International Journal of Advances in Engineering and Management (IJAEM)
Volume 8, Issue 02 Feb. 2026, pp: 47-62www.ijaem.net ISSN: 2395-5252

Prospects for the Hybrid Use of Solar and Wind Energy for the Uninterrupted Energy Supply of the Methanol Plant of the State Oil Company of Azerbaijan

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Date of Submission: 01-02-2026 Date of Acceptance: 10-02-2026

ABSTRACT: The present work examines the issue of providing electricity to the Gobustan region of Baku, in particular, through solar and wind energy sources. Detailed information is provided on the role of methanol in industry and in people's lives and its numerous application areas, as well as methods of obtaining methanol, and less environmental pollution when using it. Information on solar and wind energy resources available in Baku is provided in the form of graphic materials and tables. Methods for selecting the energy parameters and types of wind power plants (WPPs) and solar power plants (SPPs) necessary to provide the 4.0 MW demand power of the methanol plant are given. Theoretically, it is determined how many of the 700 kW WPPs existing and operating in Azerbaijan and the largest solar panels currently produced are needed. It has become clear that it is impossible to meet the energy needs of that plant without any advantages by using a separate WPP or SPP. Therefore, it has been concluded that it is more correct to use solar and wind energy in a hybrid way.

KEYWORDS: methanol, methane, natural gas, associated gases, oil and gas industry, synthesis gas, carbon dioxide, solar energy, wind energy, solar cadaster, wind cadaster.

I. INTRODUCTION

It is known that Azerbaijan is a country rich in natural gas reserves, more than 90% of which is methane. A number of chemical products, including methanol, are obtained from methane. Methanol is considered the energy of the 21st century - an environmentally friendly fuel. It should be borne in mind that oil reserves in the world are limited and are being depleted over time. Therefore, methanol is an environmentally friendly and inexhaustible fuel of the future, as well as an irreplaceable raw material. Methanol has an octane number of 130, so it has no negative impact on the environment. Methanol also allows for cleaner combustion of fuel when added to gasoline. Fuel cells created on the basis of methanol operate silently and at relatively low temperatures, and their service life is longer. Methanol is a transparent, colored chemical liquid that is usually obtained from natural gas, or rather methane, and can be decomposed naturally. Synthetic textiles, plastics, household paints, adhesives, foam pillows and pillows, etc. are made from methanol. It is used as a raw material in the production of a large number of industrial and consumer goods, as well as in the preparation of various medicines.

Another important feature of methanol is its indispensable role in the oil industry. Thus, there are a number of problems in the oil industry, which are related to the production and use of methane.

The first problem is the burning of associated gases generated during oil and gas production in flares, which causes the emission of large amounts of greenhouse gases (GHG) and other toxic waste gases into the environment. However, this associated gas can be used as a raw material in the production of methanol. According to the World Bank, 150 billion m^3 of associated gas was burned worldwide in 2019 alone. This is as much as the natural gas imported by Japan and South Korea together that year.

As a result of the burning of associated gases in flares, 350 million tons of CO_2 gas is released into the atmosphere every year, which leads to climate change and very serious environmental pollution. Also, a significant amount of valuable energy resources are wasted, and if this amount of gas were used to produce electricity, then 750 billion kWh of electricity could be produced, which is equal to the annual electricity demand of the entire African contingent.

To eliminate flares, it is sufficient to use small powerful methanol plants. Thus, the use of 102-103 m^3 of associated gas burned in a flare allows you to get up to 1.0÷10 thousand tons of methanol per year, respectively, while the amount of CO_2 gas emitted into the atmosphere decreases by 3.0÷30 thousand tons per year.

The processes of obtaining methanol from synthesis gas or natural gas on an industrial scale are carried out at a temperature of 250-350^{0}C and a pressure of 20-25 MPa, and for this purpose, traditional fuels (Fuel) are used. Therefore, in terms of saving FUE and electricity, as well as in order to prevent the emission of CO_2 and other GHGs into the environment, it was considered more efficient to pay for the energy supply of the methanol plant at the expense of the State Energy and Natural Resources Fund, and the current research work is devoted to this issue [1-3].

Previously, we prepared cadastral data on the existing solar energy [4,5] and wind energy [6-8] resources in Baku. Thus, the daily, monthly and annual amount of solar energy entering 1 m2 of horizontal and inclined planes during the day, month and year, as well as the hours of sunshine, were determined, and the data obtained were presented in the form of tables and graphs. Similarly, for the climatic conditions of Baku, it was studied how the instantaneous wind speed changes at different average monthly speeds, and the results obtained were prepared in the form of graphical materials and tables. Based on the results obtained, it was determined what type and number of WPPs were appropriate to use in order to provide the Methanol Plant with electricity and heat energy continuously and sustainably. Since both the average monthly values of wind speed and the instantaneous wind speed in Baku vary

The methanol plant was built by AzMeCo. An investment of 500 million US dollars was allocated for the construction of the plant. The industrial capacity of the plant is 720 thousand tons of methyl alcohol per year.

The entire production process at the plant is automated. Up to 240 employees work here.

The plant uses ICI technology from the British company Johnson Matthey.

In general, methanol production is the most harmless production area in the chemical

differently in different months, it was concluded that it is not possible to unambiguously solve this problem using WPPs alone, and in parallel, the use of solar energy was considered more expedient. It was shown that it is more appropriate to provide the 4.0 MW demand power of the Methanol Plant through hybrid solar-wind power plants, theoretically, the daily and monthly energy production of each type of power plant was determined, and the results obtained were presented in the form of tables.

II. STATISTICAL DATA ON THE METHANOL PLANT OF THE AZERBAIJAN STATE OIL COMPANY

As in all countries of the world, methanol production is of great importance in Azerbaijan. Therefore, back in 2013, a Methanol Plant was built in the Garadagh district by the “AzMeCo” company, but unfortunately, due to certain financial difficulties, it stopped operating after a short period of operation. Only in 2021, after being purchased by SOCAR for a payment of 476.5 million US dollars, was the plant overhauled and put into operation at full capacity. Currently, the amount of methanol produced by the plant per day has been increased to 1,700 tons. This means 100% production.

SOCAR’s Methanol Plant produced 230.1 thousand tons of methanol between January and May 2022, which is 4.9 times more than the similar indicators of the previous year. According to data as of June 1, 2022, the enterprise has 47.2 thousand tons of methanol reserves in its warehouses. In turn, according to the State Customs Committee, the methanol plant of SOCAR exported 191,678 tons of methanol during the reporting year, which is worth 60.46 million US dollars. During the reporting year, the share of methanol exported by Azerbaijan was 0.39% of total productivity, and 5.05% of total exported petroleum products. Figure 1 depicts a general view of the methanol plant [9-13].

Figure 1. General view of the methanol plant built by the AzMeCo company in the Gobustan region

industry. It has almost no emissions into the atmosphere and sewage. On the contrary, CO_2 gas emitted into the atmosphere from various sources, such as thermal power plants (TPPs) and other facilities, plays the role of raw material during methanol production, and the plant increases its production capacity at its expense. The plant's production capacity was initially 500 thousand tons, and since November of the same year it has been increased to 720 thousand tons. The plant was built in a relatively short period of time - 3 years.

More than 1,000 specialists worked on the construction of the plant, of which 3-5 percent were foreign specialists. During the construction of the enterprise, young workers and engineers were also involved in the work processes, who have already become highly qualified specialists. By the way, many of these people have now been invited to well-known companies, including BP. During the construction of the plant, personnel in various professions were also trained, and this tradition is still being continued.

The plant management plans to open a training center for specialists. Specialists from companies such as Fluor, Emerson (USA), and Johnson Matthey (Great Britain) will be invited to train personnel.

In order to export the manufactured product to world markets, a special terminal for methanol products was built in Georgia by Turkish companies, which is also designed to store 30 thousand tons of methanol products and has the ability to load and unload more than 60 thousand tons of methanol per month. An order has also been placed for the use of 254 tankers for the transportation of methanol [14].

In addition, it is planned to create various new industrial enterprises around the AzMeCo methanol plant to develop the production of consumer goods using methanol as a raw material.

III. ANALYSIS OF THE POSSIBILITIES OF USING SOLAR ENERGY TO PROVIDEENERGY TO A METHANOL PLANT

As mentioned above, the processes of obtaining methanol from synthesis gas or natural gas on an industrial scale are carried out at a temperature of 250-350^{0}C and a pressure of 20-25 MPa, and for this purpose both heat and electricity are used. In this case, as an energy source, combustible materials such as coal, natural gas, fuel oil, etc. or directly electrical energy are used. The total amount of heat and electricity used in the methanol plant is 4.0 MW/h. Along with the gradual depletion of existing combustible materials, their use causes excessive pollution of the atmosphere near the ground. Therefore, since it is of interest to pay for the 4.0 MW of energy required for the methanol plant at the expense of SPP and WPP, these issues are considered in detail below.

To obtain large quantities of methanol, the method of synthesizing carbon monoxide with hydrogen gas is used. For this purpose, synthesis gas obtained from wood waste or natural gas is usually used, which is also of great importance for Azerbaijan. When a mixture of CO and H_2 is passed over copper oxide, especially copper zinc, and other types of catalysts at high temperature and pressure, the following reaction occurs[15-17]:

$$CO + 2H_2 \longleftrightarrow CH_3OH + 90,8\ kC$$

As can be seen, this reaction is a homogeneous, exothermic, and also reversible reaction. However, since the reaction rate is low at low temperatures, it is necessary to preheat the gas mixture entering the reaction. For this reason, methanol is usually obtained from synthesis gas at a temperature of 250-300^{0}C and a pressure of 5-10 MPa. For this reaction to proceed at a normal rate without a catalyst, a pressure of 20-25 MPa is required, which means a large amount of additional energy loss.

Methanol can also be obtained from various types of biomass of plant and animal origin. In this case, the process is carried out in stages. Thus, depending on the type of biomass or organic waste (OBW) used, synthesis gas, a combustible gas mixture (CGM) consisting of H_2+CO+CH_4, or biogas consisting of CH_4+CO_2 are obtained in the first stage. In the second stage, methanol is produced from these gas mixtures. Detailed information about the first stage of these processes is given in the literature [18-20].

In order to investigate the issue of separately covering the energy needs of the methanol plant with solar energy, or rather SPP, the possibilities of using solar panels (SP) manufactured in Azerbaijan by “Azguntex” LLC, and then modern SPs with a higher useful work factor manufactured in other countries, especially China, were considered and comparative analyses were conducted. For this purpose, the results of research conducted on the SPP installed on the facade of the entrance to the Institute of Radiation Problems of the Institute of Radiation Sciences of the Republic of Azerbaijan on the basis of the SP created by “Azguntex” LLC, in the climatic conditions of Baku city, in different months of the

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year, and the indicators obtained from the VAX family, which were produced at different values of solar radiation intensity (SRI), were used. Figure 2 depicts a general view of the SPP with a maximum power of 750 W (at a SRI value of 1000 W/ m^2), which consists of 3 SPs with a maximum output power of 250 W each [21,22].

Table 1 shows the main parameters of one of the SPs used by us.

The size of one GP is 1.66 m^2 (1663x99.7 mm), and if we find the amount of electrical power generated from 1 m^2 of surface, we get 250/1.65 = 152 W. However, these figures are for standard test conditions, that is, for the case of illumination of 1000 W/m^2, temperature of 20^0C, radiation spectrum AM 1.5 and wind speed of 1.0 m/s. In real life, the average power of one panel is at most 200 W, and the power generated from 1 m^2 of surface is 200/1.66 = 120.5 W. Such a low power is not due to a decrease in the efficiency of the panel, but to the operating conditions and a number of other conditions.

Figure 2. General view of the SPP with a power of 750 W and consisting of 3 SPs installed on the facade at the entrance to the Institute of Radiation Problems

Figure 2. General view of the SPP with a power of 750 W and consisting of 3 SPs installed on the facade at the entrance to the Institute of Radiation Problems

Thus, if we determine the total number of GPs required to provide 4.0 MW/h of energy for the SOCAR Methanol Plant based on the power provided by one panel, then we get [1.3]:where, P_{MP}- the power demand of the methanol plant for electricity, W; P_{SP}- the maximum value of the real power provided by one SP, W.

If we calculate the total area of the SP in this amount, we get:

$$S_{SP}^{gen} = N_{SP} \cdot S_{SP} = 20000 \cdot 1{,}66 = 32000 \text{ m}^2$$

where, S_{SP} - is the surface area of one SP, m^2.

$$N_{SP} = \frac{P_{MP}}{P_{SP}} = \frac{4000000}{200} = 20000 \text{ piece}$$

Table 1. Main parameters determined under standard test conditions (STC) of a single panel of GFCM installed on the facade at the entrance of the Institute of Radiation Problems

Parameter name	Parameter value
Maximum electrical power	250 Vt
Voltage at maximum power point	30,5 V
Current at maximum power point	8,25 A
Short circuit current	8,77 A
No-load operating voltage	37,9 V
Operating temperature range	$-40 \leq T \leq +80^0 C$
SP's useful work coefficient	15,2 % (72

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However, when calculating the area occupied by the SPP, it is necessary to take into account the distances between individual panels. Since these distances are intended to ensure the accessibility of each panel for the workers installing the SP, as well as to periodically clean their surface from the layer of dust.

Thus, to determine the total area occupied by one panel, it is necessary to multiply the area of the panel by the filling factor, which usually varies between k = 1.3-1.5. If we assume k = 1.4, then the area occupied by one panel of "Axguntex" LLC is 1.66x1.4 = 2.324 m^2. Then the total area occupied by the SPP required to provide 4 MW of power is 20000x 2.324 = 46480 m^2.

Thus, when using the mentioned number of SPs, at the maximum values of the SRI (700-950 W/m^2), the energy demand of the Methanol plant is fully covered by the SPP and a significant amount of excess energy is generated, which is transmitted to the centralized electricity grid. During periods of low SRI and at night, the energy transmitted from the SPP to the grid is reused. Thus, the uninterrupted energy demand of the Methanol plant can be met by the SPP. However, all this refers to the summer season. In the winter months of the year, both the daily and monthly amounts of sunlight hours and the monthly values of SRI vary significantly. In order to see the above more clearly, Figure 3 shows the average monthly change graphs of the sunshine hours (SSH), Figure 4 shows the average daily values for different months of the year in the form of diagrams, Figure 5 shows the optimal values of the SP inclination angles for different months of the year during the month, and Figure 6 shows the average monthly values during the year.

The diagrams shown in Figure 3 show the changes in monthly SSHs values during the year for cases where the number of sunless days is taken into account (green columns) and for cases where it is not taken into account (red columns). As can be seen, since the number of sunless days is greater in the autumn and winter seasons, a significant difference arises between the two graphs for the months corresponding to those seasons. Thus, in cases where sunless days are taken into account, the amount of SSHs decreases by 15÷25%. In the summer season, since sunless days are not observed as much in Baku, the amplitudes of the graphs almost equalize. As shown in Figure 4, a graph of changes in daily SSHs values for different months of the year is given. It is also clearly seen from this graph that in the climatic conditions of Baku, located at $40^0 24^I$ North latitude, the amount of SSH in the winter season decreases by up to two times compared to the summer season. It should also be noted that the graph depicted in Figure 4 refers to the case where sunless days are not taken into account. When sunless days are taken into account, this ratio is more than 2.0 times. Thus, while in May-August the amount of GPS per day in Baku conditions even exceeds 15 hours, in autumn and winter this indicator does not exceed 6÷7 hours, which makes it impossible to use solar energy efficiently throughout the year. On the other hand, the amount of solar energy entering 1 m^2 of surface per day in different months of the year depends significantly on the angle of inclination of the surface of the SP. Thus, while for horizontal surfaces the ratio between the summer and winter months of the year is up to 2.5÷3.0 times, for inclined planes this ratio is at most 2.07 times,

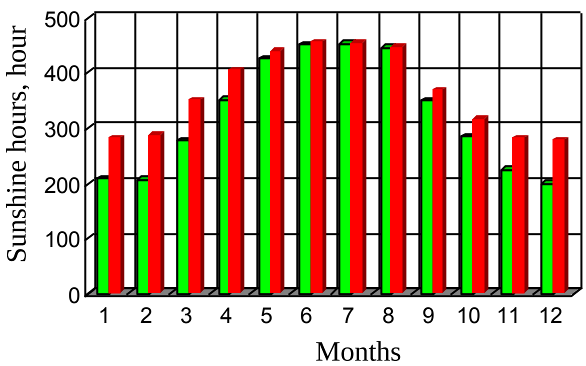

Figure 3. Annual variations in average monthly sunshine values for latitude $40^0 24^I$ (Baku) without (column) and with (column) non-sunny days

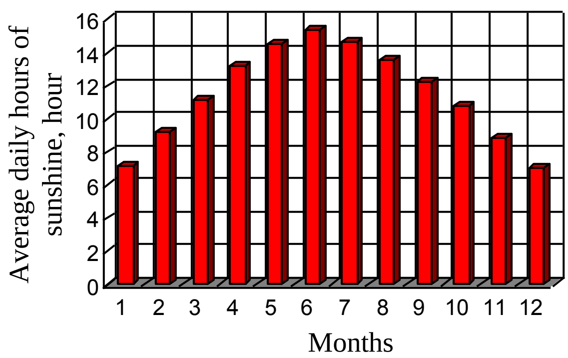

Figure. 4. Annual variation in the average daily value of sunshine ($H_{daily}^{aver.}$)for latitude $40^0 24^I$ (Baku)

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which indicates that installing the SP in an inclined direction is more efficient in terms of maximum use of solar energy throughout the year [23]. Taking this into account, we have determined the optimal values of the SP inclination angle during the month for all months of the year. The results obtained are given in the form of graphical dependencies in Figure 5. It should also be noted that in order to obtain more accurate values of the optimal inclination angles, the same number of days in all months of the year, i.e. 31 days, was assumed. As can be seen from Figure 5, the maximum value of the optimal inclination angle observed in January (curve 12) is ~ 64^0, while the minimum value observed in June (curve 6) is ~ 16^0. How the optimal inclination angle changes in other months of the year is more clearly seen from the graph depicted in Figure 6.

It is closer to the northern latitude angle of the area where Baku is located ($40^0 24^I$). Therefore, this angle is considered optimal for other months of the year. Thus, solar energy devices, including SP, have a large number of connecting and communication elements, which does not allow changing the inclination angles of the surfaces of these devices throughout the year. Therefore, it is impossible to change their inclination angles not only in accordance with the optimal values shown in Figure 6 during different months of the year, but even once a month. Thus, changing the optimal inclination angles in this way, that is, once a month, can lead to mechanical failure of both the communication lines themselves and the SP. Therefore, as is currently the case in all countries of the world, the optimal value of the inclination angles of the SP throughout the year has been accepted by us as equal to the northern latitude angle of the area where Baku is located, that is, $40^0 24^I$.

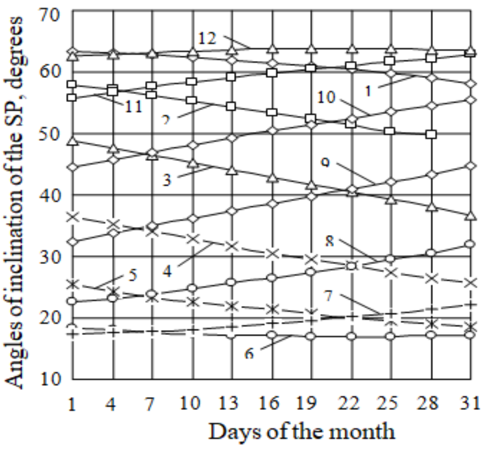

Figure 5. Graphical progression of the change in the optimal tilt angle of the PSC relative to the horizon for different months of the year:curves 1-12 were taken for months 1-12 of the year, respectively.

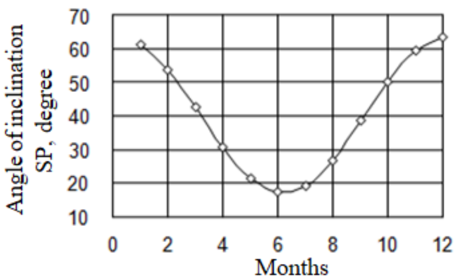

Figure 6. The annual course of changes in the optimal angle of inclination of the SPs relative to the horizon

As a result of additional studies, it was determined that while the annual amount of total solar radiation (TSR) falling on 1 m^2 of horizontal surface in Baku is 1754.6 kWh/m^2, for surfaces installed at an angle of inclination of $40^0 24^I$, this figure is 1864.9 kWh/m^2, which means 110.3 kWh of additional energy per m^2 of surface. As mentioned above, for a SPP with a total surface of 32,000 m^2, this figure is equal to 3529600 kW/h, that is, ~ 3.53 GW/h of energy. Considering that

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the total demand power of the methanol plant is 4.0 MW, this additional power is 938.7 kW, which is 23.47% of the total demand power. This once again confirms how efficient the use of inclined surfaces is [23].

Taking all of these into account, additional studies have shown that using SPP alone in the spring, autumn, and especially in the winter seasons does not yield the expected results. Therefore, in these seasons, WPP should be used in addition to SPP so that the energy demand of the methanol plant can be fully met. For this purpose, cadastral data on wind regimes in the Absheron Peninsula, especially in Baku, were analyzed, and then the possibilities of using WPP that exist and are currently used in Azerbaijan were investigated. These issues are discussed in detail below.

Currently, leading global companies specializing in the production of solar panels are producing SPs with higher f.i. and output power, the use of which can be considered more efficient. Thus, the world-renowned SP manufacturer Junko Solar China has launched the SP called Jinko Solar Tiger Pro with the highest output power, whose output power is 560 /700 W. Thanks to the application of advanced Tiling Ribbon, Bifaccial, Twin Power and Multi technologies, the efficiency of this SP is 25% higher than existing panels and the useful work factor is 20.48%. However, depending on the surface and angle of inclination, the output power can increase by 5-25% and reach 700 W, which corresponds to the value of the useful work factor of 25.6%. SP with an output power of 560 W is applied in both industrial and household SPP. The SPP is equipped with batteries, a hybrid grid inverter, a controller that automatically regulates the charging and discharging processes, as well as connecting and protective equipment for a complete set. Figure 2 illustrates the installation of this type of SP on the roof of a house, provided that the necessary distance is maintained, and Table 2 gives their energy, structural and technical characteristics [25].

If the methanol plant is powered by a GFCM made of this type of GP, then the following number of GPs is required for the maximum value of the GRI:

$$N_{SP} = \frac{P_{MP}}{P_{SP}} = \frac{4000000}{560} = 7143 \text{ units,}$$

The number of SPs required for the average value of the SRI is approximately 10,000 units. In this case, taking into account the filling factor of the area occupied by the SPP made of that number of SPs, it is equal to the following:

$$S_{SP}^{gen} = N_{SP} \cdot S_{SP} = 10000 \cdot 2{,}73 \cdot 1{,}4 = 38220 \text{ m}^2,$$

where, the figures 2.73 and 1.4 are, the surface area and the filling factor value of one unit of the Jinko Solar Tiger Pro type SP, respectively.

Figure 2. Installation of Jinko Solar Tiger Pro type SP on the roof with the required spacing

Thus, compared to the SP produced by “Azguntex” LLC, the total area of the SPP with the same power made of the Jinko Solar Tiger Pro type SP made in China is 46480 - 38220 = 8260 m^2 less, which can be considered a very good indicator in terms of area capacity and operation.

Table 3. Average monthly and average annual wind speeds for Baku and Puta meteorological stations (weather vane height 10 m)

Meteorological stations	Average monthly wind speed, m/s												$V_{av.an}^{year}$, m/s
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Puta	6,9	7,4	7,5	7,2	7,0	8,1	8,1	7,8	6,5	6,2	5,4	5,5	7,0
Baku	6,7	6,5	7,3	6,5	6,4	6,7	6,6	6,8	6,4	6,3	5,9	5,4	6,5

IV.ANALYSIS OF THE POSSIBILITIES OF USING WIND ENERGY TO SUPPLY ENERGY TO A METHANOL PLANT

As mentioned above, the use of SPP alone is not sufficient to provide the methanol plant with uninterrupted and stable heat and electricity throughout the year. Therefore, in order to ensure the reliability of the plant's energy supply in the winter months, when the SRI and the number of hours of sunshine per day are less, it is considered more efficient to use wind energy, i.e. WPP, along with solar energy. For this purpose, the study of wind regimes in Baku, especially in the area where the methanol plant is installed, is of exceptional importance. Previously, we studied, systematized, and conducted certain analyses of wind regimes throughout Azerbaijan, including the Absheron Peninsula and Baku [6-8]. However, since there is no meteorological station in the Garadagh region, it was considered more expedient to use indicators from the Puta and Baku weather stations, which are relatively close to that area, in order to determine the efficiency of wind energy use. Table 3 shows the average monthly and average annual ($V_{av.an}^{year}$) wind speeds for these weather stations.

As can be seen from Table 3, July is considered the month of more intense winds for the Baku and Puta meteorological stations. In general, the intensity of the wind in the Caspian coastal strip is observed with winter minima and spring maxima, and in some cases a second maximum is observed in the summer season.

It was found that, depending on the height, the relative strength of the wind flow varies in a wide range, which is a very serious indicator. Taking into account this, as well as the fact that the height of the axes of modern wind turbines with large diameters and output power from the ground is 100-150 m, and the distance of the blades from the ground when they are rotating and in the upper position is even 200 m and more, the estimated values of the average wind speed (V_H^{aver}) at heights up to 200 m were found by calculation. For this purpose, the following simple formula was used [6-8]:

$$V_H^{aver} = V_h^{aver} \cdot \left(\frac{H}{h}\right)^{\alpha} = K \cdot V_h^{aver}, \qquad (1)$$

where, V_h^{aver} - the average annual wind speed at the height of the weather vane, m/s; H - the height at which the average annual or instantaneous wind speed is determined (the height at which the wind wheel is installed), m; α - is the Hellman coefficient (dimensionless force coefficient), which depends on the roughness of the ground surface in the area where the wind turbine is installed, or rather, on the height of obstacles that will create a shadow on the movement of the wind flow in that area; V_H^{aver} - the average or instantaneous wind speed at the height H, m/s; K- is the dimensionless adjustment coefficient.

Table 4. Variation of average annual wind speed depending on altitude for Baku and Puta meteorological stations

Name of the meteorological stations	Average annual wind speed at height *H*, m/s							
	H=10	*H*=30	*H*=60	*H*=90	*H*=120	*H*=150	*H*=180	*H*=200
Baku	6,5	8,52	9,75	11,12	11,96	12,61	13,26	13,59
Puta	7,0	9,17	10,50	11,97	12,88	13,58	14,28	14,63

Table 4 shows the average annual wind speed at different heights for Baku and Puta weather stations calculated according to formula (1). As can be seen from Table 4, the average annual wind speed at a height of 200 m is more than twice its value at the height where the weather vane is installed. In general, the average annual wind speed at heights above 60 m is 9.5 m/s for Baku weather station and 10.5 m/s for Puta weather station, which indicates that large-diameter industrial-scale wind turbines can be used effectively all year round in the climatic conditions of Baku, including the efficiency of using this wind turbine to provide electricity to the SOCAR methanol plant. The maximum output capacity of most wind turbines currently installed and in use in Azerbaijan is 700 kW, and the diameter of the wind turbine is 70 m,

which allows the rotation axis of the turbine to be installed at a height of 60 m and to operate at maximum power during most of the year.

On the other hand, it should be noted that the WPP works on the basis of the instantaneous wind speed, not the average wind speed. Taking this into account, we also determined the variation of the instantaneous wind speed depending on the height through the report. The results obtained are given in Table 5.

Table 5. Variation of instantaneous wind speed depending onaltitude for Baku city

Height, m	**Correction factor**	**Instantaneous wind speeds, m/s Zone A (Baku city)**			
10	1	6	12	18	24
20	1,16	6,96	13,92	20,88	27,84
30	1,29	7,74	15,48	23,22	30,96
40	1,39	8,34	16,68	25,02	33,36
50	1,49	8,94	17,88	26,82	35,76
60	1,56	9,36	18,72	28,08	37,44
70	1,63	9,78	19,56	29,34	39,12
80	1,68	10,08	20,16	20,24	40,32
90	1,74	10,44	20,88	21,32	41,76
100	1,78	10,68	21,36	32,04	42,72
110	1,82	10,92	21,84	32,76	43,68
120	1,85	11,10	22,20	33,30	44,40
130	1,88	11,28	22,56	33,84	45,12
140	1,91	11,46	22,92	34,38	45,84
150	1,94	11,64	23,28	34,92	46,56

As can be seen from Table 5, even in cases where the instantaneous wind speed at the height of the vane (10 m) is not sufficient for the normal operation of a high-power industrial-scale wind turbine (the optimal operation of this type of WPP under load is ensured in the range of instantaneous wind speeds of 9÷25 m/s), the instantaneous wind speed at a height of 150 m is sufficient for the wind turbine to enter the optimal operating mode. For example, if the instantaneous wind speed at the height of the vane is 6 m/s, at a height of 150 m its value reaches 11.64 m/s, which is sufficient for the operation of most industrial-scale WPPs under load.

It is of great importance to determine the energy that any WPP can produce per day, month, and year. In this case, to determine the relative (P_{WPP}^{rel}) and total (P_{WPP}^{total}) power produced by a WPP with a wheel area of 1 m^2, the following equations are used, respectively [1]:

$$P_{WPP}^{rel} = 0,615 \cdot 10^{-3} \cdot V_{inst.sp}^{3} \cdot \xi \eta_{gen} \eta_{mult} \,, \quad (2)$$

$$P_{WPP}^{total} = \rho \cdot \frac{\pi D^2}{8} \cdot V_{inst.sp}^{3} \cdot \xi \eta_{gen} \eta_{mult} = 4,828 \cdot 10^{4} V_{inst.sp}^{3} \cdot D^2 \xi \eta_{gen} \eta_{mult} \,, \quad (3)$$

where, ρ- air density (for the normal case ρ = 1.23); D - diameter of the wind wheel; $V_{inst.sp}$ - instantaneous wind speed, m/s; ξ - is the wind energy utilization coefficient, which is ξ = 0.45÷0.48 for fast-moving wind turbines; ξ = 0.35÷0.38 for slow-moving wind turbines (in our case ξ = 0.45 was taken and this is the correct choice for most of the current industrial-scale wind turbines).

It should be taken into account that an industrial-scale WPP can operate at its nominal output power only in the range of 9÷25 m/s of instantaneous wind speed when under load. When calculating the output power of the WPP according to formula (3), it seems that with an increase in wind speed (since there is a cubic dependence), the power of the WPP can increase infinitely. However, when the instantaneous wind speed increases beyond 11 m/s, the output power of the WPP remains constant. At the same time, the frequency and amplitude of the output voltage of the WPP are also kept stable.

From the analysis of the results of the meteorological measurements, it was determined that the operating times of the WPP at its nominal output power for the area where the Puta and Baku meteorological stations are located and the areas close to them are 2840 hours and 2521 hours, respectively [1]. This means that the WPP can operate with optimal output power for only 28.76% of the total hours (8766 hours) during the year for the Baku meteorological stations, and 32.4% for the Puta station. At the same time, the gradations of the instantaneous wind speed in a wide interval (0÷30 m/s) were taken into account, which allows obtaining more accurate results.

In order to more accurately determine the daily, monthly and annual energy production of any WPP, it is also necessary to know the number of daily, monthly and annual quiet hours possible in the place where the WPP is installed (currently Garadagh district). Since these hours are not working hours, they affect the amount of daily, monthly and annual energy produced by the WPP. Table 6 shows the values of the repetition coefficients determined by calculating quiet periods of different duration for the Baku and Puta meteorological stations in the thousands system and in hours.

Table 6. Recurrence coefficients of energetic calms of various durations for Baku and Puta meteorological stations in thousands and in hours

Name of the meteorological stations	**Duration of energy calms, days**												
	≤0,5	0,5	1	2	3	4	5	6	7	8	9	10	≥10
	Recurrence rates of energetic calms, in the thousands system and per hour												
Puta	627	305	56	10	2	-	-	-	-	-	-	-	-
	1866	908	167	30	5	-	-	-	-	-	-	-	-
Baku	415	365	182	31	6	1	-	-	-	-	-	-	-
	1006	885	441	75	15	2	-	-	-	-	-	-	-

The number of days during which both slow and fast-moving wind turbine, as well as WPP, operate and remain inactive during a year in the Baku and Puta areas was determined by calculation, and the results are given in Table 7.

Table 7. Estimated values of the number of days of operation and standstill per year for slow fast wind turbines, as well as for industrial-scale wind turbines

Name of the meteorological stations	**Slow-speed wind turbine**		**High-speed wind turbine**		**Industrial scale WPP**	
	Working time, days	Quiet time, days	Working time, days	Quiet time, days	Working time, days	Quiet time, days
Puta	255	110	197	168	118	247
Baku	241	124	180	185	105	260

As can be seen from Table 7, a relatively small power sharp and slow-moving wind turbine has the ability to work for a year, which indicates the efficiency of using this type of wind turbine in the climatic conditions of Baku. However, using such wind turbine to provide energy to the Methanol Plant is inefficient. Since in this case it is necessary to use numerous WPP, which is not efficient either in terms of the area they occupy, or in terms of energy, economy and management. The issue of using industrial-scale WPP for this purpose is analyzed in detail below.

Since the most common WPP in Azerbaijan currently has a power of 700 W, let us consider the possibilities of using this type of WPP in the power supply of the Methanol Plant. Table 8 shows the values of the mechanical power generated in the wind wheel of this type of WPP and the electrical power obtained at the output of the electric generator determined by the formula (3), as well as the values of the wind energy utilization coefficient depending on the instantaneous wind speed.

Table 8. Variation of the mechanical power generated by the impeller of a WPP with a impeller diameter of 70 m and an output power of 700 kW, the electrical power generated by the electric generator, and the wind energy utilization coefficient depending on the instantaneous wind speed

Instantaneous wind speed, m/s	**Power obtained from windmills, kW**	**Electric power generated by the WPP, kW**	**Wind energy utilization rate, %**
7	240,3	240,3	100,0
8	358,8	358,8	100,0
9	510,8	510,8	100,0
10	700,7	700,7	100,0
11	932,6	700,7	75,13
12	1210,8	700,7	57,87
13	1539,4	700,7	45,52
14	1922,7	700,7	36,44
15	2364,9	700,7	29,63
16	2870,1	700,7	24,41
17	3444,5	700,7	20,34
18	4086,5	700,7	17,15
19	4806,1	700,7	14,58
20	5605,1	700,7	12,50
21	6489,2	700,7	10,80
22	7461,1	700,7	9,39
23	8525,4	700,7	8,22
24	9686,5	700,7	7,23
25	10948,4	700,7	6,40

As can be seen from Table 8, at values of instantaneous wind speed above 10 m/s, the power received at the output of the WPP electric generator reaches its maximum limit and then remains stable. However, since the mechanical energy produced in the wind wheel is directly proportional to the cube of the wind speed, this power increases sharply compared to the useful power received at the output of the electric generator. For this reason, the wind energy utilization coefficient from the last column of Table 8 decreases analogously when the instantaneous wind speed increases. This is not considered a negative situation, as it may seem at first glance, but rather a positive situation for the WPP to operate more reliably under load. However, when using the WPP as a current source, maintaining the output power stable is especially aimed at maintaining the output voltage of the electric generator and its frequency, which is considered one of the most important conditions for most consumers of electricity.

Thus, if we calculate based on the maximum output power, then the number of 700 kW WPPs required to meet the 4.0 MW demand of the Methanol Plant is equal to:

$$N_{WPP} = 4000/700 = 5{,}71 \text{ pieces}$$

Therefore, in order to provide the methanol plant with electricity, according to preliminary calculations, it is considered sufficient to use 6 WPPs with an output power of 700 kW. However, if we take into account that the operating hours of industrial-scale WPPs with a large output power for the areas where the Puta and Baku meteorological stations are located in a year are 2832 hours and 2520 hours, respectively, and 118 days and 105 days in days, it can be concluded that the continuous and stable use of WPP alone with electricity from that plant is not sufficient, and for this purpose, their combined use with SPP is more efficient.

At this time, if the WPP consisting of the above-mentioned number of WPPs is accepted as the main energy source, then the power they will provide should be calculated in the case when the average monthly wind speed in Baku is the highest. When the wind speed is less than the optimal limit, as well as on windless days, the missing part of the energy should be provided by SPP. Therefore, the ratios of the output power of SPP and WPP should be selected correctly, and when the energy of one of these energy sources is not enough for the Methanol Plant, the missing part of the energy should be provided by the other energy source. When both plants operate at maximum energy output, the energy produced by one of them can be transmitted to the centralized electricity grid for further use. Thus, since the demand for heat and electricity of the Methanol Plant is fully met from renewable energy sources, both traditional fuels are saved and emissions of gases that cause a warming effect to the atmosphere are prevented. Considering that currently in the TPPs operating in Azerbaijan, 0.25÷0.35 m^3 of natural gas is used to produce 1 kWh of electricity, depending on the type. If we take this figure as an average of 0.3 m^3, then the amount of natural gas saved per year due to the provision of the total demand power of the Methanol Plant (4 MW) from SPP and WPPs is 4000·0.3·8760 = 10.5 million m^3, which is equivalent to 7.875 tons of conventional fuel equivalent. On the other hand, as is known, for every m^3 of natural gas burned in the TPP, 1.8÷2.3 kg of CO_2 gas is emitted into the atmosphere. If we take this figure as an average of 2.05 kg, then by meeting the total energy demand of the methanol plant through SPP and WPPs, 10.5·106·2.05 = 21,550 tons of CO_2 gas are prevented from being released into the atmosphere per year, which can be considered a very good indicator from an ecological perspective.

It should be noted that currently, in a number of countries around the world, not only photovoltaic converters are used to convert solar energy into electricity, but also parabolic trough concentrator solar thermal power plants (STPPs), which are considered to be very environmentally friendly since they do not have any negative impact on the environment. In our opinion, the installation of this type of STPP in the Garadagh region, directly near the Methanol Plant, and their use to provide the Methanol Plant with energy can be very effective.

V. CONCLUSION

1. In the present work, the possibilities of covering the total energy demand of the Methanol plant built by the State Oil Company of Azerbaijan in the Gobustan region of the Absheron Peninsula with solar and wind energy were investigated, and detailed information was provided on the physicochemical properties, environmental advantages, application areas and production methods of methanol. The raw material base available in Azerbaijan for the production of this type of fuel, in particular, the prospects for using it to prevent the emission of 350 million tons of CO_2 gas into the atmosphere during the burning of associated gases obtained in the oil industry in flares and to obtain methanol from this gas were

International Journal of Advances in Engineering and Management (IJAEM)
Volume 8, Issue 02 Feb. 2026, pp: 47-62www.ijaem.net ISSN: 2395-5252

disclosed. The advantages of this process in terms of both ecology and economy and energy were evaluated. It was found that the use of 102-103 m^3 of associated gas burned in a flare allows the production of up to 1.0÷10 thousand tons of methanol per year, respectively, while the amount of CO_2 gas emitted into the atmosphere decreases by 3.0÷30 thousand tons per year.

2. It was determined that the total energy demand of the Methanol Plant, including electricity and heat energy, is 4.0 MW·h, and the issue of providing this energy by using environmentally friendly and inexhaustible SPP and WPP both separately and in a combined (hybrid) manner was investigated. For this purpose, statistical and cadastral studies were conducted on the existing solar and wind energy resources in the territory of Azerbaijan in general, including the area where the Methanol Plant is located, and the results obtained were presented in the form of graphs, diagrams and tables. When determining the wind regimes, the indicators of the Puta and Baku meteorological stations, which are closer to the area where the Methanol Plant is built, were used, which were determined for the heights at which the weather vane was installed (10 m). Then, the wind regimes existing at heights up to 200 meters were determined by means of a report, which is of exceptional importance for the accurate determination of the energy parameters of a large-scale industrial-scale WPP. It was determined that even if the instantaneous wind speed at the height where the weather vane is installed is not working for the wind turbine, at higher altitudes its value reaches the required working level, which makes the use of large-scale wind turbine promising. In this work, as well as from the studies conducted on the solar energy resources in the area where the methanol plant is being built, it became clear that the lowest daily and monthly values of SSHs observed in that area in January are 6÷7 hours and 186÷217 hours, respectively, and the highest values observed in July are 15 hours and 450 hours, respectively, which means a difference of 2.07÷2.42 times. Similarly, the values of TSR, entering 1 m^2 of horizontal and inclined surfaces during the year were determined and it was found that while this indicator for horizontal surfaces is 1754.6 kWh/m^2, for inclined surfaces installed at an angle of inclination of $40^0 24^I$ it is 1864.9 kWh/m^2, which means 110.3 kWh of additional energy per m^2 of surface. Taking this into account, the optimal values of the inclination angle for different months of the year were determined and presented graphically. On the other hand, it was determined that the amount of solar energy entering 1 m^2 of surface during the day in different months of the year also depends significantly on the angle of inclination of the surface of the SP. Thus, while the ratio between the summer and winter months of the year for horizontal surfaces is up to 2.5÷3.0 times, for inclined surfaces this ratio is at most 2.07 times, which indicates that installing the SP in an inclined direction is more efficient in terms of maximum use of solar energy throughout the year.

3. In this work, in order to provide the Methanol Plant with 4.0 MW·h of energy, the possibilities of using both the SP manufactured by the "Azguntex" company of the Republic of Azerbaijan, with a maximum power of 250 W, and the SP manufactured by the Chinese company Junko Solar, each with a maximum output power of 560/700 W, were investigated and it was found that when using the first type of SP, their total number is 20,000 units, and the total area they occupy, taking into account the filling factor, is 46,840 m^2, and for the second type of SP, these indicators are 7,143 units and 38,220 m^2, respectively, which shows that the use of the second type of SP is more efficient. Despite all this, taking into account the current climatic conditions of Baku, it becomes clear that the use of SPP alone is not enough to continuously and sustainably meet the energy needs of the Methanol Plant.

4. As for the use of wind energy, it is considered sufficient to use 6 WPPs with an output power of 700 kW to provide the Methanol plant with electricity. However, if we take into account that the operating hours of industrial-scale WPPs with a large output power for the areas where the Puta and Baku meteorological stations are located in a year are 2832 hours and 2520 hours, respectively, and 118 days and 105 days in days, it can be concluded that the use of WPP separately is not sufficient for the purpose of uninterrupted and stable electricity supply to the plant. Therefore, the joint, i.e. combined use of SPP and WPP is considered more efficient. In this case, the additional electricity generated in the summer season can be transmitted to the grid and the energy transmitted to the grid can be reused in adverse weather conditions, as well as in the winter months.

LIST OF ABBREVIATIONS USED

PVC – photovoltaic converters;
PC – parabolic concentrator;
PCC – parabolic cylindrical concentrator;
WPP – wind power plant;
RES – renewable energy sources;
NPP – nuclear power plant;

TPP – thermal power plant;
GHG – greenhouse gases;
BM – biomass;
OW – organic waste;
AFT – alternative fuel type;
HEPP – hydroelectric power plant;
SHWIP – Solid household waste incineration plant;
SPP – solar power plant;
SP – solar panel;
SRI – solar radiation intensity;
FPSC – flat plate solar collector;
TSR – total solar radiation;
SSH– sunshine hours;
DSR – direct solar radiation
SA – surface albedo;
CGM – combustible gas mixture;
GFVS – solar photovoltaic source;
ETN – Ministry of Science and Education;
SOCAR – State Oil Company of Azerbaijan;

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