A Mid-Term Forecast of Maximum Demand for Electricity in Poland

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ABSTRACT

Forecasting of demand for electricity plays an important role in planning of seasonal operations and expansion of power facilities. Power plants must ensure the continuity of supply of energy, without producing the excess due to problems associated with its storage, and at the same time they must be prepared for increased demand e.g. during the periods of cold weather. These factors make that energy companies need accurate forecasts, which in the best way will help plan all the processes associated with this activity. In the article, based on data from the years 2002-2015, the medium-term forecast of electricity demand in Poland until the end of 2017 has been presented. Forecasts have been determined using the exponential smoothing Winters and SARIMA models, and their results have been compared with each other and the months, when a rise and a fall for energy demand is predicted, have been quoted.

1. INTRODUCTION

Demand for electricity is the amount of energy that must be generated and distributed. Power distribution is not only to provide it to electrical equipment, but also to ensure its continuity, which directly translates into customer satisfaction. Ensuring continuity of energy demand cannot be solved by its excessive overproduction since electricity storage is problematic and expensive. Therefore, its proper forecasting is very important, and thanks to this the outages of electricity and its overproduction will be reduced. From the point of view of electricity producers, the correct forecast of the demand for electricity also allows to plan fuel supplies such as coal or gas. Problems of this type apply to energy systems in every country and region of the world, and is still valid due to the continual development of equipment, of which a significant part re-

quires electrical power. In addition, the update of forecasts forces their nature - the most accurate, i.e. short and mid- term must be based on the most current data. In this publication the energy demand forecasts have been based on the data from the Polish National Energy System (NES) from the years 2002 to 2015, and their horizon covers the period till the end of 2017. The forecasts have been determined on the basis of two models: the exponential smoothing of Winters and SARIMA, which provides greater certainty regarding their relevancy.

2. A REVIEW OF RESEARCH

The invention of electricity in the nineteenth century was the revolution that shaped the modern world and the economy (Yergin, 2012) and contributed to the development of many sciences, which had not existed before. Along with the electricity the issues concerning forecasting the demand for it appeared. Scientific approach to forecast the demand for electricity has been conducted for many years (Wilson, 1971; Halvorsen, 1975; Taylor, 1975), and it became particularly important in the 60s of last century, when a very fast growth in electricity consumption started (Smil, 2010). This theme is still up-to-date and it is the object of interest of both practitioners (Piekut, et al., 2012), as well as scientists who use a wide range of forecasting models (Armstrong, 2001; Zhou et al., 2006; Dongxiao, et al., 2010; Balitskiy et al., 2016. Research related to energy requirements apply to each region and country, regardless of its degree of economic development. In case of Poland an article by Maciejewski can be quoted as an example, in which the author in 2007 forecasts of the demand for national electricity until 2012 (Maciejewski, 2007). Ringwood et al., using three different scale (annual, weekly and hourly), forecast domestic demand for electricity in the Republic of Ireland (Ringwood, et al., 2001). Küçükdeniz in his article in 2010, using the SVM model, predicts long-term demand for electricity in Turkey (Küçükdeniz, 2010). An example of forecasts using data from the fastest growing economies in the world, the Chinese economy, is the work by Zhout et al., in which the authors present a trigonometric gray prediction approach by combining the traditional gray model GM (1,1) with the trigonometric residual modification technique (Zhou et al., 2006). Taylor et al., using several different models, compared them with data from Rio de Janeiro, and England and Wales (Taylor et al., 2006). One should not forget about the most developed US economy and cite the works including both forecast ofonly some regions, for example. California (Nowicka-Zagrajek and Weron, 2002); (Wang et al., 2012), New England (Daneshi et al., 2008), as well as the whole country (Pielow et al., 2012).

Forecasts can be divided into short (Smith, 2000), medium (Pedregal and Trapero, 2010); (De Gooijer & Hyndman, 2006) and long-term ones, but regardless of the forecast period, they must be considered as guidelines to make certain decisions, not a ready-made solution (Zeliaś, 1997). Forecast horizon does not only mean the period where the values will be forecast, but also, depending on the test object, it has additional meaning and purpose. In the case of medium-term forecasts in the energy sector, this aim is planning of fuel purchase in order to ensure continuity of supply and optimize costs that are associated with the turn of the final price of energy (Nogales et al., 2002); (Karakatsani and Bunn, 2003).

In the literature one can find a large number of items describing and comparing different methods of forecasting for energy demand. Cottet & Smith (Cottet and Smith, 2003) have used for this purpose the procedures by Bayes; Blum & Riedmiller (Blum and Riedmiller, 2013) predict energy demand using Gaussian processes, and Dongxiao et al. (Dongxiao et al., 2010) use a support vector machine and ant colony optimization. However, the most popular models used to forecast electricity demand are ARMA / ARIMA / SARIMA models and exponential smoothing, which have been used, among others, in the works (Pappas et al., 2008; Taylor, 2003; Chen, et al., 1995; Lee and Ko, 2011; De Andrade &and da Silva, 2009; Bratu, 2012; Kasperowicz, 2014a,b) and they have been selected in this article to calculate forecasts for the Polish energy system.

3. DISCUSSION OF DATA FROM THE NATIONAL ENERGY SYSTEM IN POLAND

Data on the demand for electricity in the National Energy System (NES) in Poland have been downloaded from the website of Polish Power Grid[1], where they are given from January 2002 in megawatts [MW] every fifteen minutes. The forecasts in this article will be carried out for two years on a monthly basis and they relate to maximum demand for energy. These factors make that the retrieved data, before making the forecasts, must be appropriately converted into the same form as the forecast data. Thus, the most appropriate cycle in this case is a period of one month for which \ the maximum energy demand needs to be found. Since the collected data refer to the period of January 2002 - December 2015, then by converting the data in this way, it is possible to obtain a sample containing 168 monthly data (Table 1). In addition, to increase the readability, the data has been presented in gigawatts [GW].

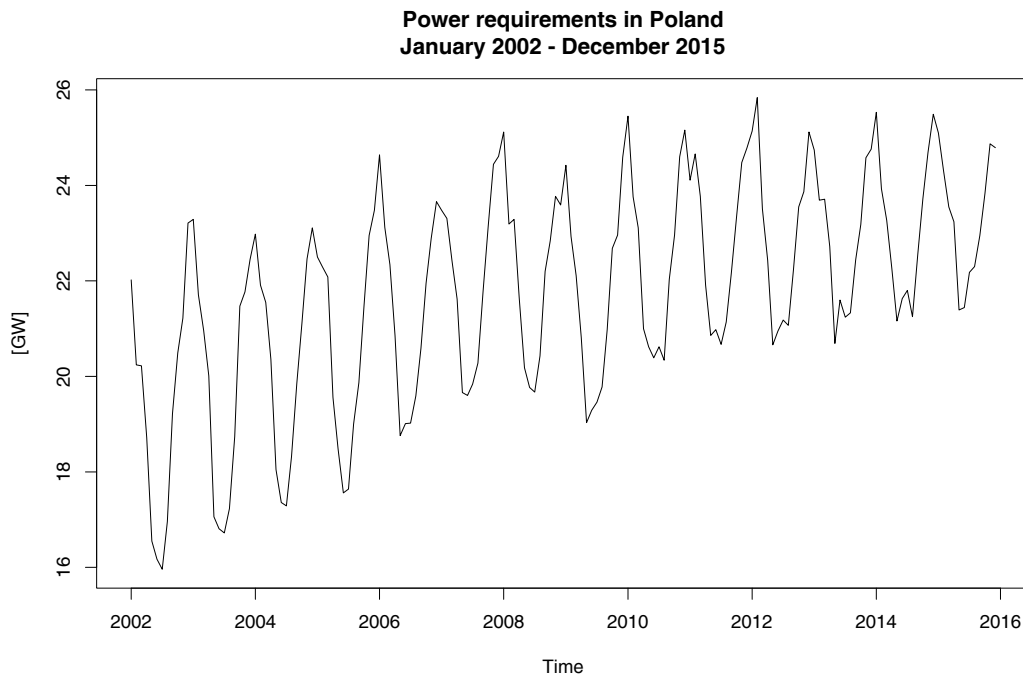**Table 1.** Energy demand in the National Energy System in Poland [GW]

		Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year	2002	22.02	20.24	20.22	18.72	16.55	16.17	15.96	16.96	19.22	20.49	21.22	23.21
	2003	23.29	21.71	20.96	20.01	17.06	16.81	16.72	17.23	18.74	21.47	21.77	22.45
	2004	22.98	21.91	21.55	20.36	18.05	17.36	17.29	18.32	19.85	21.11	22.46	23.11
	2005	22.50	22.29	22.08	19.56	18.48	17.56	17.64	19.00	19.87	21.47	22.95	23.48
	2006	24.64	23.12	22.34	20.85	18.76	19.01	19.02	19.59	20.59	21.95	22.89	23.66
	2007	23.48	23.31	22.42	21.62	19.66	19.60	19.84	20.28	21.77	23.13	24.44	24.61
	2008	25.12	23.19	23.29	21.65	20.18	19.77	19.67	20.43	22.20	22.84	23.77	23.59
	2009	24.42	22.93	22.11	20.81	19.03	19.29	19.46	19.78	20.98	22.68	22.96	24.59
	2010	25.45	23.76	23.11	21.00	20.62	20.39	20.62	20.34	22.03	22.96	24.60	25.16
	2011	24.11	24.66	23.77	21.91	20.86	20.98	20.67	21.14	22.17	23.36	24.48	24.78
	2012	25.14	25.84	23.51	22.43	20.66	20.95	21.18	21.07	22.23	23.55	23.87	25.12
	2013	24.74	23.69	23.71	22.72	20.69	21.60	21.24	21.33	22.44	23.18	24.58	24.76
	2014	25.53	23.93	23.27	22.26	21.16	21.63	21.80	21.25	22.55	23.72	24.69	25.49
	2015	25.10	24.31	23.55	23.24	21.39	21.44	22.18	22.30	22.95	23.83	24.87	24.79

Source: Own study

By supporting the graph of so prepared data (Figure 1) the annual seasonality (s = 12) can be observed, the smallest energy demand in summer and the largest in winter. Greater demand for energy in winter can be explained by the shorter day, which results in longer duration of any kind of lighting and lower temperatures which, in turn, affects the need to use heating devices.

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[1] Polskie Sieci Elektroenergetyczne, http://www.pse.pl/index.php?dzid=77 (04.01.2016r.)

Figure 1. **Monthly energy demand in the National Energy System in Poland**

**Power requirements in Poland
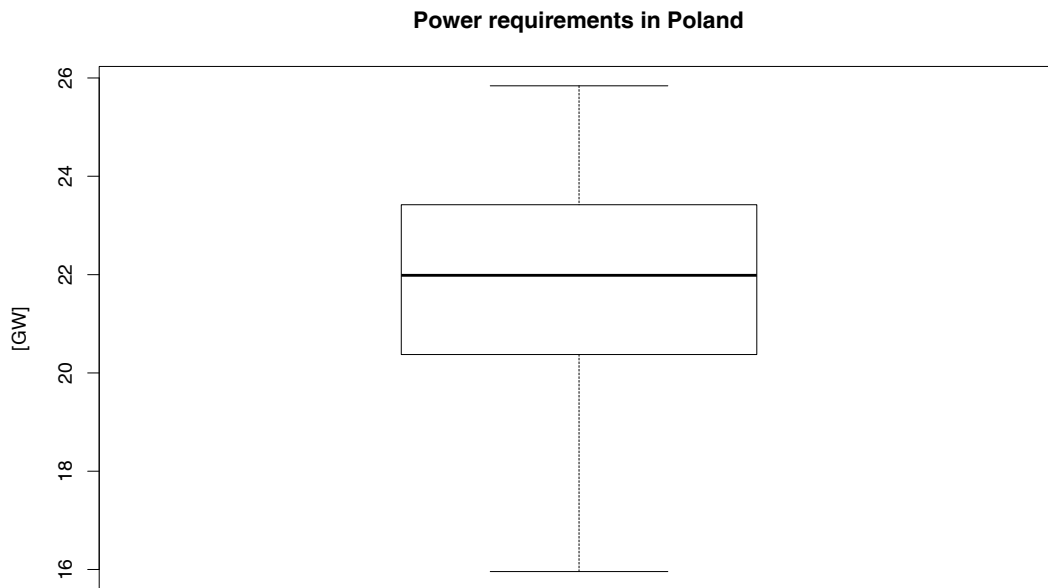January 2002 - December 2015**

Source: Own study

Descriptive statistics of the presented data have been included in Table 2. On their basis one can see significant, reaching 10 GW, differences between the minimum and the maximum energy demand. Considering that the data include fairly short, because only 14-year period, the differences are significant and they indicate a rapid increase in energy demand.

Table 2. Descriptive statistics of the monthly energy demand in the National Energy System in Poland [GW]

N	Min.	1stQu.	Median	Mean	3rdQu.	Max.
168	15.96	20.38	21.98	21.76	23.39	25.84

Source: Own study

Figure 2. Boxplot of power requirements in Poland
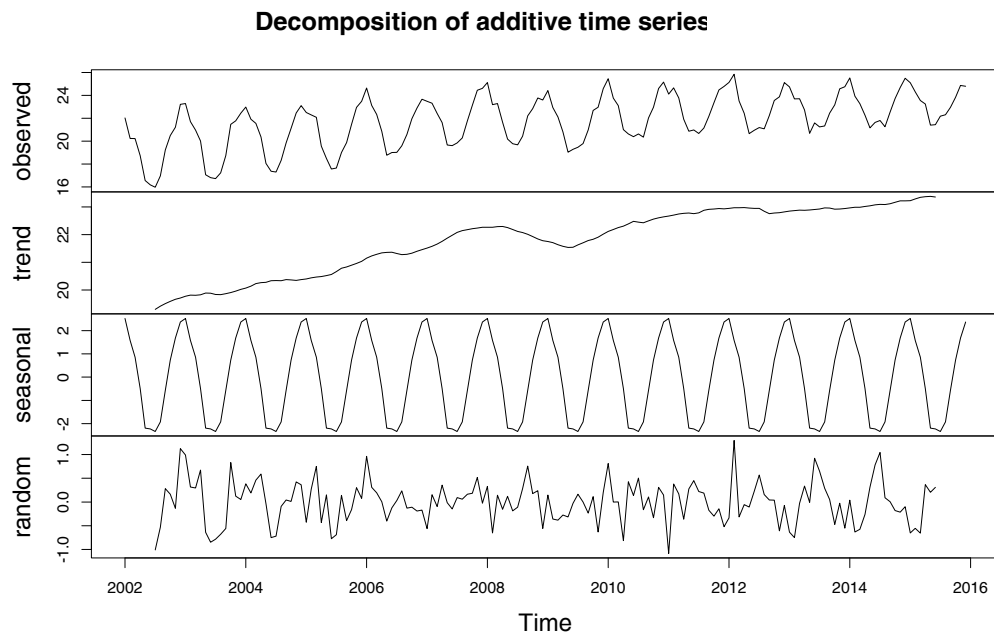
Power requirements in Poland

Source: Own study

3.1 Models and forecasts

A series shown in Figure 1, is of additive nature, which is also confirmed by the graph after the classical decomposition in Figure 3. In this graph seasonal fluctuations with an amplitude of about 2.3 GW are visible, small values of the random component and a clear upward trend with the value of 19.3 GW at the beginning of the year 2002, and 23.4 GW at the end of 2015. The decomposition graph will allow in the next points to adjust better the models of exponential smoothing and ARIMA.

Figure 3. Decomposition of time series of power demand of NES.

Decomposition of additive time series

Source: Own study.

The most commonly used in the literature means to assess the quality of the forecasts are MAE (Mean Absolute Error), RMSE (Root Mean Squared Error), MAPE (Mean Absolute Percentage Error) (Brother, 2012). In this study other measures will be used: ME (Mean Error), MPE (Mean Percentage Error) and MASE (Scaled Mean Absolute Error) (Gardner, 1985).

3.2 Forecast using Winters exponential smoothing model

The first model that will be used to forecast the maximum demand for electricity in Poland is a model of exponential smoothing (Hyndman, et al., 2008). The most appropriate model for the series tested will be additive model of Winters ETS (AAA) (Errors = Additive, Trend = Additive, seasonality = Additive) (Winters, 1960) in the form:

$$F_{t-1} = \propto (y_{t-1} - C_{t-1-r}) + (1-\propto)(F_{t-2} - S_{t-2}) \qquad (1)$$
$$S_{t-1} = \beta(F_{t-1} - F_{t-2}) + (1-\beta)S_{t-2} \qquad (2)$$
$$C_{t-1} = \gamma(y_{t-1} - F_{t-1}) + (1-\gamma)C_{t-1-r} \qquad (3)$$

where:

F_{t-1} – the equivalent of the smoothed value obtained from a simple model of exponential smoothing (the average rating)

S_{t-1} –assessment of the trend growth for the moment or period t-1

C_{t-1} –assessment of an indicator of seasonality for the date or the period t-1

r –length of the seasonal cycle - number of phases

α, γ, δ –model parameters accepting the values from the range [0 to1]

α – parameter characterizing the degree of smoothing is required for all models,

δ – parameter of seasonal smoothing and determined only in the case of seasonal choice of models,

γ – smoothing parameter of linear and exponential trend.

The equation of the forecast for a moment or period t> n (n - is the number of terms of the series of variable forecast) for the additive alternative of the model:

$$y_t^* = F_n + S_n(t-n) + C_{t-r} \qquad (4)$$

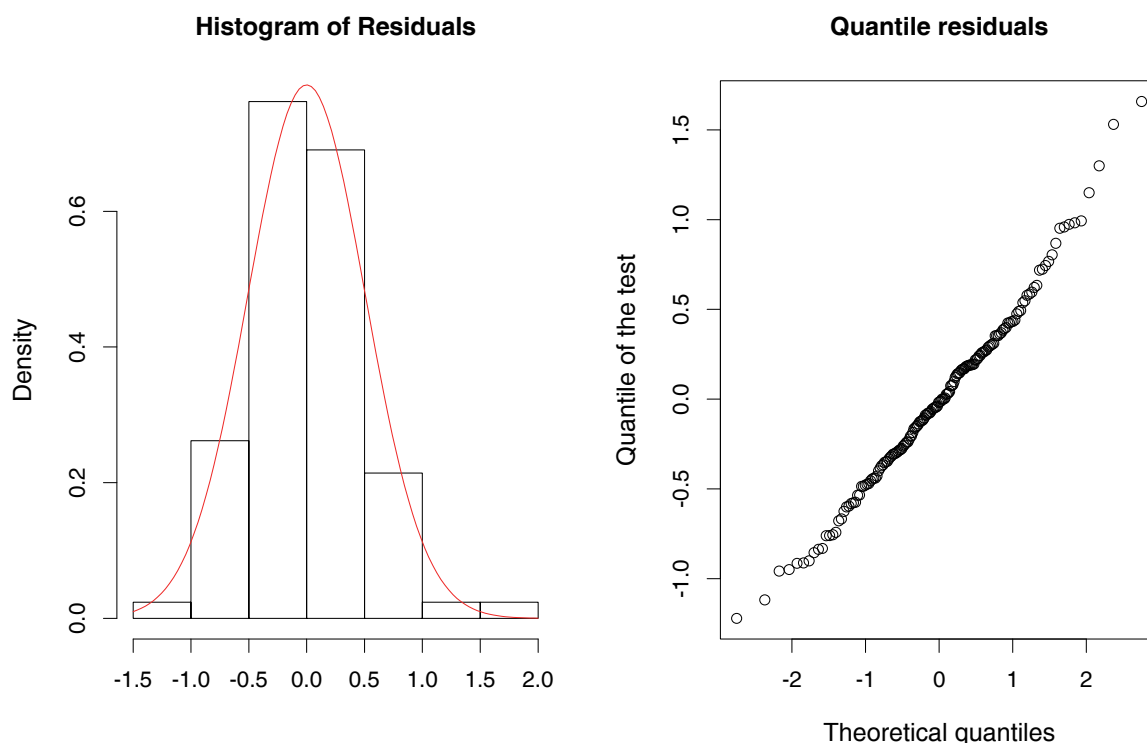The exponential smoothing of such a selected model can be:

alpha = 0.5627
beta = 0.0001
gamma = 0.0001

The correctness of the model adjustment to the data has been verified by analyzing the histogram and the graph of quantile residuals (Figure 4), and carrying out further test of normality Shapiro,

Figure 4. The distribution of residuals in Winters ETS(AAA) model

Source: Own study

The p-value of the Shapiro test residuals is 0.2195, so it can be assumed that the distribution of residuals is normal, which allows to determine the point and interval forecast for the confidence levels 0.80 and 0.95.
The point and interval forecast for the confidence levels 0.80 and 0.95 for a period of 24 months has been presented in Table 3 and Figure 5.
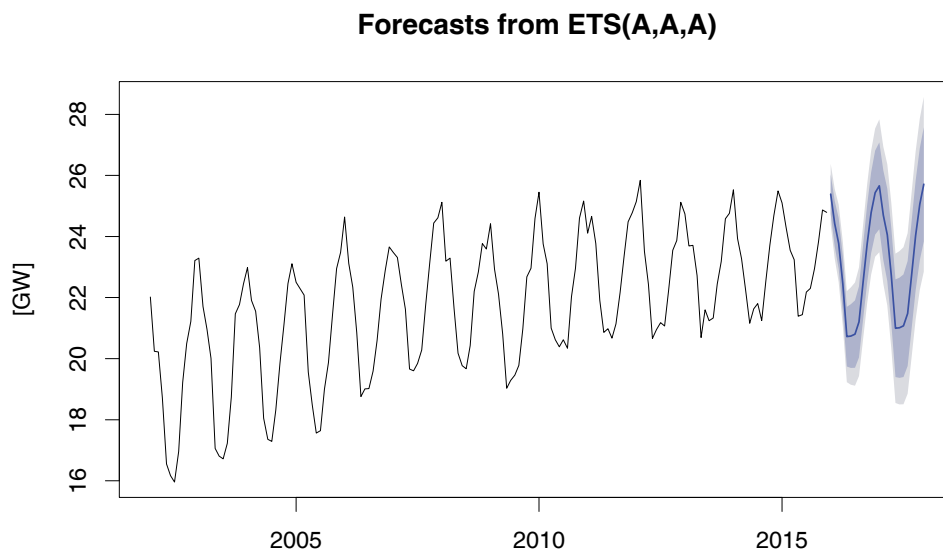
Table 3. The forecast for energy demand in the National Energy System in Poland for the years 2016-2017 using the exponential smoothing model.

Date	Forecast [GW]	Lo 80 [GW]	Hi 80 [GW]	Lo 95 [GW]	Hi 95 [GW]
Jan 2016	25.39	24.74	26.04	24.40	26.38
Feb 2016	24.42	23.68	25.17	23.28	25.56
Mar 2016	23.77	22.95	24.60	22.51	25.04
Apr 2016	22.44	21.54	23.35	21.06	23.83
May 2016	20.72	19.75	21.70	19.23	22.21
Jun 2016	20.74	19.70	21.78	19.14	22.33
Jul 2016	20.80	19.70	21.91	19.11	22.49
Aug 2016	21.21	20.04	22.37	19.43	22.99
Sep 2016	22.47	21.26	23.69	20.61	24.34
Oct 2016	23.76	22.49	25.03	21.81	25.71
Nov 2016	24.78	23.46	26.11	22.76	26.81

Dec 2016	25.44	24.06	26.81	23.34	27.54
Jan 2017	25.66	24.24	27.08	23.49	27.84
Feb 2017	24.70	23.23	26.16	22.45	26.94
Mar 2017	24.05	22.54	25.56	21.74	26.36
Apr 2017	22.72	21.16	24.27	20.34	25.10
May 2017	21.00	19.40	22.59	18.55	23.44
Jun 2017	21.01	19.37	22.65	18.50	23.52
Jul 2017	21.08	19.40	22.76	18.51	23.65
Aug 2017	21.48	19.76	23.20	18.85	24.11
Sep 2017	22.75	20.99	24.51	20.06	25.44
Oct 2017	24.03	22.24	25.83	21.29	26.78
Nov 2017	25.06	23.22	26.89	22.25	27.86
Dec 2017	25.71	23.84	27.58	22.85	28.57

Source: Own study

Figure 5. The forecast for energy demand in the National Energy System in Poland for the years 2016-2017 using the Winters exponential smoothing model
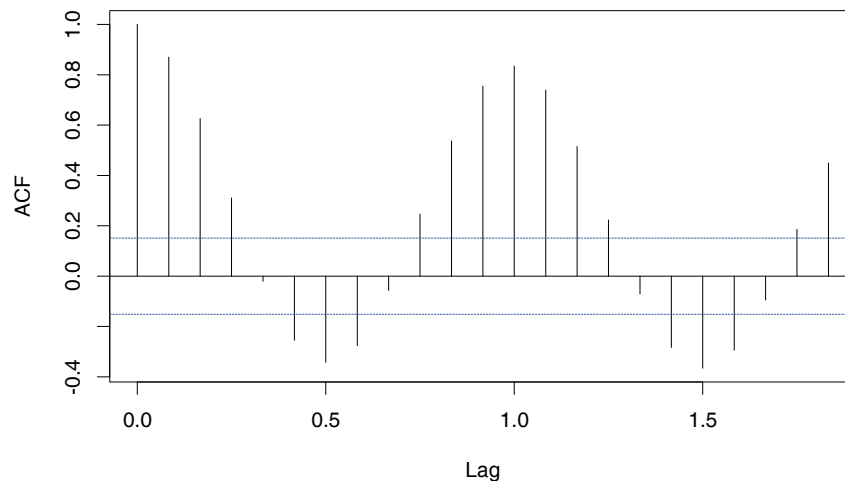
Forecasts from ETS(A,A,A)

Source: Own study

The results of the obtained forecasts have the tendency and fluctuations of the observed series. The errors of such forecasts are:

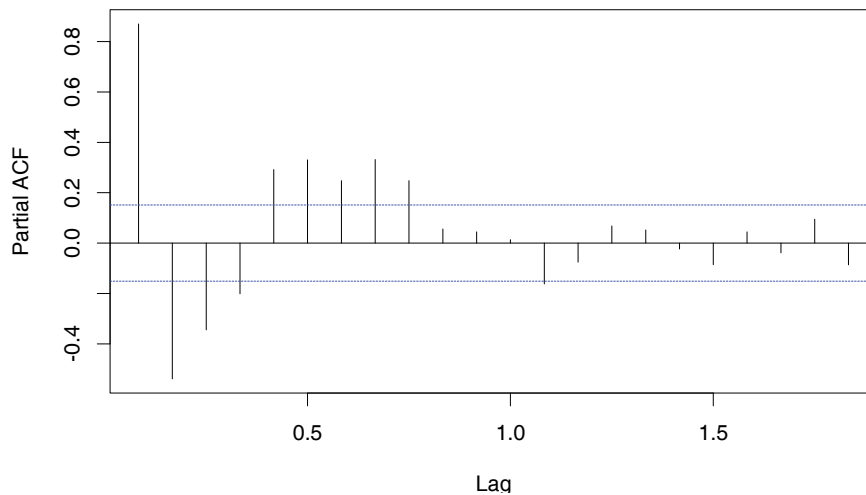|	
ME	-0.0006212085
RMSE	0.5057831000
MAE	0.3947103000
MPE	-0.0480970300
MAPE	1.8322730000
MASE	0.6493178000

3.3 Forecast using ARIMA model

The second model, which has been used to forecast is the ARIMA model (Asteriou & Hall, 2011) in the seasonal version SARIMA. Models of this type can be applied to stationary series, that is, those in which there are only random fluctuations around the average, or non-stationary brought to stationary ones. As autocorrelation graphs (Figure 6) and partial autocorrelation (Figure 7) show, a series is not stationary and requires additional treatments to meet the requirements of the ARIMA model.

Figure 6. Autocorrelation
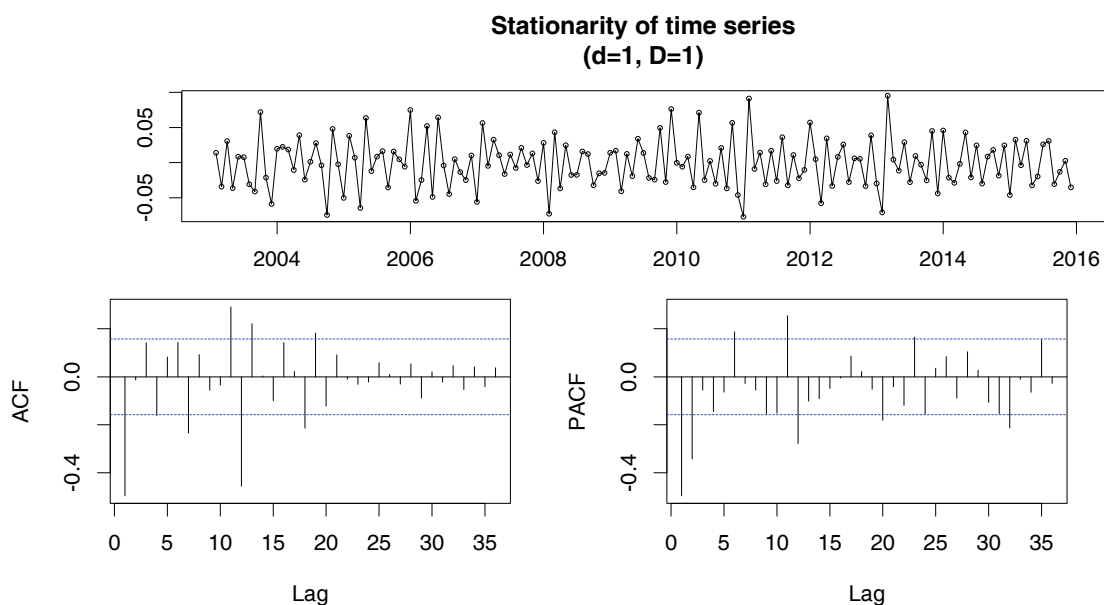

Source: Own study

Figure 7. Partial autocorrelation

Source: Own study

After adjusting the series to stationarity (Figure 8) by a single seasonal differentiation (D = 1) and a single differentiation due to the trend of (d = 1) and taking into account one parameter of the moving average of the trend (q = 1), and seasonality (Q = 1), the best-fitting model is the seasonal ARIMA model (0,1,1), (0,1,1) [12].
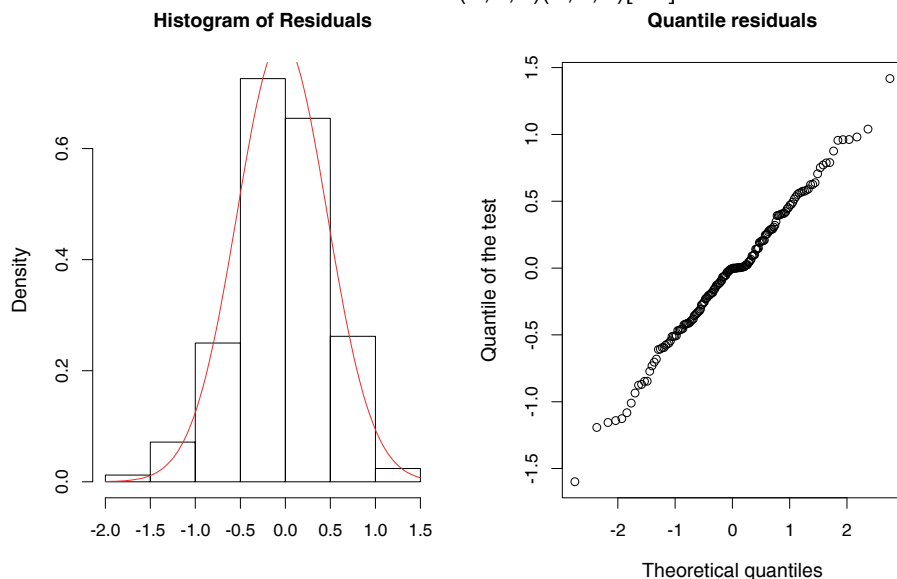
Figure 8. Time series of energy demand reduced to stationarity

Source: Own study

As in the Winters exponential smoothing model, checking the adjustment of ARIMA model to the data has been made by analyzing the histogram and the graph of quantile residuals (Figure 9) and using the test of normality Shapiro.

Figure 9. The distribution of residuals in SARIMA(1,1,0)(1,1,0)[12] model
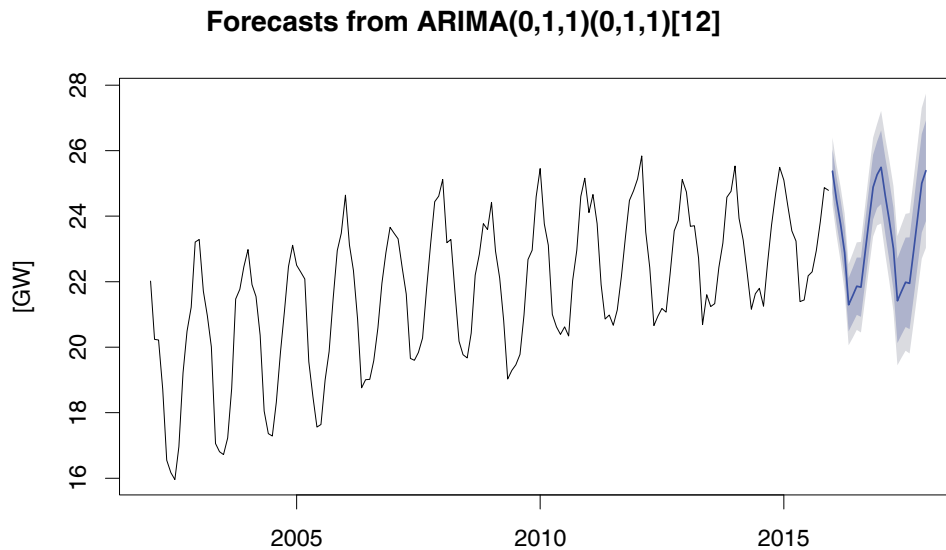

Source: Own study

The residuals test of Shapiro has shown that the residuals are normally distributed (p-value = 0.6869), so it is possible to make forecasts with the use of the selected model. The resulting forecasts for the years 2016-2017 have been presented in Table 4 and Figure 10.

Table 4. The forecast for energy demand in the National Energy System in Poland for the years 2016-2017 using the ARIMA model

Date	Forecast [GW]	Lo 80 [GW]	Hi 80 [GW]	Lo 95 [GW]	Hi 95 [GW]
Jan 2016	25.37	24.70	26.04	24.35	26.39
Feb 2016	24.50	23.80	25.21	23.42	25.58
Mar 2016	23.75	23.00	24.49	22.61	24.88
Apr 2016	22.89	22.11	23.67	21.70	24.08
May 2016	21.30	20.49	22.11	20.06	22.54
Jun 2016	21.58	20.74	22.42	20.29	22.87
Jul 2016	21.86	20.99	22.74	20.53	23.20
Aug 2016	21.83	20.93	22.73	20.45	23.21
Sep 2016	22.85	21.92	23.78	21.42	24.27
Oct 2016	23.86	22.90	24.82	22.40	25.33
Nov 2016	24.88	23.90	25.87	23.37	26.39
Dec 2016	25.27	24.25	26.28	23.72	26.82
Jan 2017	25.49	24.37	26.61	23.78	27.21
Feb 2017	24.62	23.46	25.79	22.84	26.41
Mar 2017	23.87	22.66	25.08	22.02	25.72
Apr 2017	23.01	21.76	24.26	21.10	24.92
May 2017	21.42	20.13	22.71	19.45	23.39
Jun 2017	21.70	20.37	23.03	19.67	23.73
Jul 2017	21.98	20.62	23.35	19.89	24.07
Aug 2017	21.95	20.55	23.35	19.81	24.09
Sep 2017	22.97	21.53	24.41	20.77	25.17
Oct 2017	23.98	22.51	25.46	21.74	26.23
Nov 2017	25.01	23.50	26.51	22.70	27.31
Dec 2017	25.39	23.85	26.92	23.03	27.74

Source: Own study

Figure 10. The forecast for energy demand in the National Energy System in Poland for the years 2016-2017using the SARIMA model

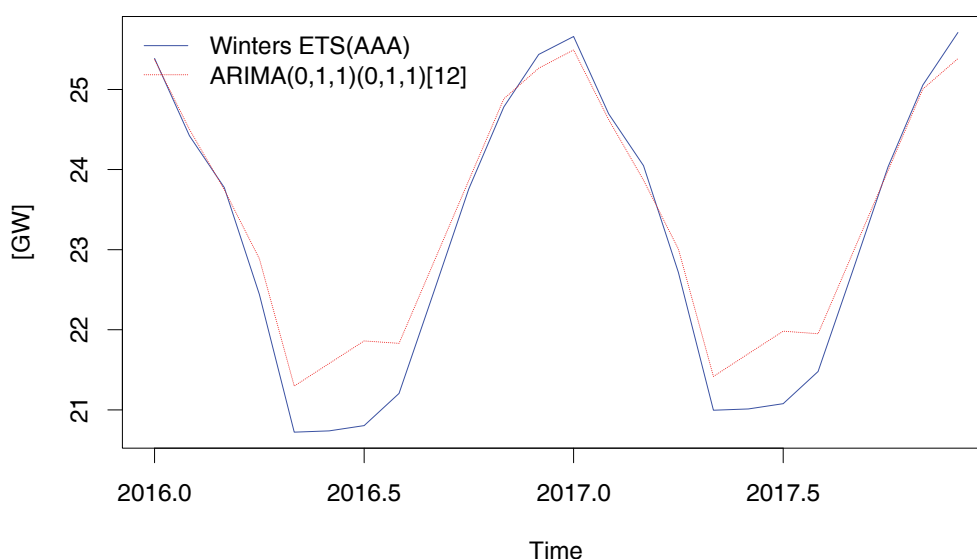**Forecasts from ARIMA(0,1,1)(0,1,1)[12]**

Source: Own study

In Figure 10 one can see the trend and volatility of forecasts in line with the course of the observed series. The errors of such forecasts are:

ME	-0.03575571
RMSE	0.50070100
MAE	0.38277560
MPE	-0.15095150
MAPE	1.73664300
MASE	0.62968460

3.4 Comparison of forecasts

The forecasts made by using both the Winters exponential smoothing model and SARIMA model have given similar results (Figure 11). The average difference between the forecast was only 0.26 GW and 1.06 GW maximum for July 2017 year. Also the errors of forecasts for both models are similar - except for a Mean Error, which is higher for SARIMA model, but it is still low enough that it does not raise concerns about the quality of forecasts.

Figure 11. Comparison of forecasts

Source: Own study

Comparing the results of both forecasts and comparing the forecast a month-to-month to the year 2015 (Table 5 and Table 6), it is possible to make a qualitative assessment of forecasts conformity. As onecan see, the trend in energy demand coincides in both models for the winter months (January, February, March) and summer months (July and August), and for April. For the remaining months (mostly in spring and autumn), the trends vary depending on the year of the forecast, and for June are definitely different - in the model Winters ETS a decline in demand for energy is expected, and in the model SARIMA its growth. Problematic forecasts for the months of spring and autumn may result from the large differences between the energy demand in such periods in the past. This can be caused by substantial weather changes in spring and autumn, and is is one of the main factors affecting the demand for energy.

Table 5. Witers ETS: Comparison of forecasts month to month

Winters ETS		Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year	2015	25.10	24.31	23.55	23.24	21.39	21.44	22.18	22.30	22.95	23.83	24.87	24.79
	2016	25.39	24.42	23.77	22.44	20.72	20.74	20.80	21.21	22.47	23.76	24.78	25.44
	2017	25.66	24.70	24.05	22.72	21.00	21.01	21.08	21.48	22.75	24.03	25.06	25.71
	'16/'15	↑	↑	↑	↓	↓	↓	↓	↓	↓	↓	↓	↑
	'17/'15	↑	↑	↑	↓	↓	↓	↓	↓	↓	↑	↑	↑

Source: Own study

Table 6. SARIMA: Comparison of forecasts month to month.

SARIMA		Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year	2015	25.10	24.31	23.55	23.24	21.39	21.44	22.18	22.30	22.95	23.83	24.87	24.79
	2016	25.37	24.50	23.75	22.89	21.30	21.58	21.86	21.83	22.85	23.86	24.88	25.27
	2017	25.49	24.62	23.87	23.01	21.42	21.70	21.98	21.95	22.97	23.98	25.01	25.39
	'16/'15	↑	↑	↑	↓	↓	↑	↓	↓	↓	↑	↑	↑
	'17/'15	↑	↑	↑	↓	↑	↑	↓	↓	↑	↑	↑	↑

Source: Own study

CONCLUSION

To construct the forecasts of maximum demand for energy in Poland two models have been used: Winters exponential smoothing, and seasonal ARIMA. The forecasts show tendencies and fluctuations and the observed series, and errors are at low, similar to each level, which confirms the correctness of the models selection. Forecast charts have a similar shape, and the average difference between them is small and it is only 0.26 GW. However, one can see the differences by comparing the months of forecasts of both models with data from the last year. In forecasts made using the Winters model of exponential smoothing more often than in the SARIMA model, the predicted values for the years 2016 and 2017 are lower than in 2015. For both models a drop in energy demand is forecast for the summer months, while an increase for the winter months. In spring and autumn months there are differences between the forecasts in terms of the direction of change in relation to the demand for energy from the last year, however, as previously mentioned, the same course of the two forecasts is similar.

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