Public Utilities Commission of Sri Lanka

Electricity Demand Response to Price Changes in Sri Lanka

November 2023

Contents

1. **Introduction** 2
2. **Literature Review** 2
3. **Methodology** 4
4. **Data Collection** 6
4.1. **Domestic Consumers** 6
4.2. **Commercial Consumers** 6
4.3. **Industrial Consumers** 7
5. **Results** 7
5.1. **Domestic Consumers** 7
5.2. **Commercial Consumers** 8
5.3. **Industrial Consumers** 9
5.4. **Summary of Results** 10
6. **Discussion** 10
7. **Conclusions** 12
8. **References** 12

1. Introduction

Electricity prices in Sri Lanka has seen several unprecedented revisions in recent times including 75% increase in August 2022, 66% increase in February 2023, 14% reduction in July 2023 and 18% increase in October 2023. The demand for electricity has also experienced significant changes amidst of these price revisions. Government's latest policy decision calls for no subsidies on electricity and this provides a situation where the price of electricity is very much cost reflective. Under these circumstances, it would be in the interest of many parties including the regulator, utilities, consumers and the government to see the kind of relationship that exists between the price and demand for electricity. This empirical study focuses on identifying this relationship, with the use of actual data from the Sri Lankan electricity market, by analyzing the impact of the February 20223 tariff revision. The study would provide insights to the stakeholders on designing effective tariffs for different consumer groups, promoting demand side management and energy conservation through electricity tariffs and electricity demand forecasting.

This study has been carried out considering a six-month window around the February 2023 tariff revision and data from LECO consumers. The findings of the study are subject to following limitations.

- Only one tariff revision considered.
- Data sample does not cover the whole country.
- Impact of variations in the income is not considered.

2. Literature Review

In the literature, number of past studies on electricity demand response to price changes is available. These studies are based on different countries and electricity market structures. Some studies focus on identifying the response by different consumer groups to electricity price changes.

According to the economic theory, increase in the price of a commodity causes a reduction in the demand for the commodity, given that the other factors remain constant. Demand sensitivity of a commodity to price change is measured using the coefficient of elasticity. This is defined as the ratio of percentage change in demand to that of price. Based on the value of this coefficient, commodities are identified as price elastic, when the absolute value of elasticity is greater than 1, implying a high sensitivity to price. Other commodities with absolute value of elasticity between 0 to 1 are identified as inelastic and these are less-price sensitive. In this study the demand response to electricity price changes in Sri Lanka is to be studied by means of estimating price elasticities.

Being an essential commodity, Electricity is generally considered to be price inelastic, meaning that the change in demand due to price variations is small. This is mainly because of not having any perfect substitute for electricity. Anyhow, as per literature, electricity price signals can be used for encouraging energy efficiency, load shifting and other demand response measures, which is ultimately seen as a change in demand. M. H. Albadi (2007)(3), states "Demand Response (DR) can be defined as the changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time".

Price elasticity has two main variations, as short run elasticity and long run elasticity, defined based on the time elapsed from the price change. In the short run, demand changes in electricity for price changes would be very less. As per Derya Eryilmaz (2017)[(1)], Consumers may not be able to adjust instantly to the optimal amount of electricity consumed when the price fluctuates, due to technological barriers (e.g., adjusting/adopting smart meters may take some time), production constraints (e.g., some industrial consumers cannot change their production schedule immediately in response to price changes). Therefore, the long run price elasticity is usually higher than the short run value. Most of the studies in the literature focus on estimating the long run price elasticities considering the annual variations. But, Anise Rouhani (2022)[(7)] estimates the short run price elasticity for residential consumers in Iran considering a period of two months, to be -0.048.

Substitution elasticity is a means of measuring consumer response to substantial electricity price variations from one period to another. In such situations, customers can shift their usage among the periods. Shu Fan (2011)[(6)] states, the substitution elasticity is defined as the relative change in usage in the two periods (e.g., the ratio of the peak to off-peak usage) for a one percent change in the relative prices in those periods (the ratio of the off-peak to peak price). Massimo Filippini (2011)[(10)], has studied the residential demand for electricity by time-of day for Switzerland and reports positive cross price elasticities among peak and off peak consumptions. This result implies that peak and off-peak electricity are substitutes.

Demand response to price changes might depend on market conditions. Liddle and Hasanov (2021)[(4)] together with the findings of Liddle and Huntington (2021)[(5)], states that for high income countries the price elasticity of electricity is nearly the same for both industry customers and residential customers, while for middle-income countries, residential customers may be more sensitive to price than industry customers.

Himanshu A (2007)[(2)], estimated the overall long-run price elasticity of electricity in Sri Lanka to be ranging from 0 to –0.06, considering market data from 1970 to 2000. Another study on Sri Lankan residential electricity market by Athukorala (2009)[(8)], identifies the long run price elasticity to be -0.62 and the short run price elasticity to be -0.16. Based on these results Athukorala (2009)[(8)], states the government revenue by electricity would not reduce by removing subsidies existed on electricity at that time.

Electricity demand depends on number of factors including the price. Shu Fan (2011)[(6)] identifies, temperature, calendar effects, demographic variables and economic variables as the main demand drivers. The model used for the demand estimation by Shu Fan (2011)[(6)] considers temperature and calendar effects to contribute to the daily variation, while the demographic and economic variables separately contributing to the annual variations. Thus, in this study, the annual component of the demand is used to estimate the price elasticity based on the available annual demographic and economic variables.

Several studies on estimating the price elasticity of electricity have used the logarithmic model for the electricity demand. Paul J. Burke (2017)[(9)], in modeling the annual electricity demand for United States has equipped logarithmic model, where the logarithm of electricity price, population and per capita GDP serves as independent variables. According to Paul J. Burke (2017)[9], the log-log specification has some attractive properties, including (a) directly providing elasticities, (b) producing residuals with more desirable distributions, (c) ensuring that the predicted values of electricity consumption are always positive, and (d) reducing the potential influence of any outliers.

3. Methodology

The price elasticity of electricity demand is used for assessing consumer behavior in this study. The study specifically focuses on the short-term price elasticities considering a period of six months, which includes a tariff revision. Domestic, Commercial and Industrial Consumers are analyzed separately.

A regression-based analysis is carried out for the estimation of the price elasticities. Log transformed model of electricity demand is used as in the study by Paul J. Burke (2017)[9] to get the advantages of (a) directly providing elasticities, (b) producing residuals with more desirable distributions, (c) ensuring that the predicted values of electricity consumption are always positive, and (d) reducing the potential influence of any outliers. Anise Rouhani (2022)[7] also utilizes a log transformed demand model for estimating short-run price elasticity for Iran electricity market. Further, as per Anise Rouhani (2022)[7], the fixed effect regression model avoids omitted variable bias, removes the effect of those time-invariant consumer characteristics and controls unobserved heterogeneity in the panel data. Therefore, fixed effect log transferred regression models formulated for the analysis of consumer panel data collected for the period of six months.

For the direct price elasticity models of all three consumer categories, price is taken as the independent variable in determining the consumer monthly consumption. The other unobserved consumer specific variables are accounted with the fixed effect regression model as below.

$$\ln E_{i,t} = a_i + b \ln P_{i,t} + e_{i,t}$$

Where,

E –Monthly electricity unit consumption,

P – Unit price of electricity,

i – Consumer number,

t - Month

Also, b is constant and a_i accounts for the time invariant consumer specific effects and $e_{i,t}$ represents the error term. The value of constant 'b' in the model directly provides the estimation on the price elasticity.

According to the above model, a percentage change in electricity price by X% would result in a demand change as below;

Percentage Change in Demand $=\{ (1+X)^b - 1\}$ %

The substitution elasticity between peak time and non-peak time is also tested for Commercial and Industrial consumers to figure out the shift in usage among the periods. The methodology used is based on the definition of Shu Fan (2011)[6], that identifies relative change in usage in the two periods (e.g., the ratio of the peak to off-peak usage) for a one percent change in the relative prices in those periods (the ratio of the off-peak to peak price), as the substitution elasticity. Accordingly, the below regression model is formulated for the purpose.

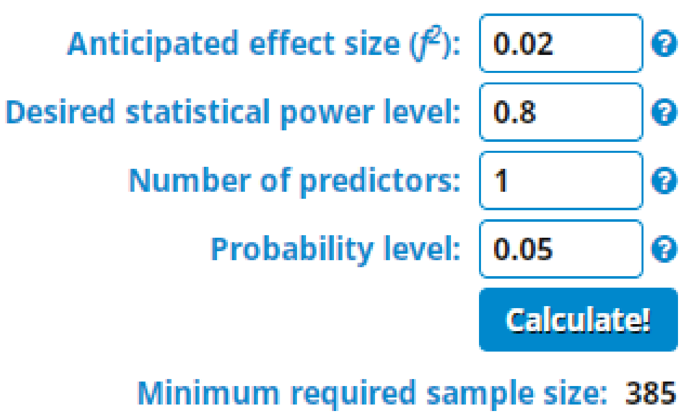
$$\ln(E_{NP}/E_P)_{i,t} = c_i + d\ln(P_P/P_{NP})_{i,t} + e_{i,t}$$

Where,

E_{NP} –Monthly non-peak time (0000h-1830h & 2230h-1830h) electricity unit consumption,
E_P –Monthly peak time (1830h - 2230h) electricity unit consumption,
P_P – Peak time unit price of electricity,
P_{NP} – Non-peak time average unit price of electricity,
i – Consumer number,
t - Month

Also, d is constant and c_i accounts for the time invariant consumer specific effects and $e_{i,t}$ represents the error term. The value of constant 'd' in the model directly provides the estimation on the substitution price elasticity of peak and non-peak periods.

The minimum sample size required for the study is determined based on the statistical power analysis. As per Jason T. Newsom (2023)[11], the acceptable sample size for a regression study depends on the statistical power, effect size, significance criteria and the number of predictors considered in the model. Accordingly, the sample size for this study is chosen considering a statistical power of 80%, significance criteria (α) of 0.05, small effect size considering Cohen's d coefficient of 0.02 and single predictor. This implies, 80% of the samples chosen from the population of the identified size, will provide results with +/-5% variation and the difference between samples is small. An online statistics calculator[12] was used to calculate the minimum sample size requirement to satisfy the criteria above. The result from the calculator is shown below and it identifies the minimum sample size to be 385 observations.



4. Data Collection

Non-probabilistic convenience sampling is used for the data collection. Lanka Electricity Company (Pvt.) Ltd. (LECO) distribution licensee was contacted for the collection of required data due to the availability of significant number of telemeters in its network. Data from telemeters have the advantage of being highly accurate and readings coinciding with the calendar month. Accordingly, monthly electricity consumption data obtained from LECO for telemetered Household, Commercial and Industrial consumers, for the period of December 2022 to May 2023. This time period has been considered to capture the short-term effects of February 15, 2023 tariff increase of 66% average, over all consumer categories. To eliminate the impact of routine power cuts prior to February 15, 2023, data collected only from the consumers connected to the feeders exempted from the demand management scheme. Average unit electricity rates for the consumers were calculated using applicable approved tariff tables.

4.1. Domestic Consumers

Summary of household electricity consumption and billing data used is shown in the table below.

No. of Consumer Accounts: 7704 No. of Observations: 46224						
Description	Dec – 2022	Jan – 2023	Feb – 2023	Mar – 2023	Apr – 2023	May – 2023
Average Consumption per Consumer (kWh)	154.88	152.39	151.96	145.16	166.28	168.56
Average Unit Price (Rs./kWh)	32.93	32.57	46.75	56.44	58.00	57.73

Received data for domestic consumers is well above the minimum sample requirement.

4.2. Commercial Consumers

Summary of commercial consumer (General Purpose) electricity billing data used is shown in the table below.

No. of Consumer Accounts: 156 No. of Observations: 936						
Description	Dec – 2022	Jan – 2023	Feb – 2023	Mar – 2023	Apr – 2023	May – 2023
Average Consumption per Consumer (kWh)	12,751.02	13,098.35	12,755.81	11,931.89	14,111.26	13,860.12
Average Unit Price (Rs./kWh)	40.73	41.27	53.45	65.66	63.90	65.05
Average Day Consumption per Consumer (kWh)	8,474.81	8,519.85	8,333.71	7,858.31	9,425.87	9,143.51
Average Peak Consumption per Consumer (kWh)	2,072.99	2,255.72	2,151.96	1,968.67	2,307.69	2,312.92
Average Off Peak Consumption per Consumer (kWh)	2,203.22	2,322.78	2,270.15	2,104.91	2,377.70	2,403.69
Average Maximum Demand per Consumer (kVA)	54.16	53.17	53.71	53.08	56.97	59.36

Received data for commercial consumers is well above the minimum sample requirement.

4.3. Industrial Consumers

Summary of Industrial consumer electricity billing data used is shown in the table below.

No. of Consumer Accounts: 48 No. of Observations: 288						
Description	Dec – 2022	Jan – 2023	Feb – 2023	Mar – 2023	Apr – 2023	May – 2023
Average Consumption per Consumer (kWh)	31,871.69	31,018.15	33,057.40	30,771.58	36,734.77	30,528.19
Average Unit Price (Rs./kWh)	42.19	41.91	46.34	53.30	50.74	55.30
Average Day Consumption per Consumer (kWh)	20,383.42	19,907.75	21,237.46	20,073.79	23,849.71	19,408.08
Average Peak Consumption per Consumer (kWh)	4,032.81	3,942.17	4,129.85	3,823.50	5,020.27	4,351.44
Average Off Peak Consumption per Consumer (kWh)	7,455.46	7,168.23	7,690.08	6,874.29	7,864.79	6,768.67
Average Maximum Demand per Consumer (kVA)	127.50	127.81	127.98	131.54	129.23	130.35

Received data for industrial consumers is slightly less than the minimum sample requirement. Sufficient sample size could not be obtained due to the criteria of selecting only consumers that were not part of the routine power cut scheme. This could be identified as a limitation of this study.

5. Results

5.1. Domestic Consumers

Fixed effect regression analysis carried out with panel data collected for 7704 household consumer accounts over 6 months periods (46,224 observations), yields following results for the direct price elasticity model.

Regression Statistics	
Multiple R	0.049449
R Square	0.002445
Adjusted R Square	0.002424
Standard Error	0.317305
Observations	46224

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-7.2E-17	0.001476	-4.9E-14	1	-0.00289	0.002893
$Ln(P_i)$ – {Avg. of $Ln(P_i)$}	-0.04502	0.00423	-10.6442	1.99E-26	-0.05332	-0.03673

The low P-value obtained suggests the existence of a significant relationship between the dependent and independent variable. Accordingly, the short-term price elasticity of demand for household consumers could be identified to be -0.04502.

5.2. Commercial Consumers

Fixed effect regression analysis carried out with panel data collected for 156 commercial consumer accounts over 6 months periods (936 observations), yields following results for the direct price elasticity model.

Regression Statistics	
Multiple R	0.258893719
R Square	0.067025958
Adjusted R Square	0.066027056
Standard Error	0.209532964
Observations	936

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-2.1E-17	0.006849	-3.1E-15	1	-0.01344	0.013441
$Ln(P_i)$ – {Avg. of $Ln(P_i)$}	-0.25623	0.03128	-8.19144	8.44E-16	-0.31762	-0.19484

The low P-value obtained suggests the existence of a significant relationship between the dependent and independent variable. Accordingly, the short-term price elasticity of demand for commercial consumers could be identified to be -0.25623.

Similarly, the analysis with the substitution elasticity regression model for commercial consumers yields following results with peak and non-peak time periods being considered.

Regression Statistics	
Multiple R	0.026519
R Square	0.000703
Adjusted R Square	-0.00037
Standard Error	0.198416
Observations	936

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	-3.5E-18	0.006485	-5.3E-16	1	-0.01273	0.012728
$Ln(P_{pi}/ P_{npi})$ – {Avg. of $Ln(P_{pi}/ P_{npi})$}	0.083871	0.103448	0.810754	0.417714	-0.11915	0.286887

The low P-value obtained suggests the existence of a significant relationship between the dependent and independent variable. Accordingly, the short-term substitution price elasticity between peak to non-peak periods for commercial consumers could be identified to be 0.083871.

5.3. Industrial Consumers

Fixed effect regression analysis carried out with panel data collected for 48 industrial consumer accounts over 6 months periods (288 observations), yields following results for the direct price elasticity model.

Regression Statistics	
Multiple R	0.293682
R Square	0.086249
Adjusted R Square	0.083054
Standard Error	0.229148
Observations	288

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	1.64E-16	0.013503	1.21E-14	1	-0.02658	0.026577
$Ln(P_i) - \{Avg.\ of\ Ln(P_i)\}$	-0.53049	0.1021	-5.19573	3.88E-07	-0.73145	-0.32952

The low P-value obtained suggests the existence of a significant relationship between the dependent and independent variable. Accordingly, the short-term price elasticity of demand for commercial consumers could be identified to be -0.53049.

Similarly, the analysis with the substitution elasticity regression model for industrial consumers yields following results with peak and non-peak time periods being considered.

Regression Statistics	
Multiple R	0.145228
R Square	0.021091
Adjusted R Square	0.017519
Standard Error	0.298995
Observations	276

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	5.27E-17	0.017997	2.93E-15	1	-0.03543	0.035431
$Ln(P_{pi}/ P_{npi}) - \{Avg.\ of\ Ln(P_{pi}/ P_{npi})\}$	0.386959	0.159261	2.429718	0.015753	0.073429	0.70049

Accordingly, the short-term substitution price elasticity between peak to non-peak periods for commercial consumers could be identified to be 0.386959.

5.4. Summary of Results

Following short term price elasticity coefficients are obtained in this study.

Consumer Category	Direct Price Elasticity of Demand	Substitution Price Elasticity between Peak and Non-peak Periods
Domestic	-0.04502	N/A
Commercial (General Purpose)	-0.25623	0.083871
Industrial	-0.53049	0.386959

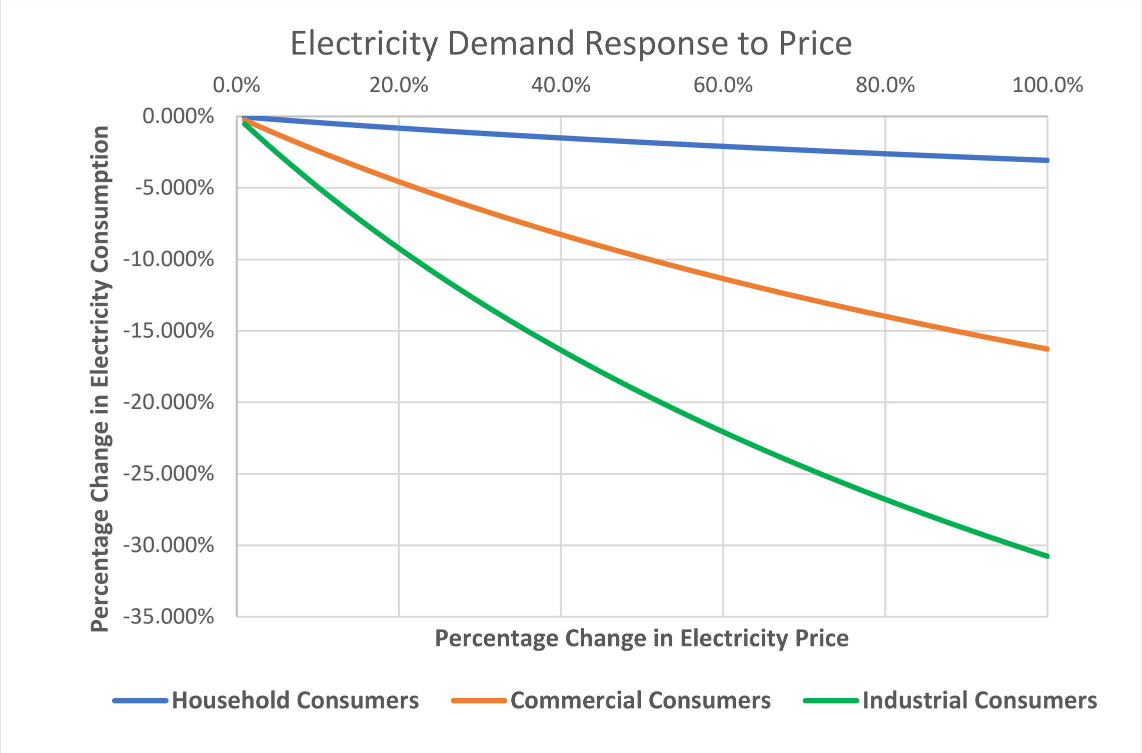
6. Discussion

The data analysis provides a short-term price elasticity figure of -0.04502 for household consumers. The result could be compared with Anise Rouhani (2022)[(7)] estimate of -0.048, for short run price elasticity of residential consumers in Iran. Further, this value is in the range of 0 to -0.06, as identified by Himanshu A (2007)[(2)] for overall long term coefficient of price elasticity in Sri Lanka. But the coefficient obtained for the same for Commercial and Industrial consumers in this study are well above this range. This implies a significant price sensitivity from Industrial and Commercial consumers. This could be due to the business entities being unable to accommodate anymore cost increases in the shrinking economy prevailed during the period.

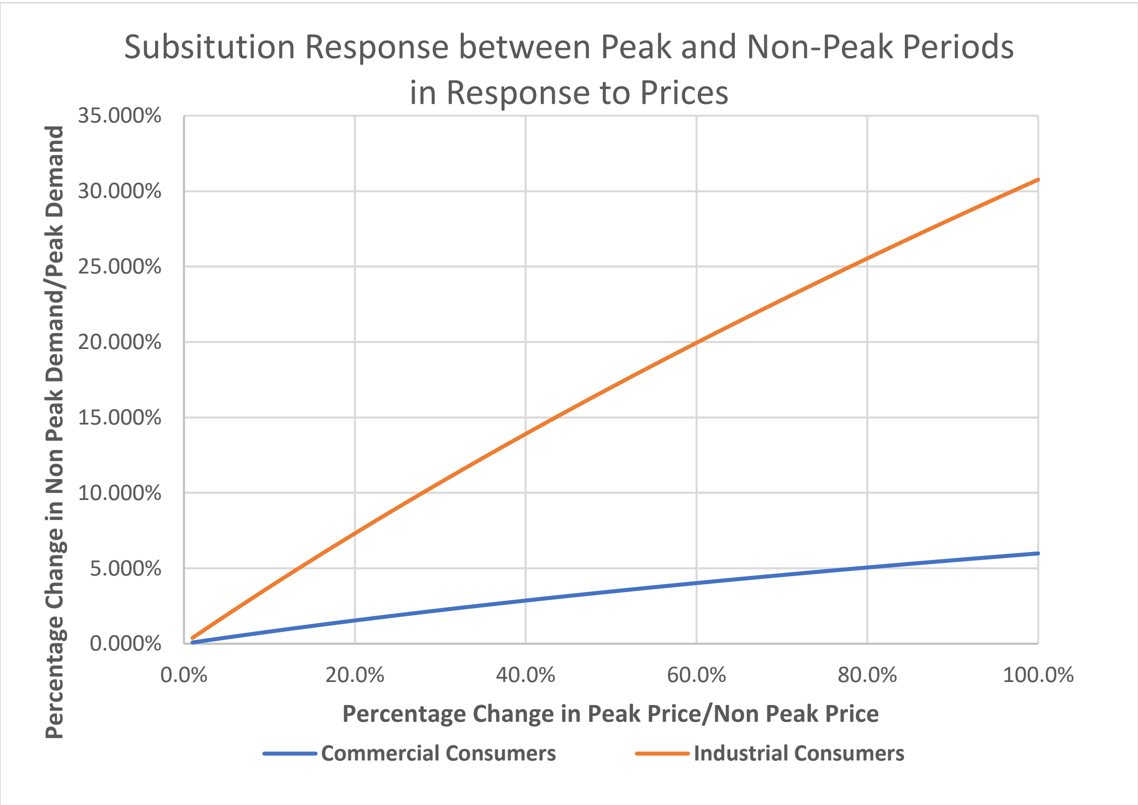
Liddle and Hasanov (2021)[(4)] together with the findings of Liddle and Huntington (2021)[(5)], stated that for middle-income countries, residential customers may be more sensitive to price than industry customers. Anyhow the results of this study indicate otherwise with a considerable difference in the elasticity coefficients obtained. This disparity could be due to the households already being placed at a low consumption level with the tariff increase that took place about 4 months prior to the data collection period considered in this study.

The peak to non-peak substitution price elasticities obtained in this study are positive values as mentioned by Massimo Filippini (2011)[(10)], based on the study in Switzerland. Analysis results suggests a greater substitutability between consumption periods for industrial consumers, compared to commercial consumers. This could be due to the significant portion of commercial consumers being in operation during the day period. The off-peak period operation is expected to be minimum. Thus, no significant change in inter-period consumptions can be expected from the commercial consumers and this explains the low coefficient obtained for the substitution elasticity.

Based on the analysis results, the demand response of each consumer group to price could be plotted as below.



The substitution between peak and non-peak consumption in response to price could be plotted as below, as per the analysis results.



7. Conclusions

Overall, domestic consumers are seen to be less responsive to price changes. Therefore, it is recommendable to study on the awareness among domestic consumers on electricity conservation measures and to address any gaps identified. Further, the Tariff determination of commercial and industrial consumers needs to be done with the understanding of the impact the prices can directly have on the economy, due to the significant level of price sensitives observed. It is also seen that the Peak/Off-peak rates can be effectively used to shift the demands among consumption periods for industrial consumers.

8. References

(1). Derya Eryilmaz, Timothy M. Smith, Frances R. Homans, *Price responsiveness in electricity markets: Implications for demand response in the Midwest,* Energy Journal, Jan 2017

(2). Himanshu A. Amarawickrama and Lester C Hunt, *Electricity Demand for Sri Lanka: A Time Series Analysis,* 2007

(3). M. H. Albadi, Student Member, E. F. El-Saadany, *Demand Response in Electricity Markets: An Overview* , 2007

(4). Brantley Liddle, Fakhri Hasanov, *Industry electricity price and output elasticities for high-income and middle-income countries, 2021*

(5). Brantley Liddle, Hillard Huntington, *How prices, income, and weather shape household electricity demand in high-income and middle-income countries,* 2021

(6). Shu Fan, Rob Hyndman, *The price elasticity of electricity demand in South Australia*, 2011

(7). Anise Rouhani, Habib Rajabi Mashhadi and Mehdi Feizi, *Estimating the Short-term Price Elasticity of Residential Electricity Demand in Iran,* 2022

(8). Athukorala, P. P. A. W. and Wilson, Clevo, *Estimating short and long-term residential demand for electricity: new evidence from Sri Lanka*, Energy Economics, 2009'

(9). Paul J. Burke, Ashani Abayasekara, *The price elasticity of electricity demand in the United States: A three-dimensional analysis*, 2017

(10). Massimo Filippini, *Short- and long-run time-of-use price elasticities in Swiss residential electricity demand*, 2011

(11). Jason T. Newsom, *Multiple Regression and Multivariate Quantitative Methods,* 2023

(12). Free Statistics Calculators, https://www.danielsoper.com/statcalc/calculator.aspx?id=1