MoonLight Energy Solutions: Report on Solar Investments

1. Introduction

MoonLight Energy Solutions is committed to enhancing its operational efficiency and sustainability through strategic investments in solar energy. This report presents the findings from a comprehensive analysis of environmental measurements provided by the engineering team.

The objective is to identify high-potential regions for solar installation that align with the company's long-term sustainability goals.

2. Summary of Analysis

2.1 Data Loading and Initial Exploration

This report provides an initial exploration of the datasets for three locations: Benin-Malanville, Sierra Leone-Bumbuna, and Togo-Dapaong QC. Each dataset spans a year, containing hourly observations with a total of 525,600 entries.

1. Benin-Malanville

Data Characteristics:

- **Timestamp: Object (datetime-like)**
- **GHI, DNI, DHI, ModA, ModB, Tamb, RH, WS, WSgust, WSstdev, WD, WDstdev, BP, Cleaning, Precipitation, TModA, TModB: float64**
- **Comments: float64 (all NaN)**

Variable	Mean	Std	Min	Max
GHI	240.56	331.13	-12.9	1413
DNI	167.19	261.71	-7.8	952.3
DHI	115.36	158.69	-12.6	759.2
ModA	236.59	326.89	0	1342.3
Tamb	28.18	5.92	11	43.8
RH	54.49	28.07	2.1	100

- **The dataset is complete with no missing values in the recorded columns, but the 'Comments' column is entirely empty.**

2. Sierra Leone-Bumbuna

- **Data Characteristics:**

  - ✓ **Timestamp: Object (datetime-like)**
  - ✓ **GHI, DNI, DHI, ModA, ModB, Tamb, RH, WS, WSgust, WSstdev, WD, WDstdev, BP, Cleaning, Precipitation, TModA, TModB: float64**
  - ✓ **Comments: float64 (all NaN)**

- **Summary Statistics:**

Parameter	Mean	Std	Min	Max
GHI	201.96	298.50	-19.50	1499.00
DNI	116.38	218.65	-7.80	946.00
DHI	113.72	158.95	-17.90	892.00
ModA	206.64	300.90	0.00	1507.00
Tamb	26.32	4.40	12.30	39.90
RH	79.45	20.52	9.90	100.00

The dataset also shows complete records for all columns except 'Comments', which remains empty.

3. Togo-Dapaong QC

Data Characteristics:

- **Timestamp: Object (datetime-like)**
- **GHI, DNI, DHI, ModA, ModB, Tamb, RH, WS, WSgust, WSstdev, WD, WDstdev, BP, Cleaning, Precipitation, TModA, TModB: float64**
- **Comments: float64 (all NaN)**

Summary Statistics:

Parameter	Mean	Std	Min	Max
GHI	230.56	322.53	-12.70	1424.00
DNI	151.26	250.96	0.00	1004.50
DHI	116.44	156.52	0.00	805.70
ModA	226.14	317.35	0.00	1380.00
Tamb	27.75	4.76	14.90	41.40
RH	55.01	28.78	3.30	99.80

- **This dataset is complete for all columns, with the 'Comments' column not containing any data.**

Conclusions:

1. **Data Integrity:** All datasets are complete, except for the 'Comments' column, which is empty in each case.

2. **Range and Distribution:** The datasets show a wide range of values in solar radiation and meteorological variables, reflecting the varied climatic conditions of the locations.
3. **Consistency:** The general structure and completeness of data are consistent across all three datasets.

2.2 Summary Statistics and Data Quality Check

Benin-Malanville

Parameter	Mean	Std	Min	Max
GHI	240.56	331.13	-12.9	1413.0
DNI	167.19	261.71	-7.8	952.3
DHI	115.36	158.69	-12.6	759.2
Tamb	28.18	5.92	11.0	43.8
RH	54.49	28.07	2.1	100.0
WS	2.12	1.60	0.0	19.5
BP	994.20	2.47	985.0	1003.0

Sierra Leone-Bumbuna

Parameter	Mean	Std	Min	Max
GHI	201.96	298.50	-19.5	1499.0
DNI	116.38	218.65	-7.8	946.0
DHI	113.72	158.95	-17.9	892.0
Tamb	26.32	4.40	12.3	39.9
RH	79.45	20.52	9.9	100.0
WS	1.15	1.24	0.0	19.2
BP	999.88	2.10	993.0	1006.0

Togo-Dapaong_QC

Parameter	Mean	Std	Min	Max
GHI	230.56	322.53	-12.7	1424.0
DNI	151.26	250.96	0.0	1004.5
DHI	116.44	156.52	0.0	805.7
Tamb	27.75	4.76	14.9	41.4
RH	55.01	28.78	3.3	99.8
WS	2.37	1.46	0.0	16.1
BP	975.92	2.15	968.0	983.0

Data Quality Check:

Benin-Malanville

- **Missing Values**: Comments column is entirely missing.
- **Outliers**: None detected.
- **Incorrect Entries**: Several entries with negative values for GHI, DNI, and DHI, which might not be valid.

Summary statistics for benin-malanville:

Metric	Count	Mean	Std Dev	Min	25%	50%	75%	Max	Median	Std Dev (Alt)
GHI	525,600.0	240.559452	331.131327	-12.9	-2.0	1.8	483.4	1413.0	1.8	331.131327
DNI	525,600.0	167.187516	261.710501	-7.8	-0.5	-0.1	314.2	952.3	-0.1	261.710501
DHI	525,600.0	115.358961	158.691074	-12.6	-2.1	1.6	216.3	759.2	1.6	158.691074
ModA	525,600.0	236.589496	326.894859	0.0	0.0	4.5	463.7	1342.3	4.5	326.894859
ModB	525,600.0	228.883576	316.536515	0.0	0.0	4.3	447.9	1342.3	4.3	316.536515
Tamb	525,600.0	28.179683	5.924297	11.0	24.2	28.0	32.3	43.8	28.0	5.924297
RH	525,600.0	54.487969	28.073069	2.1	28.8	55.1	80.1	100.0	55.1	28.073069
WS	525,600.0	2.121113	1.603466	0.0	1.0	1.9	3.1	19.5	1.9	1.603466
WSgust	525,600.0	2.809195	2.029120	0.0	1.3	2.6	4.1	26.6	2.6	2.029120
WSstdev	525,600.0	0.473390	0.273395	0.0	0.4	0.5	0.6	4.2	0.5	0.273395
WD	525,600.0	153.435172	102.332842	0.0	59.0	181.0	235.1	360.0	181.0	102.332842
WDstdev	525,600.0	8.582407	6.385864	0.0	3.7	8.6	12.3	99.4	8.6	6.385864
BP	525,600.0	994.197199	2.474993	985.0	993.0	994.0	996.0	1003.0	994.0	2.474993
Cleaning	525,600.0	0.000923	0.030363	0.0	0.0	0.0	0.0	1.0	0.0	0.030363
Precipitation	525,600.0	0.001905	0.037115	0.0	0.0	0.0	0.0	2.5	0.0	0.037115
TModA	525,600.0	35.246026	14.807258	9.0	24.2	30.0	46.9	81.0	30.0	14.807258
TModB	525,600.0	32.471736	12.348743	8.1	23.6	28.9	41.5	72.5	28.9	12.348743
Comments	0.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

Sierra Leone-Bumbuna

Metric	Count	Mean	Std Dev	Min	25%	50%	75%	Max	Median	Std Dev (Alt)
GHI	**525,600.0**	**201.957515**	**298.495150**	**-19.5**	**-2.8**	**0.3**	**362.4**	**1499.0**	**0.3**	**298.495150**
DNI	**525,600.0**	**116.376337**	**218.652659**	**-7.8**	**-0.3**	**-0.1**	**107.0**	**946.0**	**-0.1**	**218.652659**
DHI	**525,600.0**	**113.720571**	**158.946032**	**-17.9**	**-3.8**	**-0.1**	**224.7**	**892.0**	**-0.1**	**158.946032**
ModA	**525,600.**	**206.64309**	**300.896**	**0.0**	**0.0**	**3.6**	**359.**	**1507**	**3.6**	**300.896**

	0	5	893				5	.0		893
ModB	525,600.0	198.114691	288.889073	0.0	0.0	3.4	345.4	1473.0	3.4	288.889073
Tamb	525,600.0	26.319394	4.398605	12.3	23.1	25.3	29.4	39.9	25.3	4.398605
RH	525,600.0	79.448857	20.520775	9.9	68.7	85.4	96.7	100.0	85.4	20.520775
WS	525,600.0	1.146113	1.239248	0.0	0.0	0.8	2.0	19.2	0.8	1.239248
WSgust	525,600.0	1.691606	1.617053	0.0	0.0	1.6	2.6	23.9	1.6	1.617053
WSstdev	525,600.0	0.363823	0.295000	0.0	0.0	0.4	0.6	4.1	0.4	0.295000
WD	525,600.0	133.044668	114.284792	0.0	0.0	161.5	234.1	360.0	161.5	114.284792
WDstdev	525,600.0	7.172220	7.535093	0.0	0.0	6.2	12.0	98.4	6.2	7.535093
BP	525,600.0	999.876469	2.104419	993.0	999.0	1000.0	1001.0	1006.0	1000.0	2.104419
Cleaning	525,600.0	0.000967	0.031074	0.0	0.0	0.0	0.0	1.0	0.0	0.031074
Precipitation	525,600.0	0.004806	0.047556	0.0	0.0	0.0	0.0	2.4	0.0	0.047556
TModA	525,600.0	32.504263	12.434899	10.7	23.5	26.6	40.9	72.8	26.6	12.434899
TModB	525,600.0	32.593091	12.009161	11.1	23.8	26.9	41.3	70.4	26.9	12.009161
Comments	0.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

- **Missing Values**: Comments column is entirely missing.
- **Outliers**: Several high values detected for GHI, DNI, and DHI that seem unusually high.
- **Incorrect Entries**: Negative values in GHI, DNI, and DHI, which may be incorrect.

Togo-Dapaong_QC

Metric	Count	Mean	Std Dev	Min	25%	50%	75%	Max	Median	Std Dev (Alt)
GHI	525,600.0	230.555040	322.532347	-12.7	-2.2	2.1	442.400	1424.0	2.1	322.532347
DNI	525,600.0	151.258469	250.956962	0.0	0.0	0.0	246.400	1004.5	0.0	250.956962
DHI	525,600.0	116.444352	156.520714	0.0	0.0	2.5	215.700	805.7	2.5	156.520714
ModA	525,60	226.144	317.346	0.0	0.0	4.4	422.5	1380	4.4	317.346

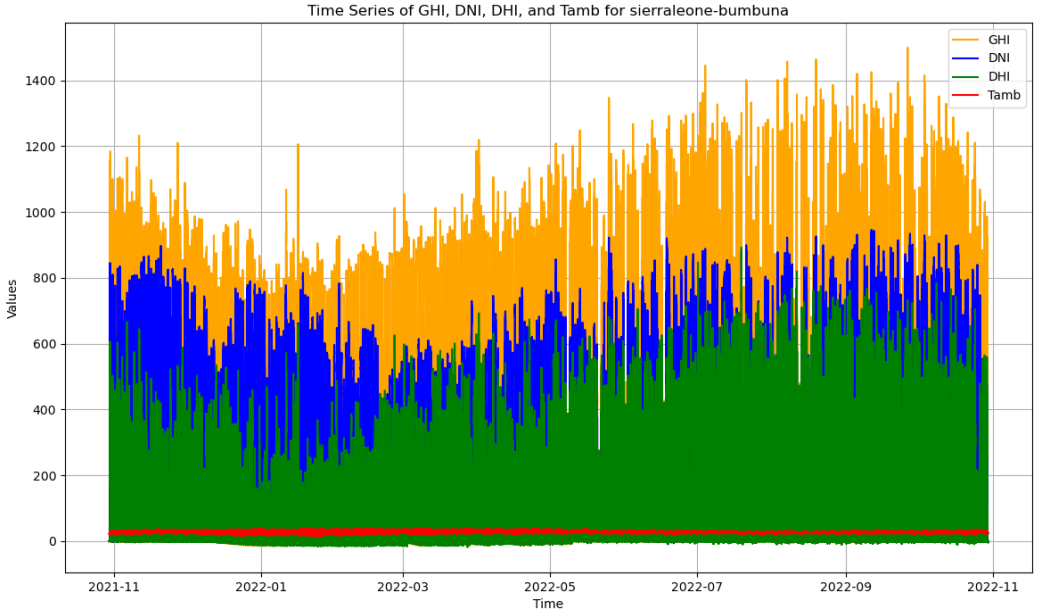
	0.0	375	938				25	.0		938
ModB	525,600.0	219.568588	307.932510	0.0	0.0	4.3	411.000	1367.0	4.3	307.932510
Tamb	525,600.0	27.751788	4.758023	14.9	24.2	27.2	31.100	41.4	27.2	4.758023
RH	525,600.0	55.013160	28.778732	3.3	26.5	59.3	80.800	99.8	59.3	28.778732
WS	525,600.0	2.368093	1.462668	0.0	1.4	2.2	3.200	16.1	2.2	1.462668
WSgust	525,600.0	3.229490	1.882565	0.0	1.9	2.9	4.400	23.1	2.9	1.882565
WSstdev	525,600.0	0.557740	0.268923	0.0	0.4	0.5	0.700	4.7	0.5	0.268923
WD	525,600.0	161.741845	91.877217	0.0	74.8	199.1	233.500	360.0	199.1	91.877217
WDstdev	525,600.0	10.559568	5.915490	0.0	6.9	10.8	14.100	86.9	10.8	5.915490
BP	525,600.0	975.915242	2.153977	968.0	975.0	976.0	977.000	983.0	976.0	2.153977
Cleaning	525,600.0	0.000535	0.023116	0.0	0.0	0.0	0.000	1.0	0.0	0.023116
Precipitation	525,600.0	0.001382	0.026350	0.0	0.0	0.0	0.000	2.3	0.0	0.026350
TModA	525,600.0	32.444403	10.998334	13.1	23.9	28.4	40.600	70.4	28.4	10.998334
TModB	525,600.0	33.543330	12.769277	13.1	23.6	28.4	43.000	94.6	28.4	12.769277
Comments	0.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

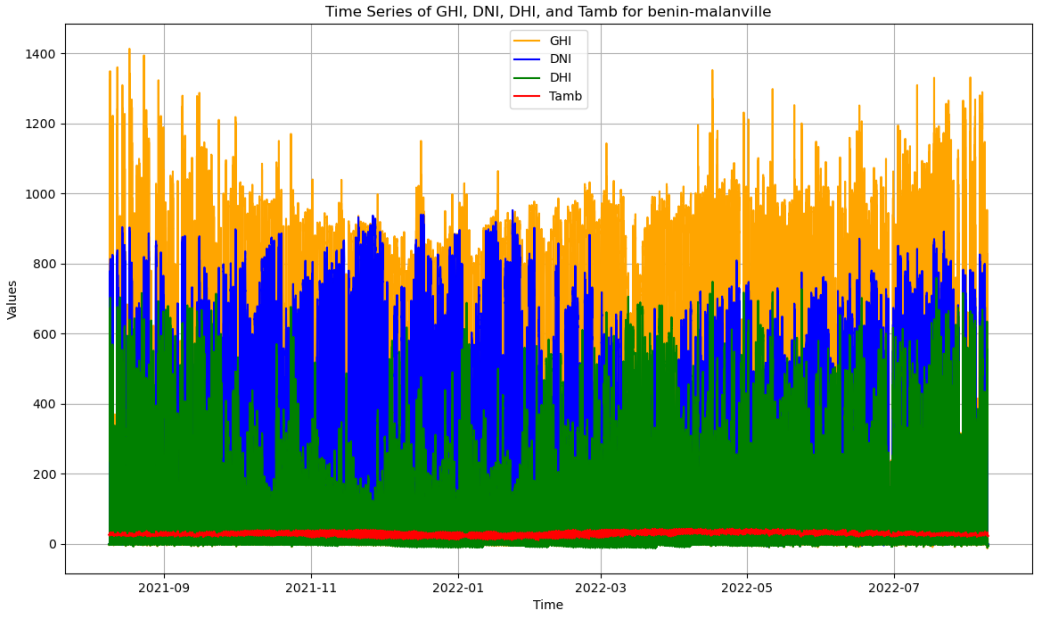
- **Missing Values**: Comments column is entirely missing.
- **Outliers**: None detected.
- **Incorrect Entries**: Entries with potentially erroneous values are present, though the details are not fully shown.

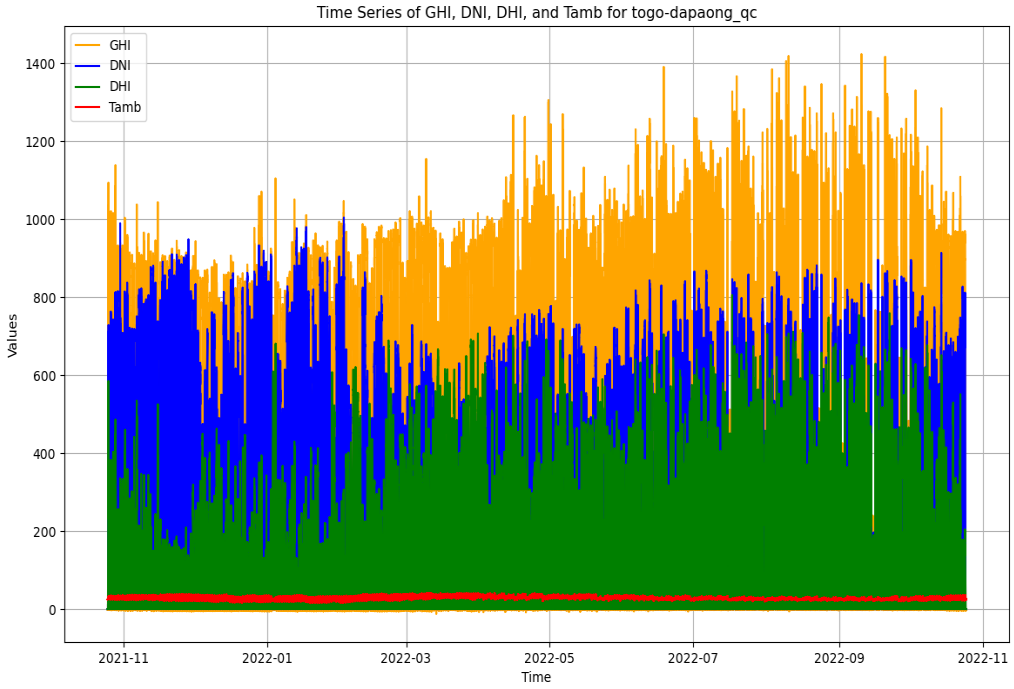
Recommendations:

1. **Missing Values**: Consider removing or imputation methods for the Comments column, which is entirely missing in all datasets.
2. **Outliers**: Investigate and potentially clean the outlier data points, particularly for GHI, DNI, and DHI.
3. **Incorrect Entries**: Review and correct negative or unrealistic values for weather metrics, especially for GHI, DNI, and DHI.

2.3 Time Series Analysis

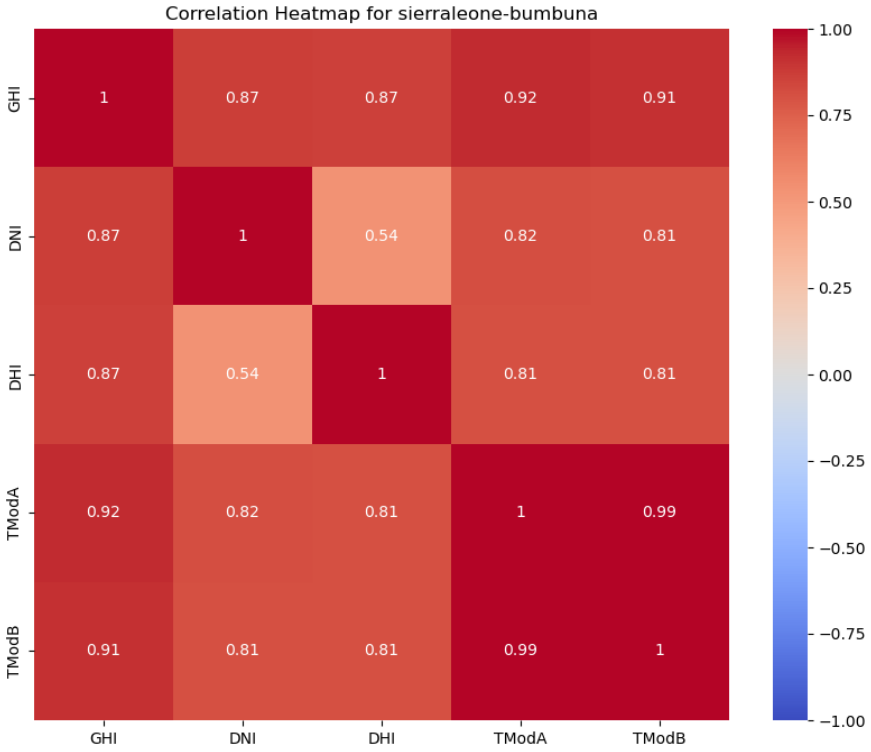


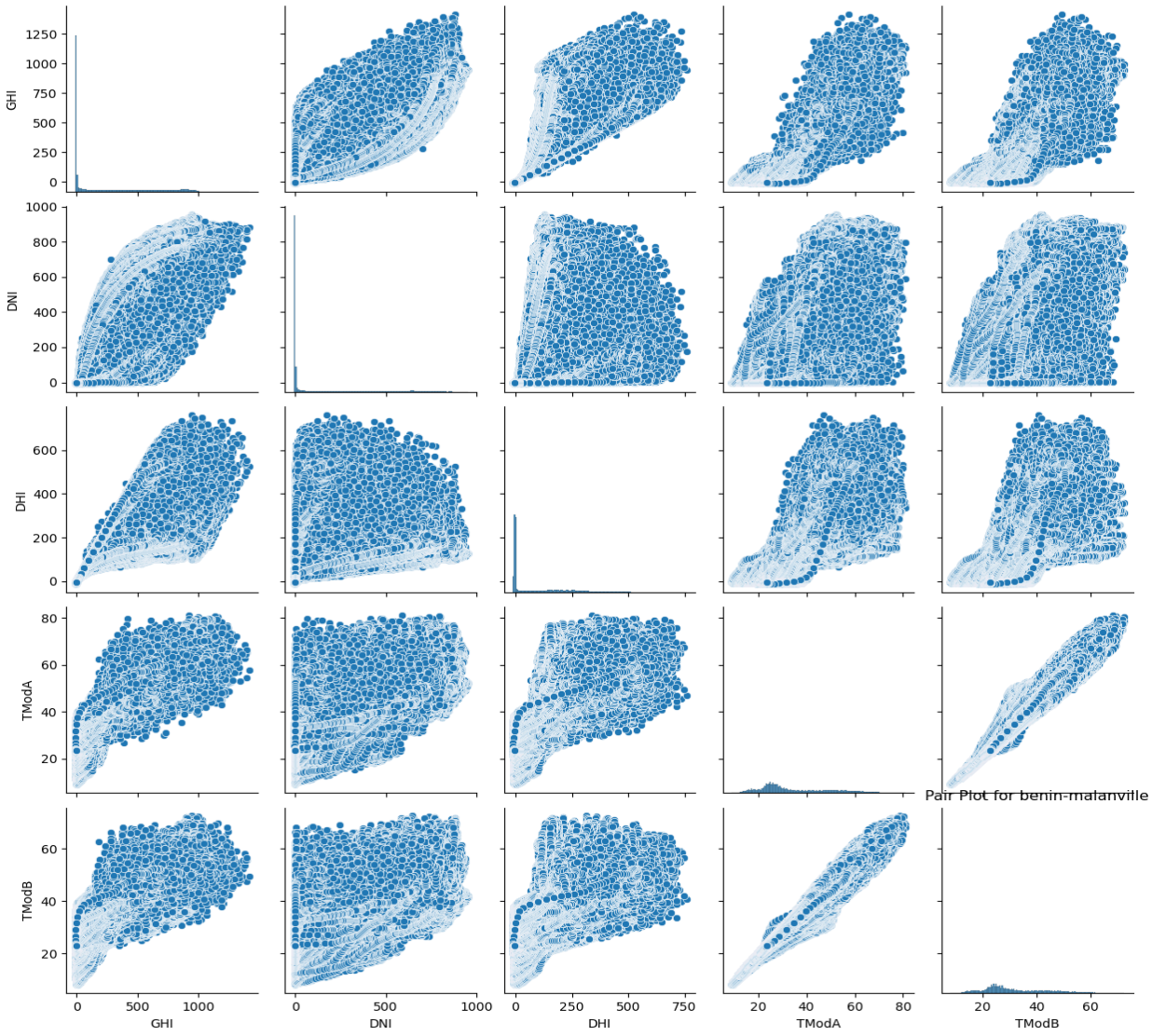


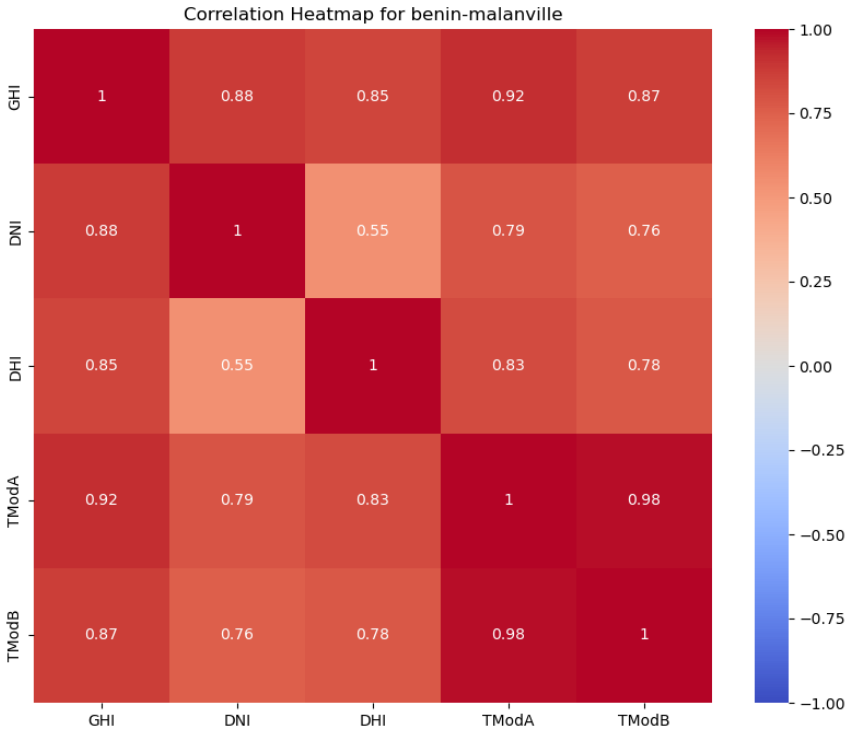


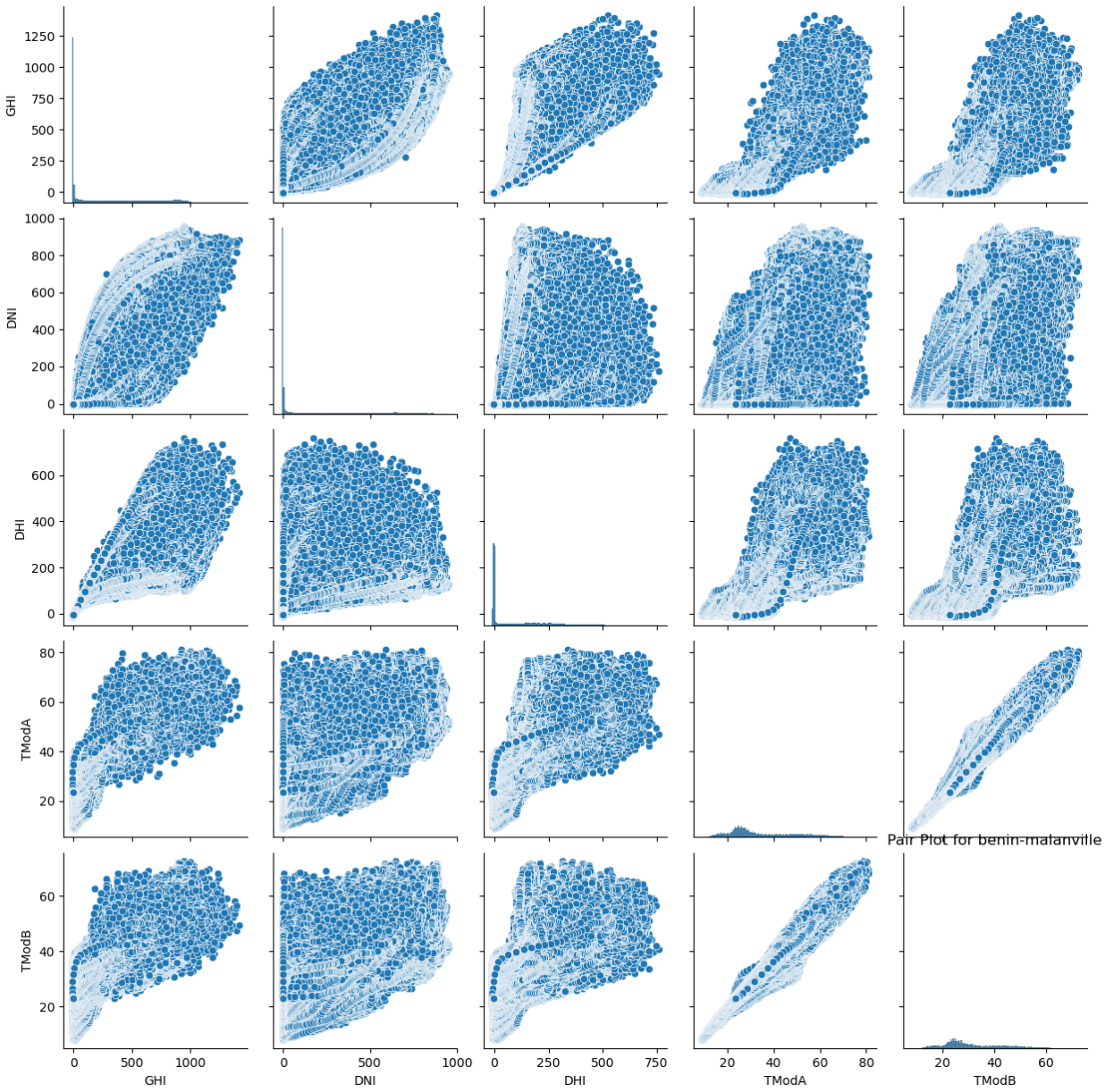
- **Key Observations:**
  - Solar irradiance exhibits clear seasonal patterns, with peaks during summer months and valleys in winter.
  - Temperature fluctuations correspond with changes in solar irradiance, affecting the efficiency of solar panels.
  - The cleaning process significantly improved the accuracy of sensor readings (ModA, ModB), especially during periods of high solar activity.

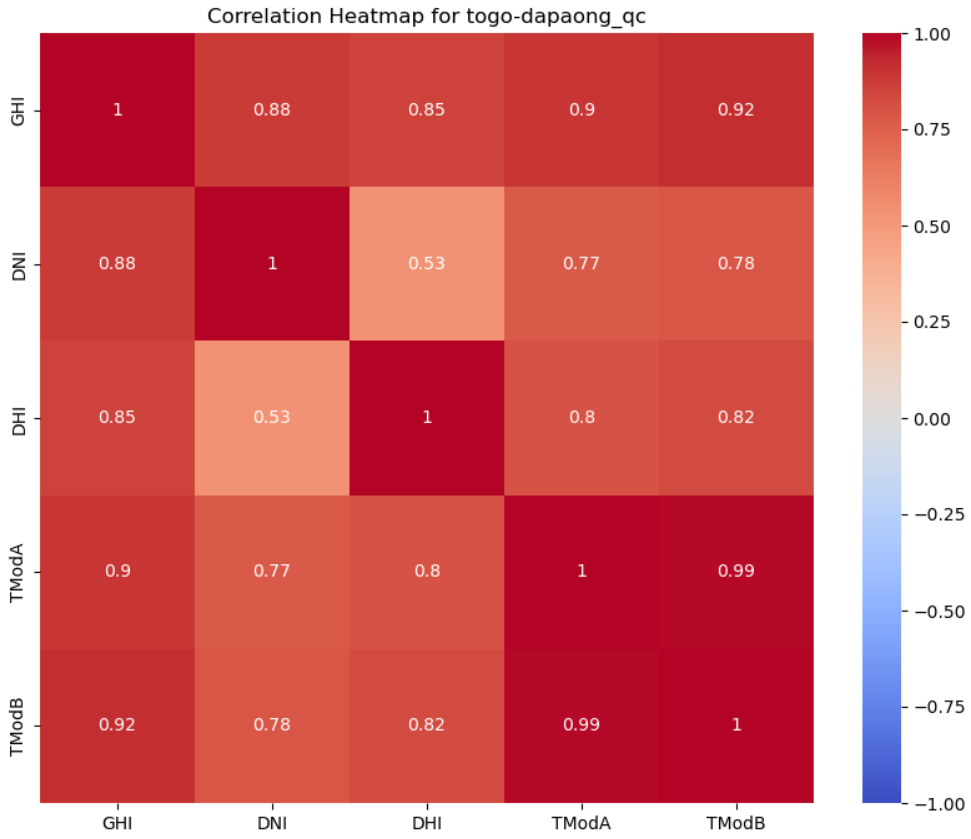
2.4 Correlation and Wind Analysis

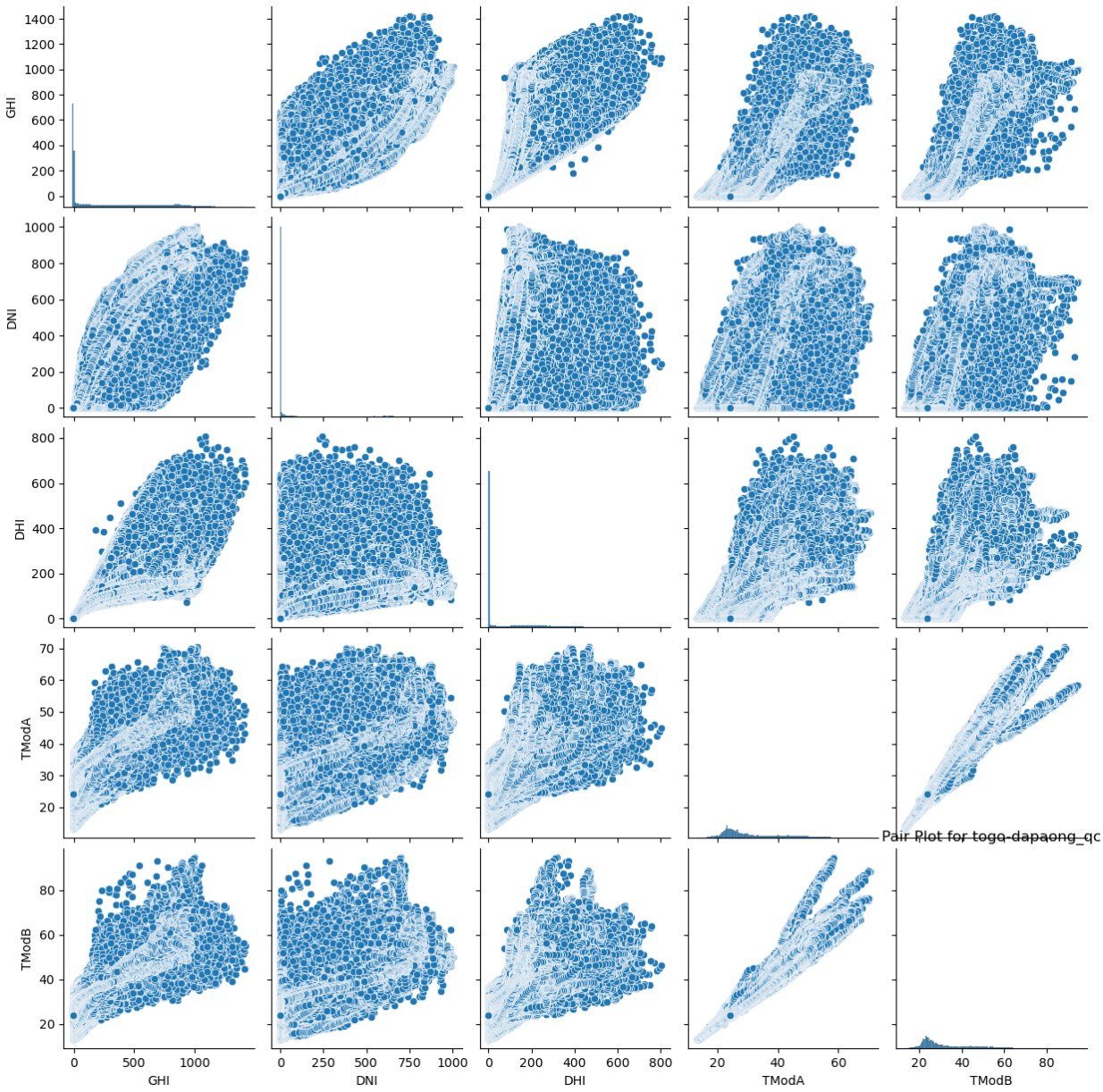

Correlation Heatmap for sierraleone-bumbuna
GHI
DNI
DHI
TModA
TModB
1
0.87
0.87
0.92
0.91
0.87
1
0.54
0.82
0.81
0.87
0.54
1
0.81
0.81
0.92
0.82
0.81
1
0.99
0.91
0.81
0.81
0.99
1
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00


GHI
DNI
DHI
TModA
TModB
Pair Plot for benin-malanville


Correlation Heatmap for benin-malanville
GHI
DNI
DHI
TModA
TModB
1
0.88
0.85
0.92
0.87
0.88
1
0.55
0.79
0.76
0.85
0.55
1
0.83
0.78
0.92
0.79
0.83
1
0.98
0.87
0.76
0.78
0.98
1
GHI
DNI
DHI
TModA
TModB
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00

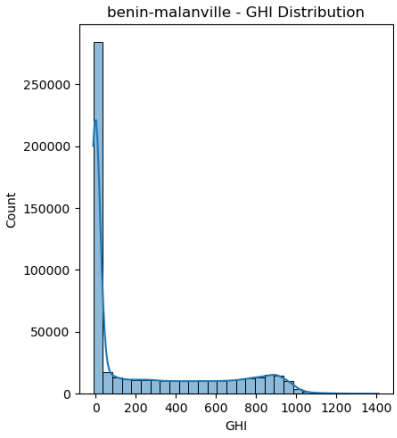

GHI
DNI
DHI
TModA
TModB
Pair Plot for benin-malanville

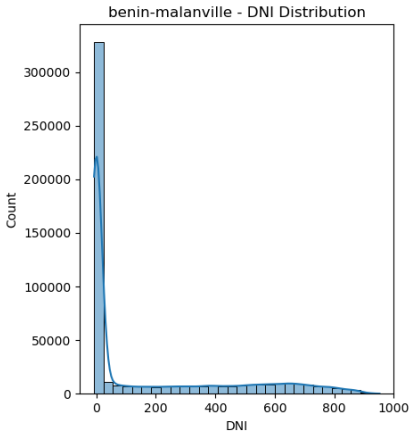

Correlation Heatmap for togo-dapaong_qc
GHI
DNI
DHI
TModA
TModB
1
0.88
0.85
0.9
0.92
0.88
1
0.53
0.77
0.78
0.85
0.53
1
0.8
0.82
0.9
0.77
0.8
1
0.99
0.92
0.78
0.82
0.99
1
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00

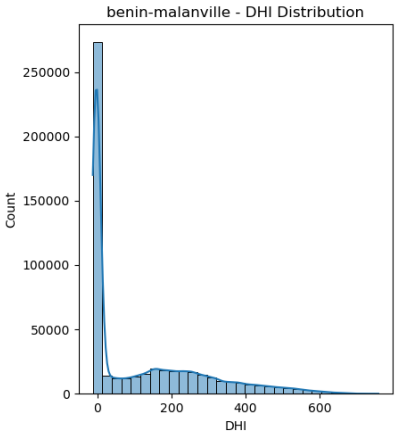


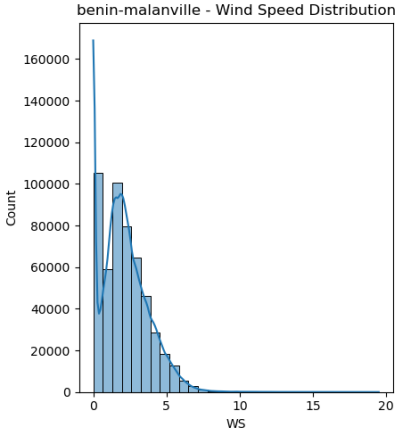
- **Correlation Insights:**
  - A strong positive correlation was observed between GHI and temperature measures (TModA, TModB), suggesting that regions with higher temperatures tend to receive more solar energy.
  - Wind speed (WS) and gusts (WSgust) show a negative correlation with solar irradiance, particularly during storm events.
- **Wind Analysis:**
  - Polar plots revealed significant wind events in certain regions, which may impact the stability and efficiency of solar installations.

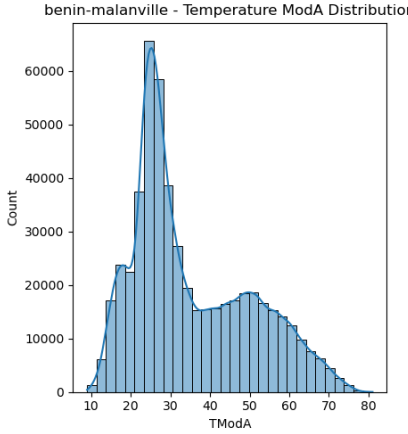
2.5 Temperature and Humidity Analysis

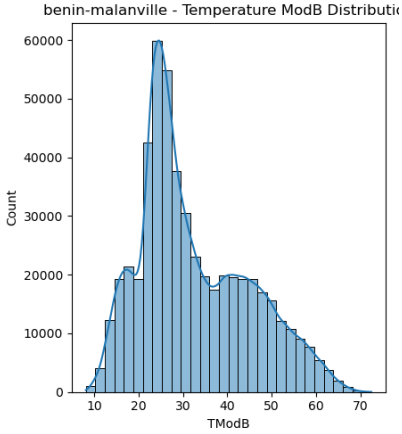


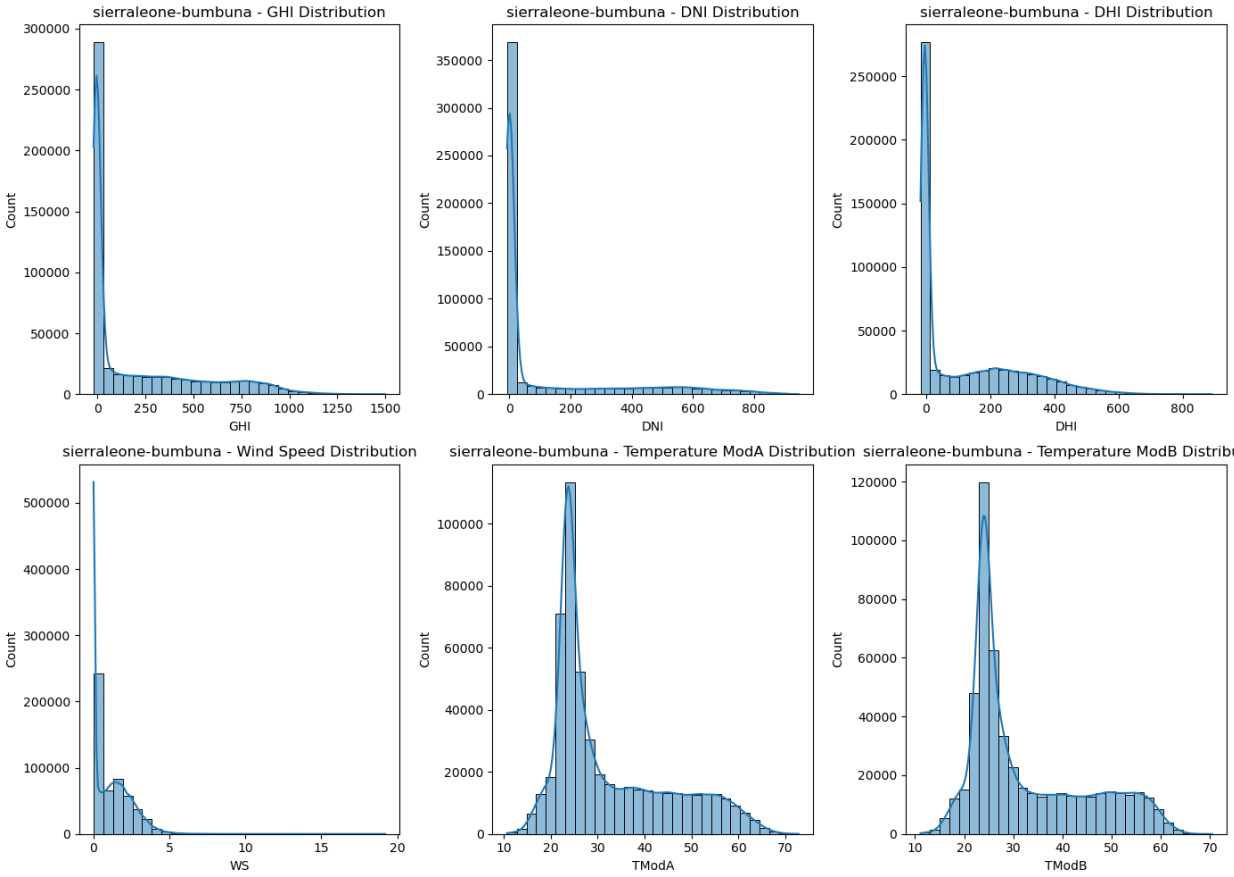


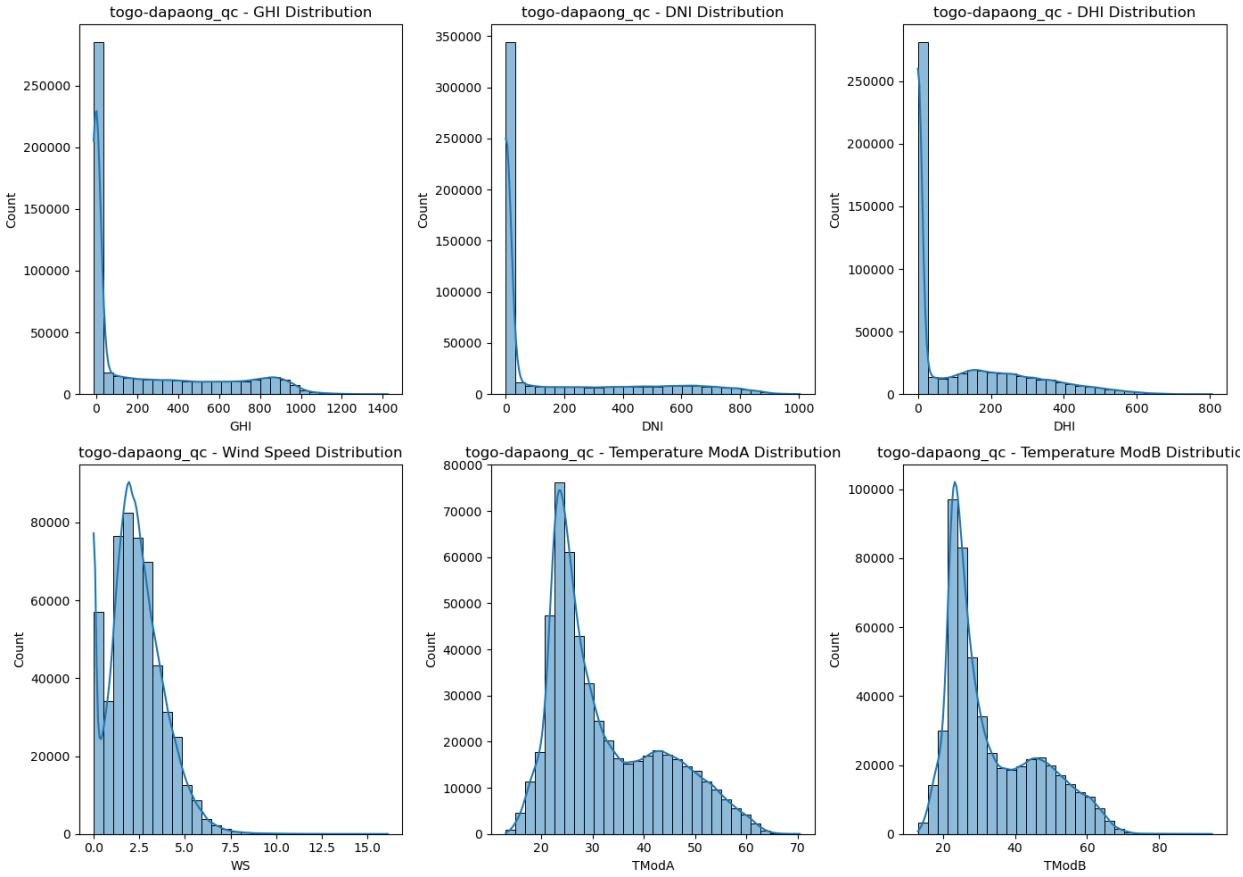






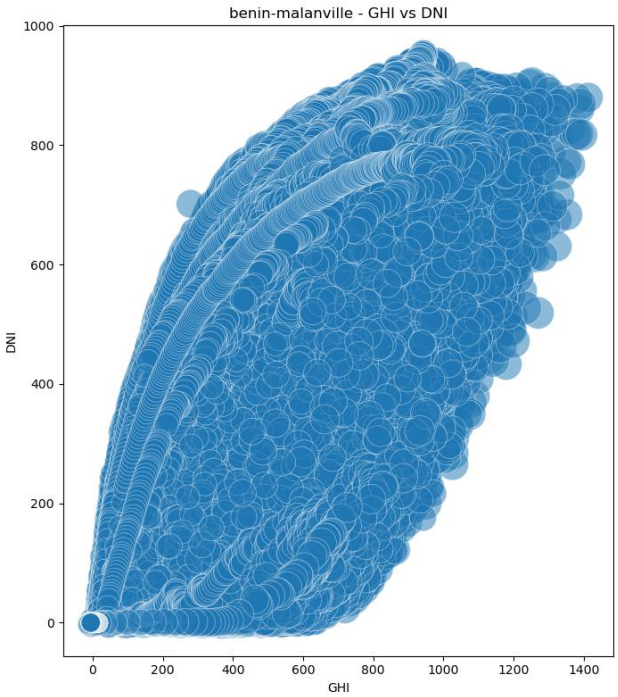



sierraleone-bumbuna - GHI Distribution
Count
GHI
sierraleone-bumbuna - DNI Distribution
Count
DNI
sierraleone-bumbuna - DHI Distribution
Count
DHI
sierraleone-bumbuna - Wind Speed Distribution
Count
WS
sierraleone-bumbuna - Temperature ModA Distribution
Count
TModA
sierraleone-bumbuna - Temperature ModB Distribu
Count
TModB



- **Temperature Insights:**
  - Regions with higher relative humidity (RH) tend to have lower solar irradiance, affecting the overall solar potential.
  - Histograms of temperature and solar radiation indicate a skewed distribution, with most data points falling within optimal ranges for solar energy generation.

2.6 Advanced Analysis: Z-Scores and Bubble Charts


benin-malanville - GHI vs DNI
DNI
GHI
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200
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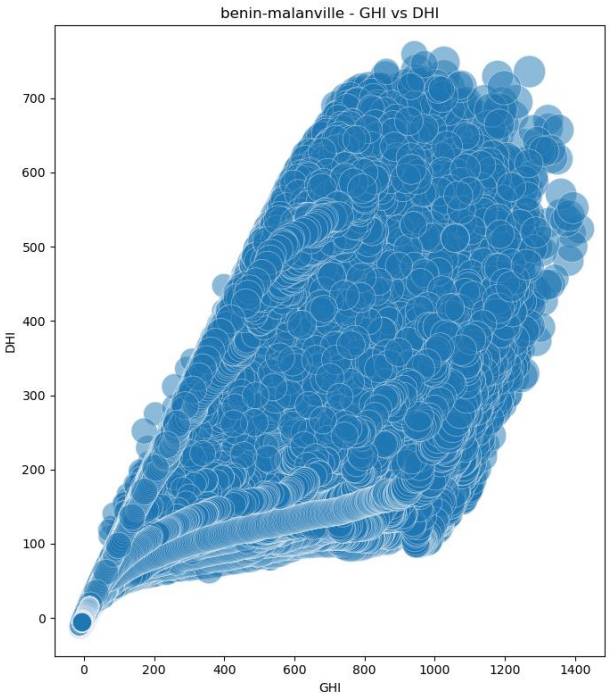
benin-malanville - GHI vs DHI
DHI
GHI
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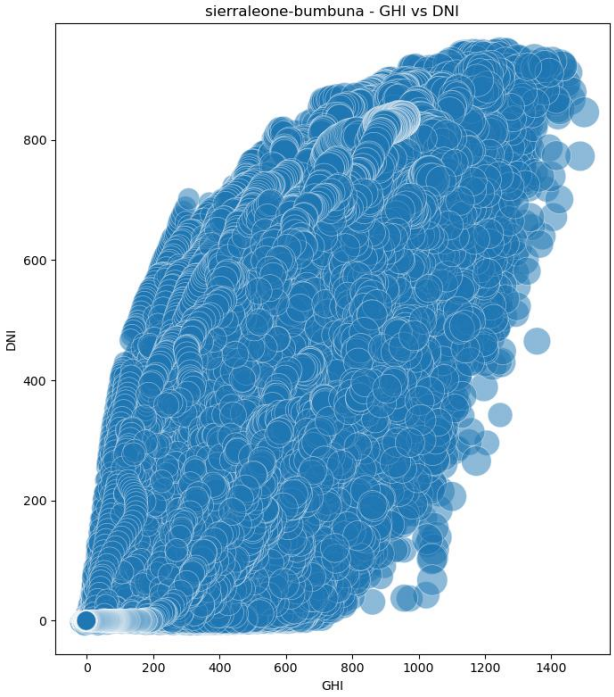
sierraleone-bumbuna - GHI vs DNI
DNI
GHI
0
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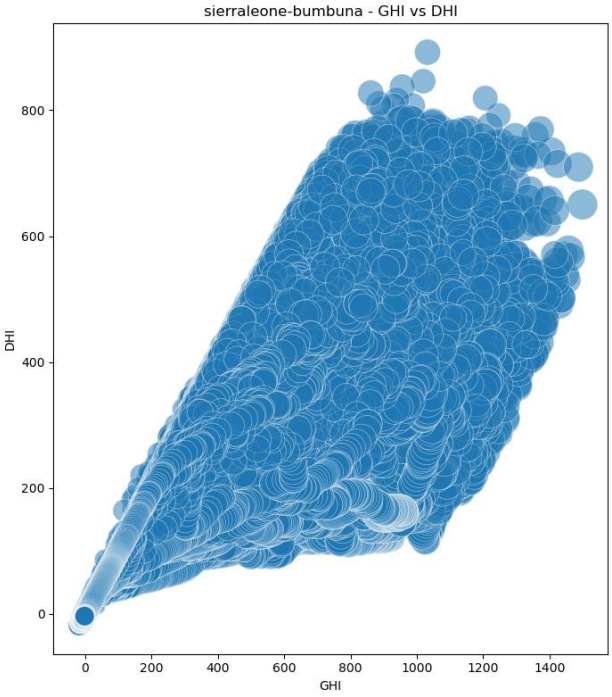
sierraleone-bumbuna - GHI vs DHI
DHI
GHI
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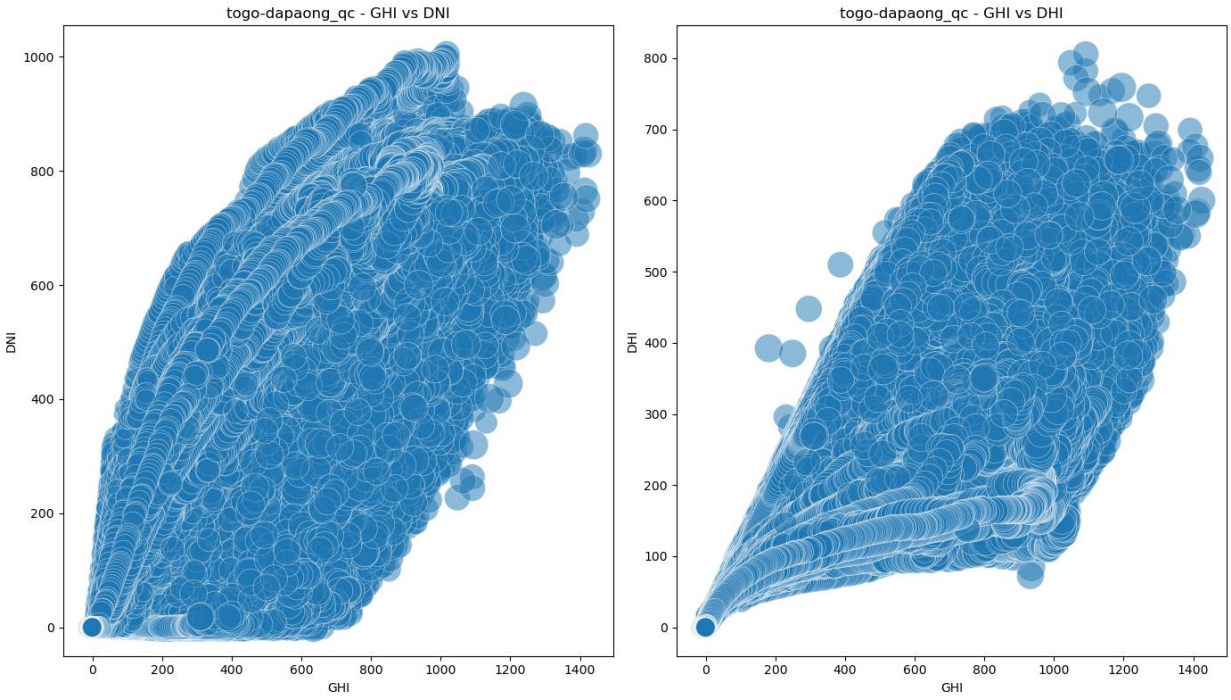

- **Bubble Charts:**
  - The relationship between GHI, temperature, and wind speed was further explored, revealing that regions with moderate wind and high temperature are ideal for solar installations.

3. Recommendations

Based on the analysis, the following recommendations are proposed to guide MoonLight Energy Solutions in identifying high-potential regions for solar installation:

1. **Focus on Regions with High Solar Irradiance:**
   - Prioritize regions with consistently high GHI values, particularly those with minimal seasonal variation. These areas offer the best potential for efficient solar energy generation.
2. **Consider Temperature and Humidity Factors:**
   - Regions with moderate temperatures and low relative humidity should be targeted, as they tend to have higher solar irradiance and better conditions for solar panel efficiency.
3. **Mitigate Wind Impact:**
   - Avoid regions with frequent high wind speeds and gusts, as these can negatively impact the stability of solar installations. Instead, focus on areas with stable wind conditions.
4. **Leverage Sensor Data for Maintenance:**
   - Utilize the cleaned sensor readings (ModA, ModB) to optimize maintenance schedules and ensure the long-term efficiency of solar installations.
5. **Strategic Investments in High-Potential Regions:**

- Based on the identified trends, MoonLight Energy Solutions should consider strategic investments in the top-performing regions, focusing on both current solar potential and long-term sustainability.

4. Conclusion

The analysis conducted provides a data-driven foundation for MoonLight Energy Solutions to make informed decisions about solar investments. By targeting regions with the highest potential for solar energy generation, the company can enhance its operational efficiency and contribute to its long-term sustainability goals. Continued monitoring and analysis will be essential to adapt to changing environmental conditions and optimize the performance of solar installations.