An initial assessment of wind measurements in Qatar

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Overview

In order to reduce greenhouse gas emissions, Qatar started development of renewable energy sources. Solar and wind energy are both viable options with a great level of maturity worldwide in terms of technology development and deployment, whether at small or large scales. However, and to be able to use these renewable technologies efficiently in a specific location, it is essential to assess the potential and availability of the resources to be harnessed, especially if this resource is intermittent, with spatial and temporal variations, as in the case of wind and solar energy. QEERI monitors the solar radiation in several locations in Qatar since 2013, with the objective to provide an accurate solar resource assessment for the country. For the wind resources, QEERI monitors wind speed and direction at two sites in Qatar. In this study, we present an analysis of the measured wind parameters, with a comparison with the solar radiation components measured at the same locations.

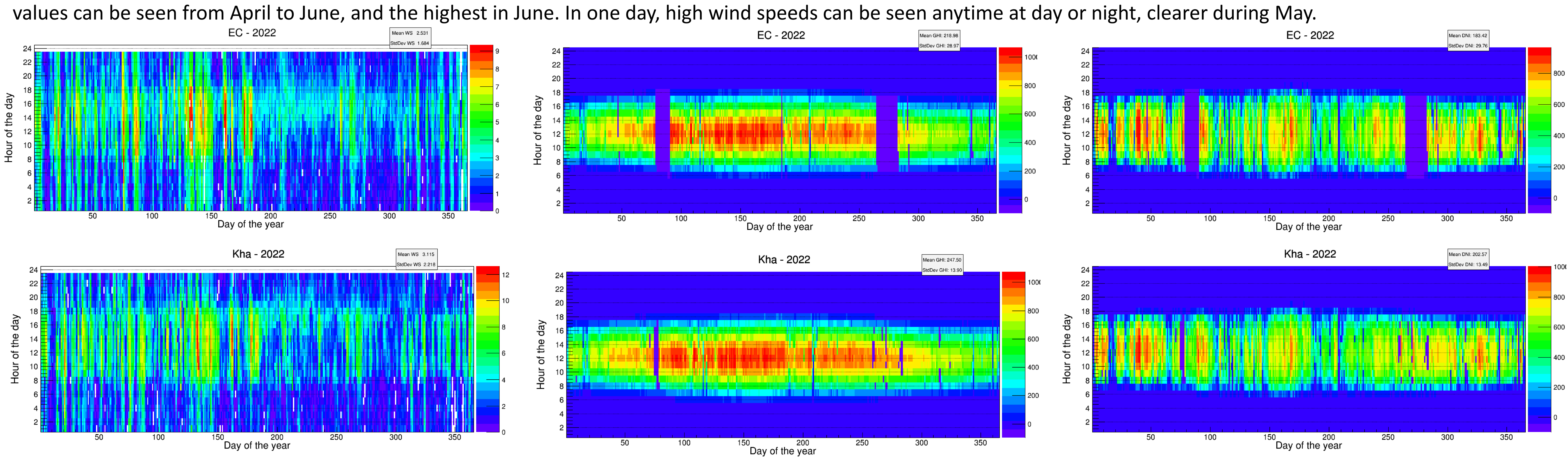
Data and Analysis

Data used here are collected by Solar Radiation Monitoring Stations (SRMS) and Automatic Weather Stations (AWS) at two different sites in Qatar: Education City (in Doha) and Al Kharsaah, denoted here as EC and Kha, respectively. Records of 1-min averages are available for the solar radiation components: direct normal irradiance (DNI), global horizontal irradiance (GHI), and diffuse horizontal irradiances (DHI), as well as for the meteorological parameters in Kha; for the AWS in EC, the data are recorded every 10 minutes. Wind speed and direction are measured at a height of 2 and 3 m above the ground respectively for EC and Kha, with the difference that in EC the AWS is installed on the rooftop of a building with the rooftop at ~ 13 m from the ground, and in Kha the AWS is installed on a tower at 3 m height from the ground. Preventive maintenance is done routinely on both stations. Data analyzed here covers the period 2019-2022. The solar radiation data are averaged using 1-min data that passes the BSRN quality control (QC) standard, so when the average is shown as missing, it results from data that are either missing or did not pass the QC checks.

QEERI's SRMS and AWS

Results

The frequency distributions of hourly wind speed, DNI and GHI throughout one year are shown below for year 2022, represented in the colored histograms. The mean and standard deviation are also displayed on the graphics and reported in the tables. Daily variability shows that solar radiation, mainly GHI, is season-dependent, while DNI is more sensitive to aerosols and clouds in the atmosphere and thus seasonality is not noticeable. Wind speed does not follow a clear seasonal trend; however, relatively high values can be seen from April to June, and the highest in June. In one day, high wind speeds can be seen anytime at day or night, clearer during May.



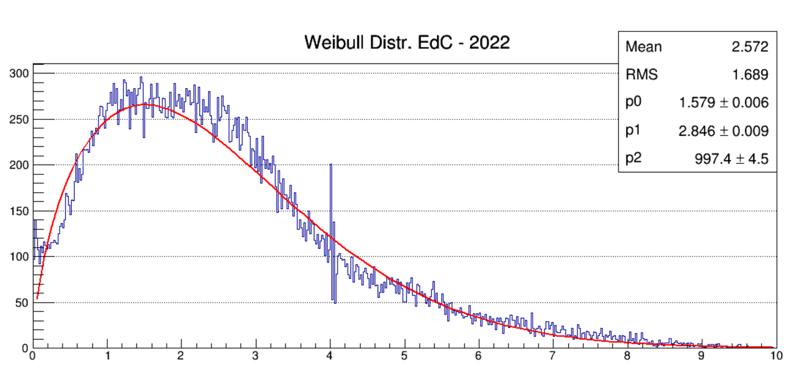
Wind	2019		2020		2021	
	Mean	STD	Mean	STD	Mean	STD
EC	2.472	1.589	2.451	1.594	2.481	1.548
KHA	-		-		3.465	2.369

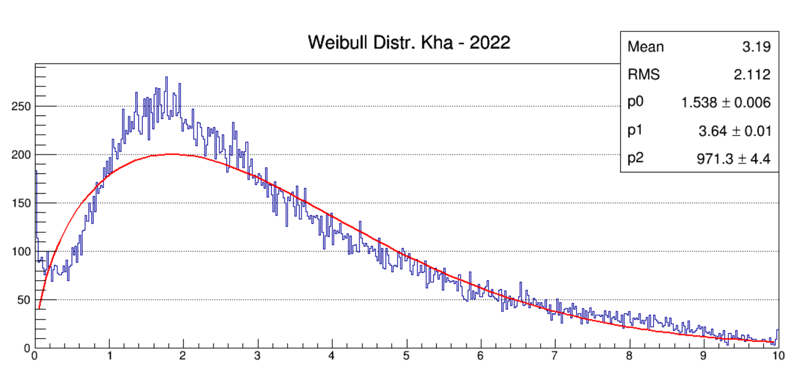
GHI	2019		2020		2021	
	Mean	STD	Mean	STD	Mean	STD
EC	-		239.14	20.83	252.10	11.72
KHA	232.97	30.58	251.33	14.53	223.63	31.67

DNI	2019		2020		2021	
	Mean	STD	Mean	STD	Mean	STD
EC	-		-		237.88	11.96
KHA	212.28	30.47	201.66	32.05	196.61	32.48

The wind speed distribution is shown below; the Weibull Distribution (WD) is fitted on the data using: F(ws) = p2* (p0/p1)*(ws/p1)^(p0−1)*exp [-(x/p1)^p0], where p0 is the shape parameter with values between 1 and 3, and p1 is the scale parameter in m/s, p2 is a scale factor to match the wind speed distribution.

The fitting parameters are shown on the statistics box of the graphics. Visually the WD fits better on the data of EC mainly on the mid-values of wind speed. To evaluate the goodness of the Weibull fit, we used the chi-squared test by calculating the chi-square Ψ^2 divided by the number of degrees of freedom NDF, the results are shown in the table and have higher values for Kha location but acceptable and comparable with EC.



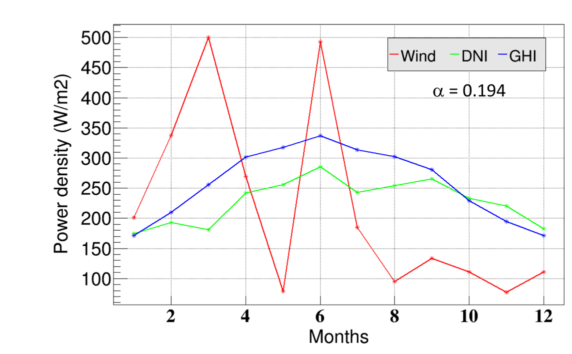


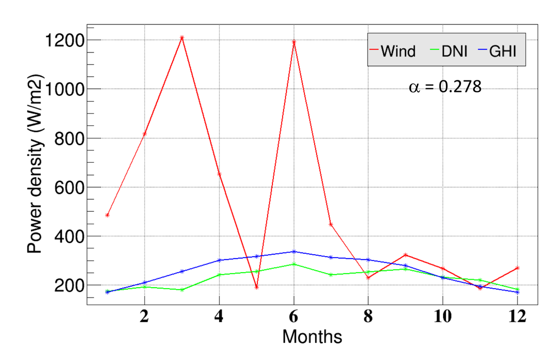
Ψ^2/NDF	2019	2020	2021	2022
EC	3.031	3.67	4.04	2.89
KHA			4.18	3.75

Wind speed distribution for 10-min measured data, for both locations in year 2022.

The power density of wind and solar were compared for Kha by estimating the monthly averaged power per unit area (W/m^2). For wind, the average power per unit area is given by: wP = 1/2ρws^3: ρ is the air density calculated from temperature and atmospheric pressure. To calculate ws at 100m height we use: $\frac{ws2}{ws1} = (\frac{h2}{h1})^{\alpha}$, α is the shear factor. Two cases are considered here:

1. α is estimated from ws data in Doha averaged over 6 years using height 2m to 5m
2. α is taken from [1], using 3 years ws data in KSA*, and heights of 20, 30, 40m





[1] Wind shear coefficients and their effect on energy production. Energy Conversion and Management 46(15):2578-2591. DOI:10.1016/j.enconman.2004.12.005

* KSA: Kingdom of Saudi Arabia

Discussion

- Considering the results of power density (Pin) over one year in Kha, we estimate a total annual energy in kWh/m^2/year as follows: for wind at 100 m height Pin = 1892.72 (considering shear factor case#2), Pin = 2252.16 for GHI, and Pin = 1993.44 for DNI. While solar and wind power density have a comparable value, Pin is not the power generated by the conversion systems, it is only the input; other efficiency and loss factors should be considered when determining the power output.
- Wind and solar have different daily and seasonal trend during one year in Qatar. The wind analysis shown here, although based on some approximation, gives a preliminary assessment of the wind pattern at Kha (the location of the solar plant in Qatar), and shows that wind and solar can complement each other, mainly during night time.