Planning and Analysis for Solar Energy in Libya

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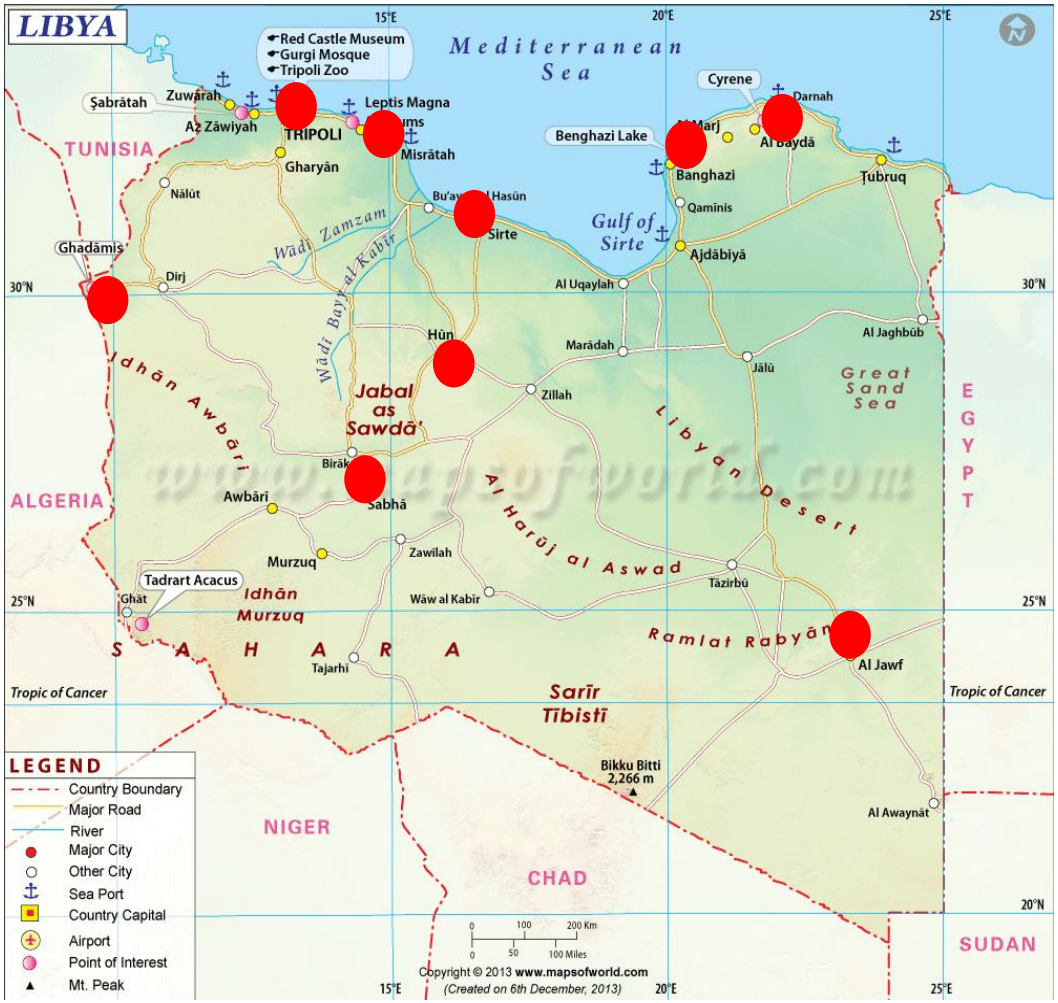
July 19th, 2021

Presentation Outline

- Solar Energy Modeling
- Capacity Factor of Solar Energy Resources
- Variability of Solar Energy Resources
- Aggregation of Solar Energy Resources

Solar Energy Analysis for Some Locations in Libya

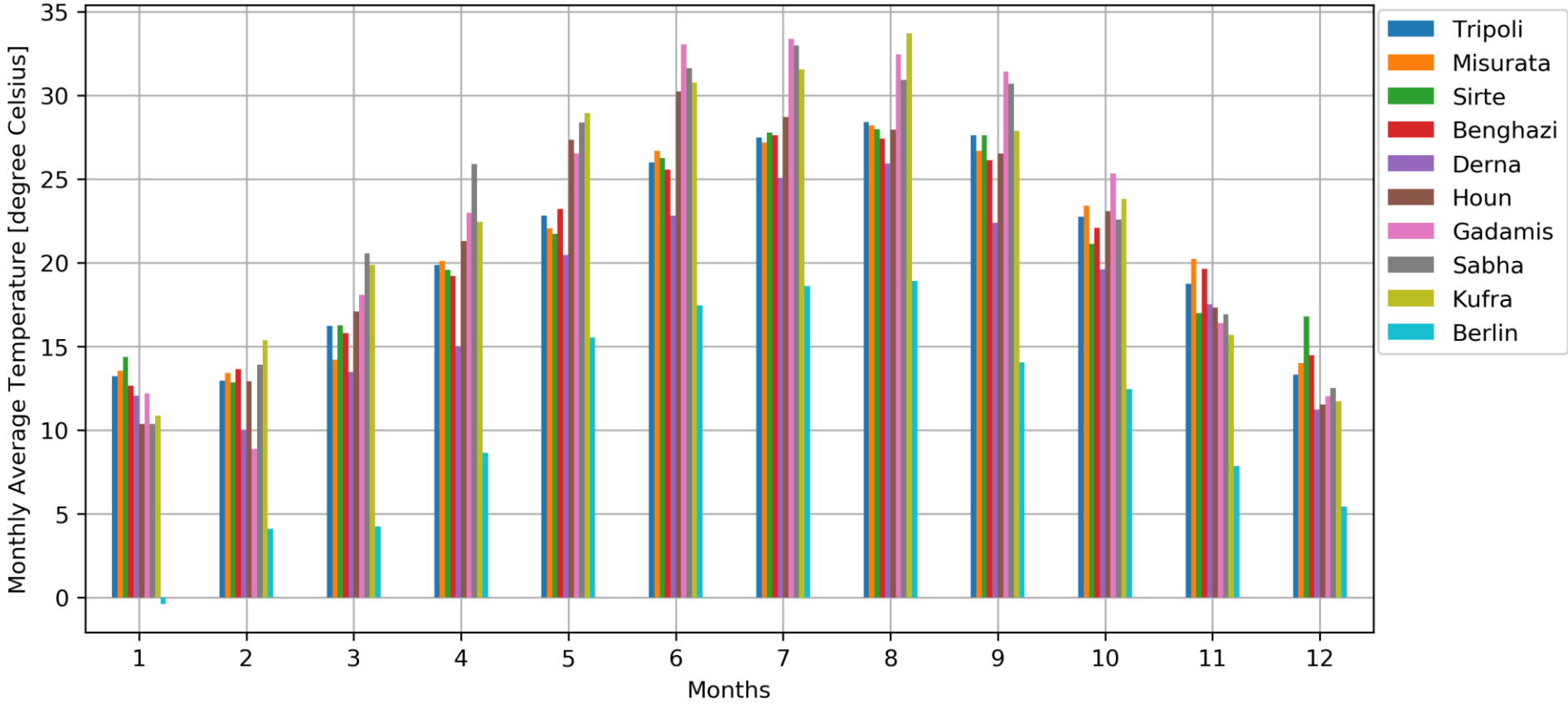


9 Locations for Comparison of Solar Energy Modeling and Analysis:
Tripoli, Misurata, Sirte, Benghazi, Derna, Houn, Gadamis, Sebha, Kufra

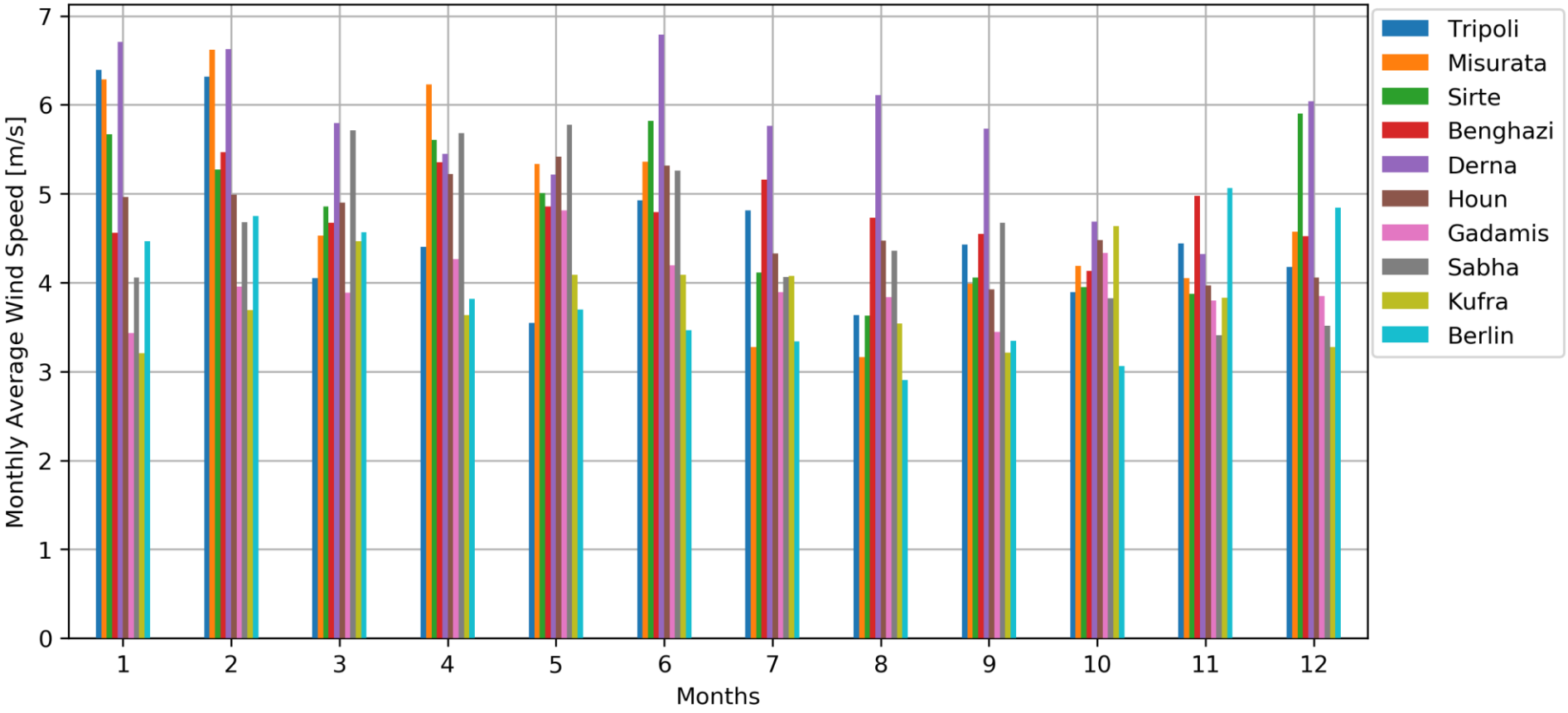
Typical Meteorological Year (TMY) data represents the weather for a "median year".
Data are retrieved from NREL's Developer Network: https://developer.nrel.gov/

Comparison of Monthly Average Temperature, in degree Celsius (°C)

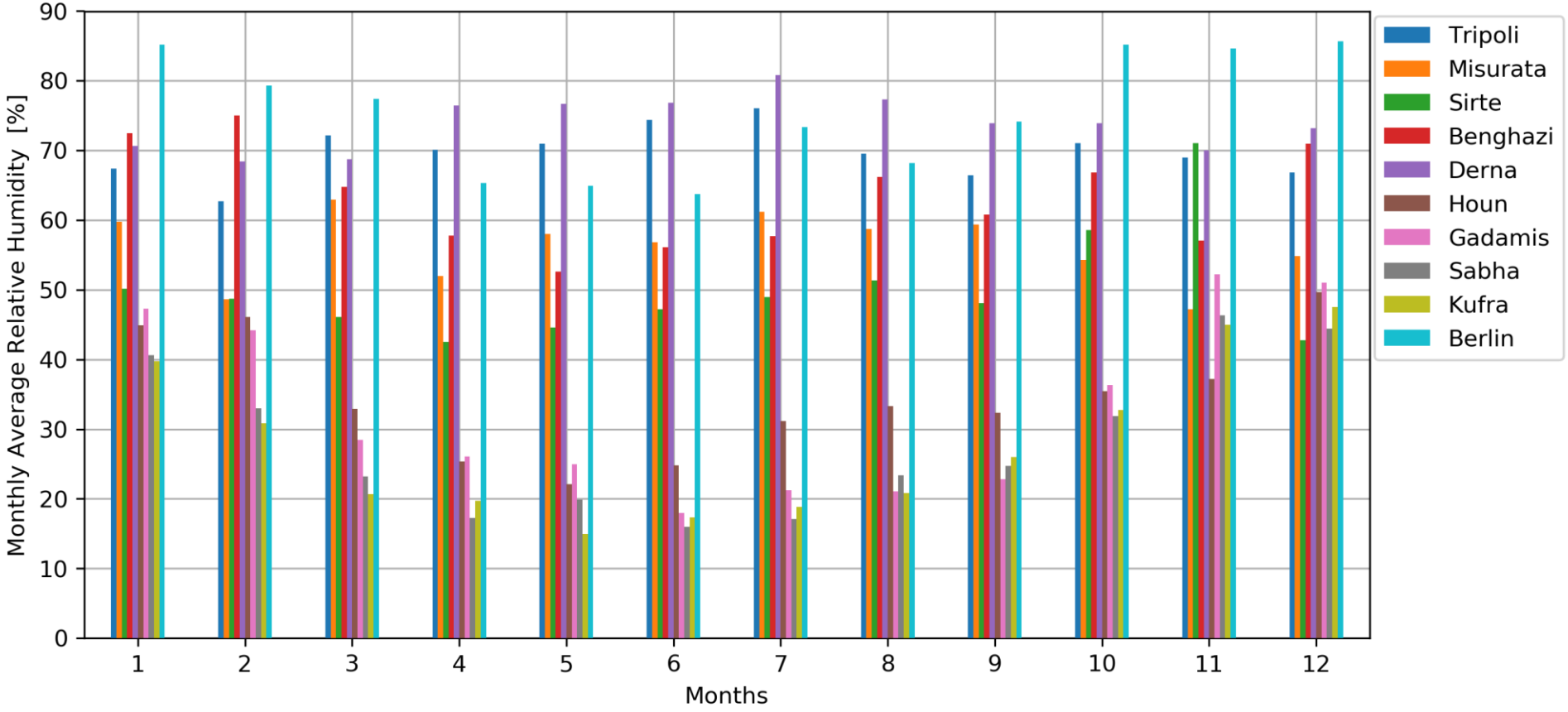
Berlin in Germany has been added just for sake of comparison.



Comparison of Monthly Average Wind Speed, in meter per second (m/s)

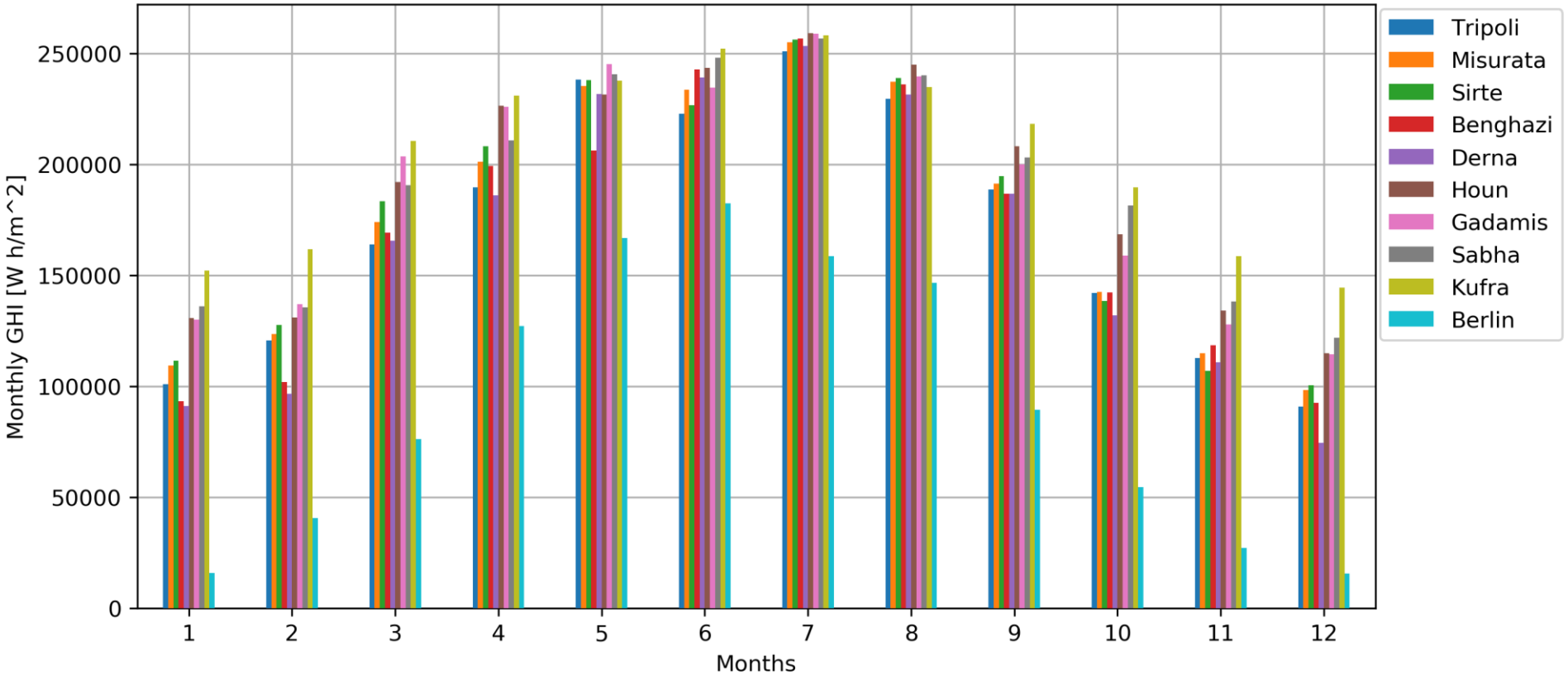


Comparison of Monthly Average Relative Humidity, in percentage (%)



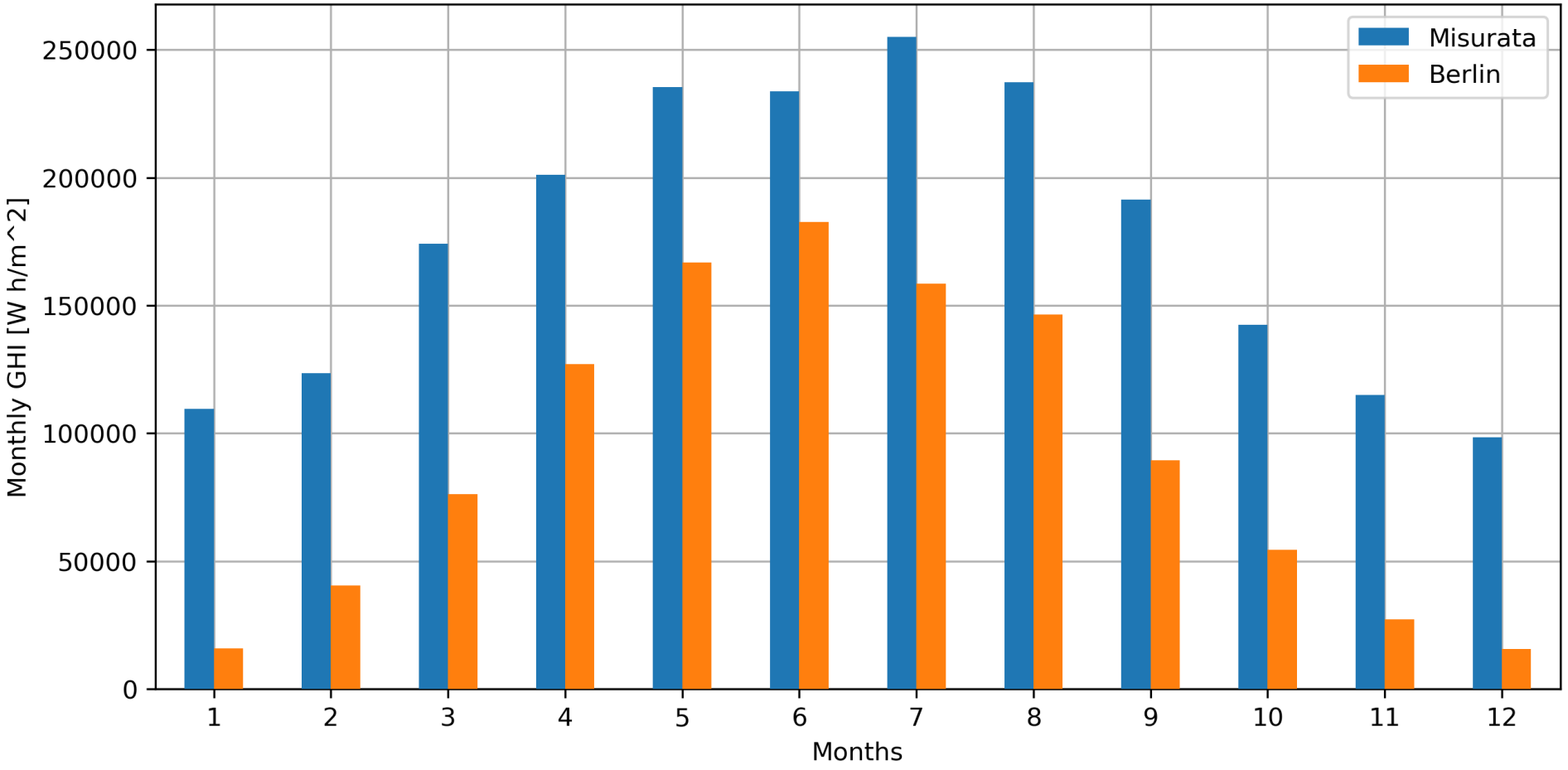
Comparison of Solar Energy by the Global Horizontal Irradiance (GHI), Watt-Hour accumulated monthly per Square-Meter, (Wh/m^2)

Berlin in Germany has been added just for sake of comparison.

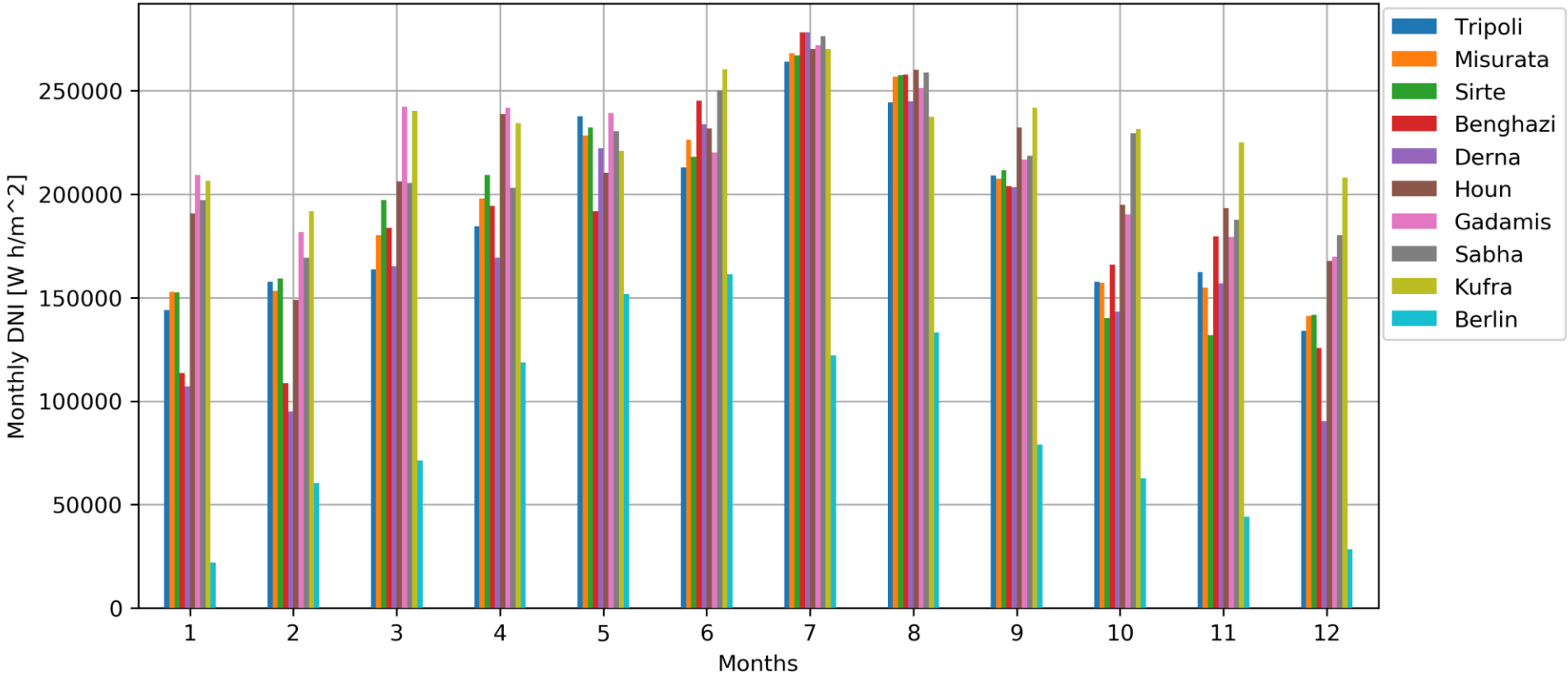


Comparison of Solar Energy by the Global Horizontal Irradiance (GHI), Watt-Hour accumulated monthly per Square-Meter, (Wh/m^2)

Comparison between Misurata, Libya and Berlin, Germany

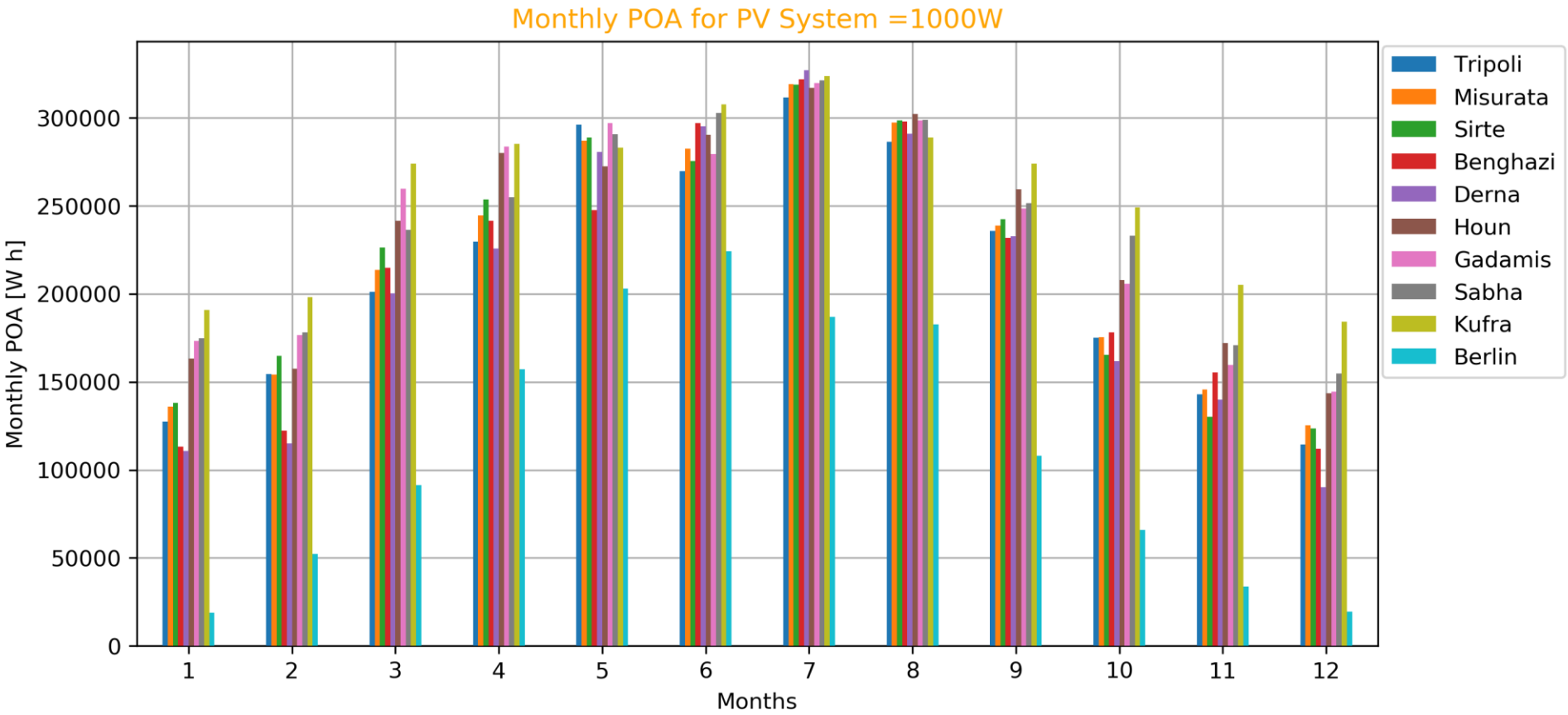


Comparison of Solar Energy by the Direct Normal Irradiance (DNI), Watt-Hour accumulated monthly per Square-Meter, (Wh/m^2)



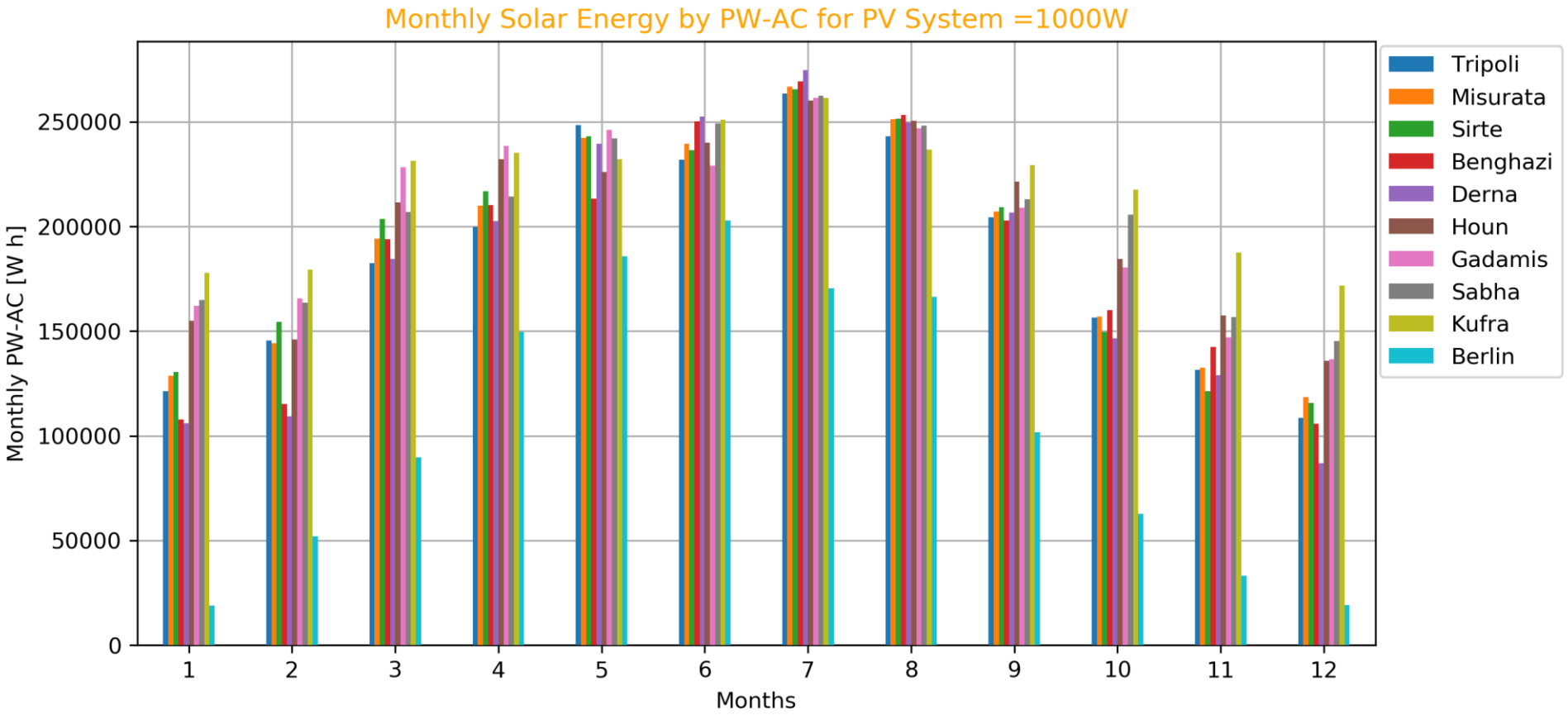
Comparison of Solar Energy by the Plane of Array (POA),
Watt-Hour accumulated (Wh) for PV system of rating PW=1000W

The POA irradiance is modeled for solar panels with double-axis orientated, in other words, with optimal tilt and azimuth angles at each locations, for a Solar PV System with capacity of 1000W.



Comparison of Solar Energy by an Output Power AC-PW (PWac), Watt-Hour accumulated (Wh) for PV system of rating PW=1000W

The POA irradiance is modeled for solar panels with double-axis orientated, in other words, with optimal tilt and azimuth angles at each locations, for a Solar PV System with capacity of 1000W.



Comparison of Net Capacity Factors (NFC)

The Capacity Factor is calculated based on Several Irradiances and Output Powers (DC) and (AC). The Rating of Solar PV System =1000W during 4729hours.

Location	GHI_CFs	POA_CFs	PWDC_CFs	PWAC_CFs	DNI_CFs	POA_DNI_CFs
Tripoli	0.433830	0.538279	0.499001	0.473013	0.480438	0.410475
Misurata	0.447654	0.554033	0.512897	0.484679	0.491524	0.420456
Sirte	0.450760	0.555556	0.515920	0.486032	0.490356	0.423268
Benghazi	0.432640	0.535881	0.498632	0.470497	0.475489	0.408298
Derna	0.422890	0.522464	0.492705	0.462791	0.446249	0.390651
Houn	0.483285	0.593843	0.545671	0.511832	0.538249	0.464438
Gadamis	0.481450	0.602020	0.547774	0.518446	0.552813	0.472614
Sabha	0.487043	0.606654	0.553102	0.522807	0.551281	0.479424
Kufra	0.517995	0.648138	0.587502	0.552255	0.585554	0.516174
Berlin	0.232882	0.284139	0.277328	0.264893	0.223141	0.174912

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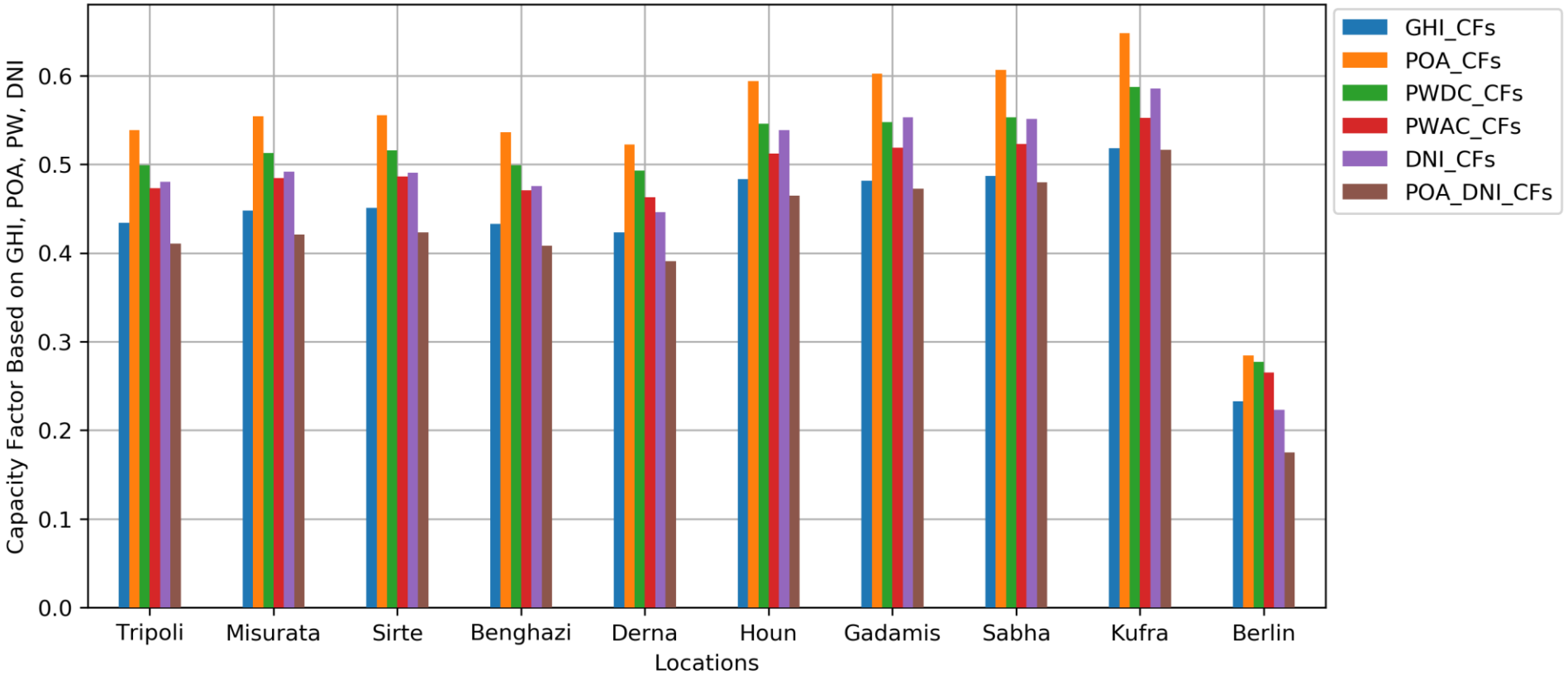
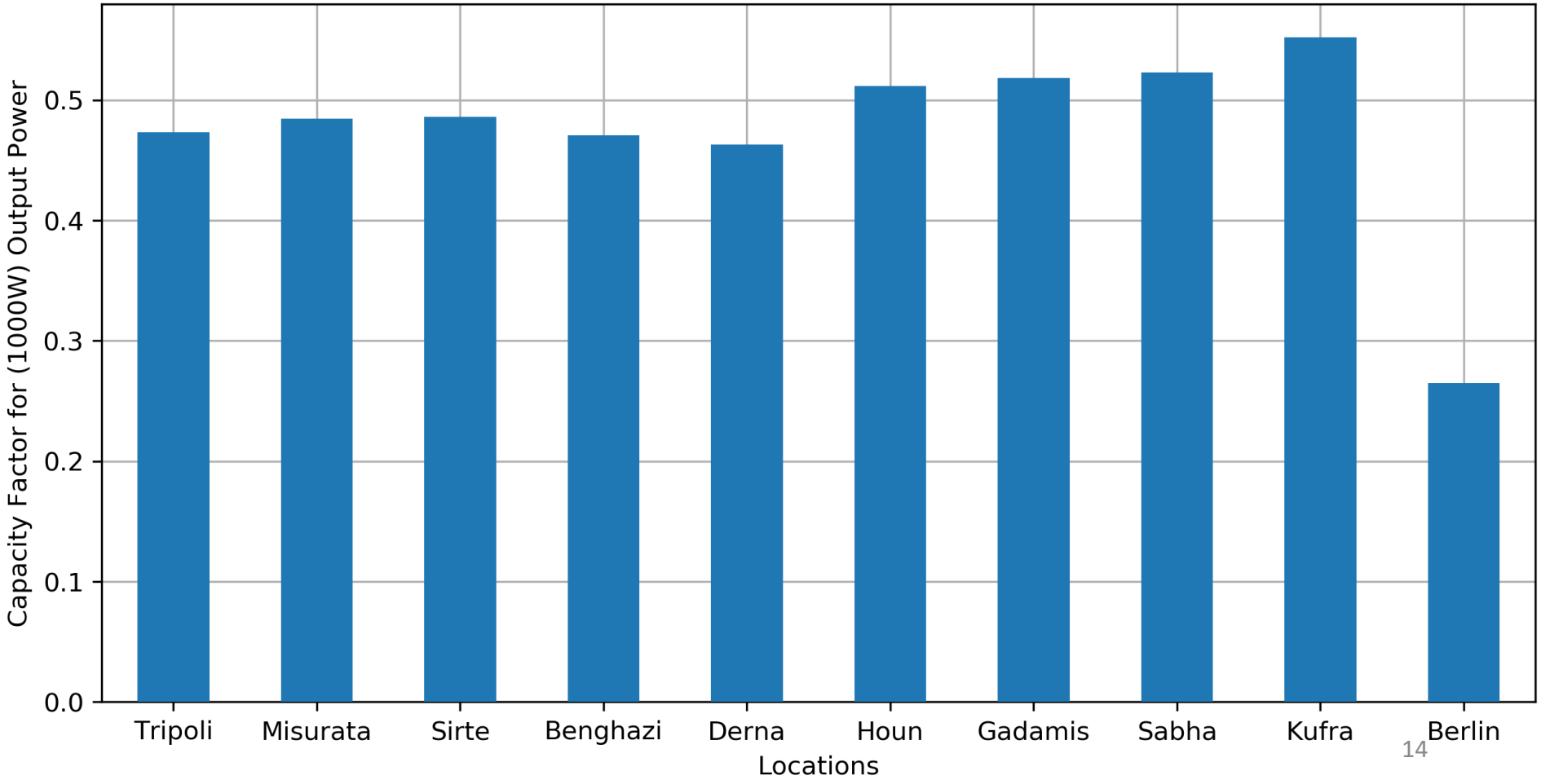
The Rating of Solar PV System =1000W during 4729hours.



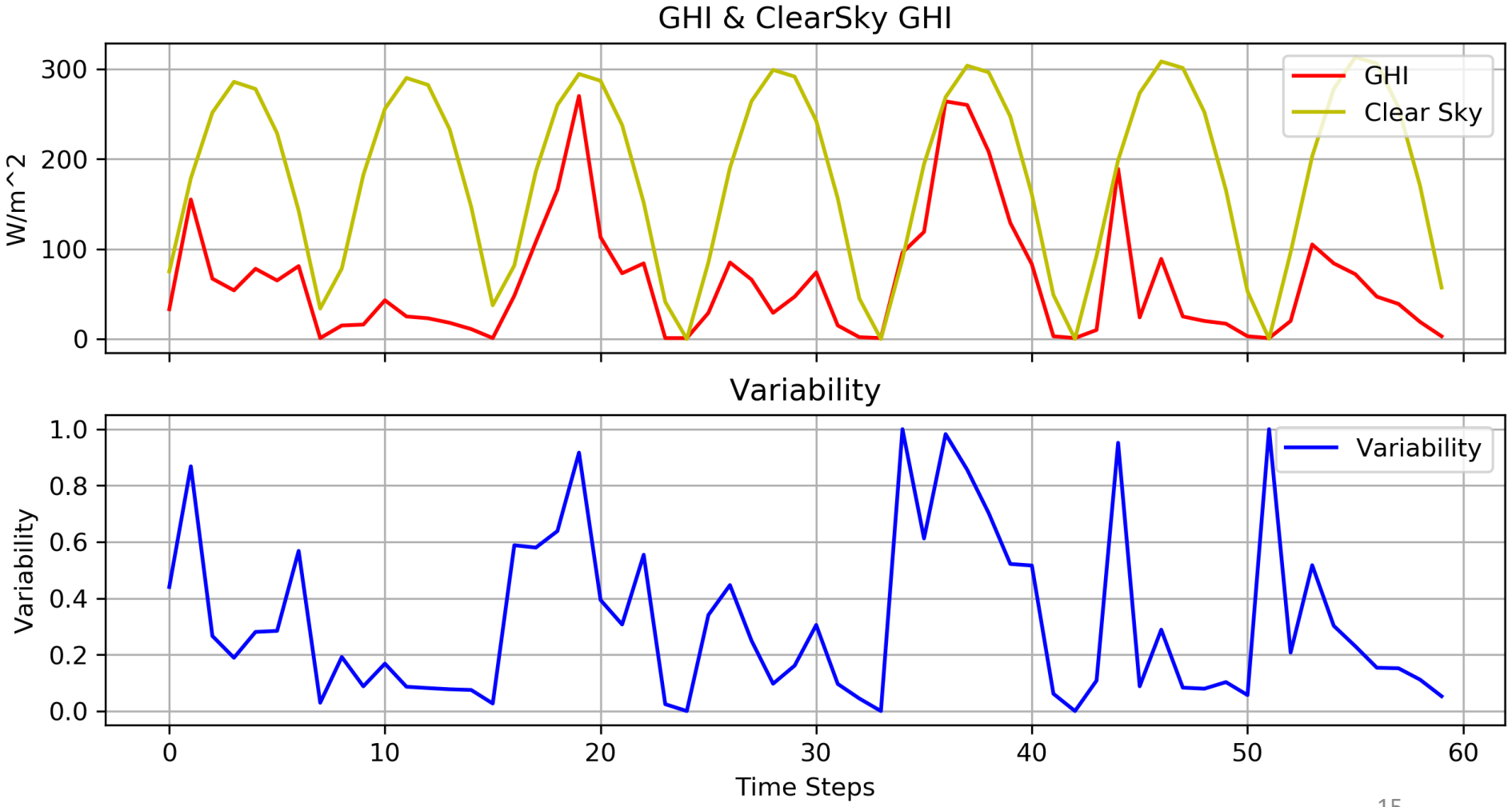
Comparison of Net Capacity Factors (NFC)

The Capacity Factor is calculated based on Output power (PWac).
The Rating of Solar PV System =1000W during 4729hours.



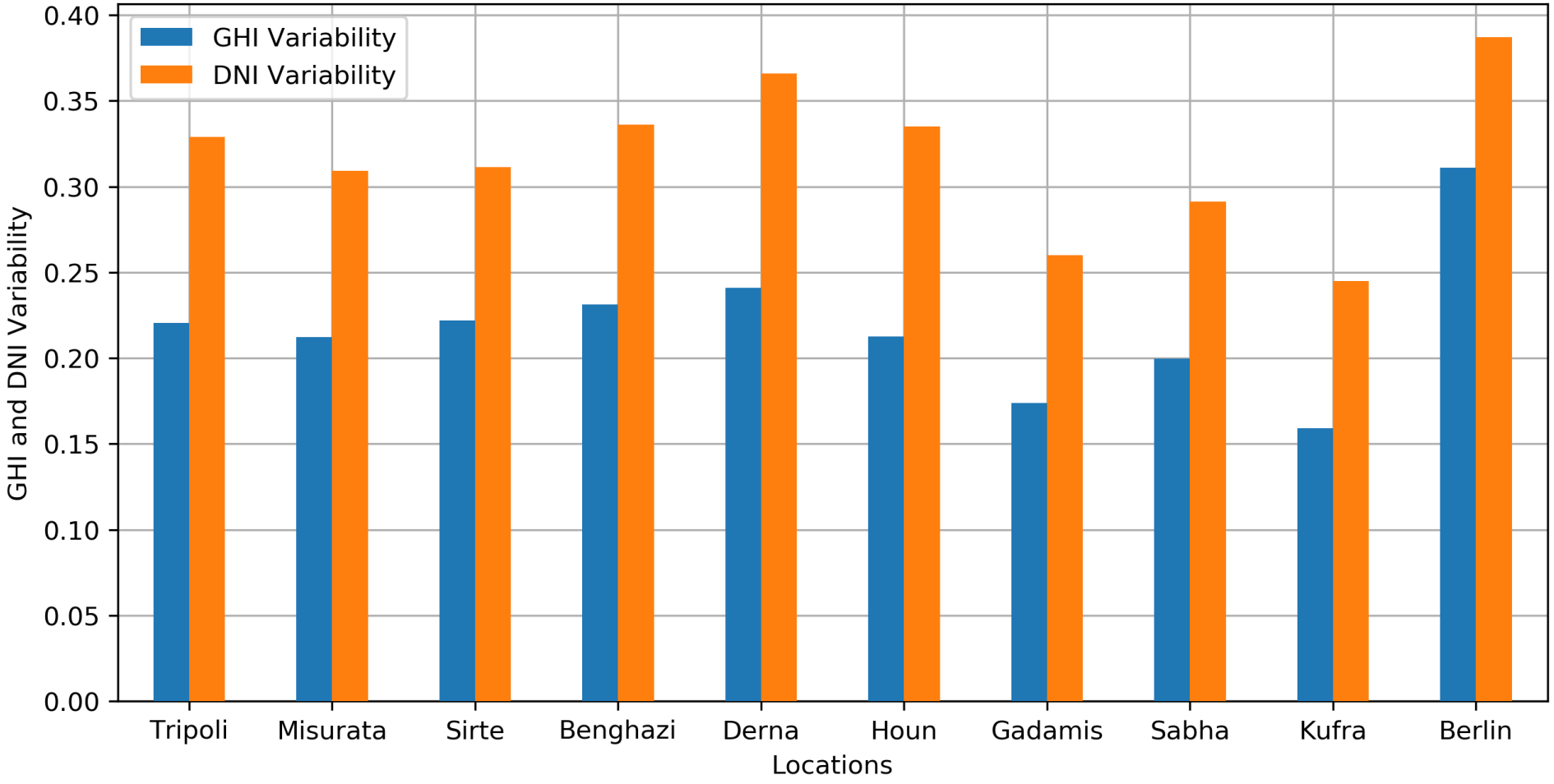
Comparison of Solar Power Variability

The Variability solar energy at a given location is determined based on the irradiance deviation from the clear-sky irradiance, (GHI/Cl-GHI).



Comparison of Solar Power Variability

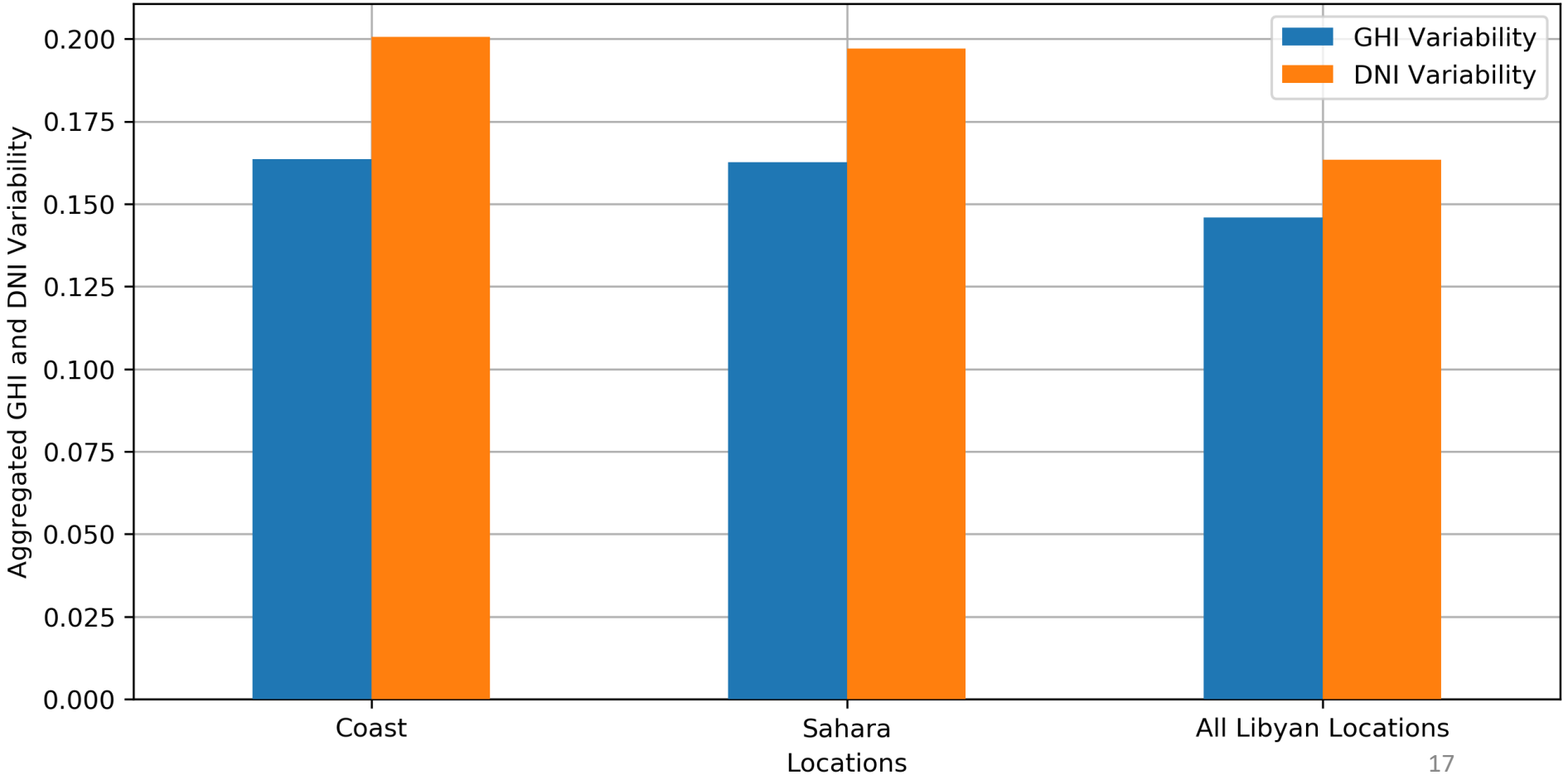
The Variability solar energy at a given location is determined based on the irradiance deviation from the clear-sky irradiance. The standard deviation of this (GHI/Cl-GHI) or (DNI/Cl-DNI) is used as an indication to the solar variability at a given location.



Comparison of Aggregated Solar Power Variability

The solar resources are aggregated based to their locations:

- Coast Region: Tripoli, Misurata, Sirte, Benghazi, Derna.
- Sahara Region: Houn, Gadamis, Sabha, Kufra.
- and the All Locations: Tripoli, Misurata, Sirte, Benghazi, Derna, Houn, Gadamis, Sabha, Kufra.



Improvement of Variability Due to Aggregated Solar Resources

The solar resources are aggregated based to their locations:

- Coast Region: Tripoli, Misurata, Sirte, Benghazi, Derna.
- Sahara Region: Houn, Gadamis, Sabha, Kufra.
- and the All Locations: Tripoli, Misurata, Sirte, Benghazi, Derna, Houn, Gadamis, Sabha, Kufra.

GHI_Improvement at Aggregated Locs=(1 - (Agg GHI_var/min_Agg_Var@Region))*100

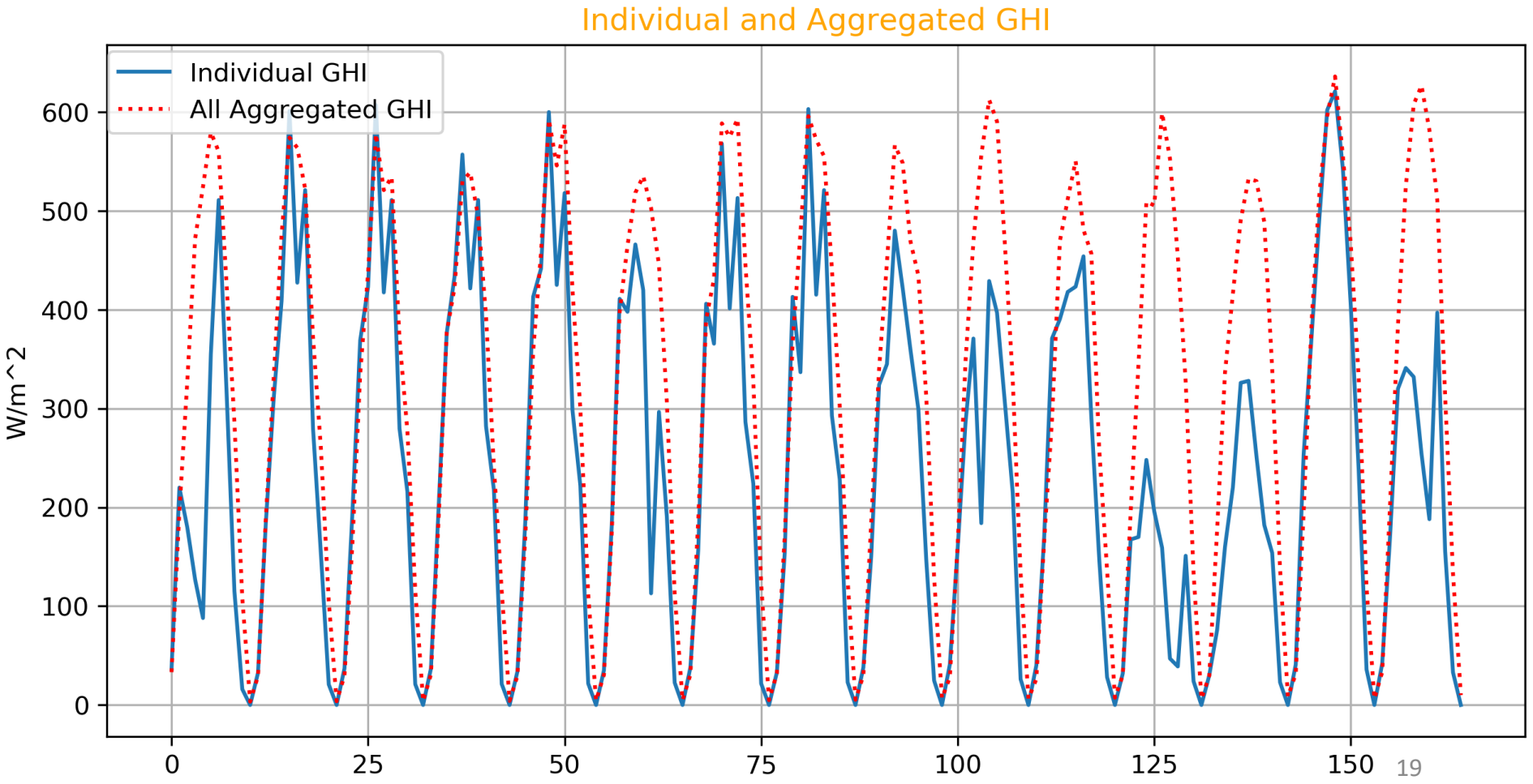
Improvement (%)	Agg vs. Best Coast	Agg vs. Best Sahara	Agg vs. Best All
Coast	22.866774	-2.955564	-2.955564
Sahara	23.329008	-2.338584	-2.338584
All	31.228778	8.205837	8.205837

DNI_Improvement at Aggregated Locs=(1 - (Agg DNI_var/min_Agg_Var@Region))*100

Improvement (%)	Agg vs. Best Coast	Agg vs. Best Sahara	Agg vs. Best All
Coast	35.079876	18.053005	18.053005
Sahara	36.248064	19.527579	19.527579
All	47.168813	33.312558	33.31255

Visualization of Aggregated Solar Power Variability

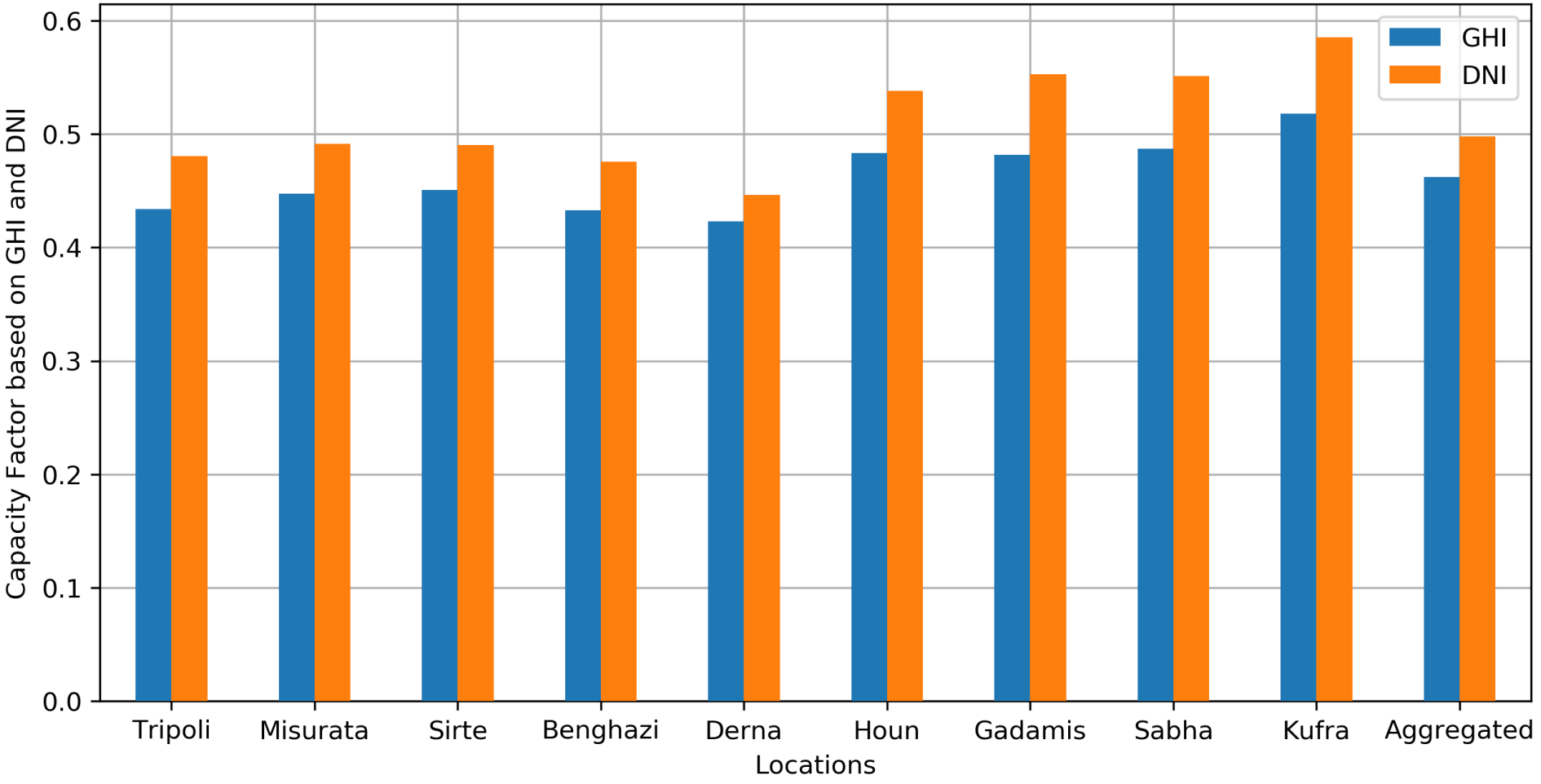
The solar resources are aggregated based to their locations:
Aggregated All Location against an individual location is Derna
During days from January 1st to January 15th



Net Capacity Factor for Aggregated Locations

The aggregated net capacity factor for all aggregated locations:

- and the All Locations: Tripoli, Misurata, Sirte, Benghazi, Derna, Houn, Gadamis, Sabha, Kufra.



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NCF based on GHI

Net Capacity Factor based on GHI for All Aggregated Locations=**0.462**

While Average Net Capacity Factor based on GHI=0.439
And Max Net Capacity Factor based on GHI=0.518 @ Kufra location

NCF based on DNI

Net Capacity Factor based on GHI for All Aggregated Locations=**0.498**

While Average Net Capacity Factor based on GHI=0.484
And Max Net Capacity Factor based on GHI=0.586 @ Kufra location

Conclusions

- In Libya, the southern locations yield more solar energy, but the northern locations have a good yielding compared to some locations in the world with significant solar power deployment.

- The average net capacity factor is about 0.5, and it can be considered high for solar power plants.

- The variability of the Coast locations is higher than the southern “Sahara” locations, which means a need for more auxiliary services at the coast region, such as more energy storage.

- The aggregation of Coast, Sahara, and All locations leads to a reduction in the variability and slightly increasing the capacity factor.

- Aggregation different solar plants from various regions can lead to more enhancement in solar power deployment.

Thanks for Listening

Any Question?

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