International Journal of Engineering Processing & Safety Research
Published by Cambridge Research and Publications

Vol. 25 No.5
September, 2022.

INTEGRATED RESOURCE PLANNING IN ENERGY SECTOR

BOYA SAMSON[1], YUNUSA M. A.[2], G. N. JOLA[3], C. S. ONATE[4].

[1234]*Department of Electrical Electronics Department Federal Polytechnic Bauchi, Bauchi state Nigeria*

ABSTRACT

The energy crises have brought about different level and forms of generating power to meet the need of the immediate environment and as such the availability of the available source can be utilized to meet the need of the demand available. the implementation of time of user (TOU) tariff turns out to be a double-edged sword since the new tariff is much higher than the original block tariffs. Even after load shifting is done, the electricity bill decreases but still comes out higher than the original bill using block tariff. Only after the equipment are changed to more efficient ones, the monthly electricity bill is lower than the original bill. Based on the above observations, it is observed that DSM program could only work and be beneficial with economic potential towards consumer only if load shifting is done.

INTRODUCTION

With the recent affluent in AI technologies handling of big data is a necessity with enormous computational power, improved machine learning (ML), information technology, and also deep learning (DL) algorithms(Ahmad et al., 2021). Some developed countries have tried to encourage new economic development from the viewpoint of technical innovation. The focus of their efforts has been on an attempt to advance natural resource utilization efficiency and environmental protection capability. Technological in- novation can be divided mainly into production-saving and resource- saving approaches(Song et al., 2018). The former stimulates production development, but may not be favourable to environmental protection. The latter is helpful to save energy and reduce emissions, but may not stimulate production. Under the condition of limited resources, only when resources are al- located to these two approaches in appropriate proportions can co- ordinated development between the environment and economy be achieved and maximized.

With the use of deep mind AI technology, Google has been able to minimize its field device management bill by about 40% as a result that would be hard to achieve with more traditional methods(Namany et al., 2019). The conservative power grid was not really designed to manage the integration of renewable energy sources (RES). Variations in the characteristics of the RES which include solar, wind, geothermal, hydrogen e.t.c. create challenges in meeting the adjustable loads of the power grid. Now a-days new advancements in AI technology with IoT, machine learning, big data deep learning, etc. are revolutionizing the energy industry(Dorotić et al., 2019). In many countries, AI technology has been incorporated to perform different types of tasks, which includes forecasting, controlling and other power efficient system operations . With that in mind we have integrated different energy for loads that a consumer will be using for different periods of time as stated below.

LOAD RESEARCH

From previous works, the following loads estimation of a household were identified.

Table 1: load analysis

Load Type	*Price/Unit (RM)*	*Quantity*	*Power Consumption Rating*	*Daily Hour Usage*	*Daily Energy Consumption (Wh/day)*
1.5 hp AC (5*)	2500	2	700 W	7	9800
2.5 hp AC (3*)	3500	1	2100 W	6	12600
3-Blade Ceiling Fan (3*)	200	3	70 W	12	2520
Washing Machine (3*)	1000	1	600 W	1	600
Refrigerator (5*)	2500	1	336 kWh/year	24	920.55
LED Bulb	8	4	15 W	6	360

Compact Fluorescent Lamp	10	5	36 W	6	1080
				TOTAL	**27880.55**

Figure 1, below shows the load consumption pattern that is recreated based on the one given in the assignment. From the load pattern, we can observe that most of the heavy loads such as air conditioners are operating during the day.

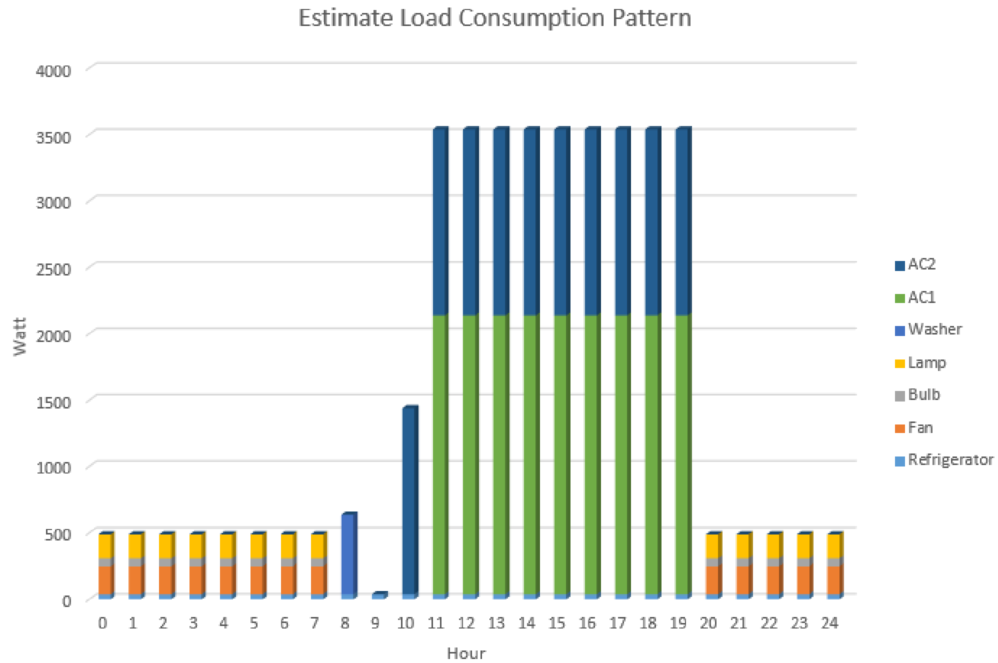


Figure 1: load consumption pattern (a)

LOAD SHAPE OBJECTIVE

Since the demand-side load management strategy is for domestic application, we have assumed that the best strategy to be the implementation of time-of-use (TOU) tariff in order as this method could encourage load shifting behaviour in consumer(Wang & Su, 2020).

Figure 2, below shows the desired load consumption pattern that could be done by load shifting. Considering the TOU tariff (tariff A for domestic load) given in the assignment, the usage of some of the loads could be shift to reduce usage during peak time where the rate is high to off-peak time where the rate is lower.

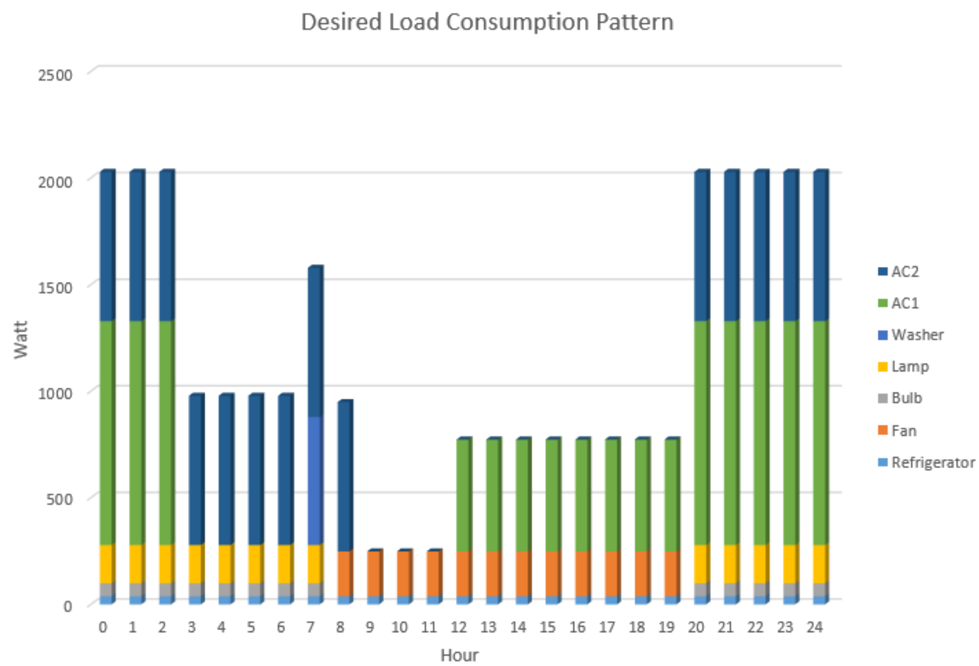


Figure 2: load consumption pattern (b)

The rates from Tariff A (domestic tariff) given in the assignment is used for electricity bills calculation based on time-of-use(Bogdanov et al., 2020). At first sight, we could observe that the given tariff will bring quite a significant impact as the rate is quite high for both peak and off-peak time and this is especially true if the energy consumption is below 300 kWh monthly. Fortunately, the household example used in this assignment consumed more than 800 kWh a month thus is less affected by the bill increasement.

Table 2: Time of use during the day

Time of Use	***Rate (RM/kWh)***
Off-Peak (8.00 p.m. to 7.00 a.m.)	0.437
Peak (7.00 a.m. to 8.00 p.m.)	0.571

Electricity Bill Calculations:

i. Bill using old tariff (Block Tariff):

Blok Tariff (kWh)	*Prorata Block (kWh)*	*Rate (RM/kWh)*	*Amount (RM)*
200	200	0.218	43.60
100	100	0.334	33.40

300	300	0.516	154.80
300	237	0.546	129.40
Total	**837**		**361.20**

ii. Bill using new tariff (Tariff A – Domestic Tariff) and no changes in consumption behaviour:

	Consumption/day (kWh)	*Total Consumption/day (kWh)*	*Rate (RM/kWh)*	*Amount/day (RM)*
Off-peak	2.52+0.461+0.36+1.08	4.421	0.437	1.932
Peak	9.8+12.6+0.6+0.461	23.461	0.571	13.396
			Total	**15.328**
			Total (30 days)	**459.84**

iii. Bill using new tariff (Tariff A – Domestic Tariff) and load shifting:

	Consumption/day (kWh)	*Total Consumption/day (kWh)*	*Rate (RM/kWh)*	*Amount/day (RM)*
Off-peak	9.8+8.4+0.6+0.461+0.36+1.08	20.701	0.437	9.051
Peak	4.2+2.52+0.461	7.181	0.571	4.106
			Total	**13.157**
			Total (30 days)	**394.71**

With the implementation of TOU tariff, the consumer could expect an increase in the electricity bill from RM 361.20 to RM 459.84 if there are no changes done in consumption behaviour. The increasement is about RM 98.64 (27.31%)Even with an extreme load shifting where in this case, the usage of air conditioner is swap with fan during the day time and night time, the consumer will still be getting a slight increase of electricity bill of about RM 33.51 (9.3%). With this DSM option of using energy efficient load are suggested.

DSM STRATEGY OPTIONS:

For DSM strategy options, energy-efficient programs are introduced for air conditioner, washing machine and lighting equipment to encourage the consumer to purchase their home appliances(Nikolic et al., 2021).

Based on the previously ended SAVE program, instant rebate program for air conditioner should again be re-introduced which also include washing machine in the scheme. With this rebate program, a rebate of RM 200 will be given for any purchase of 5-star air conditioner and washing machine.

For lighting, in conjunction with the phase out program for incandescent type lighting to compact fluorescent type lighting, a promotional discount for LED light is also introduces. Typical 30% discount of any purchase of LED lighting bulb or lamp will be implemented.

Table 4: Original load:

Load Type	*Price/Unit (RM)*	*Quantity*	*Power Consumption Rating*	*Daily Hour Usage*	*Daily Energy Consumption (Wh/day)*
1.5 hp AC (5)*	2500	2	700 W	7	9800
2.5 hp AC (3)*	3500	1	2100 W	6	12600
3-Blade Ceiling Fan (3)*	200	3	70 W	12	2520
Washing Machine	1000	1	600 W	1	600
Refrigerator (5)*	2500	1	336 kWh/year	24	920.55
LED Bulb	8	4	15 W	6	360
Compact Fluorescent Lamp	10	5	36 W	6	1080
				Total	**27880.55**

Replacement Load:

For energy efficiency upgrades, the only possible replacements that can be done are for 2.5 hp air conditioner, ceiling fans and fluorescent lamps. The 3-star rating 2.5 hp air conditioner and ceiling fans are replaced by 5-star rating unit while the compact fluorescent lamps are replaced by LED lamps. For the washing machine it is important to understand that the energy star reflect the usage using hot water so it is assumed here that the house is operating the washing machine using hot water. Other equipment remained the same.

Table 5: Different Load for a Particular Room

Load Type (After)	*Quantity*	*Power Consumption Rating*	*Daily Hour Usage*	*Daily Energy Consumption (Wh/day)*
1.5 hp AC (5) – No change*	2	700 W	7	9800
2.5 hp Daikin AC (5*)	**1**	**1520 W**	**6**	**9120**
Panasonic Ceiling Fan (5*)	**3**	**41 W**	**12**	**1476**
Samsung Washing Machine (5*)	**1**	**450 W**	**1**	**450**
Refrigerator (5) – No change*	1	336 kWh/year	24	921
LED Bulb – No change	4	15W	6	360
Philip LED Lamp	**5**	**16 W**	**6**	**480**
				22607

With the new appliances that are more energy efficient, new electricity bills as follow are calculated to identify how electricity bills are reduced if there is no change in consumption behaviour and with load shifting done.

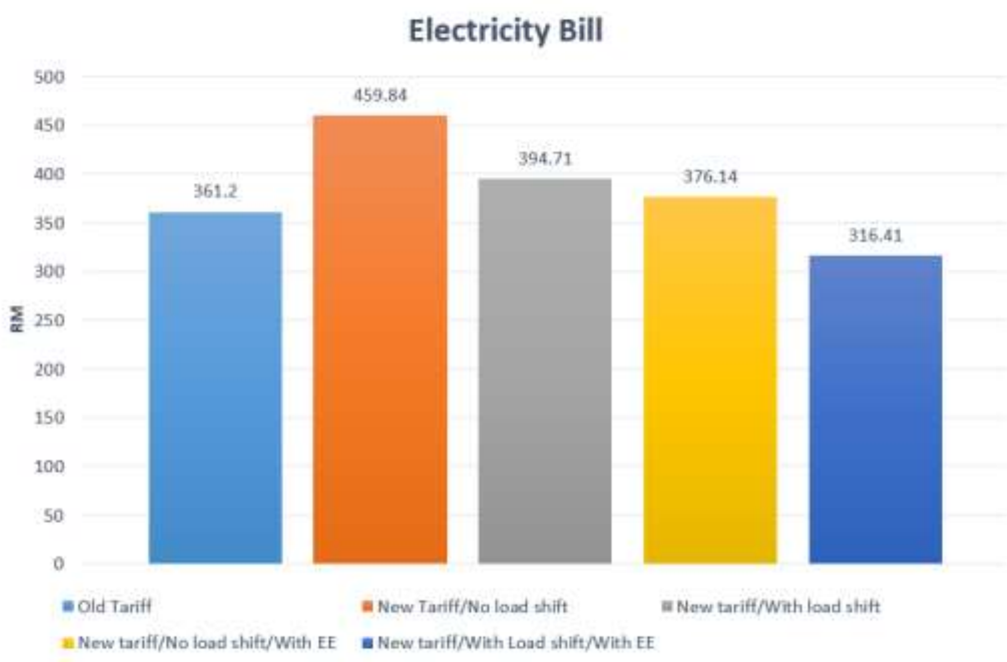
i. Electricity bill using energy efficient equipment and new tariff (Tariff A – Domestic Tariff) and no changes in consumption behaviour:

	Consumption/day (kWh)	*Total Consumption/day (kWh)*	*Rate (RM/kWh)*	*Amount/day (RM)*
Off-peak	1.476+0.461+0.36+0.48	2.78	0.437	1.215
Peak	9.8+9.12+0.45+0.461	19.83	0.571	11.323
			Total	**12.538**
			Total (30 days)	**376.14**

ii. Electricity bill using energy efficient equipment, new tariff (Tariff A – Domestic Tariff) and load shifting:

	Consumption/day (kWh)	*Total Consumption/day (kWh)*	*Rate (RM/kWh)*	*Amount/day (RM)*
Off-peak	9.8+6.08+0.45+0.461+0.36+0.48	17.631	0.437	7.705
Peak	3.04+1.476+0.461	4.977	0.571	2.842
			Total	10.547
			Total (30 days)	**316.41**

Comparing these new bills with the bills using new tariff before energy efficient load replacement, we could observe a reduction of RM 83.70 if there are no changes in consumption behaviour. Unfortunately, the electricity bill is still quite high even with replacement of energy efficient load. If load shift is done after the replacement with energy efficient load, the bill is now decrease substantially by RM143.43. While it is shows that replacement of load technology with a more energy efficient technology could help consumer to reduce electricity bill(Papadis & Tsatsaronis, 2020), it is not proven if the changes are worth the investment in the long run.



COST AND BENEFIT ANALYSIS

From previous analysis, it is understood that for this particular household, energy efficient load replacement is required in order to reduce electricity bill from initial bill due to implementation of TOU tariff rate. For the calculation in this section, discount rate, r of 8% is considered.

Initial Cost:

Load Type (After)	*Price/Unit (RM)*	*Quantity*	*Price (RM)*	*Price After Rebate/Discount (RM)*
2.5 hp Daikin AC (5)*	5500	1	5500.00	5300.00
Panasonic Ceiling Fan (5)*	450	3	1350.00	1350.00
Samsung Washing Machine (5)*	2000	1	2000.00	1800
Philip LED Lamp	15	5	75.00	52.50
		Total	**8925.00**	**8502.508**

From the calculation results, both the investments of replacing the load with energy efficient load either with or without load shifting seem to be viable using simple payback method as both have lesser payback period than 10 years. However, this method does not consider discounted rate for the 10 years and thus are less accurate. By using IRR, it yielded 3.422% and 15.78% shows that both IRR are positive since it is more than 'r' which is 8%. Theoretically it should be accepted(Aryanpur et al., 2019).

Next, using NPV, we could observe that without load shifting, the NPV will yield a negative NPV which mean that it is not actually profiting. From this, it is important to educate the consumer of the particular house that only if they want to consider changing their electricity consumption by load shifting will the investment become profitable for them.

i. Cost of Saved Energy (CSE):

a. Lifetime:

The lifetime for air conditioner and washing machine are advertised to have lifetime of about 10 to 15 years while the ceiling fan could work up to 10 years. The Philip LED lamp is advertised to work for 50000 hours. Table below shows the lifetime assumed for calculation. In the calculation later, it is also assumed that the appliances work perfectly for the duration of their lifetime with only uncounted self-cost maintenance (e.g. self-cleaning) done.

Load Type	*Advertised Lifetime*
Air conditioner	10 years
Ceiling fan	10 years
Washing Machine	10 years
LED Lamp	$Lifetime = \frac{50000\ hours}{2190\ hour/year} = 22.83\ year \approx 23\ years$

b. Annual Cost:

$$CRF \rightarrow A = P\left(\frac{r}{1-(1+r)^{-t}}\right) = 8502.5\left(\frac{0.08}{1-(1+0.08)^{-10}}\right) = RM\ 1267.12$$

For profit calculations, it is important to note that some of the equipment that are to be replaced may have been operating for about 3 to 5 years. Thus, to be completely fair, it is assumed in the calculation that the equipment that are to be replaced are brand new and having full lifetime of 10 years in order to get the minimum value for cost of saved energy. So here, the replacement of compact fluorescent lamp to LED lamp gives of profit while others are not. This is because it is identified that fluorescent lamp has a typical lifetime of 15,000 hours.

CONCLUSION

Initially, the implementation of TOU tariff turns out to be a double-edged sword since the new tariff is much higher than the original block tariffs. Even after load shifting is done, the electricity bill decreases but still comes out higher than the original bill using block tariff. Only after the equipment are changed to more efficient ones, the monthly electricity bill is lower than the original bill. Based on the above observations, it is identified that DSM program could only work and be beneficial with economic potential towards consumer only if load shifting is done. If the residential consumer of this particular house is not doing any load shifting, the electricity bill will get even more expensive.

For cost and benefit analysis, after replacing the equipment, the NPV could only be accepted if load shifting is done. The CSE is still within acceptable value with only just RM0.656 to save a kWh of energy.

REFERENCES

Ahmad, T., Zhang, D., Huang, C., Zhang, H., & Dai, N. (2021). Arti fi cial intelligence in sustainable energy industry : Status Quo , challenges and opportunities. *Journal of Cleaner Production*, *289*, 125834. https://doi.org/10.1016/j.jclepro.2021.125834

Aryanpur, V., Saeid, M., Marzband, M., & Siano, P. (2019). An overview of energy planning in Iran and transition pathways towards sustainable electricity supply sector. *Renewable and Sustainable Energy Reviews*, *112*(October 2018), 58–74. https://doi.org/10.1016/j.rser.2019.05.047

Bogdanov, D., Gulagi, A., Fasihi, M., & Breyer, C. (2020). Full energy sector transition towards 100 % renewable energy supply : Integrating power , heat , transport and industry sectors including desalination. *Applied Energy*, *xxxx*, 116273. https://doi.org/10.1016/j.apenergy.2020.116273

Dorotić, H., Doračić, B., Dobravec, V., Pukšec, T., & Krajačić, G. (2019). Integration of transport and energy sectors in island communities with 100 % intermittent renewable energy sources. *Renewable and Sustainable Energy Reviews*, *99*, 109–124. https://doi.org/10.1016/j.rser.2018.09.033

Namany, S., Al-ansari, T., & Govindan, R. (2019). Sustainable energy, water and food nexus systems: a focused review of decision-making tools for efficient resource management and governance. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2019.03.304

Nikolic, J., Gordic, D., & Jurisevic, N. (2021). *Energy auditing of indoor swimming facility with multi-criteria decision analysis for ranking the proposed energy savings measures*.

Papadis, E., & Tsatsaronis, G. (2020). Challenges in the decarbonization of the energy sector Keywords : *Energy*, 118025. https://doi.org/10.1016/j.energy.2020.118025

Song, M., Fisher, R., & Kwoh, Y. (2018). Technological Forecasting & Social Change

Technological challenges of green innovation and sustainable resource management with large scale data. *Technological Forecasting & Social Change*, *xxxx*, 0–1. https://doi.org/10.1016/j.techfore.2018.07.055

Wang, Q., & Su, M. (2020). Integrating blockchain technology into the energy sector — from theory of blockchain to research and application of energy blockchain. *Computer Science Review*, *37*, 100275. https://doi.org/10.1016/j.cosrev.2020.100275