Black Sea Journal of Engineering and Science
doi: 10.34248/bsengineering.1618933

Open Access Journal
e-ISSN: 2619 – 8991

Research Article
Volume 8 - Issue 5: 1525-1530 / September 2025

OPPORTUNITIES FOR THE USE OF AGRIVOLTAIC SYSTEMS IN ANIMAL BARNS: A CASE STUDY OF WATER BUFFALO BARNS

Elif TÜRKBOYLARI[1]*, Ahmet Nedim YÜKSEL[2]

[1]Tekirdağ Namık Kemal University, Vocational School of Technical Sciences, Department of Plant and Animal Production, 59030, Tekirdağ, Türkiye
[2]Tekirdağ Namık Kemal University, Faculty of Agriculture, Department of Biosystem Engineering, 59030, Tekirdağ, Türkiye

Abstract: The utilization of fossil fuels has accelerated with technological advancements and population growth. The increase in harmful gas emissions from non-renewable energy sources is a significant contributor to climate change. To mitigate this threat, there has been a shift towards renewable energy sources, particularly solar energy. The placement of solar panel systems on agricultural land has given rise to agrivoltaic systems, which combine energy production and agricultural use of the same land. However, the installation of agrivoltaic systems often requires considerable agricultural land. In livestock farming, such as water buffalo barns, solar panels can be installed on barn roofs or over cooling ponds used by buffaloes, thus preventing the loss of agricultural land. For a closed water buffalo barn with a floor area of 588.3 m^2 (11.1 × 53.0 m), housing 70 animals, 13 fans with a capacity of 9500 m^3 h^{-1} are required for ventilation and cooling. Additionally, 23.5 m^2 of cooling pads and a circulation pump with a 0.2 kWh capacity are necessary. A solar panel system of 14–15 kWh can meet the energy requirements for ventilation and cooling. When controlled, the panel system would occupy 156 m^2 of land, which expands to 312 m^2 if designed as an agrivoltaic system. Installing solar panels over buffalo cooling ponds can significantly reduce water loss caused by evaporation in summer.

Keywords: Agrivoltaic, Anatolian water buffalo barn, Solar panel system, Ventilation, Cooling

***Corresponding author:** Tekirdağ Namık Kemal University, Vocational School of Technical Sciences, Department of Plant and Animal Production, 59030, Tekirdağ, Türkiye
E mail: eyuksel@nku.edu.tr (E. TÜRKBOYLARI)
Elif TÜRKBOYLARI https: //orcid.org/0000-0003-4658-8068
Ahmet Nedim YÜKSEL http: //orcid.org/0000-0002-0278-7498

Received: January 13, 2025
Accepted: August 22, 2025
Published: September 15, 2025

Cite as: Türkboyları E, Yüksel AN. 2025. Opportunities for the use of agrivoltaic systems in animal barns: A case study of water buffalo barns BSJ Eng Sci, 8(5): 1525-1530.

1. Introduction

Human life depends on the fulfillment of fundamental needs such as clean air, water, food, and energy. Among these essentials, energy is particularly critical, as it not only supports daily activities but also plays a central role in economic development, technological progress, and environmental sustainability. To address their energy needs, people have turned to fossil energy sources, as they are the most accessible and convenient to use. However, the production and use of fossil-based energy bring significant environmental problems. The environmental damage caused by fossil fuels increases with each passing day (Karaağaç et al., 2020). The greenhouse gases released into the atmosphere as a result of fossil fuel use, particularly the accumulation of CO_2 in the troposphere, leading to a greenhouse effect, contribute to rising air temperatures and global warming. Developed countries, where industrialization and technological advancement progress rapidly, through increasingly threatening the ecological balance of the planet through the emission of gases such as CO_2 and CH_4.

With the increasing global population, the demand for energy and food is also rising. Food security necessitates an increase in arable land to meet the growing demand for food. Generally, the predicted trend of rising temperatures in the lower troposphere and surface air layers contributes to an accelerated and intensified hydrological cycle. This situation indicates that the frequency and severity of extreme weather and climate events may increase in many regions of the world. Extreme events such as heatwaves, floods, and droughts, resulting from these intensified and undesirable weather phenomena, could disrupt the stability of food supply (Türkeş, 2020).

Policies adopted to reduce fossil fuel-based energy production, which contributes to climate change, are increasing investments in renewable energy. Investments in renewable energy require the use of more land for energy production purposes. Among renewable energy investments, solar energy is the fastest-growing sector, and as a result, solar panels significantly impact land use (Adeh et al., 2018).

The dimensions of solar panels to be used in agrivoltaic systems are 1.67 m^2 (1.67 m x 1.00 m = 1.67 m^2). The panel thickness is 32 mm, and its maximum power output is approximately 275 W. When two panels are placed one on top of the other lengthwise, 4 panels generate 1 kWh of electricity. If the panels are placed on the ground at a 40° angle, 4 panels occupy a land area of 2 m x 3.2 m = 6.4 m^2. A 5 kWh panel array occupies a land surface of 10.0 m x 3.2 m = 32.0 m^2. At least a 2 m wide path should be left at the front of the panel rows. This path serves two purposes: facilitating panel maintenance and preventing shading of the subsequent panel row, which could reduce energy production. For a 1 kWh panel system, the area occupied by this path is 2.0 m x 2.0 m = 4.0 m^2. For a 10 kWh system, this value increases to 20.0 m x 2.0 m = 40.0 m^2. Therefore, the total land area occupied by a 10 kWh panel system, including the path, is 64.0 m^2 + 40.0 m^2 = 104.0 m^2. If the panels are arranged with spacing suitable for agrivoltaic farming, the system occupies a total land area of 208.0 m^2. Since the planned panel system is 14–15 kWh, the required area for the panel system and the access path is 156 m^2. If the system is arranged in an agrivoltaic layout, the required area is calculated as 312 m^2.

Agrivoltaic systems are systems that combine photovoltaic panels placed on agricultural land to produce energy while allowing agricultural products to grow underneath the panels. The solar panels in agrivoltaic systems provide shade over plants, helping to preserve soil moisture, reduce heat-induced plant stress, and promote growth (Kırbaş, 2023).

However, a disadvantage of cultivating crops under solar panels is a reported yield reduction ranging from 5% to 20%, depending on the cultivated product. Additionally, the elevated installation of the panel system significantly increases the costs of support structures and wiring. This leads to extra expenses compared to traditional panel systems (Toledo and Scognamiglio, 2021).

There is no existing system to protect such investments in agricultural production areas. Panel systems utilize valuable equipment, such as panels, inverters, and chargers. These devices, located in open fields like farms, are always at risk of theft (Ağır et al., 2023).

Another issue is the transfer of energy produced by the solar panel system to the operation center. Direct current requires cables with a thick cross-section for transmission. Furthermore, significant energy loss occurs during the transmission of direct current. Therefore, the generated direct current should first be converted into alternating current using a charge regulator and an inverter before attempting to transfer it.

However, in solar energy electricity production systems equipped with photovoltaic technology planned to be established in various regions of our country, the production of electricity at the point of consumption offers high feasibility outcomes. Considering all the results obtained, it is stated that investors should prioritize investments where electricity is produced at the point of consumption, as this represents the most profitable investment (Bakır and Yılancı, 2023).

1.1. Placement Areas of Solar Panels in Crop Production

Agricultural production is divided into two main categories: crop production and livestock production, forming the foundation of food security. In agrivoltaic systems utilized in crop production, areas designated for electricity generation and agricultural production often overlap. The land is typically shared between the panel system and crop cultivation on a 50-50 basis. The key factor here is the equitable distribution of photons from sunlight. While this division may result in reduced agricultural yield, it is highlighted as a system that supports food security by mitigating climate change and provides an additional income stream to producers through electricity generation (Ağır et al., 2023).

The best locations for installing solar energy systems without losing agricultural land are water surfaces such as lakes, reservoirs, and ponds. Inactive areas not utilized for activities such as transportation or shipping can accommodate floating solar panels. A notable example in this context is Türkiye's first floating solar power plant installed on Büyükçekmece Lake (Yılmaz and Can-Öziç, 2018). Large energy systems established in these locations can be effectively protected against damage, theft, and other security risks.

In climate change scenarios, Türkiye and the Mediterranean basin are among the regions most affected by rising temperatures, posing significant challenges. A major issue here is the evaporation losses caused by elevated air temperatures. Approximately 55% of the country's water resources are lost to evaporation into the atmosphere. Among these losses, reservoirs, lakes, and rivers account for nearly 90% of the total. However, with floating panel systems installed over water surfaces, it is possible to reduce evaporation losses by approximately 60%, while simultaneously generating electricity (Korkmaz, 2015).

The impact of wind, another factor that increases evaporation from water surfaces, is also mitigated by solar panels. With reduced wind effect on water surfaces, evaporation rates decrease.

On the other hand, a regulation introduced by the General Directorate of Agricultural Research and Policies under the Ministry of Agriculture and Forestry has imposed restrictions on installing solar panels on agricultural land.

1.2. Placement of Solar Panels in Livestock Production Areas

In livestock farming, the other form of agricultural production besides crop farming, there is no conflict between agricultural production areas and solar panel system locations. In livestock facilities, solar panels can be installed on the roofs of animal barns and feed storage areas. Energy can also be generated from locations unsuitable for any other purpose. By placing panels in elevated positions, potential damage from animals or agricultural machinery and equipment can be prevented.

In this study, solar panel systems were designed for buffalo barns among various types of animal housing.

Buffaloes are water-dependent animals. Particularly during the summer and warmer seasons, their semi-aquatic nature requires access to water for cooling. Therefore, having a pond or water source near the barn is beneficial (Koyuncu et al., 2021).

Using the water surfaces around buffalo barns as locations for solar panel placement can be highly advantageous. Solar panels installed over water bodies near barns can generate electricity for the farm. Additionally, placing panels on the water surface significantly reduces water evaporation. At the same time, the panels block excessive sunlight from reaching the water surface, thereby protecting buffaloes from intense heat and sunlight.

1.3. Buffalo Farming

Buffaloes are known globally as water buffaloes, and in our country as the Anatolian water buffalo. The Anatolian water buffalo, a subspecies of river buffalo originating from the Mediterranean buffalo, is raised in various regions. Knowledge about buffalo farming is limited, and practices generally known for cattle farming are often applied to buffalo farming as well (Satılmış and Kul, 2024).

In Türkiye, Anatolian water buffalo farming is typically carried out on a pasture-based system within traditional family farms (Satılmış and Kul, 2024). Buffaloes can be kept in wetlands throughout the year, where cattle cannot sustain life. Regions with an abundance of marshes, wetlands, and reed-covered pastures are suitable for buffalo farming. Due to their thick and dark skin with limited sweat glands, buffaloes are highly sensitive to heat. In hot weather, they avoid reduced productivity by cooling off in water. Maximum productivity from buffaloes is achieved in areas like seas, lakes, ponds, rivers, and marshes (Koyuncu et al., 2021). When buffaloes are kept in barns during summer and hot seasons, effective ventilation and humidity control must be ensured to prevent them from being affected by the heat.

Buffaloes are economically valuable animals in the regions where they are found worldwide. While raised for meat and milk production, their hide, horns, and manure are also utilized. Additionally, in some countries like those in Southeast Asia, buffaloes are used as draft animals in agriculture. With these characteristics, buffalo farming can play a significant role in rural development as an economically viable branch of farming (Kul et al., 2018).

Some of the key advantages of buffaloes include their ability to produce higher levels of protein, superior weight gain, resistance to diseases, and high load-carrying capacity. Furthermore, they are long-lived animals and make better use of low-quality roughage compared to cattle (Koyuncu et al., 2021).

In recent years, buffalo farming has been significantly supported by the Ministry of Agriculture and Forestry. Through support for projects such as the "On-Farm Improvement of Anatolian Buffalo" program, interest in buffalo products has increased as part of efforts to promote healthy nutrition among the population. This has raised awareness about the production and consumption of buffalo products in recent years (Koyuncu et al., 2021).

In this study, it was aimed to provide the energy required for the fan-pad system used for ventilation and cooling in a 70-head closed buffalo barn with an area of 588.3 m^2 under the conditions of Tekirdağ province, using solar panel systems installed on the barn roof and over the water pool.

2. Materials and Methods

2.1. Material

The project area, Tekirdağ province, is located north of the Sea of Marmara on the Thrace Peninsula. The Thrace Peninsula is the part of Türkiye situated on the European continent. It is bordered by the Black Sea to the north, the Bosphorus Strait to the east, the Sea of Marmara and the Dardanelles Strait to the south, and the Aegean Sea to the west.

The research area, Tekirdağ province, is strategically situated in the Marmara Region between the longitudes of 26°41' and 28°10' east, and latitudes of 40°35' and 41°35' north. Tekirdağ covers an area of 6,313 km^2, with an elevation ranging from 0 to 200 meters above sea level. Its terrain is slightly undulating, with no high mountains, steep slopes, or deep valleys. The geological structure is relatively young. Tekirdağ has a semi-humid climate type based on its overall humidity conditions. It is windy during both summer and winter seasons (MCT, 2024).

There are many buffalo barns located to the west of Istanbul and around Tekirdağ. These producers supply buffalo milk, yogurt, cream, and butter to confectioneries, patisseries, and restaurants in Istanbul and the surrounding areas.

To ensure that buffaloes, which are highly sensitive to heat, do not experience productivity losses, ventilation and cooling systems must be implemented in buffalo barns in Tekirdağ and its vicinity. Appropriate ventilation and cooling for all seasons require mechanical ventilation in the animal barns.

The barn where the project will be implemented accommodates 70 buffalo, arranged in double rows. The dimensions of this barn are approximately 588.3 m^2 (11.1 m x 53.0 m = 588.3 m^2) (Avcı, 2015).

2.2. Method

The internal temperature of animal barns can be reduced through various water-based methods. Cooling systems for buffalo barns may include misting systems, mini-sprinkler nozzles, or fan-pad systems. These systems or sprinkler nozzles are used to wet the walkways, structural elements, and the buffalo inside the barn. When water evaporates from these moist surfaces, the latent heat of vaporization is drawn from the surfaces and the air. This principle is based on the fact that, during evaporation, 1 g of water absorbs approximately 598 calories (≈2500 J) of latent heat from its surroundings. The designed fan-pad system likewise utilizes water evaporation to cool the air and lower the barn's indoor temperature.

A pad is installed on one wall of the barn, while fans are placed on the opposite wall. The fans exhaust the indoor air, while humidified and cooled air that passes through the pad enters the barn. Consequently, the indoor air temperature decreases.

For a closed buffalo barn measuring 11.1 m × 53.0 m = 588.3 m^2 and housing 70 buffalo, a fan-pad cooling system and a solar photovoltaic (PV) system were designed.

2.3. Solar Energy Potential in Türkiye

Due to its geographical location, Türkiye benefits from an average annual sunlight duration of 7.5 hours, which is significantly higher than that of many countries. Regarding solar energy potential, the annual total sunshine duration is approximately 2.741 hours, and the total solar energy yield is about 1.527 kWh m^{-2} year^{-1} (with a daily average of 4.18 kWh m^{-2}) (MENR, 2024). These factors make Türkiye highly suitable for utilizing solar energy.

The radiation intensity in Tekirdağ province, where the project was implemented, is 1.450 kWh m^{-2} year^{-1} (3.97 kWh m^{-2} day^{-1}), which is close to Türkiye's average. The adequacy of solar energy encourages electricity use in agricultural enterprises in rural areas. In barns, electricity generated by solar panel systems is utilized for lighting, ventilation, cooling, and milking operations.

Solar panels, which consist of solar cells, directly convert sunlight into electricity. Most solar cells are made from inorganic materials, with an efficiency rate of approximately 15-20% (Grätzel, 2009).

2.4. Ventilation and Cooling of Buffalo Barns Using a Fan-Pad System

Buffaloes are physiologically different from other large ruminants. Their thick, dark skin and insufficient sweat glands make them highly susceptible to heat stress. Indoor air temperature is critical for buffaloes, as their limited sweat glands make it challenging for them to regulate their body temperature. The air temperature in the barn significantly impacts milk production and lactation duration (Kocaman and Kurç, 2018). A rapid deterioration of air quality within the barn induces stress in buffaloes, resulting in notable decreases in both meat and milk productivity (Avcı, 2015).

To design a fan-pad cooling system for buffalo barns, certain dimensions and parameters of the barn need to be considered. Ventilation requirements are calculated based on either the volume of the barn or the number of animals. Generally, calculations focus on the number of animals. The barn in this project houses 70 buffalo. The total floor area of the barn is 588.3 m^2 with a height of 3 m.

For water-cooled barns, it is required to have 1 m^2 of pad area per 25 m^2 of floor space (Yüksel and Yüksel Türkboyları, 2018). Based on this ratio, the required pad area for the barn is calculated as follows (equation 1):

$$588.3/25 = 23.5\ m^2 \tag{1}$$

In addition to managing excess heat and humidity, harmful gases from the animals' metabolism must also be removed from the environment (Koç and Şahin, 2023). Thus, the ventilation requirements of the fan-pad system need to be determined. Along with pad area, the number of fans (ventilators) should be calculated. Ventilation capacity varies depending on the season and the live weight of the animals. For buffaloes, this value is approximately 1.925 m^3 h^{-1} kg^{-1} (Wathes and Charles, 1994). The average live weight of Anatolian buffaloes is 500 kg (Atasever and Erdem, 2008). Therefore, the ventilation volume required for a barn housing 70 buffaloes of average 500 kg each is calculated as follows (equation 2):

$$\begin{aligned} 1.925\ m^3h^{-1}kg^{-1} \times 500\ kg \times 70\ heads \\ = 67375\ m^3h^{-1} \end{aligned} \tag{2}$$

Fan systems should be designed to operate both individually and collectively. For quiet operation, fans with a diameter of 60 cm are preferred. These fans have a capacity of 9500 m^3 h^{-1}, a power of 0.75 kW, a speed of 1400 rpm (dd^{-1}), and operate on a single-phase 230 V power source (Anonymous, 2024a). The number of fans needed to ensure proper ventilation is calculated as follows (equation 3):

$$67375\ m^3h^{-1}/9500\ m^3h^{-1} = 7.1\ fans \tag{3}$$

Due to the barn's length exceeding 30 m (it is 53 m), fans should also be placed within the barn at 15–17 m intervals for effective ventilation (Yüksel and Yüksel Türkboyları, 2018). At least two sets of ventilators should be installed at these intervals to increase ventilation efficiency. Including six additional fans for interior placement, the total number of fans required for the system is 13. The system will use 13 fans with a power of 0.75 kW each and a circulation pump for pad wetting with a power of 0.2 kW. The total energy demand of the system is calculated as follows (equation 4):

$$13 \times 0.75\ kWh + 0.2\ kWh = 9.95\ kWh \tag{4}$$

3. Results and Discussion

Data obtained for the ventilation and cooling systems planned for a closed barn housing 70 Anatolian water buffaloes are presented in Table 1.

Table 1 provides the project details for the solar panel system designed for a closed buffalo barn with a capacity of 70 buffalo. To achieve the desired environmental conditions within the barn, a solar panel system with a capacity of 9.95 kWh is required. This system necessitates 13 ventilators, each 60 cm in diameter, to ensure ventilation at a rate of 67375 m^3 h^{-1}. Additionally, a pad area of 23.5 m^2 is required for cooling, along with a circulation pump of 0.2 kWh to supply water to the pad. The floor plan of the ventilation and cooling system for a closed buffalo barn with a capacity of 70 head is presented in Figure 1.

Climatic conditions may hinder the expected efficiency of the solar panel system. Factors such as dirty solar panel surfaces, extreme hot or cold temperatures, the oblique angle of sunlight during morning and evening hours, cloudy weather, or night hours without sunlight could prevent the system from generating the desired amount of energy (Anonymous, 2024b). To ensure the system delivers optimal performance, a system with a capacity of 14-15 kWh—25-30% higher than the calculated 9.95 kWh—should be selected. When the system operates at full capacity, the excess energy produced can be stored in batteries. This stored energy can be utilized during times without sunlight, and for other equipment and lighting within the barn (Yüksel and Türkboyları, 2021).

The 15 kWh solar panel system planned for this buffalo barn requires an area of 156 m^2. If designed as an agrivoltaic structure, the necessary land area doubles to 312 m^2. Installing this system at a height of 3-4 meters would be costly due to the need to accommodate the operation of agricultural machinery underneath (Toledo and Scognamiglio, 2021). Since agricultural production is carried out beneath the panels, the operation of agricultural machinery and equipment should be enabled (Kırbaş, 2023).

For solar panels intended for buffalo barns, the most suitable installation locations are identified as above the water pool or on the barn roof (Figure 2). One advantage of installing the panels above the water pool is reducing water evaporation and loss, as the panels provide shade over the pool (Korkmaz, 2015). Furthermore, during the summer, the panels shield buffaloes in the pool from excessive sunlight, enhancing their comfort and well-being (Koyuncu et al., 2021).

Table 1. Ventilation and cooling system data for a 70-head Anatolian buffalo barn

Pad Area (m^2)	Ventilation Volume (m^3 h^{-1})	Number of Fans (units)	Energy Requirement (kWh)
23.5	67375	13	9.95

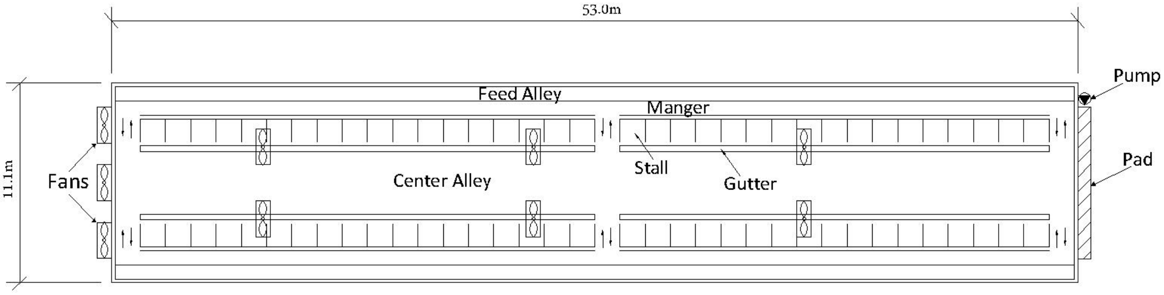

Figure 1. Floor plan of the ventilation and cooling system for a closed buffalo barn with a capacity of 70 head.

Figure 2. Placement of solar panels on the roof of the barn and over the water pool in the buffalo barn (OpenAI's ChatGPT platform generated this image).

4. Conclusion

The increased use of renewable energy sources, particularly solar panel systems, in agriculture has been causing a loss of arable land. In agricultural areas, conflicts can arise between energy production and crop cultivation. However, in livestock production, the use of solar panels does not result in land loss. In this context, the roofs of livestock barns and feed storage facilities can be utilized to contribute to energy generation.

In buffalo barns, the roof of the barn and the top of the water pools used by the buffalo for cooling can also be utilized as installation areas for solar panels. This approach avoids the use of arable land for panel systems, as seen in agrivoltaic systems. The energy generated by these systems can be used for ventilating and cooling buffalo barns. Ventilation systems help remove excessive heat, humidity, harmful gases, and dust from the barn. If ventilation is inadequate, the development and productivity of buffalo’s decline. Proper ventilation and cooling conditions in buffalo barns can only be achieved through mechanical ventilation systems. The energy required for operating these systems can be supplied by solar panel energy systems.

In rural areas lacking access to electricity grids, renewable energy systems can meet the energy demands of agricultural operations. Solar panel systems not only fulfill energy needs but also provide backup power during outages and help reduce energy costs for the operation.

Author Contributions

The percentages of the authors' contributions are 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	60	40
DCP	60	40
DAI	60	40
L	60	40
W	60	40
CR	60	40
SR	60	40
PM	60	40
FA	60	40

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, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

This study did not involve human participants or animal; therefore, ethics committee approval was not required.

References

Adeh EH, Selker JS, Higgins CW. 2018. Remarkable agrivoltaic influence on soil moisture, micrometeorology and water-use efficiency. PLoS ONE, 13(11): e0203256. https: //doi.org/10.1371/journal.pone.0203256

Ağır S, Derin-Güre P, Şentürk B. 2023. Türkiye'de Tarım ve Enerjinin Kesişimi, TarımFV: Güncel Yazın Işığında Bir Ön Değerlendirme. Hacettepe Univ İktisadi ve İdari Bil Sci Fac Derg, 41(Tarım özel sayısı): 1-22. https: //doi.org/10.17065/huniibf.1250434

Anonymous. 2024a. URL: www.fansanmarket.com (accessed date: October 10, 2024)

Anonymous. 2024b. Güneş enerji sistemlerinin (GES) güç çıkışını etkileyen faktörler URL: https: //mirsolar.com.tr/gunes-paneli-cikisini-ne-etkiler/ (accessed date: October 17,2024)

Atasever S, Erdem H. 2008. Manda yetiştiriciliği ve Türkiye'deki geleceği. OMÜ Zir Fak Derg, 23(1): 59-64.

Avcı H. 2015. İstanbul ili Avrupa yakasındaki manda işletmelerinin yapısal ve mekansal özelliklerinin belirlenmesi üzerine bir çalışma. Yüksek lisans tezi, Namık Kemal Univ Fen Bil Enst, Tekirdağ, Türkiye, pp: 69.

Bakır C, Yılancı A. 2023. Türkiye'deki farklı iller için şebekeye bağlı arazi ve çatı tipi lisanssız fotovoltaik güç santrallerinin tekno-ekonomik analizi. Mühendis ve Makina, 63(709): 560-584. https: //doi.org/10.46399/muhendismakina.114780

Grätzel M. 2009. Recent advances in sensitized mesoscopic solar cells. Acc Chem Res, 42(11): 1788-1798.

Karaağaç MO, Oğul H, Bardak S. 2020. Güneş enerji sistemi tasarımı: kanatlı hayvan çiftliği örneği. Düzce Univ J Sci Technol, 8(1): 711-722. https: //doi.org/10.29130/dubited.490154

Kırbaş İ. 2023. Agrivoltaik sistemler ve tarım alanlarının hibrit kullanımı. Uluslar Müh Tasarım Teknol Derg, 5(1-2): 9-19.

Kocaman İ, Kurç HC. 2018. A research on the determination of lactation length and milk yield of Anatolian water buffaloes under different environmental conditions. J Sci Eng Res (JSER), 5(8): 39-44.

Koç K, Şahin O. 2023. Bitlis ili, Güroymak ilçesi, Gölbaşı beldesindeki Anadolu mandası işletmelerinde barınak içi karbondioksit (CO2) emisyonu üzerine barınak hacmi ve sürü büyüklüğünün etkisi. J Anim Sci Econ, 2(2): 44-52. https: //doi.org/10.5152/JASE.2023.1224595

Korkmaz MS. 2015. Buharlaşma kayıplarının yüzer fotovoltaik paneller ile azaltılması. Yüksek lisans tezi, İstanbul Teknik Univ Fen Bil Enst, İstanbul, Türkiye, pp: 89.

Koyuncu M, Çetin İ, Sargın HG, Çetin E. 2021. Bursa ili Mustafakemalpaşa ilçesi manda yetiştiriciliği "Karaoğlan mahallesi örneği". Hayvansal Üretim, 62(1): 25-34. https: //doi.org/10.29185/hayuretim.820358

Kul E, Filik G, Şahin A, Çayıroğlu H, Uğurlutepe E, Erdem H. 2018. Effects of some environmental factors on birth weight of Anatolian buffalo calves. Turk J Agric-Food Sci Technol, 6(4): 444-446. https: //doi.org/10.24925/turjaf.v6i4.444-446.1716

MCT (Republic of Türkiye Ministry of Culture and Tourism). 2024. https: //tekirdag.ktb.gov.tr/TR-75726/genel-bilgiler.html (accessed date: October 03,2024)

MENR (Republic of Türkiye Ministry of Energy and Natural Resources). 2024. https: //enerji.gov.tr/eigm-resources-en (accessed date: October 08, 2024)

Satılmış AS, Kul E. 2024. Herd management practices in water buffalo enterprises in Amasya province: Feeding, milking and health protection. Turk J Agric-Food Sci Technol, 12(5): 753-762. https: //doi.org/10.24925/turjaf.v12i5.753-762.6593

Toledo C, Scognamiglio A. 2021. Agrivoltaic systems design and assessment: A critical review, and a descriptive model towards a sustainable landscape vision (three-dimensional agrivoltaic patterns). Sustainability, 13(12): 6871. https: //doi.org/10.3390/su13126871

Türkeş M. 2020. İklim değişikliğinin tarımsal üretim ve gıda güvenliğine etkileri: bilimsel bir değerlendirme. Ege Coğrafya Derg, 29(1): 125-149.

Yılmaz EA, Can Öziç H. 2018. Türkiye'nin yenilenebilir enerji potansiyeli ve gelecek hedefleri. ODÜ SOBİAD, 8(3): 525-535.

Yüksel AN, Türkboyları E. 2021. Use of solar panels in water buffalo barns for providing climatic environmental conditions. Iğdır Int Appl Sci Congr, April 14-15, Iğdır, Türkiye, pp: 301-310.

Yüksel AN, Yüksel-Türkboyları E. 2018. Using the photovoltaic cells for ventilation and cooling of the animal barns. 1st Int 14th Natl Cong Agric Struct Irrig (ICASI-2018), 26-28 September, Antalya, Türkiye, pp: 49-55.

Wathes CM, Charles DR. 1994. Livestock housing. CAB Int: Wallingford, Oxon, UK, pp: 428.