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A review of electricity pricing in peninsular Malaysia: Empirical investigation about the appropriateness of Enhanced Time of Use (ETOU) electricity tariff

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ABSTRACT

This paper presents the foundation of the Peninsular Malaysia's electricity market reform and development towards successful of Incentive Based Regulation (IBR) implementation, when revising also the Special Industry Tariff (SIT), Time of Use (TOU) and Enhanced Time of Use (ETOU) tariff. The Malaysian characteristics of Price Based Program (PBP) pointed out are compared with other countries across several continents. Since PBP benefits the energy providers in order to enhance power system efficiency, the effectiveness of consumer side strategies to gain benefit from PBP should be given attention too. In this study, investigation has been focused on one of the PBP which is ETOU tariff; with regard to the impact of this new tariff in communicating to selected real data energy profile for all commercial and industrial tariff types through congruent analysis. Without any effort towards load management as well as Demand Side Management (DSM) strategies implementation, the dedicative consumers' electricity bill has increased significantly to approximately 0.5%–12% during ETOU tariff shifting. In order to overcome this issue, a novel formulation by using simultaneous demand side management strategies such as valley filling, load clipping and load shifting for the ETOU tariff optimization is proposed. Meanwhile, the momentous simulation analysis results has demonstrated that major commercial and industrial consumers should find out for about 20%–50% of load management; by selecting PBP activities before they can switch to new tariff program.

1. Introduction

Environment, energy and climate change are major issues in Malaysia; thus awareness is continuously spread among citizen to protect the environment by implementing efficient energy management system. The correlation of electricity consumption to CO2 emission has been identified to be 3rd largest source, while generation capacity is forecasted to increase every year. In 2016, in line with the increase of economic growth in Peninsular Malaysia, the electricity is expected to increase approximately by 4% between 2015 and 2016, that is from 117,219 MWh to 121,956 MWh [1]. Meanwhile, the total Maximum Demand is achieved it highest value in October 2017 that is 17,790 MW, which is an increment of about 5% compared to in 2015. Along with the increment of population in the country, the per capita number has changed tremendously. The current key economic data in terms of GDP per capita is 37,685 in Ringgit Malaysia (RM), while the per capita of total energy usage is 1.758 tonne of oil equivalent (toe) and per capita electricity consumption being 4482 kWh [2]. It was reviewed that the intensity of the electricity consumption per GDP in Malaysia shows a positive improvement in which value has increased to 8.5% due to proper planning of the energy balance to secure supply of the electricity energy by reflecting consumers demand congruently. Since the electricity supply act was gazetted in 1990 and efficient electricity energy management regulation had been revised in 2008, the structure by which government manages electricity energy has been changed too. The central focal agency under ministration related to energy is the Energy Commission which is responsible to ensure the act of the electricity supply 1990 is satisfied. In general, Energy

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Nomenclature

TOU	Time of Use	TNB	Tenaga Nasional Berhad
ESI	Energy Supply Industry	STR	Sunday Tariff Rider
ETOU	Enhance Time of use	SIT	Special Industrial Tariff
OPEX	Operational Expenditure	MD	Maximum Demand
IBR	Incentive Based Regulation	LF	Load Factor
CAPEX	Capital Expenditure	LS	Load Shifting
PBP	Price Based Program	VF	Valley Filling
IBP	Incentive Based Price	PC	Peak Clipping
DSM	Demand Side Management	PSO	Particle Swarm Optimization
OPTR	Off Peak Tariff Rider	WTP	Water Treatment Plant
		CP	Cement Plant
		LDC	Load Duration Curve

Commission has contributed to designation of the electricity market and authorization of regulation, promoting competition for technical personnel in electrical and gas, issuing installation license and protecting consumers' interests. At the moment, Tenaga Nasional Berhad (TNB) is the only electricity distributor in Peninsular Malaysia, which owns partial of the total generation plant and fully owns the transmission and distribution system [3–5]. The establishment of the Energy Commission since year of 2001 has contributed much in determining transparency of energy market in Malaysia. The Energy Commission portfolio to regulate TNB in terms of electricity price, as well as base price, for the design of consumers' tariff, helps to develop the electricity market congruently. The average tariff pricing has been regulated based on baseline price for the design of tariff in each category of consumers, where TNB has provided the average of selling price in annual report correspondingly. Base price for the tariff design has been set through the consideration of marginal cost made by Energy Commission, with government approval. Compared to other liberalized market models as discussed in Refs. [6,7], the Energy Supply Industry (ESI) in Malaysia has been designed based on Manage Market Model which is TNB's entities has been split to five unbundling account [8]. Instead of three conventional entities like generation, transmission and distribution, Manage Market Model introduces Single Buyer Operation and Generation System Operator to manage their own power dispatch scheduling and generation bidding as well as power purchase agreement [9,10]. Thus, by considering all the costs of each entity under ESI, from generation to distribution/customer service of electricity operation and maintenance, the base tariff rate has been produced. Energy providers are tied to the base tariff for the consumer's tariff design, in which the average tariff rate could be equal to the regulated one. Different to deregulated market system such in most European countries [11], Australia [12] and Singapore [13], retailers have exercised dynamic pricing rate based on their own innovative design, where the setting could be higher than marginal cost while providing more charge reduction of electricity consumption during the incentive price based program. However, it is also interesting to discuss on static tariff rate under regulated market, which also bring benefits if the demand response program has been embedded righteously. The factor of dynamic pricing under deregulated has caused consumers to reject the program of time varying electricity rate, which should be given attention due to bias in transition of retailers' selection and new plan, unclear channel of communication, very short trial time and variance in price with unpredictable manner, as addressed in Ref. [14]. Thus, by authors' finding, most consumers prefer static electricity rate, but demand response time based program is applied, such as Time of Use (TOU) tariff.

Consequently in Malaysia, through the Incentive Based Regulation (IBR) where the electricity market has been reformed since 2014, TNB in Peninsular Malaysia has provided affordable selling price to the consumers. Nevertheless, there are opportunities for the improvement

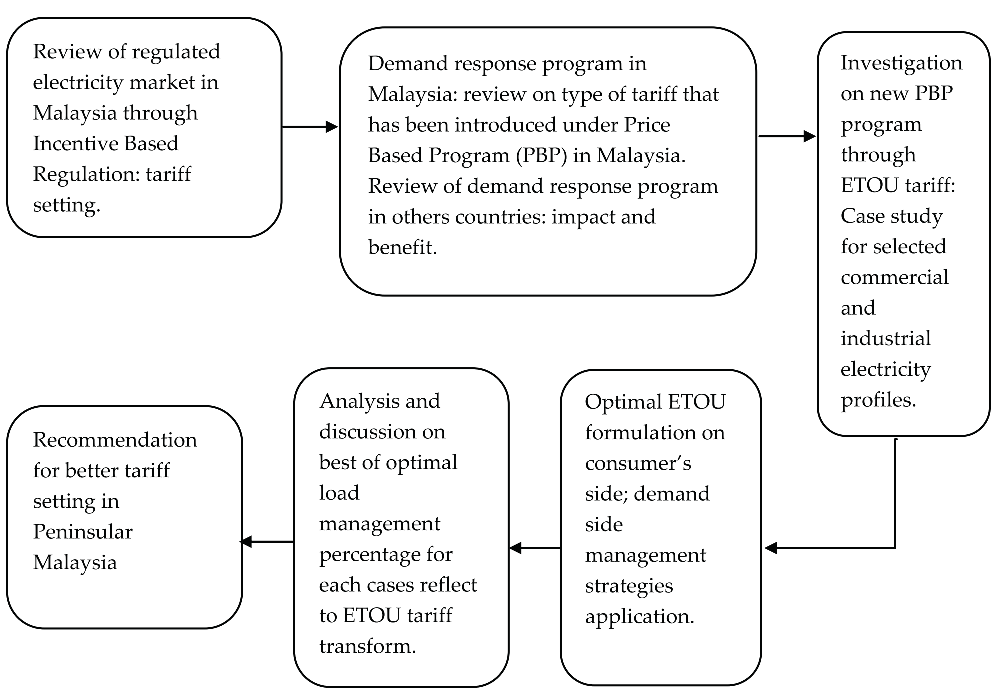

Fig. 1. Framework of the paper.

of IBR implementation where the price signal for each tariff categories should also be referred to consumers' need. Thus, consumers may respond to change their tariff structures. The derivation of the customers' classification per tariff category is important to providers. The identification of consumers load profiles will enable provider and regulator to categorize them into several tariff structure accordingly. Due to that reason, in 2015, TNB has introduced a new tariff structure to give alternative preference for commercial and industrial tariff consumers to transform from conventional two zones tariff to multiple zones tariff for better demand response program among consumers. The Enhance Time of Use (ETOU) tariff has been approved by Energy Commission to be applied to two types of consumers, with different time zone compared to conventional Time of Use (TOU) tariff. The "mid peak" time zone has been applied in the time segmentation, consist of 10 h, while the "peak" time segmentation has been reduced to 4 h only [15]. Numerous seminars have been conducted by the authority and providers; through respectable channel in publishing, and advertising the efficacy of ETOU through their website as well. Nevertheless, until end of the year 2016; this effort has attracted only small number of participants and have not achieved the target as expected by the former Energy Commission Chief Executive Officer (CEO) in Ref. [1]. Commercial and industrial consumers still struggle to understand the method of ETOU; some even admitted that they are not ready for the load shifting.

With regard to this issue, to our best knowledge, there is not yet review paper to date that discusses specific electricity pricing in Malaysia based on empirical analysis to holistically categorize of each consumer's profile relative to the effectiveness of the new tariff scheme promoted by the utility. Even though renewable energy issues have been discussed based on opinions and continuity [16,17], the sustainable of electricity supply should be also considered the important of electricity pricing determination, to reflect the demand response program accordingly. Therefore, the significant of effective pricing programs implemented in Malaysia will be addressed in this paper that has been set as the main contribution.

This paper is organized as follows: Section 2 describes the electricity market in Malaysia, Section 3 discusses demand response as well as presents a comparison on electricity pricing and demand response experiences in other countries. Empirical analysis is presented in Section 4. Finally, Section 5 concludes while Section 6 recommends. For the sake of the clarification, the schematic overview of the paper is presented in Fig. 1.

2. New era of regulated electricity pricing in Peninsular Malaysia

2.1. Incentive Based Regulation (IBR)

Incentive Based Regulation (IBR) is a mechanism to strengthen the economic framework regulation of tariff price setting in Malaysia, which has been implemented since 2014. The Energy Commission through Energy Supply Industry has decided to conduct a pilot program in 2014, in which regulatory period one of the program has been set for 3 years from 2015, 2016 and 2017, respectively. IBR has been a basis in enhancing the principle of tariff design, while providing virtuous tariff review process for the nation in order to consider the promotion of service efficiency with proper standard by energy providers in Malaysia. Under the IBR regime, each business entity has separate account (unbundling account) with the initiative to clear the annual review process of regulated account, while satisfying customers' expectations congruently. As the practitioner of the monopoly energy market system where Tenaga Nasional Berhad is the only utility in Peninsular Malaysia, where IBR framework is able to control the unjustified profit by the utilities that control electricity charge to the consumers. In the regulation of market model of energy economic, the regulation must be set to meet the economically efficient energy prices, and the resource of each every single department in industry should be clear enough. The market share of the providers and consumers in the monopoly system should be prevented where the fare tariff structure must has been a reason [18]. Meanwhile the initiative term is expected to focus on the innovation and utilities performance such as service quality, network resilient, quality of supply and society commitment, rather than cost minimization for operational and capital only [19,20].

2.2. Regulated tariff setting under IBR

After each business entity has been regulated to have revenue requirement per annum, the next step of the regulatory process is to establish the average tariff for each business entity of TNB. The total average of single tariff have been summarized in order to get consumers' average tariff, as well as represent the base tariff for various classes of tariff that belong to TNB's consumer. Recent setting of the base tariff for the consumers has been set as 38.53sen/kWh compared to the previous tariff setting in 2011, which was 33.88 sen/kWh, considering 18% for Distribution, 7% for Transmission, and the rest 75% for Generation which is Capacity Payment gain about 32% while 68% for Fuel Payment respectively. With regard to the average base tariff history, the tariff has been revised by TNB in Peninsular Malaysia, as demonstrated in Table 1.

Meanwhile, the breakdown of the new base tariff of 38.53 sen/kWh to each entities are 68.5% for Single Buyer generation, 0.5% for Single Buyer operation, 0.1% for Generation System Operation, 9.5% for Transmission and 21.4% for Customer Service which is also included Distribution. The dedicative structure of separate account price per entity is illustrated in Table 2, where four entities have their own tariff pricing based on the revenue requirement framework under IBR. The base tariff set for regulatory period one was 38.53sen/kWh. As mentioned earlier, the base tariff rate was used by TNB in order to determine consumers' tariff, while the early settings of average tariff per main category were 31.66sen/kWh for domestic, 47.92sen/kWh for commercial and 36.15sen/kWh for industrial in respectively. It should be noted that, the setting of the average will be not accurate due to change of consumers' numbers. Average selling rate will either increase or decrease every year but not much.

2.3. Sustainable Malaysia electricity market under IBR

Since the introduction of IBR regime, the electricity market in Malaysia has had much improvement, where TNB, Energy Commission and government can sustain benefiting each other. Regulatory period one acts as a learning curve for regulators and providers. The base tariff has been announced surging to 39.45sen/kWh at national electricity market for Peninsular Malaysia while ESI structure has few upgrades [22,23]. Although the base tariff has increased, tariff rate at consumer level has not changed due to balance in tariff rate design since regulatory period one, besides contribution from the increase of consumers range for all sectors on top. In regulatory period two for the year 2018 until 2020, the distribution and customer service entity in regulatory

Table 1
History of base tariff revision for consumers in Peninsular Malaysia [22].

Approval date	May 2006	Jun 2008	Feb 2009	Jun 2009	May 2011	Dec 2013	Feb 2015	Jun 2015	Dec 2015
Effective date	Jun 2006	Jul 2008	Mar 2009	Jul 2009	Jun 2011	Jan 2014	Mar 2015	Jul 2015	Jan 2016
Average Tariff (sen/kWh)	26.2	32.5	31.3	31.3	33.5	38.5	38.5	38.5	38.53

Table 2
Separate account structure of price under ESI for regulatory period one [21].

Components	Generation	SBO	GSO	Transmission	Distribution/CS
Sen/kWh	26.76	0.19	0.05	3.66	7.87

Table 3
Base tariff change for regulatory period two with split unit of generation and CS [21].

Component	Generation	SBO	GSO	Transmission	Distribution	CS
Sen/kWh	27.09	0.19	0.06	4.03	7.15	0.96
Percentage (%)	68.6	0.5	0.2	10.2	18.1	2.4

period one has been split due to securing the OPEX and CAPEX cost for power distribution network. The distribution entity under regulatory period two will be based on the revenue cap regime while consumer service will remain under price cap regime. Derivation of the tariff rate per entity's split account for regulatory period two is presented in Table 3. On top of that, the average selling price of electricity gradually increases while the selling price for all sectors increases correspondingly. Table 4 presents the list of average selling price by TNB from 2011 until 2016 based on six tariff categories. It can be observed that the ratio of the average selling price for residential to industrial is approximately 1.1–1.3 in the last 5 years. This is slightly different compared to the international standard ratio for the tariff design as practiced in UK and US (ratio: 1.5-2.0) [24]. In the beginning of the tariff arrangement, residential leads the industrial selling price but the change in government policy to lower down living cost has contributed to the significant gap and increased the range of the rate. In fact, industries in Malaysia have contributed a lot in the last 10 years in sustaining the ability of the regulated electricity market to improve the country's economy. Although selling price of electricity has increased tremendously during the implementation of IBR system, the tariff by TNB in Peninsular Malaysia is still in the range of affordable rate compared to other countries' electricity selling price. Fig. 2 demonstrates the comparison of average tariff in selected countries in Asia in 2015.

On the other hand, the efficiency carry over account for the KPIs' achievement in regulatory period one has been announced to remain the same rate.

For industrial consumers, special industrial tariff has been announced to be reduced to 2% discount only and the program will be totally shut down by 2020 [25]. New applications for this tariff have been closed since 2016. Although new application condition has been revised towards supporting the DSM program such as applicants must be appointed as registered energy managers and prepare planning for the demand response and energy efficiency program, it has been concluded that demand side management program would be more successful without special industrial tariff. Malaysia Energy Commission and TNB have prepared other options for the upmost demand response program through tariff initiative, which is Enhance Time of Use (ETOU) tariff for commercial and industrial consumers. The difference between ETOU and conventional tariff is that, ETOU has an additional zone of time which is mid-peak. The consumers receiving the flat tariff in conventional tariff C1 and E1 will still be able to enjoy time of use tariff program, as well as open opportunity to get cost reduction. Table 5, Table 6 and Table 7 present the special industrial tariff, conventional Time of Use (TOU) tariff and ETOU tariff rates for both commercial and industrial tariffs.

3. Demand response on price based program in Malaysia

Demand Response (DR) has been expressed as a highly challenging program, due to representative commitment from customers. In general, DR means the changes in energy usage by demand side from their normal profile of electricity usage, in response to the price of electricity in time frame. Participation and agreement from utilities and consumers in the DR framework should drive the DSM program to become successful. In line with background of this study, the authors in Ref. [26] classified DR programs into two parts, which are Incentive Based Program (IBP) and Price Based Program (PBP). PBP is the focus of this proposed study. Programs under the PBP include Critical Peak Pricing, Extreme Day Pricing, Extreme Day Critical Peak, Real Time Pricing and Time of use (TOU) tariffs [27]. TOU program is designed in various time frames, depending on the power profile of consumers. The daily load profile consists of peak and off-peak time frame, which indicates the consumption of the electricity usage per time. Conceptually, consumers will respond to the rates which have been set for each time frame (peak and off-peak, or mid-peak in some countries) by changing or shifting their load consumption to minimize electricity cost. TOU can be implemented in both regulated and deregulated market, but the effect to energy consumption would be different. As mentioned in Ref. [28], in regulated market, there are independent authorities which monitor the interest of both consumers and utilities in terms of benefit, incentive and the arrangement of the power system. Meanwhile, in deregulated market, both consumers and utilities are free to discuss on the competition, value, and opportunity for profit and cost saving.

Following the practice suggested by literature, TOU study has been classified into three separate groups: a) TOU tariff design as in Refs. [29–31], b) TOU consideration for both utilities and consumers as in Refs. [32,33] while the importance of the cost factor for the retailers/providers revenue is as in Ref. [34]; and c) TOU consideration for consumers only load profile management as discussed in Refs. [35–38]. In Malaysia, TOU has been considered and embedded in all those studies, but in the context of implementation, Energy Commission and TNB have rather designed a holistic program focusing on the PBP significantly. As discussed earlier, the projection of DR through PBP in Malaysia started with TOU tariff design for industrial and commercial consumers; after that, flat tariffs C1 and E1 for both categories have been given the option to apply for the Off-Peak Tariff Rider (OPTR) and still be able to enjoy same tariff of peak period as C2, E2 and E3 groups of tariff; both benefitting providers and consumers. OPTR 20% discount will be given to participants with requirement that they must able to improve Load Factor (LF) within six months average for baseline setting. LF would be improved with conditions that i) the installation should be able to reduce maximum demand or peak demand, ii) consumers are able to shift some amount of loads to off-peak hours in order to reduce peak demand consumption for about 12 h. Another option of

Table 4
Average electricity selling price in Peninsular Malaysia by TNB [2].

Year	Domestic (sen/kWh)	Commercial (sen/kWh)	Industrial (sen/kWh)	Mining (sen/kWh)	Public Lighting (sen/kWh)	Agriculture (sen/kWh)	Average (sen/kWh)
2011	27.97	39.10	29.77	20.21	20.87	38.48	32.48
2012	28.93	40.98	30.89	20.81	21.53	39.64	33.83
2013	29.15	40.76	31.00	20.55	21.55	39.35	33.87
2014	32.28	47.10	35.88	23.99	25.06	45.29	38.86
2015	32.67	47.68	36.56	25.00	25.49	45.86	39.45
2016	33.21	46.76	37.13	25.34	25.57	45.78	39.55

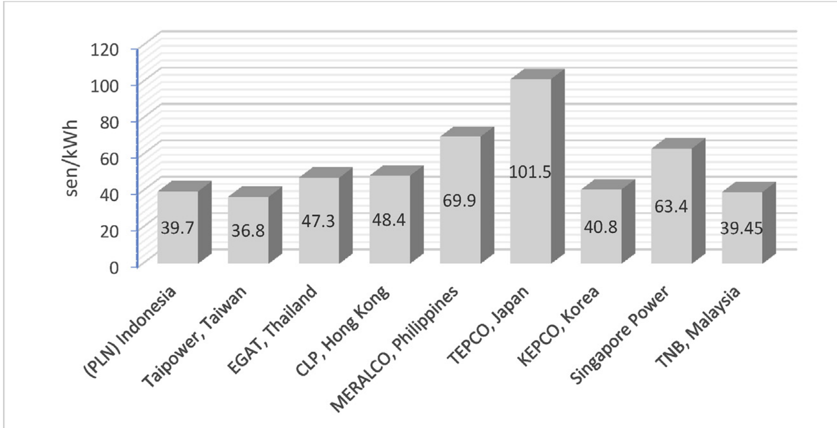

Fig. 2. Average of electricity selling price per country [2].

Table 5
SIT rate (since 2014 until present).

Tariff Category	MD: RM/kW	Peak: sen/kWh	Off Peak: sen/kWh
Industrial Ds	NA	42.70	NA
Industrial E1s	23.7	33.60	NA
Industrial E2s	32.90	33.60	19.10
Industrial E3s	29.00	31.70	17.50

Table 6
Flat & TOU tariff rate (since 2014 until present).

Tariff Category	MD: RM/kW	Peak: sen/kWh	Off Peak: sen/kWh
Commercial C1	30.30	36.50	NA
Commercial C2	45.10	36.50	22.40
Industrial D	NA	38.00 < (200 kWh) < 44.10	NA
Industrial E1	29.60	33.70	NA
Industrial E2	37.00	35.50	21.90
Industrial E3	35.50	33.70	20.20

the PBP under DR in Peninsular Malaysia is Sunday Tariff Rider (STR). The consumers that register under STR program are advised to move their peak demand and arrange the operation on Sunday so that TNB will not charge any Maximum Demand (MD) rate on Sunday. Although STR is available for commercial and industrial consumers, the significant authentic program of STR would be advantageous to industrial sectors since they handle their own operation and process. The production line, for instance, is able to produce output with better arrangement and response to price signal as to as enjoy MD charge mitigation for the monthly electricity bill. Over decade, TNB under the tariff incentive program has also offered certain consumers under domestic and commercial category that involve in welfare, religious place and education buildings to be eligible to get 10% discount. The service tax of 6% on consumers has been exempted for the domestic consumers

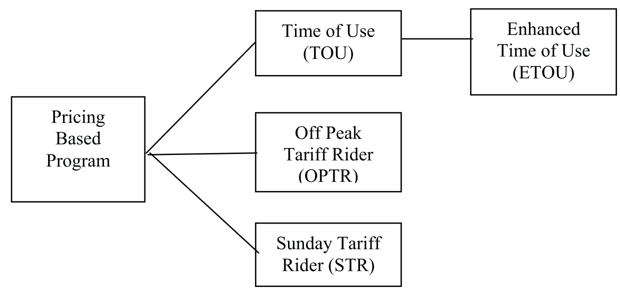

Fig. 3. Load response initiatives in Malaysia under regulated electricity market.

who use electricity under 300 kWh every month. All those initiatives under PBP program has been continued for the restoration design of Time of Use (TOU) with the introduction of Enhanced Time of Use (ETOU). This new tariff promises additional benefits to the demand side management program, while compromising to reduce the cost of electricity among consumers. Unlike conventional tariff scheme, TOU is available for commercial and industrial consumers only with tariff categories of C2, E2, E3 and Special Industrial Tariff (SIT); ETOU has positive impact to huge numbers of consumers with C1, C2 and all types of E tariff categories [39]. Based on remaining two periods of peak and off-peak, with additional mid-peak considered within compatible rate, consumers can adjust their activities and operation hours to enjoy cost saving from this new tariff scheme. For instance, the current load profile of consumers only deals with the peak charge, or commonly called as Maximum Demand (MD). By managing the load pattern through scheduling appropriate machineries system or workers activities, the consumers would be able to reduce the cost by switching the peak to mid-peak period of MD. Varied pricing of ETOU in six segmentations of time is another advantage to the consumers to mitigate the cost of energy consumption, by applying the DSM strategies, which will be explained in the case study in Section 4.

To summarize, after several decades of the market pricing

Table 7
ETOU tariff rate (since 2015 until present).

Tariff Category	Demand Charge (RM/kW/Month)		Energy Charge (sen/kWh)		
	Peak	Mid-Peak	Peak	Mid-Peak	Off Peak
Commercial C1 MV ETOU	34.00	28.80	58.40	35.70	28.10
Commercial C2 MV ETOU	48.40	42.60	63.60	33.90	22.40
Industrial D LV ETOU	42.10	37.20	48.40	32.70	24.90
Industrial E1 MV ETOU	35.50	29.60	56.60	33.30	22.50
Industrial E2 MV ETOU	40.00	36.00	59.20	33.20	21.90
Industrial E3 HV ETOU	38.30	35.00	57.60	32.70	20.20

Table 8
Related finding by other countries with regard to electricity pricing, market and DR reformation.

Countries	Policy & Revamp Introduced	Action taken in economic setting & promotion	Impact to country	Opportunity for Improvement
China Ref: [52–55], [24,56],	i. Hybrid electricity market to open market under regional regulation. ii. National electricity pricing was set from four integrated elements: a) purchasing cost from generation, b) variables of transmission and distribution cost, c) fixed cost for transmission and distribution, d) government funding. iii. Direct electricity purchasing for huge consumption of consumers especially for industrial installation. iv. Dynamic system of electricity market; integrated regulatory strategies (DSMs implementation). v. Electricity Market Oriented Mechanism	i. Reforming the electricity market by applying regional/provinces electricity pricing, and open for the competition and bidding system to electricity providers. ii. Investigating the impact of the reformation of electricity market in China towards on grid tariff setting. iii. In terms of tariff structure, in Malaysia, the residential pricing is slightly lower compared to commercial and industry in order to secure the stability of living cost, in comparison to in US and UK. iv. Introduction of Time of Use tariff based on regional setting for regular large consumption consumers of commercial & industry. Some parts of heavy residential consumers are also adopted. v. Tiered Pricing for Household Electricity (TPHE) to increase the level of environmental awareness while promoting demand reduction. vi. Hybrid tariff pricing of TPHE and TOU vii. Consideration of price based on Demand Response and DSM in designing power system reform.	i. Increasing efficiency of the electricity providers' service, improvement of generation compatibility in stabilizing the price setting for the grid network. ii. Enhancement of the stability of the social impact through better arrangement of subsidies. iii. Large number of consumers are able to reduce operation cost in purchasing the electricity while contributing to boosting up the industrial development. iv. Reduction of the government subsidies for household consumers. v. Effective load shifting among consumers through combination of TPHE and TOU method. vi. Fair arrangement between high-income citizens to subsidize lower income through arrangement of tiered pricing tariff.	i. Price signal should be transparent and understandable by all market participants including consumers themselves. ii. Competitive bidding in generation level should be imposed so that the effectiveness of forecasting action in determining the future volatile market will be better done. iii. Integration of Smart Grid system should influence the TOU design for better electricity market balancing. iv. Segregate and widen the level in TPHE price for residential consumers which are labeled based on average usage of electricity (kWh). However, it is recommended to investigate the capping of the setting gap of the consumption level based on regional locality so that it will be able to enhance social economy in terms of equity and efficiency.
India Ref: [57,58], [59]	i. Deregulated system of electricity market; Distribution Franchisee (DF) model or privatization of power distribution in stages level. ii. Unbundling tariff for each component involved in power system. iii. 100% Foreign Direct Investment Policy.	i. Execution program in Bhiwandi where private companies are able to manage distribution process of electricity. ii. Tariff setting considering four main departments: a) power purchase from generation, b) transmission cost, c) distribution cost, d) management cost of metering and maintenance. iii. Allowing power generation, and distribution owned by compatible experiences power providers around the world. Increasing the level of spot market competitiveness.	i. Increasing efficiency in operational and maintenance management while reduction of losses in financial return. ii. Secured margin and reduced losses for government Link Company in power sector. iii. Enhancement of private sector, open new supporting sectors for power system operation while increasing job opportunities.	i. DFs program should be dynamic in engaging the DSM philosophy so that the quality of the electricity supply with current innovation strategies can increase the efficiency and quality of the socioeconomic and survival of the power system. ii. Efficiency spot market forecasting in stakeholders level of specific regions should be focused while the integration of the regional center for spot market pricing signal could be improved as well.
UK Ref: [60–63], [64,65]	i. Deregulated electricity market with privatization system utilities as well as competitive market. ii. Fully implementation of RE demand response price based signal.	i. Implementation of dynamic tariff TOU on all levels of consumers. Aggregation of low price and high price based on topology of energy consumption by consumers during peak and mid-peak. ii. Engagement of Real Time Pricing (RTP) in dynamic tariff setting such as TOU.	i. Demand response program benefit consumers and providers by reduction of peak demand and sustaining the energy balance.	i. The variation of max load shifting percentage reflecting price signal, such as normal TOU day and Critical Peak (22% and 38%) as reported in Ref. [66] should be considered as the baseline for the better design of dynamic tariff. ii. The design of DR-price base program should consider marginal profit of utilities and the commitment limitation of consumers. iii. TOU design should also consider smart home domestic consumers' uncertainty such as battery storage as simulation example in Ref. [67], to reflect highest objective of demand response TOU which are to mitigate peak demand and reduce the cost.
US/Canada Ref: [68,69]	i. Standardizing the centralized provision of energy price information during Real Time Pricing (RTP) implementation. ii. Enhance Demand Response through installation of Smart Metering.	i. Ensuring customer's education and information transparency in terms of energy pricing knowledge was widely implemented. ii. Creating household shifting technique guidelines and TOU tariff promotion through government and private related bodies.	i. Consumers are able to predict and manage electricity consumption and gain benefit of various demand responses time based programs. ii. Sustaining energy conservation and reducing environmental impact. Less new development of conventional electricity generation.	i. Benchmarking process of the end user experiences through complexities of demand response strategies should be done in order to produce better service for the nation. ii. Extreme tariff change should be avoided where the information should be delivered prior to change of any decision as experimented in Refs. [70,71].

(*continued on next page*)

Table 8 (*continued*)

Countries	Policy & Revamp Introduced	Action taken in economic setting & promotion	Impact to country	Opportunity for Improvement
Brazil Ref: [29,72], [73,74]	i. "White Tariff" as well as TOU tariff for low voltage consumers policy. ii. Monthly variables of energy market signal policy so-called Flags Tariff.	i. Multi annual tariff review for consumer satisfaction. ii. Introduction of three levels of flags which are green, yellow and red, to indicate the relationship of generation especially thermal plant response to price setting.	i. Creating better nation that participate in managing power system efficiency.	i. Tools to access of TOU tariff effect should be transparent to public [75] so that it will enhance the awareness of demand response program among consumers. ii. Before considering demand response pricing program, it is recommended to perform simulation study to measure the effect on consumers, utilities and government needs.
European	i. Demand Side Management through Demand Response price based initiative in Poland [76,77]. ii. Energy transition Policy in German [78]. iii. Switzerland "Energy Strategy 2015" [79].	i. Balance diversification of tariff zones by introducing TOU zoning to different voltage level of consumers. ii. Enhancing the energy sector in terms of electricity consumption forecasting to be part of the assessment in order to balance the market and achieve reduction of GHG emission. iii. Electricity demand through energy tax could influence consumers' electricity consumption as the propose idea in Internal Energy Market Project as stated in Ref. [80].	i. Introduction of TOU method in energy market to control energy providers' profit, while increasing the level of energy purchasing in hourly transmission especially for off-peak zone, such as shifting heating process from peak hours. ii. A framework in determining good forecasting results and any tax for the energy use able to accommodate the force of the nation continue to reduce the CO2 emission as well as secure the environment sustainability through proper action.	i. Dynamic model for elasticity measure of energy consumption in the new era of power system management could be improved through virtuous integration as in European energy market. ii. Even with consideration of environmental sustainability in the market strategy, this action is still far away from target. It is recommended to regionalize the implementation through internal management at state level, so that the success will be part for the evidence and benchmark to others. iii. Existing barriers and the step ahead of the dynamic pricing and time based tariff should be given attention to reduce the gap for any action towards success of the program as mentioned in Ref. [81].
Others	i. Potential of dynamic electricity in Indonesia through TOU, CPP and RTP [82]. ii. Consideration of demand response price-based program to Smart Grid [83,84]. iii. High government subsidies tend to lower awareness among consumers but can help to enhance DSM program as in Kuwait [85] and Saudi Arabia [86]. iv. Financial rewards policy to consumers for managing the energy profile in Korea [87]. v. Demand response tariff based initiative in low income countries as in Bangladesh [88].	i. Suggestion of the implementation of electricity market planning to crash the monopoly system. ii. Purchasing price flexibility allows various tariff designs for residential micro grid consumers. iii. Opportunity to create better electricity market opportunity by considering benchmarking program to other countries since Kuwait's effort was rather vague in the past. iv. Practicing demand response program pricing based according to the types of energy consumption. Consumers are expected to individually analyze the energy profile that reflects to price signal. v. Consideration of several levels of residential consumers such as income, life style and area to be merged in tariff structure consideration.	i. Reduction of national transmission and distribution losses while inculcating consumers to apply energy efficiency practice. ii. Consumers enjoy low price rate for electricity while retailers could provide innovative tariff design for the integration of efficient economic demand response program. iii. Consumers are still eligible to gain subsidies but need to take the action of the integration balance of the DSM program as holistic process.	i. Education level and awareness are very important for the successful of improve or revamp program in modern energy market. As proven in Ref. [89], the level of education among participants in demand response program should be considered during the market design, where the maturity process should be taken as the investment block too. ii. Selection of DSM programs should be based on the specification required by country, by considering other uncertain factors such as political issues, level of education, availability for the DSM or renewable energy priority, research input and etc.

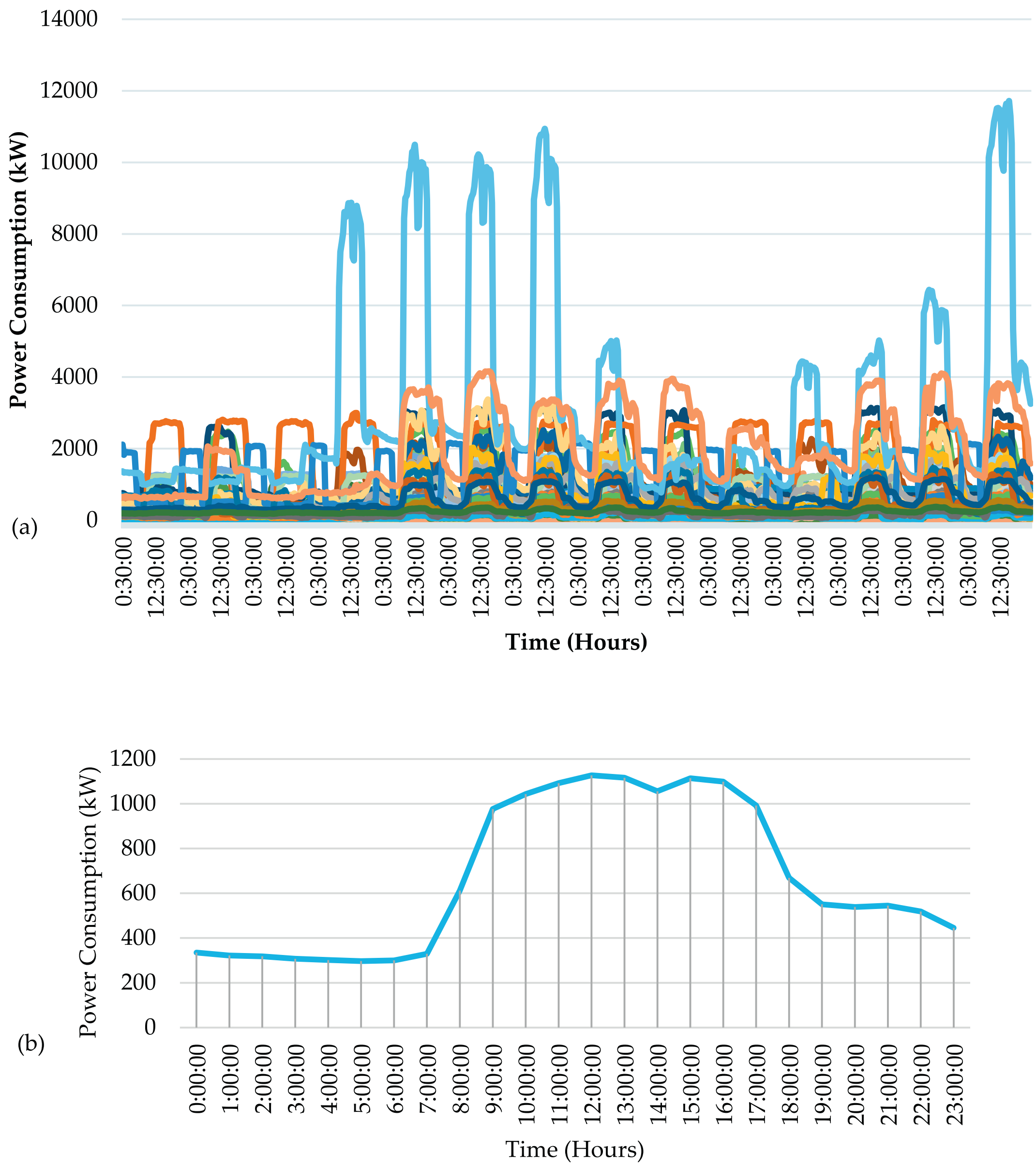

Fig. 4. (a) Load profiles for universities (two weeks average). Average of universities' load profile in 24 h.

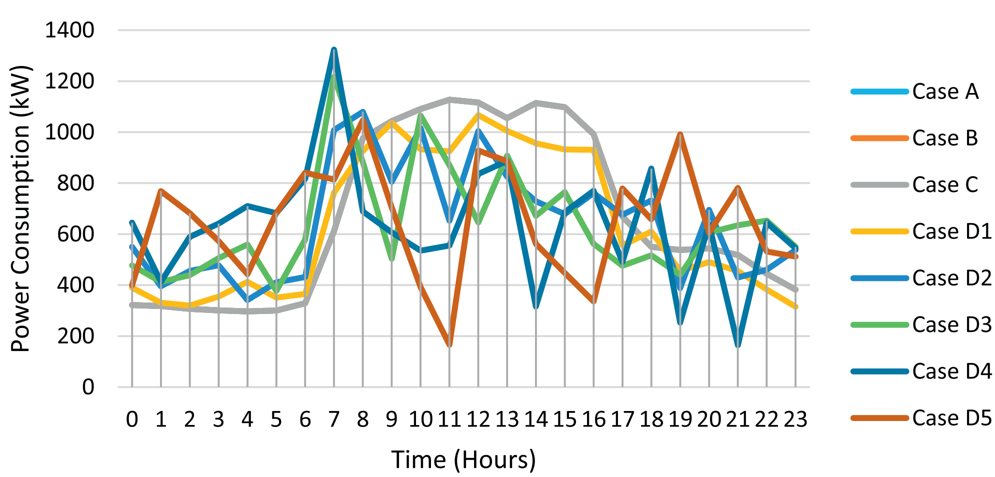

Fig. 5. Simulation of optimal ETOU load profile C1 (university) tariff.

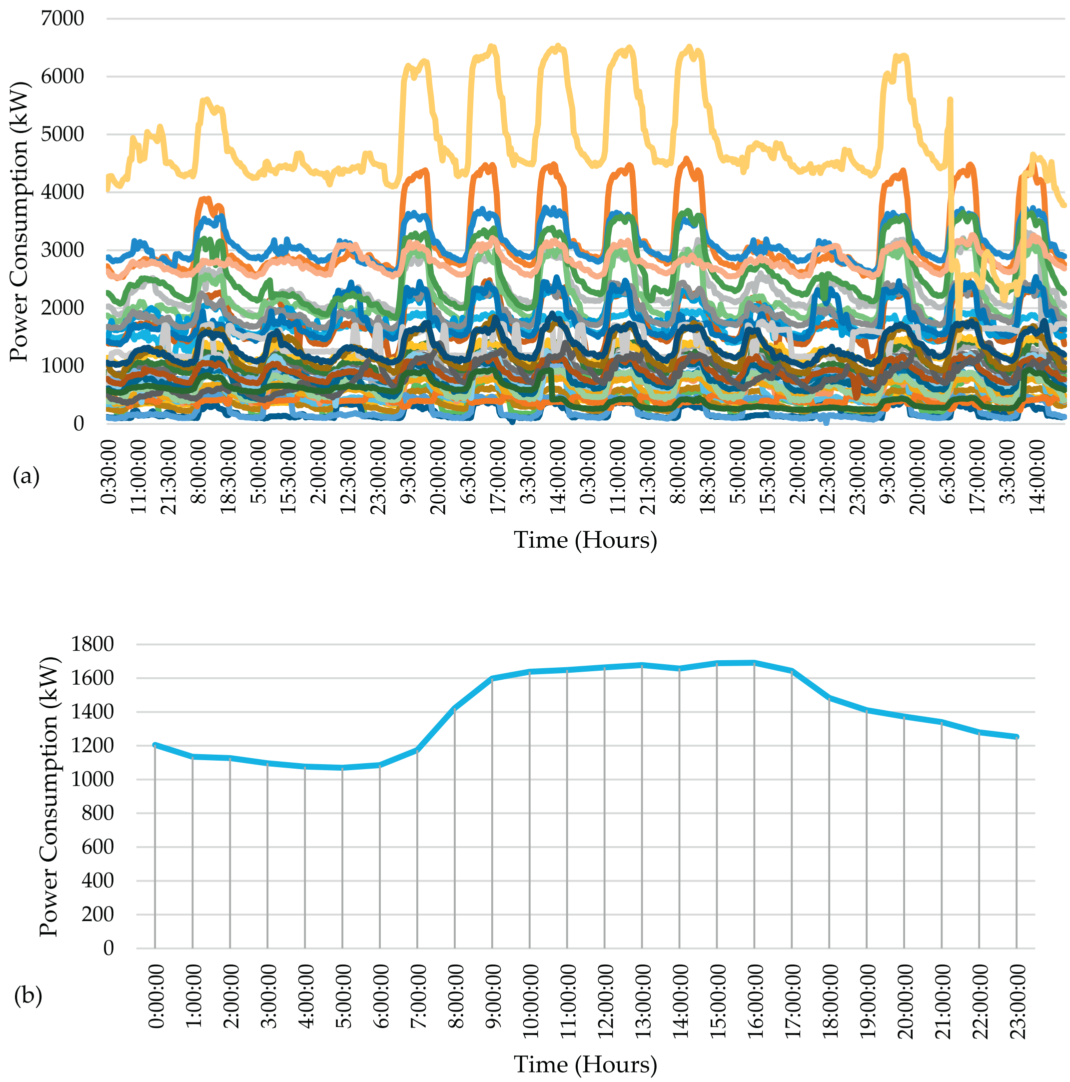

Fig. 6. (a) Two weeks average load profile for hospitals. (b): average of hospitals' load profile in 24 h.

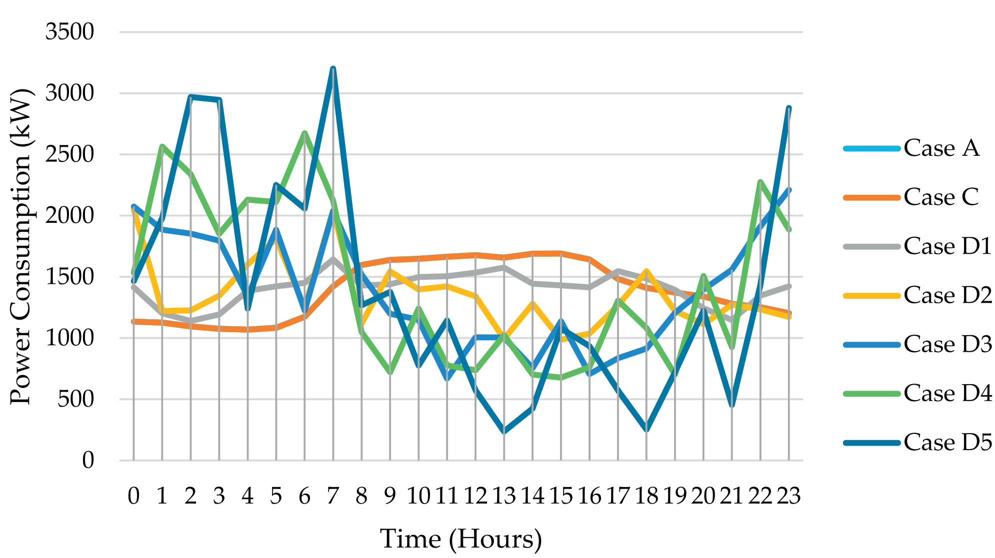

Fig. 7. Simulation optimal ETOU load profile for C2 (hospital) tariff.

Table 9
Comparison of all cases for tariffs C1 and C2

Commercial C1-Tariff	Case A	Case B	Case C	Case D1	Case D2	Case D3	Case D4	Case D5
Energy Consumption (kWh)	16,044.00	16,044.00	16,044.00	15,264.00	15,540.00	15,318.00	15,295.00	15,531.00
Different (%)	NA	NA	NA	−4.86	−3.14	−4.53	−4.67	−3.20
Maximum Demand (MD) (kW)	1127.00	1127.00	1127.00	1067.00	1080.00	1065.00	887.00	1047.00
MD Location Zone	Peak	Peak	Peak	Mid Peak	Mid Peak	Mid Peak	Mid Peak	Mid Peak
Load Factor	0.59	0.59	0.59	0.60	0.60	0.60	0.72	0.62
Energy Consumption Cost (RM)	5856.06	5592.31	6436.26	5996.20	5802.68	5681.19	5455.78	5412.94
Maximum Demand Cost (RM)	34,148.10	34,148.10	38,318.00	30,729.60	31,104.00	30,672.00	25,545.60	30,153.60
Total Cost (RM)	40,004.16	39,740.41	44,754.26	36,725.80	36,906.68	36,353.19	31,001.38	35,566.54
Commercial C2-Tariff	**Case A**	**Case B**	**Case C**	**Case D1**	**Case D2**	**Case D3**	**Case D4**	**Case D5**
Energy Consumption (kWh)	33,426.00	NA	33,426.00	33,714.00	32,501.00	33,278.00	34,702.00	33,463.00
Different (%)	NA	NA	NA	0.86	−2.77	−0.44	3.82	0.11
Maximum Demand (MD) (kW)	1690.00	NA	1690.00	1576.00	1546.00	1558.00	1506.00	1377.00
MD Location	Peak	NA	Peak	Mid Peak	Mid Peak	Mid Peak	Mid Peak	Mid Peak
Load Factor	0.82	NA	0.82	0.89	0.88	0.89	0.96	1.01
Energy Consumption Cost (RM)	10,559.53	NA	11,978.79	11,583.04	10,701.59	10,156.65	10,160.03	9828.82
Maximum Demand Cost (RM)	76,219.00	NA	82,472.00	67,137.60	65,859.60	66,370.80	64,155.60	58,660.20
Total Cost (RM)	86,778.53	NA	94,450.79	78,720.64	76,561.19	76,527.45	74,315.63	68,489.02

development and reform, Peninsular Malaysia has reformed its regulated electricity market which is currently called as IBR regime. Meanwhile, the currently available demand response pricing based program can be divided into several strategies, which are STR, OPTR, TOU and ETOU programs, as summarized in Fig. 3. Moving to other countries, findings and works related to electricity pricing, market and DR reforms are highlighted in Table 8, where inputs and comments are presented as well.

4. Case study: an empirical analysis of TOU and ETOU tariff effectiveness at selected installation in Peninsular Malaysia

This section reviews analysis and comparison of the effectiveness of the newly introduced ETOU in detail. For this part of study, the real load profile provided by the authority of Energy Commission Malaysia. The load profile caters 1 year period with 30 min time interval, which has been combined to be average load profile in 1 h interval time for the purpose of simulation for 24 h's load profile pattern. However, only few normal and critical selected consumers are presented in order to show the effectiveness of each category of tariff consumers involved in demand response price based program. The analyses on case studies for both commercial and industrial tariff have been arranged as follows:

Case A: Energy consumption which either applies flat tariff or TOU tariff pricing for each category (C1 & E1: flat tariff as baseline; C2, E2 & E3: TOU tariff as baseline).

Case B: Energy consumption which applies either C1 or E1 tariff pricing with OPTR (discount of 20% is considered for Off-Peak demand and Case B as baseline).

Case C: Energy consumption with ETOU tariff pricing without load profile management (no optimization technique is applied).

Case D: Energy consumption with ETOU tariff pricing and optimization techniques. This case has been divided into sub cases which are Case D1: 10% effort of load profile management, Case D2: 20% effort of load profile management, Case D3: 30% effort of load profile management, Case D4: 40% effort of load profile management, Case D5: 50% effort of load profile management.

Also for this study, load profile management based on DSM strategies as overall commitment from user to response was considered, but limited to 50% load changing as maximum adjustment. DSM strategies such as Peak Clipping, Conservation, Load Building, Valley Filling, Flexible Load Shape and Load Shifting have been widely used for load profile management. Most researchers who implemented the strategies for load profile management such as Peak Clipping in Refs. [40,41], Conservation in Ref. [40], Load Building, Valley Filling in Ref. [32], and Flexible Load Shape and Load Shifting in Refs. [27,42–45] have also implemented the strategies in single application for different load profile but not in concurrent strategies application. To our knowledge, no comprehensive investigation has been done to date which considers simultaneous demand strategies in response to TOU in other countries or ETOU specifically in Malaysia. With regard to studies related to ETOU in Malaysia, authors in Ref. [46] have presented load shifting formulation to reflect ETOU tariff for an industrial load profile. However, there is no other optimum shifting technique or optimization algorithm applicable for that particular objective as to lower down the electricity cost. Thus, Evolutionary Algorithm (EA) has been applied in order to shift the load profile in ETOU tariff environment as in Ref. [47]. The six-time segmentation ETOU structure has been analyzed and the formulation for the ETOU pricing had been justified but the changing load curve for the load management effort percentage was not convincing enough to find appropriate load profile after load shifting. Meanwhile, the authors in Ref. [48] proposed an assessment method for ETOU commercial consumers to identify the optimum percentage of the load shifting to be done in time zone of peak, mid-peak and off-peak respectively. It is noticed that, except load shifting, no other technique of DSM strategies has been discussed in the context of six-time segmentation tariff like ETOU in Malaysia to date.

Therefore, in Case D, empirical analysis had been done in order to investigate the impact of load profile management with simultaneous demand side strategies such as peak clipping, valley filling and load shifting to mitigate electricity cost, while improving the arrangement of Maximum Demand (MD) and Load Factor (LF) towards optimal six block time frames of ETOU formulation accordingly. Temporarily, Particle Swarm Optimization (PSO) algorithm had been selected to be the optimal driver for those strategies to find the best load profile management for the ETOU cost minimization. It was expected that TOU pricing and design would be different depending on basis in each country, as mentioned in Ref. [49]. Thus, in Case D, optimization formulation was applied based on regulated ETOU pricing, as demonstrated below:

Since the ETOU formulation is determined in pricing unit, along with the objective of study to optimize the ETOU load management, the general ETOU cost saving can be written as Eq. (1):

$$ETOU_{min}^{cost\ saving} = \Delta ETOU_{cost} + MD_{optimum}^{cost} \quad (1)$$

where $\Delta ETOU_{cost}$, is the energy cost of desired load curve after DSM strategies are applied with six-time segmentation as presented in Eq. (2) accordingly. Meanwhile, $MD_{optimum}^{cost}$, is the optimal adjustment of Maximum Demand (MD) allocation that will be explained later in constraints section.

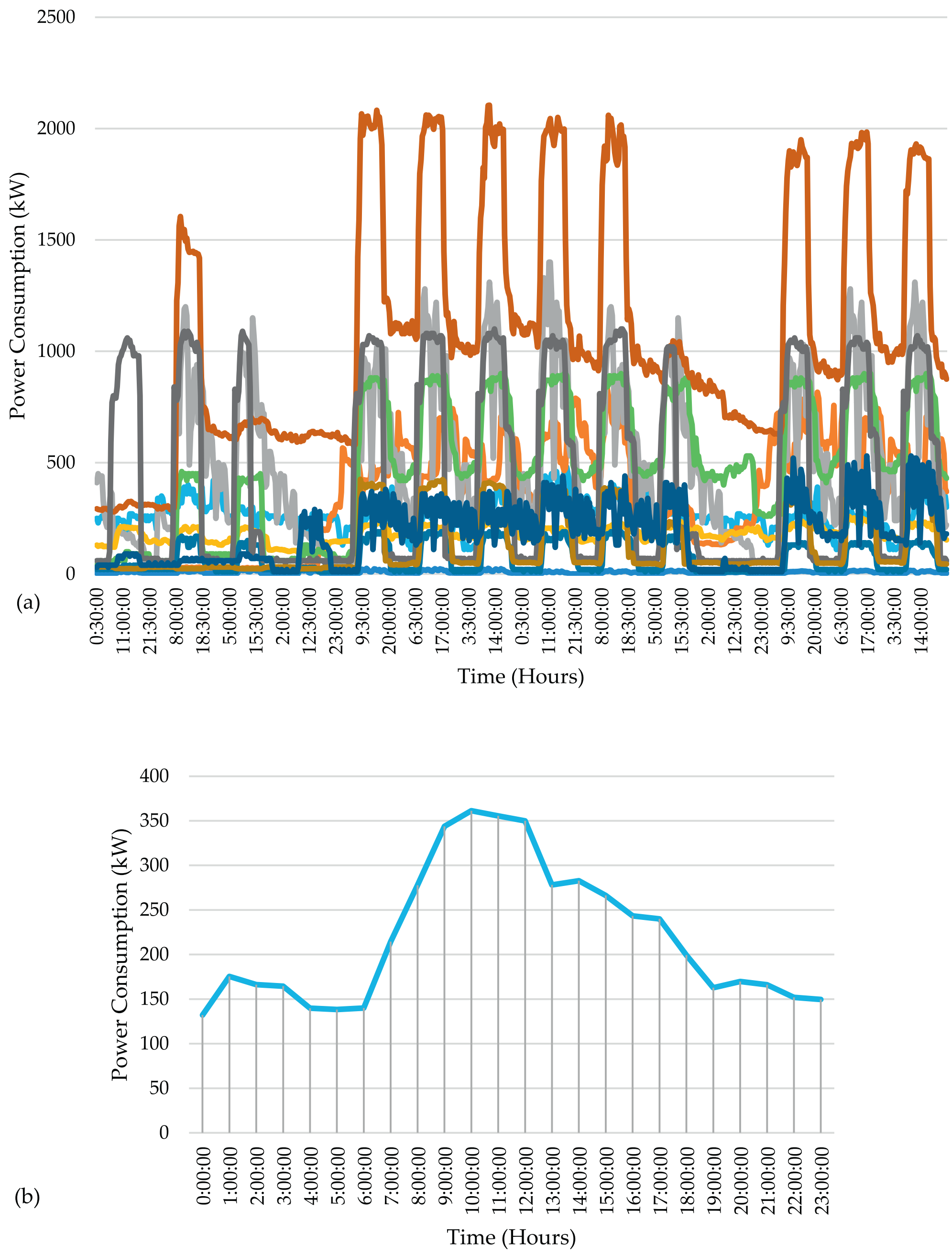

Fig. 8. (a): Twoweeks profile for E1 Semi-Con Manufacturing consumers. (b): Average profile of E1 Semi-Con consumers.

$$\Delta ETOU_{cost} = \left(\left(\sum_{t}^{N=10} \Delta P_{op}\right) \times TP_{op}\right) + \left(\left(\sum_{t}^{N=3} \Delta P_{mp1}\right) \times TP_{mp}\right) + \left(\left(\sum_{t}^{N=1} \Delta P_{p1}\right) \times TP_{p}\right) + \left(\left(\sum_{t}^{N=2} \Delta P_{mp2}\right) \times TP_{mp}\right) + \left(\left(\sum_{t}^{N=3} \Delta P_{p2}\right) \times TP_{p}\right) + \left(\left(\sum_{t}^{N=5} \Delta P_{mp3}\right) \times TP_{mp}\right) \tag{2}$$

where:

ΔP_{op} = changing of off-peak desired load curve with changing of time, with N = 10;
ΔP_{mp1}, ΔP_{mp2}, ΔP_{mp3} = changing of mid-peak desired load curve with different time changing, with N = 3, N = 2 and N = 5 respectively; ΔP_{p1}, ΔP_{p2} = changing of peak desired load curve at time changing, with N = 1 and N = 3 separately;
TP_{op} = utility ETOU tariff price for off-peak time zone;
TP_{mp} = utility ETOU tariff price for mid-peak time zone;
TP_{p} = utility ETOU tariff price for peak time zone.

The general total solution of DSM strategies selection for six-time segmentation profile can be written as in Eq. (3). Demand side strategies which had been proposed to be included were Valley Filling (VF), Peak Clipping (PC) and Load Shifting (LS).

$$\Delta P^{General}_{OP,MP1,P1,MP2,P2,MP3} = \sum_{ts,i} (\Delta P^{VF}_{ts,i} \times W_{VF}) + (\Delta P^{PC}_{ts,i} \times W_{PC}) + (\Delta P^{LS}_{ts,i} \times W_{LS}) \tag{3}$$

where $\Delta P^{VF}_{ts,i}$, is the changing amount of desired load based on VF strategy by DSM at random load (i) in time segmentation (ts). $\Delta P^{PC}_{ts,i}$ and $\Delta P^{LS}_{ts,i}$ are the changing amount of desired load based on PC and LS

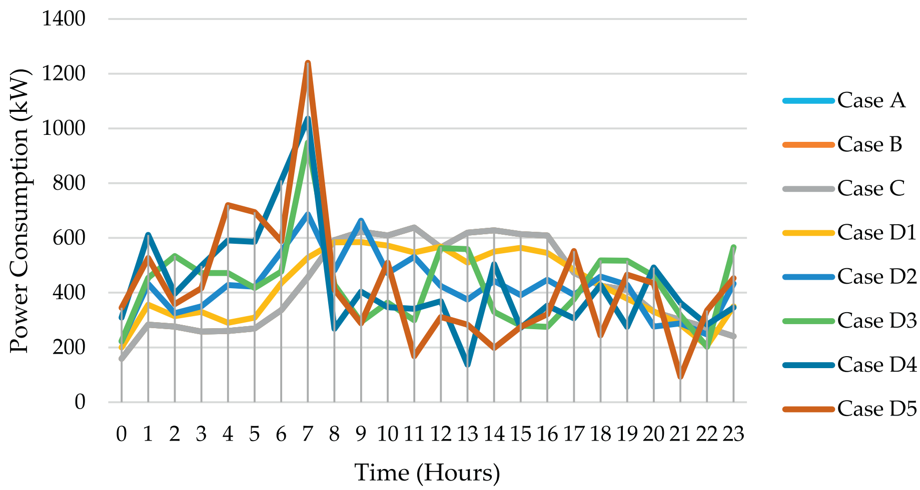

Fig. 9. E1 after optimal ETOU simulation profile.

strategies ssby DSM at random load (*i*) in time segmentation (*ts*) respectively. Meanwhile, the lower bound and upper bound of random load setting selection (*i*) had been set as in Eq. (4) accordingly.

$$0.15 < i < 0.85 \tag{4}$$

Meanwhile, W_{VF}, $W_{PC,}$ and W_{LS} are the weightage of DSM strategies to be implemented in every single load profile concurrently; which is set by consumers depending on the controlled and uncontrolled load at particular time segmentation.

Apart from that, the constraints of the demand side strategies to achieve satisfying performance had been decided as follows:

a. Constraints for VF

$\Delta P_{ts,i}^{VF}$, will be selected during time segmentation with minimum value of base load. The (*ts*) adjustment of VF selection must be as

$$Average\ load > \Delta P_{ts,i}^{VF} \geq \text{Min}baseload \tag{5}$$

b. Constraints for PC

$\Delta P_{ts,i}^{PC}$, will be selected during two highest time segmentation loads, where (*ts*) adjustment of PC selection must be as

$$Average\ load < \Delta P_{ts,i}^{PC} \leq \text{Max}base\ load \tag{6}$$

c. Constraints for LS

LS in the ETOU program shall lead to perform at randomly selected three time segmentations, different from the previous formulation by Ref. [48] who proposed ETOU load shifting to be best from peak to mid-peak time zone. However, in this investigation, especially for the simultaneous DSM strategies application, the best way to put LS is after VF and PC selection, while the rest of time segmentations will be the location for LS to perform randomly. The process of the proposed LS procedure in ETOU load profile is written as in Eq. (7), Eq. (8) and Eq. (9) accordingly.

$$\Delta P_{ts,i}^{LS} \cong \Delta Z_{ts,i}^{shift} \tag{7}$$

$$\Delta Z_{ts,i}^{shift\ down} = (\Delta Z_{up}^{shift} - ((\Delta Z_{up}^{shift} - \Delta Z_{down}^{shift}) \times \omega)) \tag{8}$$

$$\Delta Z_{ts,i}^{shift\ up} = (\Delta Z_{up}^{shift} - ((\Delta Z_{up}^{shift} + \Delta Z_{down}^{shift}) \times \omega)) \tag{9}$$

where.

ΔZ_{down}^{shift} = changing of load decrease at certain time segmentation (*ts*) for the load, *i*.
ΔZ_{up}^{shift} = changing of load increase at certain time segmentation (*ts*) for the load, *i*.
ω = random weightage of load decrease and increase at lower bound and upper bound load setting as in Eq. (4).

d. Constraints for optimal Maximum Demand (MD) selection

An important element of the ETOU tariff cost reduction on the demand side is Maximum Demand. In Eq. (1)$MD_{optimum}^{cost}$, is the variable to $ETOU_{min}^{cost\ saving}$. Due to that reason, optimal selection and arrangement of MD at particular time segmentation are crucially needed. First, the arrangement of the Maximum Load for each time segmentation must be identified, where the segregation of MD at mid-peak load and peak load are determined, respectively. The selection of MD at a daily power (kW) capture is by mapping to both MD costs, either mid-peak charge or peak charge. Eq. (10) and Eq. (11) summarize the selection of MD power load to respective MD charge congruently.

$$MD_{MP}^{cost} = Max\,[L_{T2}; L_{T4}; L_{T6}] \times MD_{MP}^{TP} \tag{10}$$

$$MD_{P}^{cost} = Max\,[L_{T3}; L_{T5}] \times MD_{P}^{TP} \tag{11}$$

where.

MD_{MP}^{cost} = Optimum power load selection at Mid-Peak area;
MD_{P}^{cost} = Optimum power load selection at Peak area;
L_{Tn} = Selected power load for *n* number at particular time segmentation (*ts*);
MD_{MP}^{TP}, and MD_{P}^{TP} = the MD charge for different mid-peak and peak;

e. Constraints for total energy

Total energy before and after of the optimization throughout the process of demand side strategies should not be more than± 5%[47]. Eq. (12) describes the constraints of six segmentation for total energy before and after optimization consequently.

$$\sum (E_{TS1} + E_{TS2} + E_{TS3} + E_{TS4} + E_{TS5} + E_{TS6}) \approx \sum (E'_{TS1} + E'_{TS2} + E'_{TS3} + E'_{TS4} + E'_{TS5} + E'_{TS6}) \tag{12}$$

Based on all the optimum formulation and effectiveness of the constraints setup for two variables in load profile adjustment, which are energy and power demand, the verification of the load profile improvement would be referred to Load Factor Index (LFI) as shown in Eq. (13).

$$LFI = \frac{\sum E_{TSn}}{MD_{Optimum}^{kW} XdayXt} \times 100\% \tag{13}$$

where $MD_{Optimum}^{kW}$ is optimum selection of MD (kW) at peak or mid peak zones, $\sum E_{TSn}$ is total energy for total *n* time segmentations, and *t* is time of energy usage. According to the command procedure in Eq. (13), lower MD arrangement in load profile leads to more improvement of

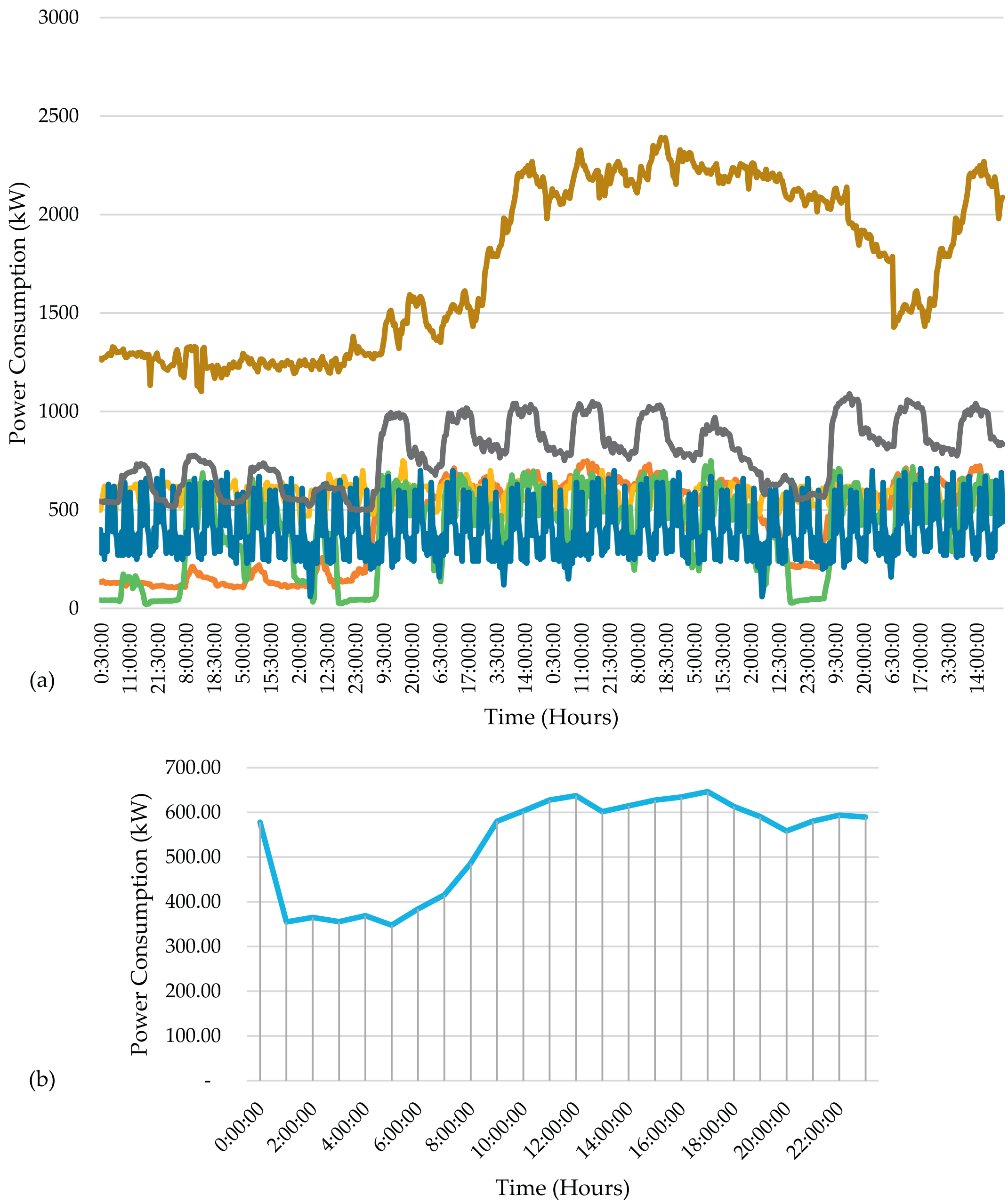

Fig. 10. (a) Twoweeks profile for E2 Water Treatment Plant. (b): Average energy profile for Water Treatment.

LFI. Next section reviews the implementation of multi-objectives of ETOU tariff cost reduction and LFI formulation for optimization of algorithm accordingly.

In supporting the optimization process, here is explanation on the implementation of PSO algorithm in Case D. As the fundamental concept. PSO algorithm was introduced by Ref. [50] and then updated by Ref. [51] to add the weightage factor in the equation to find the best solution. The concept of PSO was inspired by birds and fish schooling, while PSO has been basis of comprising between new algorithms to test their superiors. The stage of implementation is as follows:

Initialization: MATLAB programming in form of PSO algorithm is designed to execute the formulation accordingly. The process starts with the initialization of population, which is determined by calling the load profile in 24-h form, and setting yearly to monthly load profile, where 24-h load in average is used to present consumers' energy consumption pattern. Those variables are generated by the system via a random generator available in the program to compute the electricity cost for the profile in the next step. PSO parameters are then initialized, such as number of particles N, weighting factors, C1 and C2 and maximum number of iteration. In order to ensure the effectiveness of energy cost, optimization is maintained, and all the constraints as in Eq. (5) until Eq. (12) are applied strategically.

Fitness Calculation: An initial population of particles with random position, and velocities, in dimension in the solution space is randomly generated. For each particle that fulfills the constraints as in initialization stage, the load profile will be analyzed and the total ETOU energy cost is calculated by using Eq. (1), by adopting the correlation from Eq. (2) and Eq. (3) simultaneously. Meanwhile, the input of the calculation and constraints is used to calculate LFI as well (refer Eq. (13)).

Determine P_{best} and G_{best}: During the searching process, the two best values are updated and recorded. These values are related with the best solution that has been extended so far by each particle which retains path of its coordinate in the solution space. This value is noted as

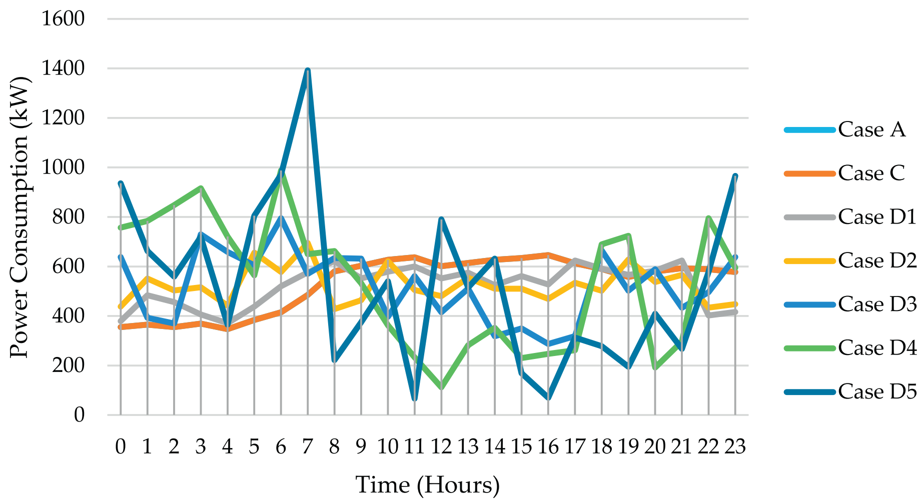

Fig. 11. E2 optimal ETOU after simulation results.

P_{best} and another best value is G_{best}, which is the whole best value so far by any particle. The P_{best} and G_{best} represent the generation of best ETOU energy cost and LFI.

New Velocity and Position: In this process, the particles' velocity and position is updated by applying Eq. (14) and Eq. (15), respectively. The particle's velocity signifies a load profile curve changing. Meanwhile, the total load profile in all segments is evaluated by using the new position.

$$V_j^{k+1} = (\omega \times V_j^k) + (C_1 r_1 (P_{bestj}^k - X_j^k)) + (C_2 r_2 (G_{bestj}^k - X_j^k)) \quad (14)$$

$$X_j^{k+1} = X_j^k + V_j^{k+1} \quad (15)$$

where.

V_j^k = velocity of particle j in iteration k
X_j^k = position of particle j in iteration k
ω = inertia weightage
P_{bestj}^k = the best value of fitness function that has been achieved so far by particle j in iteration k
G_{bestj}^k = the best value among the fitness values
C_1& C_2 = constants that represent weightage factor of random acceleration terms
V_j^{k+1} = new velocity
X_j^{k+1} = new position

Convergence Test: The new position set will be tested for convergence. If convergence is not achieved, the process will be repeated.

4.1. Commercial types: consumers tariff investigation

For this study, two types of consumers for every tariff category had been decided for analysis, which were commercial tariff C1 and C2, while all other cases had been presented simultaneously. By default, C1 and C2 represent flat tariff and TOU tariff to date for commercial consumers. Thus, all electricity installations of 6 kV, 11 kV and 33 kV for C1-University which is 31 locations of load profile by combination of selected college universities, private university and public university through online electricity provider metering in Peninsular Malaysia; and C2-Hospital which is 35 locations of load profile by combination of selected public and privates hospitals in Peninsular Malaysia. The overall 31 energy consumption profiles for C1 consumers in average of 2 weeks period are presented in Fig. 4(a). Since universities function as education hub for teaching and learning activities, other activities such as management, sport, and accommodation contribute to the volatility of load profile at peak time from 12:00pm to 15:00pm, as illustrated in Fig. 4(b). Hospital load profile under C2 tariff category is shown in Fig. 6(a), while the average load curve gained for the hospital electricity consumption is shown in Fig. 6(b) respectively. The base load for the hospital was observed to be more 50% since its operation is for 24 h in major areas except in certain sections, for example outpatient clinic, specialist clinic, and admin office. Figs. 5 and 7 present the obtained simulation load curve for all Cases in C1 and C2 tariff, respectively, with regard to justify the effectiveness of ETOU optimization load management versus others baseline TOU, TOU (OPTR) and basic ETOU without load management. The load curve of Case D5 for both university and hospital was found to be far away from baseline load Case A, where the lowest demand chronicle was below 15% of total demand, respectively. Case D1 was observed to have slight change but still followed the original patent of Case A, while Case B and Case C remained having the same pattern. It was noticed that most of the loads for Case D1, Case D2, Case D3, Case D4 and Case D4 were transferred from peak zone to mid-peak zone for university load profile and peak to off-peak zone for hospital load profile. Table 9 presents results obtained from the simulation, including the consideration of Load Factor, differential percentage before and after simulation for energy consumption, MD value and MD allocation, respectively. For tariff type such as C1 (university), there were options for immediate cost saving by considering Case B instead of tariff offer in Case A, Case C and Case D, where they are able to get 4.5% energy cost saving when compared to baseline. Meanwhile, Case C did not perform well, as it was standalone without any implementation of load management. The electricity energy cost increased approximately 9.01%, while total electricity cost surged to about 11.87% compared to baseline Case A. Thus, Case C was examined to be risky for C1 type of consumers, especially universities, if they are not able to implement load management such as implementation of DSM strategies. Encouraging results of ETOU tariff switching was significantly presented by Case D1 until Case D5, where there were reductions of total electricity cost (respective saving Case D1: 8.2%; Case D2: 7.74%; Case D3: 9.13%; D4: 22.50%; D5: 11.02%). The proposed simultaneous program of DSM such as Peak Clipping, Valley Filling and Load Shifting were able to give impact to the universities' load profile. The peak demand had been moved to mid-peak zone which then lowered down the MD charge per kW power usage. Nevertheless, in terms of energy consumption cost, the load management was applied only until 40%, and significant saving was gained, better than in Case A, Case B and Case C. It was observed that load factor had not much improved in all Cases except Case D4 that was able to reduce MD below 90% of normal peak demand. Even though the percentage of different before and after simulation of about −4.67% could be considered as one of the factors contributing to the decline of energy consumption

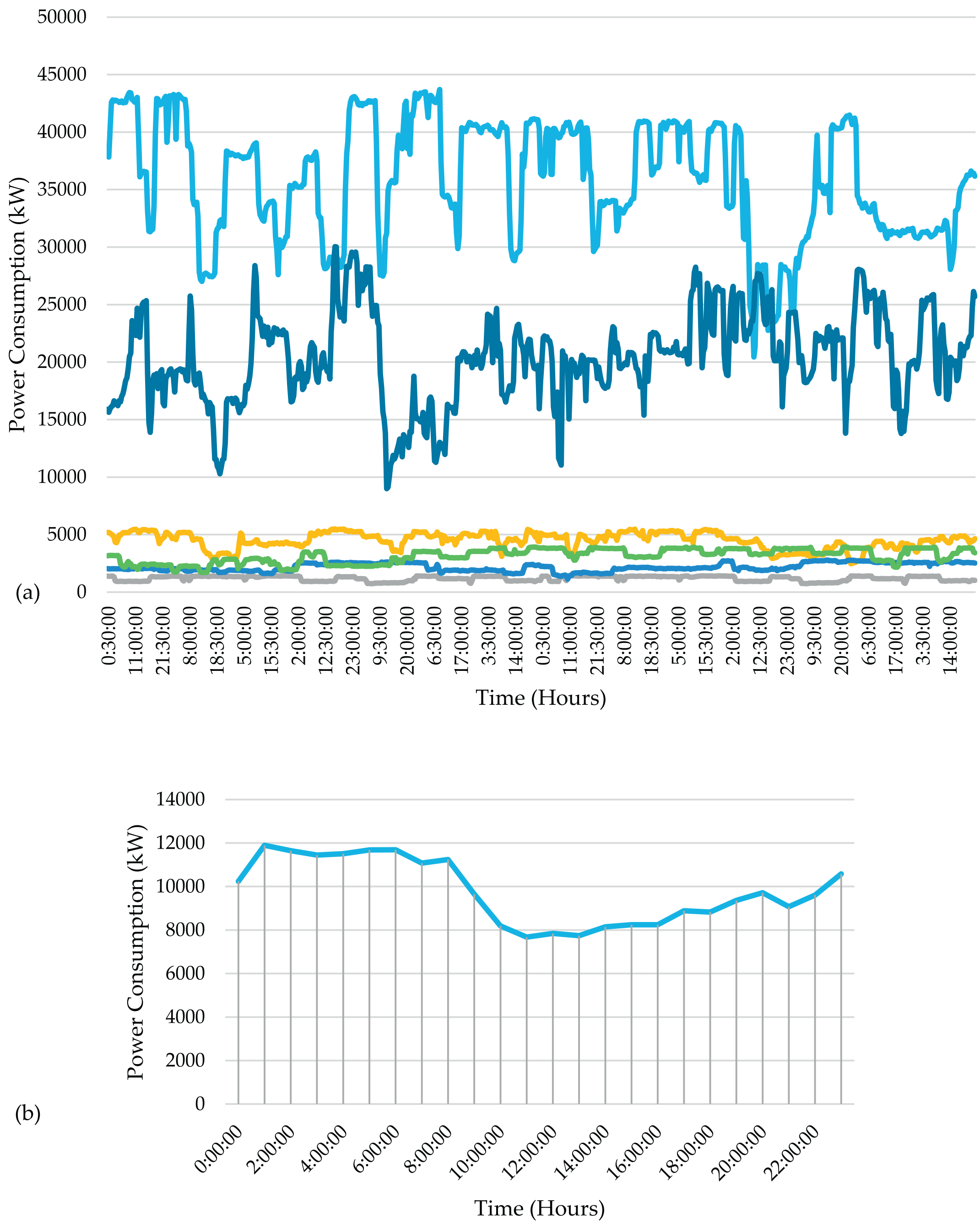

Fig. 12. (a): Twoweeks profile for cement plants. (b): Average profile for cement plants.

cost in Case D4, a contrary finding was found in Case D5 for C1 and Case D4, Case D5 for C2 tariff.

On the other hand, for C2 commercial tariff which is presented by hospitals load profile was already embedded in off-peak period, Case B was not in for comparison. Without any optimization taken for ETOU tariff switching as in Case C, the energy consumption cost, MD cost, as well as total cost for electricity, had increased tremendously (8.84%). The energy consumption cost started to decrease approximately 3.82% in Case D3, when 30% of load management (DSM strategies) was applied. However, it was observed that, the MD cost increased starting from Case D1 until Case D5, respectively (11% up to 23% MD cost saving). Meanwhile, total cost of electricity was recorded to decline, from Case D1 (9.29%), Case D2 (11.77%), Case D3 (11.81%), Case D4 (14.36%), and Case D5 (21.08%). Case D3 and Case D4 of C2 hospital tariff could be considered as best given impact, which fulfilled all the requirements for cost saving, but with less values of different energy taken after simulation which were −0.44% and 3.78%, respectively.

4.2. *Industrial types: consumers tariff investigation*

Industrial types of consumers under E1 tariff was Semi-Conductor manufacturing (11 locations), under E2 tariff was Water Treatment Plant (6 locations), and under E3 was Cement Plant (6 locations). All the data were taken within Peninsular Malaysia border. Fig. 8 (a) and 8(b) shows the load profile in two weeks and the average load curve for Semi-con manufacturing, respectively. It was noticed that, the baseline of load was less than 50% (average 260 kW), while the peak demand and energy consumption in average were approximately 638 kW and 10,246 kWh disparately. Different load curve was observed from E2 and E3 consumers, as in Fig. 10 (a, b), Fig. 12 (a), Fig. 12(b), where load

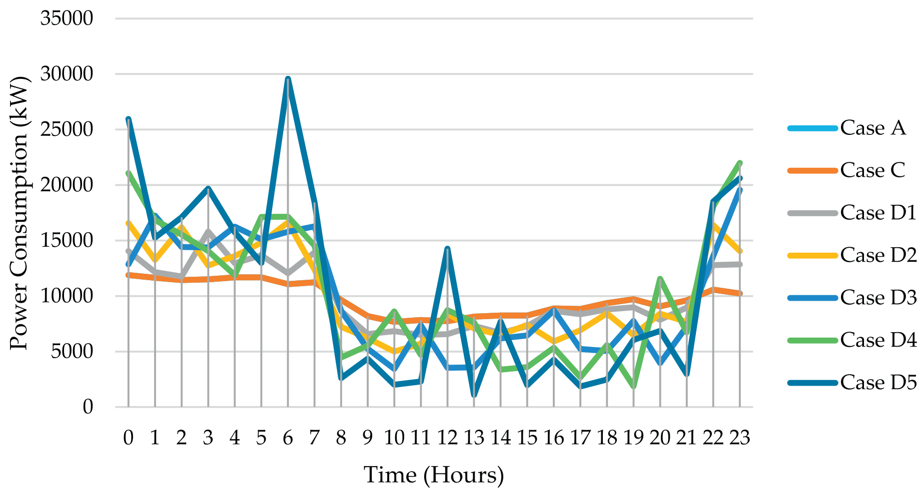

Fig. 13. E3 optimal ETOU after simulation.

Table 10
Comparison of all cases for tariffs E1, E2 and E3.

Industrial E1 Tariff	Case A	Case B	Case C	Case D1	Case D2	Case D3	Case D4	Case D5
Energy Consumption (kWh)	10,246.00	10,246.00	10,246.00	10,247.00	10,166.00	10,346.00	10,325.00	10,231.00
Different (%)	NA	NA	0.00	0.01	−0.78	0.98	0.77	−0.15
Maximum Demand (MD) (kW)	638.00	638.00	638.00	585.00	663.00	563.00	504.00	552.00
MD Location Zone	Peak	Peak	Peak	Mid Peak	Mid Peak	Mid Peak	Peak	Mid Peak
Load Factor (%)	0.67	0.67	0.67	0.73	0.64	0.77	0.85	0.77
Energy Consumption Cost (RM)	3452.90	3261.82	3688.38	3567.91	3365.21	3206.47	3190.41	3018.06
Maximum Demand Cost (RM)	18,884.80	18,884.80	22,649.00	17,316.00	19,624.80	16,664.80	17,892.00	16,339.20
Total Cost (RM)	22,337.70	22,146.62	26,337.38	20,883.91	22,990.01	19,871.27	21,082.41	19,357.26
Industrial E2 Tariff	**Case A**	**Case B**	**Case C**	**Case D1**	**Case D2**	**Case D3**	**Case D4**	**Case D5**
Energy Consumption (kWh)	12,745.00	NA	12,745.00	12,528.00	12,569.00	12,507.00	12,794.00	12,795.00
Different (%)	NA	NA	NA	−1.70	−1.38	−1.87	0.38	0.39
Maximum Demand (MD) (kW)	646.00	NA	646.00	624.00	628.00	665.00	724.00	790.00
MD Location Zone	Peak	NA	Peak	Mid Peak	Mid Peak	Mid Peak	Mid Peak	Mid Peak
Load Factor (%)	0.82	NA	0.82	0.84	0.83	0.78	0.74	0.67
Energy Consumption Cost (RM)	3947.56	NA	4413.43	4231.79	4096.86	3880.46	3662.89	3592.76
Maximum Demand Cost (RM)	23,902.00	NA	25,840.00	22,464.00	22,608.00	23,940.00	26,064.00	28,440.00
Total Cost (RM)	27,849.56	NA	30,253.43	26,695.79	26,704.86	27,820.46	29,726.89	32,032.76
Industrial E3 Tariff	**Case A**	**Case B**	**Case C**	**Case D1**	**Case D2**	**Case D3**	**Case D4**	**Case D5**
Energy Consumption (kWh)	234,178.00	NA	234,178.00	240,057.00	243,958.00	237,916.00	248,667.00	254,621.00
Different (%)	NA	NA	0.00	2.51	4.18	1.60	6.19	8.73
Maximum Demand (MD) (kW)	9711.00	NA	9711.00	8980.00	8431.00	8708.00	11,552.00	14,262.00
MD Location Zone	Peak	NA	Peak	Mid Peak	Mid Peak	Peak	Mid Peak	Mid Peak
Load Factor (%)	1.00	NA	1.00	1.11	1.21	1.14	0.90	0.74
Energy Consumption Cost (RM)	63,664.61	NA	70,722.99	69,251.38	67,805.99	65,508.20	64,512.60	63,075.70
Maximum Demand Cost (RM)	344,740.50	NA	339,885.00	314,300.00	295,085.00	333,516.40	404,320.00	499,170.00
Total Cost (RM)	408,405.11	NA	410,607.99	383,551.38	362,890.99	399,024.60	468,832.60	562,245.70

demand from Water Treatment Plant (WTP) started to increase from 7:00am until mid-night hour (12:00am), while the daily operation of Cement Plant (CP) started to decrease from 7:00am to 5:00pm.

Figs. 9, Fig. 11, and Fig. 13 present the effectiveness of the load movement in line to load management effort percentage with regard to the formulation for optimal ETOU implementation. The application of PSO algorithm led to the surge of E1 load curve from 7:00am to 9:00am, and then decrement of the load from 15:00pm to 17:00pm, reflecting the ETOU price signal accordingly. It was observed that, Case D4 and Case D5 decrement of the minimum load to under 20% of total load demand. Temporarily, Case D3 presented bell curve load profile from 12:00pm to 15:00pm, while Case D1 and Case D2 showed only slight change compared to baseline profile Case A. Meanwhile, Case B and Case C remained having the same load curve as baseline (refer to Fig. 9). On the other hand, the E2 tariff, after simulation results, showed that Case D2, Case D3, Case D4 and Case D5 had simultaneous increment of the load from 5:00am to 9:00am. Case D1 followed the load pattern of baseline Case A and Case C, but with less change compared to other cases (refer Fig. 11). For simulation status of load profile E3 tariff CP consumer as in Fig. 13, it was perceived that Case D3, Case D4 and Case D5 had decrement of their average load demand from 9:00am to 22:00pm to under 5000 kW, which was abnormal under load operation for the CP. However, it was noticed that significant load was amplified starting from 23:00pm to 8:00am enormously for all D cases. The overall patterns of the load profiles were not too much different compared to baseline Case A since CP has already operated at TOU price signal initially.

Table 10 presents tabulated data in accordance to the pricing results for all tariff categories under industry. Energy consumption cost was greatly improved when optimization technique had been applied starting from 20% of load management effort in Case D2. However, 2.54% of saving was less than that of C1-OPTR tariff in Case B when better energy consumption and cost saving of 5.53% gained. For the overall performance of ETOU optimization E1 tariff consumer, significant total cost saving was unstable for Case D1 (6.51%), Case D2 (−3.92%), Case D3 (11.76%), Case D4 (5.26%), and Case D5 (13.34%)

Table 11
Challenge and suggestions to demand side consumers for tariff selection.

Types of Tariff	Challenge to Apply DSM program	Appropriateness of DSM Strategies	Best Range of Load Management Effort to enjoy ETOU	Suggestion to TNB's Consumers on tariff selection
C1-University	Scheduling the operation for cooling system [90], sustaining energy management activities [91,92], and rearranging student timetable in terms of classroom allocation and outdoor activities [93].	It is possible to apply Valley Filling, Peak Clipping and Load Shifting separately or simultaneously.	20%–40%	Load Factor for universities' load profile is between the range of 0.45–0.65; there is space for the PBP program to design as well as promote demand response. TOU (OPTR) with discount 20% for off-peak is a better tariff for universities which are not able to manage 20% loads. It is advisable to only control MD value so that load factor can be sustained or improved when compared to baseline load factor, according to TNB requirement.
C2-Hospital	Two types of loads in hospital, which are essential and none-essential load, are designed for critical operations such Operation Theatre and others. Most major equipment are controllable and uncontrollable motors in the operation system [94]. It is a challenge for hospital to maintain cooling comfort for patient, staff and others medical equipment [95].	It is possible to apply Valley Filling, Peak Clipping and Load Shifting separately or simultaneously.	30%–40%	Since hospital load profile needs minimum 30% of load to be manageable in order to get benefit from ETOU program, the best way is to maintain being under C2 tariff or transform to C1-OPTR vice versa. The existing load factor for hospital is already optimal for the demand response program to be applied. In this case, baseline load factor was 0.82. It is risky to shift to be in ETOU program if the planning for the load management is not yet ready. As presented in Table 11, the cost of Case C critically increases.
E1-Semi-Con Manufacturing	Operational and workers schedule should be given attention in order to join the demand response program PBP. The indicator of the machine scheduling to make span effectiveness [96,97]; and the sustainability of the tariff design such as TOU tariff [98]; and less awareness of the demand side management program by manufacturer [99].	It is possible to apply Valley Filling, Peak Clipping and Load Shifting separately or simultaneously.	30%–50%	As referred to Table 10, consumers of E1 tariff especially for Semi-Con industry, could select the E1-OPTR as in Case B in order to enjoy initial cost effectiveness. It is possible to achieve 5% saving by maintaining or improving the load factor every month in order to get lower off-peak rate charge as E2, and better rate for MD. Since the base load factor is 0.67, there are opportunities for this type of consumers to enter the ETOU program but with proper arrangement of controllable load, at least minimum of 30%. Otherwise, it is risky to lose approximately 6% if they are not able to do so.
E2-Water Treatment Plant	The operation of WTP is based on consumer's water demand. More demand at certain time contributes to more loads to be shown online. Scheduling supply and demand is the most challenging task for the demand response program in WTP [100]. The type of demand side management strategies must correlate to the quality of water produced [101].	Simultaneous DSM strategies like valley filling, peak clipping and load shifting are not suitable for the load profile of WTP. Load shifting, peak clipping and valley filling would be better to apply discretely.	30%–40%	It is risky for WTP consumers to enjoy ETOU because the requirement of the best load management effort percentage is high. It was recommended for WTP to remain under the same TOU E2 tariff or transform to E1-OPTR tariff to reduce the risk of losses in operational cost. If not, they will lose approximately 8% if WTP enters the ETOU program without any proper load management plan. Since the baseline load factor achieved so far is 0.82 in Case A, it will be the indicator that WTP load profile is already efficient for the demand response PBP to be embedded as cost reduction program for them.
E3-Cement Plant	Maintaining the product output and the scheduling for the demand response program is a challenging task for CP [102]. Too much load shifts will affect operation and lead to ineffectiveness of MD arrangement, as presented in Table 10. Thus, it is difficult to sustain the DSM program in CP [103].	Setting of simultaneous DSM strategies is not in best condition, even to use load shifting technique. It is recommended to apply valley filling and peak clipping only.	0%–30%	It has been observed that CP is able to shift into ETOU tariff even though with no effort of load management, and able to get cost reduction for about 1.45% of maximum demand charge. However, incompatible arrangement of the ETOU time zones has caused the energy consumption cost to be reduced, not reflecting the load management as to optimize implementation of demand side strategies. Since the load factor for CP (1.0) is closed for any load response of PBP, it is suggested to CP consumers to join the ETOU program for better MD charge reduction, but the energy consumption must be controlled. It can be done by implementing energy efficiency program such as ISO 50001 for sustainability of energy management [103].

due to improper allocation and volatile value of maximum demand. The proposed optimization strategy would be in multi-objectives to tackle energy cost, MD and load factor but the tied constraints for the energy after simulation had contributed to the unstable results. However, it was different for the E2 tariff consumer since they were using TOU tariff as baseline. The total cost of electricity was reduced only in Case D1 (4.14%), Case D2 (4.11%) and Case D3 (0.11%) which was contributed by MD cost saving, while energy consumption cost remained positive only in Case D3 (1.7%), Case D4 (7.21%) and case D5 (8.99%) individually. On the other hand, consumers under E3 tariff had only slight decline in Case D5 (0.93%) when the proposed ETOU optimization was applied. Other performance improvement could be seen in total electricity cost, where cost saving was recorded in Case D1 (6.09%) and Case D2 (11.14%); but they were started to decline in Case D3 (2.30%), Case D4 (−14.80%) and Case D5 (−37.67%). MD allocation and value had played an important rule for the reduction of total electricity bill for the ETOU cases under E3 tariff as well as CP environment. It was thoroughly observed that for all tariffs of E1, E2 and E3, there were increases of electricity cost for all C cases simultaneously. It was deduced that, shifting to the ETOU program without any proper planning as well as implementation of DSM strategies would lead to surging of operational cost for the manufacturing and plants. Since overall different percentage of energy consumption before and after was in control, except for E3 tariff in Case D4 and Case D5, performance of other cases by algorithm implementation was acceptable. Load Factor (LF) was observed to be in line to the MD performance; more optimal MD value would contribute to better LF improvement, as demonstrated in Table 10 accordingly. In many cases of optimal ETOU, the LF had been improved with better value compared to baseline in Case A. Best improvement of LF under E1 was Case D3, while for E2 was Case D1 and E3 was D2, respectively.

4.3. Challenge and suggestion for the tariff selection appropriateness

Table 11 presents summary on the challenge and suggestion for the tariff selection with regard to the examples of every single tariff consumers. The finding of best percentage range of load management effort and challenge to the concurrent DSM strategies implementation could be valuable info for consumers when they decide to subscribe ETOU tariff transformation in the future. The percentage of load management setting depends on the appropriateness of buildings based on the challenge what they can afford to enjoy ETOU rate, which includes energy cost reduction, load factor limitation or range and MD cost reduction. If not, total cost with MD cost reduction would be given priority. For this study, suggestions have been decided based on the current simulation results, as well as to prevent consumers from missing the tariff selection, as the result will downgrade the PBP Program in Peninsular Malaysia.

5. Conclusion

This study has reviewed significant and critical issues in energy market, particularly electricity pricing in Peninsular Malaysia. Upright program with regard to demand response price based program to demand side consumers and impact of demand strategies on energy industry have also been explained accordingly. Apart from that, ETOU tariff investigation has been analyzed where the significant findings on load management weightage setting in helping commercial and industrial consumers to better understand demand side management strategies has been presented accordingly. Thus, ETOU tariff needs to be given attention by all major consumers, especially involving high tension voltage installation such as cement plant and others. However, significant investigation has shown that, without any proper planning for the demand response PBP, consumers will risk to lose operational electricity charge, as well as increase in monthly bill. Throughout this paper, the findings of critical review and case study investigation is hoped to be notable reference for the newly developed electricity tariff references while contributing to enhance Malaysia energy market sustainability, in addition to improving the electricity pricing structure continuity for better consumer friendly design consideration. Future work could be explored much on optimum price based program which is load management strategy for greater impact on consumers' side cost reduction at the same time benefitting others stakeholders.

6. Recommendation

The ETOU program can be reformed to consider several innovations, especially for the tariff design on provider's side, where consumers' side shall take serious action from DSM strategies, as presented in next two recommendations. The first recommendation is providers to consider fragmented allocation of ETOU tariff design based on their own average Load Duration Curve (LDC), as proposed by Ref. [104]. The determination of time frame and zoning section for the time of use tariff through LDC will specifically define the actual load profile for certain consumers' categories. Meanwhile, dedicative price rate setting should consider average price for the existing flat or conventional TOU tariff, so that the electricity charge will be balance to consumers' effort for applying demand side management program. Truthful formulation in order to generate best tariff structure will be established based on the success of new tariff implementation as well. Example of formulation of TOU is presented in Ref. [105] and best practice is presented in Ref. [106]. Second recommendation is consumers should understand the availability of their energy system before they decide to accept new tariff system. Percentage of DSM strategy limitations such as controlled and uncontrolled load shall be given attention through several initiatives, such as combined program with details energy audit under energy efficiency program, which will create good sustainable procedure for tariff selection and weightage of controlled loads to be involved in DSM strategies implementation. Meanwhile, demand side consumers should consider the current status of their load factor, which indicates the availability of the system to communicate with PBP through time of use tariff. Load factor consideration also has been discussed in view of providers, as the system performance would be better when load factor percentage is increased [107,108].

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