UDC - 53.043:620.91

THE USE OF WIND POWER AND THE CONVECTION EFFECT OF AIRFLOW IN THE ENERGY SECTOR

Mher V. Markosyan
Yerevan Telecommunication Research Institute CJSC
26, Dzorapi str., Yerevan
e-mail: mark@yetri.am
ORCID iD: 0000-0003-1972-5266
Republic of Armenia

Hrant.H.Ayvazyan
Yerevan Telecommunication Research Institute CJSC
26, Dzorapi str., Yerevan
e-mail: hrant_ayvazyan@yahoo.com
ORCID iD: 0009-0009-5223-6238
Republic of Armenia

https://doi.org/10.56243/18294898-2026.4-32

Abstract

This article examines trends in the development of technologies for harnessing wind power for human benefit, ranging from ancient sails and windmills to modern generators, which—for economic efficiency—are grouped into onshore and offshore wind farms and are increasing their share of the global energy balance year by year. At the same time, the article examines the growing environmental problems that are being pushed into the background due to humanity's urgent need for renewable energy sources. From this perspective, the article reviews the stages of development of convection-based energy generation methods, which are characterized by high environmental performance. Several methods for increasing the efficiency of "solar tube" technology are proposed; an analysis of the properties of its new design is conducted based on computer modeling; and a comparison with existing technologies is carried out.

Keywords: renewable energy sources, wind turbine, onshore and offshore wind farms, solar trough in the energy sector, solar tower.

Introduction

Humans have known about the destructive power of the wind since the earliest days of their conscious existence—the wind toppled the huts in their settlements, uprooted trees, and whipped up waves at sea. It was not until the fourth millennium B.C. that people learned to harness the wind for their own benefit. The oldest depiction of a sailboat was found on an Egyptian vase dating back to 3500 B.C. The Egyptians took advantage of their region's unique geography: ships sailed north along the Nile's current to the Mediterranean Sea, and returned by traveling upstream, propelled by a tailwind that blew steadily from the north into

the sun-warmed African continent. It should be noted that the technique of utilizing tailwinds, characteristic of the use of "straight" sails, persisted for several millennia in both river and maritime navigation, the latter of which became extremely widespread.

However, it was precisely on such ships—equipped with several rows of oars and using sails only when sailing with the wind—that the Phoenicians not only explored the entire Mediterranean Sea but also ventured into the Atlantic and circumnavigated Africa. The square sail remained in use during the period of Greek dominance at sea. Several centuries later, Rome began to travel and wage war under this sail, while also establishing great trade routes. It was not until the 8th century that the wind came to fully serve seafarers, with the invention of the "gaff sail," which allowed ships to sail at an acute angle to the wind. This sail, combined with the use of oars, was skillfully employed by the Vikings, who gave a powerful impetus to the development of medieval civilization. Shipbuilding abandoned oars and switched entirely to wind power only in the 15th century, when the Portuguese caravels—famous for Columbus's voyages—began to be built.

The idea of using wind for mechanical work on land emerged much later than the sail. However, over the centuries, this idea came to be used not only for grinding grain, but also for pumping water, powering sawmills, in cloth manufacturing, and in other industrial applications. The first windmills were built in Central Asia in the 8th century and later spread to China and India. They did not appear in Europe until the 12th century, and by the 17th century had been significantly improved in the Netherlands, where there was an urgent need to continuously pump water from land reclaimed from the sea and where a method was developed to orient the blades toward the wind to increase efficiency. In the late 18th century, mechanisms were invented in Great Britain and France that automatically adjusted the blade area to the wind speed.

In the 19th century, the use of windmills declined significantly due to the invention of the steam engine and electric motors. However, it was during this period that the idea arose to convert windmill mechanisms into devices for generating energy. The world's first wind turbine was built in Cleveland (U.S.) in 1888 and had a diameter of 17 meters and a capacity of 12 kW. Since then, over the course of less than 140 years, the wind energy sector has demonstrated remarkable growth—between 2015 and 2025 alone, wind energy generation tripled and accounted for 12% of the global energy mix [1]. However, as our understanding of how wind turbines operate has deepened, undesirable environmental impacts have begun to emerge; some of these are already evident, while the cumulative effects of others will become apparent many years from now, by which time significant sums will already have been spent on their widespread construction.

From this perspective, it seems advisable to investigate the potential for generating electricity from the convective energy of air currents, which is based on the same process of the sun heating various surfaces—a process that gives rise to such a common phenomenon as a horizontal wind. However, the convective flow moves vertically, which requires different methods for converting its energy into electricity; this makes it possible to develop designs using turbine-type wind generators and move closer to the concept of absolute environmental sustainability.

Trends in the Development of Offshore and Onshore Wind Farms

The most powerful impetus for the accelerated development of wind energy came in the 1950s with the invention of three-bladed horizontal-axis turbine designs and the development of an improved aerodynamic profile for blades cast from lightweight composite materials. Since 2000, the wind energy sector has been marked by a sharp increase in the pace of innovation, rising from 2,000 patents per year to 9,000 patents by 2016 and up to 14,000 patents by 2025. Over the 10-year period from 2015 to 2025, 169,822 patents for wind turbines and wind power plants were granted worldwide [2]. As a result, by 2000, wind turbines with a rotor diameter of 50 m and a capacity of 1 MW had entered mass production, and by 2010, the capacity of the turbines had increased to 3 MW with a diameter of 100 m. In 2025, turbines with a rotor diameter of 250 m began to be commissioned, and the capacity of a single wind turbine reached 16 MW.

This rapid pace of development in the wind energy sector began to reveal certain trends driven by economic feasibility. As wind turbines grew in size, the challenges of transporting their components to the assembly site increased year by year. Transporting a 100-meter blade along winding roads seemed practically impossible. This necessitated the construction of special roads and access routes to each wind turbine, which increased the overall cost of construction. An obvious solution to this problem was to select sites for wind turbines where they could be installed in large groups, requiring only a single access road. A similar situation arose with regard to the transmission of generated energy—a single wind turbine required a separate substation and kilometers of cables to connect to the main grid. In a wind farm, hundreds of turbines can be connected to a single powerful distribution substation, which drastically reduces energy logistics costs. Maintenance of a wind farm, calculated per unit of capacity, is significantly cheaper compared to sending a team of specialists to individual wind turbines, especially considering the need to transport specialized equipment—such as heavy cranes, forklifts, and other machinery—to each one.

The world's first wind farm was built in the U.S. state of New Hampshire in 1980 and consisted of 20 wind turbines, each with a rotor diameter of 12 meters and a capacity of 30 kW. The power plant demonstrated the high efficiency of the wind farm concept and dramatically increased interest in wind energy, especially against the backdrop of the oil crisis of the 1970s. Wind farms began to be built everywhere, and the diameter and capacity of the turbines increased year after year (Fig. 1). The "Alta" wind farm, built in California in 2014 [3], already comprised 586 wind turbines with rotor diameters ranging from 90 m to 100 m and an average capacity of 1.5–3 MW each. The total capacity of the power plant was 1,548 MW. Capital expenditures, driven by economies of scale, reached a record low for that time of $1,870 per 1 kW of rated capacity. It should be noted that the capital costs for installing a single wind turbine—which stood at $5,600 per 1 kW of capacity in 1990 and had been steadily declining by an average of $100 per year—had reached $3,200 per 1 kW of capacity by that time [4]. However, China leads the way in this area thanks to its large-scale,



Fig. 1 Onshore wind farms consist of thousands of turbines.

well-established wind turbine manufacturing industry, whose capacity not only meets the country's own needs but also enables China to participate in 72% of wind projects under construction worldwide [1]. A prime example of this is the "Zhangjiakou" wind farm, which was built in 2022 to provide "green" energy for the Winter Olympics. The wind farm consisted of 5,300 turbines with rotor diameters ranging from 140 m to 165 m and an average capacity of 2.5–6 MW. The wind farm's total capacity was 21.2 GW, and capital costs amounted to $1,270 per 1 kW of capacity, which was due to the exclusive use of domestic production resources.

At the same time, the concentration of a large number of wind turbines at a single site requires compliance with specific technical standards related to the properties of the composite material used in the blades and their failure due to aging or casting defects. If a blade breaks, its rotational inertia causes it to fly hundreds of meters and potentially damage neighboring wind turbines, triggering a so-called "domino effect." Consequently, a minimum permissible distance between wind turbines has been established, which, according to standards in various countries, ranges from 5 to 10 times the turbine's rotor diameter. Taking this distance into account, the "Zhangjiakou" wind farm covers an area of 3,500 square kilometers, which, when calculated in terms of generated power, amounts to 60 kW per hectare. It is interesting to note, however, that solar panels convert only 15–22% of the solar energy reaching their surface into electricity, and each hectare of the Earth's surface receives 10 MW of solar energy, based on the standard test value for solar panel irradiance of 1,000 W/m². Consequently, a solar panel can generate approximately 1,800 kW of power per hectare, which is 30 times more than a wind farm.

However, in the real-world context of constructing solar power plants, there are also technical standards governing the distances between solar panels, which are dictated both by the need for maintenance aisles and by the "shading" effect on neighboring panels. Consequently, the efficiency of land use for solar power plants is significantly reduced; this is also due to the fact that daily insolation starts and ends at zero and reaches its maximum at noon only in equatorial regions. For example, the "Bhadla" solar power plant (India) generates 2,245 MW of power over an area of 56 square kilometers, which corresponds to a land-use efficiency of 400 kW/ha, while the "Tengger" power plant (China) generates 1,547 MW of power over an area of 43 square kilometers (360 kW/ha), which is nonetheless

six times higher than the figure for the "Zhangjiakou" wind farm (60 kW/ha). This pattern is also observed at other well-known wind farms—the 240 turbines at the "Fantanele-Cogelac" wind farm (Romania) cover an area of 120 square kilometers and generate 600 MW of power, which corresponds to a land-use coefficient of 50 kW/ha, while at the "Markbigden" wind farm (Sweden), 1,101 turbines are located across an area of 460 square kilometers and generate 2,007 MW of power (45 kW/ha). Consequently, wind farms are far less space-efficient than solar power plants, which is a significant drawback that is most pronounced in densely populated European countries. For this reason, wind farms are most prevalent in countries with large uninhabited or desert areas, such as the United States, India, China, Australia, Latin American countries, and Central Asian countries.

This distinction among countries based on the feasibility of constructing wind farms on their land became the main driving force behind the trend of moving wind farms out to sea, a move whose feasibility was also dictated by a number of technical considerations. The steady increase in turbine size year after year complicated the process of delivering them from the manufacturer to the customer's site, while offshore wind farm construction technology made it possible to build shipyards for manufacturing the most bulky turbine components, such as blades, right on the shore and transport them unimpeded to the installation site on special vessels (Fig. 2). It was precisely this that made it possible to install wind turbines with the aforementioned rotor diameter of 250 m and achieve capacities of 16 MW. In addition, offshore winds are significantly stronger and more consistent, as they are not obstructed by hills, forests, or ravines. Consequently, the capacity factor for offshore turbines reaches 45–55%, whereas for onshore turbines, a good result is 30–35% [5].



Fig. 2 An offshore wind farm and the construction process.

The first offshore wind farm, "Vindeby," was built in Denmark in 1991 and consisted of 11 wind turbines, each with a capacity of 450 kW. The project was experimental in nature; to study how the turbines would perform in salt-laden sea air, their housings were sealed, and air conditioners were installed inside to maintain stable humidity and temperature levels. After 25 years of stable operation, the wind farm was dismantled in 2017 for research purposes and to be replaced with more advanced wind turbine models. The experience gained from its construction and operation served as the foundation for the rapid development of offshore wind energy. As early as 2019, construction began on the Hornsea wind farm (United Kingdom), which consisted of 339 wind turbines with an average capacity of

7–8 MW and rotor diameters ranging from 154 m to 167 m [6]. The wind farm covered an area of 869 square kilometers and generated 2,604 MW of power, which corresponded to a land-use coefficient of only 30 kW/ha—half that of onshore wind farms—but was justified by the use of vast offshore expanses. At the same time, capital expenditures of $4,000 per 1 kW of capacity reflected a natural increase in the cost of constructing offshore wind farms compared to onshore ones. This was primarily due to the use of expensive, marine-corrosion-resistant materials in all structural components, the high cost of constructing platforms for installing wind turbines—whose foundations were driven into the seabed at a depth of 40–60 meters—and the expensive cables used to transmit energy to shore, which were equally costly to lay along the seabed. However, all these costs were offset by high energy generation from strong offshore winds and the conservation of vast land areas, which contributed to increased interest in the construction of offshore wind farms in all countries. The “Hai Long” wind farm (Taiwan), completed in late 2025, utilized turbines with a diameter of 222 m and a capacity of 14 MW each. These turbine specifications made it possible to generate 1,044 MW of power on just 150 square kilometers (70 kW/ha) and significantly increase land-use efficiency compared to “Hornsea.” The more advanced technology of 2025 also made it possible to slightly reduce capital expenditures, which amounted to $3,735 per 1 kW of capacity.

However, the further development of offshore wind energy was hindered by the variability of the seabed topography—over time, it became difficult to find areas sufficiently far from the adverse effects of the coastline that had a seabed depth of no more than 60 meters, within the technical limits of driving piles into the seabed. This served as the driving force behind yet another trend in offshore wind energy—the installation of wind turbines on floating platforms, which could be transported far out to sea and anchored to the seabed. The first experimental prototypes using this method began testing as early as 2009 [7], and it was not until 2017 that the world’s first offshore wind farm on steel “semi-submerged” platforms, “Hywind Scotland” (Fig. 3), and as early as 2023, the “Hywind Tampen” wind farm was built in Norway “Hywind Tampen” (Fig. 4) was built in Norway, in which the wind turbines were mounted on hollow reinforced concrete “floats” 18 m in diameter and 107 m long, 90 m of which were submerged.

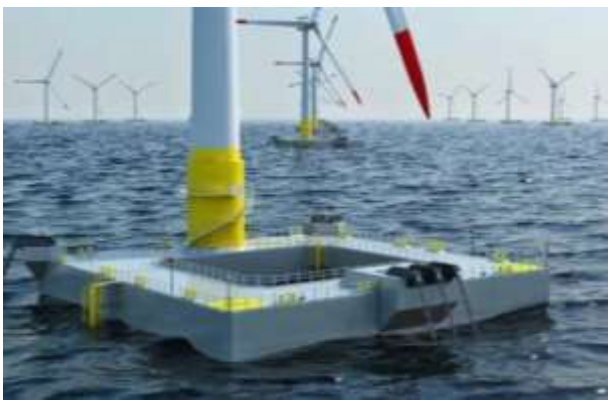

Fig. 3. A wind farm on floating platforms.



Fig. 4. A wind farm on floating buoys.

The obvious technical advantages of this method have inevitably affected the cost of wind farms. Capital investments in the construction of wind farms with fixed towers driven into the seabed average $4,000 per 1 kW of capacity, while the new technology currently costs significantly more—ranging from $6,000 to $8,000 per 1 kW. This is primarily due to the current lack of mass production, complex mooring systems, a sharp increase in the length of the cables connecting to the shore, and the extremely high material intensity of floating platforms compared to standard towers. A modern offshore wind turbine weighs 1,000–1,600 metric tons, with its center of gravity located at a height of 150–200 meters; given the wind pressure on the blades—which enables the generation of 10–16 MW of power—this creates a colossal overturning moment. Therefore, to ensure the platform's stability, its weight must be many times greater than that of the wind turbine itself, and its center of gravity must be located at the lowest point of its structure in the form of ballast. By comparison, fixed supports (Fig. 2) weigh 600–1,500 metric tons, a floating steel platform (Fig. 3) weighs 3,000–5,000 metric tons, while a reinforced concrete "float" weighs as much as 10,000–20,000 metric tons (Fig. 4), since its stability is achieved through the weight of ballast in its lower section, rather than through the width of the steel platform's base. The decision to use concrete was driven by its resistance to deterioration in the corrosive marine environment—tests have shown that concrete breakwaters last up to 100 years without any maintenance. Also of great interest is the highly expensive technology used to manufacture the "floats"—concrete is poured into "sliding" formwork directly at sea on special platforms and lowered into the water as it sets.

The remarkable technological advances in wind energy and the ever-increasing global demand for electricity are overshadowing the multifaceted spectrum of environmental problems that grows with each passing day, the dominant effects of which will be scientifically studied only with a further expansion of the research base and presented to the governments of leading countries by the time it is already impossible to abandon this form of energy generation. Turbulent air flows, as they exit contact with the blades, generate infrasound at a frequency that is highly harmful to humans and animals. It travels for many kilometers and, unlike frequencies in the audible range, has a high penetrating ability—neither the walls of houses nor the ear protection worn by maintenance personnel can shield against it. It causes headaches, dizziness, nausea, and a general feeling of malaise [8]. This makes it impossible for people to live near wind farms or to graze livestock beneath them; in addition to the effects of infrasound, the livestock are also frightened by the shadows cast by the blades, which reduces milk yield and overall weight. Vibrations from the turbine mechanisms are transmitted through the support structures to the ground, scaring away snakes and rodents, which leads to the proliferation of pests; as a result, any crops grown beneath wind farms are completely destroyed. Therefore, wind farms are built only in desert areas or in areas that soon become desert-like (Fig. 1). It is regrettable to note that this also applies to offshore wind farm areas, with the sole difference being that the absence of visible changes on the sea's surface masks the destructive impact of wind turbines on the life of seabed inhabitants, and vibrations from the towers travel through the water for tens of kilometers, causing precisely those higher marine mammals—which possess echolocation and the ability

to communicate with one another through sound—to be washed ashore in large numbers. Wind turbines also pose a danger to birds—American scientists from the wildlife protection service have determined that in just one year, wind turbine blades killed 440,000 birds, and this figure will continue to rise. Among the slowly emerging threats is the fact that the composite materials used in the blades cannot be recycled at the end of their service life, and by 2050 we will have to address the problem of disposing of approximately 40 million metric tons of end-of-life blades [8], a practice that progressive countries such as Austria and Germany have already banned by law within their territories.

Development of "Solar Tube" Technology

Power plants that use the "solar tube" concept operate on a principle similar to that of wind turbines—generating energy from airflow—but are more environmentally friendly because they do not produce infrasound, mechanical vibrations, or industrial waste that requires disposal or landfill. Such a power plant requires an area of several hundred hectares, covered with glass or transparent plastic at a height of 2–3 meters, which creates the power plant's collector heating zone. The air heated by the sun rises and is drawn into a pipe located in the center of the collector, at the base of which a turbine is installed to generate energy. This design eliminates the possibility of harm to birds within the power plant's operational zone, thereby addressing the aforementioned drawback of wind power plants and bringing performance closer to that of hydroelectric power plants, which are completely environmentally friendly. The use in such power plants of a tube that concentrates the kinetic energy of air masses from the entire collector area defines the unique characteristics of these power plants. Multi-bladed turbine-type wind generators are installed inside the tube; these operate at significantly higher wind speeds than traditional three-bladed wind turbines. The resulting higher rotational speeds eliminate low-frequency vibrations, and the design of the turbines—which do not exceed 10 meters in diameter—allows them to be manufactured entirely from metal, which not only increases their durability but also ensures that the equipment's depreciation processes are waste-free.

The first recorded use of rising air currents in history was achieved by Leonardo da Vinci as far back as 500 years ago. His "smoke rotisserie" used a gear system to rotate an animal carcass over a fire by turning a wheel with blades attached to it inside the chimney. It was not until 1896 that a patent was officially granted for a "convection mill"; a model of this mill, built in 1919 by the company "Albert Holmes & Son," is on display at the Science Museum in London. The device was a kind of "thermal engine," whose blades were set in motion by the heat flow generated by a gas burner, a lamp, or a candle. The design was intended primarily to demonstrate the phenomenon of convective flows and for use in relatively large devices; however, it later became popular in Christmas pyramids, where the heat from candles caused the figurines to move in a circle.

Between 1931 and 1981, numerous patents were filed for industrial-scale solar-powered convection power plants, and it was not until 1982 that a prototype of such a power plant was built in Manzanares (Spain) [9]. The project was funded by the German Federal Ministry of Research and Technology (BMFT); construction cost 5.6 million German marks, which at today's exchange rate would amount to $4.5 million. The diameter of the

plant's heat-collecting tube was 244 m, corresponding to an area of 4.7 hectares; the tube was 195 m high and 10 m in diameter (Fig. 5), providing an output power of 50 kW. The power plant had a very low efficiency—only 0.5 percent—meaning that only 1/200th of the solar



Fig. 5. A solar tower in Spain and a view of it through the collector's transparent roof.

energy reaching its surface was converted into electricity. As noted above, solar panel power plants generate an average of 400 kW of power per hectare of surface area. Consequently, if the surface area of the Mansanares power plant were used to install solar panels, it would produce 1.88 MW of power—which is incomparably greater than its rated 50 kW and underscores the unprofitability of using the surface area for this method of energy generation. This explains why the power plant was not rebuilt after the severe storm in 1989 that toppled its chimney, which was constructed from steel sheets only 1.25 mm thick and held in place by tension rods that were not protected against corrosion.

Further development of this technology was marked by a number of unfinished projects. In 2010, the first phase of such a power plant, generating 200 kW of power, began operating in the desert area of Jinshawan Beach (China). By 2013, the plan was to make capital investments totaling $208 million and generate 27.5 MW of power on a 277-hectare site. The project's estimated figures correspond to construction costs of $7,600 per 1 kW of capacity (40% higher than the record-high figures for nuclear power—$5,500 per 1 kW of capacity), and the land utilization coefficient is 100 kW per hectare, which is four times lower than that of solar panel power plants. Consequently, the project was discontinued after the collector glass cracked due to incompatibility with the thermal expansion coefficient of the steel frames into which it was inserted.

In 2001, the Australian company "EnviroMission" announced the start of construction of the "Solar Updraft Tower" in Burunga, with plans to build similar power plants in Texas and Arizona in the future. The company's experts calculated that for a rated capacity of 200 MW, the collector's radius would need to be 7 km (3,847 hectares), and the tower's height 1,000 m—which was necessary to achieve sufficient draft due to the large difference in

atmospheric pressure between the tower's top and bottom. However, the land-use efficiency was half that of the Chinese project—50 kW/ha. The estimated cost of the project was $1 billion, which corresponded to a capital investment of $5,000 per 1 kW and was comparable to that of nuclear power. Although the project was never implemented, it is notable for the engineering innovations it involved in addressing the challenges of constructing a 1,000-meter-tall pipe. Australian experts proposed placing such a pipe on a mountainside and using it as a support, thereby resolving the issues of the pipe's stability and the high cost of its construction. However, even in this version, the "solar tube" project was not implemented due to a number of technical reasons—airflow resistance increases sharply in an inclined tube. Furthermore, both inclined and vertical tubes require perfect thermal insulation, which entails corresponding costs, since as the air moves away from the collector, it begins to cool and the draft decreases. Mountains with suitable topography may be located far from major cities and in hard-to-reach areas, making the delivery of construction materials and equipment there very expensive. From this perspective, the use of solar panels appears significantly more cost-effective, especially given that, following the invention in 1980 the development of thin-film solar cells in 2010, this technology has accelerated its growth, and over the past 10 years, the cost of its products has fallen by 80–90%.

"Solar Tower" Technology

Nevertheless, "solar tower" technology retains its environmental appeal compared to solar panel technology, which—despite all its noted comparative advantages—has a highly harmful production cycle [10] and unresolved issues regarding the disposal of panels at the end of their service life—according to estimates by the Foundation for Environmental Education (FEE), by 2050 the mass of discarded end-of-life panels sent to landfills worldwide will total 160 million metric tons. Therefore, the Armenian University of Architecture and Construction has developed several technical improvements to solar tube technology [11] that increase its efficiency and reduce construction costs, which could make it competitive in the global energy market, given its high environmental sustainability. The new design (Fig. 6) is notable in that each of the proposed technical solutions can be used on any scale in the construction of power plants, regardless of whether the others are appropriate for the application.

The first design improvement is achieved by considering the movement of air beneath the collector, where it is drawn in unimpeded and only then gains the energy needed to move upward and spin the turbine. Consequently, the kinetic energy of the air entering beneath the collector can be fully converted into electricity if the entire perimeter of the collector, down to its base, is enclosed by a casing made of the same material as the turbines (Fig. 6)—the collector's size has been significantly reduced for a clear illustration of all structural elements. With a central pipe diameter of 10 m, the collector must contain 12 turbines, each 3 m in diameter, so as not to restrict the flow of air into the central pipe. In this case, the same volume of air that is drawn into the central pipe will pass through the collector's turbines; therefore, the total power they generate will correspond to the power of the central pipe, thereby doubling the power plant's output without increasing its footprint. It should be noted that the power plant will operate more efficiently if the collector's surface has at least a slight

slope toward its center, since if it is positioned horizontally, the heated air will expand in all directions and be partially forced back out of the collector. The power plant's performance can also be improved by using well-known methods of solar energy storage—if the ground beneath the collector is covered with metal shields, which have a higher solar energy absorption coefficient than soil or desert sand. The power plant's efficiency will increase even further if tanks containing water or vegetable oil are installed beneath the shields, since the heat accumulated by the ground cannot sustain round-the-clock operation of the power plant, as its builders claim.

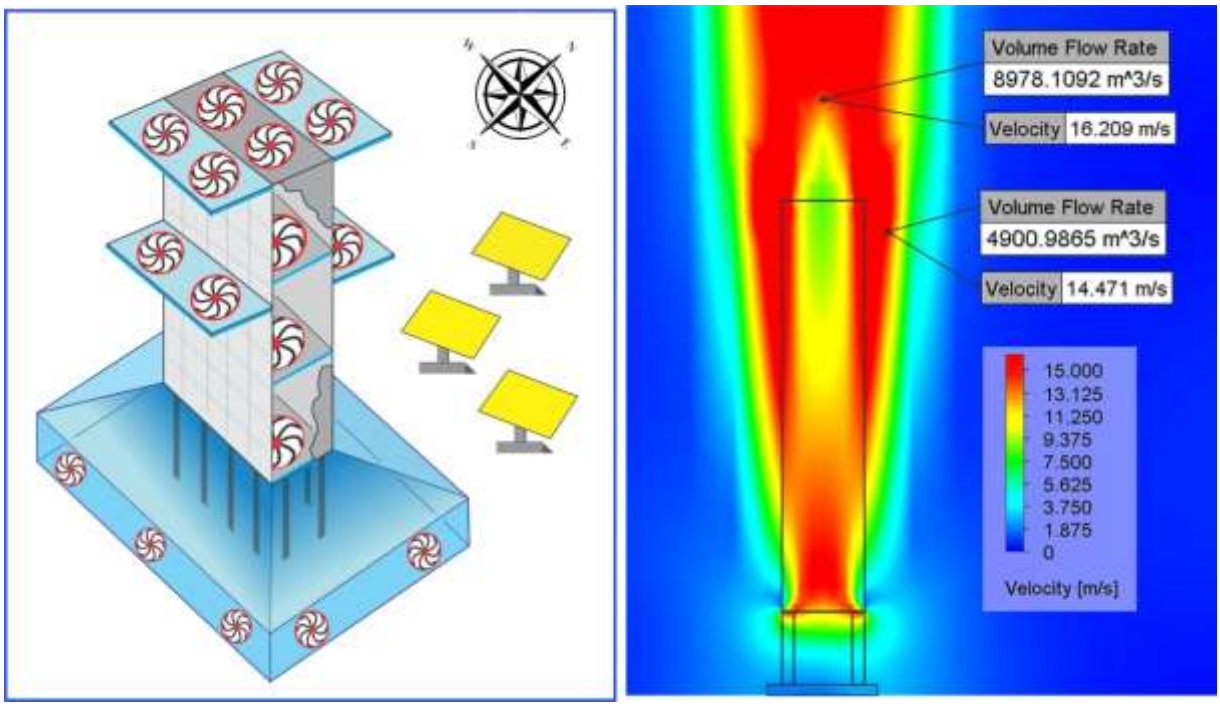

Fig. 6. A solar tower and its computer model (cross-section from the east).

The next improvement to the "solar tube" technology aims to eliminate a drawback caused by the air cooling as it moves upward through the tube, which reduces the draft within it. In the simplest case, this can be avoided if the tube's design allows it to be heated by the sun; to achieve this, it must be made of a heat-absorbing material and shaped like a polyhedron, with each face becoming very hot when oriented perpendicular to the sun and transferring heat to adjacent faces. For full-scale implementation of this technology, the pipe must be replaced with a rectangular tower made of heat-absorbing material, with its wide side facing south; this tower may also be designed to allow for additional heating of its northern wall using heliostats (Fig. 6). Such a design will not only maintain the temperature in the pipe generated by the collector but will also generate an updraft itself, in accordance with the phenomenon—common in the architecture of large cities—of hurricane-force winds forming at the base of skyscrapers, caused by an updraft of air along their facades, which are heavily heated by the sun. Computer simulations of solar heating of the Bridgewater Place skyscraper (England), which is 112 m tall and 80 m wide [12] , show that at noon on June 22 (the summer solstice), it heats up to 73^0C and generates an updraft with a speed of 11 m/s and a

power of 830 kW, resulting in winds with speeds of 20–30 m/s forming on the streets near the skyscraper.

A study of the potential industrial applications of this physical phenomenon [10] shows that 3-mm-thick AD1 (1050) aluminum panels, when coated with Thurmalox 250 selective paint—which reduces the thermal emissivity coefficient—can heat up to 200^0C, while a vertical surface measuring 100 × 100 m (1 ha), when heated by the sun to 100–130^0C, generates an updraft with an average power of up to 2 MW during both the winter and summer seasons. Computer modeling of the central tower in the structure shown in Fig. 6, clad with 3-millimeter panels heated by the sun to 130^0C, shows that their uniform heating throughout their entire thickness contributes to the formation of the noted airflow both on the tower's outer surfaces and inside it. Such a structure not only makes it possible to install turbines on both sides of each wall but also allows them to be installed along the entire height of the tower, since the air, after exiting each turbine, gains additional energy from the heated wall and accelerates its upward movement.

The calculations based on the computer model of the tower were performed assuming a height of 100 m, a width of 50 m, and a distance between the walls of 20 m. A gradient of decreasing air temperature with increasing distance from the tower walls was entered into the simulation program; measurements based on the computer model of temperature distribution within the tower show that within a distance of 40 cm from the walls, the average temperature is 125 ^{0}C. Calculation results for this temperature value and the averaging zone show that an updraft with a power of 1.44 MW is generated in the central part of the tower, while on the outer side of the walls, an updraft with a power of 0.65 MW is generated (the kinetic energy of the airflow, given the known air density and the values of velocity and volume of the updraft measured on the model). Thus, the proposed design (even without a collector) generates three updrafts with a total power of 2.74 MW, which—taking into account the Betz limit (59.3%), corresponds to an output power of 1.62 MW and is 32 times greater than that of the solar tower in Manzanares (50 kW over an area of 4.7 hectares). This design utilizes two vertical surfaces measuring 100 × 50 m with a total area of 1 hectare, which—based on the standard test value for solar panel irradiance of 1,000 W/m²—corresponds to an efficiency of 16.2%. This falls within the efficiency range of solar panels; however, the design in question possesses the aforementioned high environmental performance characteristics of a "solar tube" and provides a 10-fold saving in land area, since its active surfaces are arranged vertically and occupy an area of only 0.1 hectares (20 × 50 m).

Thus, replacing the "passive" solar tube design with a "solar tower" that generates its own updraft lays the foundation for a new direction in the energy sector, allowing power plant capacity to be scaled up by adding stories—similar to skyscrapers—thereby conserving urban land. A particularly interesting challenge is determining the optimal distance between turbines, which will ensure the multiple utilization of the updraft's power—a power that will be replenished at a rate dependent on the turbines' power, the tower's temperature, and its cross-sectional area. A solution can be found both experimentally and through the use of specialized computer simulation software, which will significantly increase the output power of power plants designed on this principle compared to the calculated values of the tower's

updraft at its upper cross-section. This is precisely the fundamental difference between the proposed design and the "solar tower" in Manzanares, which allows for only a single heating of the air in the collector area and is described by the simplest chimney formula—the application of which is no longer valid for the case under consideration, involving additional heating of the chimney along its entire length, which requires a fundamentally new analytical method. The mode of autonomous generation of an updraft in the tower makes it possible to significantly reduce the size of the collector, limiting its purpose to the function of pre-drawing in, from all adjacent areas, volumes of air sufficient for the effective operation of the turbines in the tower.

A computer model of temperature distribution on both sides of the tower shows that as the air moves away from the walls, which are heated to 130^0C, the temperature begins to drop and reaches ambient temperature at a distance of 8–10 m from the walls. At the same time, the average temperature inside the tower is 58.60^0C, and on the outer surface of the walls it is 46.30^0C, which broadens the range of turbine options based on their maximum operating temperature. The low operating temperature of the proposed design allows for the use of a significantly smaller number of heliostats than in the "Gemasolar" tower-type solar power plant in Spain [13], where 2,650 heliostats heat water to a temperature of 600^0C, sufficient for operating steam turbines. In this design, however, the energy of the rising flow is directly converted into the rotational energy of the turbines without multiple energy conversions in steam turbines. Another comparison with "Gemasolar" is particularly interesting if the tower shown in Fig. 6 were scaled to the dimensions of the plant in Manzanares—a tower height of 195 m and a collector diameter of 244 m.

This structure will consist of two vertical surfaces, each measuring 195 × 244 m, spaced 20 m apart and aligned along the central axis of a base with a diameter of 244 m and an area of 4.7 hectares, the southern portion of which will be reserved for the collector, and the northern portion for the heliostats. Simulations using a computer model of this structure show that it generates three updrafts with a combined capacity of 15.4 MW, which is comparable to the capacity of the "Gemasolar" plant (19.9 MW), located on a 185-hectare site. This represents a 10-fold increase in land-use efficiency, with the potential to further increase capacity by accounting for the preheating of air in the collector and installing multiple tiers of turbines within the tower, all within the same area.

This comparison can be extended to solar panels, which, as noted above, generate 1.88 MW of power from an area of 4.7 hectares—8.2 times less than the power output of the structure under consideration (15.4 MW), located on the same site. This allows for a new assessment of the inexhaustible potential of solar energy [14, 15]—to supply the entire planet with electricity, it would be sufficient to install solar panels across a country the size of Spain (505,994 square kilometers). It is highly symbolic that the scientists' calculations were performed specifically for the country that was the first to build a "solar tube"; however, the comparison provided shows that "solar towers" could supply all of humanity with energy if they were installed on an area just one and a half times the size of Switzerland (41,290 square kilometers). Consequently, the proposed "solar tower" technology is many times more efficient than all known "solar technologies"—solar panels, solar towers, and tower-type solar

power plants. In addition, this technology could pose serious competition to traditional wind turbines, since the turbine-type generators it uses are completely environmentally friendly [10], and the tower's design allows it to generate its own airflow for the turbines on any terrain, regardless of its "wind rose." The construction of such power plants and the subsequent maintenance of their internal turbine structures—with a diameter of no more than 10 m and metal components—will be incomparably cheaper than working at heights of 100–200 m with modern wind turbines that have blades up to 120 m long.

Thus, "solar tower" technology—which is based on the unconventional "solar tube" technology—has the potential to compete effectively in the global energy market, which justifies the need for scientists to conduct comprehensive research on it in order to maximize its technical performance and develop methods for constructing power plants.

Conclusion

The rapid growth of the wind energy sector is the dominant factor driving its integration into economically viable onshore and offshore wind farms and the development of increasingly advanced offshore turbine designs. At the same time, there is a clear and growing threat of environmental problems—wind turbines generate infrasound and low-frequency vibrations that are hazardous to humans and animals, making it impossible for people to live within tens of kilometers of wind farms, as well as for livestock grazing and agricultural activities in these areas. Assessing the destructive impact of offshore wind farms on the ocean's ecology is complicated by the specific nature of deep-sea research, and its consequences will only become apparent in the future, when it will be impossible to abandon this form of energy. From this perspective, convection-based energy generation methods appear to be significantly more environmentally friendly, although they have not yet been sufficiently developed due to their low efficiency. The methods proposed in this article for improving "solar tube" technology allow for a significant enhancement of its technical characteristics. Furthermore, computer modeling of the "solar tower" reveals a number of advantages over other "solar" technologies and, in particular, a 10-fold increase in surface utilization efficiency due to the ability to increase the power plant's capacity by adding additional floors equipped with turbine-type wind generators.

References

1. Stefan Gsanger. WWEA Half-year Report 2025. // World Wind Energy Association. Nov10, 2025.
2. By Editor. Wind Energy: Patent Landscape Report. // Origin IP Solutions. July 4, 2025
3. By Editor. Alta Wind Energy Center (AWEC), California. // Power Technology. July 15, 2014.
4. Dan Blewett. Wind Turbine cost: how much? // Weather Guard Lighting Tech. Feb 20, 2026.
5. Md Shahrior Tanvir. Comparative analysis of offshore and onshore wind turbines. // Sade Journals.Oct 6, 2025

6. By Editor. First Turbine at Hornsea One Offshore Wind Farm Producing Electricity. // Ocean News and Technology. Feb 18, 2019.
7. Emma Edwards. Trends in floating offshore wind platforms. // ResearchGate. Jan 12, 2024.
8. Sharkovskaya M. Wind turbines are actually harmful and pollute the environment // Arguments of the Week. 23 April 2023.
9. Haaf W. Solar Chimneys. // International Journal of Solar Energy. Apr.20,1983. pp. 141-161.
10. Markosyan M.V., Ayvazyan H.H. Technology for generating artificial wind and its application in energy production. // Bulletin Of High Technology N 1 (37) 2026 - pp. 19-34. https://doi.org/10.56243/18294898-2026.1-19
11. Markosyan M.V., Ayvazyan H.H. Convection Power Plant. // Patent AM 1066Y. Priority: April 10, 2026.
12. Markosyan M.V., Ayvazyan H.H. Physical principles of ground-level wind formation at the base of high-rise buildings // Bulletin Of High Technology N 3 (35) 2025.-pp. 65-77. https://doi.org/10.56243/18294898-2025.3-65
13. By Editor. Gemasolar - Concentrated Solar Power.// Power Technology. November 10, 2011.
14. By Editor. Here`s how much of the world would need to be covered in solar panels to power Earth. // Paul McAlister Architects. 29 September, 2015.
15. Steve Clemmer. How Much Land Would it Require to Get Most of Our Electricity from Wind and Solar?// Union of Concerned Scientists. February 22. 2023.

ՔԱՄՈՒ ՈՒԺԻ ԵՎ ԿՈՆՎԵԿՑԻԱՅԻ ԵՐԵՎՈՒՅԹԻ ՕԴԻ ՀՈՍՔԻ ՕԳՏԱԳՈՐԾՈՒՄԸ ԷՆԵՐԳԵՏԻԿԱՅՈՒՄ

Մ. Վ. Մարկոսյան, Հ. Հ. Այվազյան
Երևանի կապի միջոցների ԳՀԻ ՓԲԸ

Հոդվածում դիտարկված են քամու ուժի օգտագործման տեխնոլոգիաները սկսած նախնադարյան արագաստներից և հողմաղաձներից մինչև ժամանակակից հողմագեներատորները, որոնք տնտեսական նպատակահարմարությունից ելնելով, միավորված են ցամաքային և ծովային հողմապարկերում և տարեց տարի ավելացնում են էներգիայի արտադրման բաժնեմասը համաշխարհային էներգետիկ հաշվեկշռում: Միաժամանակ հոդվածը դիտարկում է էկոլոգիական խնդիրների աճ, որոնք անտեսվում են հանրության կյանքում էլեկտրական էներգիայի խիստ անհրաժեշտության պատճառով: Այդ կտրվածքով հոդվածը դիտարկում է էներգիայի ստացման կոնվեկցիոն տեխնոլոգիաներ, որոնք բնութագրվում են բարձր էկոլոգիական ցուցանիշներով: Առաջարկված են նախկինում հայտնի «արևային խողովակի» տեխնոլոգիայի մի քանի կատարելագործում, իրագործված է նրա նոր կառուցվածքի հատկությունների

հետազոտություն համակարգչային մոդելավորման հիման վրա, կատարված է համեմատություն հայտնի տեխնոլոգիաների հետ:

Բանալի բառեր՝ վերականգնվող էներգիայի աղբյուրներ, հողմագեներատոր, ցամաքային և ծովային վետրոպարկեր, արևային խողովակը էներգետիկայում, արևային աշտարակ:

ИСПОЛЬЗОВАНИЕ СИЛЫ ВЕТРА И ЭФФЕКТА КОНВЕКЦИИ ВОЗДУШНОГО ПОТОКА В ЭНЕРГЕТИКЕ

М.В.Маркосян, Г.Г.Айвазян
Ереванский НИИ Средств Связи

В статье рассмотрены тенденции развития технологий использования силы ветра в интересах человека, начиная с древних парусов и ветряных мельниц до современных генераторов, которые в целях экономической целесообразности объединяются в наземные и морские ветропарки и с каждым годом увеличивают свою долю в мировом энергетическом балансе. Вместе с тем статья рассматривает нарастание экологических проблем, которые отодвигаются на второй план в связи с острой потребностью человечества в возобновляемых источниках энергии. В этом ракурсе статья рассматривает этапы развития конвекционных методов получения энергии, технология которых характеризуется высокими показателями экологичности. Предложено несколько методик по увеличению эффективности технологии "солнечной трубы", реализован анализ свойств её новой конструкции на основе компьютерного моделирования, проведено сравнение с известными технологиями.

***Ключевые слова*:** возобновляемые источники энергии, ветровой генератор, наземные и морские ветропарки, солнечная труба в энергетике, солнечная башня.

Submitted on 03.08.2026
Sent for review on 06.08.2026
Guaranteed for printing on 02.11.2026