# Planning and Analysis for Solar Energy in Libya

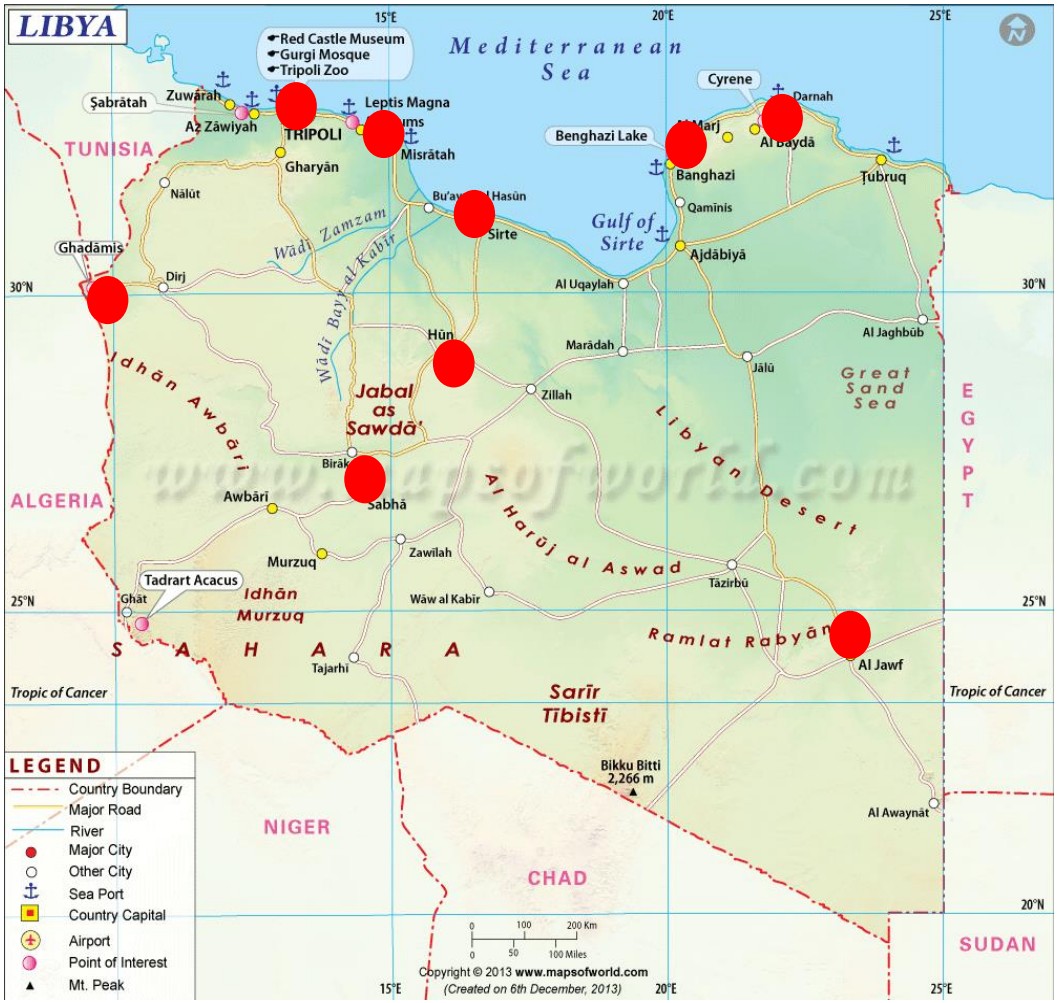
Mohamed Abuella
Department of Electromechanical Engineering
College of Industrial Technology, Misurata, Libya
كلية التقنية الصناعية، مصراتة، ليبيا


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

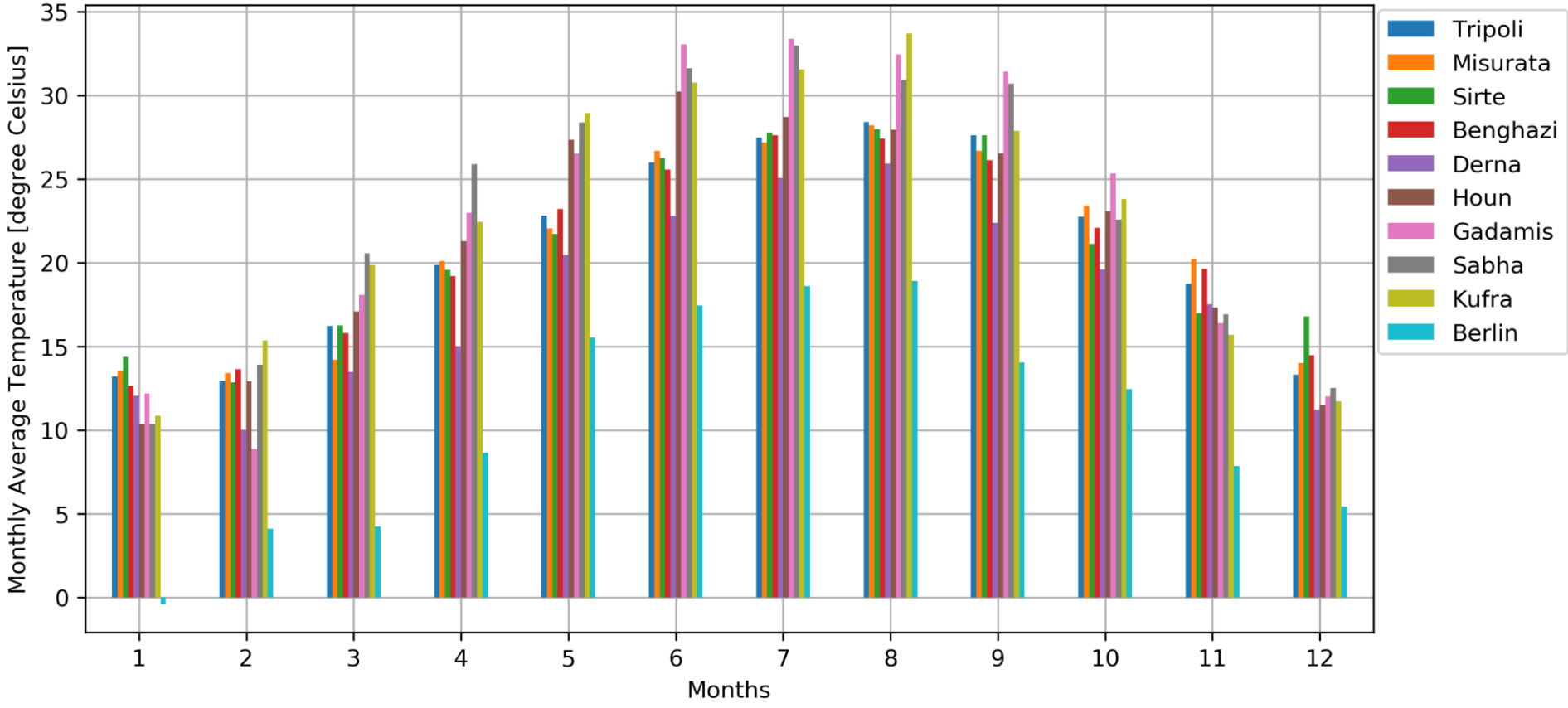



9 Locations for Comparison of Solar Energy Modeling and Analysis:
Tripoli, Misurata, Sirte, Benghazi, Derna, Houn, Gadamis, Sebha, Kufra

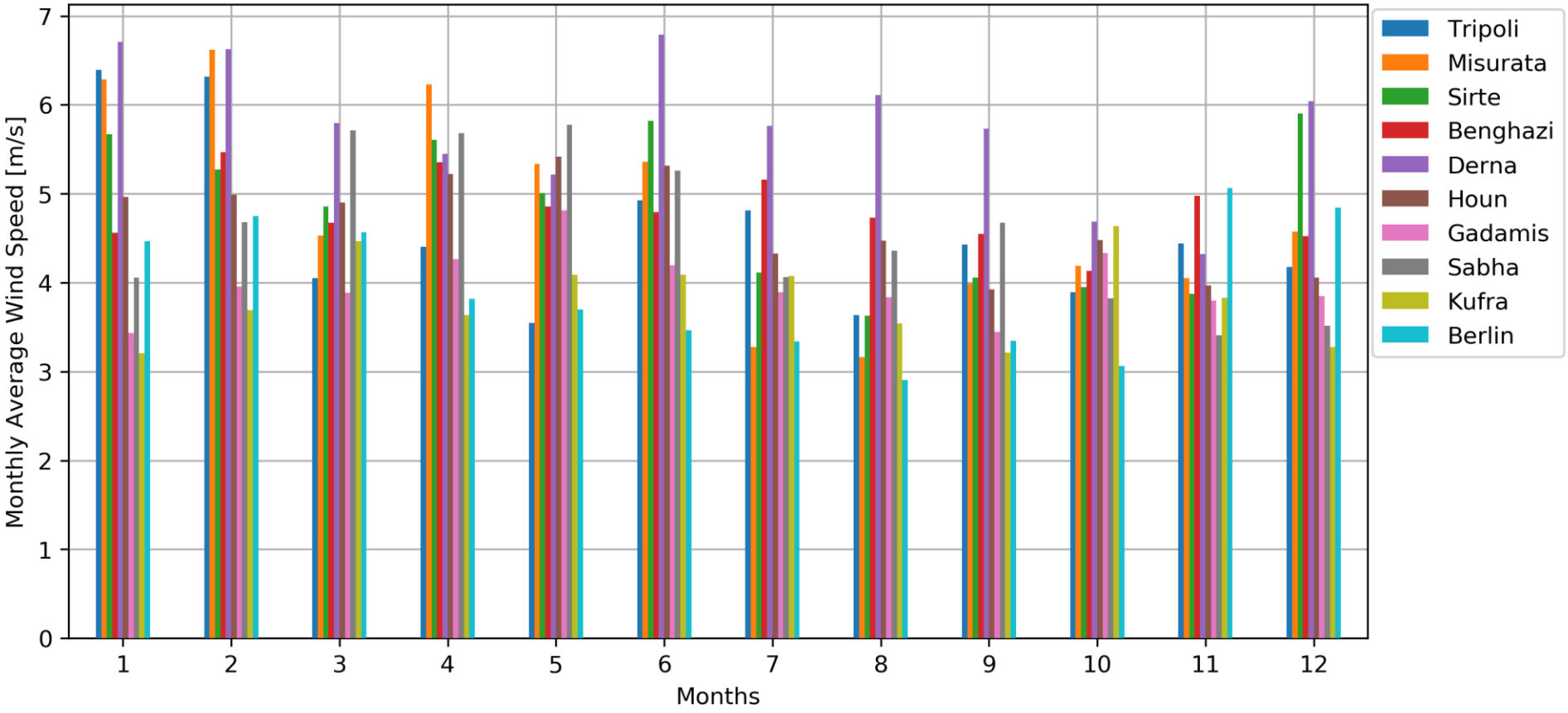
Typical Meteorological Year (TMY) data represents the weather for a "median year".
Data are retrieved from NREL's Developer Network: https://developer.nrel.gov/

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

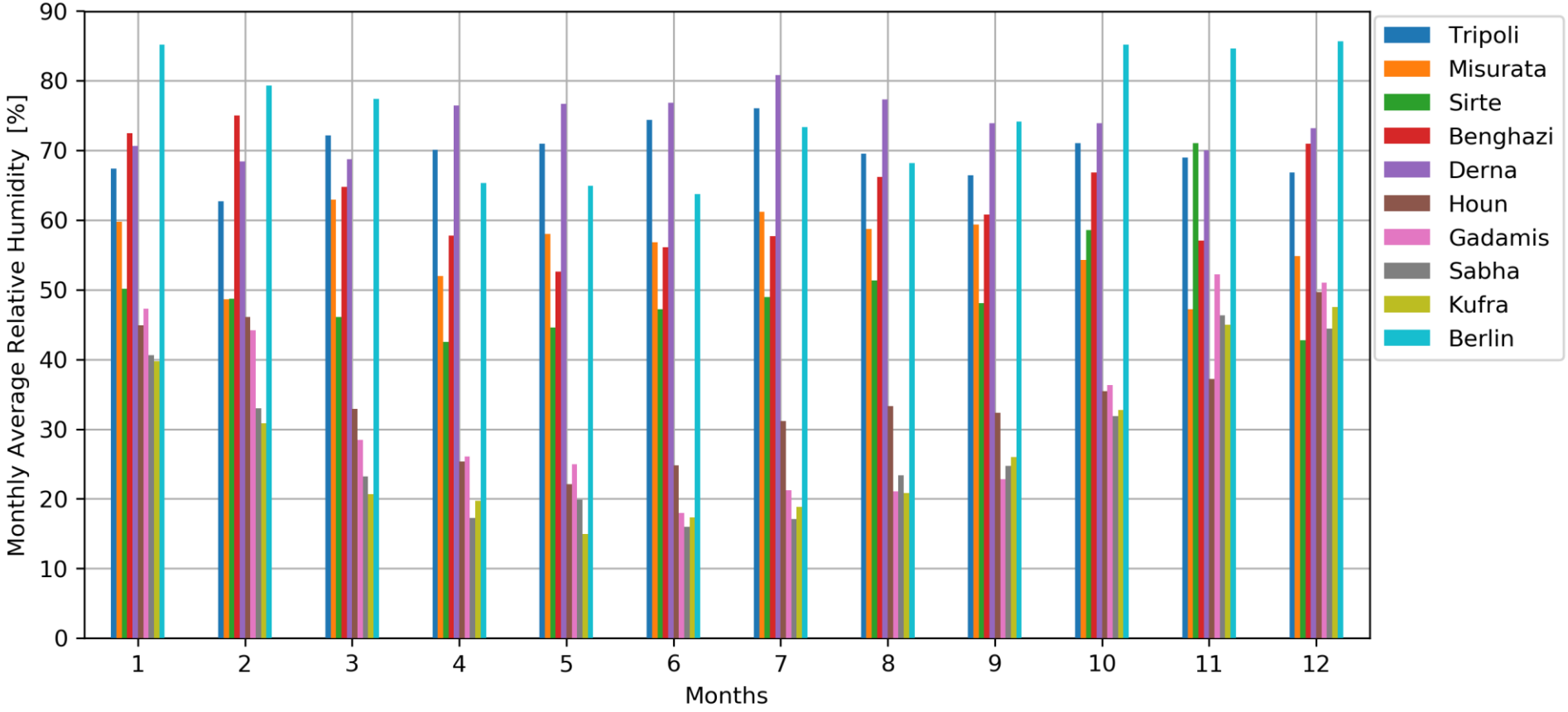
Berlin in Germany has been added just for sake of comparison.



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

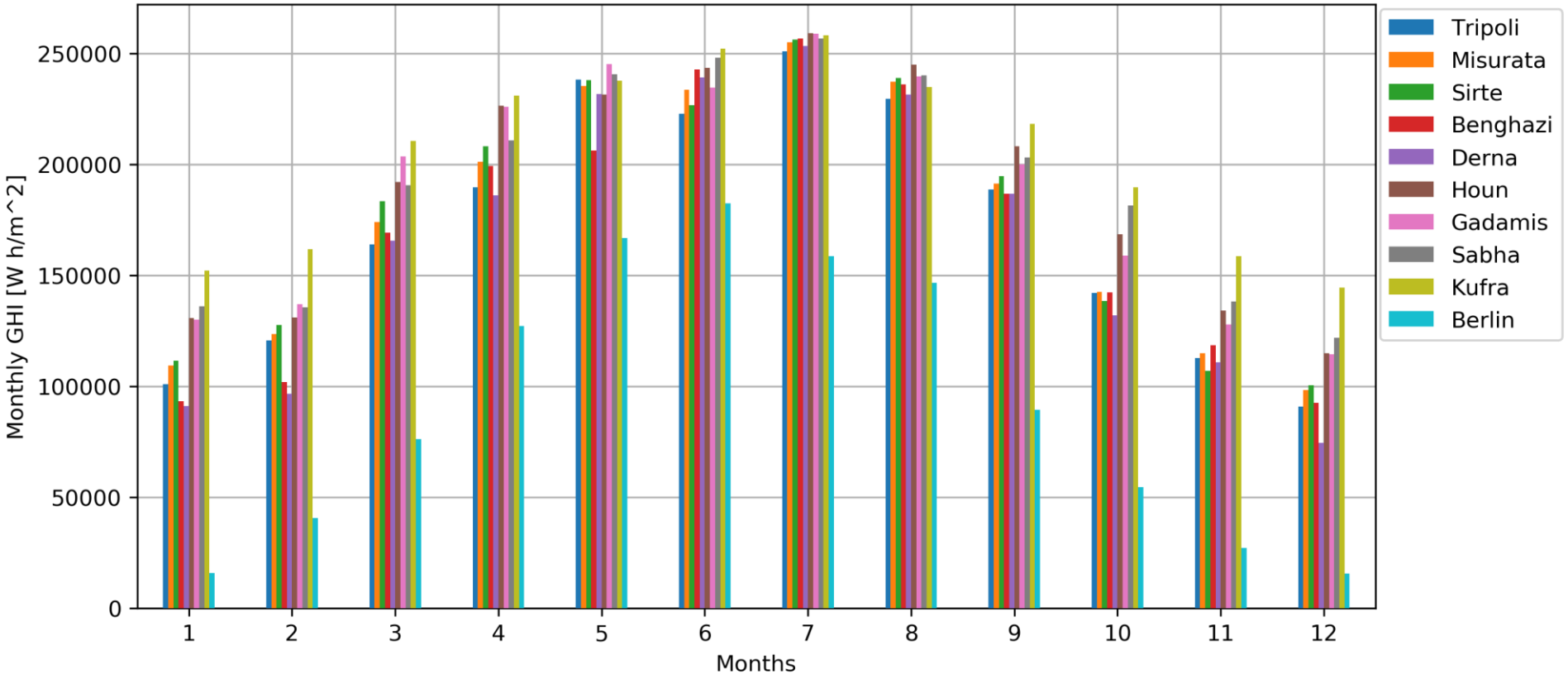


# Comparison of Monthly Average Relative Humidity, in percentage (%)



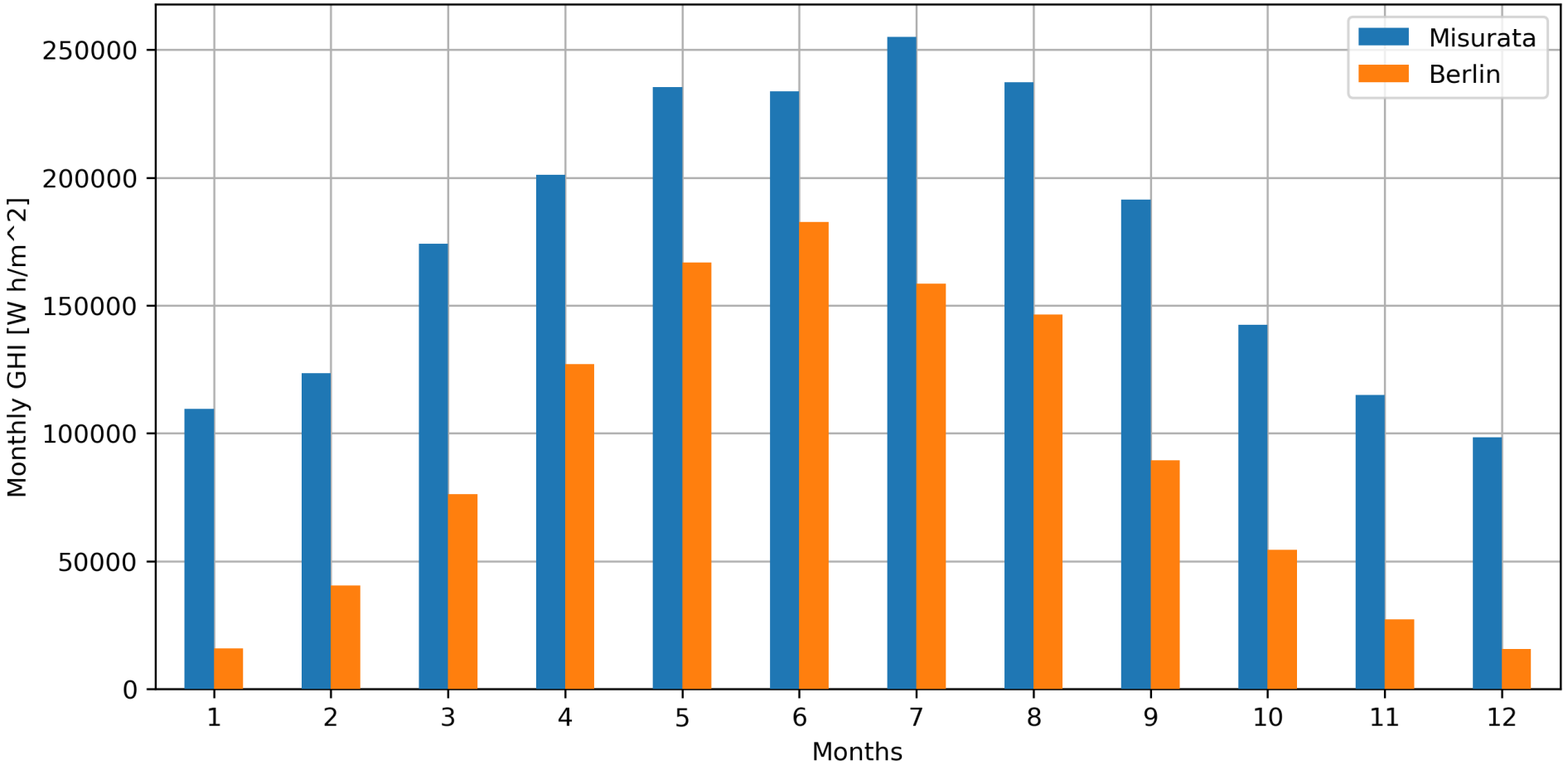
# Comparison of Solar Energy by the Global Horizontal Irradiance (GHI), Watt-Hour accumulated monthly per Square-Meter, ($Wh/m^2$)

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

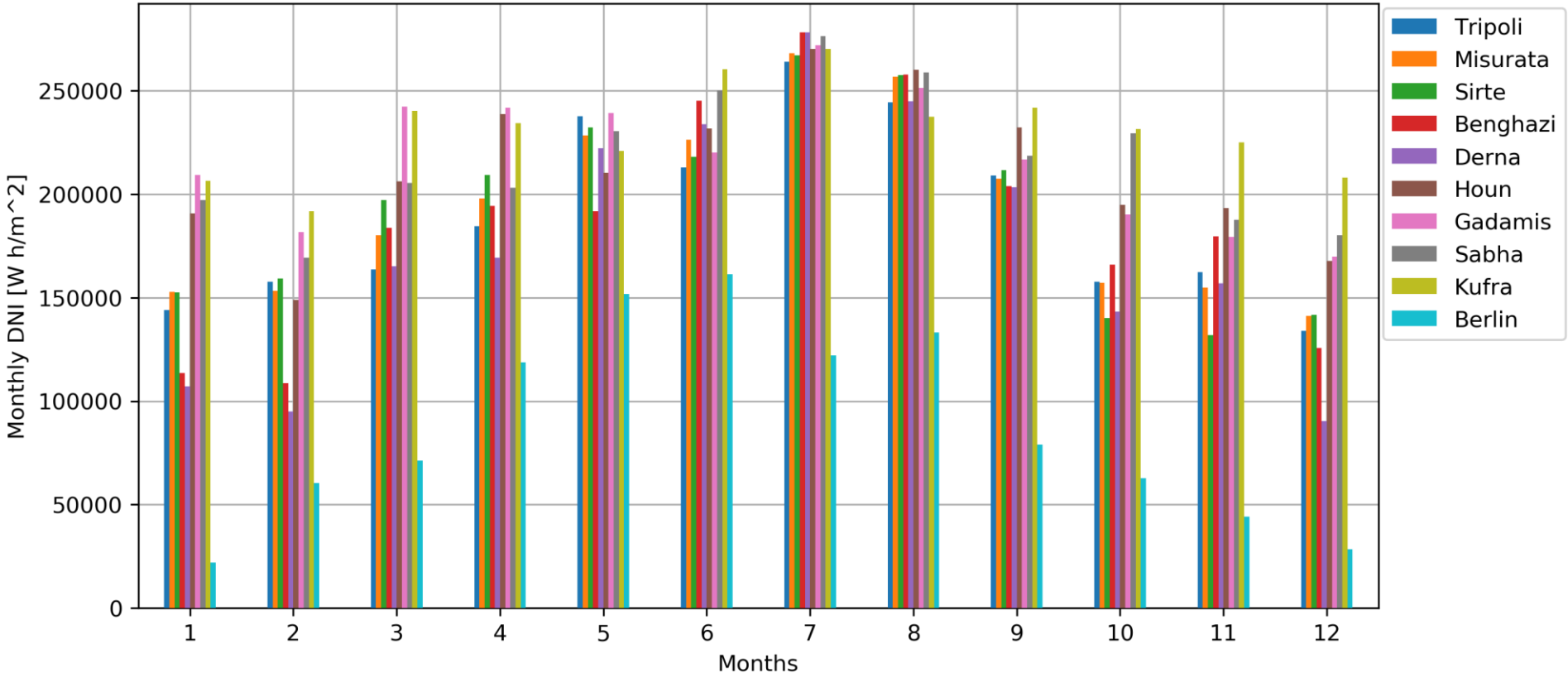


# Comparison of Solar Energy by the Global Horizontal Irradiance (GHI), Watt-Hour accumulated monthly per Square-Meter, ($Wh/m^2$)

## Comparison between Misurata, Libya and Berlin, Germany

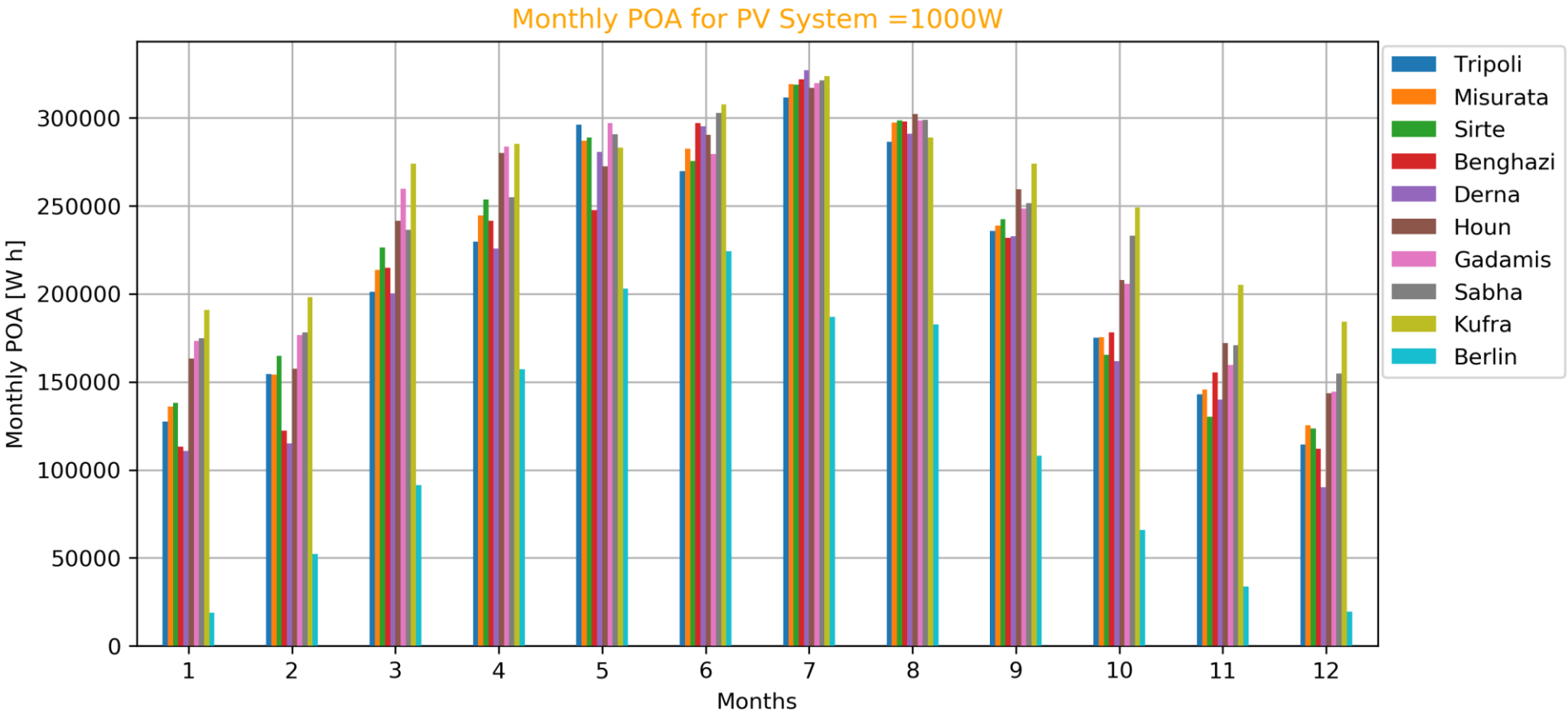


# Comparison of Solar Energy by the Direct Normal Irradiance (DNI), Watt-Hour accumulated monthly per Square-Meter, (Wh/m$^2$)



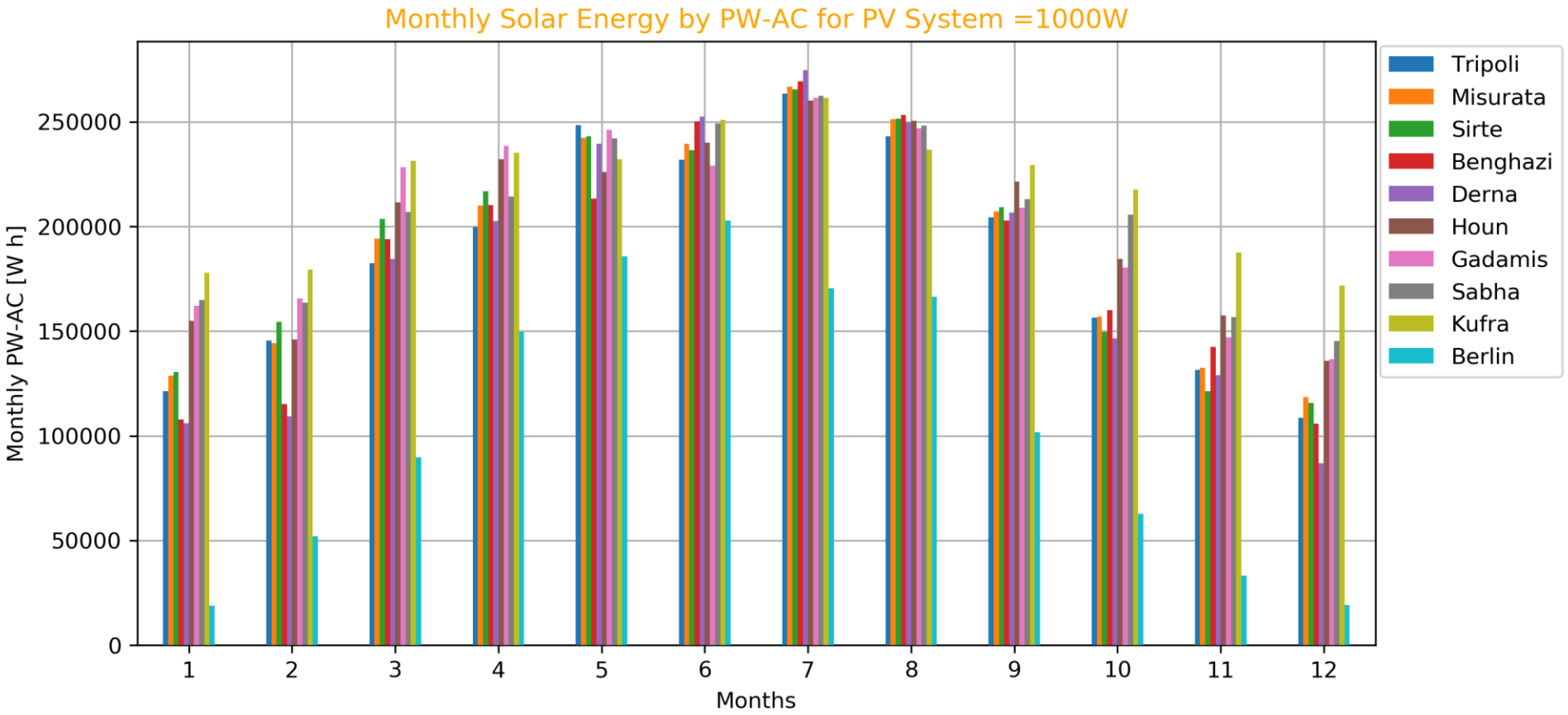
Comparison of Solar Energy by the Plane of Array (POA),
Watt-Hour accumulated (Wh) for PV system of rating PW=1000W

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.



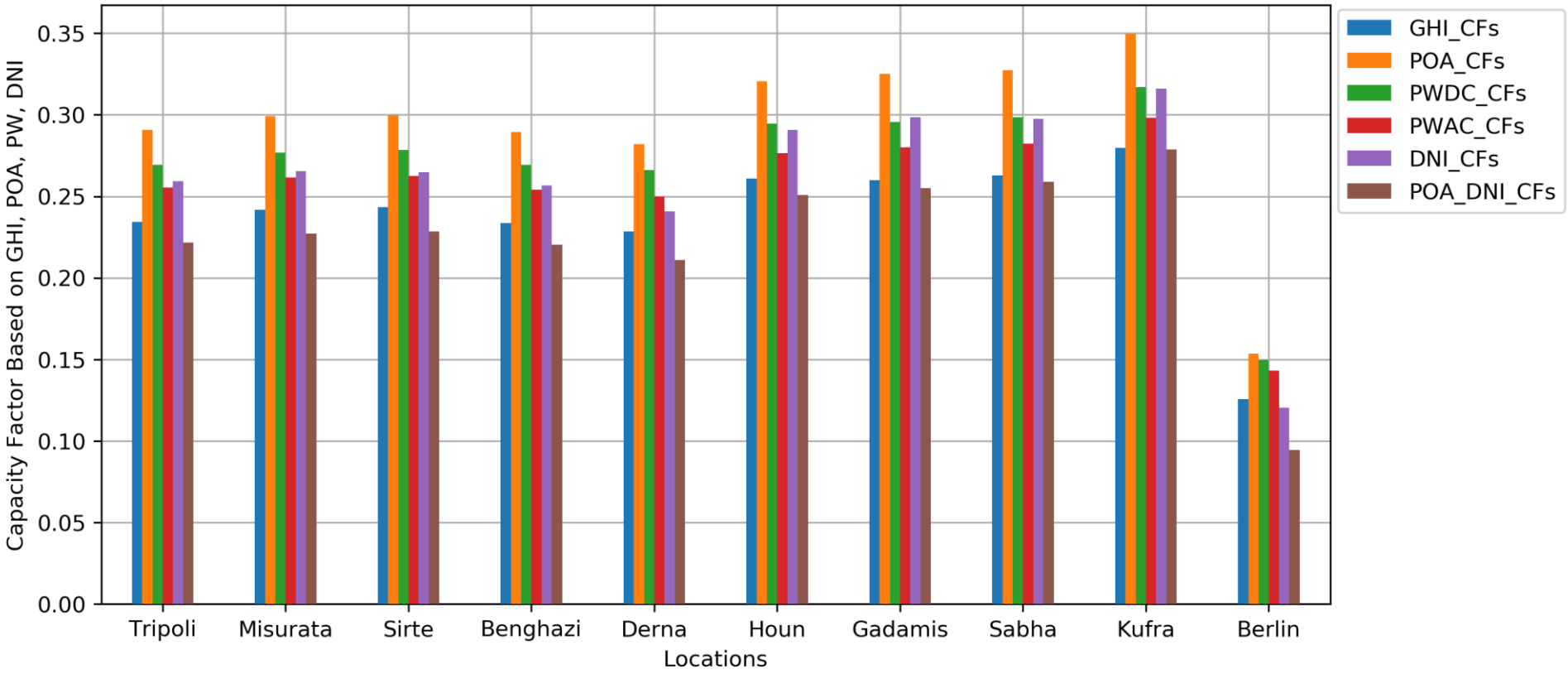
# Comparison of Net Capacity Factors (NFC)

The Capacity Factor is calculated based on Several Irradiances and Output Powers (DC) and (AC).
The Rating of Solar PV System =1000W during an entire year = 8760 hours.

| Location | GHI_CFs | POA_CFs | PWDC_CFs | PWAC_CFs | DNI_CFs | POA_DNI_CFs |
|---|---|---|---|---|---|---|
| Tripoli | 0.234199 | 0.290585 | 0.269381 | 0.255352 | 0.259360 | 0.221591 |
| Misurata | 0.241662 | 0.299089 | 0.276883 | 0.261649 | 0.265344 | 0.226979 |
| Sirte | 0.243338 | 0.299912 | 0.278514 | 0.262380 | 0.264714 | 0.228497 |
| Benghazi | 0.233556 | 0.289290 | 0.269182 | 0.253993 | 0.256688 | 0.220415 |
| Derna | 0.228293 | 0.282047 | 0.265982 | 0.249833 | 0.240903 | 0.210889 |
| Houn | 0.260896 | 0.320580 | 0.294575 | 0.276308 | 0.290568 | 0.250722 |
| Gadamis | 0.259906 | 0.324995 | 0.295710 | 0.279878 | 0.298431 | 0.255136 |
| Sabha | 0.262925 | 0.327496 | 0.298587 | 0.282232 | 0.297604 | 0.258812 |
| Kufra | 0.279635 | 0.349891 | 0.317157 | 0.298130 | 0.316106 | 0.278651 |
| Berlin | 0.125719 | 0.153390 | 0.149713 | 0.143000 | 0.120461 | 0.09442 |

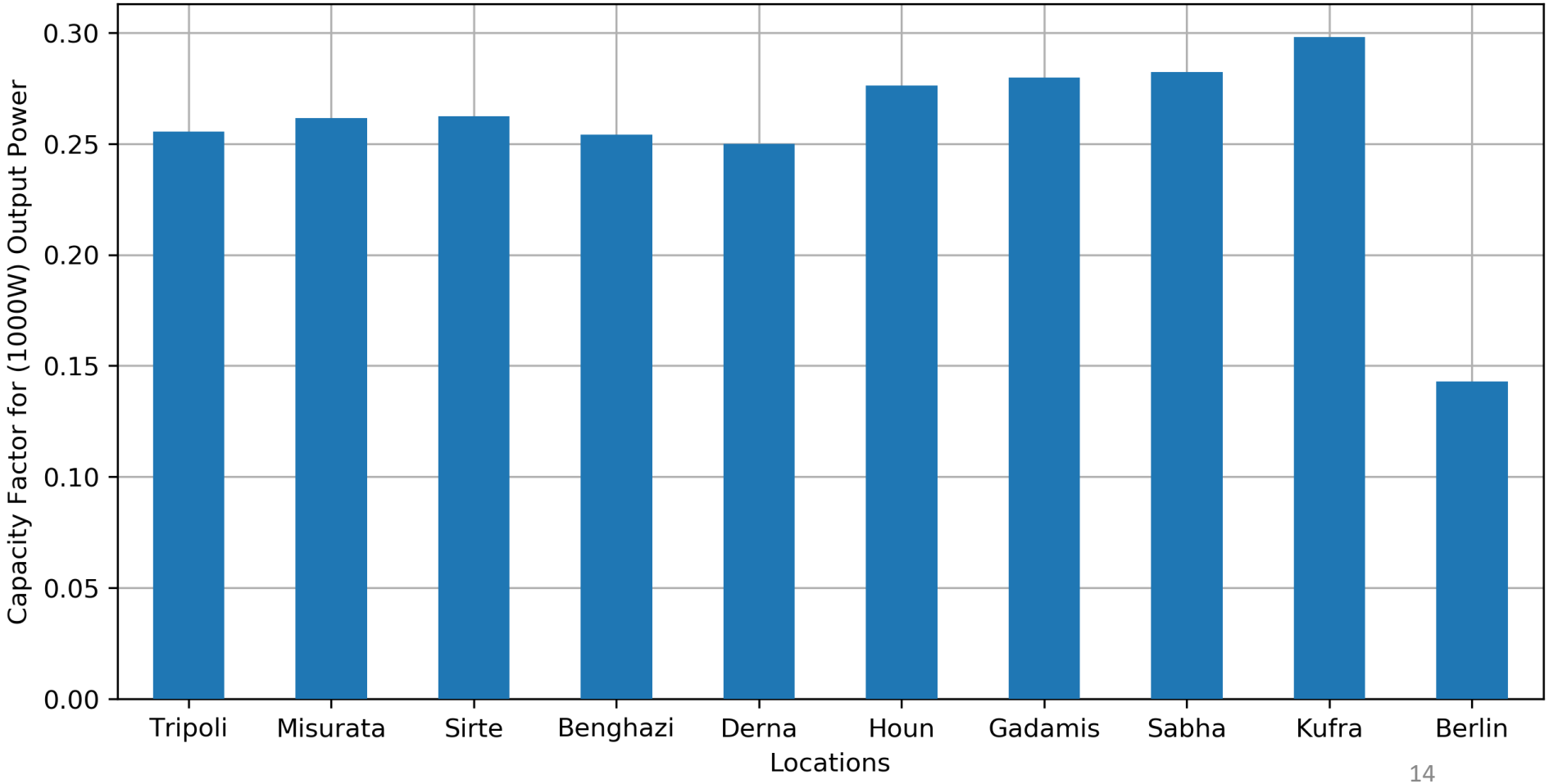
# Comparison of Net Capacity Factors (NFC)

The Capacity Factor is calculated based on Several Irradiances and Output Powers (DC) and (AC).
The Rating of Solar PV System =1000W during an entire year = 8760 hours.



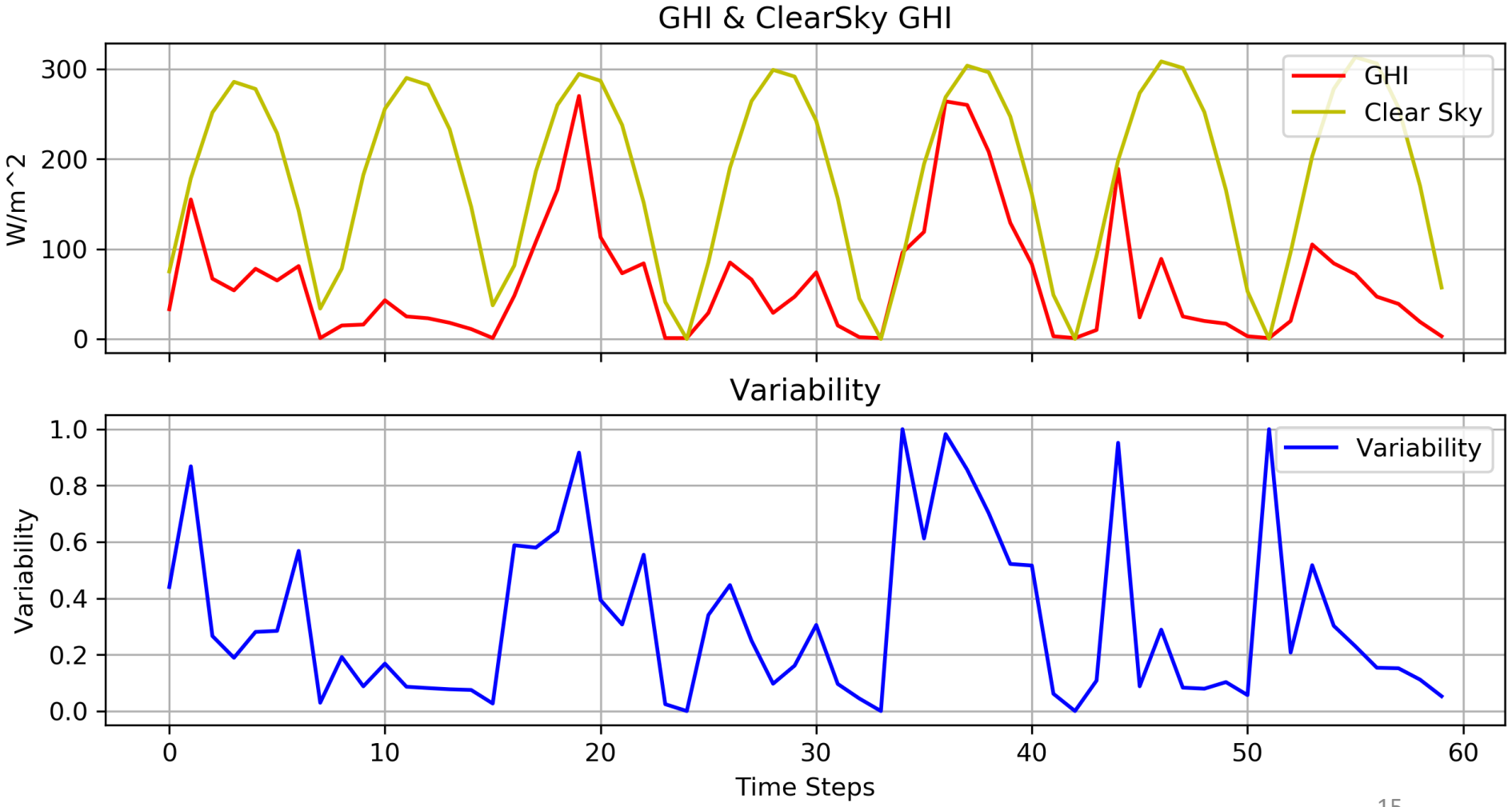
# Comparison of Net Capacity Factors (NFC)

The Capacity Factor is calculated based on Output power (PWac).
The Rating of Solar PV System =1000W during an entire year = 8760 hours.



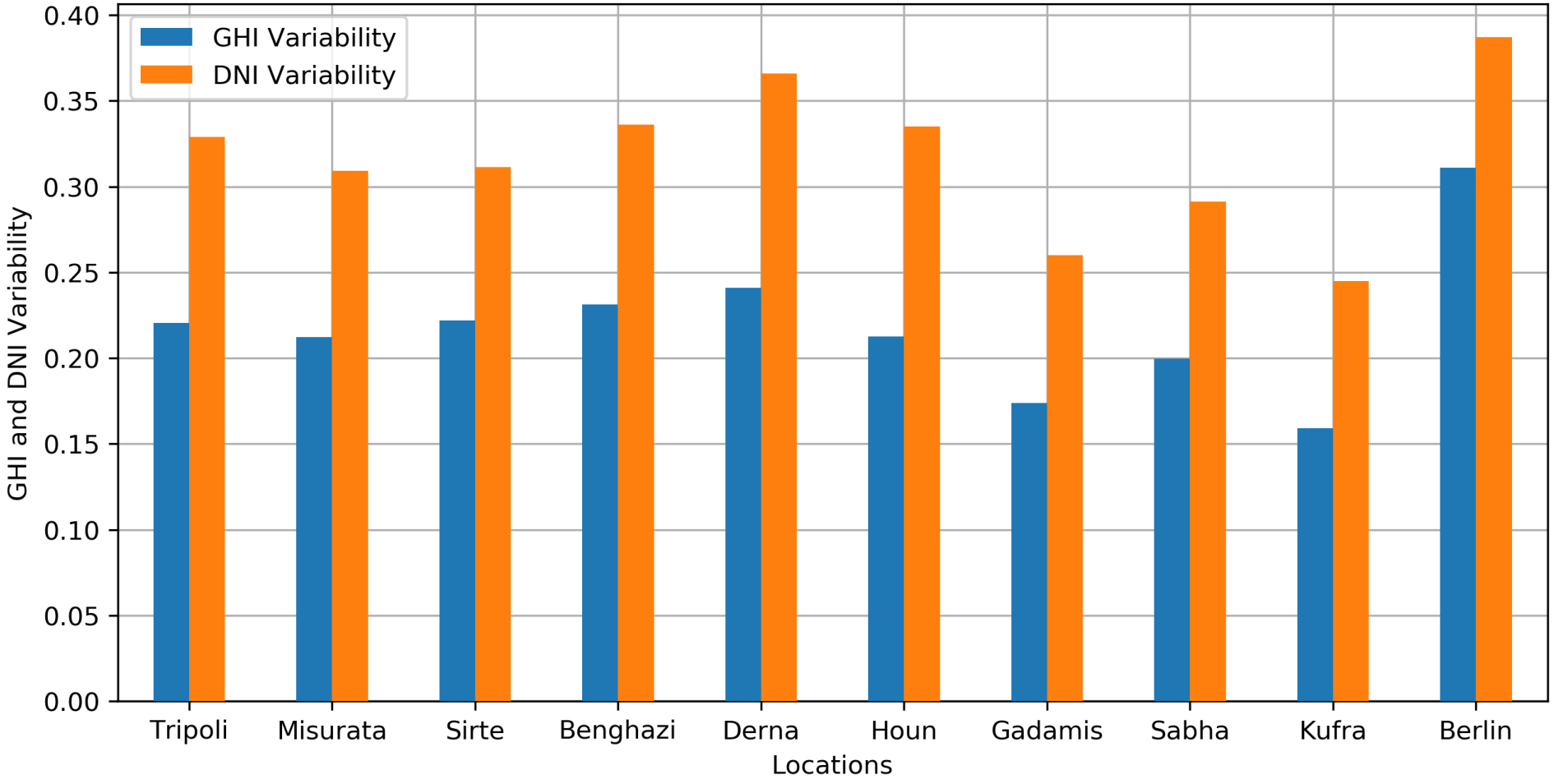
# Comparison of Solar Power Variability

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

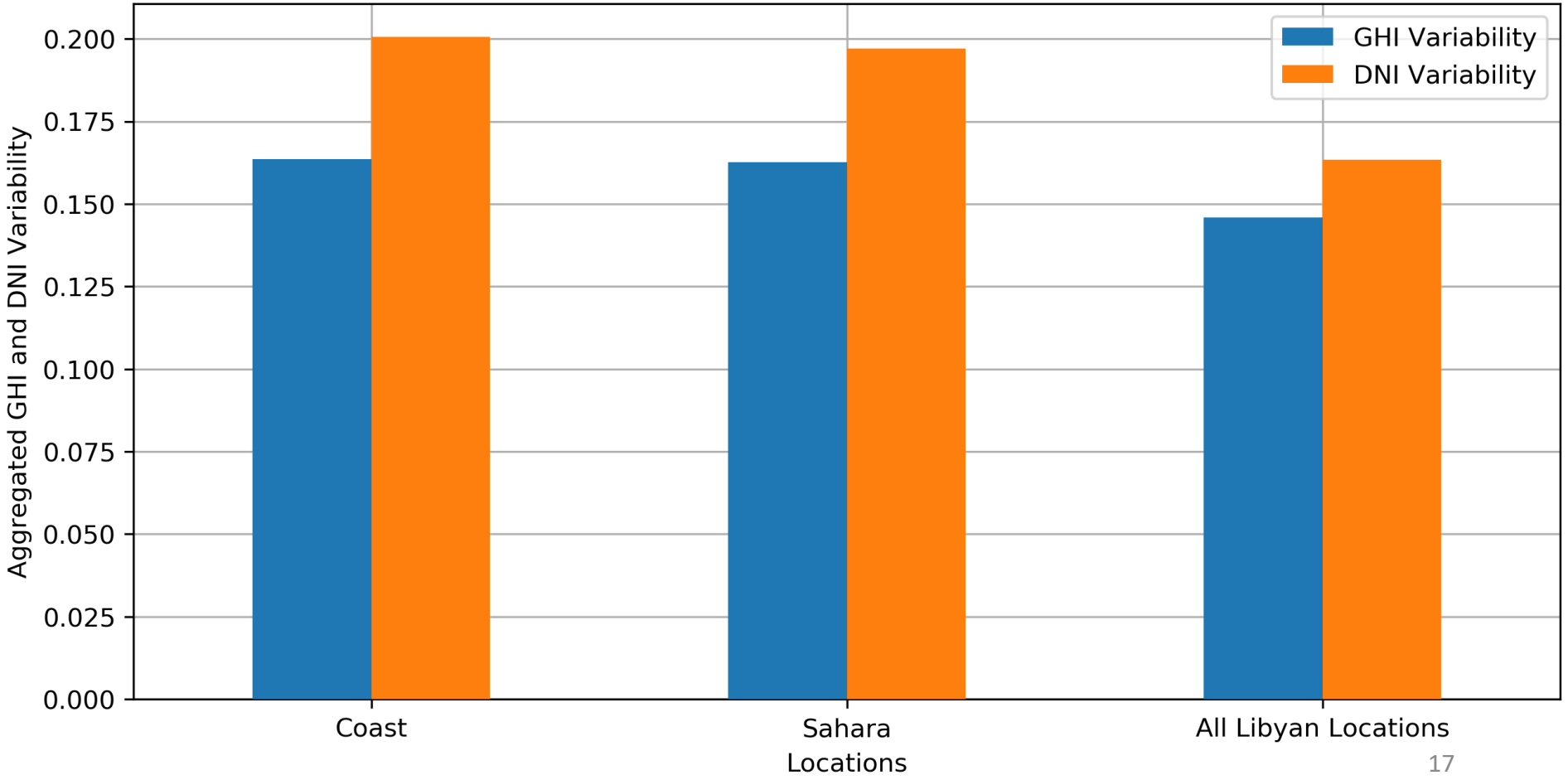
The Variability solar energy at a given location is determined based on the irradiance deviation from the clear-sky irradiance. The standard deviation of this (GHI/Cl-GHI) or (DNI/Cl-DNI) is used as an indication to the solar variability at a given location.



# 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

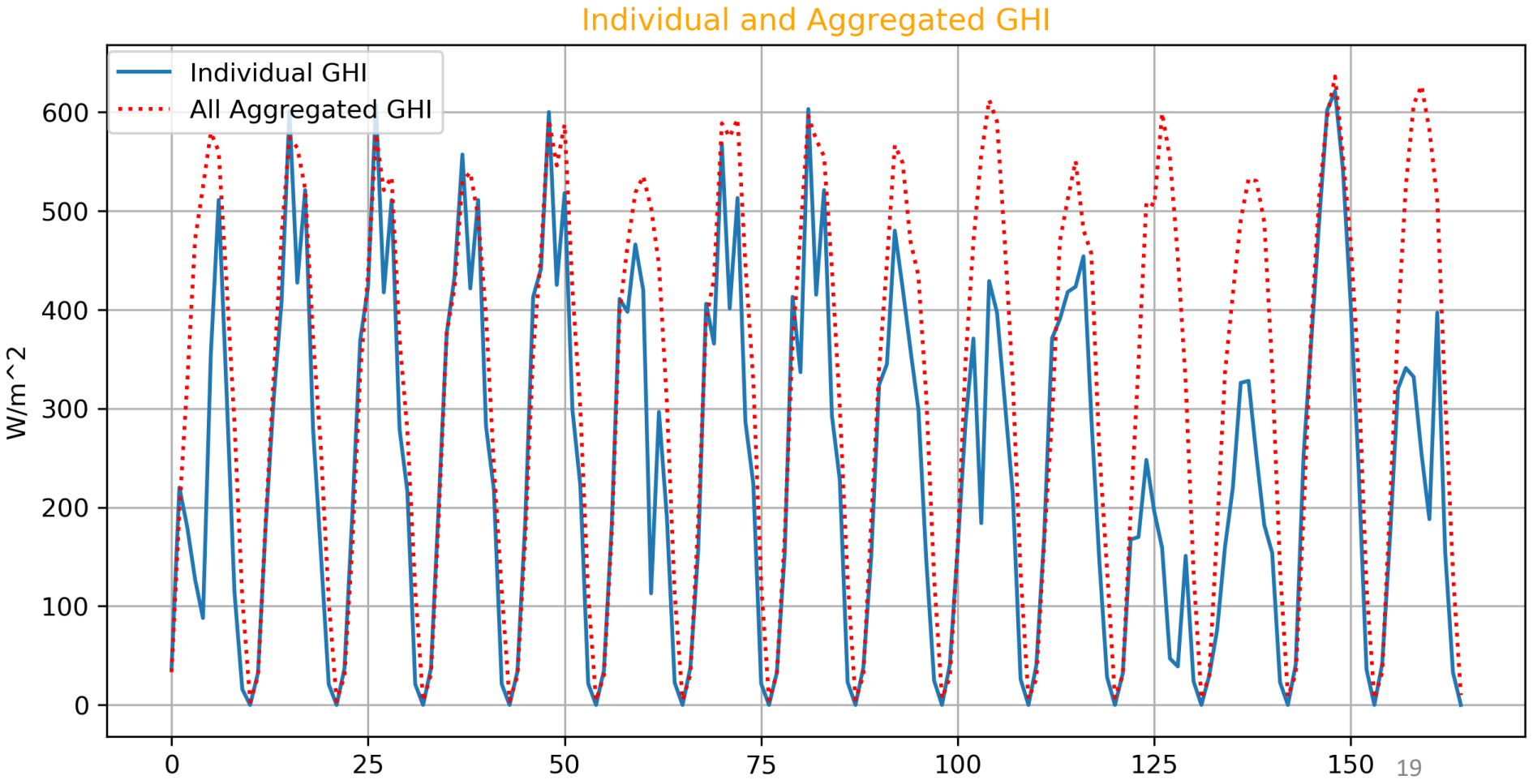
| Improvement (%) | Agg vs. Best Coast | Agg vs. Best Sahara | Agg vs. Best All |
|---|---|---|---|
| Coast | 22.866774 | -2.955564 | -2.955564 |
| Sahara | 23.329008 | -2.338584 | -2.338584 |
| All | 31.228778 | 8.205837 | 8.205837 |

**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

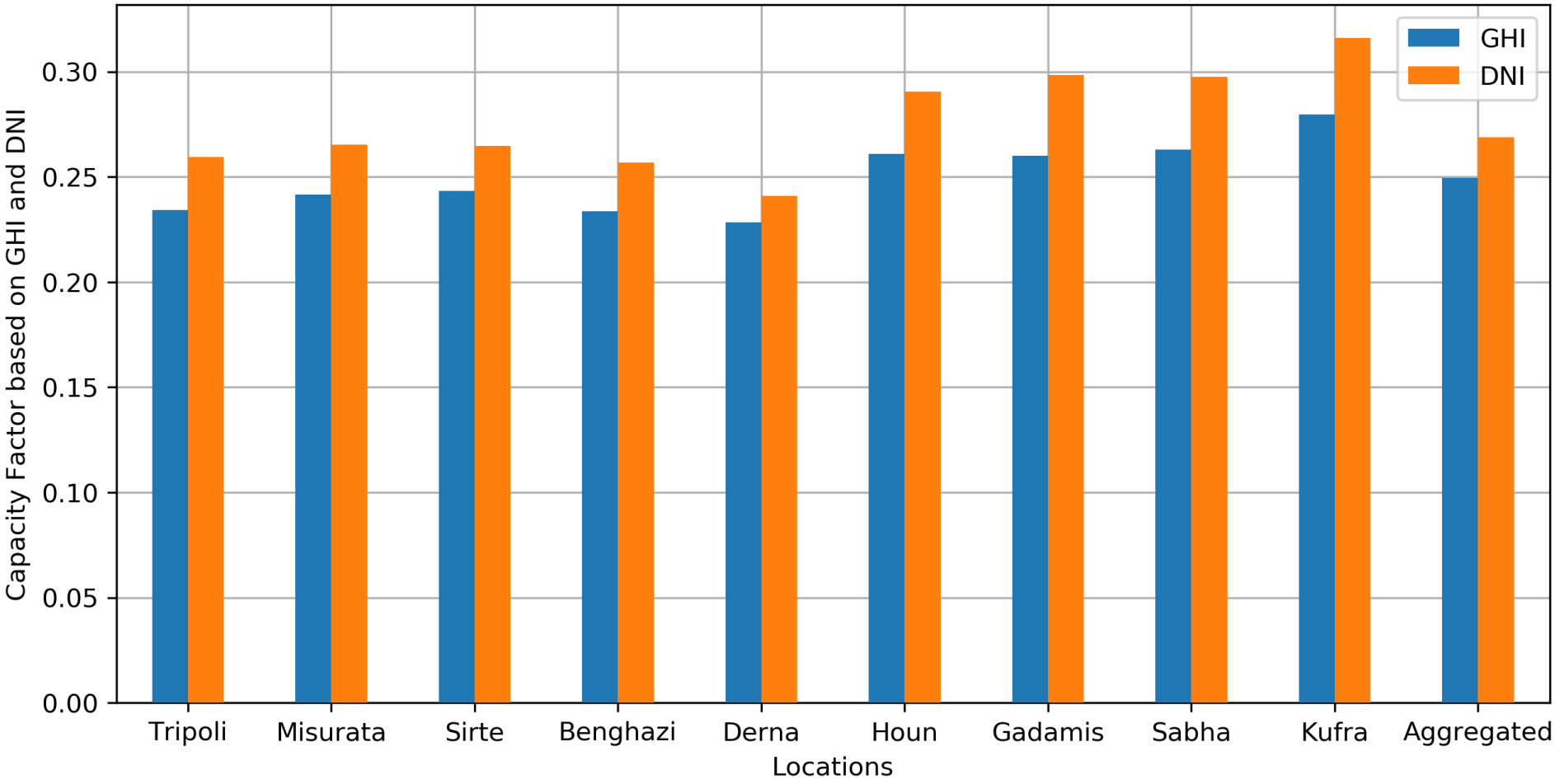
The solar resources are aggregated based to their locations:
Aggregated All Location against an individual location is Derna
During days from January 1st to January 15th



# 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.



# 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.

## NCF based on GHI

Net Capacity Factor based on GHI for All Aggregated Locations=**0.249**

While Average Net Capacity Factor based on GHI=0.237
And Max Net Capacity Factor based on GHI=0.279 @ Kufra location

## NCF based on DNI

Net Capacity Factor based on DNI for All Aggregated Locations=**0.269**

While Average Net Capacity Factor based on DNI=0.261
And Max Net Capacity Factor based on DNI=0.316 @ 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 0.30, 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?

**Mohamed Abuella**
mabuella@cit.edu.ly

https://mohamedabuella.github.io


كلية التقنية الصناعية_مصراتة
The College Of Industrial Technology_Misurata