Black Sea Journal of Engineering and Science
doi: 10.34248/bsengineering.1451683

Open Access Journal
e-ISSN: 2619 – 8991

Research Article
Volume 7 - Issue 3: 594-600 / May 2024

MEETING THE ENERGY NEEDS OF POULTRY HOUSES WITH WIND TURBINE SYSTEM UNDER TEKİRDAĞ CONDITIONS AND ITS ENVIRONMENTAL EFFECTS

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Abstract: Türkiye has a favorable geographical location for renewable energy sources such as wind and solar. Accordingly, renewable energy sources can be used in the fast-growing bovine, ovine, and poultry farms that perform plant and animal production. Marmara Region is the leading production center of the Turkish poultry production industry. However, there are problems in maintaining environmental conditions in poultry houses. The fan-pad system plays an essential role in maintaining environmental conditions in the poultry houses. For this reason, the fan-pad system required for evaporative cooling in the poultry houses in Tekirdağ region was designed. The project was carried out in poultry houses with 6000 chickens and the dimension of the poultry house is 14 x 30 (420 m^2). In the poultry house, a 16.8 m^2 pad is needed for cooling, and a circulation pump with 0.2 kWh power is required for water circulation in the system. For mechanical ventilation, 11 units of aspirators with a diameter of 60 cm a power of 0.75 kWh, and a flow rate of 9500 m^3h^{-1} will be sufficient for the system. For the ventilation and cooling system, an 8.45 kWh wind turbine system will supply the required energy. However, due to the variability of wind power, a turbine system larger than 8.45 kWh, such as 10 kWh, should be used. The cost of the cooling system planned with the wind turbine energy system reaches 35953 $. The use of wind turbine systems to generate electricity in agriculture will significantly reduce CO_2 emissions to nature. In Tekirdağ conditions, 18250 kWh of electricity can be produced annually with a 10-kWh wind turbine system. With eco-friendly energy generation, it can play a major role in preventing climate change by avoiding the emission of 17155 kg of CO_2 which is equivalent to the annual electricity production.

Keywords: Wind turbine system, Poultry houses, Ventilation, Pad system, CO_2 emission

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Received: March 13, 2024
Accepted: May 10, 2024
Published: May 15, 2024

Cite as: Türkboyları E, Yüksel AN. 2024. Meeting the energy needs of poultry houses with wind turbine system under Tekirdağ conditions and its environmental effects. BSJ Eng Sci, 7(3): 594-600.

1. Introduction

The increase in the world population, developments aimed at increasing the comfort of human life, particularly in the last century, and the industrial activities carried out have led to a great increase in the consumption of fossil resources. The use of these resources leads to imbalances in the gas composition present in the atmospheric layer and, in particular, to an increase in the CO_2 gas that retains heat. As a result, the greenhouse gas emission into the atmosphere is increased and this creates a greenhouse effect triggering global warming on our planet. Global warming is the increase in the long-term average temperature of the earth (Kurucu, 2015). The effects of global warming can be listed as temperature increase, drought, desertification, soil erosion and salinization, deterioration in soil structure, changes in underground and surface water resources, melting of glaciers, increase in ocean and sea water levels, deterioration of the global economy and socio-economic structure (Doğan, 2005). To cope with the negative effects of global warming countries have been shifting towards renewable energy sources as healthy, clean, and sustainable energy sources (Karık et al., 2017). Although there are several definitions of renewable energy, briefly it is a type of energy that continues its natural processes, has continuity, does not end with its transformation into secondary energy, and continues to renew and flow (Gençel and Tarhan, 2019). In addition to diversifying the country's energy resources, renewable energy resources can also reduce the negative pressure on the environment (Koçaslan, 2010).

It is possible to meet the part of electrical energy needs without harming nature and people with renewable energy sources. Electricity generation methods using wind and solar energy sources are the fastest-growing methods in the world. This growth has particularly made wind power an important source of energy worldwide. The wind power is recognized as an essential source of energy worldwide. At the same time, the wind power has been recognized as one of the least environmentally damaging sources of electricity generation (Warren et al.,

2005). It does not cause any harmful pollutant emissions including greenhouse gases such as CO_2. It does not require mining or drilling for fuel, does not produce radioactive or hazardous waste, and does not use steam generation or cooling water (Schiermeier et al., 2008). In this perspective, the wind power generation is of great importance due to its high potential in northwestern parts of Türkiye, ease of use, and being eco-friendly (Taktak and Ilı, 2018).

Due to its geographical location, Türkiye has more advantages in terms of wind and solar energy as compared with many countries. In particular, Türkiye should work to expand the wind and solar energy use. In this context, rapidly growing bovine, ovine, and poultry farms that produce plants and animal products can easily benefit from the renewable energy source. Although the initial investment cost of these systems is high, the absence of raw material costs reduces the cost of energy generation. Studies have shown that renewable energy resources can be cost-effectively used in livestock farms way (Yüksel and Yüksel-Türkboyları, 2018; Orhan and Şahin, 2022).

Agricultural production is composed of plant and animal production. Animal husbandry is a major area of production in the world and our country in terms of economic, social, and nutritional aspects. For societies to have a healthy and balanced diet, the nutritional substances that the body needs must be provided. This means that calories, protein, fat, and carbohydrates should be taken in a balanced way (Karacan, 2017). Although it has a great importance in human nutrition, our meat production, which is the source of animal protein, is not sufficient for domestic consumption. Based on 2019 data our country's meat consumption per capita is 36.1 kg (cattle 13.6 kg, poultry 21.0 kg, sheep 1.5 kg), lower than the developed countries (BESD-BİR, 2023).

1.1. Poultry Farming in Türkiye

In terms of poultry broiler production, Marmara and Central Anatolia regions are the leading regions in Türkiye (Dağtekin, 2012). The poultry production sector has an important role in terms of production, national income, and employment. White meat and eggs account for approximately 60% of the annual animal protein production in Türkiye. In recent years, our poultry population and egg production had been increased significantly. This significant increase in production has also been reflected in the number and capacities of poultry houses and has played a major role in the spread of poultry houses having full environmental control (Erensoy et al., 2015).

This development in poultry farming can play an essential role in eliminating our animal protein deficit. Additionally, poultry farming can be carried out in smaller areas and in a faster way as compared with other animal husbandry types. Chicken meat has a strategic value since it is rich in energy, protein, and minerals, easy to digest, and relatively inexpensive. For this reason, the demand for chicken meat has been increasing day by day recently (Yüksel and Türkboyları, 2019).

1.2. Climate Conditions in Poultry Houses

In the design of modern animal barn systems, efforts should be focused on ensuring animal health and welfare. This will ensure animal welfare in the shelter environment and the efficiency of the business. It is reported that the biggest problem encountered in poultry houses is the regulation of indoor environmental conditions (Karaca et al., 2016; Karacan, 2017). High air temperature, among all environmental conditions, strongly affects the animals. High temperatures decrease feed conversion ratio, increase mortality rates, and decrease live weight gain in chickens (Bilgili and Dağtekin, 2019).

One of the important measures in ensuring environmental control in poultry houses is ventilation. A good ventilation system is needed to ensure adequate ventilation. The ventilation system in the poultry houses should be able to replace the required fresh air with the polluted poultry house air depending on the change in outdoor weather conditions all year round. Therefore, when planning an adequate ventilation system in the poultry houses, first of all, the ventilation capacity should be determined (Atılgan et al., 2010).

In agricultural buildings, electrical energy is needed to meet the desired amount of ventilation (Yüksel and Yüksel-Türkboyları, 2018). In rural areas, in case of a lack of electrical energy or power outage or reducing energy costs, electrical energy might be generated with wind turbines using wind power and it can be used in animal barns.

1.3. Wind Power Potential in Türkiye

Turkiye is located in an advantageous geographical location for wind and solar energy potential as compared to many other countries. The use of these resources will help to reduce dependence on foreign energy resources. In addition, it will contribute to reducing the current account deficit in the state budget due to energy expenses (Karık et al., 2017).

Wind is the result of the solar radiation warming the earth's surface at different levels. This difference in the levels of warming of the earth's surface leads to differences in the air temperature, humidity, and pressure, and to the formation of low- and high-pressure areas. Low- and high-pressure areas allow the air to circulate and therefore create winds. A 2% of the energy of the sun's rays reaching the Earth is converted into wind power. The characteristics of the wind vary depending on local geographical conditions and temperature differences between these geographical locations. Wind is expressed in two different parameters: direction and speed (MENR, 2023).

1.4. Wind Power Potential of Tekirdağ Province

Tekirdağ province, located on the Thracian peninsula, is in a very favorable condition in our country in terms of wind power potential, one of the renewable energy sources. The wind power potential data of Tekirdağ province, where wind speed is high, is given in Table 1.

Table 1. Long-term average monthly predominant wind speed, wind direction, and percentage (%) data (1940-2018) for Tekirdağ (Merkez) (MoEU, 2020)

Months	Wind Speed (ms^{-1})	Wind Direction	Months	Wind Speed (ms^{-1})	Wind Direction
January	3.1	NW (15.40%)	July	2.7	NE (% 12.60)
February	3.0	NW (12.81%)	August	2.9	NE (% 15.80)
March	2.9	NE (11.56%)	September	2.7	NE (% 12.69)
April	2.3	WNW (10.49%)	October	2.8	NW (% 14.29)
May	2.2	WNW (10.89%)	November	2.7	NW (% 14.77)
June	2.3	WNW (13.09%)	December	3.0	NW (% 15.98)
			Annual Average	2.7	NW (% 13.36)

Wind speeds change as they rise above the ground. As approaches the earth, the wind speed decreases due to the effect of friction force. The wind speed measured at any height can be used to estimate the wind speed measured at another height (Çelikdemir and Özdemir, 2020).

Wind speeds increase as the altitude increases. In a related study conducted in Burdur-Ağlasun area, possible wind speeds at a height of 60 m above the ground were calculated with various methods based on the wind speeds measured in the local meteorology stations. The approximate speed of the wind at a height of 60 m can increase up to 3 times compared to the speed measured at a height of 2 m above the ground (Dikmen and Örgen, 2018). The reason for using the wind speed at 60 m height is that it corresponds to the height of the hub (rotor hub) of the wind turbines. It should be noted that the wind speeds given in Table 1 also increased significantly with height.

This study aims to meet the electrical energy needs required for forced ventilation in poultry houses with the wind turbine energy system. Generally, there is no electricity network in rural areas where poultry houses are located. Ventilation and cooling can be done using the electrical energy obtained from the wind turbine system to be installed in a poultry house, using a fan and wet pad system.

2. Materials and Methods

2.1. Material

Tekirdağ province, the research area, is located on the Thracian peninsula in the southeast of Europe. The Thrace region is located between 26°-29° east longitudes and 40°-42° north latitudes on the continental Europe. Tekirdağ is located to the north of the Marmara Sea and south of the Black Sea and has a surface area of 6313 km^2. Koru Mountain, located in the province, is the highest point (762 m) and there are no steep slopes, valleys, and high mountains in other places. Tekirdağ generally has rainy winters and dry and hot summers. According to the general humidity indices, it belongs to the semi-humid climate type among the hydrographic regions and is windy in the summer and winter seasons (MCT, 2023).

According to the wind power potential atlas, Tekirdağ and Marmara Sea coasts have high wind speeds in our country (Karık et al., 2017; Tunus, 2019). Therefore, in Tekirdağ, electrical energy generated by wind turbines can be used for agricultural purposes.

Due to high temperatures causing decreases in animal productivity, the project was designed to ventilate and cool the poultry houses, when the air temperature is high in Tekirdağ. Therefore, the fan-pad system required for evaporative cooling in the poultry house was designed. The floor area of the poultry house is 420 m^2 and its dimensions are 14x30 m. In the poultry house, 6000 chickens are housed (Şenköylü, 2001).

For the poultry house with these dimensions (14x30 m = 420 m^2), ventilation fans and cooling pads (wet pad) sections and a wind turbine system that will generate electrical energy for them were designed.

2.2. Wind Turbine System Design

The wind turbines are machines that convert the kinetic energy of the moving air first into mechanical energy with the turbine blades and then into electrical energy with the generator. The wind turbines can start generating electrical energy only at a certain wind speed (2-4 ms^{-1}). After high wind speeds (25-35 ms^{-1}), wind turbines are automatically switched to the stop position to prevent damage to the system and to protect it (MENR, 2023).

The structure of the wind turbine system may include a wind turbine, batteries, battery charge control unit (charge regulator), inverter, command center, and various electronic circuits (Toprak, 2011; Şenel and Koç, 2015). In this designed system, the wind turbine is used as an energy source. Batteries were added to the system to provide energy in case the wind power cannot generate energy when needed or the system operates off-grid. Batteries store electrical energy as chemical energy and provide electrical energy to the system when needed. To prevent overcharging or discharging of the batteries, a charge regulator is added to the system. This extends the life of the batteries. If the system is on a grid or 220 V 50 Hz alternating current will be used in the system, an inverter should be used in the system (Toprak, 2011; Şenel and Koç, 2015).

2.3. Evaporative Cooling Systems in Poultry House

Providing a certain degree of cooling in the barns during the hot seasons will help minimize the heat stress on the animals. This allows for maintaining a healthy, high-quality, and efficient production. For this reason, the

evaporative cooling method is used in poultry houses located in the southern and hot regions of our country. Fans, which are operated continuously 24 hours a day during the summer season, work as an important element of the cooling system. This increases the energy consumption of the facility. As a result of the increase in the electrical energy consumption, production input costs increase too. This results in expensive products and weakens the competitive edge of producers (Bilgili and Dağtekin, 2019).

With the use of the wind turbine system, a renewable energy source, in the poultry houses in Tekirdağ region, the electricity cost burden on the producer can be reduced significantly. If planning is made properly, the generated excess energy can be given to the system and income can be earned. The system of the study is illustrated in Figure 1.

3. Results and Discussion

3.1. Design of Fan-Pad Systems to Be Used in Poultry Houses

A fan-pad cooling system was designed for the poultry house accommodating 6000 chickens. The width of the poultry house is 14 meters, the length is 30 meters, and the height is 3 meters (Şenköylü, 2001). The floor plan, ventilation, and cooling system of the projected poultry house are given in Figure 2.

For each 25 m^2 of floor area (A_1) of the animal barn, 1 m^2 of wet pad area is needed. The required pad area (A_p) for a barn with a floor area of 420 m^2 (A_b) can be found as follows (Equation 1) (Yüksel and Yüksel-Türkboyları, 2018).

$$A_p = \frac{A_b}{A_1} = \frac{420}{25} = 16.8\ m^2 \quad (1)$$

The daily water requirement of the wet pad is about 1 L on hot days (Bucklin et al., 1993). A small circulation pump is used to wet the pad.

The quantity of ventilation in animal barns is determined by the geographical location of the barn, the season, and the number of animals. The quantity of ventilation in the poultry houses is between 7 and 9 m^3h^{-1} (Q_1) for 1 kg live weight in the insulated poultry houses. Since the average weight of chickens is 1.5 kg, the total quantity of ventilation (Q_t) for 6000 chickens was calculated as follows (Equation 2) (Şenköylü, 2001).

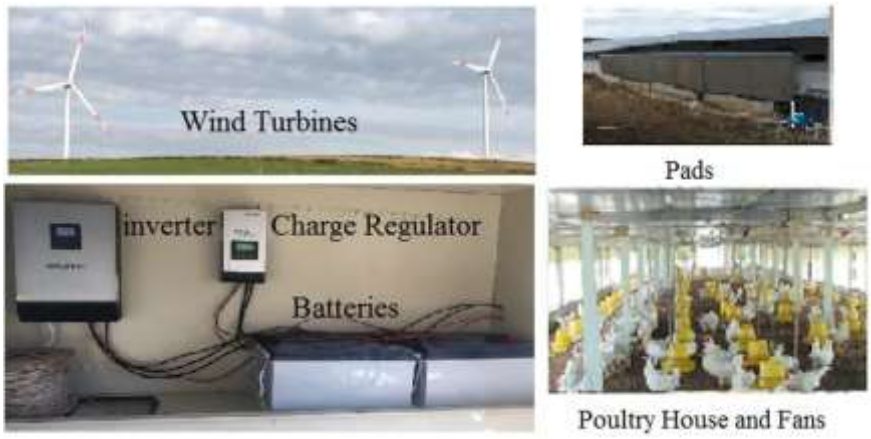

Figure 1. Poultry house, wind turbine system, and elements.

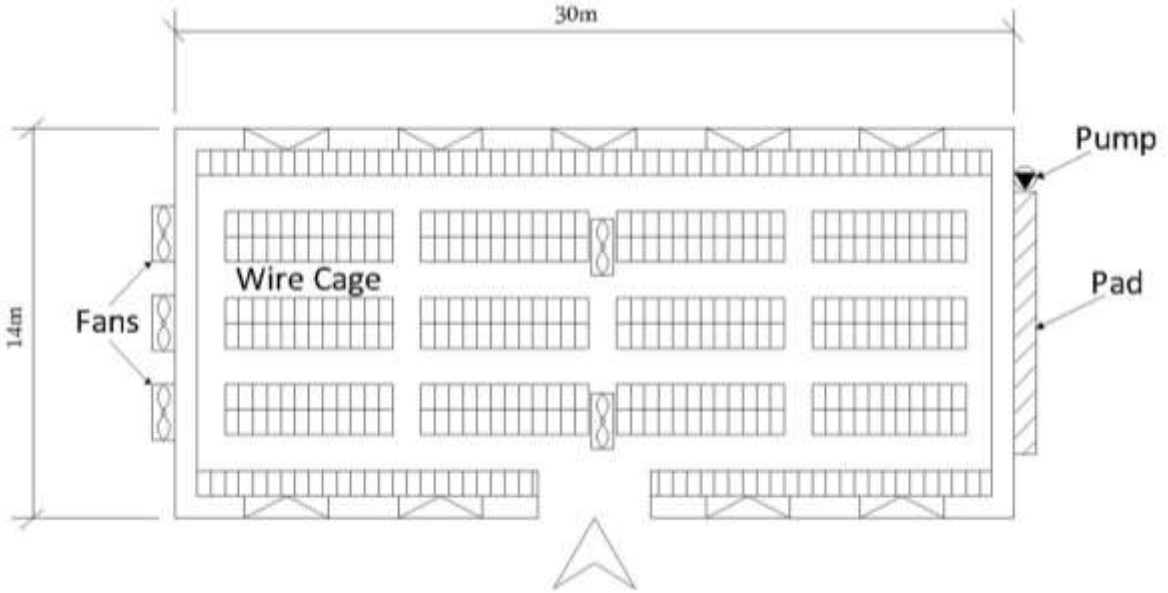

Figure 2. Poultry house floor plan and ventilation-cooling system.

$$Q_t = Q_1 \times 1.5 \times n$$
$$Q_t = 9 \times 1.5 \times 6000 = 81000\ m^3h^{-1} \quad (2)$$

If the length of the barn is between 25 and 30 meters, 2 aspirators should be placed in the middle of the barn for the aspirators to have a sufficient effect (Yüksel and Yüksel-Türkboyları, 2018).

The aspirators may be operated individually or in groups according to the needs of the animals in the poultry houses. 1400 rpm (dd^{-1}) and 0.75 kWh aspirators with a diameter of 60 cm and a flow rate of 9500 m^3h^{-1} (Q_a) were used to provide this quantity of ventilation in the poultry house (Equation 3) (Anonymous, 2022).

$$n_a = Q_t/Q_a$$
$$n_a = 81000/9500 = 8.5 \sim 9\ piece \quad (3)$$

Since the investigated poultry house is 30 m long 2 aspirators need to be placed in the middle of the house. Accordingly, the number of aspirators in the system is increased up to 11.

The energy requirement of the wind turbine system was calculated as follows (Equation 4):

$$0.75 \times 11 + 0.2 = 8.45\ kWh \quad (4)$$

This ventilation system needs a wind turbine system of approximately 10 kWh, which is greater than the calculated 8.45 kWh, to operate efficiently. Depending on the wind conditions, the wind turbine system will have periods that it does not generate energy or its output is low. Therefore, a system having a capacity greater than the need should be preferred. When the system is working efficiently, the excess energy from the system can be supplied to the network or stored in off-grid systems in batteries.

3.2. Cost Analysis of Wind Turbine Energy System

Among renewable energy sources, wind turbine and solar panel energy production systems play a leading role. The wind turbine energy system is also suitable for per unit energy cost. The cost of the energy system varies depending on the manufacturer and country. However, the installation cost of the wind turbine system is quite high. It is known that the installation cost is around $ 2500 per kWh (Erkoç, 2019; Türkdoğan et al., 2020; Türkboyları and Yüksel, 2024).

The wind turbine energy system to be installed is 10 kWh, whose value is 25000 $. The transportation and installation cost of the system is around $5000. The total cost of the wind turbine system to be installed in the system will be 30000 $.

The unit cost of the fans used in ventilation, including transportation and installation, is $500. The total cost of 11 fans used in the system is $5500 (Anonymous, 2023a). The unit price of the pad used to cool the air of the chicken coop is $20. The total price of a 16.8 m^2 pad is $336. If transportation and assembly of the pad system are added, it costs $403 (Anonymous, 2023b). The cost of the water pump used in the system is $50 (Anonymous, 2023c).

The cost of the ventilation and cooling system to be installed with the wind turbine is $35953.

3.3. Environmental Impact of Wind Turbine Energy System

Countries meet their electricity needs from various sources such as coal, natural gas, hydroelectricity, geothermal, biomass, and nuclear. These sources pollute the environment with a wide range of wastes and cause climate change. To reduce this impact, renewable energy sources such as wind and solar energy are preferred as clean energy sources.

Coal-fired thermal power plants have a significant share of 21% of Türkiye's electricity production (Orhan and Şahin, 2022). Thermal power plants that run on coal burn coal to generate electricity and release significant amounts of CO_2 gas into the atmosphere.

According to the Carbon Neutral Charitable Fund, the amount of CO_2 released into the atmosphere by thermal power plants (1 kWh) to generate electricity from coal is 0.94 kg (CNCF, 2023). According to this calculation, the amount of CO_2 that is prevented from being released into the atmosphere is calculated in kg by multiplying the amount of energy produced in kWh per year by 0.94 for a facility that generates electricity with renewable energy sources. This shows how important it is to switch to renewable energy sources in terms of environmental protection.

It is concluded that a 10-kWh wind turbine system was suitable for this project. In other words, the system will generate 10 kWh of electricity. It is expected that the turbine system's operating time is less on some days while more on other days. When it operates for a longer period, excess energy is stored in the network in the on-grid system and the batteries are activated in the off-grid system. On days when the system works for a shorter period, the system is supported either from the grid or from batteries. If the power of the wind turbine system is 10 kWh and assuming operate for 5 hours a day on an average, the amount of energy generated in a year (365 days) can be calculated as follows (Equation 5):

$$10\ kWh \times 5\ h\ day^{-1} \times 365\ day\ = 18250\ kWh \quad (5)$$

This electricity generation will prevent the emission of 17155 kg (18250 x 0.94=17155 kg of CO_2) into the atmosphere. Shifting towards renewable energy sources is a good solution to reduce the high amount of CO_2 to be released into the atmosphere in case of generating electricity with fossil fuels and to protect the environment.

4. Conclusion

In the regions where wind power is sufficient, it is possible to generate and use electrical energy with the wind turbine systems. Thus, on the one hand, energy could be provided to agricultural businesses in rural areas having no electricity network, on the other hand, significant amounts of greenhouse gas emissions into the atmosphere could be avoided.

The main objective in animal production is to ensure

appropriate living comfort in the poultry house environment for a good and high-quality yield. Chickens are very sensitive to high air temperatures. For this reason, the poultry houses should be ventilated and cooled when the air temperature is high. Fans and pads are necessary to ventilate and cool the poultry houses as desired. In the animal barns located in rural areas, the electrical energy required for operating the fans and pads can be supplied by a wind turbine system. At the same time, the cost burden of the business can be reduced with the electrical energy generated from renewable energy sources. If proper planning can be achieved, the excess energy generated can be used in other parts of the facility, or it can be supplied to the network to get income for the facility.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	E.T.	A.N.Y.
C	50	50
D	50	50
S	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	100	

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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