]. The objective of this research paper is to present the impact of MCO implementation on electricity consumption on the university buildings particularly at University Malaysia Perlis (UniMAP) which covered the analysis on the electricity bill for UniMAP Main Campus at Kampus Alam Pauh Putra, Perlis. This research paper is structured as follows: Introduction and objective of the research work are presented in Section 1 while relevant literature reviews are provided in Section 2. The research processes are explained in Section 3 while the results and discussion are presented in Section 4. Finally, in Section 5, the conclusion is summarized.

2. Literature Review

Global Energy Review in 2020 reported by International Energy Agency (IEA) has highlighted that the global energy demand has experienced more 30% reductions due to the impacts of the Covid-19 crisis for strict lockdown implementation, which has resulted in the stunning declines in global CO_2 emissions as shown in Figure 1. It has been reported that $18\% - 25\%$ energy reductions which is approximately equivalent to 40,000 tonnes of CO_2 emissions can be eliminated during full lockdown period [1, 18, 31, 2]. Furthermore, the effect of partial lockdown has an average reduction of weekly energy demand by 17% and less stringent movement restrictions has cushioned the immediate impact of energy demand cut less than 10% on average [17].

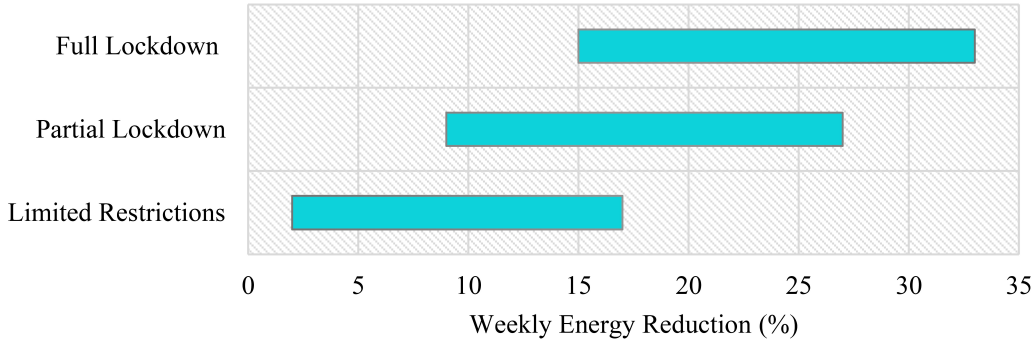

Figure 1: Global weekly energy demand reductions after lockdown measures implementation.

The share of renewable energy in power generation has been diminished significantly due to loss of energy demand which may lead to power system imbalance and reduced of reliability [23, 22]. On the other hand, this crisis could be a blessing in disguise in term of global warming issue since coal power generation worldwide has been decreased by 10% during the lockdown period from January until April 2020 [32]. Air quality has been improved accordingly since the greenhouse gas emissions such as carbon dioxide (CO_2), nitrogen oxides (NO_x) and fine particles ($PM_{2.5}$) have remarkable reductions as compared to normal condition [15, 28, 40, 21].

The lockdown measures or commonly referred as MCO in Malaysia are related to number of active COVID-19 cases to ensure that the spread and mortality rate under control. This is a proven measures since the pandemic in Wuhan, China can be suppressed by isolating the infected people and following social distancing guidelines [36]. This lockdown measures can avoid the collapse of the healthcare system due to uncontrollable cases of critically ill patients and shortage of medical personnel. As illustrated in Figure 2, Malaysian Government has enforced several phases of MCO as listed below [26, 4]:

1. MCO: 18th March until 3rd May 2020 (46 days)
2. Conditional MCO (CMCO): 4th May until 9th June 2020 (36 days)
3. Recovery MCO (RMCO): 10th June until 31st December 2020 (205 days)

However, there were several Targeted Enhanced Movement Control Order (TEMCO) in the northern region which affected Kedah, Perlis, and Penang that indirectly affected UniMAP operation. On 3rd August 2020, four localities in Kubang Pasu, Kedah were immediately put under TEMCO due to the emergence of Sivagangga cluster and followed by TEMCO at Kuala Sanglang in Perlis on 8th August 2020. The Sivagangga cluster was one of the biggest and most active infection hitting Malaysia during Covid-19 pandemic outbreak. Another TEMCO that has been implemented in the northern region was in Kota Setar, Kedah starting 11th September 2020 due to the high number of active cases [14]. In November 2020, National Security Council (MKN) has reinstated CMCO in all states except Pahang, Perlis, and Kelantan in curbing the spread of Covid-19 cases. All schools and higher education institutions were closed while staffs in the affected areas must work from home since interstate traveling were prohibited.

Figure 3 has shown the impact of electrical energy demand in Peninsular Malaysia under different periods of MCO starting from 1st February until 31st July 2020. The average electrical energy maximum demand in February 2020 for pre Covid-19 trends were 18,206 MW and reduced further by 22% with 14,207 MW as observed in April 2020 due to total lockdown or MCO implementation. To flatten the curve of Covid-19, drastic immediate movement restriction was enforced, and people

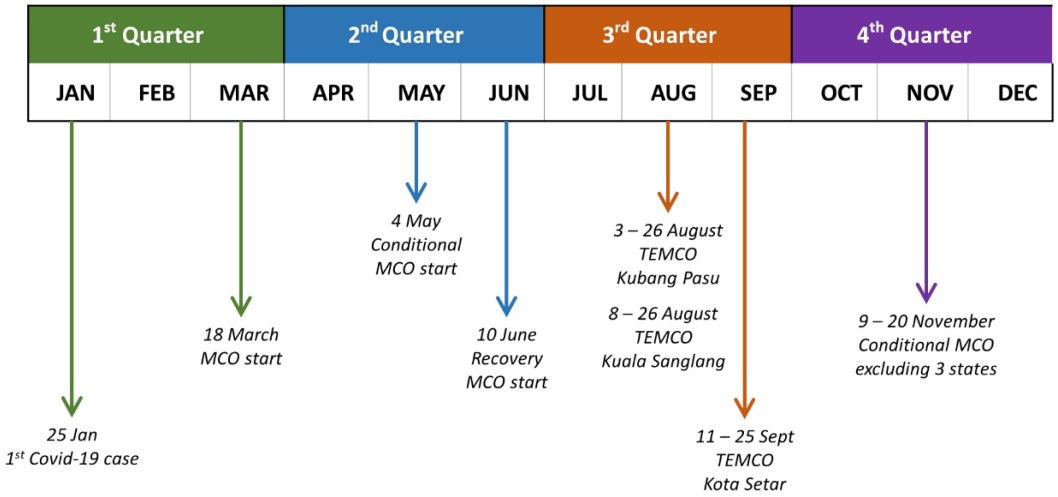

Figure 2: Timeline of MCO phases in Malaysia.

are required to stay at home which resulted in a significant reduction of energy consumptions. All mass gatherings and movement of person are prohibited including religious, sports, social and cultural activities. Schools and higher education institutions were ordered to remain closed to safeguard the students. Consequently, the reduction in energy consumption for Peninsular Malaysia during fully lockdown period is consistent with global energy demand reductions as shown previously in Figure 1 which were decreased in the range of 15% to more than 30% [17, 26]. The load profile of energy demand for Peninsular Malaysia for normal hectic weekdays have similar pattern with weekends' load profile specifically on Sunday as typical peak demands occur in the morning and evening peaks for household chores and mealtimes [37]. There are two main factors that influenced the change of load profile which are meal preparations by using electrical equipment and professional practices including working from home as well as online learning for children [9].
Moreover, average electrical energy maximum demand was cut by 4.3% for CMCO or partial lockdown starting from 4th May 2020 which was 17,415 MW from pre-pandemic trends. The decrease was quite lower than the average global energy demand for partial lockdown which is 17%. Since CMCO allows all economics activities and industrial chain to operate as usual with adherence to strict standard operating procedures (SOP) such as social distancing, premises must be equipped with hand sanitizers, thermometers and mySejahtera code or registration books as well as maintaining good personal cleanliness [19].

Thus, the impact of CMCO has cushioned the impact of Covid-19 on the electrical energy demand since people can start to work as usual even there are interstate travel restrictions. However, companies still implemented work from home policy and reduced the number of staffs in the workplaces as preventive measures to avoid the exposure of Covid-19. Later, CMCO has been replaced with RMCO on 10th June since the movement restrictions have shown good results in curbing the spread of the pandemic. All business and education activities can be resumed but subjected to strict SOPs. The movement control order with further relaxations have led in higher average energy demand in Peninsular Malaysia which is 17,724 MW in July 2020 with only 2.7% reduction from pre Covid-19 trends in February 2020. The impact was lower than the global average energy demand for less stringent restrictions which is only 10%. Since MCO, all students in higher education system were continuing their studies through online learning and e-learning platform [30, 27]. This approach has an excellent affect in reducing the risk of Covid-19 infection and energy consumption in higher education buildings. Researches have been found that the reduction of energy consumption in higher

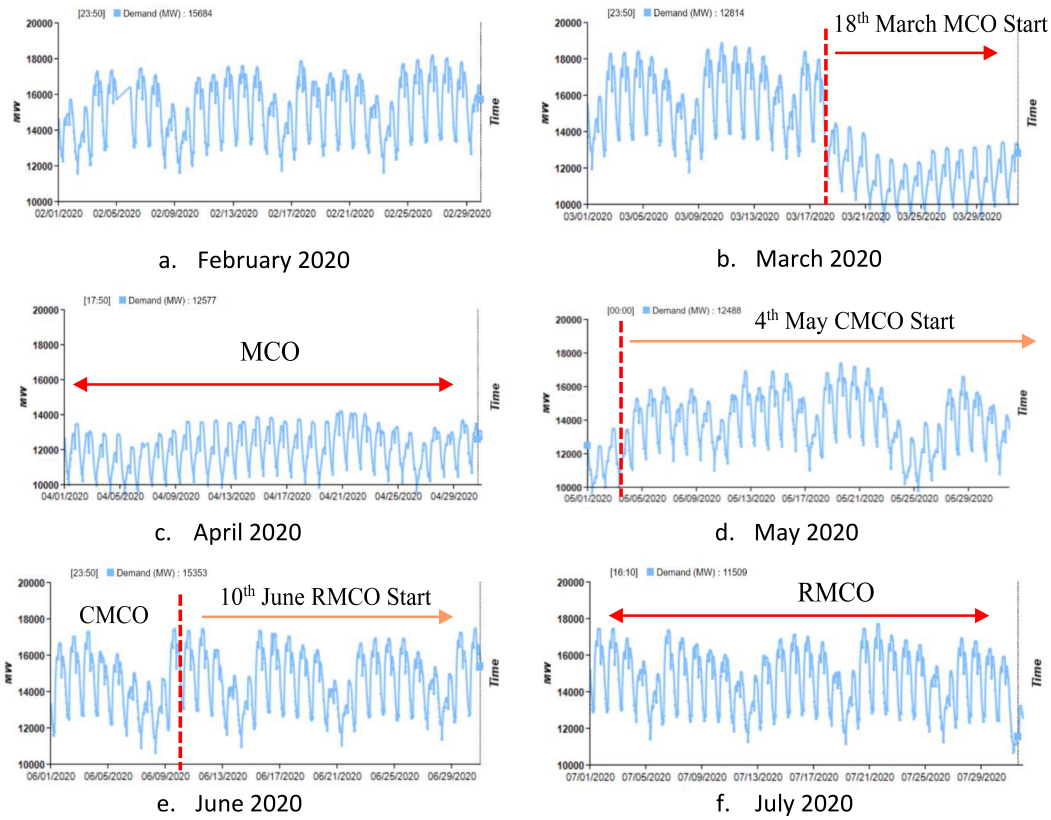

Figure 3: Electricity demand in Peninsular Malaysia from February until July 2020 [10].

education buildings can reach up to $32\% - 85\%$ during the lockdown period for several building such as lecture halls, administration offices, library and etc [6, 20, 8, 12].

3. Research Method

The methodology processes of the research work is covered in this section, which involve study of the energy usage in 2019 as the baseline data together with energy usage in 2020 as the assessed data. Then both set of data are compared and analyzed for every 3 months or quarterly for reporting. The parameters involved in this study are energy consumption in kilowatt-hour (kWh) for overall, peak, and off-peak period, maximum power demand in kilowatt (kW), electricity bill in Malaysian Ringgit (RM), carbon dioxide (CO_2) avoidance in kilogram (kg) and building energy intensity (BEI) index. Figure 4 shows the flowchart of the research processes.

3.1. Information on Electricity Tariff

UniMAP is one of the public universities located in the State of Perlis at the Peninsular Malaysia's northern region. Its campus at Kampus Alam Pauh Putra is the largest campus and currently enrolling under Medium Voltage General Commercial Tariff (C1) plus Off-Peak Tariff Rider (OPTR) scheme. Under C1 tariff, UniMAP needs to pay for energy usage in kWh and maximum power demand in kW. However, by enrolling under OPTR scheme, UniMAP will enjoy a 20% discount on electricity usage during off-peak hours (10.00 p.m. to 8.00 a.m.) every day provided the condition for minimum monthly load factor is met. Table 1 summarized the C1 OPTR tariff price.

In general, the monthly electricity cost could be calculated by using Equation (3.1):

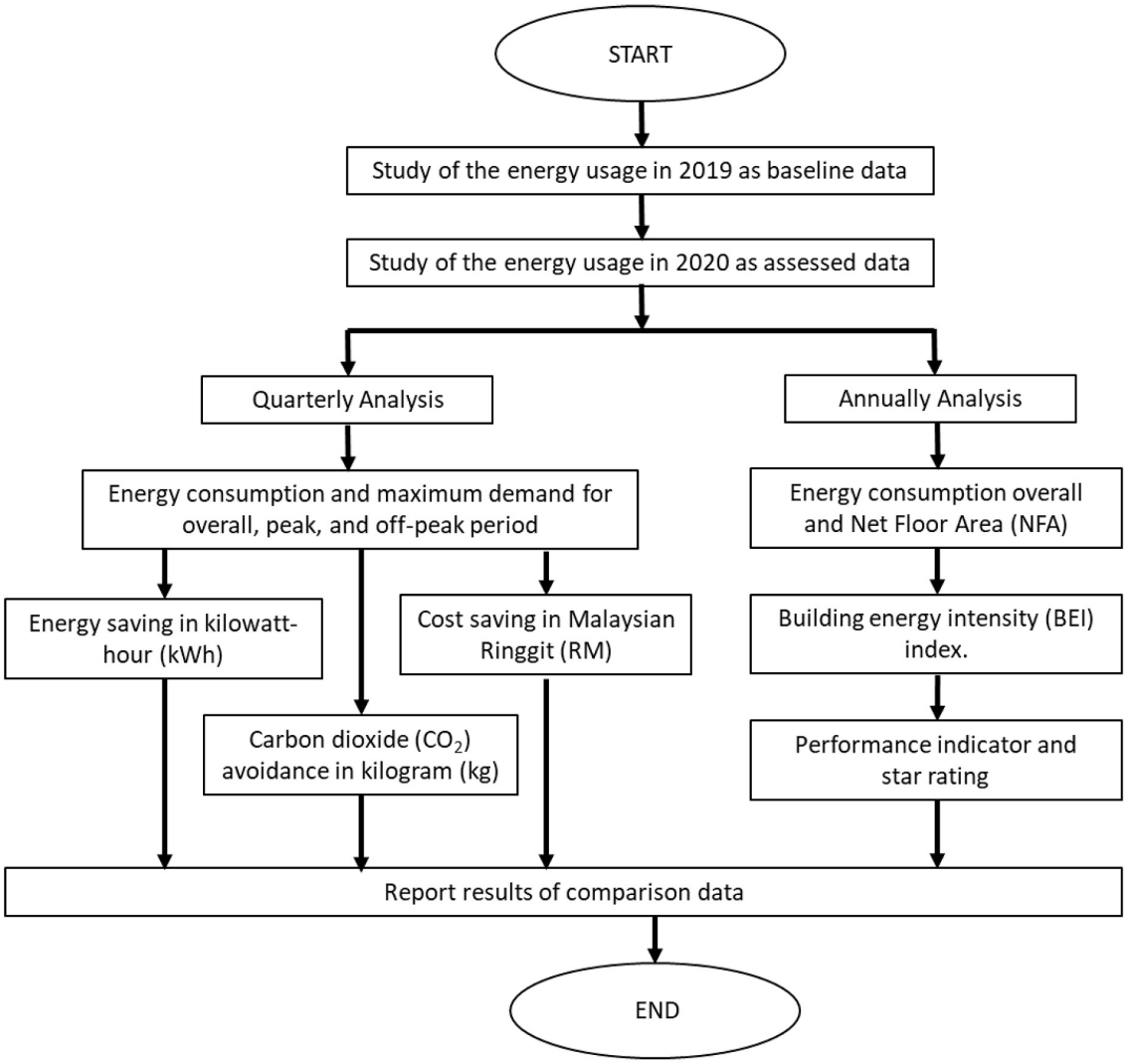

Figure 4: Flowchart of the research processes.

Table 1: C1 OPTR Tariff Price

Parameter	Cost	Unit
Energy (Peak)	0.365	RM / kWh
Energy (Off-Peak)	0.292	RM / kWh
Maximum Demand	30.3	RM / kW

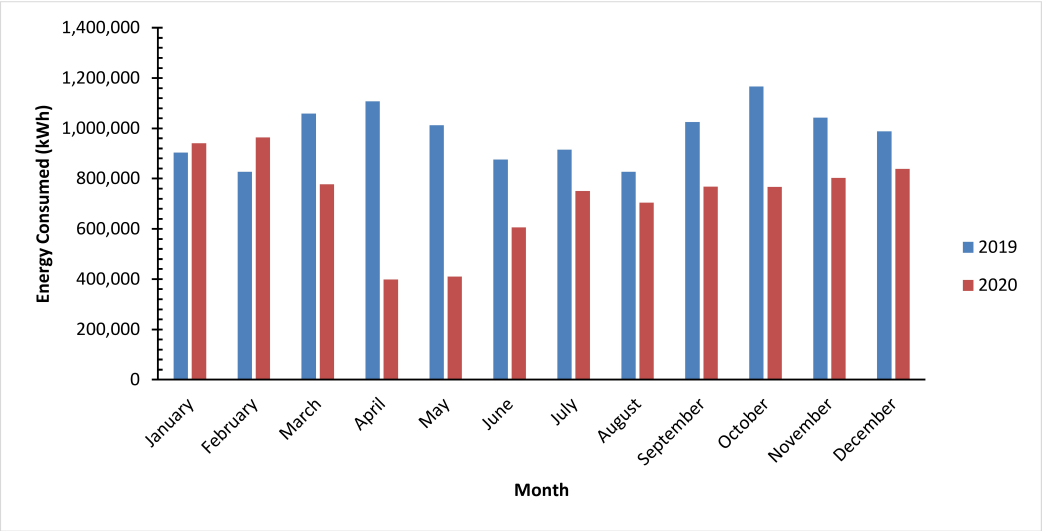

Figure 5: Monthly energy consumption in 2019 and 2020.

$$EC_{month} = EC_{peak} + EC_{off-peak} + C_{MD} \tag{3.1}$$

where EC_{month} is monthly electricity cost in RM, EC_{peak} is energy cost during peak period which is between 8.00 am until 10.00 pm in RM, $EC_{off-peak}$ is energy cost during off-peak period which is between 10.00 pm until 8.00 am in RM, and C_{MD} is maximum demand cost in RM.

3.2. Data on Energy Consumption

UniMAP consumes large amount of electricity annually which is more than 3 million kWh in 6 consecutive months. This condition required UniMAP to comply with Efficient Management of Electrical Energy Regulations 2008 (EMEER 2008), a regulation under Energy Commission of Malaysia. Generally, monthly energy consumption could be obtained by using Equation (3.2):

$$E_{month} = Epeak + E_{off-peak} \tag{3.2}$$

where E_{month} is total monthly energy usage in kWh, $Epeak$ energy usage during peak period which is between 8.00 am until 10.00 pm in kWh and $E_{off-peak}$ energy usage during off-peak period which is between 10.00 pm until 8.00 am in kWh.

Figure 5 shows monthly energy consumption in both 2019 and 2020. The total consumption in 2019 was 11,751,920 kWh where intensive energy usage occurs during academic semester such as March, April and May for Semester 2 and September, October, and November for Semester 1. However, the situation is quite different in 2020 where the energy consumption has decreased to 8,729,261 kWh. The monthly usage has dropped rapidly in April and June but gradually increased starting from June until the end of the year. In terms of consumption period, 9,791,120 kWh has been consumed during peak period in 2019 which is 83.32% from total consumption compared to 1,960,800 kWh during off-peak period. However, the amount has decreased to 6,879,982 kWh during peak period in 2020 which is 78.82% from total consumption compared to 1,849,279 kWh during off-peak period. Figure 6 shows peak and off-peak energy consumption in 2019 and 2020.

3.3. Data on Maximum Power Demand

Maximum demand or simply MD is the maximum level of power demand recorded every month during peak period. For UniMAP, MD reflects the maximum amount of electrical load that operates

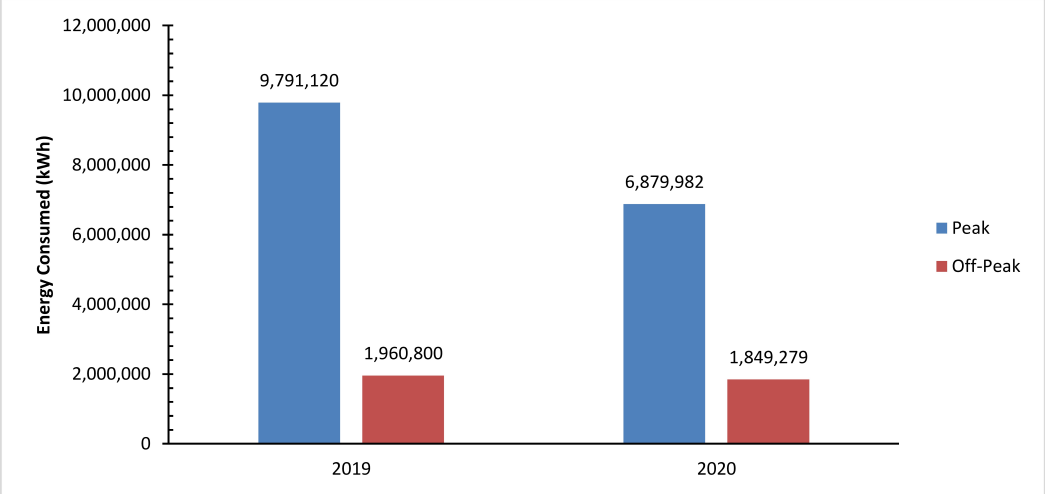

Figure 6: Peak and off-peak energy consumption in 2019 and 2020.

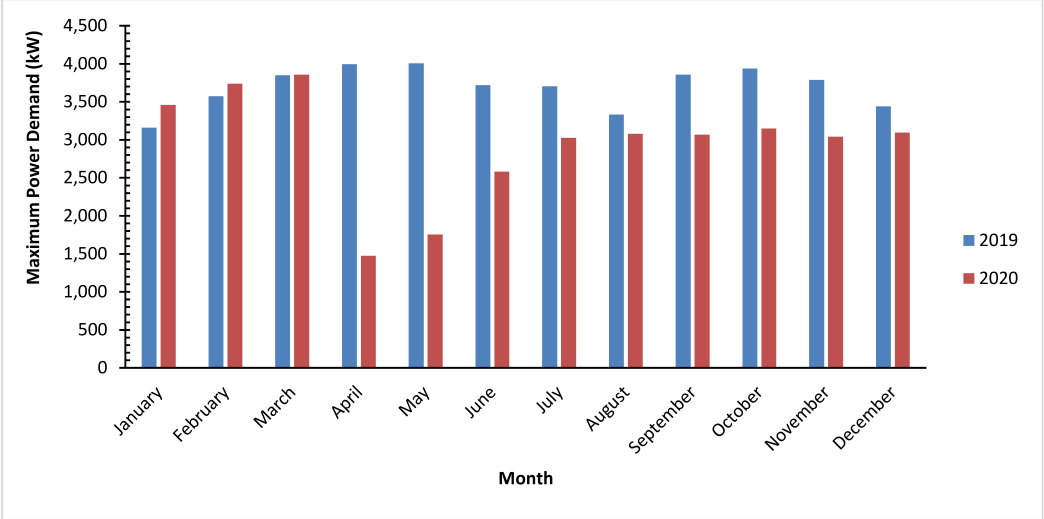

Figure 7: Monthly maximum demand in 2019 and 2020.

during normal operation time. Figure 7 shows monthly MD in both 2019 and 2020 where MD shows almost similar pattern with energy consumption. The total power demand in 2019 was 44,370 kW where intensive energy usage occurs during academic semester. Similar to the energy consumption, the situation is quite different in 2020 where the total power demand has decreased to 35,311 kW. The monthly usage has dropped rapidly in April and June but gradually increased starting from June until the end of the year.

3.4. Building Energy Intensity Index

Energy Intensity (BEI) is a labelling index used by the Energy Commission of Malaysia to monitor building energy performance by indicating the intensity of energy used per meter square area of the building [11]. The index is computed by measuring the ratio of a building's annual energy usage to its net floor area as shown in Equation (3.3):

$$BEI = \frac{AEC}{NFA} \tag{3.3}$$

Table 2: Performance indicator based on BEI index value

BEI Range	Performance Indicator	Star Rating
$BEI > 250$	Highly Inefficient	1
$160 < BEI \leq 250$	Inefficient	2
$130 < BEI \leq 160$	Moderately Efficient	3
$100 < BEI \leq 130$	Efficient	4
$BEI \leq 100$	Very efficient	5

Table 3: Analysis on Energy Consumption and Power Demand.

Period	2019		2020		Different	
	Energy (kWh)	Power (kW)	Energy (kWh)	Power (kW)	Energy (%)	Power (%)
1st Quarter	2,790,078	10,583	2,682,552	11,056	-3.85	4.47
2nd Quarter	2,996,455	11,724	1,415,004	5,811	-52.78	-50.44
3rd Quarter	2,767,925	10,893	2,223,987	9,175	-19.65	-15.77
4th Quarter	3,197,462	11,170	2,407,718	9,289	-24.70	-16.84

where BEI is Building Energy Intensity Index in kWh per m^2, AEC is annual energy consumption of the building in kWh and NFA is the building's net floor area in m^2. This index will provide benchmarking on the energy performance of the buildings based on the amount of energy consumed per year and floor area [38]. The performance indicator based on BEI index value obtained is shown in Table 2. As been discussed in previous section, the annual energy consumption in 2019 is 11,751,920 kWh but has declined to 8,729,261 kWh in 2020. In both years, the net floor area for the campus buildings is unchanged at 79,637 m^2.

4. Results and Discussion

Analysis on energy consumption and total power demand are shown in Table 3. For energy consumption, 1st quarter of 2020 has shown only 3.9% reduction in energy usage due to the MCO has just started on 18 March 2020. Later, energy usage has tremendously plunged during 2nd quarter of 2020 where only 47.2% of energy has been consumed compared to 2019. Currently, MCO is at its peak due to the implementation of MCO, CMCO (starting 4 May 2020) and then RMCO (starting 10 June 2020). During this period, almost all sectors including universities have been closed except for essential services only. However, during 3rd and 4th quarters of 2020, demand for electricity has gradually increased to 80.4% and 75.3% respectively due to MCO implementation has been converted into RMCO where the economic and social sectors including UniMAP have been allowed to operate under strict procedures. For total power demand, 1st quarter of 2020 has shown 4.5% increment compared to 2019. Identical to energy consumption, total power demand has significantly dropped to just 49.6% during 2nd quarter of 2020 while during 3rd and 4th quarters of 2020, demand for power has risen progressively to 84.2% and 83.2% respectively compared to 2019.

Analysis on peak and off-peak energy consumption are shown in Table 4. Peak energy consumption is heavily affected by the MCO implementation where the amount of energy has decreased 50.4% in 2020 compared to 2019. This is due to the lack of learning activities on campus since learning activities have been completely converted to online sessions. In addition, most on the facilities on campus such as lecture halls and laboratories were completely closed during the MCO. On the other

Table 4: Results for Peak and Off-peak Energy Consumption.

Period	**2019(kWh)**	**2020 (kWh)**	**Different** (%)
Peak	9,791,120	6,879,982	−29.73
Off-Peak	1,960,800	1,849,279	−5.69
Total	11,751,920	8,729,261	−25.72

Table 5: Summary of the Impact of MCO Implementation

Parameter	**Energy (kWh) / Power (kW) Savings**	**Cost Savings (RM)**	**CO_2 Avoidance (kg)**
Peak Energy	2,911,138	1,062,565	2,020,330
Off-Peak Energy	111,521	32,564	77,395
Power Demand	9,039	273,882	
Total Energy	3,022,659 [a]	1,369,011	2,097,725

[a] Peak and off-peak energy only.

hand, off-peak energy consumption is less affected by the MCO implementation where the amount of energy just reduced 5.7% compared to 2019. This is because university main operation is during peak period time.

As a summary, MCO implementation in 2020 has resulted in total energy reduction of 3,022,659 kWh which is 25.72% less compared to 2019. This condition is mainly due to absence of activities on campus during peak period hours. In addition, this reduced amount of energy is equivalent to RM 1,369 million based on the electricity tariff used. Furthermore, in terms of environmental sustainability, the amount of energy saving is equivalent to 2,097,725 kg of CO_2 avoidance at rated value 0.694 tCO_2 per MWh [23]. Table 5 summarized the impact of the MCO implementation to UniMAP's electricity consumption.

In addition, the BEI index of the buildings has declined from 147.57 in 2019 to 109.61 in 2020 as shown in Table 6. This condition showed that the building energy performance has progressed from 3-Star range (moderately efficient) to 4-Star range (efficient) as a result from annual energy reduction.

5. Conclusion

The impact study of MCO implementation on electricity consumption at University Malaysia Perlis campus buildings has been presented in this paper. As a conclusion, MCO implementation has shown positive impact to the energy conservation where 3,023 MWh of electrical energy has been reduced in 2020 which is 25.72% less than the same period in 2019. This condition has been extremely beneficial to the university's operations where RM 1.369 million of electricity bill has been saved. In terms of environmental sustainability, the amount of energy reduction is equivalent to more than 2,000 tonnes of CO_2 avoidance at rated value 0.694 tCO_2 per MWh. As a result from energy

Table 6: Results for Peak and Off-peak Energy Consumption.

Year	**BEI Index**	**Performance Indicator**	**Star Rating**
2019	147.57	Moderately Efficient	3
2020	109.61	Efficient	4

reduction, the BEI performance of the buildings has improved from 3-Star (moderately efficient) to 4-Star (efficient).

Acknowledgement

The authors would like to acknowledge the support from the University-Private Matching Fund (UniPRIMA) Research Grant 2020 under a grant number of UniMAP/RMC/9001-0000643 from University Malaysia Perlis.

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