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Relationship between Installed Capacity with Total Installation Cost on Solar PV among Prosumer NEM 2.0 in Malaysia

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***Abstract*---**Generate energy by Solar PV installation among prosumer, i.e; domestic, commercial, industrial as well as agriculture for self-consumption under Net Energy Metering (NEM) system become more popular in Malaysia. One, if not the only reason, is that day-to-day installation costs are kept at a decreasing rate and this is one of the reasonable ones for future investments and energy savings. By considering this issue, this study is motivated to investigate the relationship between installed capacity with the total installation costs as represented by equipment costs, installed costs, and operating costs. Secondary data was utilized provided by Sustainable Energy Development Authority (SEDA) Malaysia and retrieved from Malaysian Energy Information Hub (MEIH). The data is then run by multivariate regression, which is focused on the random and fixed-effect model. Overall, the findings indicate that there is a significant relationship between installed capacities with total installation costs among all categories of the prosumer in Malaysia. It would be recommended that the policymaker can increase the quota capacity allocation to the prosumer since the costs are at a diminishing rate that led to the take-up rate increase.

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Introduction

The Net Energy Metering (NEM) scheme was introduced in Malaysia starting in 2016, where consumers are encouraged to produce their energy using solar PV systems. The energy generated from the solar PV system first be absorbed by loads through the NEM scheme, and any surplus energy will be exported and sold to the grid at a predetermined rate of RM 0.31 per kWh for residential customers and RM 0.23 per kWh for commercial and industrial customers (Mansur et al., 2017). To continue the initiative to install solar PV on the roofs of buildings and residential premises, the Ministry of Energy and Natural Resources will launch the NEM 3.0 program with a quota rate of 500 MW for the period 2021-2023. The NEM 3.0 program implemented new technologies using the idea of virtual NEM or virtual NEM, enabling owners of commercial and industrial buildings to share excesses.

The Malaysian Government has set an ambitious target to achieve higher Renewable Energy (RE) penetration in the Malaysian energy mix. To date, Malaysia has approximately 2% of its energy coming from RE generation sources compared to the total generation mix and targets achieving 20% penetration by 2025 (Gielen et al., 2019) Hence, the Ministry has introduced a few solar PV initiatives to encourage Malaysia's Renewable Energy (RE) uptake. From the RE townhall held on 12 July 2018, one of the key issues highlighted by the PV industry is the need to change the concept of NEM from the existing net billing to true net energy metering. This will help improve the return of investment of solar PV under the NEM. Meanwhile, the Government's RE initiatives are bearing their fruits with SEDA Malaysia has approved a total of a cumulative Net Energy Metering (NEM) program quota of 108MW as of November 2019. The total approved quota portrays positive growth of 7.8 times increment compared with the previous three years, which only stands at a 13.86MW take-up rate.

The newly improved NEM 2.0 program largely contributes to this success. Effective early this year, the NEM program has been updated by adopting the true net energy metering concept, which allows excess solar PV-generated energy to be exported back to the grid on a "one-on-one" offset basis. This has managed to reduce the period for Return of Investment (ROI) to a mere three years, especially for commercial and industrial installation that benefited from the various tax incentive given by the Government. So far, only five percent of applications under the NEM 2.0 program are domestic consumers of electricity. The program maintains the concept of a "1 to 1 offset" rate of 10 years with a quota of 100MW (megawatts) or until all quotas are exhausted and provides the benefit of reducing electricity bills to 10,000 - 25,000 TNB (Tenaga Nasional Berhad) domestic account owners or about 40,000 - 100,000 households in Peninsular Malaysia. The remainder of the paper is organized as follows. Next, discussion on past studies on the issues arises from NEM and NEM 2.0 related to the costs. Next, it further explains the data and methodology used. Then, proceed with regressions results analysis. This paper concludes with conclusion and policy recommendations (Kubli, 2018; Donaldson & Jayaweera, 2020; Santosa & Yusuf, 2017).

Data and Methodology

The concept of NEM is that the energy produced from the installed solar PV system will be consumed first, and any excess will be exported to TNB on a "one-on-one" offset basis. NEM is one of the options to generate electricity from one's own solar PV system and offset or reduce the electricity bills (TNB). This system is designed to provide credit for any excess of solar energy that is generated. It is then used to offset for the next electricity bill. It helps to save on electricity bills and also protects the user from the rising costs of electricity in the future (Abdullah et al., 2019; Cameron & Goodrich, 2010). This is also a part of the clean energy movement to reduce the effects of climate change (TNB). This scheme applies to all domestic, commercial, industrial, and agricultural sectors as long as they are the customers of TNB. The PV systems can be installed at available rooftops or car porches within their premises. (SEDA). A bi-directional meter is installed for these types of connections and it ensures that an adequate communication signal is available since the meter reading is done remotely. Before the solar PV system is connected, TNB conducts a technical assessment to ensure the safe operation and reliability of the network (TNB) (Bano & Rao, 2016; Tabunshikov et al., 2021; Rinartha et al., 2018).

With regards to the data collection, this study uses secondary data. The data was mainly gathered from SEDA by signing NDA and MEIH. In this study, we only shared the results to explain the objective of the study since all the raw data provided to us is highly confidential. Next, all the data was sorted, screened, and matched. For missing data are then omitted, for instance from the commercial category. Therefore, the total usable observation data under NEM 2.0 are 3071 consists of 4 main customer categories, i.e; domestic, industrial, commercial and agriculture from the period of January 2019 until October 2020. Concerning the testing, the relationship among these variables is considered as an estimation model for the multivariate regressions analysis used in this study. This model is developed based on prosumer categories by panel data where, panel A represents a pooled sample, panel B for domestic, panel C for commercial, panel D for industrial and panel E for agriculture (Nikolaidis & Charalambous, 2017; Darghouth et al., 2016).

Next, the OLS model has treated standard error of estimations represented by ε as identically and independently distributed disturbances that are uncorrelated with the correlations of standard error for independent variables (equipment costs, installation costs, and operating costs), x, or $Cor(\varepsilon_i, X_i) = 0$. In this case, the data can be pooled, and OLS can be used to estimate the model by denoting the estimator of the slope β_{OLS}. The intercept and slope coefficients are constant across N and T represented by tranche issuances of each issuer which postulates that both the intercept and the slope are the same across observations. However, these assumptions might be restrictive and lead to heterogeneity bias needed to handle the robustness checks analysis. Otherwise, the model does not require any additional technique for such estimations. The regression model equation for pooled OLS can be represented as follows:

$$ICit = Bo + B1(TEit) + B2(TIit) + B3(TOit) + eit$$

Then, the fixed-effect model used is when the constant value for each costs category, x_{it} is correlated with the independent variables of the issuers for the period, t λ_i and within variation in the data only, but is the most flexible in that it allows for the endogeneity of regressors. Where:

β_{fe} = the coefficient estimates in the fixed effect of the explanatory variables

$(\beta_{fe} + \lambda_i)$ = the intercept for fixed effect, and

u_{it} = the error term for fixed effect.

Concerning the random effect model, it assumes that the costs category has their intercepts while restricting the slope to be homogenous for installed capacity (Razali et al., 2019; Razali et al., 2020; Şahin, 2020). Their spread is probably in random-effect as liquidity movement which required technique of these regressions to accommodate such heterogeneity, the random-effect model decomposes the ε into two composite error terms as, $\varepsilon_{it} = \lambda_i + u_{it}$.

Results and Discussion

Descriptive statistics

4 categories are implementing NEM which are agriculture, commercial, domestics, and industrial as shown in figure 1. From that, 3071 prosumers enjoyed NEM from SEDA starting January 2019 until October 2020 where the domestic category has the highest application and the agriculture category is an unpopular category among NEM prosumers.

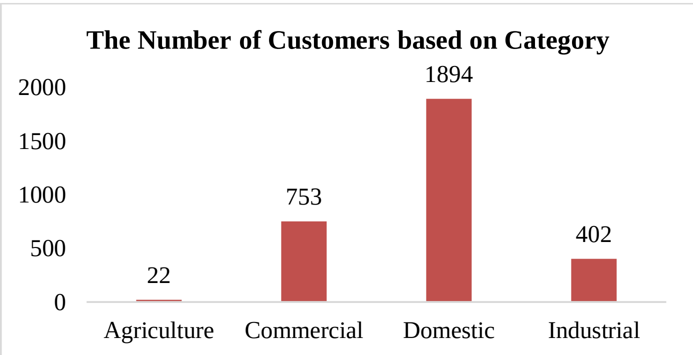

Figure 1. The number of customers based on category

Nevertheless, figure 2 shows the industrial category has the biggest contribution in the total installed capacity to SEDA, at 71% whereas the popular category, domestic only contributes 5%. This pattern is due to the huge installation capacity of the industrial category itself. In addition, the commercial category gives 23% of the total installation cost (Celvakumaran et al., 2018; Cengiz & Mamiş, 2015).

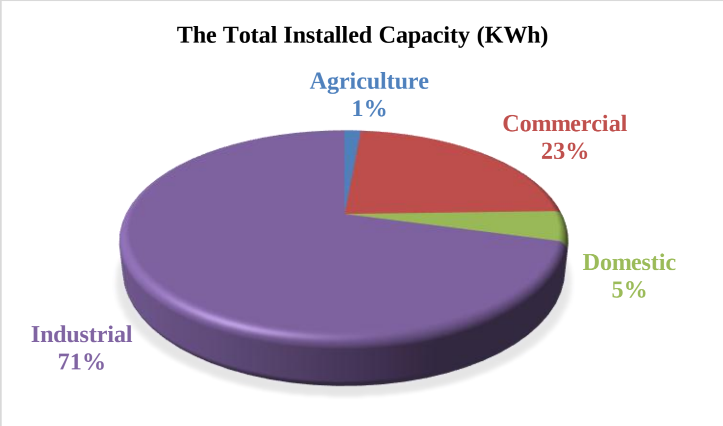

Figure 2. The total installed capacity (kwh) based on category

As a popular category, domestic shows the maximum capacity installed (IC) is only 54kWh. Also, the maximum total installation cost is RM100,640 whereas the highest total operation cost is RM31,428.40. For the commercial category, the maximum capacity installed is 3,564kWh and the highest cost incurred in equipment is RM6,868,000. In addition, the maximum total installation cost is RM1,515,000 where the highest total operation cost is RM707,000. For the industrial category, 29,666.63kWh is the maximum capacity that has been installed and the cost incurred in equipment is RM120,000,000. In addition, the maximum total installation cost is RM5,980,022 where the highest total operation cost is RM1,766,318. All the amount shows the highest contribution from the industrial category. Besides that, the maximum capacity installed in the agriculture category is 560.88kWh and the highest cost incurred in equipment is RM1,226,610. In addition, the maximum total installation cost is RM525,690 where the highest total operation cost is RM175,230. The details for each category as follow:

Table 1
Descriptive statistics results

Panel A: Pooled					
Variables	Obs	Mean	Std.Dev.	Min	Max
Category	3072	1.52832	0.744356	1	4
Installation Capacity (IC)	3072	114.7283	643.5377	1	29666.63
Total Equipment Cost (TE)	3072	308167.1	2314340	4760	120000000
Total Installation Cost (TI)	3072	60124.25	225714.3	400	5980022
Total Operating Cost (TO)	3072	11791.25	56748.61	0	1766318
Panel B: 1 Domestic					
Installation Capacity (IC)	1894	8.770691	5.856995	1	54
Total Equipment Cost (TE)	1894	33216.07	24083.64	4760	491360
Total Installation Cost (TI)	1894	9739.932	10973.27	400	100640
Total Operating Cost (TO)	1894	1086.656	1635.636	0	31428.4

Panel C: 2 Commercial					
Installation Capacity (IC)	753	108.0404	236.8229	2.1	3564
Total Equipment Cost (TE)	753	280835.3	521461.3	8343	6868000
Total Installation Cost (TI)	753	61549.28	122813.1	800	1515000
Total Operating Cost (TO)	753	12970.17	42700.92	0	707000
Panel D: 3 Industrial					
Installation Capacity (IC)	402	620.3637	1659.732	12	29666.63
Total Equipment Cost (TE)	402	1642712	6193044	39780	120000000
Total Installation Cost (TI)	402	286768.3	543407.8	3500	5980022
Total Operating Cost (TO)	402	58711.09	135198.6	0	1766318
Panel E: 4 Agriculture					
Installation Capacity (IC)	22	231.0991	163.4742	4.32	560.88
Total Equipment Cost (TE)	22	500984.9	340677.1	24280	1226610
Total Installation Cost (TI)	22	209866.2	157396.8	4000	525690
Total Operating Cost (TO)	22	36141.18	56757.03	0	175230

Total installation cost for each customer

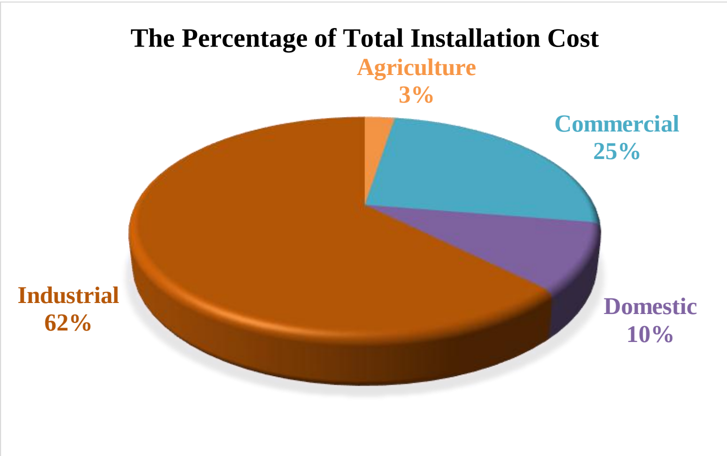

Figure 3. The percentage of total installation cost

However, figure 3 shows industrial contributes up to 62% in the total installation cost to SEDA where the popular category, domestic only contributes 10%. This pattern is due to the huge installation capacity of the industrial category itself. In addition, the commercial category gives 25% of the total installation cost (Castro-Santos et al., 2018; Hobbs et al., 2001).

Percentage of solar PV prosumer in Peninsular of Malaysia

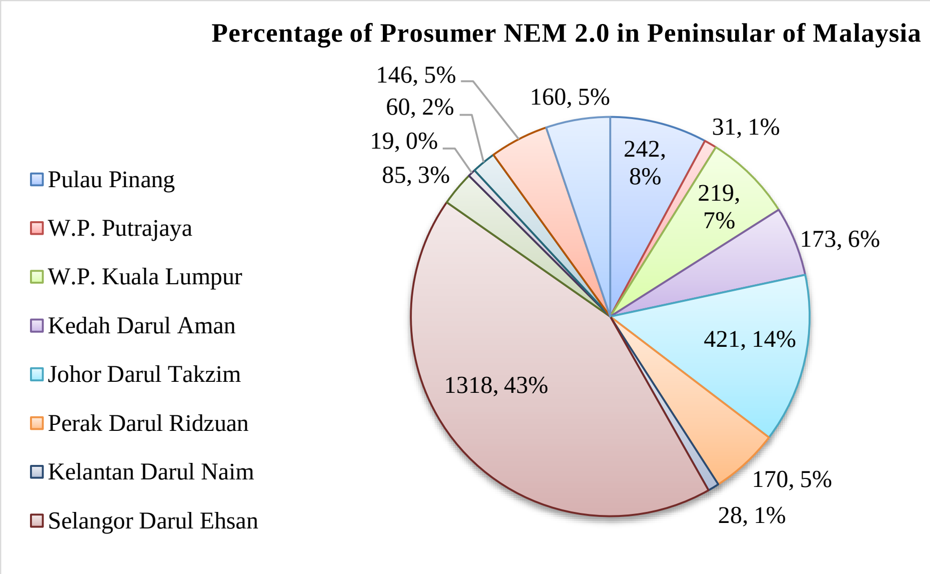

Figure 4. The percentage of prosumer NEM 2.0 in Peninsular of Malaysia

As for the results in figure 4, the percentage of the Solar PV Prosumer has been divided into the state in Malaysia respectively. Selangor Darul Ehsan represented the highest percentage which is 43% while Johor Darul Takzim in second place has been contributed 14%. Out of 3072, the percentage reveals 8% of them are Pulau Pinang, 7% is W.P. Kuala Lumpur and 6% of them are Kedah Darul Aman. Perak Darul Ridzuan, Melaka Bandaraya Bersejarah and Negeri Sembilan Darul Khusus representing the same percentage which are 5% for three of them. Furthermore, Terengganu Darul Iman only 2% while W.P. Putrajaya and Kelantan Darul Naim reveal the same percentage for both which are 1% and the lowest one is Perlis Indera Kayangan. In addition, if the listed have been divided into the category (Agriculture, Commercial, Domestic and Industrial) more than half are in Domestic which is 1898 while 753 of them are Commercial, 399 are Industrial and only 22 for Agriculture (Dale, 2013; Mansur et al., 2017; Razali et al., 2019).

Multivariate regression result

Table 2
Multivariate regression result

Panel A: Pooled		
	RE	FE
Constant	3.945488	6.460732**
Total Equipment Cost (TE)	0.0002272***	0.000228**
Total Installation Cost (TI)	0.0005193***	0.000487**
Total Operating Cost (TO)	0.0008093***	0.0007408
Observations	3071	3071
R-square	97%	97%

Wald-chi2	99122.18	
F-value	-	0.000000
BP-LM	264.4	
RE Effect	Yes	
FE effect		Yes
Panel B: 1 Domestic		
	RE	FE
Constant	2.2358934	
Total Equipment Cost (TE)	0.0001745***	
Total Installation Cost (TI)	0.0000124	
Total Operating Cost (TO)	0.0005706***	
Observations	1894	
R-square	59.68%	
Wald-chi2	-	
F-value	0.0000	
BP-LM	-	
RE Effect	Yes	
FE effect		No
Panel C: 2 Commercial		
	RE	FE
Constant	-13.78154	
Total Equipment Cost (TE)	0.0003946***	
Total Installation Cost (TI)	0.0000726***	
Total Operating Cost (TO)	0.000504***	
Observations	753	
R-square	94.05	
Wald-chi2	-	
F-value	0.0000	
BP-LM	-	
RE Effect	Yes	
FE effect		No
Panel D: 3 Industrial		
	RE	FE
Constant	66.18104	
Total Equipment Cost (TE)	0.0002279***	
Total Installation Cost (TI)	0.0004844***	
Total Operating Cost (TO)	0.0006978***	
Observations	402	
R-square	97.06	
Wald-chi2	-	
F-value	0.0000	
BP-LM	-	
RE Effect	Yes	
FE effect		No
Panel E: 4 Agriculture		
	RE	FE
Constant	-8.445496	
Total Equipment Cost (TE)	0.0001376***	
Total Installation Cost (TI)	0.0009295***	
Total Operating Cost (TO)	-0.0006768	

Observations	22	
R-square	97.51	
Wald-chi2	-	
F-value	0.0000	
BP-LM	-	
RE Effect	Yes	
FE effect		No

Based on Table 2, Panel A shows the coefficient of determination is 97% of the variation in the capacity installed is explained by the three predictor variables respectively and the remaining of 3% variance in the install capacity is an unexplained variation which due to the randomness or omission of some important independent variable in the model. In addition, the p-value for F-statistic is 0.000 which is below than 5% significance level. 4. The regression model would be:

$$IC = 3.94549 + 0.00023TE + 0.00052TI + 0.00081TO$$

Generally, all the predictors are significant as the p-value of the t-test is less than 5% significance level%. All the variables have a positive relationship with one another, which for every RM10,000 increase in total equipment cost will increase the installed capacity by 2.3kWh. As RM10,000 increases in total installation cost, the capacity installation will be increased by 5.2kWh in installation capacity. As RM10,000 increase in total operation cost is associated with 8.1kWh increase in capacity installed. Finally, the total operation cost is the most dominant factor in determining the NEM installation capacity as compared to total equipment cost and total installation cost (Marques et al., 2019; Sergici et al., 2019; Gamez et al., 2016).

According to Panel B Domestic shows 59.68% of the variation in the capacity installed is explained by the three predictor variables respectively and the remaining of 40.32% variance in the install capacity is an unexplained variation which due to the randomness or omission of some important independent variable in the model. While the value of R^2 of Panel C Commercial is 0.9407. The determination of coefficient in Panel D Industrial is 97.06%, where the variation of installation capacity explained by all the predictor variables. Lastly, the R^2 of Panel E Agriculture shows 97.51% of the total variation in the NEM installation cost can be explained by all predictor variables. In addition, the F-statistics in all according panels shows 0.000, the model is significant fit. Thus, the regression models of each panel would be:

Panel B domestic

$$IC = 2.2359 + 0.0001745TE + 0.0000124TI + 0.0005707TO$$

Based on above, only two predictors (total equipment cost and total operating cost) are significant as the p-value of t-test is less than 5% significance level. The remaining variable has insignificant impact with the capacity installed of NEM. It can be proof by the all variable has positive relationship with one another, which for every RM10,000 increase in total equipment cost, will increase the installed capacity by 1.745kWh. As RM100,000 increase in total installation cost, the capacity installation will be increase by 1.24kWh in installation capacity. As RM10,000 increase in total operation cost is associated with 5.707kWh increase in capacity installed. Finally, the total operation cost is the most dominant factor in determining the NEM installation capacity as compared to total equipment cost and total installation cost.

Panel C commercial

$$IC = -13.78154 + 0.0003946TE + 0.0000726TI + 0.000504TO$$

From this equation, every RM10,000 increase in total equipment cost, installed capacity of NEM will increase by 3.946kwh. As total installation cost increase by RM100,000 then installed capacity increase by 7.26kWh and lastly, for every RM10,000 total operation cost increase, then installation capacity increase by 5.04kWh. Finally, the total operation cost is the most dominant factor in determining the NEM installation capacity as compared to total equipment cost and total installation cost.

Panel D industry

$$IC = 66.18104 + 0.002279TE + 0.0004844TI + 0.0006978TO$$

Generally, the three independent variables are significantly affected installation capacity at 5% significant level by observing the t-test of the p-value. Specifically, an RM10,000 increase in total equipment cost will increase the capacity installed by 2.279 kWh. As every RM10,000 increase in total installation cost, kWh of installed capacity will be increased by 4.844. Lastly, in every RM10,000 increment of the total operation of NEM, the capacity installed will be increased by 6.978 kWh.

Panel E agriculture

$$IC = -8.445496 + 0.0001376TE + 0.0009295TI - 0.0006768TO$$

As per regression model, total operating cost has negative relationship to installation capacity. It means, in every increment of total operating cost, installed capacity will be decreased by 0.0006768 kWh. The insignificant relationship occurs due to lack of data. Therefore, overall, the multivariate regression results postulated a significant relationship between the installed capacity with the total installation costs as represented by total equipment costs, installation, and operation costs among prosumer NEM 2.0 in Malaysia (Pérez et al., 2021; Privitera et al., 2011; Jackman, 2020).

Conclusion

Energy regulators and policymakers presently are tapping an exertion to enhance its system and policies of the solar PV prosumer tariff to stimulate all parties involved. It should cost reflectively and justifiable to particularly four types of the consumer group, i.e., domestic, commercial, industrial, and agriculture, towards their installed capacity. Overall, as presented by pooled sample, there is a relationship between total installation costs with installed capacity using a random effect model; however, operating costs show insignificant results based on the fixed-effect model. This implies that the cost of operating in solar PV among prosumer is probably not charged under the fixed effect model towards installed capacity. Since the trend of installation costs offered by solar PV contractors shows a diminishing rate, the prosumer should consider investing in this energy investment (energy saving) besides self-consumption. While this link is for the MEIH data: https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=323&bul_id=c3JpRzRqeTNPamMxL1FpTkNBNUVBQT09&menu_id=amVoWU54UTl0a21NWmdhMjFMMWcyZz09

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Ethical declaration

The data are provided by SEDA by signing Non-Disclosure Agreement (NDA). Noted that, all the data are screened and not published in the original version.

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