CLIMATE IMPACTS ON MICRO-HYDROPOWER GENERATION IN KALAM

In the remote Kalam region of Pakistan, micro-hydropower plants (MHPs) provide essential electricity to off-grid communities. However, natural variability in water flow and climate conditions affects power generation, leading to supply fluctuations. Understanding how weather patterns influence MHP performance can help improve energy forecasting and resource management.

Analyzing energy generation (kWh) alongside climate factors, we uncover key insights:

1) **Total Precipitation (Corr = 0.50, Feature Importance = 0.29)**

Insight: Rainfall has the strongest direct impact on power generation—more precipitation means higher water flow into MHPs. Its high feature importance confirms that rainfall remains a dominant factor in sustaining hydropower output.

2) **Dewpoint Temperature (Corr = 0.06, Feature Importance = 0.05)**

Insight: Although dewpoint (a measure of atmospheric moisture) has a weak correlation, its feature importance suggests an indirect effect. It may influence snowmelt rates and long-term water availability for hydropower.

3) **Temperature (Corr = 0.005, Feature Importance = 0.07)**

Insight: Daily temperature changes have minimal direct impact on power output, as the data covers August to December. However, its importance suggests long-term seasonal effects—such as influencing snowmelt or evaporation, which alter water availability over time.

4) **Snowfall (Corr = -0.045, Feature Importance = 0.09)**

Insight: Fresh snowfall does not immediately contribute to energy generation, leading to a slight negative correlation. Since snow takes time to melt and feed into the water system, its impact is delayed, making it a secondary factor.

5) **Snow Cover (Corr = -0.09, Feature Importance = 0.06)**

Insight: A thick snow cover initially reduces water availability for hydropower, delaying energy generation. However, its feature importance suggests that as snow melts over time, it sustains water flow, making it crucial for long-term power reliability.

6) **U Wind Component (East-West Winds) (Corr = -0.33, Feature Importance = 0.17)**

Insight: Strong east-west winds reduce power generation, possibly by influencing precipitation patterns (e.g., causing drier conditions) or increasing evaporation losses from water sources.

7) **V Wind Component (North-South Winds) (Corr = -0.05, Feature Importance = 0.27)**

Insight: Despite weak correlation, north-south winds have the highest feature importance, suggesting an indirect but critical role in shaping storm systems. These winds may affect precipitation, snowfall, or even power system stability in the mountainous terrain of Kalam.

Key Takeaways for MHP Energy Forecasting

• Rainfall is the most important direct driver of power generation.

• Snowfall and snow cover influence long-term water availability, making them essential for seasonal energy planning.

• Temperature and dewpoint impact energy generation indirectly, by affecting evaporation and snowmelt cycles.

• Wind components play an unexpected but significant role, likely by shaping local climate patterns that impact precipitation.

By incorporating these insights into energy forecasting models, micro-hydropower plants in Kalam can optimize power distribution, reduce blackouts, and improve system reliability—ensuring sustainable energy access for off-grid communities.