International Journal of Applied Power Engineering (IJAPE)
Vol. 15, No. 1, March 2026, pp. 37~45
ISSN: 2252-8792, DOI: 10.11591/ijape.v15.i1.pp37-45

Current state of production of alternative energy on the Absheron Peninsula

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Article Info

Article history:

Received Dec 30, 2024
Revised Aug 11, 2025
Accepted Oct 16, 2025

Keywords:

Benefits
Biogas
Chemical fertilizers
Environmental problems
Renewable energy
Waste management

ABSTRACT

The article is devoted to the study of the relationship between sustainable development and the introduction of innovative technologies, and the formation of smart cities. The Azerbaijan Republic is a land-poor country and has exhausted most of its natural resources. Therefore, the use of renewable energy sources and scientific research in this direction are important and topical issues for the country's scientists. Wind demand: in 10 months (from January to October) showed 3.000 GWh-4.000 GWh in Absheron (2020-2024 years). Since bioenergy can be produced in any weather, it is more reliable than solar and wind energy in Azerbaijan's regions. Seasonal variations in the availability of agricultural residues can lead to uneven energy production and create difficulties in ensuring a constant supply. The study is innovative given the importance of non-competition with food production, as well as the unique environmental, economic, and technological implications of each biofuel production method.

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1. INTRODUCTION

In recent years, the ways and technologies of using renewable raw materials have changed significantly. In-depth research and development have made it possible to achieve efficient use of renewable resources. Advanced technologies for the energy and industrial use of plant raw materials have become available. One of the important elements of a smart city is the environment. Its exceptionally important feature as a component of a smart city is the fact that the functioning of almost all areas of urban life is reflected to some extent in the state of the ecological situation. The key concept that determines the formation of conceptual provisions underlying smart cities is the concept of sustainability [1], [2]. Since energy is produced using local and renewable resources, import-based fossil fuel consumption decreases and energy security increases. Alternative energy sources can reduce energy costs, increase the profitability of businesses, and support rural development by creating new employment areas [3]. This paper proposes innovative methods for siting wind power and wind turbines in arid zones based on the fuzzy integrated assessment method, as established in Figure 1(a). The development of energy has an impact on various components of the natural environment. Biogas and its production technologies are an important part of sustainable energy supply for enterprises and provide economic benefits. The problem of resource depletion is minimized [4]. Comprehensive wind potential mapping methods help identify the most promising sites for wind turbine installations. These studies aim to improve the efficiency and sustainability of wind energy systems in Absheron, taking into account environmental and socio-economic factors (see Figure 1). From the standpoint of decentralized power supply, environmental protection, and agriculture, the advantages of biogas are undeniable, as established in Figure 1(b). As wind energy continues to grow, developing cost-effective solutions to detect and deter wildlife from wind energy infrastructure is essential. Converts the kinetic energy of the wind into electricity (see Figure 1(c)). Furthermore, electricity production research in the station, as illustrated in Figure 1, focuses on monitoring and optimizing the output of wind-powered systems through on-site measurement instruments and data analysis to ensure reliable and efficient operation. Today, this impact is becoming global in nature, affecting all structural components of our planet. The way out of this situation for society should be: the introduction of new technologies (for cleaning, recycling emissions; for processing and storing radioactive waste) [5], [6], the spread of the use of renewable energy sources. The main difficulty in the practical implementation of the idea of the relationship between ecology and innovation in Azerbaijan is the need to create a mechanism to stimulate the transition to new resource-saving and environmentally friendly technologies, the introduction of which would bring tangible economic and environmental benefits.

Movement towards sustainable development at the city level is achieved through the implementation of smart city projects. The main areas of achieving sustainable development goals in modern conditions are the formation of a green economy [7]. This is aimed at the socio-economic development of the territory, subject to the preservation of natural capital and the prevention (or reduction) of risks from anthropogenic impact on the environment. A smart city is a complex system of effectively interacting main urban segments, including infrastructural, economic, and environmental ones [8]. This is a serious contribution to sustainable development, minimization of environmental pollution, waste recycling, resource conservation and resource efficiency, modernization of production, introduction of new technologies, and, in general, increasing the competitiveness of production [9], [10].

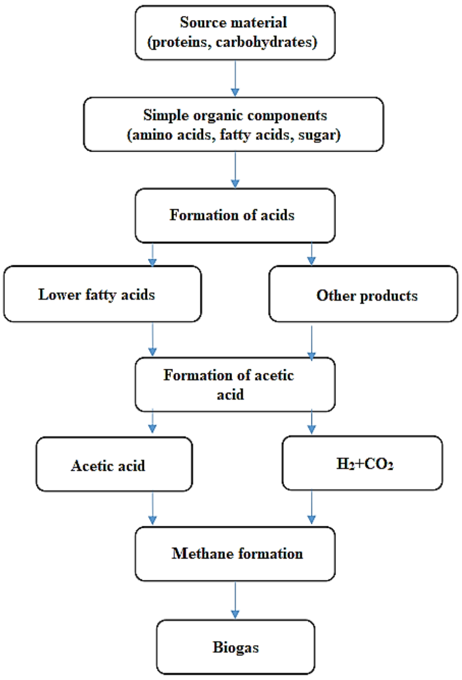
Even though biomass is a limitless resource, finding feedstock is still the biggest obstacle to producing biofuel. Crops and nonfood-based feedstock compete for land in the production of second-generation biofuel. In emerging nations, where crops occupy the majority of the land, the land issue would be considerably more acute [11]. Because biomass feedstock is widely distributed, logistics present another difficulty for the manufacturing of biofuel. It may require a lot of energy to collect, store, and transport biomass from fields to centralized processing facilities [12], [13]. Transportation expenses and emissions would be greatly increased by the unequal distribution of biomass feedstock across various regions and nations. Seasonal changes in the availability of agricultural waste could lead to uneven energy output and make it challenging to sustain a constant supply [14]. Operational complexity: Unlike solar panels, which run relatively simply, bioenergy systems are more complicated and need maintenance since their many stages of collecting, processing, digestion, and energy conversion may cause mechanical issues. Land use is a big issue [15], [16]. Converting food crops like corn and soy into fuel raises concerns about food security. Expanding biofuel farms can also destroy natural habitats, as seen with palm oil plantations replacing tropical forests. Some alternatives, like growing diverse native plant species for biofuel, could help restore degraded land, improve biodiversity, and reduce erosion. In comparison to certain food or energy crops, agricultural byproducts offer a number of benefits (Figures 1(a)-1(c)). Free or inexpensive byproducts help avoid food vs. fuel conflicts [17]-[19]. By using them, waste management goals are met, reducing the environmental damage caused by open burning or disposal. Soil nitrogen cycling and organic matter renewal can both be enhanced by getting rid of leftovers. Biomass supply networks and conversion technology are more economically sustainable when agricultural waste is turned into energy [20], [21].

(a) (b) (c)

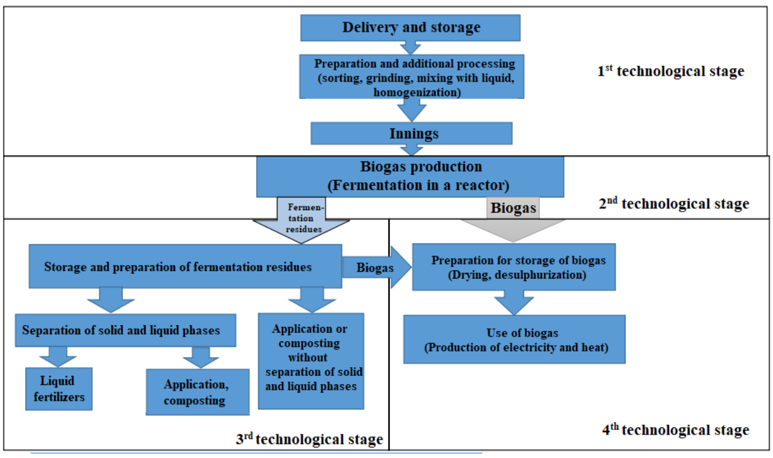
Figure 1. Overview of energy research in the Absheron Peninsula: (a) wind energy turbine station, (b) green energy storage, and (c) electricity production

2. THE PROPOSED METHOD

Hydrolytic, acid-forming, and methane-forming bacteria participate in the decomposition process. They initiate anaerobic fermentation. Bacteria consume the biomass and convert it into biogas. Biofuels can be produced from lignocellulose, a rich carbon source, using bacterial enzymes like cellulases and hemicellulases. Since most bacteria are unable to break down lignocellulose naturally, metabolic engineering is used to boost their ability [22]. By adjusting variables including pH, temperature, substrate loading, and enzyme dosage, the process can be improved and sugar yields increased. Using enzymes or acid, hydrolysis converts lignocellulosic biomass into monomers. Enzymes are used in enzymatic hydrolysis to break down lignocellulose. Endoglucanase, exoglucanase, and β-glucosidase are the three main enzymes that break down cellulose and release glucose from complex molecules. Cellulases, which include β-glucosidase, endoglucanase, and exoglucanase, convert cellulose to glucose to be ready to ferment. Hemicellulases convert hemicellulose into mannose, glucose, and xylose, among other sugars. A major challenge influencing the general economics of making ethanol is the cost of manufacturing the cellulase enzyme. Obtaining biogas from waste takes an average of 40-60 days, as established in Figure 2(a). This is a completely waste-free process, which is a big advantage of this method of processing. When fermentation is complete, a dry and liquid product remains as established in Figure 2(b). It does not smell and contains a large amount of minerals that are easily absorbed by plants [23], [24].



(a)



(b)

Figure 2. Technical stages of biogas production: (a) schematic representation of the anaerobic decomposition process and (b) 4 technological stages of obtaining and storing biogas

3. RESULTS AND DISCUSSION

3.1. Biogas energy in Absheron Peninsula

Biomass can be used as fuel directly or processed into liquid or gaseous forms for electricity, heat, or fuel production. There are two main ways to convert biomass into biofuels: biochemical and thermochemical conversion. Biochemical methods include anaerobic digestion, saccharification, and hydrolysis. Using agricultural crops for biofuel production can impact the development of the agricultural sector, create jobs in rural areas, and contribute positively to the economy. Mostly in solid state, produced from food crops such as corn, wheat, soybeans, palm oil, sugarcane, and others, first-generation biofuels arose as substitutes for fossil fuels [25], [26]. Although these biofuels are biodegradable and can be mixed with traditional fuels, they can be a threat to food crops with extensive farming and a lot of inputs. Benefits include being biodegradable, having easy access to feedstock, and being good for the environment and society. Through chemical or fermentation processes, the biomass's oils, sugars, and starches are converted into liquid fuels. Biodiesel in Absehron is made by chemical transesterification (triglyceride plus methanol creates 3 methyl esters (biodiesel) and glycerol). Bioethanol is usually made by fermentation with yeast strains. Land plots belonging to the category of agricultural land, including 3.376 hectares of state ownership in the city of Baku, Mushfigabad settlement of Garadagh district, 19.886 hectares of state ownership in the administrative territory of Absheron district, and 11.24 hectares owned by Pirekeshkul-Gobustan municipality of Absheron district [26] shall be established as a territory of renewable energy sources for the purpose of constructing a wind power plant with an installed capacity of 240 MW. An alternative main approach to forecasting is based on purely statistical modeling. The site-specific and power curve modeling steps are replaced by a unique step that directly converts input variables into power. Statistical models can also be used to forecast wind speed. However, this intermediate step is often neglected, and a unique model is developed that directly targets power forecasting. The adaptivity of model parameters over time is an important property that wind energy forecasting models must take into account when application conditions change, such as changes in the environment or even the number of wind farms in the area under consideration.

3.2. Wind energy in Absheron Peninsula

The analysis of the presented results shows that the wind blows on average 95% of the time in the Absheron region. At the same time, the specific generation of electricity is approximately 132 kWh/m^2 per year, and only in the north of the region - 358 kWh/m^2. The obtained results allow us to estimate the economic indicators for the production of electricity on wind turbines in the Absheron region. The length of each spoke from the center indicates the percentage of time the wind blows from that direction. The diagrams clearly display the prevailing wind directions and speeds for each of the four locations.

Charts are a graphical method of displaying multivariate data as a two-dimensional chart consisting of three or more quantitative variables plotted on axes starting from the same point. The spokes are divided into color-coded bands, which correspond to specific wind speed ranges as shown in the legend. The legend indicates the following speed ranges in meters per second (m/s). The length of each spoke indicates how often the wind blew from that direction. Longer spokes represent a higher frequency. The concentric circles provide a scale, most often representing a percentage of the total time (see Figures 3(a)-3(d)). Each diagram shows the frequency of different wind speeds from different directions. Colored lines correspond to different ranges of wind speeds.

Table 1 presents data on electricity production (EP), specific power (SP), and total electricity generation (TEG) from a wind turbine at different wind speeds. The table shows a breakdown of how wind share and electricity production change with increasing wind speed. Electricity production (EP) shows the amount of electricity produced per year (kWh) for different wind speed ranges. Specific power (SP) provides the specific power in watts per square meter for each wind speed range. Total electricity generation (TEG) is listed at the bottom of the table, representing the sum of all EP values for each scenario. The wind speed data are categorized into specific ranges, from 0–1 m/s up to greater than 10 m/s.

In the smart city project, electricity generated from wind turbines is used for various purposes. Electricity consumption by economic sector is shown in Figure 4 about 70% of electricity is consumed by industrial enterprises. The largest share of electricity consumption in the structure of the manufacturing industry is occupied by metallurgical enterprises - 47.2%, as well as chemical industry enterprises (about 5%). The significant share of industry in total electricity consumption is due to the predominance of heavy industry sectors, high depreciation of assets (fixed assets), and the use of outdated technologies, as established in Figures 4(a)-4(d). Electricity consumption in housing and public utilities currently amounts to more than 23% of all electricity in the country, and the largest consumers of electricity in housing and public utilities are residential buildings.

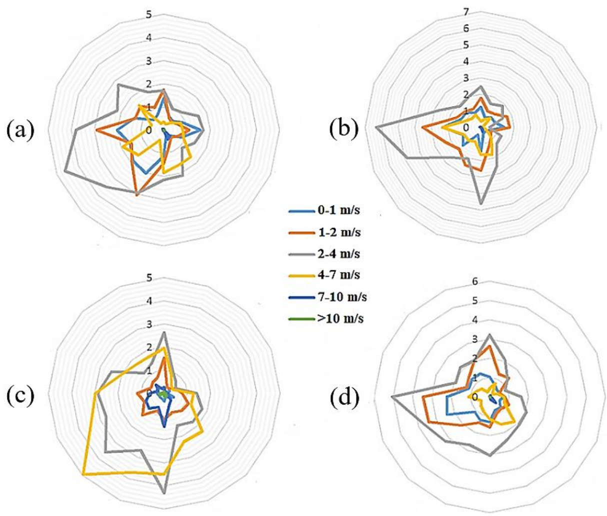


Figure 3. Wind diagrams at control points: (a) 0-1 and 2-4 m/s, (b) 1-2 and 2-4 m/s, (c) 2-4 and 4-7, and (d) 1-2 and 2-4 m/s higher frequency

Table 1. Electricity production, power research results

Wind speed, m/s	SP, W/m^2	Wind share %	EP, kWh/year	Wind share %	EP, kWh/year	Wind share %	EP, kWh/year	Wind share %	EP, kWh/year
0-1	0.046	17.7	0.07	17.65	0.07	16.7	0.07	3.83	0.02
1-2	1.24	21	2.28	26.3	2.86	27.12	2.95	13.92	1.51
2-4	9.92	35.5	30.85	39.5	34.33	39.9	34.67	32.56	28.29
4-7	61.14	15.8	84.62	12.5	66.95	14.6	78.20	34.8	186.38
7-10	225.7	1.06	20.96	0.82	16.21	0.58	11.47	7.25	143,34
>10	367.5	0.034	1.09	0.034	1.09	0	0.00	1.2	38.63
TEG kWh/year	-	-	138.78	-	120.41	-	127.35	-	359.55

Note: EP is electricity production, SP is specific power, and TEG is total electricity generation (source by authors in 2024)

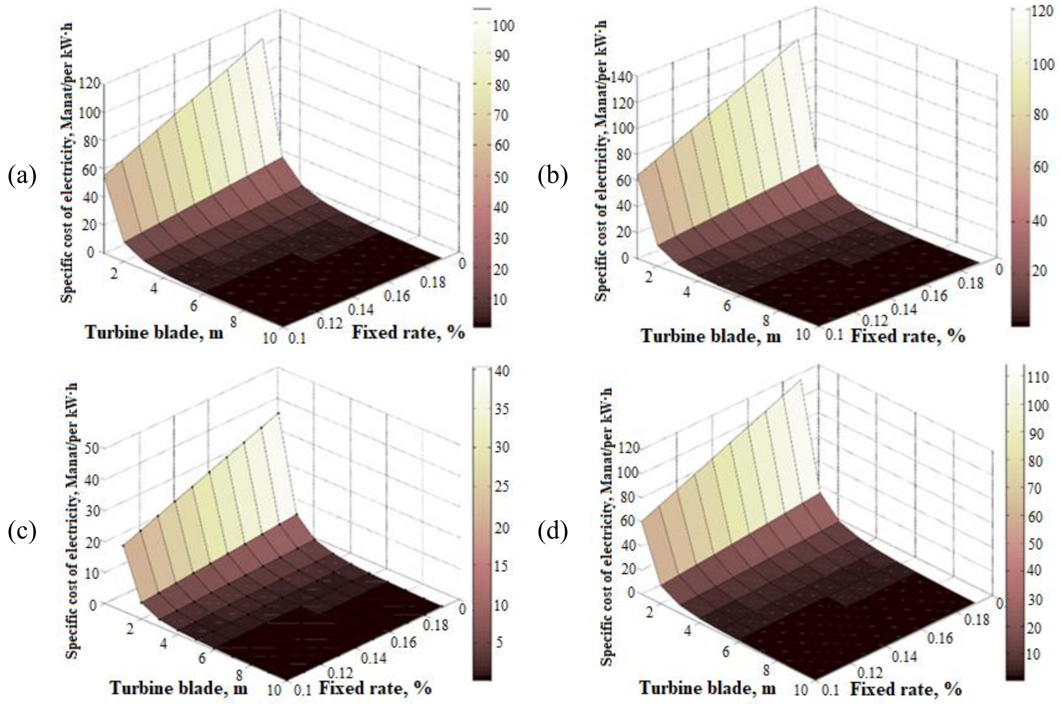


Figure 4. Dependences of the specific cost of electricity on the span of the turbine blades - value of the fixed rate: (a) 120 m - 100%, (b) 140 m - 120%, (c) 50 m - 40%, and (d) 120 m - 110%

The main result of the set of measures for environmental regulation in a smart city is ultimately the improvement of the urban ecological environment, increasing the accuracy and reliability of assessments of the state of the environmental situation through the use of digital technologies, reducing damage from negative impacts on the environment, and adapting the city to climate change. Renewable energy has many benefits and significant impacts on the economy, environment, national security, and human health. Wind energy is considered the largest source of renewable electricity. Onshore and offshore wind farms produce electricity by turning the blades of wind turbines. The turbines convert the kinetic energy of the rotating blades into electrical energy by turning a drive shaft and gearbox connected to a generator. The electricity is converted to a higher voltage and fed into the national grid. Advantages of wind energy for Absheron: renewable energy source, low operating costs, low initial cost for energy production, and environmentally friendly technology. Possibility of placement on wastelands and polluted areas, and reduction of unemployment. The absence or significant reduction of pollutant emissions compared to burning fossil fuels is one of the most important advantages of clean energy. The emissions of all kinds of greenhouse gases and dust from burning oil and coal have so many consequences that it is really difficult to list them all. Disadvantages: i) high cost of construction and maintenance, ii) disfigures the landscape, to replace a large conventional power station will require the use of several windmills, iii) occupies vast areas lost to agriculture, iv) turbine noise, v) dependence on the wind, and vi) they interfere with the reception of radio waves. A wind power plant produces electricity from wind energy using a wind turbine connected to an electric generator. Electricity from wind is environmentally friendly because its production does not involve the burning of any fuel. A large conventional power plant has a capacity of about 1,000 MW; to replace it, up to 1,000 such wind turbines would be needed. In some countries, wind power plants are being built that consist of many turbines located close to each other. It should be recognized, however, that small single turbines are an excellent source of energy in places remote from the centers of civilization, where there is no connection to the national power grid. There is great potential for increasing electricity production from renewable energy sources both in Azerbaijan and in the world, and targeted use of this potential can play an important role in the sustainable supply of electricity to countries.

4. CONCLUSION

The aim of the work is to systematize study and analyze information on obtaining biogas from plant materials, in particular from activated sludge. The process of obtaining biogas based on the decomposition of an organic substrate. The process of anaerobic decomposition is presented in the form of a diagram. It is important to note that all stages of biogas formation should be maximally adapted to each other to ensure the continuity of the process. Cooking three meals a day for a family of four will require 3.7 m^3 of biogas, and heating a 100 m^2 room will require 21 m^3 of biogas per day. The turbine rotor diameter used in the study was estimated as 115 m and the hub height was 100 m, taking into account the installed wind turbines in Azerbaijan and the current wind turbine technology. In order not to adopt a brand-specific and model-specific approach, no turbine model of any brand was taken as a reference. The approach used in this study can be applied taking into account different hub heights and pre-defined turbine specifications. The problems that wind farm owners may encounter technically, such as incorrect calculation of the power factor for the turbine, which may lead to maintenance costs in the future. Therefore, more suitable results can be obtained if the approach to determining the wind energy potential in this study is re-applied to projects to be implemented in smaller areas according to a specific turbine type, taking into account meteorological conditions.

ACKNOWLEDGMENTS

The authors express gratitude for the support of the scientific and technological research project to the Ministry of Science and Education of Azerbaijan Republic, Baku State University, and the Center for Organization of Laboratory Work in Azerbaijan State University of Economics.

FUNDING INFORMATION

Authors state no funding involved.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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Nazila Alverdiyeva Farman	✓		✓	✓			✓		✓	✓	✓		✓	✓
Gunay Mammadova Israphil	✓		✓	✓	✓		✓		✓	✓		✓	✓	✓
Vusala Isaqova Gudrat		✓			✓	✓	✓	✓	✓	✓	✓			
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Muhammad Madnee		✓			✓			✓		✓	✓	✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

ETHICAL APPROVAL

This study complies with the research ethics code, ensures that all procedures are carried out in accordance with established ethical standards, and has received approval from the relevant ethics committee.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [THA], upon reasonable request.

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