DESIGN AND FABRICATION OF A SOLAR WATER HEATER FOR DOMESTIC USE

BY

OPIA KELVIN AVWEROSUOGHENE

(B.Eng Engineering)

ENG1604448

DEPARTMENT OF PRODUCTION ENGINEERING,

FACULTY OF ENGINEERING,

UNIVERSITY OF BENIN,

BENIN-CITY,

APRIL, 2024

DESIGN AND FABRICATION OF A SOLAR WATER HEATER FOR DOMESTIC USE

BY

OPIA KELVIN AVWEROSUOGHENE

(B.Eng Engineering)

ENG1604448

A PROJECT SUBMITTED TO THE DEPARTMENT OF PRODUCTION ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN, BENIN, EDO STATE, NIGERIA.

IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE AWARD OF THE BACHELOR OF ENGINEERING (B.Eng HONOURS) DEGREE IN ENGINEERING.

SEPTEMBER, 2023.

CERTIFICATION

This is to certify that this research work was carried out by **OPIA KELVIN AVWEROSUOGHENE** in the Department of Production Engineering, Faculty of Engineering, University of Benin, Nigeria under my supervision

ENGR.DR. F. INEGBEDION **DATE**

______________________ ___________________

(Project Supervisor)

PROF. P.E. AMIOLEMHEN **DATE**

_______________________ ____________________

(Head of Department)

EXTERNAL EXAMINER **DATE**

______________________ ____________________

DEDICATION

This Project Work is dedicated to God Almighty for His protection and guidance throughout my entire four years of studies at the University of Benin. To my parents, who have always supported in me all my activities and also for their love and support. This work is dedicated to all of you with Love and words of appreciation.

CERTIFICATION OF DISSERTATION ON PLAGIARISM

We the undersigned, attest to and declare that the dissertation of **OPIA KELVIN AVWEROSUOGHENE** , titled **DESIGN AND FABRICATION OF A SOLAR WATER HEATER FOR DOMESTIC USE** has successfully passed the anti-plagiarism test, and does not violate any copyright regulations.

ENGR.DR. F. INEGBEDION **DATE**

_________________________ ______________________

(Project Supervisor)

PROF. P.E. AMIOLEMHEN **DATE**

_________________________ ______________________

(Head of Department)

ACKNOWLEDGEMENTS

My Profound gratitude goes to the Almighty God for unending love, support, guidance, and His grace that has sustained me throughout my stay at the University of Benin.

I also appreciate my project supervisor, ENGR.DR. F. INEGBEDION for his patience, support, and guidance throughout my project.

I also want to thank my parents MR STANLEY and Evelyn Opia**,** for their financial, and moral support in the pursuit of this degree.

I thank all my team members for their contributions, ideas, and dedication in seeing that our project was successful.

I also appreciate my friends, especially for their love and support during this demanding but rewarding process, your support and motivation kept me going when times were rough.

Thank you all for your contributions to this project, I could not have done it without you.

TABLE OF CONTENT

LIST OF FIGURE

LIST OF PLATE

ABSTRACT

Solar energy is a promising renewable energy source that can play a crucial role in addressing global energy challenges and mitigating climate change impacts. This research focuses on assessing the impact of climate change on solar energy potential, specifically in regions vulnerable to environmental shifts. The study employs a multi-faceted approach combining data analysis, modeling techniques, and machine learning algorithms to analyze solar radiation data under varying atmospheric conditions.

The methodology involves collecting historical climate data, satellite-based solar radiation data, and ground-based measurements to create comprehensive datasets. Clear sky and all-sky solar radiation parameters such as Global Horizontal Irradiance (GHI), Direct Normal Irradiance (DNI), and Diffuse Horizontal Irradiance (DHI) are analyzed using established models and algorithms. Machine learning techniques are utilized to develop predictive models for solar energy forecasting, considering factors like cloud cover variations, aerosol content, and long-term climate trends.

The research aims to provide insights into how climate change trends impact solar energy resources, enabling better decision-making for solar energy infrastructure development and energy policy formulation. By understanding the complex interactions between climate dynamics and solar radiation, this study contributes to the advancement of sustainable energy practices and adaptation strategies in a changing climate scenario.

CHAPTER 1

INTRODUCTION

1.1 SOLAR ENERGY

This is the energy from the sun in the form of radiant light and heat which is harnessed using a range of technologies such as solar heating (solar thermal energy), and Photovoltaic. (Mints,2011) Solar Energy Technologies Solar-Thermal Systems.

In our modern society, we see power is utilized for operation on most daily activities both domestically and industrially. Solar energy is a prominent renewable energy source that has gained increasing attention worldwide due to its environmental benefits and potential to address energy challenges. Solar energy harnesses the power of sunlight, converting it into usable electricity or heat through various technologies like photovoltaic (PV) systems and solar thermal collectors. Central to understanding solar energy is the concept of solar irradiance, which quantifies the amount of solar power received at a particular location on Earth. (Klaus, 2014).

The amount of solar radiant energy falling on a surface per unit area and per unit time is called irradiance. The mean extraterrestrial irradiance normal to the solar beam on the outer fringes of the earth's atmosphere is approximately 1.36 kW/m2. Since the earth's orbit is elliptical, the sun-to-earth distance varies slightly with time of year, and the actual extraterrestrial irradiance varies by

±3.4% during the year. The angle subtended by the sun when viewed from the earth is only 0.0093 rad (approximately 32 min of arc); the direct beam radiation reaching the earth is therefore almost parallel. (Goswami. 2015).

1.2 SOLAR RADIATION

The sun is the central star of our solar system. It consists mainly of hydrogen and helium, The mass of the sun is so large that it alone contributes 99.68% of the total mass of the solar system. The sun has temperature of about 6000K. It behaves quite perfectly as a blackbody and is the source of radiation that hits the Earth.

1.3 SOLAR INSOLATION / IRRADIANCE

Solar insolation also know as solar irradiance refer to the power per unit area (watt per square meter) received from the Sun in the form of electromagnetic radiation. It is a key factor in determining the feasibility and efficiency of solar energy systems. Understanding solar insolation is essential for harnessing solar energy through photovoltaic systems, solar thermal technologies, and other renewable energy applications. (Lelege, 2020)

1.3.1 Types of Solar Irradiance

Solar irradiance comprises direct irradiance, which is the solar radiation that reaches the Earth's surface in a straight line from the Sun, and diffuse irradiance, which is the solar radiation that is scattered and reflected by the atmosphere before reaching the Earth's surface. Global irradiance represents the sum of direct and diffuse irradiance, depicting the total solar radiation received at a particular location. (Solanki**.** 2015).

1.3.2 Factors Affecting Solar Irradiance

Solar irradiance is influenced by various factors such as the, time of day, seasonal variations and geographical location's latitude and specific conditions:

Solar irradiance varies throughout the day, with maximum intensity around noon when the Sun is directly overhead. The angle of the Sun changes with seasons, affecting the amount of solar radiation received. Solar irradiance varies with geographical location due to differences in solar angles and atmospheric conditions. (Solanki,2015)

1.4 SOLAR RESOURCE ASSESSMENT

A solar resource assessment is a comprehensive analysis of the solar energy potential at a specific location. This assessment is crucial for understanding the feasibility of solar energy projects and optimizing their design.

Solar resource assessment involves evaluating the solar energy potential of a particular location to determine its suitability for solar energy applications.

In the face of global climate challenges and the increasing demand for sustainable energy sources, renewable energy technologies have gained unprecedented attention. Among these technologies, solar energy stands out as a promising and rapidly growing sector in the renewable energy landscape. Harnessing energy from the Sun not only reduces greenhouse gas emissions but also offers a reliable and abundant source of power for diverse applications.

1.4.1 Importance and Goal of Solar Resource Assessment

Central to the effective utilization of solar energy is the process of solar resource assessment. This assessment involves evaluating the solar energy potential of specific locations, considering factors such as solar irradiance levels, geographic conditions, and environmental variables.

Solar resource assessment is very important and crucial for

- **Site selection:** It helps in identifying optimal locations for solar power plants or solar panel installations based on solar irradiance data.
- **System sizing:** Solar resource assessment aids in determining the size and capacity of solar energy systems needed to meet energy demands.
- **Energy yield estimation:** By assessing solar irradiance levels, one can estimate the expected energy production of a solar power system over time.
- **Financial analysis of solar projects:** Accurate solar resource assessment is crucial for financial viability assessments and return on investment calculations for solar projects.

The goal of solar resource assessment is to provide accurate data and insights that enable informed decision-making throughout the lifecycle of solar energy projects.

1.4.2 Steps in Solar Resource Assessment

The process of solar resource assessment includes

Data Collection: This involve gathering of historical solar irradiance data for the target location from reliable sources such as meteorological stations or satellite data. (Francis and Morse 2018).

Data Analysis: Analyze the solar irradiance data to understand daily, monthly, and seasonal variations, as well as long-term trends. (Kalogirou 2009)

Shading Analysis: Assess potential shading factors such as nearby buildings, trees, or terrain that may impact solar irradiance at the site. (Capizzi et al.2012)

Modeling and Simulation: Use solar simulation software or models to predict solar energy generation based on the collected data and site-specific factors. (Hoffmann et al 2005).

Validation: Validate the modeled results with actual performance data from existing solar installations or test sites to improve accuracy. (Solanki, 2015).

The Solar Energy Industries Association (SEIA) and National Renewable Energy Laboratory (NREL) websites offer valuable resources, data, and tools for solar resource assessment and solar energy analysis, including validation methods.

1.4.3 Role of Advanced Technologies in Solar Resource Assessment

Remote Sensing and Satellite Data: Advanced remote sensing techniques, coupled with satellite data, provide valuable insights into solar irradiance patterns at different spatial and temporal scales. Satellite-based solar irradiance data, such as that from NASA's Solar Radiation and Climate Experiment (SORCE) or the European Space Agency's (ESA) satellites, offer comprehensive coverage and long-term data sets for accurate resource assessment.

Machine Learning and Data Analytic: Utilizing machine learning algorithms and data analytic, stakeholders can process vast amounts of solar irradiance data, identify patterns, and create predictive models. These models enhance the precision of solar energy yield predictions and improve the efficiency of solar power systems through data-driven optimizations.

Geographic Information Systems (GIS): GIS technology enables the integration of solar irradiance data with geographical and topographical information. This integration allows for spatial analysis, site suitability mapping, and the identification of potential constraints or opportunities for solar energy development in specific regions.

By leveraging advanced technologies and considering environmental factors in solar resource assessment, stakeholders can achieve more precise energy predictions, optimize system designs, and make informed decisions that maximize the efficiency and resilience of solar energy projects. These approaches contribute to the ongoing evolution and effectiveness of renewable energy solutions in addressing global energy challenges.

1.4.4 Importance of Considering Environmental Factors in Solar Resource Assessment

Shading Analysis: Assessing shading effects from surrounding structures, vegetation, and terrain is crucial in accurately estimating available solar irradiance. Tools like shade analysis software or solar path calculators help identify potential obstructions and optimize solar panel placement for maximum sunlight exposure.

Micro-climatic Influences: Local micro-climates can significantly impact solar resource availability. Factors such as elevation, temperature variations, humidity levels, and wind patterns can affect solar panel performance and energy production. Integrating micro-climatic data into resource assessment models enhances accuracy and resilience against environmental fluctuations.

Climate Change Considerations: Long-term solar resource assessment should also account for climate change effects on solar irradiance patterns. Historical data analysis and climate projection models help anticipate potential shifts in solar energy availability due to climate variability, ensuring sustainable energy planning and adaptation strategies.

1.5 AIM AND OBJECTIVES

The aim of this project is to determine the optimum insolation for utilization of solar energy resources for sustainable energy production.

The objectives of this project are to;

1. determine the resource assessment data of University of Benin (2014 – 2023)
2. identify the period where solar panels are able to harness maximum solar energy in University of Benin.
3. identify the periods of great and poor insolation in University of Benin.
4. study the monthly sunshine intensity distribution.
5. study the working principles of solar installation.
6. ensure solar installation are designed to harness maximum solar energy.

CHAPTER 2

LITERATURE REVIEW

2..1 SOLAR ENERGY/ SOLAR ENGINEERING

The field of solar energy can be broadly categorized into four parts:

1. Solar resource assessment and forecasting.
2. Photovoltaic(PV) technology's
3. Concentrating solar power (CSP) technology, and
4. Solar heating and cooling.

So far as solar radiation is concerned, solar engineering takes a vital role in connecting atmospheric science, which deals with the atmospheric chemistry and physics governing the amount of solar radiation reaching the Earth’s surface, and downstream applications, such as grid integration, day lighting, or heating, ventilation, and air-conditioning (HVAC). However, unlike atmospheric science, ,electrical engineering, architecture, or mechanical engineering, it is not entirely clear whether or not solar engineering can be viewed as a subject on its own, very few universities offer a curriculum on that, and very few people would attain a certificate that says "Bachelor of Solar Engineering" at the end of the day.

In this regard, it is thought that a review of review has now become absolutely necessary. It is on this account that a review of review on solar resource assessment and forecasting is herein presented.

Presenting a review of review is by no means a simple task, because the literature contains many out date,duplicated, and non-representative reviews that can be misleading or even harmful, particularly to those who are not familiar with the domain.In fact, even highly cited recent textbooks and handbooks can be outdated, and may contain questionable information. Since solar resource assessment and forecasting is a fasts advancing field with many parallel works, this review of review is composed of carefully selected and most representative reviews from credible sources that could fully reflect the state-of-the-art. (Dazhi , Wenting, and Xiang'ao 2022).

2.2 SOLAR RESOURCE ASSESSMENT

The idea central to solar resource assessment resides in identifying suitable and reliable data, without which no conclusion made can be deemed valid. Data for solar resource assessment are presented in three main forms:

- ➔ ground-based measurements,
- ➔ remote-sensing retrievals, and
- ➔ Output of numerical weather prediction(NWP) models.

Among these three forms, carefully calibrated ground-based measurements are most accurate,followed by remote-sensing retrievals, whereas NWP output is the least accurate.

Living in an age of data explosion, one must not forget that solar radiation data was once scarce. Before the advent of modern remote sensing and we, researchers used sorely on low-accuracy empirical models for the estimation of solar radiation, such as the Ångström–Prescott type of models, which are based on sunshine duration. As compared to the current data practice and ways of estimating or retrieving solar radiation, sunshine duration data are of poor and inconsistent quality, and empirical correlations obtained at one location rarely apply to another.

2.2.1 Analysis of Solar Resource Assessment Data

In solar resource assessment, various types of data are needed to accurately evaluate the potential of a location for solar energy generation. Two crucial type of data is the all-sky data and clear-sky data, which helps in understanding the solar radiation levels that can be expected under ideal atmospheric conditions.

2.2.2 All-sky Solar Radiation Data

All-sky solar radiation data refers to measurements or models that take into account the presence of clouds and atmospheric conditions, providing a more realistic estimation of solar radiation levels compared to clear-sky data.

1. All-Sky Solar Radiation Data Types:

A. Global Horizontal Irradiance (GHI):

Definition: Total solar radiation received on a horizontal surface, including both direct and diffuse components, under all sky conditions.

Importance: Crucial for assessing solar energy potential in real-world scenarios with varying cloud cover. (Sengupta et al.,2015).

B. Direct Normal Irradiance (DNI) under All-Sky Conditions:

Definition: Solar radiation received per unit area by a surface perpendicular to the sun's rays, considering cloud effects.

Importance: Essential for concentrating solar power (CSP) and tracking systems that rely on direct sunlight. (Perez et al., 2002).

C. Diffuse Horizontal Irradiance (DHI) under All-Sky Conditions:

Definition: Solar radiation reaching a horizontal surface after scattering by clouds and atmosphere.

Importance: Influences energy capture in PV systems and helps understand diffuse radiation behavior. (Perez et al., 2008).

2. Measurement Technologies and Models for All-Sky Data:

A. Ground-Based Solar Radiation Measurements:

Technologies such as pyranometers and pyrheliometers are used to measure GHI, DNI, and DHI under varying sky conditions. (Remund,1987).

B. Satellite-Based Solar Radiation Models:

Models like the Heliosat-2 model and the REST2 model use satellite imagery and atmospheric data to estimate solar radiation under all-sky conditions. (Lefèvre et al., 2020).

3. Impact of Cloud Cover and Aerosols:

Cloud cover, aerosol content, and atmospheric properties significantly affect all-sky solar radiation. Models often incorporate these factors to improve accuracy. (Renne et al., " 2015).

2.2.3 Clear-sky Solar Radiation Data

Clear sky data in solar energy refers to conditions where the sky is cloudless, allowing maximum solar radiation to reach the Earth's surface. This data is important for understanding the theoretical maximum solar energy potential at a given location under ideal atmospheric conditions.

1. Clear Sky Solar Radiation Parameters:

A. Clear Sky Global Horizontal Irradiance (GHI):

Definition: Solar radiation received on a horizontal surface under clear sky conditions, without any obstructions or atmospheric interference.

Importance: Provides a baseline for assessing the maximum solar energy potential at a location. (Myers et al., 2008).

B. Clear Sky Direct Normal Irradiance (DNI):

Definition: Solar radiation received per unit area by a surface perpendicular to the sun's rays under clear sky conditions.

Importance: Crucial for concentrating solar power (CSP) systems and high-efficiency photovoltaic (PV) systems. (Gueymard, 2006).

C. Clear Sky Diffuse Horizontal Irradiance (DHI):

Definition: Solar radiation reaching a horizontal surface after scattering by the atmosphere under clear sky conditions.

Importance: Helps understand the direct and indirect solar radiation components contributing to overall energy capture. (R. Bird et al.,1974).

2. Clear Sky Models and Algorithms:

A. Bird Clear Sky Model:

Description: A widely used empirical model for estimating clear sky solar radiation parameters based on solar position and atmospheric characteristics. (Bird and Hulstrom, 1981).

B. Ineichen Clear Sky Model:

Description: Another empirical model that considers aerosol optical depth, water vapor content, and atmospheric conditions to estimate clear sky solar radiation. (Ineichen and Perez, 2002).

3. Application in Solar Resource Assessment:

Clear sky data is used as a reference or baseline to compare actual solar radiation measurements and assess the performance of solar energy systems. (Reno et al., 2010).

CHAPTER 3

METHODOLOGY

The objective of this research is to investigate the impact of climate change on solar energy potential and also for optimizing solar energy forecasting in the University of Benin, Edo State, Nigeria.

The steps I toke to achieve these objective are as follows;

3.1 DATA COLLECTION

I collected data for solar insolation of the University of Benin, for a period of 10 years ranging from 2014 to 2023. I was able to access this data from a satellite data source, National Aeronautics and Space Administration(NASA) placing emphasis on All-sky data and Clear-sky data. This data is available in Appendix.

3.2 DATA PROCESSING

The data I collected showed the daily distribution of solar insolation over the specified period, and needed to be processed for better and easier understanding. I made use of the Microsoft Excel windows 10 to sort out the data. The daily average insolation was calculated using Microsoft excel and a histogram was plotted which gave an understanding to the months with best insolation levels**.** The data of the plot is available in Appendix.

Also with the aid of Mat-Lab, a cumulative distribution frequency curve of the average monthly insolation for low and high insolation months was plotted with the data in table of Appendix 2. The following steps were taken in the array of figures below.

Plate 3.1 Run MATLAB

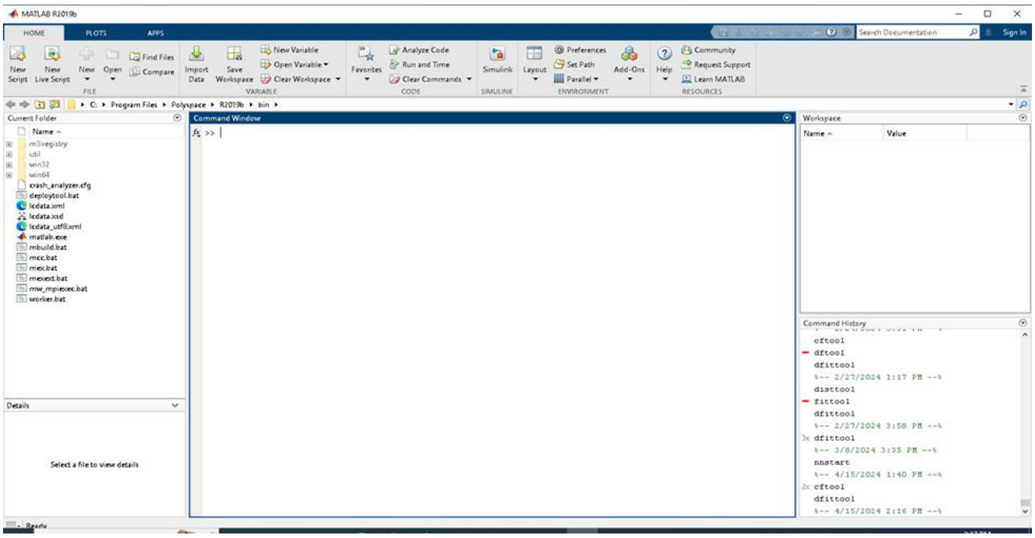


Plate 3.2: Chose column vector output type, and import the data sets from Appendix 2

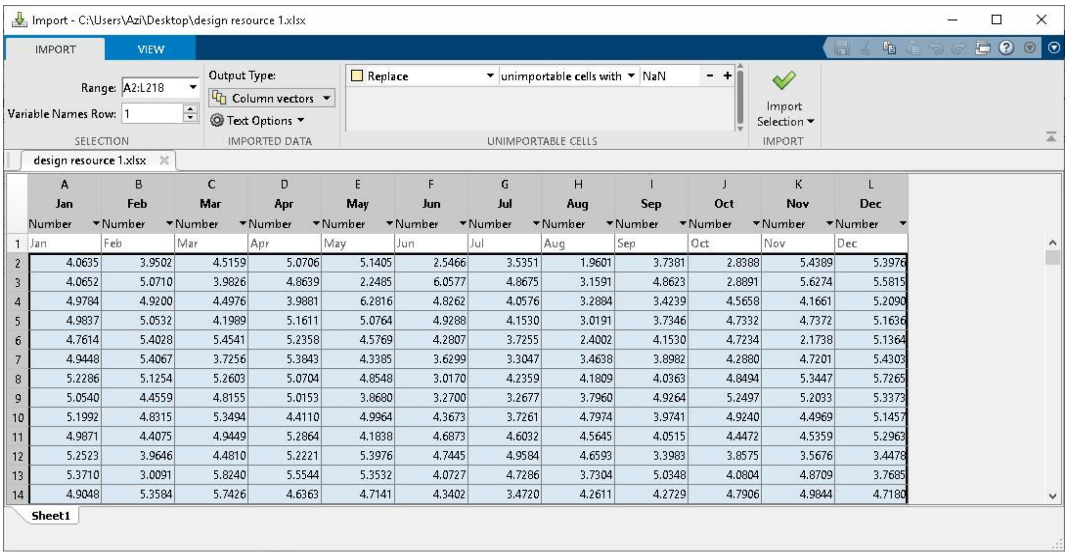


Plate 3.3: A work space column of the input data appears at the corner having all the months present

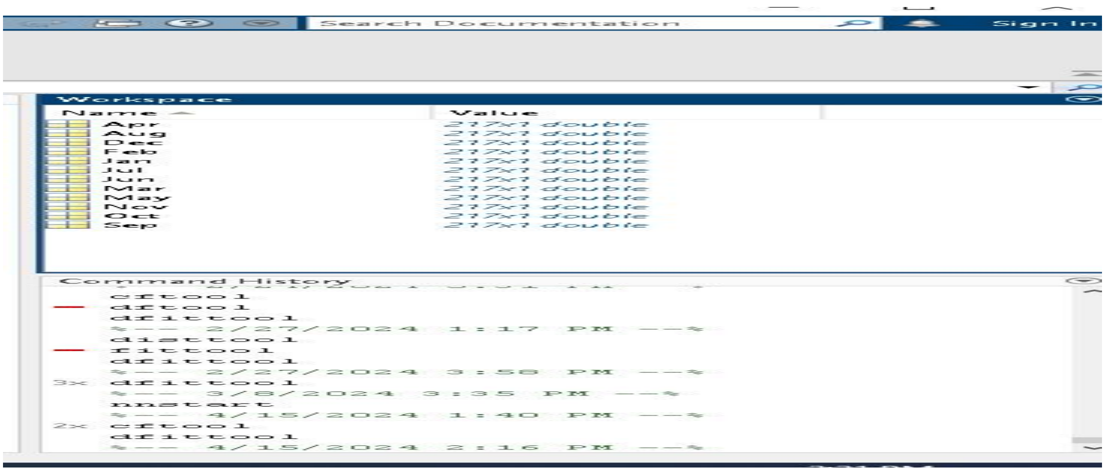


Plate 3.4: Type the command " **dfittool"** and a distribution filter comes up

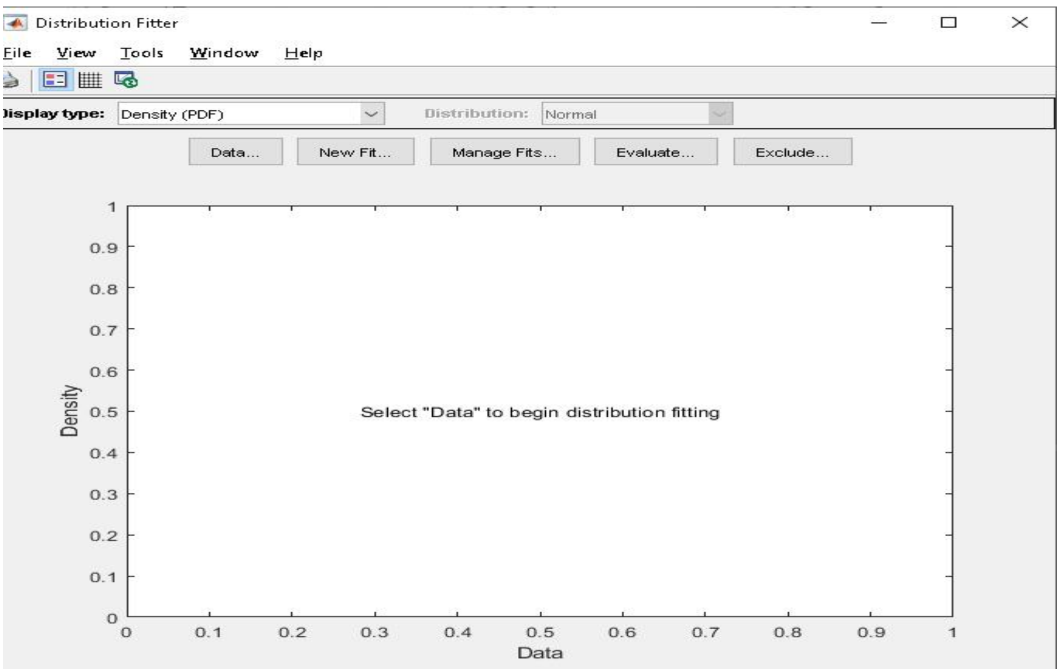


Plate 3.5: Click **"data",** input the months with highest insolation and months with lowest insolation and click **"create data set"**

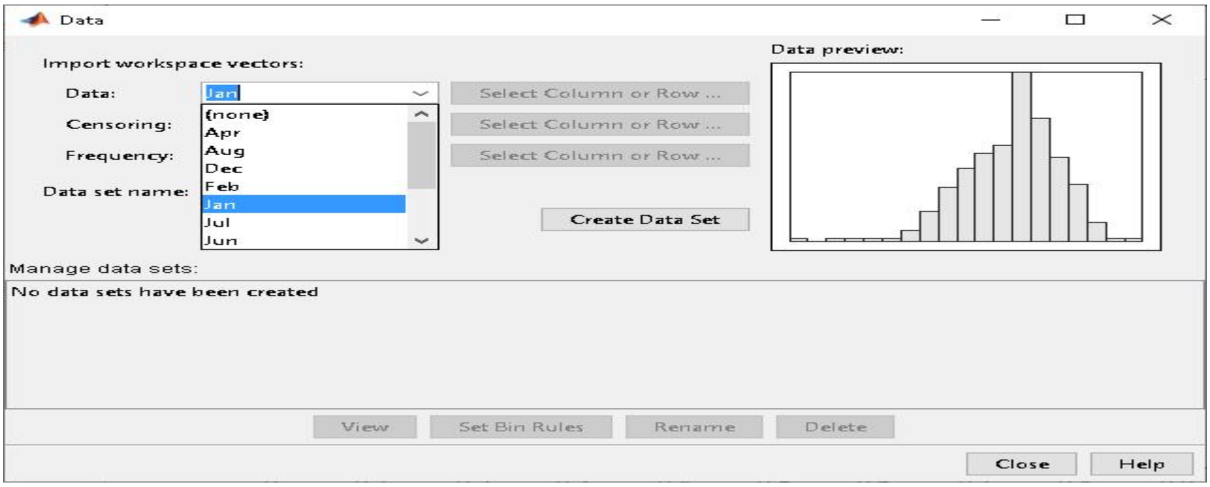
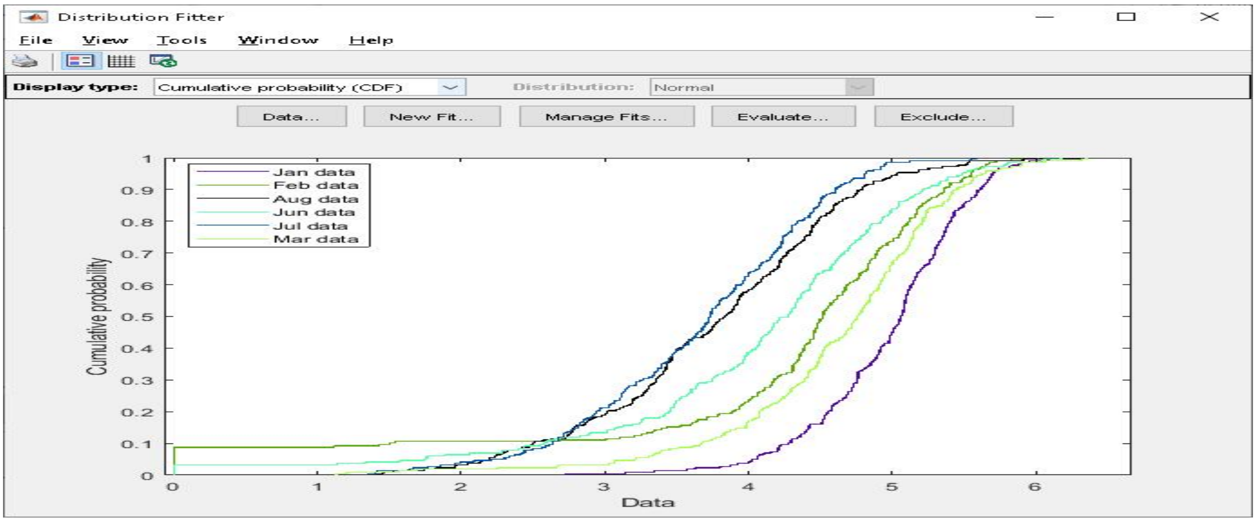


Plate 3.6: After creating **data set,** change the display type to **cumulative distribution function.**



CHAPTER 4

RESULTS AND DISCUSION

4.1 RESULTS

The data from Appendix 1 with the aid of excel generated an average insolation chart as shown in the figure below

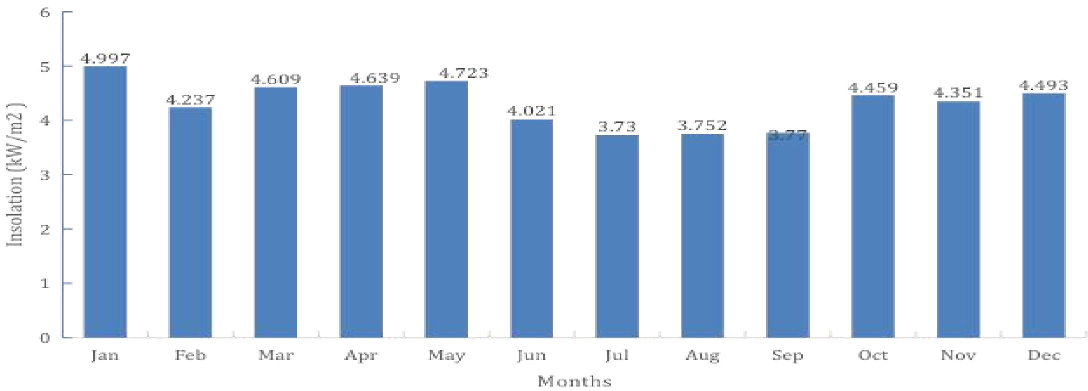


Figure 4.1: A bar chart showing average monthly solar insolation average for the University of Benin.

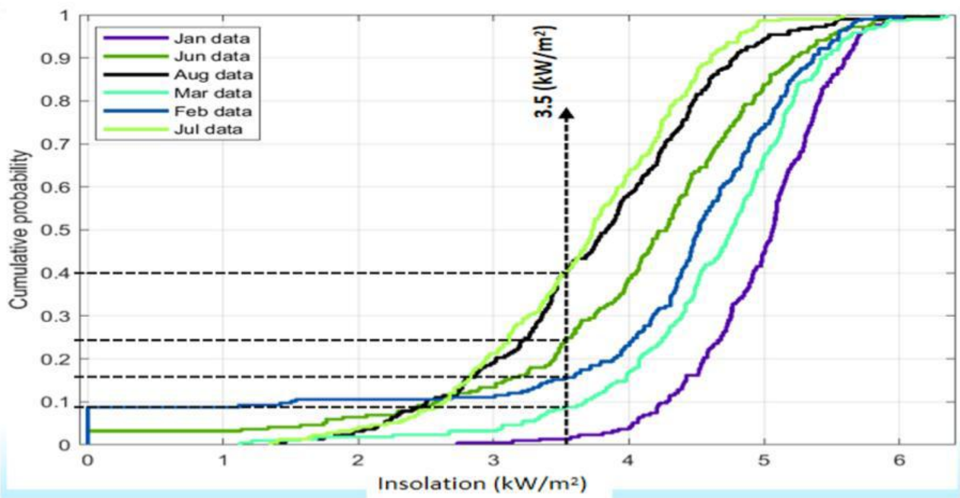


Figure 4.2: Cumulative Frequency Distribution Curve

4.2 DISCUSSION

From the chart above we observe the month with the highest isolation to be in January and also in May with the lowest to be in the months of July, August and September. The average value for the highest isolation was 15.49KWh/m2/day and the value for the lowest isolation was 3.17KWh/m2/day. The results from the Mat Lab cumulative distribution curve.

CHAPTER 5

FINDINGS, CONCLUSION AND SUGGESTIONS FOR FURTHER STUDIES

5.1 FINDINGS

The resource assessment of UNIVERSITY OF BENIN was determined and the highest solar insolation was 4.99KWh/m^2/ day while the lowest solar insolation was 3.68KWh/m^2/ day.

From figure 1; the month of January, March,April and also May has the highest insolation 5.0 KWh/m^2/ day, 4.6KWh/m^2/ day , 4.6KWh/m^2/ day , 4.7KWh/m^2/ day respectively, thus the solar panels can charge battery effectively, as the probability of sunshine intensity at this months are high.

The months with the highest insolation are usually the best where the solar cells are able to work most effectively and also to generate energy enough to charge the battery in a solar system.

5.2 CONCLUSION

A well-conducted solar resource assessment provides valuable insights for making informed decisions about solar energy projects. It ensures that solar installations are designed to harness the maximum energy available at a specific location, leading to more efficient and sustainable outcomes.

5.3 SUSGESTION FOR OTHER STUDIES

Solar engineering should be introduce in University curriculum to enhance the advancement of solar resources assessment and designs of solar equipment and machinery. Further research should be made on ways for increasing the efficiency and durability of solar cells. Studies should be carried out making solar panels more available and affordable.

REFERENCES

Mints, P.(2011), The History and Future of incentives and the Photovoltaic Industry and How Demand is Driven, Progress in Photovoltiac Research and Application 20(6)711-716.

LELEJI A.A, (2020) Stand-Alone Photovoltaic System for a Rural Health Care Center (RHCC) Iguosa and a Small Scale Enterprise(SSSE) Ugbowo.B.

Klaus Jager, (2016) Solar Energy: The Physics and Engineering of Photovoltiac Conversion. Cambridge: University of Technology press.

Chetan Singh Solanki; (2015) Solar Energy: Fundamentals, Design, Modelling, and Applications. India: Prentice Hall of India.

Francis S. Tse and Ivan E. Morse (2018): Measurement and Instrumentation in Engineering Principles and Basic Applications. Chemical Rubber Co press.

Giacomo Capizzi, Christian Napoli, Francesco Bonanno, (2012): IEEE Transactions on neural networks and learning systems: A Comparative Analysis of Photovoltaic Potential, vol 23, pp 1805 - 1815.

Goetzberger .A,Hoffmann V.U,(2005) Photovoltaic Solar Energy Generation. Berlin: Springer.

Dazhi YANG1 , Wenting WANG1, and Xiang'ao XIA2 2022: A concise overview on solar resource assessment and forecasting. Adv. Atmos. Sci., 39(8).

M. Sengupta et al.,(2015) "Validation of Satellite-Based Irradiance Models in the US," Solar Energy, vol. 113, pp. 173-185.

R. Perez et al.,(2002) "A New Operational Model for Satellite-Derived Irradiances: Description and Validation," Solar Energy, vol. 73, no. 5, pp. 307-317.

R. Perez et al.,(2008)"Modeling Solar Radiation at the Earth's Surface: Recent Advances," Springer.

F. Remund,(1987)"Solar Radiation Measurement Techniques," Solar Energy, vol. 39, no. 3, pp. 193-200, 1987.

M. Lefèvre et al.,(2020) "The Heliosat-2 Method: From On-Demand Training to Fully Operational Near Real-Time Processing," Remote Sensing, vol. 12, no. 18, 2987.

D. Renne et al.,(2015) "Evaluation of Global Horizontal Irradiance to Plane-of-Array Irradiance Models at Locations across the United States," Solar Energy, vol. 119, pp. 203-213.

D. Myers et al.,(2008) "Generation of Typical Meteorological Year Data for 200 Locations around the United States Using the TMY3 Data Set," National Renewable Energy Laboratory (NREL), Technical Report NREL/TP-581-43156.

C. Gueymard,(2006) "Clear Sky Solar Irradiance Definitions and General Categorization of Models," Solar Energy, vol. 80, no. 12, pp. 1563-1578.

R. Bird et al., (1974) "The Development of a New Source of Solar Radiation Data," Solar Energy, vol. 15, no. 6, pp. 435-444.

R. Bird and R. Hulstrom, (1981)"A Simplified Clear Sky Model for Direct and Diffuse Insolation on Horizontal Surfaces," Solar Energy, vol. 27, no. 5, pp. 443-449.

M. Ineichen and R. Perez, (2002) "A New airmass Independent Formulation for the Linke Turbidity Coefficient," Solar Energy, vol. 73, no. 3, pp. 151-157.

M. Reno et al., (2010) "Validation of Clear Sky Models for Satellite-Based Irradiance Estimates," Solar Energy, vol. 84, no. 9, pp. 1512-1527.

National Aeronautics and Space Administration(NASA) (www.eosweb.larc.nasa.gov/sse)

APPENDIX

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.06	3.95	4.52	5.07	5.14	2.55	3.54	1.96	3.74	2.84	5.44	5.40
4.07	5.07	3.98	4.86	2.25	6.06	4.87	3.16	4.86	2.89	5.63	5.58
4.98	4.92	4.50	3.99	6.28	4.83	4.06	3.29	3.42	4.57	4.17	5.21
4.98	5.05	4.20	5.16	5.08	4.93	4.15	3.02	3.73	4.73	4.74	5.16
4.76	5.40	5.45	5.24	4.58	4.28	3.73	2.40	4.15	4.72	2.17	5.14
4.94	5.41	3.73	5.38	4.34	3.63	3.30	3.46	3.90	4.29	4.72	5.43
5.23	5.13	5.26	5.07	4.85	3.02	4.24	4.18	4.04	4.85	5.34	5.73
5.05	4.46	4.82	5.02	3.87	3.27	3.27	3.80	4.93	5.25	5.20	5.34
5.20	4.83	5.35	4.41	5.00	4.37	3.73	4.80	3.97	4.92	4.50	5.15
4.99	4.41	4.94	5.29	4.18	4.69	4.60	4.56	4.05	4.45	4.54	5.30
5.25	3.96	4.48	5.22	5.40	4.74	4.96	4.66	3.40	3.86	3.57	3.45
5.37	3.01	5.82	5.55	5.35	4.07	4.73	3.73	5.03	4.08	4.87	3.77
4.90	5.36	5.74	4.64	4.71	4.34	3.47	4.26	4.27	4.79	4.98	4.72
4.85	5.68	5.57	4.99	3.48	4.11	4.22	4.49	4.05	4.24	5.40	4.76
4.21	4.39	5.25	5.92	5.37	4.72	4.31	4.20	4.47	4.99	5.20	4.41
4.53	4.36	4.56	5.22	5.61	4.09	2.81	4.43	3.82	4.70	5.37	4.72
4.21	4.66	5.18	5.41	6.15	3.53	2.71	4.61	4.68	4.01	4.45	4.43
5.11	4.42	4.69	3.33	5.15	3.57	3.61	3.79	4.32	2.37	4.23	4.44
5.08	5.48	4.91	5.02	5.17	5.20	4.48	3.92	4.36	2.37	4.80	4.71
5.08	4.47	4.71	3.98	4.07	5.32	4.44	4.15	3.46	6.20	4.89	4.66
5.16	4.48	4.51	4.96	5.16	4.91	3.96	2.20	4.27	5.29	6.07	5.46
4.30	5.17	4.87	3.17	5.16	2.65	3.64	1.83	4.96	4.99	5.60	4.94
4.58	4.22	4.27	5.11	5.04	4.48	2.83	3.72	3.27	4.15	5.43	5.23
4.85	3.60	4.48	4.14	5.44	4.32	2.44	4.37	4.56	4.68	5.09	5.45
5.09	3.29	4.07	4.34	6.10	4.60	2.09	3.57	3.76	2.53	4.93	5.40
4.53	3.72	5.38	3.18	4.74	5.03	3.50	3.39	2.55	3.93	4.73	4.40
5.00	4.55	3.61	5.72	5.27	4.57	4.72	4.40	3.30	4.55	4.81	4.74
4.79	4.06	4.85	3.44	4.64	3.13	3.58	4.79	2.23	3.63	4.71	5.00
4.60	4.01	4.40	5.01	4.10	4.82	3.88	2.20	4.65	4.88	6.10	5.28
3.92	4.31	5.14	4.75	5.90	4.61	2.71	3.00	3.51	2.59	5.64	4.82
4.42	4.57	6.06	4.11	5.72	4.28	2.49	2.88	2.16	4.85	4.02	5.07
5.42	4.54	4.02	4.86	5.42	3.60	4.82	3.90	3.89	4.52	3.53	5.12
5.82	4.35	5.13	4.08	4.81	4.46	1.96	3.94	4.43	3.99	4.27	3.07
5.07	4.52	4.75	4.39	5.01	4.71	3.43	4.24	3.52	4.84	5.76	3.49
5.41	3.89	4.57	4.41	4.50	2.44	2.97	4.09	2.38	4.77	4.87	4.33
4.76	4.06	4.80	5.00	1.92	4.57	3.17	4.60	3.38	4.60	5.20	4.94
4.34	3.94	4.53	4.71	5.72	3.19	4.92	4.44	3.15	4.83	4.88	5.02
5.17	4.52	4.30	4.60	5.56	3.58	3.11	3.75	4.02	4.66	5.09	5.62
5.29	4.18	4.39	5.00	5.54	5.21	4.30	2.48	2.77	4.66	5.09	5.71
5.22	4.68	4.36	5.14	5.56	5.14	4.61	3.38	4.58	4.60	4.08	5.33
5.68	4.57	5.14	4.07	4.77	4.34	1.42	4.48	3.25	5.80	5.51	5.26

5.13	**4.39**	**4.27**	**3.60**	**5.18**	**3.26**	**3.35**	**3.47**	**4.51**	**3.27**	**5.85**	**5.49**
5.62	**5.09**	**4.99**	**3.66**	**4.74**	**4.02**	**4.80**	**3.31**	**4.04**	**5.58**	**5.86**	**5.48**
5.62	**4.52**	**4.30**	**4.23**	**4.88**	**3.93**	**4.57**	**3.41**	**2.68**	**4.84**	**5.03**	**5.35**
5.58	**4.49**	**4.49**	**4.65**	**1.96**	**4.37**	**4.30**	**3.42**	**4.26**	**2.75**	**4.97**	**5.56**
5.89	**1.42**	**4.09**	**4.71**	**5.66**	**3.60**	**4.51**	**4.21**	**3.59**	**5.39**	**5.38**	**5.65**
5.71	**4.84**	**3.40**	**5.00**	**3.67**	**3.97**	**2.96**	**3.86**	**4.02**	**5.18**	**5.46**	**5.83**
5.30	**4.65**	**3.03**	**5.44**	**4.16**	**4.42**	**4.42**	**4.15**	**4.16**	**4.80**	**6.07**	**5.82**
5.09	**4.48**	**4.00**	**5.46**	**4.30**	**4.33**	**4.24**	**3.27**	**3.54**	**4.78**	**5.09**	**5.04**
4.66	**4.02**	**5.05**	**5.39**	**5.66**	**3.42**	**3.03**	**3.34**	**3.91**	**4.43**	**5.06**	**5.34**
5.09	**4.59**	**5.10**	**5.54**	**4.49**	**2.29**	**3.58**	**3.32**	**4.40**	**4.33**	**5.23**	**5.60**
4.69	**4.50**	**3.06**	**5.48**	**5.55**	**4.46**	**4.64**	**2.74**	**3.78**	**4.40**	**4.98**	**5.56**
4.98	**4.45**	**3.81**	**5.01**	**5.25**	**4.46**	**4.49**	**4.43**	**5.00**	**4.52**	**5.23**	**5.64**
4.00	**2.69**	**5.55**	**5.01**	**1.40**	**4.57**	**4.26**	**2.73**	**2.89**	**4.51**	**4.90**	**5.64**
4.63	**3.35**	**5.50**	**5.10**	**4.79**	**3.52**	**2.81**	**3.02**	**3.55**	**4.14**	**5.27**	**5.34**
4.52	**5.55**	**3.35**	**2.94**	**5.88**	**3.46**	**3.37**	**3.18**	**4.81**	**4.49**	**5.39**	**4.84**
3.57	**4.84**	**5.14**	**6.22**	**4.68**	**3.50**	**4.42**	**4.05**	**4.85**	**4.45**	**5.50**	**4.66**
3.14	**5.13**	**3.38**	**6.08**	**4.65**	**3.71**	**1.40**	**4.27**	**4.67**	**2.53**	**5.71**	**5.03**
4.16	**4.91**	**5.42**	**5.80**	**5.05**	**3.45**	**3.11**	**2.30**	**3.33**	**3.91**	**5.12**	**5.16**
4.30	**5.06**	**4.75**	**6.40**	**4.89**	**3.84**	**3.70**	**3.61**	**4.64**	**2.72**	**5.34**	**5.50**
4.51	**5.22**	**4.42**	**3.33**	**4.84**	**5.52**	**3.70**	**3.50**	**3.15**	**5.32**	**3.73**	**5.84**
4.41	**5.61**	**3.34**	**3.68**	**4.65**	**3.26**	**4.20**	**2.63**	**4.74**	**4.66**	**4.95**	**5.36**
5.30	**4.98**	**3.31**	**4.60**	**5.22**	**5.49**	**5.12**	**4.76**	**4.63**	**4.34**	**5.07**	**5.05**
5.95	**4.56**	**4.79**	**4.84**	**5.48**	**5.58**	**4.27**	**3.45**	**4.04**	**4.36**	**5.35**	**5.32**
4.68	**4.47**	**5.21**	**4.83**	**4.89**	**4.18**	**3.79**	**4.36**	**3.34**	**4.65**	**5.52**	**4.48**
5.41	**5.32**	**4.91**	**3.76**	**4.27**	**4.73**	**4.95**	**4.49**	**3.77**	**3.45**	**5.23**	**4.43**
4.54	**5.66**	**1.13**	**4.95**	**5.63**	**2.06**	**2.59**	**3.43**	**4.83**	**5.52**	**5.33**	**4.86**
5.09	**5.16**	**3.68**	**5.69**	**4.98**	**5.55**	**4.13**	**2.75**	**4.38**	**4.82**	**4.81**	**5.26**
5.40	**4.77**	**5.15**	**4.00**	**5.09**	**3.53**	**4.52**	**4.59**	**3.74**	**3.23**	**5.78**	**5.19**
5.18	**4.48**	**3.75**	**5.78**	**4.70**	**4.78**	**4.67**	**5.00**	**2.37**	**3.61**	**5.96**	**4.82**
4.98	**3.91**	**5.10**	**5.48**	**5.55**	**5.16**	**2.37**	**4.00**	**4.19**	**4.53**	**5.40**	**5.04**
4.72	**4.46**	**4.98**	**3.44**	**4.05**	**3.48**	**2.90**	**4.63**	**3.25**	**3.64**	**4.42**	**4.42**
4.92	**4.85**	**4.63**	**5.43**	**5.45**	**2.82**	**3.80**	**2.77**	**2.74**	**4.37**	**5.58**	**4.84**
5.69	**4.61**	**4.51**	**4.76**	**3.90**	**4.81**	**4.92**	**4.32**	**2.80**	**2.63**	**5.88**	**5.23**
5.27	**4.35**	**2.25**	**4.81**	**5.64**	**1.76**	**4.01**	**3.74**	**4.00**	**4.96**	**5.35**	**5.00**
5.26	**4.96**	**4.67**	**5.52**	**5.03**	**3.89**	**3.48**	**2.04**	**4.79**	**3.23**	**5.53**	**5.24**
5.19	**4.62**	**6.31**	**5.68**	**3.48**	**5.04**	**3.80**	**2.77**	**4.69**	**4.47**	**4.61**	**4.52**
5.10	**4.83**	**4.82**	**5.74**	**6.04**	**6.05**	**3.75**	**2.25**	**4.35**	**4.45**	**4.64**	**4.78**
4.59	**4.31**	**4.45**	**5.43**	**4.16**	**4.63**	**3.47**	**3.47**	**4.13**	**5.05**	**4.28**	**4.77**
4.08	**3.79**	**2.67**	**5.42**	**5.53**	**2.29**	**4.07**	**4.04**	**4.21**	**4.64**	**4.75**	**5.16**
4.42	**3.64**	**5.40**	**5.65**	**5.02**	**4.71**	**2.42**	**2.89**	**3.43**	**5.48**	**4.69**	**5.49**
5.32	**3.33**	**4.98**	**5.75**	**4.87**	**5.05**	**3.74**	**3.75**	**4.31**	**4.94**	**4.31**	**5.42**
5.58	**3.94**	**4.96**	**5.53**	**3.33**	**4.22**	**3.34**	**3.26**	**3.63**	**3.85**	**4.82**	**5.36**
2.73	**4.56**	**4.67**	**5.14**	**2.91**	**2.43**	**3.68**	**4.31**	**3.26**	**4.75**	**4.57**	**4.59**
5.39	**4.17**	**4.72**	**4.62**	**3.53**	**3.76**	**3.37**	**3.26**	**4.12**	**4.43**	**5.11**	**5.13**

5.35	**4.81**	**4.52**	**4.24**	**5.28**	**4.30**	**3.72**	**4.34**	**1.97**	**5.06**	**5.18**	**4.53**
4.73	**4.70**	**5.20**	**4.93**	**3.19**	**3.01**	**3.21**	**3.94**	**5.14**	**5.29**	**5.35**	**5.38**
4.88	**3.98**	**3.78**	**1.15**	**4.61**	**3.82**	**3.33**	**3.88**	**4.64**	**5.16**	**4.68**	**3.82**
5.54	**4.60**	**3.21**	**5.92**	**5.29**	**4.58**	**3.14**	**1.46**	**4.68**	**5.58**	**4.88**	**3.66**
5.43	**4.88**	**5.24**	**5.26**	**4.86**	**3.98**	**3.35**	**2.28**	**3.47**	**4.84**	**5.25**	**4.41**
5.36	**4.83**	**4.91**	**5.19**	**4.89**	**5.81**	**4.25**	**4.45**	**3.48**	**5.48**	**3.18**	**4.48**
5.47	**4.77**	**3.45**	**5.38**	**3.60**	**3.92**	**4.30**	**3.23**	**3.91**	**5.09**	**4.15**	**4.83**
4.89	**4.31**	**4.23**	**4.67**	**5.49**	**5.19**	**4.20**	**3.83**	**3.83**	**5.60**	**5.07**	**5.08**
5.17	**4.90**	**4.63**	**4.57**	**2.28**	**4.17**	**2.91**	**2.32**	**4.12**	**5.14**	**5.20**	**5.41**
5.38	**4.67**	**4.85**	**4.35**	**4.91**	**5.63**	**4.49**	**4.17**	**4.14**	**3.48**	**4.79**	**5.12**
5.30	**4.79**	**5.11**	**4.82**	**5.02**	**4.38**	**3.74**	**3.13**	**3.91**	**4.87**	**5.06**	**5.59**
5.03	**4.43**	**5.41**	**5.43**	**5.51**	**5.78**	**4.08**	**2.24**	**1.83**	**3.91**	**5.26**	**5.45**
5.16	**5.04**	**4.93**	**4.98**	**5.45**	**5.04**	**3.07**	**3.76**	**3.08**	**3.58**	**5.63**	**5.52**
5.05	**5.21**	**4.42**	**1.39**	**5.17**	**5.49**	**4.00**	**4.07**	**4.60**	**5.37**	**5.28**	**5.44**
4.62	**5.17**	**5.37**	**5.90**	**4.66**	**4.09**	**4.23**	**3.35**	**4.44**	**2.49**	**5.68**	**4.77**
5.08	**5.07**	**5.62**	**4.28**	**5.10**	**4.69**	**3.05**	**3.89**	**3.67**	**4.59**	**5.38**	**4.26**
5.49	**5.01**	**3.86**	**5.09**	**4.54**	**4.10**	**3.45**	**3.37**	**3.99**	**4.98**	**4.97**	**1.47**
5.01	**4.93**	**3.51**	**3.73**	**5.46**	**3.38**	**4.95**	**3.44**	**4.16**	**3.16**	**5.72**	**3.20**
5.09	**5.19**	**3.06**	**6.21**	**4.73**	**4.84**	**5.59**	**4.21**	**5.01**	**4.82**	**4.32**	**3.89**
5.21	**5.07**	**4.49**	**4.44**	**5.50**	**4.52**	**4.23**	**3.95**	**4.31**	**2.56**	**5.02**	**4.26**
4.21	**5.41**	**4.87**	**5.57**	**4.87**	**4.30**	**3.67**	**3.94**	**2.79**	**4.81**	**4.74**	**4.62**
5.29	**5.50**	**3.98**	**5.38**	**5.14**	**2.90**	**3.55**	**3.59**	**4.54**	**4.72**	**4.57**	**4.75**
5.10	**5.25**	**5.22**	**4.57**	**4.67**	**4.43**	**4.38**	**2.91**	**4.45**	**5.27**	**4.84**	**4.67**
5.37	**5.23**	**5.91**	**5.05**	**1.52**	**4.67**	**2.74**	**2.79**	**4.12**	**4.82**	**3.33**	**4.92**
4.80	**5.17**	**5.91**	**2.70**	**5.90**	**3.49**	**2.21**	**3.21**	**4.30**	**5.03**	**4.90**	**4.59**
4.75	**4.32**	**5.42**	**5.06**	**6.00**	**6.17**	**3.64**	**3.83**	**2.99**	**3.30**	**5.01**	**4.78**
4.58	**4.39**	**4.49**	**5.11**	**4.98**	**4.05**	**4.51**	**4.80**	**3.86**	**3.80**	**4.88**	**4.39**
4.11	**4.36**	**4.90**	**4.67**	**1.62**	**3.48**	**3.98**	**3.31**	**4.52**	**5.05**	**4.46**	**4.57**
4.82	**5.56**	**4.90**	**4.98**	**5.99**	**4.99**	**3.91**	**3.35**	**4.58**	**4.39**	**4.94**	**4.09**
4.03	**5.27**	**1.69**	**3.84**	**5.36**	**4.79**	**3.25**	**2.57**	**4.16**	**3.70**	**5.65**	**3.33**
4.39	**5.37**	**5.40**	**5.66**	**5.18**	**4.13**	**2.67**	**3.92**	**2.83**	**4.49**	**6.00**	**4.91**
4.86	**5.55**	**4.84**	**6.01**	**4.58**	**4.08**	**2.87**	**4.87**	**5.22**	**5.05**	**5.90**	**5.23**
5.63	**5.17**	**5.42**	**4.62**	**2.08**	**3.77**	**3.39**	**2.42**	**3.81**	**5.07**	**5.91**	**4.61**
4.53	**5.04**	**5.12**	**5.88**	**5.68**	**4.45**	**2.94**	**4.28**	**3.98**	**4.31**	**5.78**	**3.52**
4.98	**4.65**	**4.42**	**5.10**	**4.95**	**4.39**	**4.08**	**3.43**	**3.59**	**3.68**	**5.49**	**4.04**
4.40	**4.17**	**4.92**	**2.64**	**4.91**	**5.11**	**3.89**	**3.58**	**3.22**	**3.85**	**5.12**	**4.72**
4.36	**3.64**	**5.35**	**2.59**	**4.88**	**4.33**	**3.58**	**3.51**	**3.44**	**4.68**	**4.25**	**4.43**
4.21	**3.88**	**3.83**	**3.00**	**5.79**	**5.27**	**3.22**	**2.51**	**4.19**	**4.94**	**4.29**	**5.14**
3.88	**3.39**	**5.03**	**3.89**	**5.06**	**4.78**	**3.90**	**4.83**	**4.73**	**4.20**	**5.22**	**5.60**
5.12	**5.48**	**3.87**	**4.35**	**5.40**	**5.39**	**3.61**	**3.71**	**3.49**	**3.17**	**5.47**	**4.29**
4.89	**4.88**	**5.30**	**4.95**	**5.28**	**4.42**	**4.80**	**3.68**	**1.34**	**4.97**	**3.18**	**4.73**
5.07	**4.96**	**5.89**	**4.63**	**4.60**	**5.39**	**2.56**	**5.26**	**2.45**	**5.34**	**3.14**	**4.50**
5.66	**4.10**	**5.12**	**5.27**	**5.69**	**4.94**	**3.74**	**4.95**	**4.11**	**4.07**	**5.53**	**4.87**
5.90	**4.00**	**5.65**	**2.97**	**2.72**	**4.33**	**4.34**	**3.93**	**3.31**	**3.74**	**4.61**	**5.66**

5.15	**4.21**	**5.59**	**4.95**	**4.51**	**3.96**	**4.82**	**2.76**	**3.24**	**5.13**	**4.92**	**5.65**
5.05	**3.71**	**4.77**	**5.57**	**5.49**	**4.86**	**1.67**	**4.75**	**4.84**	**5.27**	**6.08**	**4.78**
5.11	**4.27**	**4.37**	**5.51**	**4.11**	**4.63**	**4.34**	**4.54**	**5.76**	**5.48**	**5.77**	**4.11**
5.12	**3.26**	**4.52**	**5.29**	**5.03**	**4.44**	**4.17**	**4.02**	**2.08**	**5.42**	**5.85**	**3.47**
4.92	**4.16**	**4.80**	**4.81**	**2.13**	**4.35**	**4.46**	**3.92**	**5.45**	**4.01**	**5.17**	**4.83**
4.76	**4.36**	**5.00**	**3.07**	**4.84**	**5.22**	**4.65**	**3.55**	**4.34**	**4.33**	**4.40**	**5.22**
5.09	**4.11**	**4.43**	**5.35**	**3.42**	**3.09**	**4.43**	**3.29**	**5.02**	**4.00**	**5.70**	**5.10**
5.06	**4.11**	**5.46**	**5.20**	**4.36**	**4.20**	**2.67**	**3.48**	**4.41**	**4.74**	**5.16**	**5.49**
5.01	**5.36**	**5.23**	**4.88**	**3.78**	**1.89**	**4.45**	**4.59**	**3.51**	**5.13**	**5.38**	**5.31**
5.36	**1.50**	**5.11**	**4.96**	**4.93**	**4.44**	**3.75**	**4.87**	**4.95**	**6.02**	**4.47**	**5.28**
5.14	**4.68**	**5.08**	**3.21**	**4.35**	**1.74**	**2.44**	**3.78**	**5.02**	**1.92**	**4.65**	**5.34**
5.13	**4.15**	**3.91**	**5.19**	**3.98**	**3.90**	**2.93**	**3.11**	**3.74**	**6.30**	**5.62**	**5.45**
5.04	**5.12**	**4.99**	**5.36**	**2.12**	**4.18**	**3.42**	**2.50**	**5.03**	**4.67**	**4.86**	**5.78**
5.29	**3.53**	**4.60**	**4.90**	**5.94**	**2.59**	**3.82**	**3.08**	**2.86**	**5.60**	**4.68**	**4.77**
4.84	**4.77**	**4.94**	**4.64**	**4.96**	**4.02**	**2.72**	**3.19**	**5.20**	**5.68**	**5.74**	**4.59**
4.92	**4.89**	**4.31**	**3.01**	**5.09**	**4.85**	**2.68**	**2.13**	**3.96**	**4.87**	**5.61**	**5.39**
5.36	**4.31**	**4.25**	**5.86**	**3.50**	**4.92**	**4.45**	**1.53**	**4.49**	**3.93**	**5.29**	**5.34**
5.55	**3.79**	**4.68**	**3.10**	**5.59**	**4.20**	**4.18**	**3.99**	**4.61**	**4.76**	**3.61**	**5.09**
5.02	**4.38**	**6.35**	**5.46**	**4.57**	**4.16**	**2.85**	**1.35**	**2.58**	**4.39**	**5.25**	**5.13**
4.68	**4.89**	**4.07**	**5.74**	**3.19**	**3.50**	**2.00**	**4.13**	**5.18**	**5.42**	**5.46**	**5.34**
5.40	**5.10**	**4.46**	**5.50**	**4.80**	**2.89**	**1.64**	**5.03**	**4.82**	**5.15**	**5.03**	**5.07**
5.32	**5.34**	**4.08**	**5.93**	**5.46**	**4.62**	**3.07**	**4.45**	**2.83**	**4.51**	**5.38**	**5.17**
5.26	**5.26**	**4.29**	**5.05**	**4.83**	**4.15**	**3.86**	**4.98**	**3.81**	**5.66**	**4.06**	**5.33**
5.31	**4.67**	**4.08**	**5.44**	**2.19**	**4.84**	**1.35**	**3.20**	**4.56**	**3.02**	**4.77**	**5.09**
5.33	**4.70**	**4.79**	**4.70**	**4.10**	**4.29**	**4.30**	**2.87**	**4.25**	**5.90**	**5.73**	**4.24**
5.65	**4.73**	**2.67**	**4.99**	**5.07**	**3.98**	**3.97**	**2.86**	**2.22**	**5.62**	**5.16**	**5.14**
5.15	**4.34**	**4.08**	**5.29**	**5.16**	**1.76**	**3.97**	**4.31**	**3.74**	**3.41**	**5.02**	**5.05**
5.38	**4.50**	**4.15**	**2.62**	**4.56**	**4.30**	**4.22**	**3.43**	**4.94**	**4.39**	**5.10**	**4.75**
5.43	**4.33**	**5.75**	**5.08**	**5.28**	**5.13**	**4.15**	**3.49**	**2.42**	**2.52**	**5.33**	**4.76**
5.35	**4.89**	**4.72**	**4.72**	**4.27**	**3.41**	**3.13**	**4.23**	**3.63**	**3.33**	**4.80**	**4.79**
5.43	**4.83**	**4.93**	**4.78**	**5.67**	**4.15**	**2.94**	**3.78**	**3.77**	**3.67**	**1.39**	**5.06**
5.70	**4.39**	**1.21**	**3.32**	**5.55**	**4.52**	**3.91**	**2.98**	**1.42**	**4.75**	**4.00**	**5.21**
4.75	**4.36**	**5.56**	**6.08**	**4.38**	**3.06**	**3.69**	**4.22**	**4.53**	**3.68**	**4.84**	**5.44**
4.55	**3.11**	**5.56**	**3.20**	**6.09**	**3.74**	**3.68**	**2.94**	**3.83**	**1.37**	**5.33**	**5.19**
4.76	**4.07**	**4.84**	**2.78**	**2.80**	**2.61**	**3.40**	**1.96**	**3.51**	**3.27**	**4.23**	**5.64**
4.73	**1.54**	**3.83**	**6.42**	**6.13**	**3.64**	**2.61**	**4.22**	**3.93**	**4.62**	**4.72**	**5.32**
4.58	**4.03**	**5.19**	**5.24**	**5.03**	**4.43**	**2.64**	**4.75**	**4.25**	**3.57**	**5.05**	**4.68**
4.30	**1.12**	**4.74**	**5.63**	**5.61**	**4.75**	**2.77**	**4.59**	**4.09**	**4.04**	**5.16**	**4.70**
4.89	**3.43**	**4.84**	**4.64**	**3.11**	**4.98**	**4.50**	**4.27**	**2.27**	**5.33**	**5.24**	**5.19**
4.02	**3.21**	**5.54**	**5.44**	**5.38**	**5.33**	**4.81**	**4.38**	**3.37**	**4.33**	**5.49**	**5.13**
4.28	**6.02**	**5.00**	**3.69**	**4.60**	**3.99**	**3.55**	**4.47**	**4.42**	**4.22**	**4.44**	**5.25**
4.23	**5.55**	**4.21**	**4.54**	**3.77**	**4.07**	**3.95**	**4.06**	**4.85**	**4.56**	**4.06**	**5.60**
4.69	**5.16**	**4.79**	**4.91**	**5.09**	**3.97**	**5.54**	**4.50**	**5.06**	**4.95**	**4.90**	**5.80**
4.76	**4.43**	**5.50**	**4.08**	**6.65**	**4.45**	**4.10**	**4.69**	**5.18**	**4.23**	**5.25**	**4.94**

4.94	**5.65**	**5.04**	**5.14**	**4.98**	**1.14**	**2.79**	**2.78**	**3.29**	**2.27**	**5.27**	**5.07**
4.42	**5.49**	**4.98**	**4.85**	**4.71**	**3.87**	**2.63**	**4.46**	**4.40**	**4.25**	**5.11**	**5.17**
4.40	**5.62**	**4.77**	**4.92**	**4.32**	**3.44**	**3.64**	**3.90**	**3.09**	**5.34**	**4.72**	**5.02**
4.66	**5.82**	**4.33**	**5.39**	**6.19**	**4.06**	**4.50**	**3.36**	**3.41**	**4.54**	**4.91**	**5.76**
4.72	**5.11**	**5.08**	**5.31**	**5.72**	**3.99**	**2.34**	**1.74**	**3.22**	**4.00**	**5.69**	**6.09**
3.34	**4.52**	**1.56**	**4.74**	**4.12**	**3.46**	**4.33**	**2.14**	**5.08**	**3.80**	**5.77**	**6.23**
5.59	**4.75**	**5.15**	**4.77**	**4.92**	**4.07**	**3.80**	**3.47**	**4.04**	**4.50**	**5.62**	**5.99**
5.49	**4.76**	**5.65**	**2.62**	**4.98**	**3.24**	**1.85**	**3.88**	**1.80**	**3.14**	**5.23**	**5.93**
4.92	**5.01**	**5.22**	**5.61**	**5.45**	**5.05**	**2.85**	**3.46**	**4.60**	**3.78**	**4.63**	**5.34**
3.81	**5.19**	**5.23**	**4.94**	**5.42**	**5.37**	**1.77**	**3.41**	**4.58**	**2.82**	**5.55**	**5.75**
3.63	**5.31**	**4.72**	**4.44**	**1.57**	**4.22**	**3.22**	**5.53**	**3.78**	**4.61**	**3.87**	**6.13**
4.51	**4.31**	**4.25**	**6.55**	**4.65**	**4.99**	**3.63**	**5.46**	**2.52**	**4.77**	**4.76**	**5.89**
5.30	**4.51**	**5.15**	**2.24**	**4.59**	**5.00**	**3.78**	**3.85**	**4.11**	**4.27**	**5.45**	**6.03**
5.66	**4.46**	**3.68**	**6.77**	**6.14**	**4.97**	**4.22**	**4.54**	**5.04**	**3.88**	**5.00**	**5.55**
5.74	**4.16**	**4.11**	**5.36**	**5.39**	**5.80**	**4.54**	**3.69**	**4.14**	**4.07**	**5.02**	**5.38**
5.83	**5.36**	**4.66**	**5.07**	**2.84**	**5.34**	**4.00**	**4.09**	**1.56**	**4.01**	**4.68**	**5.10**
5.51	**5.06**	**5.16**	**3.20**	**3.53**	**5.09**	**2.83**	**5.52**	**4.10**	**3.93**	**5.11**	**5.28**
5.08	**4.86**	**5.24**	**6.25**	**6.43**	**4.66**	**4.71**	**4.10**	**4.17**	**4.80**	**5.13**	**5.41**
5.33	**5.55**	**3.98**	**6.37**	**5.37**	**3.75**	**4.61**	**3.43**	**2.79**	**2.91**	**5.43**	**4.93**
4.72	**5.72**	**3.99**	**5.28**	**5.22**	**4.65**	**3.15**	**3.19**	**2.94**	**4.33**	**5.37**	**4.78**
5.00	**4.20**	**5.16**	**5.30**	**5.01**	**3.95**	**3.03**	**5.54**	**3.33**	**3.52**	**5.14**	**4.97**
5.38	**4.45**	**4.39**	**5.35**	**4.56**	**4.60**	**3.73**	**5.91**	**2.85**	**4.14**	**5.26**	**5.00**
4.37	**4.46**	**5.00**	**4.87**	**4.00**	**4.37**	**2.31**	**4.39**	**2.88**	**3.89**	**5.31**	**4.70**
4.56	**3.61**	**4.47**	**5.20**	**4.71**	**3.65**	**3.11**	**5.35**	**5.15**	**4.98**	**5.22**	**4.73**
4.73	**4.62**	**4.94**	**5.14**	**5.89**	**1.57**	**3.77**	**6.34**	**4.79**	**4.73**	**5.27**	**4.83**
4.91	**0.00**	**4.05**	**4.92**	**5.62**	**5.46**	**3.87**	**4.75**	**4.49**	**4.13**	**5.44**	**4.74**
5.47	**0.00**	**5.05**	**5.32**	**6.03**	**1.33**	**4.04**	**3.56**	**2.09**	**4.27**	**4.81**	**4.39**
5.59	**0.00**	**5.22**	**5.71**	**4.96**	**3.60**	**4.17**	**5.18**	**4.80**	**5.02**	**4.52**	**5.05**
5.50	**0.00**	**5.14**	**4.65**	**5.24**	**2.69**	**3.11**	**5.04**	**2.24**	**3.67**	**4.87**	**4.76**
5.55	**0.00**	**4.17**	**5.21**	**5.88**	**5.26**	**3.15**	**4.25**	**4.59**	**4.52**	**4.48**	**4.73**
5.30	**0.00**	**4.68**	**5.57**	**5.25**	**4.82**	**4.61**	**4.43**	**3.55**	**4.03**	**4.54**	**4.52**
5.09	**0.00**	**4.54**	**4.04**	**4.35**	**3.78**	**3.97**	**4.73**	**3.56**	**4.82**	**4.52**	**5.16**
5.06	**0.00**	**4.73**	**2.70**	**4.52**	**4.16**	**3.39**	**3.54**	**2.10**	**5.69**	**4.55**	**4.59**
4.75	**0.00**	**5.24**	**5.77**	**4.47**	**4.93**	**3.46**	**2.80**	**4.75**	**4.91**	**4.57**	**4.68**
5.64	**0.00**	**3.66**	**5.41**	**3.79**	**2.39**	**3.44**	**4.93**	**4.47**	**5.34**	**5.11**	**4.84**
5.44	**0.00**	**4.13**	**5.33**	**5.37**	**3.64**	**4.39**	**4.44**	**3.75**	**4.77**	**5.49**	**4.89**
6.33	**0.00**	**3.22**	**2.76**	**4.95**	**2.57**	**4.24**	**4.66**	**1.40**	**2.25**	**5.47**	**4.81**
6.09	**0.00**	**4.42**	**0.00**	**4.39**	**0.00**	**3.85**	**5.18**	**0.00**	**4.10**	**0.00**	**5.42**
5.74	**0.00**	**4.95**	**0.00**	**5.14**	**0.00**	**4.09**	**4.21**	**0.00**	**3.83**	**0.00**	**5.46**
5.68	**0.00**	**5.39**	**0.00**	**4.81**	**0.00**	**3.49**	**3.96**	**0.00**	**5.15**	**0.00**	**5.15**
5.17	**0.00**	**4.55**	**0.00**	**4.30**	**0.00**	**3.72**	**4.58**	**0.00**	**5.16**	**0.00**	**4.58**
5.00	**0.00**	**4.76**	**0.00**	**4.31**	**0.00**	**4.18**	**4.10**	**0.00**	**5.01**	**0.00**	**4.23**
5.59	**0.00**	**4.85**	**0.00**	**3.12**	**0.00**	**3.91**	**4.39**	**0.00**	**5.29**	**0.00**	**4.45**
5.69	**0.00**	**4.34**	**0.00**	**4.73**	**0.00**	**3.11**	**2.49**	**0.00**	**4.94**	**0.00**	**4.72**

Data from National Aeronautics and Space Administration(NASA)

www.eosweb.larc.nasa.gov/sse

Days	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	5.1	5.1	4.5	4.3	4.8	4.3	4.1	3.4	3.2	4.1	4.7	4.6
2	5.3	4.8	4.7	4.7	4.8	4.5	4.2	3.7	4.0	4.3	4.1	4.3
3	5.1	4.8	5.0	4.5	5.1	4.7	3.8	4.0	3.9	4.4	4.3	4.3
4	5.2	4.9	4.9	4.8	4.2	4.5	3.6	4.0	3.9	4.3	4.5	4.4
5	5.0	5.1	4.9	5.0	4.9	4.2	3.6	3.8	3.3	4.5	4.1	4.6
6	5.0	4.9	3.9	4.6	4.6	4.0	4.4	3.6	3.6	4.5	4.4	4.6
7	5.0	4.9	4.9	4.9	5.2	4.3	3.8	3.9	4.0	4.1	4.3	4.6
8	5.0	4.7	4.8	5.0	5.0	4.4	3.6	3.8	3.8	4.4	4.6	4.4
9	5.2	4.7	4.5	3.6	4.7	4.3	3.4	3.7	3.5	4.2	4.4	4.2
10	5.1	4.8	4.7	5.1	4.5	4.7	3.6	4.1	3.9	4.2	4.1	4.4
11	5.0	4.8	4.2	4.8	5.1	4.1	4.0	3.7	3.7	4.3	4.3	4.3
12	5.1	4.8	4.7	4.8	4.8	4.1	4.1	4.0	4.0	4.2	4.7	4.3
13	4.9	5.0	4.4	4.6	4.6	4.3	3.9	3.8	3.5	4.9	4.9	4.5
14	5.0	5.0	4.7	4.9	4.6	4.0	4.0	3.4	4.0	4.3	4.6	4.5
15	5.0	4.8	5.0	5.0	4.9	4.2	4.0	4.2	4.0	5.0	4.6	4.3
16	5.0	4.6	4.6	5.1	4.5	4.1	3.2	3.8	3.7	4.4	4.7	4.6
17	4.9	4.7	4.5	5.3	4.7	4.2	3.8	4.0	4.4	4.7	4.4	4.5
18	4.9	4.4	4.3	4.9	5.0	4.0	4.1	3.8	4.1	4.3	4.6	4.4
19	4.9	4.8	4.6	5.0	5.0	4.8	3.9	3.5	4.2	4.2	4.2	4.6
20	5.0	4.7	5.0	4.4	4.4	3.4	3.6	3.8	4.1	5.1	4.3	4.6
21	5.0	4.6	4.5	5.1	4.5	4.2	3.7	3.5	3.9	4.7	4.6	4.7
22	4.7	4.5	4.1	5.0	4.5	3.9	3.8	3.5	4.1	4.6	4.5	4.4
23	4.9	4.5	4.7	5.0	4.5	4.0	3.4	3.6	4.1	4.3	4.4	4.7
24	5.0	4.1	4.3	4.6	5.0	3.6	3.6	3.5	4.1	4.5	4.6	4.7
25	5.2	4.4	4.5	4.6	4.5	4.3	3.4	3.9	4.0	4.5	4.7	4.8
26	5.0	3.6	5.0	4.5	4.8	4.1	3.4	3.9	3.6	4.5	4.7	4.4
27	5.0	4.2	4.3	4.8	4.6	4.0	3.4	3.4	4.3	4.5	4.5	4.4
28	4.7	4.4	5.0	4.6	4.9	3.7	3.3	4.0	3.7	4.3	4.6	4.5
29	4.7	0.9	4.8	5.3	3.9	3.9	3.5	4.0	4.3	4.5	4.7	4.5
30	4.9	0.0	4.4	5.0	4.8	4.0	3.7	3.5	4.0	4.8	4.7	4.6
31	5.1	0.0	4.5	0.0	5.0	0.0	3.7	3.5	0.0	4.7	0.0	4.7

Daily Average Solar Insolation for each month across the specified period of (2014 -2023)