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ELECTRICAL DEMAND ANALYSIS ON HOUSEHOLDS AND INDUSTRY IN INDONESIA

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ABSTRACT

This research aims to determine the response of the household sector and industrial sector to electricity demand when there are changes in prices and income. The influence of price and income on electricity demand from both sectors can be seen through their elasticity. The approach used in this study is panel data from 33 provinces in Indonesia for the 2010-2020 time period. Panel data regression estimation techniques are used in this study to estimate the elasticity value. The results show that price elasticity in the household and industrial sectors is negative inelastic, but price does not significantly influence household electricity demand. Unlike price, income elasticity has a much higher value and positively and significantly influences electricity demand in both sectors. The number of customers, which reflects the increasing electrification ratio and population growth, significantly impacts electricity demand in the household and industrial sectors. Based on the results, it was found that the number of customers most influences electricity demand in the household sector. At the same time, income has the most significant influence on electricity demand in the industrial sector.

Keywords: *Electricity Demand, Price Elasticity, Income Elasticity*

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ABSTRAK

Penelitian ini memiliki tujuan untuk mengetahui respons dari sektor rumah tangga dan sektor industri terhadap permintaan listrik bila terjadi perubahan harga dan pendapatan. Pengaruh dari harga dan pendapatan terhadap permintaan listrik dari kedua sektor dapat dilihat melalui elastisitasnya. Pendekatan yang digunakan dalam studi ini adalah data panel dari 33 Provinsi di Indonesia dengan periode waktu 2010-2020. Teknik estimasi regresi panel data digunakan dalam studi ini untuk mengestimasi nilai dari elastisitasnya. Dari hasil didapatkan bahwa elastisitas harga pada sektor rumah tangga dan industri adalah inelastis negatif, namun harga tidak memiliki pengaruh signifikan terhadap permintaan listrik rumah tangga. Berbeda dari harga, elastisitas pendapatan memiliki nilai yang jauh lebih tinggi dan memiliki pengaruh positif serta signifikan terhadap permintaan listrik pada kedua sektor. Jumlah pelanggan yang merupakan refleksi dari peningkatan rasio elektrifikasi dan pertambahan populasi memiliki dampak yang positif secara signifikan terhadap permintaan listrik sektor rumah tangga dan sektor industri. Berdasarkan hasil ditemukan bahwa permintaan listrik sektor rumah tangga paling dipengaruhi oleh jumlah pelanggan, sedangkan pendapatan memiliki pengaruh paling besar terhadap permintaan listrik sektor industri.

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Kata Kunci: *Permintaan Listrik, Elastisitas Harga, Elastisitas Pendapatan*

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Introduction

Electricity is one of the main energy sources that is needed the most and has a big role in everyday life. The big role that electricity plays in life makes it one of the main factors influencing economic growth and socio-economic development, where electricity can encourage productivity and improve people's welfare (Khan & Abbas, 2016; Uhr et al., 2019: 69). The importance of electricity for everyday life has made electricity one of the 7th Sustainable Development Goals (SDGs).

Indonesia has a huge population. The World Bank (2022) stated that Indonesia's population is the fourth largest in the world. This will affect the amount of electrical energy consumed in Indonesia. According to the International Energy Agency [IEA] (2020: 70), Indonesia is in first place out of four countries with the largest electricity consumption in Southeast Asia.

As electricity consumption increases, it must be accompanied by adequate electricity availability. Based on Law 30 of 2009 concerning electricity, the state must ensure sufficient electricity is available to the entire community with good quality and reasonable prices. This effort is made so that the welfare and prosperity of the people in Indonesia can increase and sustainable development can be implemented. Electricity, secondary energy, must go through several process stages before being distributed to consumers. PT PLN (Persero) is the sole electricity supply business organizer representing the government in Indonesia with the task of carrying out all electricity activities including the stages of electricity generation, transmission and distribution (PLN, 2021). Electricity generation in Indonesia is still dominated by coal-fired power plants, meaning that Indonesia's electricity still depends on fossil fuels (Badan Pengkajian dan Penerapan Teknologi [BPPT], 2020).

The entire production and consumption process of electricity must co-occur. In the sense that both consumption and production must be balanced because of the nature of electricity, which cannot be stored in large quantities effectively (Hu & Hu, 2013). If the supply of electricity cannot meet demand, it will directly affect sectors that rely on electricity as an input. This will of course affect all economic activities, therefore the balance of supply and demand must be maintained (Mulyani & Hartono, 2018).

The two main sectors dominating electricity consumption in Indonesia are the household and industrial sectors. Data in the 2020 PLN Statistics shows that of all total electricity sales in Indonesia, 46.04% was distributed to the household sector and 29.66% to the industrial sector. These two sectors are projected to dominate domestic electricity demand until 2050 using assumptions based on population growth, economic growth, and energy prices (National Energy Council, 2019). With two main sectors that will still dominate electricity demand in the coming years, this must also be accompanied by the availability of electricity to be distributed to these two sectors. Electricity demand is directly influenced by price and income factors (Gautam & Paudel, 2018).

The electrification ratio in Indonesia has increased rapidly and stably since 2010 compared to previous years. As of the fourth quarter of 2021, the electrification ratio in Indonesia has reached 99.45% (Badan Pengkajian dan Penerapan Teknologi [BPPT], 2020). This shows that equal electricity distribution to the Indonesian people continues to achieve the 100% target set by the government. This target is expected to be achieved in 2022, meaning that by achieving this target, all regions in Indonesia will have full access to electricity (ESDM, 2021).

An increase in the electrification ratio and population will cause an increase in consumers who use electricity and increase electricity consumption. The number of customers will reflect the increase in the number of electricity users (Arnaz, 2018). Based on Egelioglu et al. (2001), the number of customers directly influences electricity consumption.

Table 1: Increase in Electricity Consumption with Increase in Population Ratio and Electrification

Year	Population	Electrification Ratio (%)	Electricity Consumption (GWh)
2016	258,705,000	91.16	247,416.06
2017	261,890,900	95.35	267,453.99
2018	265,015,300	98.30	282,031.11
2019	266,911,900	98.80	289,340.82
2020	269,603,400	99.20	293,465.27

Source: Ministry of Energy and Mineral Resources Directorate General of Electricity (2020)

This study will analyze the gaps from previous studies by estimating and analyzing electricity demand, focusing on the two sectors that dominate electricity consumption in Indonesia, namely the household and industrial sectors. Panel data will be used from 33 provinces in Indonesia using the latest period from 2010-2020, where the electrification ratio has grown rapidly and steadily since 2010, which also affects electricity consumption in Indonesia.

Knowledge of how prices, income, and number of customers influence electricity demand is needed to determine policy directions that influence electricity demand itself (Boogen et al., 2017; Campbell & Brown, 2018; Gautam & Paudel, 2018; Arnaz, 2018). The response of consumers to electricity demand when there is a change in price or income can be seen through its elasticity. With this information, electricity providers can use appropriate policies to maintain a balance between electricity consumption and production (Silva, et al., 2017; Saha & Bhattacharya, 2018).

Literature Review

Demand Theory

The definition of demand is the totality of goods demanded based on a certain price level. The buyer's desire and ability for a good or service can be measured through demand (Perloff, 2014; Hu & Hu, 2013). The demand function for a good shows how price, income, and preferences can determine the quantity of the goods demanded. The demand function in Nicholson and Snyder (2010) is written as follows:

$$Q_x = d_x(P_x, P_y I; preference) \quad (1)$$

In making a demand, determining the quantity of goods to be consumed is based on several factors, such as the price of the goods, income, preferences, information, prices of other

goods, government policies, and other factors (Perloff, 2014). In looking at the relationship between the demand for a good or service and the price of that good or service at a certain level, it can be seen through the demand curve. Price and demand themselves have an inverse relationship. This relationship is explained in the downward-sloping law of demand, where if there is an increase in the price of an item, there will be a decrease in demand for that item (Samuelson & Nordhaus, 2009).

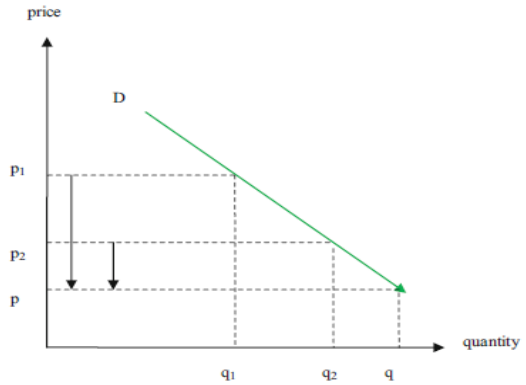

Figure 1: Demand Curve

Source: Hu & Hu (2013)

Several factors influence the demand curve (Samuelson & Nordhaus, 2009) such as:

1. Average consumer income, where when consumer income increases, consumer demand will also increase.
2. Population, an increase in population will cause an increase in demand.
3. Price of related goods: If the price of another good, namely B, which is related to good A, decreases, this will increase demand for good A.
4. Preference: if a consumer is happy with an item, he will demand that item.
5. Special influences, such as the influence of weather on AC use.

The above factors influenced the shift in the demand curve and the price of the good itself. If the curve shifts to the right there is an increase in demand, and if the curve shifts to the left, there is a decrease in demand (Samuelson & Nordhaus, 2009)

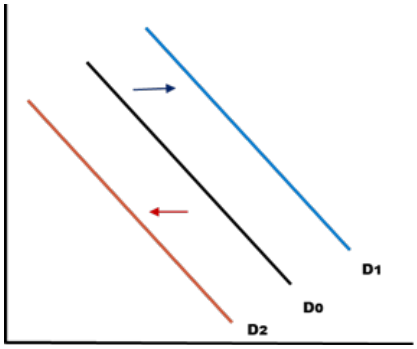

Figure 2: Shifting Demand Curve

Source: Samuelson & Nordhaus (2009)

Income Elasticity

Income elasticity measures how changes in income affect the demand for a good. The income elasticity value is obtained by calculating the percentage change in the quantity of goods demanded divided by the percentage change in income (Nicholson & Snyder, 2010). The formula for calculating the coefficient of income elasticity is:

Income Elasticity of demand = eQ,I

$$e_{Q,I} = \frac{\% \triangle Q}{\% \triangle I} = \frac{\delta Q}{\delta I} \cdot \frac{I}{Q} \quad (2)$$

Income elasticity will have a positive value for the demand for normal goods. If the elasticity value is less than 1, it means that income is inelastic or changes in income have a small effect on demand. Income elasticity values exceeding 1 generally occur if the goods are included in the luxury category (Nicholson & Snyder, 2010).

The Influence of Prices on Electricity Demand in the Household and Industrial Sectors

In demand theory, price has a very close relationship to the quantity of goods or services demanded by consumers. The law of demand explains that a price increase will cause a decrease in demand for a good. On the other hand, if there is a decrease in the price of an item it will have the impact of increasing demand for that item.

Electricity prices are important in electricity demand in the household and industrial sectors. Based on studies conducted by Arisoy & Ozturk (2014), Cialani & Mortazavi (2018), Saha & Bhattacharya (2018) and Csereklyei (2020), it was found that prices negatively and significantly influenced electricity demand from both sectors. In Arnaz (2018), the results showed that the real price of electricity in the household sector has an inelastic elasticity to electricity demand. The same thing was found in a study conducted by Mulyani & Hartono (2018) in the industrial sector, where the results showed that the actual price of electricity had inelasticity. The inelastic price elasticity of electricity demand in the household and industrial sectors means that if there is a change in price, it will not have a big impact on electricity demand from these two sectors.

The Influence of Income on Electricity Demand in the Household and Industrial Sectors

Consumer income, apart from price factors, influences demand for a good or service. According to Samuelson & Nordhaus (2009), income influences the shift in the demand curve. This is because when consumers experience an increase in income, they will also increase demand.

The results of studies conducted by Arisoy & Ozturk (2014), Cialani & Mortazavi (2018), Saha & Bhattacharya (2018), and Csereklyei (2020) show that income influences electricity demand in the household and industrial sectors positively and significantly. An increase in income in these two sectors will also increase electricity demand. Saha & Bhattacharya (2018) found that real GRDP per capita positively influences electricity demand in the household sector. Meanwhile, real GRDP, based on a study conducted by Mulyani & Hartono (2018), will also positively influence electricity demand in the industrial sector.

The Influence of the Number of Customers on Electricity Demand in the Household and Industrial Sectors

In Samuelson & Nordhaus (2009), the size of a market is one of various factors that influence demand. This can be measured through the number of populations. With the increasing population, the level of urbanization and also the increase in the electrification ratio, more and more consumers will use electricity. The number of customers describes the number of households and industries that are electricity consumers.

Research conducted by Arnaz (2018) used the variable number of customers to see the impact on electricity demand. The results showed that additional customers would have a

positive impact, as the increase in the number of customers will directly increase the amount of electricity demand.

This research has two hypotheses. First, for the household sector, Electricity prices, income, and the number of customers significantly influence electricity demand. Second, for the industrial sector, income and the number of customers significantly influence electricity demand in the industrial sector.

Data and Research Methods

This study's main objective is to analyze how the household and industrial sectors in Indonesia respond to changes in prices and income, as well as other factors, namely the number of customers. The approach used in this study was carried out quantitatively using secondary data. Panel data, a combination of time-series and cross-section data, will be used in this study for 2010-2020. It comes from 33 provinces in Indonesia. The panel data regression analysis method will estimate electricity demand from the two sectors.

In this study, the dependent variable is electricity demand in the household and industrial sectors. Factors that are likely to influence electricity demand from these two sectors, namely electricity prices, income and number of customers will be independent variables. The analysis model in this research refers to Saha & Bhattacharya (2018) and Arnaz (2018) for each sector. The model in this research was then transformed into a natural logarithmic form for the independent variables to ensure the data was normally distributed. The transformed model is as follows:

a. Household Sector:

$$\ln elec_{it} = \alpha + \beta_1 \ln\_price_{it} + \beta_2 \ln\_income_{it} + \beta_3 \ln\_cust_{it} + \nu_{it} \quad (3)$$

b. Industrial Sector:

$$\ln elec_{it} = \alpha + \beta_1 \ln\_price_{it} + \beta_2 \ln\_income_{it} + \beta_3 \ln\_cust_{it} + \nu_{it} \quad (4)$$

The variables used in the model for the study of electricity demand in Indonesia's household and industrial sectors can be seen in Table 2.

Table 2: Operational Definition of Variables

Variable	Notation	Description	Source
Electricity Demand	$elec_{it}$	Electrical energy sold (GWh) in 33 Provinces in 2010-2020 (household and industrial sectors).	PLN
Average Real Electricity Prices	$price_{it}$	Average selling price of electricity (Rp/kWh) in 33 Provinces in 2010-2020 divided by the Consumer Price Index (CPI 2010 = 100) (household and industrial sectors).	PLN BPS
Real Income	inc_{it}	Real GRDP and real GRDP per capita with base year 2010 (Rupiah) from 33 Provinces in 2010-2020.	BPS
Number of Customers	$cust_{it}$	Number of PLN electricity customers in 33 provinces in 2010-2020 (household and industrial sectors).	PLN

In this study, panel data regression was used as the analysis technique. The initial step is to carry out pooled least squares regression, fixed effect models, and random effect models. The second step is to carry out tests to determine which model to use. The third step is to carry out classical assumption tests, namely the multicollinearity test, heteroscedasticity test, and autocorrelation test.

Results and Discussion

Estimated Results

Table 3: Statistical Description of Variables

Household Sector					
Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min.**	**Max.**
elec	363	2,609.65	4,055.798	60.88	20,362.3
price	363	538.388	148.807	110.263	1,014.54
income	363	39,000,000	29,900,000	12,000,000	175,000,000
cust	363	1,684,072	2,677,564	23,960	14,100,000
Industrial Sector					
Variabel	**Obs.**	**Mean**	**Std. Dev.**	**Min.**	**Max.**
elec	363	2,002.701	4,657.449	1.52	24,051.64
price	363	752.832	71.594	374.52	1,139.149
income	363	2,74E+14	3,84E+14	1,50E+13	1,84E+15
cust	363	2,210,625	5,785,292	12	68,022

Table 4: Panel Data Regression Estimation Results

Dependent Variable: ln_elec			
Household Sector			
Variables	**PLS**	**FEM**	**REM**
ln_price	0.0517 (0.039)	-0,0363* (0,022)	-0,0268 (0,111)
ln_income	0.426*** (0.000)	0.278*** (0.000)	0,292*** (0,000)
ln_cust	0.983*** (0.000)	0.841*** (0.000)	0,904*** (0,000)
Constant	-13.95*** (0,000)	-8.930*** (0,000)	-10.07 (0,000)
Observation	363	363	363
R-sq	0.985	0.919	
Prob > F	0.000	0.000	
Industrial Sector			
Variables	**PLS**	**FEM**	**REM**
ln_price	-2.340*** (0.000)	-0.585** (0.000)	-0.615***
ln_income	0.595*** (0.000)	0.866*** (0.000)	0.893*** (0.000)
ln_cust	0.920*** (0.000)	0.581*** (0.000)	0.613*** (0.000)
Constant	-4.360 (0.192)	-22.71*** (0.000)	-23.59*** (0.000)
Observation	363	363	363
R-sq	0.884	0.652	
Prob > F	0.000	0.000	0.000

Significance level * p<0.05, ** p<0.01, *** p<0.001

The panel data regression estimation results can be seen in Table 4 which shows the estimation results for the household and industrial sectors using pooled least squares, fixed effect models, and random effect models. The next step is to test the best model which can be seen in Table 5. From the results obtained, the best model used for the household and industrial sectors is the fixed effect model.

Table 5: Best Model Selection Test Results

Chow Test Results		
Sectors	**Prob > F**	**Results**
Household	0.0000	H0: PLS rejected
Industry	0.0000	H0: PLS rejected
LM Test Results		
Sectors	**Prob > chibar2**	**Results**
Household	0.0000	H0: PLS rejected
Industry	0.0000	H0: PLS rejected
Hausman Test Results		
Sectors	**Prob > chi2**	**Results**
Household	0.0000	H0: REM rejected
Industry	0.0035	H0: REM rejected

Based on the results of the best model selection test, the fixed effect model is the best model to use in the analysis. After selecting the model, a classical assumption test was carried out with the result that the model experienced symptoms of heteroscedasticity and autocorrelation. Healing can be done by clustering cross-sections (Wooldridge, 2016). The final results of the fixed effect model regression can be seen in table 6.

Table 6: Fixed Effect Model Regression Results

Variables	**Dependent Variable: ln_elec**	
	Household	**Industry**
ln_price	-0.0363 (0.071)	-0.585** (0.004)
ln_income	0.278* (0.013)	0.866* (0.015)
ln_cust	0.841*** (0.000)	0.581** (0.004)
Constant	-8.930*** (0.000)	-22.71* (0.021)
Observation	363	363
R-sq	0.919	0.652
Prob > F	0.000	0.000

Significance level * p<0.05, ** p<0.01, *** p<0.001

Interpretation and Discussion Results

Based on the test results that have been carried out and seen in Table 6, electricity prices in both household and industry sectors have a negative sign. This is based on demand theory, which explains that electricity prices have an inverse relationship with demand. From the estimation results, the electricity price elasticity is inelastic to electricity demand

in the household sector, although it does not have a direct influence. Almost the same as the household sector, electricity prices are also inelastic to electricity demand in the industrial sector but have a significant influence. This price inelastic demand for electricity proves that electricity is a normal good and is needed for daily life, so price changes have little influence on electricity demand (Samuelson & Nordhaus, 2009; Cialani & Mortazavi, 2018).

The electricity price elasticity in the household sector is much more inelastic, with a value of -0.0363, compared to the industrial sector, which has an elasticity value of -0.585. These findings align with a study conducted by Csereklyei (2020) with the results that the household sector is more price inelastic compared to the industrial sector in the European Union. In this case, the industrial sector is more sensitive to price changes than the household sector. If there is an increase in prices, there will be a quite drastic decrease in electricity demand from the industrial sector, while the household sector will not be too affected by an increase or decrease in prices.

The results show that price has no influence on electricity demand in the household sector. This might happen because there is still little electricity consumption in the household sector, which is caused by the use of electricity only for basic needs (Agustin & Wikarya, 2019). Another possible factor is the still large role of electricity in the household sector, as well as the lack of other types of energy that can be used as a substitute for the household sector to carry out its activities. Based on the BPPT (2020), there are only two other types of energy, that are LPG and kerosene, which are used apart from electricity.

In Samuelson & Nordhaus (2009) it is explained that goods with substitute options will be more inelastic in terms of demand. This can explain the household sector's elasticity value, which is far below the industrial sector. Electricity is one of the largest sources of energy used to carry out activities in the household sector, with LPG and kerosene as other energy sources used in the household sector. In contrast to the household sector, the industrial sector has many other options to use as substitutes, such as coal, gas, biomass, and fuel as energy sources to carry out its activities (BPPT, 2020).

Inversely proportional to electricity prices, the income variable influences electricity consumption in both the household and industrial sectors significantly and positively. The real income elasticity (GRDP per capita) in the household sector for electricity demand is 0.278. The real income elasticity (GRDP) in the industrial sector has a value greater than that in the household sector, namely 0.866. Both household and industrial sectors are income inelastic to electricity demand. This positive and significant influence of income on electricity demand explains that electricity demand will increase along with increasing income in the household and industrial sectors. The results obtained in this research align with demand theory, which states that income and demand have a directly proportional relationship. This research is also supported by previous research conducted by Cialani & Mortazavi (2018), Csereklyei (2020), and Saha & Bhattacharya (2018).

In the household sector, increasing income will increase electricity consumption due to the possibility of using more electronic goods compared to before (Agustin & Wikarya, 2019). With increasing income; people will consume goods/services, including electronic goods, and this will also increase electricity consumption in the household sector. Like the household sector, the industrial sector has experienced an increase in income, so demand for electricity has also increased. Growth in income or economic activity as measured by real GRDP will cause the industrial sector to try to produce adequate output so that demand for electricity as an input factor also increases (Mulyani & Hartono, 2018: 13).

The number of customers has a positive and significant influence on electricity demand in both household and industrial sectors. The estimation results show that the number of customers in the household sector is more elastic towards electricity demand, with a value of 0.841, compared to the industrial sector, with 0.581. As the number of customers increases, electricity demand will also increase, in line with a study conducted by Arnaz (2018). The increase in customers itself is caused by several factors, such as increasing the electrification ratio, population growth, and others.

Each sector has one variable that has the most influence on electricity demand. In the household sector, when compared with prices and income, the number of customers is a factor that influences electricity demand positively and significantly. The real price of electricity itself has a negative and very small and insignificant influence on electricity demand in the household sector. In contrast to the household sector, in the industrial sector it is income that most significantly and positively influences demand for electricity. Real prices and the number of customers have a significant influence and are almost at the same level, except that real prices have a negative influence, and the number of customers has a negative influence on electricity demand.

Increasing economic growth and the number of customers caused by an increase in the electrification ratio and population growth will increase the demand for electricity from both sectors. The increasing electricity demand must be accompanied by adequate supply for these two sectors. The price of electricity itself does not have a big influence on demand. Therefore, price increases within reasonable limits in both sectors, especially in the household sector, which does not have a significant and very small influence on electricity demand, can be done. This is done to increase revenue which will then be used to increase the supply side. Reducing electricity subsidies can also be implemented and funds can then be allocated for infrastructure development considering the large amount of funds needed to carry out electricity infrastructure development (Burke and Kurniawati, 2018: 411).

Conclusions and Recommendations

Conclusion

In the household sector, income and the number of customers influence electricity demand, but price has no influence on electricity demand. An increase in income and demand will increase electricity demand, while an increase in electricity prices will reduce electricity demand. The price and income elasticity of electricity demand is inelastic, which indicates that electricity is a necessary item in daily life in the household sector. The number of customers most influences electricity demand from the household sector itself.

In the industrial sector, price, income, and the number of customers influence electricity demand. An increase in income and demand will increase electricity demand, while an increase in electricity prices will reduce it. The elasticity of price and income on electricity demand is inelastic, but income has a positive influence, which means that electricity is a normal good in the industrial sector. Electricity demand from the industrial sector itself is most influenced by income.

Recommendations

It is hoped that the results of the research carried out can be taken into consideration in making policies regarding electricity demand in the household and industrial sectors in Indonesia. Here are some suggestions: With price inelasticity regarding electricity demand

in the household and industrial sectors, tariff increases can be made within affordable limits for consumers. However, attention must be paid to the industrial sector considering that industrial sector electricity demand is significantly more sensitive to price changes. A policy of reducing electricity subsidies can also be implemented, and funds allocated for infrastructure development such as power plants. Especially considering that the fuel for power plants is still dominated by coal, the construction of power plants using renewable energy needs to be considered. This is because the increase in income and number of customers greatly influences electricity demand positively and significantly, so the supply side must be adequate so that electricity demand and distribution can occur in a balanced manner. With this, affordable and sustainable electricity can be achieved.

For further research, other variables outside this research can be used to influence electricity demand in the household and industrial sectors in Indonesia. Using microdata or, according to consumer groups, is also recommended to capture more completely the factors that influence electricity demand from both sectors.

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