

POTENTIAL APPLICATIONS OF WATER-ENERGY-FOOD NEXUS CONCEPT THROUGH PRESERVATION AND RESTORATION OF A REMARKABLE SITE FROM BULGARIAN BLACK SEA COAST

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Abstract

The Water-Energy-Food (WEF) concept is focused on the balanced management of these highly interconnected resources. It strongly emphasizes on cross-sectoral and multi-level interactions, as well as resource interdependence, by highlighting the link between the extraction and use of water, energy and food. The main goal of this article is the disclosure and argumentation of a potential local area (the northern part of the Bulgarian Black Sea coast) for applying the Nexus approach in the context of the Water-Energy-Food tripartite nexus. In the study area, there are three main components creating the conceptual framework of the Nexus approach (the lighthouse of cape Shabla, the late antique fortress of Karia and the possibilities of using the energy from the sea waves with the supporting functions of the Shabla sea flyover). The methods of field studies, scientific analysis and synthesis, as well as geographic information systems (GIS) are applied. The results obtained and the conclusions drawn indicate that the intertwining of the multiple dimensions of sustainability, short- and medium-term interdisciplinary goals, interests and preferences along with the different perspectives of stakeholders lead to a nuanced understanding of the connectivities between environmental and social processes and issues of the WEF nexus.

Keywords: *Water-Energy-Food (WEF) concept; Preservation and restoration; Bulgarian Black Sea coast*

Introduction

In the past decade, discussions on water, energy resources and food management have grown significantly, providing new insights into the social importance of the interaction and interplay of the components of the nexus concept water-energy-food (WEF). Scientists, politicians and stakeholders involved directly or indirectly in the use and management of water, energy and food resources are calling for a new approach that simultaneously addresses a number of social and environmental aspects of society [1]. Nowadays, the existence of humanity is faced with significant challenges related to climate change, changes in land cover and land use. In addition, it is threatened by a water, energy and food crisis. Each problem has potential solutions. In the pursuit of sustainable development for the currently formed natural-anthropogenic system, it is of primary importance that giving a solution for one problem does not lead to an unacceptable change in the balances followed by another problem. This, in turn,

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requires the application of an integrated or holistic approach for solving different cases [2]. In its sense, the nexus between water, energy and food is defined as multi-scale and natural Exploring Water-Energy Nexus Innovations: Sustainable Solutions for a Resilient Future [3]. Water is one of the fundamental natural resources and is potentially needed for all kinds of human activity, including industry, agriculture, tourism, transportation and energy production [4]. Energy, on the other hand, is also interconnected with water through the implementation of hydroelectric projects to secure energy resources. In this regard, water and energy can be considered as two complementary components. The interrelationship between energy and food is characterized by both synergies and clearly defined conflicts mainly in relation to the taking of arable [5, 6]. The impact of human activity on the water-energy-food (WEF) nexus and the demand for these resources are increasing globally due to changes in land use and land cover [7]. Achieving food security is the result of improving resource efficiency - water and energy, strengthening sustainability and ensuring social justice and accountability of agriculture and food systems [8]. The Water-Energy-Food (WEF) concept focuses on the balanced management of these highly interconnected resources and requires the inclusion of the three dimensions of sustainability - social, economic and environmental [9]. Linkage studies conducted in an ecological context are generally critical to sustainable resource conservation at the local level and following that they could be successfully applied in analyzes supporting the WEF link concept for larger scales [10]. The nexus approach is a useful tool for detecting the economic risk of resource scarcity, optimizing investments and evaluating the effects of implemented policies to achieve the UN Sustainable Development Goals [11].

When carrying out research dedicated to the WEF concept, it is necessary to take into account the spatial heterogeneity of natural resources and socio-economic conditions (even if it is applied for small areas) [12]. In many areas or regions, the necessary conditions for a real application of the linkage approach are in place. Very often this is a challenge that requires coordinated and sustainable cooperation between government structures, the private sector, academia and civil society [13].

In Bulgaria, the approach of the WEF connection is relatively new and not yet well known. Due to the fact that the country is characterized by diverse natural, cultural and socio-economic conditions, in some regions there is a marked need for a pilot introduction of the WEF connection concept.

The main objective of this article is to reveal the possibilities and conditions for potential application of water-energy-food nexus concept through preservation and restoration of a selected area from bulgarian black sea coast.

Materials and Methods

Study Area

The study area in this article falls within the boundaries of Shabla municipality which has an ancient history and rich culture (Figs. 1 and 2). In selected area in this research are available lighthouse, sea flyover, antique fortress, natural brackish lagoon and other specific objects which make the area a remarkable site on the north-western part of the Black Sea.

Lighthouse of Shabla

Lighthouses and navigational signs along the Bulgarian Black Sea coast have been under the care of the Bulgarian state since August 14, 1909. Facilities from north to south include the following sites. The lighthouse on Cape Shabla, located not far from the town of Shabla, is the oldest navigation facility on the Bulgarian Black Sea coast (Figs. 1 and 2).

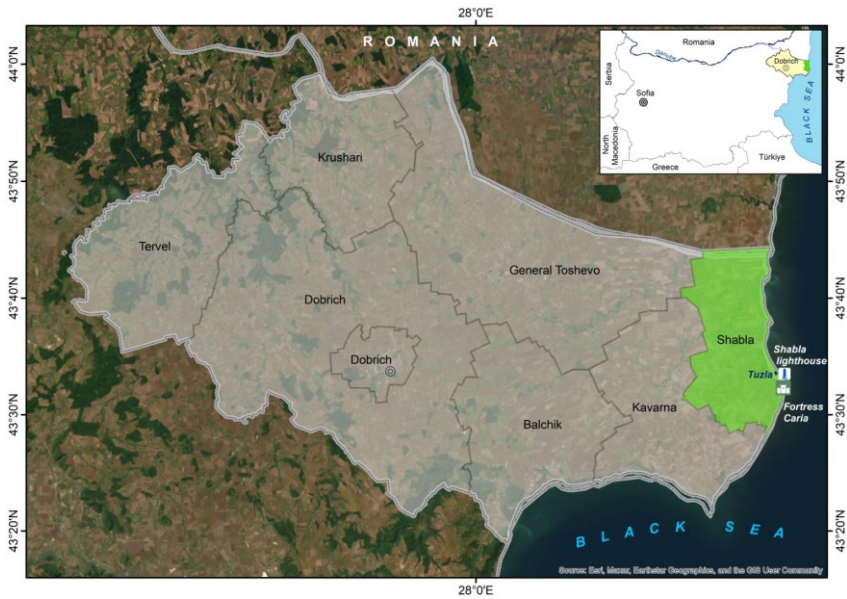


Fig. 1. Map of the Study Area



Fig. 2. The lighthouse of Shabla

The lighthouse was built in order to orientate and protect sea vessels from collision with an underwater reef nearly one mile long in the shallows between Cape Shabla and the village of Tyulenovo, at $43^{\circ} 32' N$. and $28^{\circ} 36' E$. The flash interval is 3 times every 25 sec. and the signal is visible at a distance of 17 nautical miles. Every year on August 18, the oldest and tallest lighthouse on the Bulgarian Black Sea coast at Cape Shabla is for visitors. The event is being held on the occasion of International Lighthouse Day. The facility is located about 4km east of the city of Shabla and is one of the most visited tourist sites with over one hundred and fifty years of history. The lighthouse on Cape Shabla was built in 1856-1857. Visible to this day is

the monogram of Sultan Abdul Mejid on one of the walls, the ruler of the Ottoman Empire, during whose reign the lighthouse was built. Its remarkable stability (of the facility) is due to the arches with precisely crafted keystones. A winding stone staircase leads to its top. In the 1930s, the lighthouse was modernized and its characteristic appearance dates back to that time - the entire facade is tightened in steel hoops and painted in red and white stripes. Outside, on one of the walls of the building, a plaque has been placed, behind which there is a hidden message to future generations, which will be opened in 2056, when the 200th anniversary of the construction of the lighthouse will be celebrated.

The Shable lighthouse is the northernmost Bulgarian lighthouse and is located at the easternmost point of the country. With the advancement of navigational technology, marine lighthouses remain in the background. The number of working lighthouses around the world is declining and the facilities are used mainly as a tourist attraction. Nowadays, more and more lighthouses, in addition of being an aid to navigation, also acquire auxiliary functions, especially at potential tourist sites in their entirety with their surroundings. The existence of a light keeper, for example living in or near the lighthouse, is a prerequisite for the preservation of social values by providing the opportunity for visitors to be part of the narratives of a given legend, historical event, war, art, spiritual community etc. Increasingly, historic lighthouses are serving as museums and libraries, venues for cultural events etc. The implementation of these activities generate income in a smaller or larger amount, which, added to the state budget, supports the conservation process Plan for integrated development of the municipality of Shabla 2021-2027 [14].

Sea flyover of Shabla

Since its construction in the 1960s, mainly for the needs of oil extraction, the Shabla flyover has been an attractive place for tourists and travelers. The facility, which is located in close proximity to the famous Shabla lighthouse, was the most popular and picturesque place on the Northern Black Sea coast for fishing from the shore, but later it was almost completely destroyed by sea waves. According to experts, the restoration of the sea overpass at Cape Shabla is one of the most complex projects built in water after the Danube Bridge. The complex, which is in the process of restoration, consists of a sea viaduct that extends up to 414 m into the Black Sea, with a width of 6 m and a designed island platform rising 8.5 m above sea level. At the moment, the restoration of the facility is 341 m from the shore and in January, the restoration activities on the overpass were resumed by a contract signed between the State Enterprise "Port Infrastructure" and the company "Hydrostroy" executing the order (Figs. 1 and 3).

The late antique fortress of Karia

In the area where the construction works on the Shabla flyover are being carried out, there are the remains of a beautiful ancient city (Karon Limen), the restoration and preservation of which could become a source of considerable future income. The ancient port of Kariya and the fortress near Cape Shabla have not yet been sufficiently explored, mainly due to the lack of financial resources. The ancient fortress of Karia was founded on the site of an even more ancient settlement called Karon limen. Translated from ancient Greek, limen means an artificial bay and Karon is an ethnonym explaining the origin of its creators. "The ancient Carians are an old population that inhabited the territory of the Asia Minor coast in the region of today's Bodrum and ancient Halicarnassus, even before the arrival of the first waves of Hellenic peoples. The Carians were excellent navigators. They assimilated part of the islands in the Aegean Sea. There is no data on the period of establishment of the port along our coast, but most likely it was related to shipping and the establishment of trade routes. Later, during the period of the Hellenic colonization of the northern Black Sea coast, Karon Lymen was officially included in the ancient sea routes. It is located approximately in the center of the most important trade route in the Black Sea. The port was important not only as a trading center but also as a refuge in bad weather due to the extremely difficult navigational situation in an area

known for dangerous currents, sand shoals and sea reefs. The ancient geographers Flavius Arrianus, Pomponius Mesa, as well as the Anonymous Periplus of the Black Sea give us brief descriptions of the location of the port as well as the land of the Carthians. Later authors, such as Procopius of Caesarea, also provide information about the late antique fortress of Karia, which was built to protect the ancient port. Today, most of this historically important archaeological complex has been swallowed up by the sea and other parts of it have been destroyed by later buildings. Only the remains of the western half of the ancient fortress and foundations of ancient buildings have been partially preserved. Various construction stages of the fortress from the late Roman and early Byzantine periods have been identified. Under the rectangular tower of the quadriburgium, the foundations of a Roman bath were discovered. From the pre-Roman period, numerous coins of Istria, Dionysopolis and Odessos, as well as of the Macedonian rulers Alexander the Great and Lysimachus, are also preserved and imported painted pottery and various amphora seals of the Hellenic cities prove the significant trade connections of the ancient port of Karon limen (Figs. 1 and 4).



Fig. 3. Sea flyover of Shabla



Fig. 4. The late antique fortress of Karia

Shablenska tuzla

It is a natural brackish lagoon with an open water area 24.4ha. The tuzla is separated from the sea by an approximately 80 m wide sandbank and here are the highest dunes on the northern Bulgarian Black Sea coast. It is a Salt Lake, formed mainly by the percolation of salty sea water under the sand dunes. The average depth of the seabed is 0.6m and the average salinity is 0.004‰. The lake and its adjacent territories form a unique coastal ecosystem with an extremely rich flora and fauna.

Approach/es of the WEF nexus

Water, energy and food have a decisive importance for the existence of people, animals, plants and for the development of the economy. Since all of the above-mentioned resources are, more or less, interconnected, the conservation and sustainable management of the formed dynamic *water-energy-food* system should be based on the nexus approach. The WEF nexus recognizes the interconnectedness and interdependence between water, energy and food systems and the vital role ecosystems play in sustaining them. *The ecosystem approach* considers the diverse and numerous, possibly permissible combinations of different options that can be obtained depending on one or other combinations of external impacts in ecosystems, including anthropogenic ones. As a result, a general natural-anthropogenic territorial system is formed, in which components quantitative and qualitative changes occur. In general, the anthropogenic pressure on nature is many times stronger and the negative influence is many times greater than the positive. One of the main tasks in determining the state of this system is the selection of indicators by which it could be determine the dynamics of the changes that have occurred over a certain period of time, also the reasons for these changes and the possibilities for preventing and restoring negative impacts. This is a brief explanation of the so-called *indicator approach*. The indicators serve to produce analyzes and assessments, providing new knowledge that supports the understanding and implementation of the WEF nexus approach. Today, there are still no universal quantitative and qualitative criteria that are equally applicable in all cases. However, in the scientific literature, according to the tasks, there are various developments dedicated to one or another aspect of the challenges of the concept. The concept of the WEF connection emphasizes the sustainable use of water, energy and food resources, which inherently requires an appropriate combination of policies and measures affecting economic, natural-cultural, infrastructural and human potential. Due to the complex interrelationships between the WEF subsystems and their external resources and ecological environment, the sustainability of the tri-sectoral nexus very often extends its scope and includes additional dimensions, for example *water–energy–land–food*, *water–energy–climate–food* and *ecosystem–water–food–energy*. This necessitates the adoption of the so-called *holistic approach* of the WEF nexus and aims to encourage policymakers, scientists and stakeholders to collaborate across sectors and disciplines, identify synergies and trade-offs and develop innovative strategies that optimize resource allocation [13].

Materials

This article is built on the basis of previously collected and processed information data base (scientific articles, publications, reports, strategies, development plans, websites etc.) on the topic. The selection of relevant sources was carried out by their initial, search, discovery and accumulation in groups by keywords such as: “WEF nexus”, “WEF nexus concept”, “WEF nexus approach”, “water-energy-food”, “water-energy”, “water-food”, “energy-food”, “sustainable development”, “WEF nexus and social-economic issues”, “sustainable development goals”, “lighthouses”, “sea flyover”, “wave energy”, “arable land”, “antique fortress”, “agriculture” and etc.

Methods

In this article are applied field research methods (observation, survey, description), scientific analysis and synthesis methods, as well as geographic information systems (GIS). During the field research, a visual assessment of the research area was carried out and the main

objects of analysis were photographed. The scientific analysis and synthesis were applied in the initial stage of recruitment, accumulation and selection of the relevant sources to compile the information base of the development, as well as in the subsequent stages of deriving the obtained results, discussion and formulation of the main conclusions [15]. The study area was visualized by geographic information systems (GIS).

Results and Discussion

Preservation and restoration as a valuable process for achieving sustainable development goals

The European Commission remains committed to the implementation in the EU and beyond of the UN 2030 Agenda for Strengthening Resilience, adopted by world leaders in 2015. The overall implementation of the agenda is crucial to achieving the Sustainable Development Goals (SDGs). All Sustainable Development Goals are included in one or more of the six main aspirational goals. The Sustainable Development Goals [16].

The links between many of the sustainable development goals lack coherence with each other and in many cases the complex interaction between different sectors is not taken into account. Interlinkages are recognized in five of the goals and three of them - goal 2 (addressing food security), goal 6 (ensuring access to clean water) and goal 7 (promoting modern energy solutions) are the subject of research in the approach of WEF nexus. Among the recognized interdependencies are also Goal 13 (mitigation of climate change) and Goal 15 (conservation of Earth's ecosystems) [17].

Role of potential application of the WEF nexus concept in regional development

In assessing the interconnectedness and interdependence between the resources of the WEF nexus, it is necessary to determine the impact of society on them, by establishing the extent and forms of its multifaceted influence at the regional, national and global levels, respectively. The WEF nexus concept is based on the principles of integrated water resources management (IWRM). What differentiates WEF from IWRM is WEF does not focus explicitly on water but takes into account the food and energy security of the population [13]. Despite the significant progress recorded in research and evaluation of the WEF nexus concept, the social, economic and political aspects still remain relatively under-addressed. This is a significant shortcoming because at local and regional level it is the politicians, institutions and stakeholders who influence policies and decision-making processes regarding resource management. In general, water is used to produce energy and food [18]. The energy subsystem serves to ensure water quantities in food production [19] and water and energy find a place in food production [20]. Each region has at least one or all of the resources of the WEF tripartite nexus and is dominated by synergies or trade-offs, respectively. According to some authors, *M. Van Noordwijk* [21], it is impossible to apply a universal interdisciplinary approach in the nexus for example, supports the idea that methods applied for achieving sustainability should be based solely on the space and options of a given environment and not on general models that have little or nothing to do with the case to be studied. This means that the preservation and restoration of the natural and cultural endowments of a given region, as well as the socio-economic conditions, are the basis for its well-being and development. Despite the interdisciplinary approach of the WEF relation, very often political and economic interests' conflict with the goals of the nexus. Short-term profits are usually prioritized over long-term sustainable management and use of resources. For the successful implementation of the WEF nexus concept and the prosperity of the regions, a challenge can also be the mistrust of change from already established practices. The need of time to convince decision-makers and conduct discussions between scientific and interested parties on the adoption of new approaches for long-term sustainability cannot be ruled out. Last but not least, the lack of access to comprehensive or representative data and information, as well as institutional fragmentation,

can also hinder the governance of the WEF nexus. In many countries, including Bulgaria, aspects of ownership and financing continue to be a significant challenge [9]. In summary, the WEF nexus is an applicable conceptual framework that helps manage the balance between regional development and natural resource constraints. In this sense, conservation and restoration processes at the local level become valuable tools for addressing regional challenges - for example, the state of resources and the transition to clean energy.

Main characteristics of the study area - northern Black Sea coast (Shabla Municipality)

Shabla is a Black Sea municipality in Dobrich district, the easternmost border region of the Republic of Bulgaria with the Republic of Romania. The territory of the municipality of Shabla is 329.6km², which represents 7% of the total area of the Dobrich region and about 2% of the territory of the North-East region (NER, NUTS 2), 2.67% of the population of the respective district and only 0.5% of the population of NER inhabit in the municipality (Fig. 5).



Fig. 5. Map of the Municipality of Shabla

The relief is flat and uniform. The average height above sea level in the municipality is 48m. The municipality of Shabla is poor in minerals. Deposits of coal and manganese ore have been discovered, an insignificant amount of oil is extracted from deposits with limited reserves and diminishing functions. The climate in the municipality of Shabla is moderate - continental with a pronounced influence of the Black Sea basin. The studied territory is characterized by a lack of surface water flow and the hydrographic network is represented by a small number of river currents, which form a short-term surface runoff, usually during heavy rainfall or intense snowmelt and essentially represent dry land. Water supply to populated areas is provided by underground water sources.

The area is entirely occupied by chernozem soils with a strong humus horizon, fertile, with a slightly alkaline to neutral soil reaction. Eroded soils are a rare phenomenon and are revealed in places in the lands of the villages of Tvarditsa, Bojanovo and Vaklino. The characteristic features of chernozems ensure good natural fertility. The soil-climatic and relief conditions in the municipality of Shabla are favorable for the development and productive possibilities of the main agricultural crops in the area and can be classified as "good lands" with an average rating of 71 points. They are most suitable for growing wheat, corn, sunflower and alfalfa.

In the Shabla municipality, four protected areas have been established, falling within the European ecological network NATURA 2000 - Durankulashko Lake, Shablensko Lake, Shabla Tuzla, Kaliakra and a number of natural attractions. The length of the sea coast in Shabla is about 40km and the accumulative coasts have a total length of 13.4km. The coast to the south of the city is rocky, to the north - low and marshy with numerous beaches of fine, granular sand and crushed mussel shells, forming sand dunes in many places. The dunes have an area of over 1300 dka and are located mainly in the northern part of the coast. The sea shore represents 22% of all beaches along the Bulgarian Black Sea coast. Around Cape Shabla, abrasion has formed numerous caves, underwater and above-water clips. Near the city are located the freshwater lakes - Shablensko-Ezeretsko and Durankulashko, which are distinguished by a rich variety of animal, marine and plant species.

The area is distinguished by a favorable transport and geographic location, with the main road being represented by the first-class road I-9, with European categorization E-87 and direction Romania /Durankulak-Shabla-Varna-Burgas-Malko Tarnovo/Turkey. In practice, the international passenger flow from Europe through the Durankulak checkpoint to the interior of the country and south to Asia takes place along this route.

Preservation and restoration of local resources and supporting factors for sustainable development

The resource endowment and the combination of suitable conditions in the model study area provide opportunities at the regional level for the application of the water-energy-food nexus concept. Leading sectors for the local economy are agriculture and tourism and to a lesser extent trade. The interaction and interdependencies between the components in the tripartite relationship are clearly demonstrated. In addition to water, energy and food resources, between which there are direct interactions, the coastal zone also has supporting factors in the nexus.

“Water-Energy-Food” interactions

Despite the lack of surface water flow and the scarce hydrographic network in the studied territory, water, including sea water, as a resource, finds various applications and plays a key role in the formation of multidirectional and multiscale connections. The two-way interconnection between water and energy is inseparable, even more in the modern conditions of implementation of the so-called "energy transition". While water is critical to energy production, energy is essential to water extraction, treatment and distribution. New technologies and innovations are focused on the possibilities of producing electricity from renewable sources, including sea and ocean water. The wind blowing over the sea surface continuously generates waves, transferring its energy to the sea surface. The amount of wave energy captured varies greatly in different parts of the watershed. It was found that the wave energy of the Black Sea decreases along the coast from west to east. The energy received from areas with so-called low potential, can be used in wastewater treatment plants, desalination plants or other energy-intensive activities near the coasts [22]. In Bulgaria, the innovative use of sea wave energy is even patented in the patent office and the owner is the Institute of Oceanology at the Bulgarian Academy of Sciences. According to the inventor (Trayan Trayanov) of the device, it can be used in alternative energy and in the use of renewable alternative sources. The produced electricity creates an opportunity for lighting the Shabla flyover, for heating, for pumping seawater to reservoirs, pools or other technological needs, such as decomposition of water into hydrogen and oxygen. The flyover at Cape Shabla is practically a strategic facility for the country, which demarcates the maritime spaces between Bulgaria and Romania. The facility, in addition to helping with the production of wave energy, is located in the immediate proximity where gas exploration is being carried out for gas extraction from the "Khan Asparuh" block (in the exclusive economic zone of Bulgaria) and the preliminary expectations for the capacity of the fields are optimistic.

The ocean is one of the renewable sources of energy. By using its energy, the society can reduce the rate of consumption of fossil fuels and other non-renewable resources. The energy

from the waves can be converted into electricity or other forms of usable energy. Water waves have a relatively high-power density [23].

The transformation of the thermal energy of the sea and ocean waters Ocean Thermal Energy Conversion (OTEC) is realized by the installation of a thermal engine using the surface sea water as a thermal source and the deep water as a thermal absorber. The so-called "harvesting" of wave energy is a very dynamic research area where various concepts and technologies are currently being proposed and developed. Pilot plants and full-scale devices are frequently tested [24]. Regardless of the chosen technologies, the main limitation for the implementation of these projects is the provision of the necessary financing. In this case, the active intervention of state institutions is crucial.

Apart from industrial and energy uses, water provides a wide variety of opportunities for the development of recreational and tourism activities. The nexus between water and tourism is characterized by a dual understanding of this element: as a valuable resource and as an attraction. Different types of water bodies, especially when they are located near a sea basin, can support various forms of tourism, such as beach, river, lake, thermal water tourism etc [24].

In this sense, the object of research proposed in the present article "Shablenska tuzla" is of key importance for the development of the region. The water body has reserves of high-quality healing mud, which is characterized by a silicate-carbonate crystal skeleton and low gypsum content. It is thick, black, plastic and greasy to the touch, with a strong odor of hydrogen sulfide. In this sense, the object of research proposed in the present article "Shablenska tuzla" is of key importance for the development of the region. The reservoir has reserves of high-quality healing mud, which is characterized by a silicate-carbonate crystal skeleton and low gypsum content. It is thick, black, plastic and greasy to the touch, with a strong odor of hydrogen sulfide. 7 species of herons use the reservoir for recreation and the migration channels of 27 species of songbirds pass through the site annually. During the winter months, the mute swan forms flocks, which makes Tuzla one of the important habitats of this species in Bulgaria.

The phenomenon of water resources in the aspect of thermal natural baths has been known since ancient times. Mineral water with a temperature of 41°C and a flow rate of 6000L/min was discovered near the village of Tyulenovo. It is characterized as hyperthermal, chloride-sodium, containing hydrogen sulfide and metaboric acid. Nowadays, the presence of such hot, mineral springs is a prerequisite for the realization of a complex of services such as accommodation, hydrotherapy, catering, entertainment and other additional activities that favor the economic growth of the area.

In the context of global warming, the consumption of fossil fuels is increasingly giving way to renewable energy sources. In addition to the above-mentioned marine wave energy among the promising ones, the so-called green energy sources are also the energy of the wind and the sun. The area of Shabla has favorable conditions for the production of energy from renewable sources. The municipality falls into the zone of "medium-scale wind energy" with opportunities for the construction of wind power plants, but in compliance with the requirements for the protection of biodiversity (mainly migratory birds). A major problem with the construction of wind farms and generators is related to the taking away of a large percentage of agricultural land.

The northern coast of the Black Sea within the scope of the research area, photovoltaic energy resources are of essential importance. Agrophotovoltaic involves sharing solar radiation to produce energy and food on the same land. Scientific and technological advances have contributed to various types of photovoltaic modules, increasing their flexibility and applicability in agriculture. The concept of the coexistence between photovoltaics and agricultural crops was first introduced by *A. Goetzberger and A. Zastrow* [25] and the first agrovoltaic pilot projects in Europe were introduced in 2010 in Montpellier, France for the production of cereal crops [26]. Nowadays, the rational and sustainable design of solar systems

requires a transdisciplinary approach. Solar energy used in water purification processes and its reuse mostly by utilities and for agricultural needs mainly for irrigation, reduces dependence on non-renewable energy sources and reduces operating costs. In addition, the implementation of some innovative practices, such as the use of wastewater treatment plants for bioenergy production, contribute to the creation of a more sustainable and energy-efficient hydropower infrastructure. Although the research area, as specified above, does not have large deposits of natural energy resources, about 600 drillings were made in the oil and gas field discovered on 31.05.1951 near the village of Tyulenovo. About 400 of them are currently working. Later, gas wells were also developed in the villages of Bulgarevo, Krapets and Blatnitsa. Regardless of the available, albeit insignificant, reserves of oil and gas, a distribution network for domestic gas supply in the municipality has not yet been built, but the existing one in the municipality of Kavarna represents a good opportunity to introduce natural gas as an alternative energy carrier in the model study area. Close to the border is the Dobrudja Coal Basin of Carboniferous age, in which significant reserves of black coal located at a depth of about 1200-1300m have been studied and assessed.

Water, in addition of being an energy resource, is also essential for the production, processing and consumption of food, interconnected through supply networks, trade, markets, prices etc. [27]. The main sector consuming large amounts of water and energy is agriculture. The municipality of Shabla has favorable factors, such as the presence of a flat terrain facilitating the processing of large areas, suitable soil and climate conditions, high quality of agricultural land, traditions and production experience of the population in growing agricultural crops and farm animals. Plant breeding is mainly specialized in the cultivation of grain and technical (oil) crops - wheat, corn, sunflower, coriander etc. The region is characterized by irrigated agriculture, which requires certain amounts of water. Excessive fertilization of cultivated land leads to pollution of underground and surface water resources, while their purification requires energy. In general, there is competition for land resources between the main components of the water-energy-food nexus [6]. Cultivable agricultural land according to official statistics for 2023 is about 92% of the agricultural territories. The forest fund in the municipality occupies 3% of its territory, which is the lowest percentage of all Black Sea municipalities and below the average values for the country - 33.5%. The leading branch of local animal husbandry is sheep breeding. The development of cattle breeding and pig breeding is at a slow pace and beekeeping has a relatively constant number of raised bee colonies. Fishing is a specific sub-industry related to the proximity of the Black Sea. Fishermen's cooperatives operate in coastal settlements with the main activity of catching and trading fish. The catch of turbot, mullet, saffron, grayling, black carp, shark, pike and bream is economically valuable. An alternative activity in the provision of food and energy resources is the cultivation of marine microalgae, which can be grown untreated in salt or seawater, efficiently apply fertilizers and achieve higher oil and protein yields than traditional crops [28]. The resulting biomass offers various applications, such as food, feed, biofuels, pharmaceuticals and chemicals [4].

Tourism, as mentioned above, is the second most important sector in the structure of the local economy after agriculture. The tourism endowments of the area further reinforce the inter-linkages and inter-dependencies of the WEF nexus. The main tourist resources are: the Shabla lighthouse, described in the opening section of the article, the overpass at Cape Shabla, the Shabla tuzla with reserves of 230 000t of healing mud, the archaeological sites (the ancient fortress near Shabla, the prehistoric necropolis near Durankulak, the sanctuary of the goddess Cybele at The large island of Lake Durankulak and etc.), the 40km long beach, the beautiful dunes, the rock formations along the coast and in the water area, creating conditions for the development of specific tourism - diving, underwater fishing, the thermal mineral springs, the presence of wetlands (Shablensko, Ezeretsko and Durankulashko) characterized by unique plant and animal species. A condition for the sustainable development of the area is the ecologically

clean and preserved territory with a distance of up to 15km from the sea coast to the interior of the land and the possibilities for the development of rural tourism. The implementation of various tourist activities is related to the direct and indirect use of water, energy and food resources. At the same time, the tourism industry is a source of additional income in the area and engages labor. The study area has the potential to attract tourists in all seasons of the year.

Challenges and recommendations

As a result of the analysis of the possibilities of applying the WEF nexus concept in the model study area, through the protection and restoration of key and supporting objects, the following challenges and recommendations for resolution can be outlined:

- a threat to the normal functioning of ecosystems and people's health is the contamination of groundwater due to various reasons;
- it is imperative to build new, repair and replace old water pipes, as well as additional water reservoirs for accumulating water quantities,
- lack of sewage systems in the majority of the municipality and the practice of discharging wastewater into septic tanks;
- pollution of the coastline, both from tourist activities and from episodic illegal discharge of oil, oil products and bilge water from passing by ships;
- solving the problem with taking arable land for the construction of wind and photo generators;
- priority completion of the Shabla flyover, rational and sustainable preservation and restoration of key sites in the area – the Shabla lighthouse and the medieval fortress of Karia etc.

Conclusions

The model study area provides good opportunities for potential application of the WEF nexus concept. The municipality of Shabla has all the resources of the nexus and for some of them the preservation and restoration as conservation processes proved to be of crucial importance for the sustainability of the region. As in other areas, here too political and economic interests collide with the objectives of the WEF nexus and the concept of sustainable development. In the context of respecting the social, cultural, economic and environmental aspects, it is necessary for managers, scientists and stakeholders to collaborate between sectors and disciplines, to identify synergies and trade-offs and to develop and implement innovative solutions in order to optimize the distribution and use of the resources in the nexus.

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