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Electricity Generation from Renewable Sources: A Comparative Study of Türkiye and Japan

Zeydin Pala*

Department of Software Engineering, Engineering Faculty, Muş Alparslan University, Muş, Türkiye
**z.pala@alparslan.edu.tr*

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Abstract – The study examines the trends in electricity generation from renewable sources in Türkiye and Japan from 1965 to 2023. It aims to forecast future renewable energy production using statistical models, comparing both countries' progress in renewable energy adoption. The data used for this analysis were sourced from Our World in Data and converted into time series for modeling. Several forecasting models, including AUTO.ARIMA, SES, ETS, TBATS, THETAF and Holt-Winters, were utilized to predict future trends, with the most accurate predictions evaluated based on Mean Absolute Percentage Error (MAPE) values. Türkiye and Japan's renewable energy trends reflect significant growth, particularly post-2010, with Japan showing a higher overall production.

Keywords – Renewable Energy, Electrical Energy Production, Statistically Based Models, Time Series, Energy Forecasting.

I. INTRODUCTION

For all countries in the world, generating electricity from renewable sources such as solar, wind and hydroelectricity, reducing greenhouse gas emissions, mitigating climate change and protecting the environment is of great importance. Unlike fossil fuels, renewable energy sources are abundant, sustainable and do not run out over time. This makes them a long-term solution for energy needs. They also reduce dependence on limited and polluting resources such as coal and oil, promote energy security and encourage economic growth while also protecting the environment. Advances in renewable energy technologies allow for the establishment of more cost-effective systems. This advantage means cleaner, healthier and more affordable power for communities around the world.

Between 1965 and 2023, electricity produced from renewable energy sources in Türkiye has increased significantly, especially in recent years. While hydroelectric power plants were at the forefront in the early years, major investments have been made in other renewable sources such as wind, solar and geothermal since the 2000s. Since the 2020s, the share of these sources in energy production has increased rapidly and Türkiye has significantly expanded its renewable energy capacity. As of 2023, approximately 40% of Türkiye's electricity production will come from renewable energy sources [1].

Between 1965 and 2023, Japan achieved significant growth in electricity generation from renewable sources, driven by changes in energy policy and environmental concerns. Initially, renewables had a small share. Hydropower was the dominant energy source. However, after the 2011 Fukushima nuclear disaster, Japan accelerated its move toward renewables, especially solar and wind energy. By 2023, solar energy had become a major contributor, along with the expansion of wind and biomass energy. Despite challenges such as geographic limitations and costs, Japan’s commitment to reducing carbon emissions has steadily increased the share of renewables in its energy mix [2].

This study provides future projections of electricity production from renewable sources in Türkiye and Japan for the period 1965-2023. Statistical models were employed for comparative forecasts, and the results were assessed using various metrics. The aim was to contribute to the literature through both the data and the models utilized.

II. MATERIALS AND METHOD

In this study, time series, which have a very wide application area [3], [4], [13]–[22], [5], [23], [6]–[12][24][25][26] , were used. The data used in this study were obtained from the Our world in Data (https://ourworldindata.org/energy) system and converted into time series format. Statistical information on electricity production processes and electricity production from renewable resources for Türkiye and Japan is collectively provided in Table 1.

Table 1. Statistical information about the time series of electrical energy produced from renewable sources between 1965 and 2023 of the Türkiye and Japan

Electricity generation from renewable sources (1965-2023)	Length (Year)	Min. (TWh)	1st Qu. (TWh)	Median (TWh)	Mean (TWh)	3rd Qu. (TWh)	Max (TWh)
1- Türkiye (TR)	59	2.27	10.88	30.72	37.71	45.41	134.35
2- Japan (JPN)	59	67.03	84.19	98.32	108.96	112.28	241.52

The time series given in Figure 1 shows the electricity production (terawatt-hours-TWh) from renewable sources for Türkiye and Japan between 1965-2023. Renewable sources include hydroelectric, solar, wind, geothermal, bioenergy, wave and tidal.

The graph compares the electricity production from renewable sources (in TWh) between Türkiye and Japan from 1965 to 2023.

Türkiye:

- Türkiye's renewable energy production shows a clear and sharp upward trend, particularly after 2000.
- From 1965 to the early 2000s, the growth was slow, staying below 40 TWh. However, after 2005, production increased significantly, surpassing 120 TWh by 2023.
- The most rapid growth occurs between 2010 and 2023, where there are frequent fluctuations, but the overall trajectory remains sharply upward.
- This indicates Türkiye's heavy investment in renewable energy sources, especially in recent decades, possibly driven by solar, wind, and hydroelectric power.

Japan:

- Japan's renewable energy production appears more stable and less volatile until 2010, staying mostly between 50-100 TWh.
- After 2010, there's a sharp rise, with production exceeding 200 TWh by 2023, indicating a dramatic increase in renewable energy capacity.
- The rapid increase after 2010 could be related to Japan's response to energy policy shifts following the 2011 Fukushima nuclear disaster, which likely pushed the country to invest more in renewable energy.

Both countries show a significant increase in renewable energy production after 2010, but Japan's production is notably higher. While Türkiye's trajectory shows more consistent, gradual growth, Japan's sharp increase post-2010 suggests a more policy-driven or urgent response to energy challenges.

Both countries are investing heavily in renewables, but Japan has achieved higher overall production levels, while Türkiye is experiencing rapid growth.

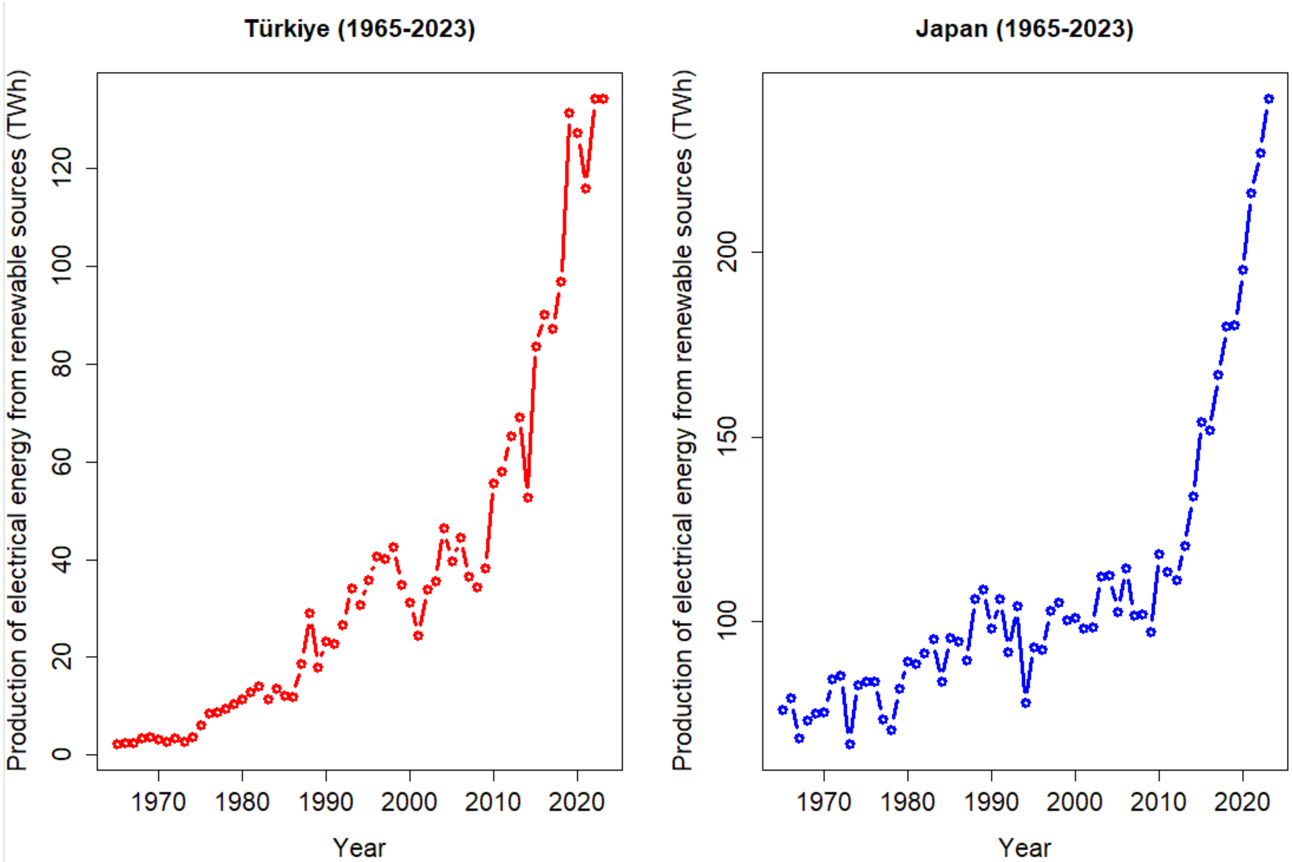

Fig. 1 Electricity production from renewable sources in Türkiye and Japan between 1965-2023

III. RESULTS

In the forecast analyses, autoregressive integrated moving (Auto.arima), simple exponential smoothing (SES), Error-Trend-Seasonal (ETS) and Trigonometric seasonality, Box-Cox transformation, ARMA errors, Trend and Seasonal components (TBATS), THETAF [9], HOLT-WINTERS [27] models were used. In making future forecasts, four different lengths of training and test data were used for each model. While the training data lengths were initially taken as 50, 48, 46, 43, the rest lengths were taken as 9, 11, 13, and 16, respectively. The mean absolute percentage error (MAPE) values of the analyses are given in Table 2. The best results for each model are shown in bold in the table. When the training and test lengths are taken as 48 (81%) and 11 (19%) respectively, the estimation graphs of the electrical energy obtained from Türkiye's renewable resources are given in Figure 2.

Table 2. MAPE values of the analyses performed on the Türkiye data set depending on four different training and test lengths

Model	**Test length :9**	**Test length:11**	**Test length:13**	**Test length:16**
	MAPE (%)	**MAPE (%)**	**MAPE (%)**	**MAPE (%)**
Auto.arima	51.01	**28.44**	30.01	40.83
SES	49.66	**35.15**	39.18	48.33
ETS	48.60	**32.25**	33.70	44.89
TBATS	31.39	**15.16**	16.53	19.85
THETAF	47.09	30.92	**30.85**	32.38
HOLT-WINTERS	44.59	**28.02**	30.62	29.58

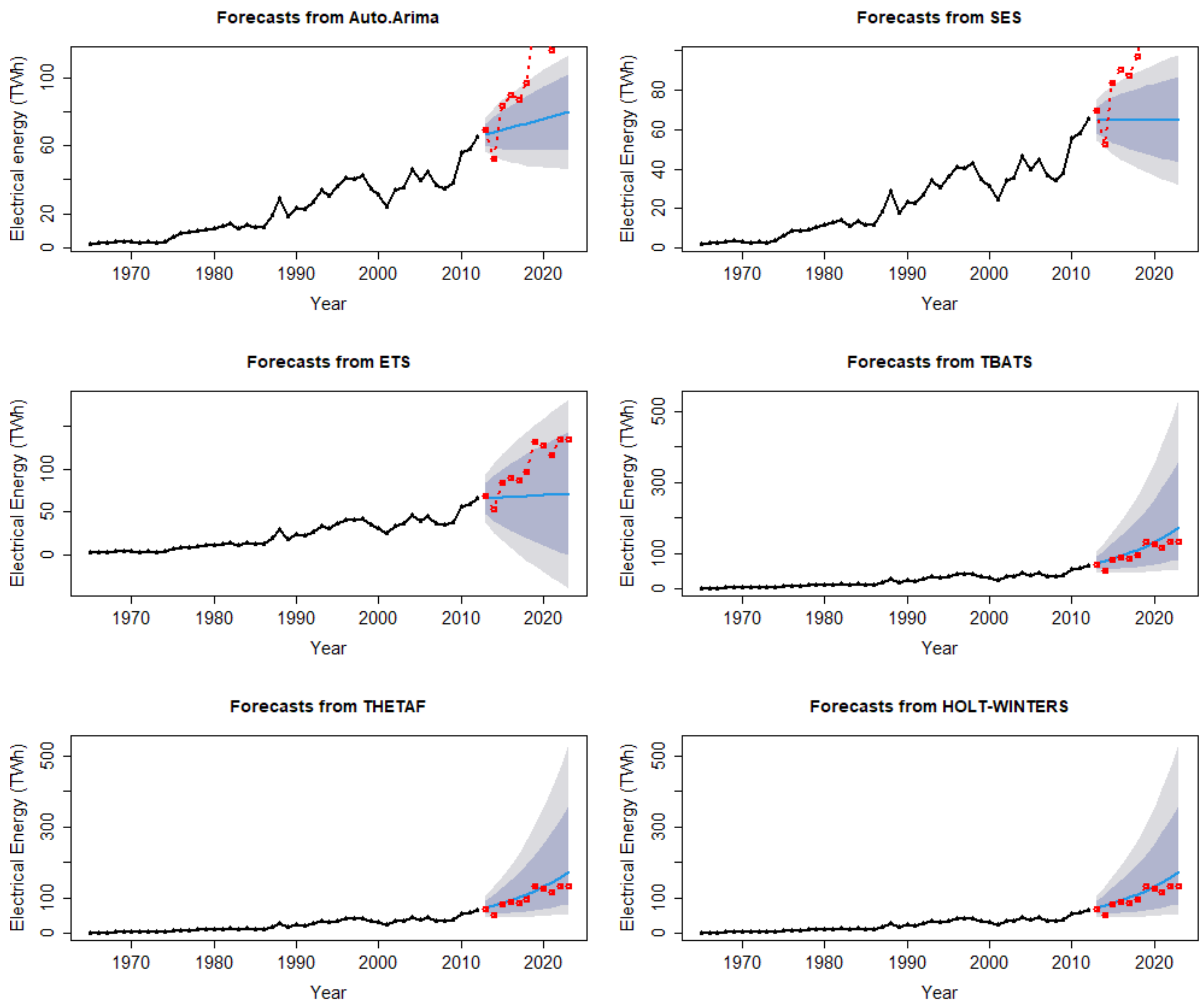

Fig. 2 Model prediction graphs obtained when the dataset of Türkiye's electricity production is divided into 81% and 19% for training and testing, respectively.

Model estimates for the data set used for Japan's electricity generation from renewable sources are given in Table 3 and model estimate graphs are given in Figure 3.

Table 3. MAPE values of the analyses performed on the Japan data set depending on four different training and test lengths

Model	**Test Length:9**	**Test Length:11**	**Test Length:13**	**Test Length:16**	**Test Length:19**
	MAPE (%)	**MAPE (%)**	**MAPE (%)**	**MAPE (%)**	**MAPE (%)**
Auto.arima	33.41	35.47	31.96	28.25	**24.09**
SES	33.61	35.54	32.05	28.26	**24.17**
ETS	36.22	32.31	27.60	23.77	**20.80**
TBATS	33.45	35.49	32.00	28.25	**24.11**
THETAF	32.21	32.00	23.93	14.66	**7.07**
HOLT-WINTERS	34.62	30.52	21.62	12.97	**6.65**

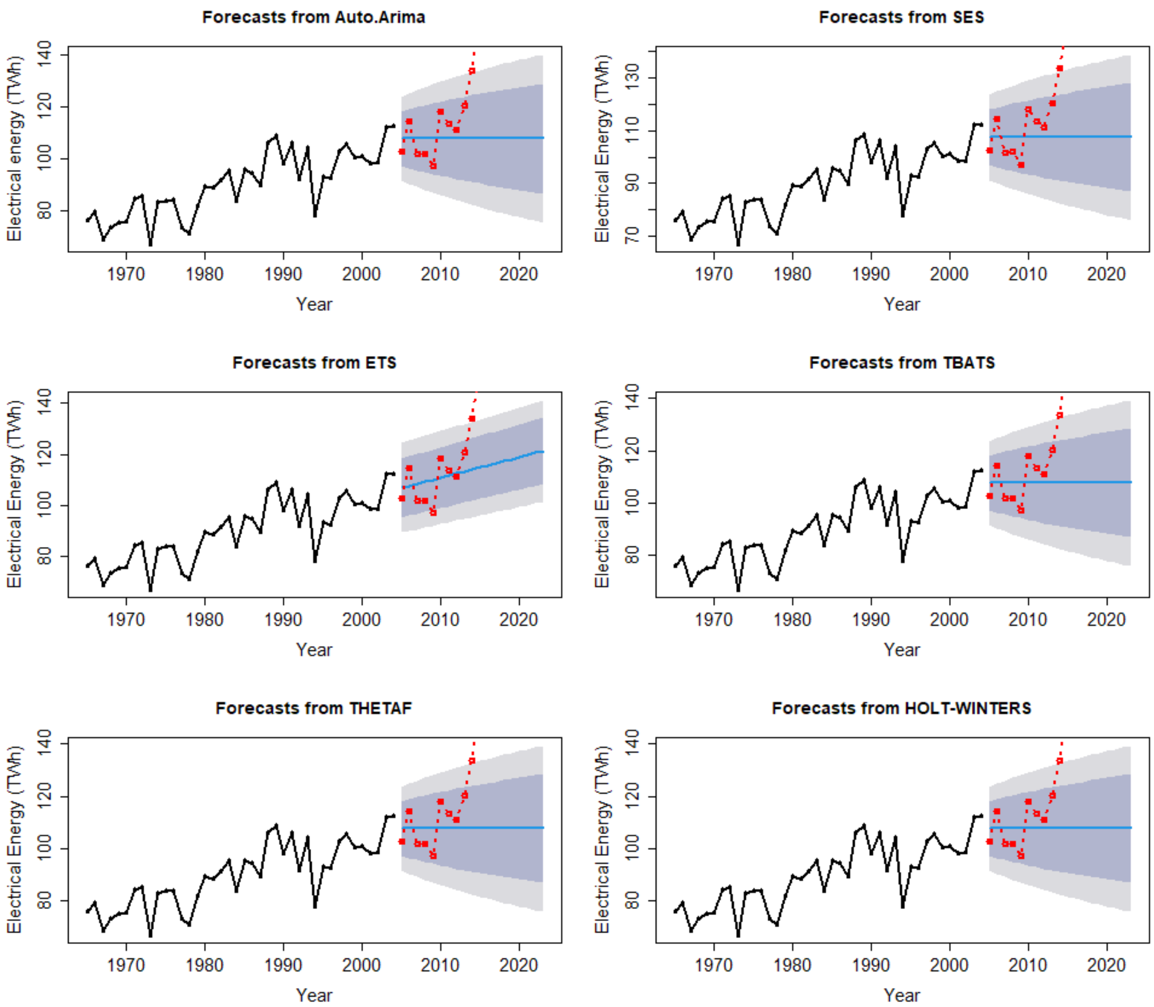

Fig. 3 Model prediction graphs obtained when the dataset of Japan's electricity production is divided into 68% and 32% for training and testing, respectively.

IV. DISCUSSION

In the analysis conducted for the Türkiye dataset, the training and test split ratio number was taken as four, while it was taken as five for Japan. In the estimation analyses made for both datasets, the TBATS model made the best estimation with a MAPE value of 15.6% on the Türkiye dataset, while the HOLT-WINTERS model made the best estimation with a MAPE value of 6.65% on the Japan dataset.

The red lines in the graphs indicate the mean of the test data, while the blue lines show the mean of the predictions for the test data. The dark gray shaded areas represent the 80% probability prediction interval, and the light gray shaded areas represent the 95% probability prediction interval.

V. CONCLUSION

The study highlights a sharp increase in renewable energy generation in both Türkiye and Japan, especially after 2010. While Türkiye's growth has been rapid in recent years, Japan's renewable energy production remains substantially higher. The most accurate forecasting models suggest that renewable energy will continue to play a critical role in both countries' future energy landscapes. This research contributes valuable insights into the comparative performance of different predictive models and offers useful projections for future renewable energy output in these nations.

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REFERENCES

[1] E. Ekonom, İ. K. V. E. Sosyal, and A. R. A. Ş. Tirmalar, "The Impact of Renewable Energy Productıo on Econmic Growth : The Case Of Türkiye," *ESAM J. Econ. Soc. Res.*, vol. 5, no. 1, pp. 90–110, 2024.

[2] A. Kuriyama, X. Liu, K. Naito, A. Tsukui, and Y. Tanaka, "Importance of long-term flexibility in a 100% renewable energy scenario for Japan," *Sustain. Sci.*, vol. 19, no. 1, pp. 165–187, 2024.

[3] R. Niu, C. Guo, Y. Zhang, L. He, and Y. Mao, "Study of ionospheric TEC short-term forecast model based on combination method," *Int. Conf. Signal Process. Proceedings, ICSP*, vol. 2015-Janua, no. October, pp. 2426–2430, 2014.

[4] I. Bozkurt, Z. Pala, and T. Etem, "Measurement and evaluation of low frequency electromagnetic field in camera observation rooms," in *2017 13th International Conference Perspective Technologies and Methods in MEMS Design, MEMSTECH 2017 - Proceedings*, 2017.

[5] T. Etem, Z. Pala, and I. Bozkurt, "Electromagnetic pollution measurement in the system rooms of a university," in *2017 13th International Conference Perspective Technologies and Methods in MEMS Design, MEMSTECH 2017 - Proceedings*, 2017.

[6] Z. Pala, "Using Decomposition-based Approaches to Time Series Forecasting in R Environment," *Int. Conf. Data Sci. Mach. Learn. Stat. - 2019*, vol. 1, no. 1, pp. 231–233, 2019.

[7] Z. Pala and R. Atici, "Forecasting Sunspot Time Series Using Deep Learning Methods," *Sol. Phys.*, vol. 294, no. 5, 2019.

[8] Z. Pala, "Comparative study on monthly natural gas vehicle fuel consumption and industrial consumption using multi-hybrid forecast models," *Energy*, vol. 263, no. PC, pp. 1–21, 2023.

[9] Z. Pala and İ. H. Ünlük, "Comparison of hybrid and non-hybrid models in short-term predictions on time series in the R development environment," *DÜMF Mühendislik Derg.*, vol. 2, pp. 199–204, 2022.

[10] Z. Pala, İ. H. Ünlük, and E. Yaldız, "Forecasting of electromagnetic radiation time series: An empirical comparative approach," *Appl. Comput. Electromagn. Soc. J.*, vol. 34, no. 8, pp. 1238–1241, 2019.

[11] Z. Pala, "Using forecastHybrid Package to Ensemble Forecast Functions in the R," *Int. Conf. Data Sci. Mach. Learn. Stat. - 2019*, vol. 1, no. 1, pp. 45–47, 2019.

[12] Z. Pala, V. Yamli, and I. H. Ünlük, "Deep Learning researches in Turkey: An academic approach," in *2017 13th International Conference Perspective Technologies and Methods in MEMS Design, MEMSTECH 2017 - Proceedings*, 2017.

[13] Z. Pala, I. Bozkurt, and T. Etem, "Estimation of low frequency electromagnetic values using machine learning," in *2017 13th International Conference Perspective Technologies and Methods in MEMS Design, MEMSTECH 2017 - Proceedings*, 2017.

[14] Z. Pala, "Examining EMF Time Series Using Prediction Algorithms With R," vol. 44, no. 2, pp. 223–227, 2021.

[15] E. Yaldız and Z. Pala, "Time Series Analysis of Radiological Data of Outpatients and Inpatients in Emergency Department of Mus State Hospital," *Int. Conf. Data Sci. Mach. Learn. Stat. - 2019*, pp. 234–236, 2019.

[16] Z. Pala, R. Atıcı, and E. Yaldız, "Forecasting Future Monthly Patient Volume using Deep Learning and Statistical Models," *Wirel. Pers. Commun.*, vol. 130, no. 2, pp. 1479–1502, 2023.

[17] H. Abbasimehr and R. Paki, "Prediction of COVID-19 confirmed cases combining deep learning methods and Bayesian optimization," *Chaos, Solitons and Fractals*, vol. 142, Jan. 2021.

[18] M. Akpinar and N. Yumusak, "Estimating household natural gas consumption with multiple regression: Effect of cycle," *2013 Int. Conf. Electron. Comput. Comput. ICECCO 2013*, pp. 188–191, 2013.

[19] E. Özgüner, O. B. Tör, and A. N. Güven, "Probabilistic day-ahead system marginal price forecasting with ANN for the Turkish electricity market," *Turkish J. Electr. Eng. Comput. Sci.*, vol. 25, no. 6, pp. 4923–4935, 2017.

[20] P. G. Zhang, "Time series forecasting using a hybrid ARIMA and neural network model," *Neurocomputing*, vol. 50, pp. 159–175, 2003.

[21] Z. Pala and M. Şana, "Attackdet: Combining web data parsing and real-time analysis with machine learning," *J. Adv. Technol. Eng. Res.*, vol. 6, no. 1, pp. 37–45, 2020.

[22] Z. Pala and O. Özkan, "Artificial Intelligence Helps Protect Smart Homes against Thieves," *DÜMF Mühendislik Derg.*, vol. 11, no. 3, pp. 945–952, 2020.

[23] I. Tugal and F. Sevgin, "Analysis and forecastıng of temperature using time series forecasting methods A Case Study of Mus," *Therm. Sci.*, vol. 27, no. 4, pp. 3081–3088, 2023.

[24] Z. Pala and F. Şevgin, "Statistical modeling for long-term meteorological forecasting: a case study in Van Lake Basin," *Nat. Hazards*, 2024.

[25] İ. Pala, Zeydin;Bozkurt, "A Historical Overview of Low-Carbon Energy Consumption in the USA, Russia, China, and Japan," in *3rd International Conference on Scientific and Academic Research*, 2023, pp. 988–992.

[26] Z. Pala, "Evolution of Low-Carbon Energy Consumption in Türkiye, United Kingdom, and France: A Historical

Perspective," pp. 546–549, 2023.

[27] S. Gelper, R. Fried, and C. Croux, "Robust forecasting with exponential and holt-winters smoothing," *J. Forecast.*, vol. 29, no. 3, pp. 285–300, 2010.