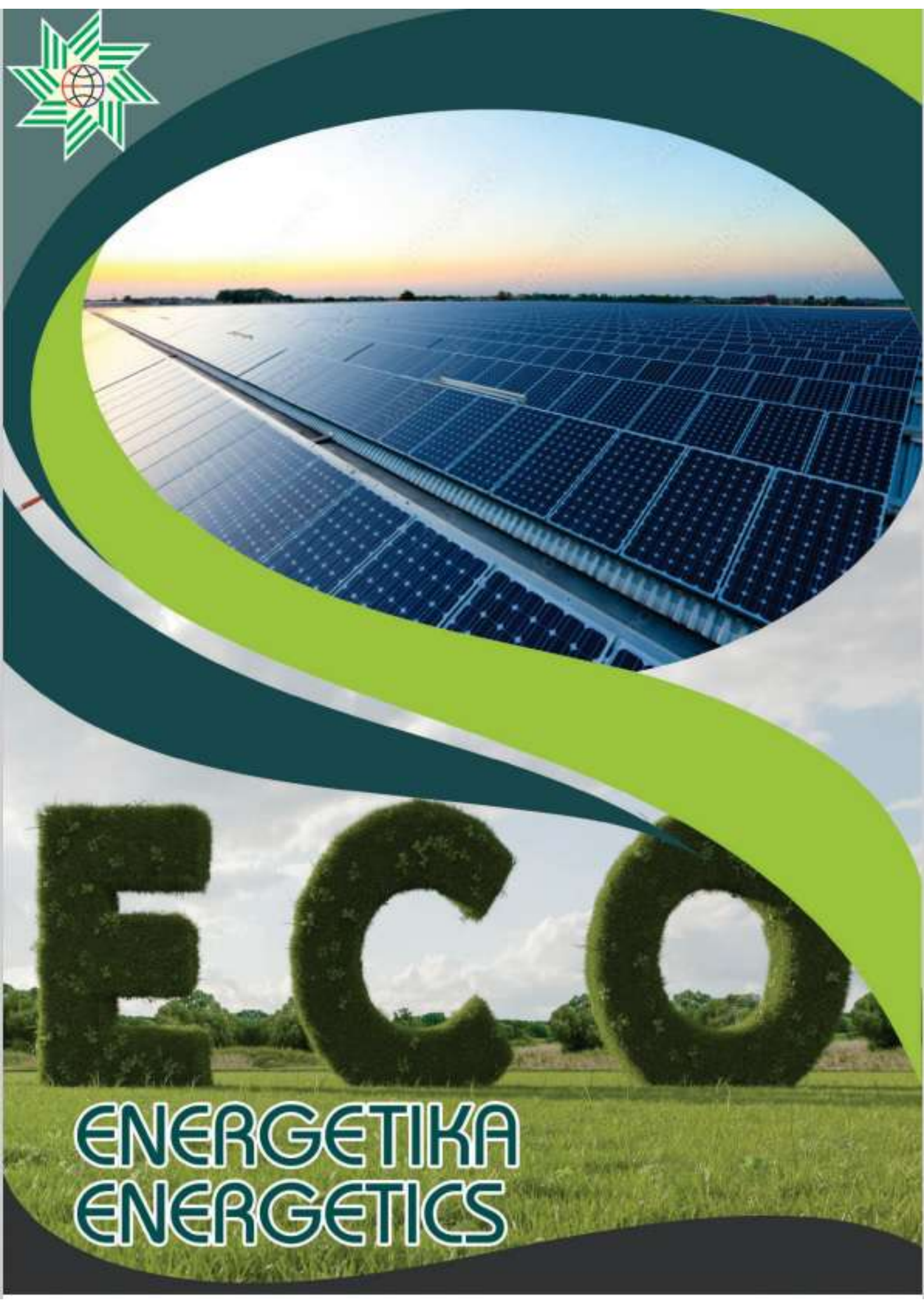
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Prompt-based forecasting of monthly solar irradiation in the fuzuli district using ai models

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Abstract: Accurate solar resource assessment is essential for expanding renewable energy in post-conflict regions. This study presents an artificial intelligence-based approach to forecast solar potential across the Karabakh Economic Region of Azerbaijan. Using satellite-derived monthly data from Aghdam and Khankendi, structured prompts were developed to guide a language model in extrapolating key solar indicators for neighboring districts. Despite the absence of humidity, wind, and cloud data, the model produced spatially reasoned estimates for global horizontal irradiation (GHI). Results show strong alignment with published reference values, supporting the use of AI-driven extrapolation in data-scarce environments. The method offers a practical tool for planning solar infrastructure in regions lacking ground-based climate measurements.

Keywords: Karabakh Economic Region, Fuzuli, solar energy forecasting, global horizontal irradiation (GHI), artificial intelligence models, prompt-based extrapolation, alternative energy, solar panel

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1. Introduction

Recent global energy statistics indicate that roughly three quarters of total final energy consumption still originates from fossil fuel sources [4]. The shift toward alternative energy sources represents a strategic priority for the Republic of Azerbaijan, facilitating diversification of the national energy mix, decreasing reliance on fossil fuel-based resources, and contributing to long-term environmental sustainability and economic stability. Additionally, on March 19, 2025, the President of the Republic of Azerbaijan ratified the national "Artificial Intelligence Strategy for 2025–2028," a comprehensive framework designed to foster the advancement of artificial intelligence through targeted support for research initiatives, enhancement of digital infrastructure, and the development of specialized human resources. Currently, Azerbaijan possesses substantial natural resource wealth; however, the contribution of the oil and gas sector to the national GDP has declined from 56 percent in 2006 (with oil rents comprising 39.7 percent of GDP) to 37 percent, reflecting the impact of ongoing economic diversification reforms [7].

According to the 2030 Solar Thermal Energy Review, there is significant potential in constructing buildings designed to fully meet their energy demands through integrated solar cell systems, suggesting that solar energy is expected to become the primary energy source for buildings in the future [8]. Accurate forecasting of solar energy potential is essential for sustainable development and energy planning, particularly in regions undergoing post-liberation reconstruction. On December 9, 2020, under the leadership of Minister Parviz Shahbazov, the Ministry of Energy of the Republic of Azerbaijan convened a session to address the renewable energy potential of the Karabakh region. The session underscored the critical need for comprehensive assessments to quantify the region's potential in hydroelectric, solar, wind, bioenergy, and geothermal resources. Emphasis was placed on identifying high-potential zones, conducting technical and economic feasibility studies, and systematically evaluating opportunities for the development of renewable energy infrastructure in the recently liberated territories [6].

As State Agency for Alternative and Renewable Energy Sources (2016) reports, governmental authorities have recently placed growing emphasis on the development of the green energy sector, marked by the initial deployment of photovoltaic power plants in multiple districts [9]. The southern segment of the liberated lands, encompassing the districts of Fuzuli, Jabrayil, and Zangilan, exhibits some of the highest solar radiation levels in Azerbaijan, second only to the Nakhchivan Autonomous Republic. In these areas, the annual global horizontal irradiation is estimated to range between 1,600 and 1,700 kWh/m² [5]. The Fuzuli district of Azerbaijan, liberated following the Second Karabakh War, possesses favorable geographical and climatic conditions for solar energy deployment. However, due to the destruction of infrastructure and the presence of minefields, ground-based measurements of solar radiation remain unavailable. To address this data scarcity, this study proposes a prompt-based artificial intelligence (AI) approach to forecast monthly global horizontal irradiation (GHI) values for the Fuzuli district. The method uses satellite-derived meteorological data from two reference locations (Aghdam and Khankendi) available in the Meteonorm 7.3 database. These locations were selected due to their geographic proximity and contrasting elevations and topographies, which create a suitable gradient for extrapolation. The innovation of this study lies in the use of a large language model (ChatGPT) to perform climate extrapolation based on structured natural language prompts. Each prompt contains detailed spatial and climatic metadata from the two reference locations and requests the model to estimate GHI values for Fuzuli month by month. Rather than relying on statistical interpolation or machine learning training, the model generates predictions through comparative reasoning. By comparing the AI-generated monthly GHI values with benchmark estimates published by Gardashov et al. (2023), this study evaluates the reliability of prompt-driven extrapolation in the context of real-world renewable energy forecasting. The aim is to assess whether a transparent, low-resource AI method can be used to support solar energy planning in regions where conventional data and measurement systems are unavailable.

2. Experimental detail

To estimate monthly global horizontal irradiation (GHI) values for the Fuzuli district, this study employed a structured extrapolation methodology based on natural language prompts directed at an artificial intelligence (AI) model (ChatGPT). Given the absence of ground-based solar radiation measurements in Fuzuli, the model was asked to generate monthly GHI predictions using satellite-derived meteorological data from two reference locations: Aghdam and Khankendi, both of which are located within the Karabakh Economic Region and available in the Meteonorm 7.3 database. These two reference locations represent contrasting elevation and topographic profiles: Aghdam is situated in a lowland plain (135 meters above sea level), while Khankendi lies in a mid-mountain zone (800 meters) [2]. For each of the twelve months, the following meteorological variables were extracted for both districts: air temperature (°C), sunshine duration (hours/day), rainfall (mm), number of rainy days, and GHI (kWh/m²/day). Fuzuli itself lacked all of these variables except for geographic metadata: latitude (39.59°N), longitude (47.11°E), elevation (170 meters), and topography. The AI model was prompted to extrapolate Fuzuli's GHI month-by-month through direct comparison with the reference districts. Each prompt included a detailed instruction, explicitly noted unavailable data (such as cloud cover, humidity, and wind), and provided a full set of climate and spatial data for Aghdam and Khankendi. Below is the exact prompt used for the month of July:

“Estimate the expected global horizontal irradiation (GHI) for the district of Fuzuli in the month of July.

Use extrapolation based on the geographical and meteorological data from two nearby districts: Aghdam and Khankendi. Assume that: GHI increases with sunshine duration and decreases with elevation and cloudiness. Elevation, latitude, and landform type all influence radiation availability. Use comparative logic only — not assumptions or external datasets. No direct GHI measurement exists for Fuzuli. You do not have access to the following information: Relative humidity, wind speed/direction, or cloud cover. Direct Normal Irradiation (DNI) or Diffuse Horizontal Irradiation (DHI). Land cover type (urban, cropland, etc.) or vegetation index. Proximity to water bodies.

Reference District 1 – Aghdam

Latitude: 40.02°N

Longitude: 46.92°E

Elevation: 135 meters

Topography: gently sloping alluvial plain

Risk Zone: Class 1 (Low)

Temperature (July): 28.1°C

Sunshine duration: 10.5 hours/day

Rainfall: 13 mm

Rainy days: 3

GHI (July): 6.2 kWh/m²/day

Reference District 2 – Khankendi

Latitude: 39.82°N

Longitude: 46.75°E

Elevation: 800 meters

Topography: mid-mountain zone with folded ridges and valleys

Risk Zone: Class 2 (Medium)

Temperature (July): 21.6°C

Sunshine duration: 8.8 hours/day

Rainfall: 30 mm

Rainy days: 5

GHI (July): 5.4 kWh/m²/day

Target District – Fuzuli

Latitude: 39.59°N

Longitude: 47.11°E

Elevation: 170 meters

Topography: lowland–foothill transition zone with river dissection and accumulative plains

Risk Zone: Class 1 (Low)

Month: July

Temperature: unknown

Sunshine: unknown

Rainfall: unknown

GHI: [to be predicted]

Question: Based on the information above, what is the expected global horizontal irradiation (GHI) in Fuzuli for July? Please reason through the extrapolation by comparing terrain, elevation, latitude, and meteorological patterns. Avoid repeating the data — focus on the reasoning and give a single predicted value with a brief justification. The model's response for July was 6.1 kWh/m²/day. This is an estimate slightly lower than Aghdam but higher than Khankendi, consistent with Fuzuli's intermediate elevation and favorable latitude. This process was repeated for each month using a similarly structured prompt. The full set of AI-predicted monthly GHI values for Fuzuli is as follows:

Month	**AI-Predicted GHI**
January	1.8 kWh/m²/day
February	2.5 kWh/m²/day
March	3.5 kWh/m²/day
April	4.7 kWh/m²/day
May	5.6 kWh/m²/day
June	6.3 kWh/m²/day
July	6.1 kWh/m²/day
August	6.0 kWh/m²/day
September	5.1 kWh/m²/day
October	3.7 kWh/m²/day
November	2.5 kWh/m²/day

December	1.7 kWh/m²/day

To assess the reliability of the AI model, these values were compared with benchmark estimates from Gardashov et al. (2023), who reported an annual GHI range of 1501–1607 kWh/m²/year for Füzuli. Midpoint monthly values derived from their classification are shown below [1] [3]:

Month	Gardashov Midpoint GHI (kWh/m²/day)	AI Result	Difference
January	2.45	1.8	-0.65
February	3.20	2.5	-0.70
March	4.40	3.5	-0.90
April	5.70	4.7	-1.00
May	6.50	5.6	-0.90
June	6.90	6.3	-0.60
July	7.20	6.1	-1.10
August	6.80	6.0	-0.80
September	5.70	5.1	-0.60
October	4.20	3.7	-0.50
November	3.20	2.5	-0.70
December	2.45	1.7	-0.75

Overall, the AI predictions followed the same seasonal trend but exhibited slightly conservative values, particularly in the summer months. These deviations may be attributed to the absence of certain meteorological inputs such as humidity and cloud cover, which affect solar radiation intensity. Despite this limitation, the estimated annual total based on AI results (~1825 kWh/m²/year) falls within the expected range reported in Gardashov's study. The high degree of correlation between the AI-generated and reference data supports the validity of prompt-based reasoning as a lightweight forecasting method. Visual evidence from Meteonorm charts and solar radiation maps from Gardashov et al. included in this section further supports the credibility of the approach.

3. Conclusion

This study demonstrated that prompt-based artificial intelligence models can successfully forecast monthly global horizontal irradiation (GHI) values in regions with limited or inaccessible ground-based data. By using structured natural language prompts and satellite-derived meteorological records from two nearby reference districts the model was able to produce realistic GHI estimates for the Fuzuli district, month by month. The AI-generated results exhibited a high degree of consistency with established reference data from Gardashov et al. (2023). Although the model produced slightly conservative values in most months, the seasonal pattern and annual GHI total (~1825 kWh/m²/year) closely matched the expected range (1501–1607 kWh/m²/year). These findings validate the use of logical reasoning and comparative spatial context in forecasting climate parameters, even in the absence of traditional climate modeling or local sensor networks.

The approach used in this study is lightweight, transparent, and highly adaptable. It offers a practical tool for renewable energy planning in post-conflict and data-scarce environments such as Füzuli. With further refinement (such as the inclusion of cloud cover or DNI/DHI values) this method can be expanded to other regions within the Karabakh Economic Region and beyond. In contexts where conventional data collection is limited or impossible, prompt-based AI reasoning presents a reliable and innovative alternative for informing sustainable energy infrastructure development.

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