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Enhanced Time of Use Electricity Pricing for Commercial Customers in Malaysia

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ABSTRACT

Malaysia has introduced a new Time of Use (ToU) tariff scheme known as Enhanced ToU (EToU) for commercial and industrial customers. EToU is a more detailed pricing scheme where one day time frame is divided into six period blocks as compared to only two period blocks in the existing ToU. Mid-peak tariff is introduced to the existing peak and off-peak tariff. Off-peak rate for EToU is significantly lower than the existing off-peak rate but the peak rate is much higher. EToU is designed to motivate users to reduce their consumption during peak hours or shift the load to mid-peak or off-peak hours, which if done correctly can reduce the electricity bill while maintaining electricity consumption. This new EToU scheme will benefit consumers if they are able to shift consumption from peak-hours into mid-peak or off-peak hours. This paper assesses the amount of load shifting that is required based on customers' load profile and EToU rates. The load profile data of an office building in Putrajaya, Malaysia is used as a case study.

Keywords: Time-of-Use, load profile, electricity consumption

INTRODUCTION

Tenaga Nasional Berhad (TNB), the electricity utility supplier in Malaysia has introduced a new EToU tariff scheme as an alternative to the existing ToU tariff. Under EToU scheme, there are three different rates for electricity consumption (kWh) charge: Peak, Mid-Peak and Off-Peak. For maximum demand (kW) charge, there are two different rates: Peak and Mid-Peak. These rates are only applicable on weekdays (Monday to Friday). For weekends

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(Saturday, Sunday) and Pubic Holidays, only Off-Peak rate are used throughout the day and maximum demand charge is waived. The new EToU scheme is offered as an option to any Low Voltage, Medium Voltage and High Voltage consumers under the following tariff category; i) Commercial: Tariff C1, C2 ii) Industrial: Tariff D, Ds, E1, E1s, E2, E2s, E3, and E3s (TNB, 2016). EToU provides price signals for customers to control their electricity usage and encourage Demand Side Management. It allows consumers to lower their electricity bill by using less electricity during peak hours or by shifting their consumption to Mid-Peak and Off-Peak hours, when the rates are lower. However, EToU may also result in higher electricity bill if customers are not able to shift their consumption. This paper presents a simple method to help customers decide whether they should opt for the new EToU scheme or stick to the old ToU scheme.

This paper is divided into six sections. The basic concept of ToU is discussed in Section 2. The relationship between ToU and DSM is presented in section 3. The mathematical formulation of the assessment method is described in section 4. Results obtained from the case study are presented in Section 5. Finally, section 6 concludes the paper.

Nomenclature	
ToU	Time of Use
EToU	Enhanced Time of Use
DSM	Demand Side Management
HVAC	High Voltage Alternate Current

ToU Electricity Pricing

ToU is an electricity tariff system based on consumers' usage hour. It varies over different time period in a day and fixed within the same time period. Unlike Real Time Pricing (RTP) that varies all the time depending on wholesale market price and Fixed-Tariff Pricing that doesn't varies at all. Comparisons between different pricing methods can be found in Nazar, N.S.M., et al, 2012. ToU pricing method divides time into different period blocks with different tariff rates for each block. Generally, peak hour periods are charged higher tariff unlike, RTP that reflects the real wholesale market price. , ToU reflects the long-term cost of producing electricity. Commonly, there are three ToU period blocks categories i.e. Peak, Mid-peak and Off-peak hours. At peak hours, utility need to deliver the highest generation. During this period, the utilities provide maximum amount of energy and use the highest number of system capacity. Use of less fuel-efficient generation plant is often required during these hours. Transmission and distribution system losses also increased, adding to increase need of supply. Although the peak hour is just a small number of hours each day, the cost implication is significantly high. At off peak hours, the utilities use a relatively small amount of total system capacity, thus it does not contribute to the need for the development of facilities. Mid-peak is when the cost of electricity production is between peak and off-peak. Significant ToU rates difference between the peak, mid-peak and off-peak hours are required to ensure the effectiveness of ToU pricing (Hussin et al, 2014).

ToU pricing is intended to encourage consumers to shift their electricity usage from peak hours into off-peak or mid-peak hours. Customers have the option to shift their electricity consumption based on the price; consuming electricity during off-peak or mid-peak period will increase savings as the electricity rates are significantly lower. Where shifting consumption levels are not possible ToU tariffs can encourage some customers to use alternative sources, such as diesel generators on site. In short, ToU pricing encouraged response from electricity consumer and hence become the most important component in DSM Program.

ToU in DSM Program

Typical daily consumer demand has peaks, which result in high generation costs. Demand Side Management (DSM) program encourages the end user to be more energy efficient to reduce these peaks. Examples of DSM measures include lighting retrofits, HVAC improvements, and automation. Some investment cost is required to implement these measures. Another important DSM measure which is cost free yet effective is load shifting i.e. shifting the load or consumption from peak to off-peak hours. For this measure to succeed, electricity consumers must be encouraged to change their electricity consumption based on the supplier's need. In other words, they must shift their load consumption to the targeted hours. It can be done by using price signal such as TOU tariffs, which specify different prices for different times of the day. The difficult part is to determine the most efficient price rate that signals the consumer to change the electricity usage behaviour (de Sa Ferreira et al, 2013). ToU must give the right signal to the consumer so that the objective of ToU can be achieved. The success of DSM program through ToU tariff depends on the following criteria: i) The right signal; utilities must ensure the accurate signal is being channelled to the electricity customer whether by electricity price or other incentive to customer to encourage load shifting ii) DSM should benefits both customer and utilities, iii) a good program would produce the expected outcome to both parties fairly.

ToU in selected Countries and Malaysia

Many countries have already implemented ToU electricity tariff for commercial customers. Different countries have different ToU design and tariff rates due to their unique load profile pattern as well as their needs and objectives. Table 1 shows the ToU period blocks that is currently being implemented to commercial customers in Sri Lanka, South Africa, New York, California, and Malaysia. Different ToU period blocks with different tariff were defined for 24 hours' consumption i.e. peak, mid-peak and off-peak block. From Table 1, it can be seen that the peak-hour block for Sri Lanka is from 6.30pm until 10.30pm, which is aside from the office buildings' common working hours (8am-5pm). Mid-peak block is from 5.30am until 6.30pm. For South Africa, there are two peak hour blocks i.e. from 7am to 10am and from 6pm until 8pm. About 80% of the office buildings' common working hours fall in mid-peak hour blocks i.e. from 10am to 6pm. For USA (New Jersey, Pennsylvania, New York), peak-hour tariff is allocated for 7 hours (from 12pm until 7pm) whereas for California, peak-hour tariff is allocated for 6 hours (from 12pm until 6pm). Meanwhile in Malaysia, the old ToU scheme consists of only two ToU blocks i.e. peak hours (from 8am until 10pm) and off-peak

Table 1
ToU Period Blocks in Selected Countries (TNB, 2016; Ceylon Electricity Board (CEB), 2016; eThekwini Municipality, 2016; Orange & Rockland, 2016; Pacific Gas and Electric Company (PG&E), 2016; Suruhanjaya Tenaga, 2016)

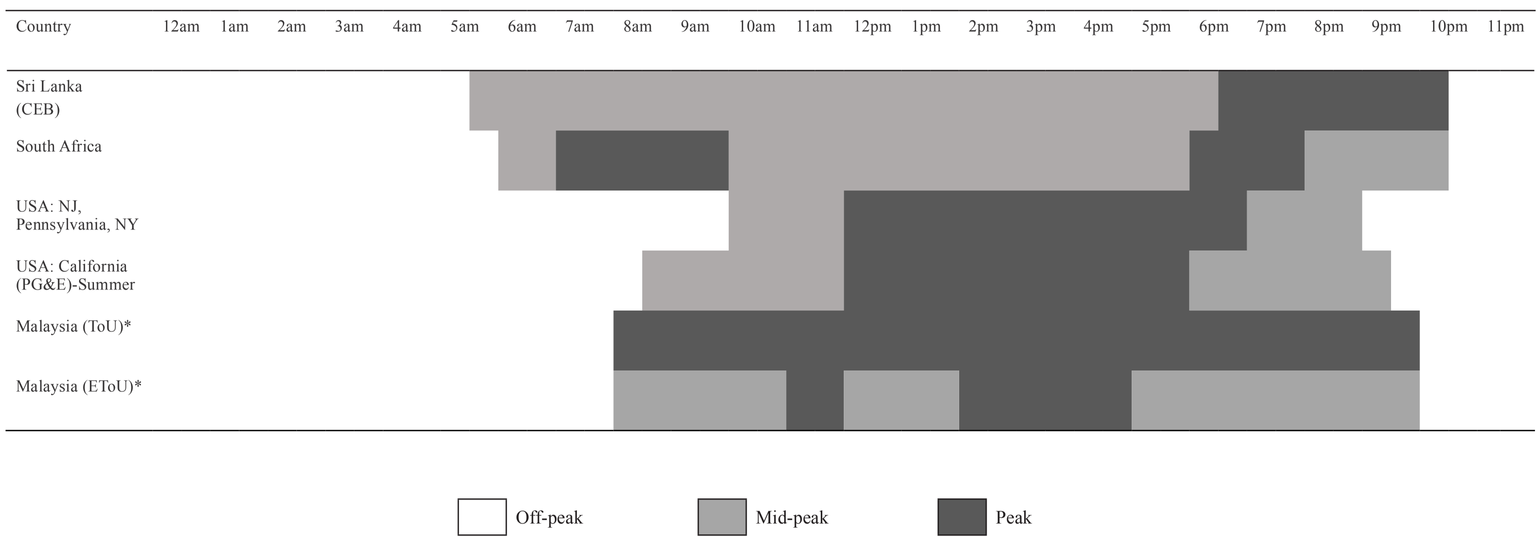

Table 2
ToU Prices in Selected Countries

No	Country	Time of Use Electricity Details	
		Period	Price
1	Sri Lanka (CEB)	Peak	Rs 23.00/kWh
	(CEB, 2016)	mid-peak	Rs 7.30/kWh
		off-peak	Rs 5.30/kWh
2	South Africa	peak	c 25758/kWh
	(eThekwini Municipality, 2016)	mid-peak	c 12887/kWh
		off-peak	c 6278/kWh
3	USA: New Jersey, Pennsylvania, New York	peak	$ 8.218/kWh
	(Orange & Rockland, 2016)	mid-peak	$ 1.976/kWh
		off-peak	$ 0.263/kWh
4	USA: California (PG&E)- summer	peak	$ 0.16585/kWh
	(PG&E, 2016)	mid-peak	$ 0.11897/kWh
		off-peak	$ 0.09367/kWh
5	Malaysia (ToU)*	peak	RM 0.365/kWh
	(TNB, 2016; Suruhan Tenaga, 2016)	off-peak	RM 0.365/kWh
	Malaysia (EToU)*	peak	RM 0.584/kWh
	(TNB, 2016; Suruhan Tenaga, 2016)	mid-peak	RM 0.357/kWh
		off-peak	RM 0.281/kWh

Note. *Commercial customers at medium voltage (tariff C1)

hours (from 10pm until 8am). Starting from January 2016, a new ToU scheme known as Enhanced Time of Use (EToU) was introduced to commercial consumers. EToU consists of six ToU blocks with peak, mid-peak and off-peak tariffs as shown in Table 1. Peak hour tariff is allocated two times during office buildings' common office hours i.e. 1 hour (from 11am to 12pm) and another 3 hours (from 2pm to 5pm).

METHOD FOR ETOU ASSESSMENT

If a consumer manages to reduce electricity bill through EToU tariffs without having to change their electricity consumption pattern, the new EToU scheme is undoubtedly better than the old ToU. Hence, the consumer may switch to the new scheme such as peak-hour load into mid-peak or off-peak hour periods. This section presents the mathematical formulation to evaluate the minimum amount of peak load shifting required for a given load profile and ToU tariffs.

Total electricity bill for the new EToU scheme must be less or at least equal to the old ToU scheme:

$$\sum_{all\ hour\ i}\left[ToU_{hour\ i}^{new\ tariff} \times P_{hour\ i}^{new\ consump}\right] \leq \sum_{all\ hour\ i}\left[ToU_{hour\ i}^{old\ tariff} \times P_{hour\ i}^{old\ consump}\right] \quad (1)$$

Where:

$$ToU_{hour\ i}^{new\ tariff} = ToU_{hour\ i}^{old\ tariff} + \Delta ToU_{hour\ i} \quad (2)$$

$$P_{hour\ i}^{new\ consump} = P_{hour\ i}^{old\ consump} + \Delta P_{hour\ i} \tag{3}$$

Rewriting equation (1) yields the following;

$$\sum_{all\ hour\ i}\left[\Delta ToU_{hour\ i}^{new\ tariff} \times \frac{P_{hour\ i}^{old\ consump}}{P_{Total}^{old\ consump}}\right] + \left[ToU_{hour\ i}^{new\ tariff} \times \frac{\Delta P_{hour\ i}}{P_{Total}^{old\ consump}}\right] \leq 0 \tag{4}$$

Where:

$$hour\ i = \{off-peak\ hour\ i, mid-peak\ hour\ i, peak-hour\ i\} \tag{5}$$

For the total electricity consumption remains the same after load shifting, then

$$\sum \Delta P_{off-peak\ hour\ i} + \sum \Delta P_{mid-peak\ hour\ i} + \sum \Delta P_{peak\ hour\ i} = 0 \tag{6}$$

Assuming the electricity consumption during peak-hours can only shifted to off-peak hours;

$$\sum \Delta P_{mid-peak\ hour\ i} = -\sum \Delta P_{peak\ hour\ i} \tag{7}$$

Thus, the total electricity consumption that must be shifted from peak to mid-peak hours;

$$P_{Total}^{Shifted\ peak\ to\ mid-peak} \geq \frac{-\sum_{all\ hour}\left[\Delta ToU_{hour\ i} \times \frac{P_{hour\ i}^{old\ consump}}{P_{Total}^{old\ consump}}\right]}{\sum ToU_{mid-peak\ hour\ i} - \sum ToU_{peak\ hour\ i}} \tag{8}$$

Applying the EToU data into equation (8), the minimum peak load shift requirement for different load percentage share between peak, mid-peak and off-peak is tabulated in a bubble chart given in Figure 1.

Bubble chart in Figure 1 shows the minimum load shift requirement according to the peak, mid-peak and off-peak. Consumers need to calculate the percentage of mid-peak and off-peak

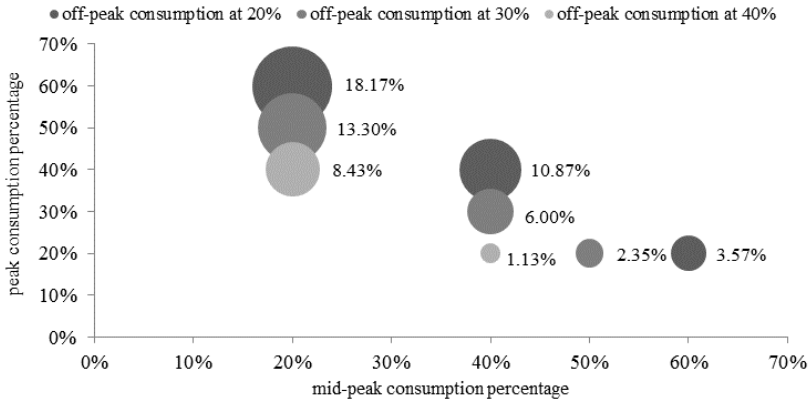

Figure 1. Bubble chart of minimum load shift requirement for different peak, mid and off-peak percentage share

consumption in order to know the minimum load shifting needed for EToU program to work. From Figure 1, it is known that when a customer percentage share of mid-peak and off-peak is 40%, a minimum shifting of peak period to mid-peak period consumption is 1.13%.

CASE STUDY

The objective of this case study is to assess the impact of the new EToU scheme for a government office building in Putrajaya, Malaysia. Figure 2 shows the hourly electricity consumption of the building during weekdays and weekends. It can be seen that the consumption for weekdays is high during working hours (8am-5pm) and low outside of working hours. During weekends, the consumption is low throughout the day. To ease calculation, it is assumed that the profile for weekdays and weekends are fixed throughout a month. Also, only electricity consumption (kWh) charge is considered.

The second column of Table 3 shows the electricity consumption for one month for each period block while the third column shows the percentage share between off-peak, mid-peak and peak hours, which is 41%, 41% and 18% respectively. The bubble chart in Figure 1 shows that load shifting around 1% is required (from peak to mid-peak hours) for the new EToU scheme to give cheaper kWh bill than the existing ToU scheme. To test these findings a base case is it is assumed that the building switched to EToU scheme without making any shifting in its daily consumption. The one month electricity bill through EToU and ToU scheme is given o the second row of Table 4. It can be seen that the EToU scheme gives higher bill than ToU scheme. For the second case, the electricity consumption during peak hours is shifted to mid-peak hours by 3% (of the total consumption). The results in Table 4 show that EToU scheme provides lower electricity bill than ToU, which validates the results given by the bubble chart in Figure 1.

Since the goal of EToU is to promote load shifting, switching tariff scheme alone without shifting consumption may result in higher electricity bill. Electricity customers can utilize the presented method to compare the two schemes. If they able to shift their load as suggested, they should opt for the new EToU scheme. If not, they should stick to the existing ToU scheme.

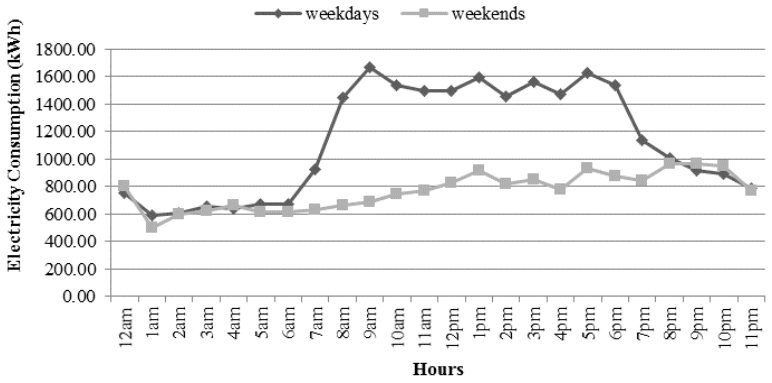

Figure 2. Average electricity consumption of an office building for weekdays and weekends

Table 3
Electricity consumption of the building during different EToU period block

Period block category	Electricity Consumption	Percentage Share
off-peak	305735 kWh	41%
mid-peak	307528 kWh	41%
peak	131667 kWh	18%
Total	744930 kWh	100%

Table 4
Electricity bill comparison between ToU and EToU scheme of the building for each case

Case	ToU	EToU
Base case	RM 271,899	RM 272,592
Load shifting case	RM 271,899	RM 267,520

CONCLUSION

This paper compared Malaysia's new Enhanced Time of Use (EToU) tariff schemes with the old ToU scheme. A mathematical method to estimate EToU's load shifting based on customers' electricity consumption profile was presented. Results from the case study support the method used allowing consumers to use it as a tool in cost-benefit analysis when deciding on the new EToU. Further studies on this method can be done by modelling the consumption and load shifting in visual basic/MATLAB software in order to provide easier usage in future works.

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REFERENCES

Ceylon Electricity Board. (2016, March11). *Tariff Plan*. Retrieved from http://www.pucsl.gov.lk/english/wp-content/uploads/2014/03/2009-tariff-notice.pdf

de Sá Ferreira, R., Barroso, L. A., Lino, P. R., Carvalho, M. M., & Valenzuela, P. (2013). Time-of-use tariff design under uncertainty in price-elasticities of electricity demand: A stochastic optimization approach. *IEEE Transactions on Smart Grid, 4*(4), 2285-2295.

eThekwini Municipality. (2016, March 11). *Electricity Tariffs* 2015-2016. Retrieved from http://www.durban.gov.za/Resource_Centre/Services_Tariffs/Electricityhttp://www.durban.gov.za/Resource_Centre/Services_Tariffs/ElectricityTariffs/ElectricityTariffs2015-2016.pdf

Hussin, N. S., Abdullah, M. P., Ali, A. I. M., Hassan, M. Y., & Hussin, F. (2014, October). Residential electricity time of use (ToU) pricing for Malaysia. In *Energy Conversion (CENCON), 2014 IEEE Conference on* (pp. 429-433). IEEE.

Nazar, N. S. M., Abdullah, M. P., Hassan, M. Y., & Hussin, F. (2012, December). Time-based electricity pricing for Demand Response implementation in monopolized electricity market. In *Research and Development (SCOReD), 2012 IEEE Student Conference on* (pp. 178-181). IEEE.

Orange & Rockland. (2016, March 10). *Tariffs & Regulatory Documents*. Retrieved from http://www.oru.com/programsandservices/timeofuserate/

Pacific Gas and Electric Company. (2016, March 11). *Time-of-Use Plans*. Retrieved from http://www.pge.com/en/mybusiness/rates/tvp/toupricing.page

Suruhanjaya Tenaga. (2016, May 4). *Enhanced Time of Use Etou Tariff Scheme*. Retrieved from http://www.st.gov.my/index.php/download-page/category/124-sesi-penerangan-sit-dan-etou.html

Son, J., Hara, R., Kita, H., & Tanaka, E. (2015, November). Operation scheduling considering demand response in a commercial building with chiller system and energy storage system. In P*ower and Energy Engineering Conference (APPEEC), 2015 IEEE PES Asia-Pacific* (pp. 1-5). IEEE.

Tenaga Nasional Berhad. (2016, 4th May 2016). *Tnb Enhanced Time Of Use (Etou)*. Available: https://www.tnb.com.my/faq/etou