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Solar Energy Meteorology in Agriculture – an X-ray of Solar Irradiance

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ABSTRACT: This study describes the role of solar energy meteorology in agriculture. The objectives of the study are to be familiar with solar meteorological parameters, evaluate the effects of solar meteorology on agricultural productivity and determine the solar irradiance of the Ado-Ekiti. The study was carried out using secondary data sourced for book, internet and from the Atmosphere 41 All-in-One automatic weather station of the Department of Agricultural and Bio-environmental Engineering of the Federal Polytechnic, Ado-Ekiti. Global solar radiation measured between 1995 and 2005 by Estonian Meteorological and Hydrological Institute was summarized. Also, sums and average solar irradiance in Ado-Ekiti as measured in the automatic weather station of the Department of Agricultural and Bio-Environmental Engineering, the Federal Polytechnic, Ado-Ekiti were determined and 1057 KW/m^2 and 7.367 KW/m^2 values were obtained for the month of August, 2020, respectively. The study concludes that these solar irradiance values are critical in the design of solar PV systems for crop drying, irrigation system and electrification of farms towards enhancing agricultural productivity in Ado-Ekiti. The study therefore recommends that the solar irradiance should be measured for a longer period of time.

KEYWORDS: Agriculture, Automatic weather station, Solar energy meteorology, Solar irradiance, Sun.

1. INTRODUCTION

Solar energy has been given more and more attention in the recent times. It is a clean and renewable energy source. The Photovoltaic (PV) cells are attained to convert solar energy from the sunlight directly to electrical energy. This energy can be utilized in many applications, like lighting, heating and performing different devices. The sun powered cell is containing semiconductor physical which utilizing the photovoltaic impact. At the point when the daylight is opposite to exterior of the PV sun powered board, can acquire higher efficient system; therefore, maximum potential electrical energy can be established. Much experimentation has been done to boost the efficiency of the solar cell (PV Education, 2021).

Research has shown that the conventional fossil fuel is depleting at a faster rate while the cost of electrical energy is increasing due to growing consumer demand, Photovoltaic (PV) energy becomes a promising renewable alternate source. The emerging renewable energy, solar and wind are expected to play a major role in supplying at least 5-10% of total electrical energy demand worldwide. As of the second decade of the 21st Century, over 2 billion people in the developing world have no access to electricity. For these people, PV is probably the most economical and abundant power source today because it has the advantages of requiring less maintenance and air pollution free, but their installation cost is still relatively high. It is anticipated that within the next 10 years, PV solar arrays will become cost competitive with traditional power sources in countries with extensive electrical infrastructure (Saglam, 2010).

Meteorological data such as solar radiation, ambient temperature, relative humidity, wind speed, air pressure and sunshine duration are accepted as dependable and widely variable renewable energy resources. These data play a very important role in photovoltaic systems. That is why the importance of solar energy meteorology has stressed in the recent times (Renewable energy, 2021).

Solar Energy Meteorology (SEM) studies how solar radiation can be utilized for solar energy conversion to provide heat or electricity to energy systems and how the performance of these conversion processes is affected by meteorological influences. The mainly interesting properties of solar radiation in this respect are its availability in time. The main instruments of solar radiation measurement had for a long time been ground-based pyranometer, integrating the incident sunlight from the hemisphere above a planar surface to the *global irradiance*, or pyrheliometers, detecting the direct sunlight within a narrow solid angle centred around the source of radiation – the *direct beam irradiance* (Saglam, 2010; Scheidsteger and Haunschild, 2020).

The potential environmental impacts associated with solar power-land use and habitat loss, water use, and the use of hazardous materials in manufacturing can vary greatly depending on the technology, which includes two broad categories: photovoltaic (PV) solar cells or concentrating solar thermal plants (CSP).

The aim of the study is to have preliminary empirical data in respect of solar energy meteorology that would serve as input data in the design of solar systems. However, the specific objectives of the study are to be familiar with solar meteorological parameters, evaluate the effects of solar meteorology on agricultural productivity and determine the solar irradiance of the Ado-Ekiti.

The outcome of the study in respect of the solar energy parameter and the values would serve as input factor for the solar energy policy formulator, designers and installers of solar project. Hence, project failure would be reduce while ensure cost effectiveness in solar energy project execution.

2. LITERATURE REVIEW

2.1 Sun as Sources of Energy

Sun is a major source of inexhaustible free energy (i.e., solar energy) for the planet Earth. Currently, new technologies are being employed to generate electricity from harvested solar energy. Nearly four million exajoules (1 EJ=10^{18}J) of solar energy reaches the earth annually, 5 × 10^4EJ of which is claimed to be easily harvestable. Despite this huge potential and increase in awareness, the contribution of solar energy to the global energy supply is still negligible (OSU, 2011; Kabar et al., 2018).

Sun is the fundamental sources of energy**.** The temperature at the very centre of the Sun is about 27 million degrees Fahrenheit. The temperature cools down through the radiative and convective layers that make up the Sun's core. The photosphere layer is the most visible to the human eye. Here the temperature is only about 5778^{o}K. Nevertheless, the intensity of the sun radiation varies from place to place on the earth surface (NASA, 2021).

The sun has been a constant source of energy for millions of years and shall continue to be so for millions of years more. The sun's energy is produced in it by the process of thermonuclear fusion. The energy from the sun consists of electromagnetic radiation ranging from short wavelength, X-rays to long wavelength radio waves, with about 99% of it in the form of light, infrared and ultraviolet. The earth's upper atmosphere receives about 1.38 kilojoules (kJ) of energy per second per square meter. It is interesting to know that the earth receives more energy from the sun in just one hour than the world uses in a whole year (Adhikari, 2007).

The entire energy falling on the upper atmosphere does not reach the earth's surface. About 30% of this energy is reflected by the atmosphere into the space. The remaining part travels towards the earth's surface. A part of it is absorbed by water vapour, ozone, dust and carbon dioxide present in the atmosphere. Only about 47% of the incident energy reaches the earth's surface. Even then it is sufficient to end all our energy problems if we can find a way to harness it (Fondriest, 2014).

As the deposits of fossils fuels such as petroleum likely to be exhausted in short time, the crisis of energy has now become a heated topic. In these circumstances, scientists are working hard to find ways to use solar energy in more efficient ways(Stanford, 2019).

As the conventional fossil fuel is depleting at a faster rate while the cost of electrical energy is increasing due to growing consumer demand, Photovoltaic (PV) energy becomes a promising renewable alternate source. The emerging renewable energy, Solar and wind are expected to play a major role in supplying at least 5-10% of total electrical energy demand worldwide. Over 2 billion people in the developing world have no access to electricity (Saglam, 2010).

2.2 Other Source of Energy

There are various sources of energy among other things are wind, water, petroleum, coal etc. These energy sources are basically grouped into two type namely renewable and non-renewable energy. TechRepublic (2021) highlighted the growing energy source in 2021 as highlighted below.

2.2.1 Wind energy

This is another renewable energy. It is air in motion and it is direct from of energy. The motion arises from locational pressure differences caused by differential heating of earth’s surface and atmosphere by the sun (Renewable energy, 2021).

The wind energy can be used to generate electricity or the pump water through a turbine.

2.2.2 Water energy

Water energy which can be used to generate electricity where precipitation is adequate with and ideal site for location of hydro-electric power station. The power generated can be transported over long distance with aid of transformer. Also it can be used to power milling machine. Also energy form the electricity can be used generate heat for cooling and housing warming.

2.3 Solar Energy Meteorology

Solar Energy Meteorology (SEM) studies how solar radiation can be utilized for solar energy conversion to provide heat or electricity to energy systems and how the performance of these conversion processes is affected by meteorological influences. The mainly interesting properties of solar radiation in this respect are its availability in time (e.g., time of day, year) and space e.g., geographical location, angular orientation.

Meteorological data such as solar radiation, ambient temperature, relative humidity, wind speed, clearness index and sunshine duration, are accepted as dependable and widely variable renewable energy sources. It is therefore required to be able to formulate forecasting and estimation models of these meteorological data. These data play a very important role in PV systems. However, in many cases these data are not available owing to the high cost and complexity of the instrumentation needed to record them (Saglam, 2010).

The average daily solar insolation in units of kWh/m^2 per day is sometimes referred to as "peak sun hours". The term "pear sun hours" refer to the solar insolation which in a particular location would receive if the sun hour were shining at its maximum value for a certain number of hours. Since the peak solar radiation is 1 kW/m^2, the number of the sun hours is numerically identical to average daily solar insolation for example, a location that receives 9 kWh/m^2 per day can be said to have received 9 hour of the sun per day 1 kW/m^2. Being able to calculate the peak sun hours is useful because PV modules are often rated at an input rating of 1kW/m^2(PV Education, 2021).

The major fields of investigation in SEM are (1) measurements and their evaluation over different time scales and (2) modelling of radiation and its components, depending on physical (e.g., available solar radiation due to Planck's law and extinction processes in the atmosphere), geometrical (e.g., position of the sun, orientation of the converter) and meteorological (e.g., cloud coverage, aerosol concentration) parameters. Both fields also involve a large amount of statistical treatment. The main instruments of solar radiation measurement had for a long time been ground-based pyranometers, integrating the incident sunlight from the hemisphere above a planar surface to the global irradiance, or pyrheliometers, detecting the direct sunlight within a narrow solid angle centred around the source of radiation – the direct beam irradiance (Scheidsteger and Haunschild, 2020).

Fundamentals and terminology of solar engineering should be known for studying with utilization of solar energy converted from the global radiation. Global (or: total) solar radiation is the sole energy carrier for the whole nature (Scheidsteger and Haunschild, 2020).

2.4 Role of Solar Energy

In the past, technical progress was based on the use of non-renewable fuels, mostly petroleum, the reserves of which accumulated during about 70 million years, but will be exhausted in the foreseeable future, meaning within one or two generation from now; at the present growth rates.

At an annual extraction of 2.774x10^9 tons, the world's known petroleum reserves remaining in the ground and which under economic and operation conditions of 2020 are recoverable in the future, would be exhausted in exactly 27 years. Alternative energy resources must be employed on a larger scale in the future. Fortunately, man is provide with other sources of energy in tremendous quantities and it is simply a question of development to make them accessible. At this point, it is appropriate to make a rough inventory of all available world energy resources, irrespective of their geographical distribution (SPE International, 2021).

Solar energy is renewable, because the sun is an enormous 'fusion reactor' provided with such large amounts of hydrogen gas for combustion that a steady power input to the earth's surface is ensured for millions of year to come (NGS, 2012).

2.5 Solar Resource in Nigeria

Nigeria, which is located in topics, lies between 3 and 14^{o} longitude East and 4 and 14^{o} latitude north. It receives almost $16.7 \times 10^{15} kJ$ of solar energy each clears day. The minimum and maximum hours of sunshine amount to 0.1 and 9.9h respectively, and the average solar insolation is between 2217 and 6264wh/m but Solar Mate Engineering Limited (2000) puts average 3.5kwh/m/day and 5.5kwh/m/day, and 4.5kwh/m/day and 7kwh/m/day respectively.

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2.6 Solar Irradiance

Irradiance is the amount of light energy from thing hitting a square meter of another each second, while solar irradiance is the output of light energy from the entire disc of the sun per unit area receive in the form of electromagnetic energy (NASA, 2008). The different types of solar irradiance are given below.

2.6.1 Total solar irradiance (TSI)

It is a measure of the solar power over all wavelengths per unit area incident on the Earth's upper atmosphere. It is measured perpendicular to the incoming sunlight. The solar constant is a conventional measure of mean TSI at a distance of one astronomical unit (AU).

2.6.2 Direct normal irradiance (DNI)

This is the measured at the surface of the Earth at a given location with a surface element perpendicular to the Sun. It excludes diffuse solar radiation (radiation that is scattered or reflected by atmospheric components). Direct irradiance is equal to the extraterrestrial irradiance above the atmosphere minus the atmospheric losses due to absorption and scattering. Losses depend on time of day (length of light's path through the atmosphere depending on the solar elevation angle), cloud cover, moisture content and other contents. The irradiance above the atmosphere also varies with time of year (because the distance to the sun varies), although this effect is generally less significant compared to the effect of losses on DNI. It is also known as beam radiation.

2.6.3 Diffuse horizontal irradiance (DHI)

Diffuse Horizontal Irradiance or Diffuse Sky Radiation is the radiation at the Earth's surface from light scattered by the atmosphere. It is measured on a horizontal surface with radiation coming from all points in the sky excluding *circumsolar radiation* (radiation coming from the sun disk). There would be almost no DHI in the absence of atmosphere.

2.6.4 Global horizontal irradiance (GHI)

This is the total irradiance from the sun on a horizontal surface on Earth. It is the sum of direct irradiance (after accounting for the solar zenith angle of the sun *z*) and diffuse horizontal irradiance.

2.6.5 Global tilted irradiance (GTI)

It is the total radiation received on a surface with defined tilt and azimuth, fixed or sun-tracking. GTI can be measured or modelled from GHI, DNI, DHI. It is often a reference for photovoltaic power plants, while photovolotaic modules are mounted on the fixed or tracking constructions.

2.6.7 Global normal irradiance (GNI)

This is the total irradiance from the sun at the surface of Earth at a given location with a surface element perpendicular to the Sun.

3. MATERIALS AND METHODS

3.1 Materials

This study was carried out using secondary data sourced for book, internet and from the Atmosphere 41 All-in-One automatic weather station of the Department of Agricultural and Bio-environmental Engineering of the Federal Polytechnic Ado-Ekiti. The Atmosphere 41 All-in-One automatic weather station was made up of a weatherproof enclosure containing the data logger, rechargeable battery, and the meteorological sensors with an attached solar panel and mounted upon a mast.

Plate 3.1 Atmosphere 41 all-in-one weather station

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3.2 Methods

The global solar energy values that were obtained as outcome of research carried out at Estonian Metrological Institution were used in this study. The graph and tables were used to show the annual, monthly, daily and hourly sum of global solar radiation Also the solar irradiance values were measured for the month of August,2020 at the Atmosphere 41 All-in-One weather station of the Department of Agricultural and Bio-environmental Engineering were obtained . The average and sum of the solar irradiance for each day and the month of August were calculated. The results obtained were thereafter presented using simple statistical tools.

4. RESULTS AND DISCUSSION

4.1 Global sums of global radiation

Global (or total) solar radiation is the sole energy carrier for the whole nature. Section 4.1 to 4.4 below show the outcome of studies undertaken to measure solar energy.

4.1.1 Annual sums of global radiation

Annual sums of global radiation are suitable for long-term process analysis and mainstream trend development. Fig. 5 shows the set of annual global irradiance Tartu-Toravere Meteorological Station (TOR) of the Estonian Meteorological and Hydrological Institute.

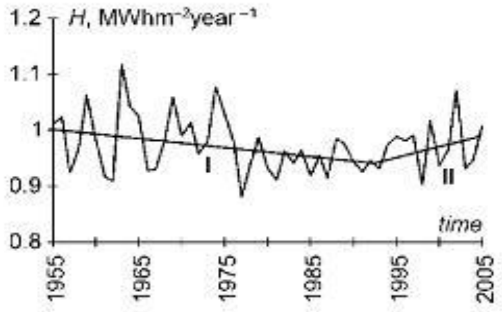

Fig. 1: A Sample graphic for annual sum of the global irradiance

4.1.2 Monthly sums of global radiation

Monthly sums of global radiation are widely used for several purposes. It is a good tool to calculate seasonal storages or analyse (seasonal, annual) efficiency of solar installations. Fig. 6 shows the time diagram of monthly sums of global radiation at Tartu-Toravere Meteorological Station (TOR) of the Estonian Meteorological and Hydrological Institute for 2003–2005, which has no trend for the selected interval.

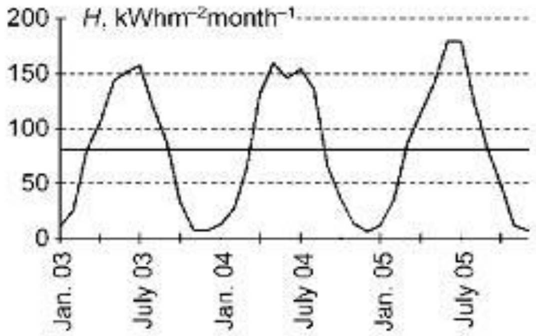

Fig. 2:A Sample graphic for monthly sum of the global irradiance

4.1.3 Daily sums of global radiation

Daily sums of radiation are the most frequently used average values. Variance of this variable has to be considered in short-time storage design used in PV systems. Fig. 7 shows the diagram of the daily sums of global irradiance in Tartu-Toravere Meteorological Station (TOR) of the Estonian Meteorological and Hydrological Institute for 2005.

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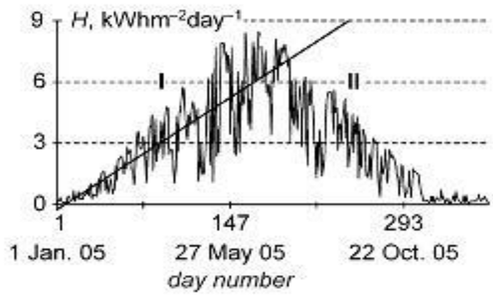

Fig. 3: A Sample graphic for daily sum of the global irradiance

4.1.4 Hourly sums of global radiation

Diurnal periodicity can be shown perfectly well at the one-hour averaging interval. Figure 10.10 presents the time diagram of global radiation between 15 and 25 May 2005 in Tartu-Toravere Meteorological Station (TOR) of the Estonian Meteorological and Hydrological Institute. In the example, successive days correlate well and this example can be classified as solar radiation "stable in general".

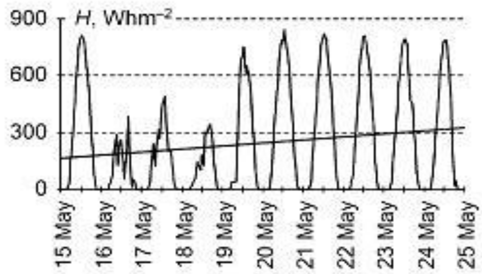

Fig. 4: A Sample graphic for hourly sum of the global irradiance

4.2 Summary of Measured Solar Irradiance

The sums and average solar irradiance in Ado-Ekiti as measured in the automatic weather station of the Department of Agricultural and Bio-Environmental Engineering, the Federal Polytechnic, Ado-Ekiti are presented in section 4.2.1 and 4.2.2 below.

4.2.1 Sums of solar irradiance

The sums of solar irradiance in Ado-Ekiti for the month of August, 2020 are presented in Figure 6.

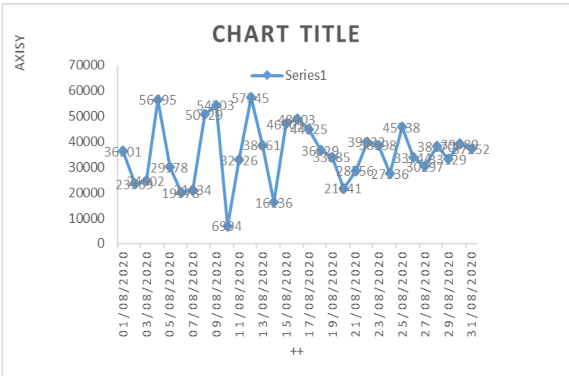

Fig. 5: Sum of solar irradiance in Ado-Ekiti

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4.2.1 Average solar irradiance

The averages of solar irradiance in Ado-Ekiti for the month of August 2020 peaked on the twelfth day of the month (Fig. 6). Also, the least average solar irradiance was recorded on the tenth day. From Fig 5 and 6, it was observed that heating of crop or operations that required energy would better be carried out on days 4, 6 and 9 of the month to achieve optimal performance from solar installations.

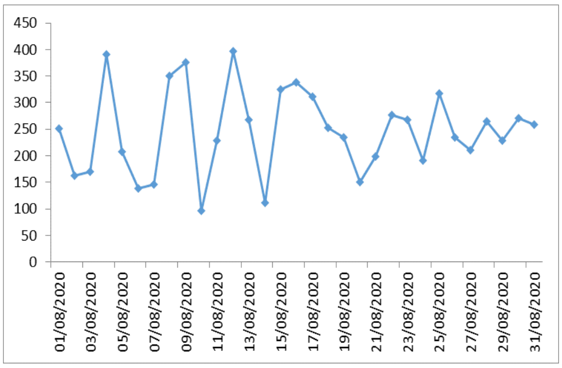

Fig. 6: Average solar irradiance in Ado-Ekiti

From the data (Table 1), the total sums of irradiance and the average solar irradiance for Ado-Ekiti were calculated and 1057KW/m^2 and 7.367 KW/m^2 values were obtained, respectively.

Table 1: August sums and average solar irradiance

DAY	AVG	SUM
8/1/2020	251	36301
8/2/2020	162	23369
8/3/2020	170	24602
8/4/2020	391	56495
8/5/2020	207	29978
8/6/2020	138	19978
8/7/2020	146	21034
8/8/2020	351	50729
8/9/2020	376	54303
8/10/2020	97	6994
8/11/2020	228	32926
8/12/2020	397	57345
8/13/2020	268	38661
8/14/2020	112	16136
8/15/2020	325	46909
8/16/2020	338	48903
8/17/2020	311	44925
8/18/2020	253	36529
8/19/2020	234	33885
8/20/2020	150	21641
8/21/2020	198	28556

8/22/2020	276	39932
8/23/2020	267	38598
8/24/2020	191	27536
8/25/2020	317	45738
8/26/2020	234	33744
8/27/2020	210	30297
8/28/2020	264	38170
8/29/2020	229	33129
8/30/2020	271	39089
8/31/2020	258	37252
TOTAL	7369	1057383

5. CONCLUSION

This study reviewed the solar energy meteorology was done. The results of the experiment carried out by Estonian Meteorological and Hydrological Institute for 2005 were summarized. Also, using the data obtained from the Atmosphere 41 All-in-One weather station of the Department of Agricultural and Bio-Environmental Engineering, 1057KW/m^2 and 7.367 KW/m^2values were obtained as the sum and average solar irradiance for the month of August, 2020, respectively. These solar irradiance values are critical in the design of solar PV systems for crop drying, irrigation system and electrification of farms towards enhancing agricultural productivity in Ado-Ekiti.

It is hereby recommended that the solar irradiance should be measured for a longer period of time.

REFERENCES

1. Adhikari, D. (2007). Solar energy as an alternative source of energy. Macmillan Publisher, Lagos, Nigeria: pp. 44 – 50.
2. Blaschke T., Biberacher M., Gadocha S., Schardinger I. (2013). Energy landscapes: meetingenergy demands and human aspirations. *Biomass- Bioenergy*x;55:3–16.
3. Fondriest (2014). Solar Radiation and Photosynethically Active Radiation. Fondriest Environmental Inc., *Fundamentals of Environmental Measurements*, https://www.fondriest.com/environmental-measurements/parameters/weather/solar-radiation/
4. IEA – International Energy Agency (2012a).⟨http://www.worldenergyoutlook.org/weo2012/⟩[Accessed March 2016].
5. IEA – International Energy Agency (2012b). 2DS-hiRen Scenario, Energy Technology Perspectives.
6. IRENA (2018). Global Energy Transformation. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Apr/IRENA_Report_GET_2018.pdf
7. Kabira, E., Kumarb, P. , Kumarc, S. , Adelodun, A. A. , Kime, K. (2018): Solar energy: Potential and future prospects, Renewable and Sustainable Energy Reviews, 82: 894 – 900.
8. NASA (2008). Solar Irradiance. Available athttps://www.nasa.gov/mission_pages/sdo/science/Solar%20Irradiance.html
9. NASA (2021): Space technology 5. https://www.jpl.nasa.gov/nmp/st5/SCIENCE/sun.html accessed 16 July 2021
10. OSU, Ohio State University (2011). The Sun: Earth's Primary Energy Source. https://beyondweather.ehe.osu.edu/issue/the-sun-and-earths-climate/the-sun-earths-primary-energy-source
11. PV Education (2021). Average solar radiation. https://www.pveducation.org/pvcdrom/properties-of-sunlight/average-solar-radiation [Accessed June 2021]
12. Saglam S. (2010). Meteorological Parameters Effects on Solar Energy PowerGeneration. *WSEAS Transactions on Circuits and Systems,* 10(9): 637 – 648.
13. Scheidsteger T. and Haunschild R. (2020). Telling the story of solar energy meteorology into the satellite era by applying (co-citation) reference publication year spectroscopy, *Scientometrics 125:1159–1177*

14. SPE International (2021). Glossary of Terms Used in Petroleum Reserves/Resources Definitions. Available at https://www.spe.org/en/industry/terms-used-petroleum-reserves-resource-definitions/
15. Stanford (2019). When Fossil Fuels Run Out, What Then?, MAHB, Stanford,https://mahb.stanford.edu/library-item/fossil-fuels-run/
16. TechRepublic (2021). 2 types of green energy projects growing in 2021: Wind and solar energy tech can help the planet. Available at https://www.techrepublic.com/article/2-types-of-green-energy-projects-growing-in-2021-wind-and-solar-energy-tech-can-help-the-planet/

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