CLIMATE RESOURCES OF THE TASHKENT REGION

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ABSTRACT

The Tashkent region in Uzbekistan represents a prime area for harnessing climate resources due to its favorable geographical and meteorological conditions. This article explores the potential of solar energy, wind energy, and atmospheric water vapor harvesting in the region. Drawing on meteorological data, including solar radiation, wind speed, and humidity levels, the discussion highlights the viability of these renewable resources for sustainable development. With Uzbekistan's push towards green energy, the Tashkent region could play a pivotal role in reducing dependence on fossil fuels and addressing water scarcity issues. The analysis is based on recent studies and data from sources like the International Energy Agency (IEA) and local meteorological records.

Introduction. Uzbekistan, located in Central Asia, is characterized by a continental climate with hot summers, cold winters, and low precipitation levels. The Tashkent region, encompassing the capital city and surrounding areas, spans approximately 15,300 square kilometers and is home to over 2.8 million people. Its topography includes plains, foothills, and mountainous areas, which influence local weather patterns. The region's climate features more than 300 sunny days annually, moderate wind speeds, and varying humidity, making it suitable for exploiting renewable climate resources.

Climate resources refer to natural atmospheric and solar phenomena that can be converted into usable energy or water. Solar energy utilizes radiation from the sun, wind energy harnesses kinetic energy from air movement, and atmospheric water vapor harvesting extracts moisture from the air to produce potable water. In the context of global climate change and resource depletion, these resources offer environmentally friendly alternatives. Uzbekistan has set ambitious targets for renewable energy, aiming for 5 GW of solar and wind capacity by 2026, with significant developments in the Tashkent region. This article examines each resource in detail, supported by meteorological data on solar radiation, wind speed, and humidity, to assess their potential for practical application.

The importance of these resources cannot be overstated. Uzbekistan relies heavily on natural gas for energy, but with reserves depleting, renewables are crucial for energy security. Water scarcity is another pressing issue, with the Aral Sea crisis exacerbating regional

droughts. Atmospheric water harvesting could provide a supplementary source in arid zones. By integrating data from meteostations, such as those operated by the Uzbek Hydrometeorological Service, this article provides a comprehensive overview of the Tashkent region's climate resource potential.

Solar energy is one of the most abundant resources in Uzbekistan, particularly in the Tashkent region, where annual solar radiation averages between 1,500 and 1,700 kWh per square meter. This high insolation is due to the region's latitude (around 41°N) and clear skies, with over 320 sunny days per year. Meteorological data from sites like meteoblue indicate that peak solar radiation occurs in summer months, with daily averages reaching up to 7-8 kWh/m^2 in June and July. In contrast, winter months see reduced levels, around 2-3 kWh/m^2, due to shorter days and occasional cloud cover.

The gross solar potential for Uzbekistan is estimated at 2,134 x 10^3 PJ, with a technical potential of 7,411 PJ—equivalent to four times the country's annual energy consumption. In the Tashkent region specifically, this translates to significant opportunities for photovoltaic (PV) and solar thermal systems. For instance, a typical 1 kWp PV system can generate 1,500-1,700 kWh annually, making rooftop installations viable for urban areas like Tashkent city.

Recent developments underscore this potential. In 2024, solar power plants in Uzbekistan generated 4.5 billion kWh, saving 1.36 billion cubic meters of natural gas. The Tashkent region is targeted for 20,000 new household solar panels in the coming years, alongside large-scale projects like the 500 MW solar parks supported by the International Finance Corporation (IFC). A new solar plant in the Bukhara region (adjacent to Tashkent) is projected to cut over 327,000 metric tons of CO2 emissions annually.

Meteorological factors influencing solar potential include air temperature and humidity. Tashkent's average annual temperature is about 14.1°C, with highs of 35.6°C in July and lows of -1.5°C in January. High temperatures can reduce PV efficiency by 0.4-0.5% per degree above 25°C, but the region's low humidity (39% in July) minimizes dust accumulation on panels. Studies using hourly data show that effective solar utilization could meet up to 40% of the region's energy needs if integrated with storage systems.

Challenges include seasonal variability and urban shading in Tashkent city. However, with government incentives and international partnerships, such as the IEA's solar roadmap for Uzbekistan by 2030, the region is poised for growth. Overall, solar energy represents a cornerstone of the Tashkent region's renewable strategy.

Wind energy potential in Uzbekistan is substantial, with a forecasted capacity of 520,000 MW nationwide. In the Tashkent region, wind speeds average 3-5 m/s at 10 meters height, with higher velocities in foothill areas like the Chimgan mountains. Meteorological data from Tashkent stations show predominant winds from the northeast and southwest, with peak speeds in spring and autumn. Annual wind roses indicate that winds blow consistently from 0°-90° (north to east) for about 20-30% of the year.

Evaluations reveal notable potential in areas like the Tashkent region, with power densities up to 94 W/m^2 in nearby Navoi. The technical wind potential is estimated at 2.2 Mtoe, with 19% developable. Uzbekistan aims for 3 GW of wind capacity by 2026, including projects in Tashkent.

Key initiatives include the Charvak Wind Power Plant, a $28 million project generating 50 million kWh annually and saving 811,000 cubic meters of gas. Another 129.6 million kWh wind farm is planned for the region. Larger complexes, like three 500 MW farms totaling 1.5 GW, are under development.

Wind patterns are influenced by topography; valleys channel winds, enhancing potential in rural areas. Humidity and temperature affect turbine performance—low summer humidity (39%) reduces icing risks, but high winter humidity (73%) may cause minor issues. Challenges include variable speeds below 5 m/s in urban zones, necessitating taller turbines.

Integration with solar could create hybrid systems, leveraging wind during cloudy periods. With international support, wind energy can contribute significantly to the region's sustainability.

Atmospheric water vapor harvesting (AWH) involves extracting moisture from the air using technologies like condensation or sorption. In arid Uzbekistan, where water resources are strained, AWH offers a promising alternative. The Tashkent region's relative humidity ranges from 39% in July to 73% in January, with average annual levels around 50-60%. Meteorological data show dew points conducive to harvesting, especially in winter and spring.

Global studies indicate AWH potential in regions with humidity above 30%, making Tashkent viable. In Uzbekistan, tests have produced drinking water from air, with units extracting moisture via condensation. The country's water vapor elasticity has increased, particularly in foothills (17%), enhancing potential.

Sorption-based AWH (SAWH) is energy-efficient for low-humidity areas, using materials like hydrogels to capture vapor. In Tashkent, with temperatures up to 35.6°C and humidity dips, passive systems could yield 1-5 liters per day per unit. Evaporation losses from reservoirs highlight the need for alternative sources.

Challenges include energy requirements for active systems and dust in arid climates. However, integration with solar power could make it sustainable. Uzbekistan's Fourth National Communication to the UNFCCC notes vulnerability to water stress, positioning AWH as a resilience tool.

Conclusion. The Tashkent region's climate resources—solar, wind, and atmospheric water vapor—offer immense potential for sustainable development. Solar energy, with high radiation levels, can drive energy transitions; wind provides complementary power in varied terrains; and AWH addresses water scarcity. Meteorological data underscore feasibility, but success requires policy support and technology adoption. By 2030, these resources could transform Uzbekistan into a green energy leader, reducing emissions and enhancing resilience.

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