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ENERGY DEMAND FORECASTING FOR TAIWAN'S ELECTRONICS INDUSTRY

This paper develops 3 different SARIMA models to forecast energy demand in Taiwan's electronic parts and components manufacturing industry. The empirical findings show that the relative growth rate of energy demand in Q2 is higher than that in Q1, but the relative growth rate of energy demand in Q4 is lower than that in Q1. In addition, the relative growth rate of energy demand increasing is accompanied by the relative growth rate of Taiwan's total exports rising. On the contrary, the relative growth rate of the USD exchange rate to the new Taiwan dollar has a slight counter effect on the relative growth rate of energy demand. The results forecast that the total annual energy demand in Taiwan's electronic parts and components manufacturing industry will increase from 1,390 to 20,582 KKLOE during the period of 2010-2020.

Keywords: *electronic parts and components manufacturing industry; forecasting, seasonal ARIMA model (SARIMA); exports; exchange rates.*

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ПРОГНОЗУВАННЯ ПОПИТУ НА ЕНЕРГІЮ В ЕЛЕКТРОННІЙ ПРОМИСЛОВОСТІ ТАЙВАНЮ

У статті розроблено 3 різні SARIMA-моделі (сезонна інтегрована модель авторегресії — ковзаючого середнього) для прогнозування попиту на енергію в тайванському виробництві електронних деталей і компонентів. Емпіричні дані показують, що відносні темпи зростання попиту на енергію в другому кварталі вищі, ніж в першому, але в четвертому кварталі вони нижчі, ніж в першому. Крім того, відносні темпи зростання попиту на енергію супроводжуються відносними темпами зростання загального обсягу експорту. І навпаки, відносна швидкість росту обмінного курсу долара США до нового тайванського долара має невеликий зворотний ефект на відносні темпи зростання попиту на енергію. За прогнозами дослідження, загальний річний попит на енергію в електронній промисловості Тайваню збільшиться з 1390 до 20.582 KKLOE в період 2010-2020 р.р.

Ключові слова: *виробництво електронних деталей і компонентів; прогнозування; сезонні ARIMA- (SARIMA-) моделі; експорт; валютний курс.*

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ПРОГНОЗИРОВАНИЕ СПРОСА НА ЭНЕРГИЮ В ЭЛЕКТРОННОЙ ПРОМЫШЛЕННОСТИ ТАЙВАНЯ

В статье разработаны 3 различных SARIMA-модели (сезонная интегрированная модель авторегрессии — скользящего среднего) для прогнозирования спроса на энергию в тайваньском производстве электронных деталей и компонентов. Эмпирические данные показывают, что относительные темпы роста спроса на энергию во втором квартале выше, чем в первом, но в четвертом квартале они ниже, чем в первом. Кроме того, относительные темпы роста спроса на энергию сопровождаются относительными темпами роста общего объема экспорта. И наоборот, относительная скорость роста обменного курса доллара США к новому тайваньскому доллару имеет небольшой

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обратный эффект на относительные темпы роста спроса на энергию. По прогнозам исследования, общий годовой спрос на энергию в электронной промышленности Тайваня увеличится с 1390 до 20.582 KKLOE в период 2010-2020 г.г.

Ключевые слова: *производство электронных деталей и компонентов; прогнозирование; сезонные ARIMA- (SARIMA-) модели; экспорт; валютный курс.*

Introduction. Taiwan's government views the electronic parts and components manufacturing (hereafter, EPCM) industry as an important targeting industry to spur national economic growth. According to the "Standard Industrial Classification of the Republic of China" issued by the Directorate General of Budget, Accounting and Statistics under the Executive Yuan, Taiwan's EPCM industry covers the semiconductor industry and other electronic parts and components manufacturing. World Semiconductor Trade Statistics (WSTS) indicates that Taiwan's IC industry showed rapid growth of 41.5% year-on-year in 2010 with overall IC revenue in Taiwan reaching USD 56 bln. From the statistical data of Market Intelligence & Consulting Institute (2011), Taiwan's 2010 semiconductor industry consists of 14 wafer-producing firms, 28 packaging firms, 36 testing firms, and 270 design companies. Most semiconductor production in Taiwan is original equipment manufacturing and export-oriented.

Taiwan lacks natural energy resources and has relied on energy imports to meet the country's total energy demand over the past decades and even up to the present. Based on data from the Bureau of Energy, R.O.C. in 2010, the ratio of imported to overall energy demand rose steadily from 90% in 1986 to 99.4% in 2010. Taiwan Power Company's energy consumption data reveal that the EPCM industry contributed 18.11% to the country's total energy consumption in 2010. The energy categories required by Taiwan's EPCM industry are electricity and thermal, with electricity accounting for 98.9% of the total energy consumption. Because energy cannot be stored economically, it is an indispensable issue for every country when developing economic activities. As a result, Taiwan's government is very much concerned about accurate energy demand forecasting in this industrial sector.

The purpose of this paper is to establish a forecasting model for policy makers' reference when they are planning energy distribution. We include three-season dummy variables (Q2-Q4) into the SARIMA model to examine different quarters' total energy demand, in order to improve the prediction accuracy relative to previous literature (e.g., Hu et al., Forthcoming). This paper also explores the relationship between USD exchange rate to the new Taiwan dollar, Taiwan's total exports, and total energy demand in Taiwan's EPCM industry.

This paper is structured as follows. Section 2 introduces the literature review. Section 3 presents the details of the proposed forecasting model, which this paper applies. Section 4 describes the results of empirical analysis such as model selection, forecasting performance comparisons, and total energy demand forecasting. Finally, Section 5 provides some relevant conclusions and restrictions.

Literature review. Since present economic phenomena are derived from past real situations, time-series forecasting appears to be an appropriate analysis technique. In the past 3 decades, the Box-Jenkins autoregression integrated moving average (ARIMA) model and artificial neural network (ANN) model have been widely used in time series prediction, with the predictive performances of the ARIMA model superior to the neural network model (Ho, Xie and Goh, 2002). Furthermore, ANN does not present a mathematical equation to explain its hidden meaning (Lee and Tong, 2011).

Many researchers have adopted the ARIMA model to forecast electricity demand in Turkey (Erdogdu, 2007; Mucuk and Uysal, 2009). Ediger et al. (2006) and Ediger et al. (2007) further applied ARIMA, regression and SARIMA methods to forecast Turkey's fossil fuel production. For Japan, Hunt and Ninomiya (2005) used an ARIMA model to examine the long-run relationship among energy demand, GNP and real energy price. Pappas et al. (2008) also found that their developed ARMA model could be useful in electricity consumption and electricity price forecasts in Greece.

Hsu and Chen (2003) proposed a modified grey prediction model of power demand forecasting, with their empirical results showing that forecasting the power demand of Taiwan with ARIMA model is a more accurate forecast than the original GM (1, 1) model. Aside from domestic total energy demand forecasting, ARIMA model also has a satisfactory degree of statistical validity (low approximation errors) when it was applied to Asturias' industry sector energy consumption forecasting (Chavez et al., 1999).

Unler (2008) suggested that medium- and long-term energy demand forecasts are based on realistic indicators, noting that the indicator of exports really improves the forecasting of energy demand. Narayan and Smyth (2009) also found a certain relationship between exports and electricity consumption in Middle Eastern countries. As most semiconductor production in Taiwan is original equipment manufacturing and export-oriented, we believe that the variation in energy demand for the EPCM industry is related to the USD exchange rate movement versus the new Taiwan dollar or Taiwan's total exports.

Hu et al. (forthcoming) used 28 yearly samples to investigate the cause-effect relationship between energy demand and economic variables in Taiwan's iron-steel industries with a vector autoregression (VAR). This paper herein employs the seasonal ARIMA model with more frequency and more data samples to explore the relationship among the USD exchange rate to the new Taiwan dollar, Taiwan's total exports, and total energy demand in Taiwan's EPCM industry. Because the time series of energy demand in Taiwan's EPCM industry really does present a seasonal trend, this paper thus adopts the Seasonal ARIMA (SARIMA) model to forecast the energy demand in Taiwan's EPCM industry.

Methodology. Up until May 2007, the EPCM industry solely used electricity for operations, and then began to use a little thermal power. Presently, thermal power occupies only about 1.1% of total energy consumption in Taiwan's EPCM industry. Ediger and Akar (2007) indicated that forecasting total primary energy demand is more reliable than the summation of individual energy forecasts when simulating Turkey's energy demand via ARIMA and SARIMA models. For this reason, this paper aggregates electricity and thermal power into 1,000 kiloliters of oil equivalent to forecast total energy demand in the EPCM industry.

We collected the historical data used in this paper from the economic statistics database of the Ministry of Economic Affairs (MOEA). All the data are monthly, from January 1998 to December 2010, separated into two panel datasets (A and B) from December 2009. Panel A is used to build the forecasting model, and panel B is employed as an out-of sample to compare the forecasting capabilities.

The time series data of Taiwan's total exports and the energy demand of the EPCM industry show strong seasonal trends (see Figures 1 and 2). The sharp drops in each year generally happen in January or February, due to plants shutting down for the Chinese New Year.

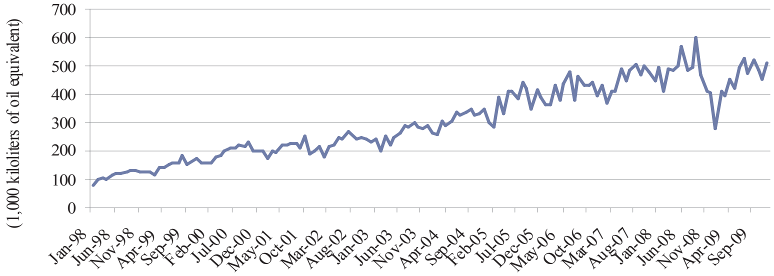

Figure 1. **Total energy demand**

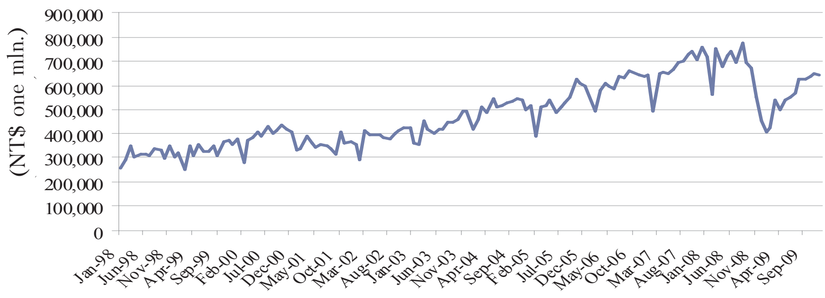

Figure 2. **Taiwan's total exports**

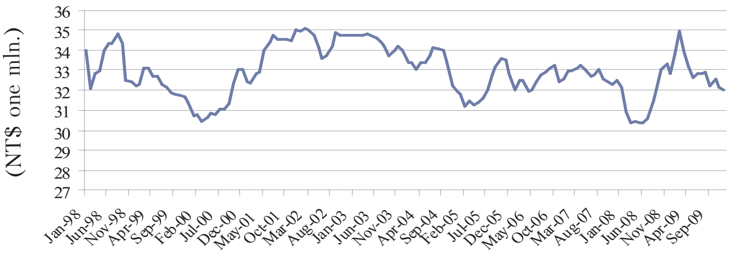

Figure 3. **Exchange rate of the US Dollar to the New Taiwan Dollar**

The SARIMA model has similar structure as the ARIMA model: it may have an AR factor, a MA factor, or an order of differencing. A seasonal ARIMA model is classified as a SARIMA$(p, d, q)x(P, D, Q)s$, where p is the number of autoregressive (AR) terms, d is the order of differences, q is the number of moving average (MA) terms, P is the number of seasonal autoregressive (SAR) terms, D is the order of seasonal differences, Q is the number of seasonal moving average (SMA) terms, and s is the number of lag periods in a time series.

The analysis performed in the SARIMA procedure is Box-Jenkins' suggestion of processing ARIMA (1976) as follows. The first step stationarizes the time series, because it is important to identify what order of differencing is needed. If the total order of differencing is more than secondary, then there is no constant term included. Therefore, this paper applies the Akaike information criterion (AIC) and Schwarz information criterion (SIC) to identify the most appropriated model. After that goes the processing of the parameter estimation and residual autocorrelation diagnostic via Ljung and Box's (1978) Q-statistic. These steps are applied iteratively until step 3 does not produce any improvement in the model.

This paper proposes 3 different SARIMA models for different purposes. Model 1 is a fundamental SARIMA model of energy demand. For examining different quarters' total energy demand purpose, Model 2 includes three-season dummy variables (Q2-Q4). In addition, January-March (Q1) is taken as a reference group for each of the 3 quarters and not included in Model 2. Model 3 encompasses the USD exchange rate to the new Taiwan dollar and Taiwan's total exports to explore their effects on total energy demand.

To evaluate the out-of-sample forecasting capability, we examine forecast accuracy by calculating the following 3 different evaluation statistics: mean absolute error (MAE), mean absolute percentage error (MAPE) and root mean square error (RMSE). Their definitions are as follows:

$$MAE = \frac{\sum_{i=1}^{n} \left| F_i - A_i \right|}{n}, \tag{1}$$

$$MAPE = \left(\frac{\sum_{i=1}^{n} \left| (F_i - A_i) / A_i \right|}{n} \right) \times 100\%, \tag{2}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} \left| (F_i - A_i)^2 \right|}{n}}, \tag{3}$$

where A_i is the actual value and F_i is the forecast value.

The results of empirical analysis. According to the results of the unit root test, ENE is not a white noise process (ADF=-0.838, p=0.805). Therefore, ENE, EXCR, and EXPORT are respectively transformed into rENE, rEXCR, and rEXPORT by taking a natural logarithm and difference to stationary.

This paper adopts Akaike information criterion (AIC) and Schwarz information criterion (SIC) to determine that the most appropriated model generated from Panel A is SARIMA $(2, 2, 0)\times(1, 0, 0)_{12}$. The residual analysis also reveals that the model is adequate. Table 2 summarizes the estimation results of the 3 SARIMA models.

This paper applies MAE, MAPE, and RMSE as out-of-sample forecasting performance criteria via Panel B. In general, a MAPE under 10% is considered very good, and a MAPE in the range 20-30% or even higher is quite common. Table 3 shows the results. The statistics of Panel A reveal that MAE $_{Model\ 3}$ < MAE $_{Model\ 2}$ < MAE $_{Model\ 1}$, MAPE $_{Model\ 3}$ < MAPE $_{Model\ 2}$ < MAPE $_{Model\ 1}$, and RMSE $_{Model\ 3}$ < RMSE $_{Model\ 2}$ < RMSE $_{Model\ 1}$. Panel B also presents the consistency results of these statistics. Therefore, Model 3 is the best forecasting model, because the values of MAE, MAPE, and RMSE are the lowest.

Table 1. **Descriptive statistics analysis of the transformed variables**

Variables	Observations	Mean	Maximum	Minimum	S. D.
Panel A: sample period 1998/01-2009/12					
rENE	143	0.013	0.384	-0.370	0.119
rEXCR	143	0.000	0.033	-0.058	0.015
rEXPORT	143	0.006	0.361	-0.291	0.116
Panel B: sample period 2010/01-2010/12					
rENE	12	0.008	0.234	-0.202	0.113
rEXCR	12	-0.004	0.025	-0.024	0.013
rEXPORT	12	0.009	0.333	-0.261	0.145

Note: *ENE* is the total energy demand, *EXCR* is the exchange rate of the USD to the new Taiwan dollar, *EXPORT* is Taiwan's total exports, *rENE* is the relative growth rate of total energy demand, *rEXCR* is the relative growth rate of the USD exchange rate to the new Taiwan dollar, *rEXPORT* is the relative growth rate of Taiwan's total exports.

Table 2. **Results of the estimations of models**

Variables	Model 1			Model 2			Model 3		
	β	p		β	p		β	p	
AR(1)	-0.75	<0.01	***	-0.86	<0.01	***	-1.02	<0.01	***
AR(2)	-0.35	<0.01	***	-0.44	<0.01	***	-0.59	<0.01	***
SAR(1)	0.60	<0.01	***	0.27	<0.01	***	0.12	0.22	
Q2				0.06	<0.01	***	0.05	<0.01	***
Q3				0.01	0.39		0.01	0.54	
Q4				-0.04	<0.01	***	-0.03	<0.01	***
rEXPORT							0.42	<0.01	***
rEXCR							-0.48	0.06	*
Adjusted R^2	0.451			0.547			0.690		
AIC	-1.955			-2.099			-2.448		
SIC	-1.888			-1.966			-2.271		

Note: *p<0.1, ** p <0.05, *** p <0.01.

Table 3. **Comparing forecasting measurement errors**

	Model 1		Model 2		Model 3	
Data source	Panel A	Panel B	Panel A	Panel B	Panel A	Panel B
MAE	46.54	31.11	39.61	31.36	35.76	29.76
MAPE	9.91%	9.09%	8.09%	9.33%	0.55%	8.72%
RMSE	60.97	42.49	47.82	42.18	40.84	40.52

As for the settings of parameters in 3 different scenarios, the EXPORT annual growth rate is the exogenous variable during 1998-2010, and EXCR is assumed to remain stable. After excluding 3 extreme values of the EXPORT annual growth rate, this paper forecasts the total energy demand with the minimum EXPORT annual growth rate of 0.70% in 2004 as scenario 1 (optimistic), average EXPORT annual growth rate of 14.10% as scenario 2 (mostly likely), and maximum EXPORT annual growth rate of 19.41% in 2004 as scenario 3 (pessimistic).

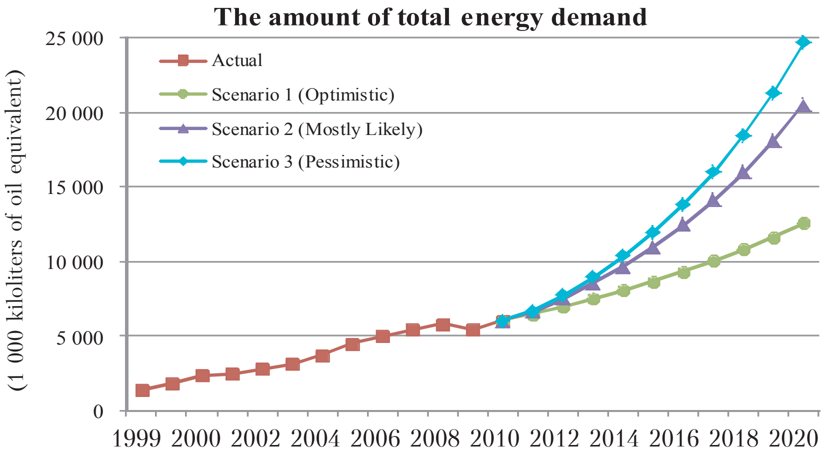

Figure 4. **Forecasts of total energy demand under different scenarios (2011-2020)**

Figure 4 presents the forecasted total energy demand under each scenario from 2011-2020. In scenario 1, the total annual energy demand is 1,390 KKLOE in 2010. With the increase in the annual growth rate of Taiwan's total exports, the total annual energy demand is forecasted to reach 12,575 KKLOE in 2020. Under the assumption of the annual growth rate of Taiwan's total exports being 14.10%, the result of scenario 2 shows that the total annual energy demand should increase to 20,582 KKLOE in 2020. In scenario 3, due to a substantial increase in the annual growth rate of Taiwan's total exports being 19.41%, the total annual energy demand is expected to rise from 1,390 KKLOE in 2010 to 24,650 KKLOE in 2020.

Conclusion. Accurate energy demand forecasting is helpful for power facilities' planning and important for the economic development of a developing country. This paper has adopted the SARIMA model to forecast the energy demand in Taiwan's EPCM industry and compare the values of MAE, MAPE, and RMSE to select the most appropriate forecasting model. The results of this paper reveal that SARIMA with exogenous variables improves forecasting capability.

The empirical findings show that the relative growth rate of energy demand in Q2 is higher than that in Q1, but the relative growth rate of energy demand in Q4 is lower than that in Q1. In addition, the relative growth rate of energy demand increasing is accompanied by a relative growth rate of Taiwan's total exports rising. On the contrary, the relative growth rate of the USD exchange rate to the new Taiwan dollar has a slight counter effect on the relative growth rate of energy demand.

The forecasting results show that the total annual energy demand in Taiwan's EPCM industry is forecasted to increase from 1,390 to 20,582 KKLOE during the period of 2010 to 2020 in scenario 2. The total annual energy demand should increase 19,192 KKLOE within 10 years under an average annual growth rate of 30.93%. Based on the above simulation results, Taiwan's EPCM industry may have excess demand for energy in the future. The results also show that the trend of total energy demand appears to grow with the annual growth rate of Taiwan's total exports.

There are some restrictions in this paper. Since Taiwan's EPCM industry began to develop in 1998, the historical monthly data only contain 156 samples from 1998 to 2010. If there were more available time series data, then the period of energy demand forecasting could be longer. The SARIMA model conducts performance forecasting quite well, nevertheless, this method also requires the empirical data to have a certain regular cycle a priori. The empirical results reveal that the relative growth rate of the USD exchange rate to the new Taiwan dollar increasing has a slight counter effect on the relative growth rate of energy demand. However, it is difficult to predict the trend of the relative growth rate in the exchange rate over the long term.

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References:

Bureau of Energy, Ministry of Economic Affairs (2010). The White Paper on Energy Technology Research and Development.

Box, G. E. P. & Jenkins, G. M. (1976). Time Series Analysis: Forecasting and Control. Holden-Day, San Francisco.

Chavez, S. J., Bernat, J. X. & Coalla, H. L. (1999). Forecasting of Energy Production and Consumption in Asturias (Northern Spain), Energy, 24(3), 183-198.

Ediger, V. S. & Akar, S. (2007). ARIMA Forecasting of Primary Energy Demand by Fuel in Turkey, Energy Policy 35(3), 1701-1708.

Ediger, V. S., Akar, S. & Ugurlu, B. (2006). Forecasting Production of Fossil Fuel Sources in Turkey Using a Comparative Regression and ARIMA Model, Energy Policy, 34(18), 3836-3346.

Erdogdu, E. (2007). Electricity Demand Analysis Using Cointegration and ARIMA Modeling: A Case Study of Turkey, Energy Policy, 35(2), 1129-1146.

Hunt, L. C. & Ninomiya, Y. (2005). Primary Energy Demand in Japan: An Empirical Analysis of Long-Term Trends and Future CO2 Emissions, Energy Policy, 33(11), 1409-1424.

Hu, J. L., Chen, C. P., Chen, Y. H. & Tso, C. (Forthcoming). Energy Consumption and CO2 Emission in Taiwan's Iron-Steel Industries, Energy Sources, Part B.

Ho, S. L., Xie, M. & Goh, T. N. (2002). A Comparative Study of Neural Network and Box-Jenkins ARIMA Modeling in Time Series Prediction, Computers and Industrial Engineering, 42(2), 371-375.

Hsu, C. C. & Chen, C. Y. (2003). Application of Improved Grey Prediction Model for Power Demand Forecasting, Energy Conversion and Management, 44(14), 2241-2249.

Lee, Y. S. & Tong, L. I. (2011). Forecasting Time Series Using a Methodology Based on Autoregressive Integrated Moving Average and Genetic Programming, Knowledge-Based Systems, 24(1), 66-72.

Ljung, G. M. & Box, G. E. P. (1978). On a Measure of Lack of Fit in Time Series Models, Biometrika, 65(2), 297-303.

Market Intelligence & Consulting Institute, http://mic.iii.org.tw/english/.

Ministry of Economic Affairs of R.O.C., Economic Statistics Database, https://2k3dmz2.moea.gov.tw/gwWeb/.

Mucuk, M. & Uysal, D. (2009). Turkey's Energy Demand, Current Research Journal of Social Sciences, 1(3), 123-128.

Narayan, P. K. & Smyth, R. (2009). Multivariate Granger Causality between Electricity Consumption, Exports and GDP: Evidence from a Panel of Middle Eastern Countries, Energy Policy, 37(1), 229-236.

Pappas, S. S., Ekonomou, L., Karamousantas, D. C., Chatzarakis, G. E., Katsikas, S. K. & Liatsis, P. (2008). Electricity Demand Loads Modeling Using Autoregressive Moving Average (ARMA) Models, Energy, 33(9), 1353-1360.

Taiwan Power Company, http://www.taipower.com.tw/.

Unler, A. (2008). Improvement of Energy Demand Forecasts Using Swarm Intelligence: The Case of Turkey with Projections to 2025, Energy Policy, 36(6), 1937-1944.

World Semiconductor Trade Statistics, http://www.wsts.org/.

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