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DATA AND MODEL TOOLS FOR ADVANCING SOLAR ENERGY TECHNOLOGY

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Abstract
Solar energy is the change of daylight into power, either specifically utilizing photovoltaics (PV), or by implication utilizing concentrated solar power (CSP). Aim of the study is to review various data and model tools for advancing solar energy technology. In this paper general introduction on solar energy was discussed, followed by the technologies of solar energy in which PV and CSP technologies were discussed. In this paper the advancement of solar energy technology in which the various area in which advancement is needed such as PV and CSP, Systems combination, soft costs and Technology to market were discussed and finally the various data and models tools for advancing solar energy technology ranging from various solar resource data to solar models and tools. From this review so far, it can inferred that various data and model tools are readily available by researchers and industrial technologist to advance solar energy to its full potential.
Key Words: Solar energy, data, model tools, photovoltaics, concentrated solar power

1. INTRODUCTION

THE utilization of renewable energy expanded incredibly soon after the principal huge oil emergency in the late seventies. Around then, monetary issues were the most vital variables, henceforth enthusiasm for such procedures diminished when oil costs fell. The present resurgence of enthusiasm for the utilization of renewable energy is driven by the need to decrease the high natural effect of fossil-based energy frameworks. Collecting energy on a huge scale is without a doubt one of the primary difficulties of our time. Future energy supportability depends intensely on how the renewable energy issue is tended to in the following couple of decades [1].

Despite the fact that in most power-creating frameworks, the principle wellspring of energy (the fuel) can be controlled, this is not valid for solar and wind energies. The primary issues with these energy sources are expense and accessibility: wind and solar power are not generally accessible where and when required. Dissimilar to customary wellsprings of electric power, these renewable sources are not dispatching the power yield can't be controlled. Seasonal and daily impacts and constrained consistency result in irregular era. Smart networks guarantee to encourage the mix of renewable energy and will give different advantages too [2].

Solar energy offers various vital advantages to the United States [3]. Supplanting fossil-fuel burning with solar energy lessens discharges of human-affected nursery gasses and air poisons. Daylight is a free asset. Therefore, once solar advances are introduced, they have low working expenses and require insignificant inputs-this gives protection against ordinary fuel supply disturbances and value unpredictability. What's more, developing the local solar energy industry could set up the United States as a worldwide pioneer in solar innovation advancement and backing a developing number of solar-related employments [4]. Aim of the study: is to

review various data and model tools for advancing solar energy technology.

2. TECHNOLOGIES OF SOLAR ENERGY

Solar power is the change of daylight into power, either specifically utilizing photovoltaics (PV), or by implication utilizing concentrated solar power (CSP). Concentrated solar power frameworks use lenses or mirrors and following frameworks to center an extensive zone of daylight into a little bar. Photovoltaics change over light into an electric current utilizing the photovoltaic impact [5].

Numerous industrialized countries have introduced critical solar power limit into their lattices to supplement or give another option to traditional energy sources while an expanding number of less created countries have swung to solar to diminish reliance on costly foreign made powers . Long separation transmission permits remote renewable energy assets to dislodge fossil fuel utilization. Solar power plants utilize one of two advances:

Photovoltaic (PV) frameworks use solar boards, either on housetops or in ground-mounted solar homesteads, changing over daylight straightforwardly into electric power.

Concentrated solar power (CSP) plants use solar warm energy to make steam that is from there on changed over into power by a turbine.

A. Photovoltaics

A solar cell, or photovoltaic cell, is a gadget that proselytes light into electric current utilizing the photovoltaic impact. The main solar cell was developed by Charles Fritts in the 1880s. The German industrialist Ernst Werner von Siemens was among the individuals who perceived the significance of this revelation [6]. In 1931, the German designer Bruno Lange built up a photograph cell utilizing silver selenide as a part of spot of copper oxide, in spite of the fact that the model selenium cells changed over less than 1% of occurrence light into power. Taking after the work of Russell Ohl in the 1940s, scientists Gerald Pearson, Calvin Fuller and Daryl Chapin made the silicon solar cell in 1954. These early solar cells cost 286 USD/watt and achieved efficiencies of 4.5–6% [6].

B. Concentrated Solar Power

Concentrated solar power, likewise called "concentrated solar warm", utilizes lenses or mirrors and following frameworks to center a substantial zone of daylight into a little shaft. As opposed to photovoltaics – which change over light straightforwardly into power – CSP utilizes the warmth of the sun's radiation to create power from ordinary steam-driven turbines [7].

An extensive variety of concentrating innovations exists: among the best known are the allegorical trough, the reduced straight Fresnel reflector, the Stirling dish and the solar power tower. Different procedures are utilized to track the sun and concentrate light. In these frameworks a working liquid is warmed by the concentrated daylight, and is then utilized for power era or energy stockpiling. Warm capacity productively permits up to 24-hour power era [8].

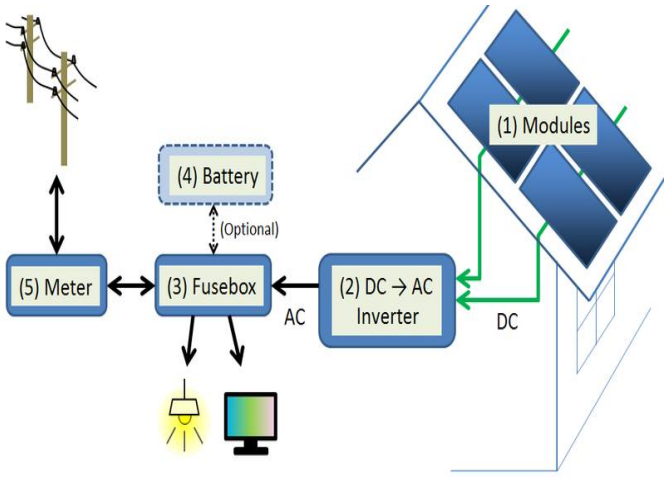

Fig. 1 Schematics of a PV power system connected to residential grid [6]

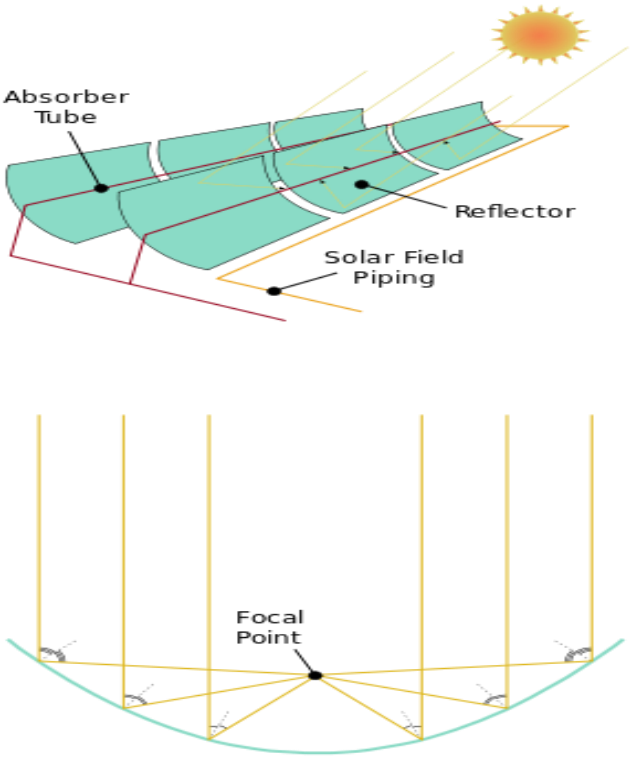

Fig. 2 A parabolic collector concentrates sunlight onto a tube in its focal point [7].

3. ADVANCEMENT OF SOLAR ENERGY TECHNOLOGIES

Since 2010 alone, the introduced cost of solar energy has dropped by as much as half. In that time, the normal cost of a photovoltaic module has dropped from $2.08/W to $0.66/Watt [9]. Examination has demonstrated that solar energy cost decreases of 40% in respect to 2015 levels could make solar power financially aggressive with customary energy sources all through the United States [10]. Further innovative and market headways are

expected to accomplish these objectives, expanding on the surprising advancement to date [11]. Work inside the territories of photovoltaics (PV), concentrating solar power (CSP), systems coordination, technology to market, and soft costs will diminish the introduced expense of solar and empower large amounts of solar energy to be incorporated into the electrical matrix. The accompanying portrays ebb and flow research, improvement, show, and sending (RDD&D) exercises, essential RDD&D opportunities going ahead, and the vital center for these sectors:

PV and CSP: Further advances in current cutting edge innovations guarantee to significantly enhance execution and decrease costs, empowering much more extensive arrangement. Transformative PV and CSP technology R&D can possibly yield significantly more noteworthy cost diminishments, productivity upgrades, and enhanced unwavering quality measures. The improvement of cutting edge PV advancements could convey development past matrix equality, and CSP innovations, including warm energy storage (TES), can give dispatchable power era and empower more prominent organization of other renewable energy (RE) sources [4].

Systems combination: Solar energy is a variable asset and in this manner requires advancements and systems that empower successful joining for abnormal amounts of infiltration to guarantee protected, dependable, cost effective, and across the board solar organization [4].

Technology to market: To guarantee a hearty marketplace, suitable methodologies for commercialization, market status, and household producing supply chains will be vital for making an element solar marketplace [4].

Soft costs: Recent innovative advances have radically lessened the expense of solar equipment, making soft costs a more prominent offer of the general expense of solar. These costs could be diminished by market straightforwardness, workforce preparing, neighborhood arrangements, and procedure changes to make solar organization speedier, less demanding, and less expensive. Further upgrades in solar equipment, for example, Building-Integrated PV or higher efficiencies, additionally lessen territory and structure-related parity of system costs [4].

Inferable from headways in these sectors, fast development has happened in the United States and worldwide marketplaces as costs have declined and request has expanded. While there have not been key changes in the solar advances accessible industrially, the efficiencies of these items have progressed relentlessly with developmental technology and assembling enhancements, adding to the watched sensational cost decreases.

4. DATA AND MODEL TOOLS FOR ADVANCING SOLAR ENERGY TECHNOLOGIES

According to National Renewable Energy Laboratory (NREL) the Renewable Resource Data Center (RReDC) offers an accumulation of data and tools to help with advancement of solar energy technology [12].

A. Solar Resource Data

The following solar resource data collections are gotten from Renewable Resource Data Center (RReDC) [13].

Cooperative Networks For Renewable Resource Measurements (CONFRRM): The CONFRRM is an agreeable exertion amongst NREL and different offices to lead long haul solar radiation and wind estimations at chose areas in the United States. CONFRRM grows the geographic scope of estimation areas and gives top notch data to deciding site-particular assets, and data for the approval and testing of models to foresee accessible assets taking

into account meteorological or satellite data [14].

The CONFRRM system supplements and gives extra geographic scope to the National Oceanic and Atmospheric Administration's (NOAA's) Integrated Surface Irradiance Study (ISIS) system [14].

Solar Radiation Monitoring Network (SRMN): SRMN worked from November 1985 through December 1996. Subsidized by the U.S. Bureau of Energy (DOE), the six-station system (areas appeared on "interactive" guide underneath) gave 5-minute found the middle value of estimations of worldwide and diffuse even solar irradiance. The data were prepared at the National Renewable Energy Laboratory (NREL) to enhance the evaluation of the solar radiation assets in the southeastern United States. Three of the stations additionally measured the immediate typical solar irradiance with a pyrheliometer mounted in an automatic sun tracker. All data are chronicled in the Standard Broadband Format (SBF) with quality-appraisal indicators. Month to month data synopses and plots are likewise accessible for every month [15].

India Solar Resource Data (ISRD): The 10-kilometer (km) hourly solar asset data were created utilizing weather satellite (METEOSAT) estimations consolidated into a site-time particular solar modeling approach created at the U.S. State University of New York at Albany. Hourly data for India, Bangladesh, Bhutan, Nepal, Sri Lanka, and parts of Pakistan and Afghanistan can be downloaded from NREL's National Solar Radiation Database (NSRDB) [16].

These maps and data were initially created in 2012 for the period from 2002 to 2007. They were overhauled in 2014 extending the period to 2011. The most recent redesign was discharged in February 2016 and incorporates data from 2002 to 2014, and consolidates upgraded vaporizers data to enhance appraisals of direct typical irradiance (DNI) [16].

Spectral Solar Radiation Data Base (SERI): SERI base was produced by The Solar Energy Research Institute (SERI), Electric Power Research Institute (EPRI), Florida Solar Energy Center (FSEC), and Pacific Gas and Electric Company (PG&E) which representing a range of atmospheric conditions (or climates) that is pertinent to a few diverse sorts of solar collectors. Data that are incorporated into the data base were gathered at FSEC from October 1986 to April 1988, and at PG&E from April 1987 to April 1988. FSEC worked one EPRI and one SERI spectroradiometer day by day at Cape Canaveral, which contributed about 2800 spectra to the data base. PG&E worked one EPRI spectroradiometer at San Ramon, Calif., as assets allowed contributing about 300 spectra to the data base. SERI gathered around 200 spectra in the Denver/Golden, Colo., territory structure November 1987 to February 1988 as a major aspect of an exploration venture to examine urban unearthly solar radiation, and added these data to the data base [17].

Solar Resource Variability: The estimation of solar radiation to portray the solar atmosphere for renewable energy and different applications is a period expending and costly operation. Full atmosphere portrayal may require quite a few years of estimations. The data sets here exhibit that the consistency of the solar asset in both time and space changes generally over the United States. The mapped results here

delineate areas with high and low variability and give fast visual data to choose where and to what extent estimations ought to be taken for a specific application. The basic data that shape these maps are additionally accessible here for site-particular examinations [18].

Lawrence Berkeley Laboratory Reduced Data Base (LBLRDB): LBLRDB contains around 200 megabytes of data, including nitty gritty power profiles of the solar and circumsolar area, the total and frightfully separated direct ordinary radiation data, and additionally the total hemispherical solar radiation in the level plane and the plane confronting the sun [19].

Data are accessible for 11 areas in the United States in the period 1976 to 1981. The estimations were made by four circumsolar telescopes working around 16 hours for every day. The Reduced Data Base speaks to around one-tenth of the total data taken by the circumsolar telescopes [19].

C. Solar Resource Models and Tools

The Renewable Resource Data Center (RReDC) features the following solar resource models and tools.

Bird Clear Sky Model (BCSM): The BCSM, created by Richard Bird, is a broadband calculation which produces evaluations of clear sky direct pillar, hemispherical diffuse, and total hemispherical solar radiation on an even surface. The Excel Spreadsheet execution was finished by Daryl Myers [20]. The model depends on correlations with results from rigourous radiative exchange codes. It is made out of basic logarithmic expressions with 10 client gave inputs. Model results ought to be required to concur inside ± 10% with rigorous radiative exchange codes. The model processes hourly normal solar radiation for each hour of the year, in view of the 10 client information parameters; however variable air parameters, for example, Aerosol Optical Depth, Ozone, Water vapor are altered for the whole year [20].

Bird Simple Spectral Model: The Bird Simple Spectral Model, created by Dr. Richard Bird and Dr. Hymn Riordan, registers clear sky phantom direct bar, hemispherical diffuse, and hemispherical total irradiances on an endorsed collector plane - tilted or level - at a solitary point in time. For tilted planes, the client indicates the rate point of the immediate bar (FORTRAN adaptation) or the tilt and azimuth of the plane (Excel@ and C variants) [21]. The wavelength dispersing is sporadic, covering 122 wavelengths from 305 nm to 4000 nm. Vaporized optical profundity, total precipitable water vapor (cm), and identical ozone profundity (cm) must be determined by the client. No varieties in air constituents or structure are accessible. There is no different calculation of circumsolar radiation. The immediate pillar ghostly irradiance is expected to contain the circumsolar radiation inside a 5° strong point. No smoothing capacities are given [22].

DISC Model: The DISC model was composed by Dr. E. Maxwell. Daryl Myers did the Excel Spreadsheet execution. The client supplies hourly normal measured worldwide level data [23]. The algorithm utilizes observational connections between the worldwide and direct clearness files (Kt, Kn) to evaluate the immediate shaft segment. Calculations depend on the solar geometry for the hour and clearness lists [24].

PVWatts Calculator: Estimates the energy generation and expense of energy of framework associated photovoltaic (PV) energy systems all through the world. It permits property holders, little building proprietors, installers and producers to effortlessly create evaluations of the execution of potential PV establishments [25].

System Advisor Model (SAM): SAM makes execution expectations and expense of energy evaluations for lattice associated power ventures in light of establishment and working costs and system outline parameters that you determine as inputs to the model. Undertakings can be either on the customer side of the utility meter, purchasing and offering power at retail rates, or on the utility side of the meter, offering power at a cost arranged through a power buy assention (PPA) [26].

The initial phase in making a SAM record is to pick a technology and financing alternative for your undertaking. SAM automatically populates information variables with an arrangement of default qualities for the sort of venture. It is your obligation as an investigator to audit and change the majority of the info data as fitting for every examination. Next, you give data around a task's area, the kind of hardware in the system, the expense of introducing and working the system, and budgetary and motivating forces suppositions [26].

Simple Model of the Atmospheric Radiative Transfer of Sunshine (SMARTS): The Simple Model of the Atmospheric Radiative Transfer of Sunshine, or SMARTS, predicts clear-sky unearthly irradiances. Earth's environment is a consistently changing channel that adjusts the daylight that goes through it. SMARTS processes how changes in the air influence the dissemination of solar power or photon energy for every wavelength of light [27].

SMARTS is an adaptable model that is utilized by scientists as a part of various fields. For instance, solar energy analysts use SMARTS to test the execution of spectroradiometers, create reference spectra, set up uniform testing conditions for materials research, enhance daylighting methods, and check broadband radiation models. Analysts likewise utilize SMARTS in the fields of design, air science, photobiology, and wellbeing material science [27].

SMARTS is an intricate model that requires critical experience and information of fundamental material science and meteorology, climatology, or environmental sciences. It is therefore utilized basically by specialists and architects [27].

Solar and Moon Position Algorithm (SAMPA): This algorithm computes the solar and lunar pinnacle and azimuth points in the period from the year - 2000 to 6000, with vulnerabilities of +/ - 0.0003 degrees for the Sun and +/ - 0.003 degrees for the Moon, taking into account the date, time, and area on Earth. The algorithm can be utilized for solar obscuration monitoring and evaluating the diminishment in solar irradiance for some applications, for example, keen matrix, solar energy, and so forth. The software has not been tried on an assortment of stages and is not ensured to deal with yours. It is given here as an accommodation [28].

Solar Position Algorithm (SPA): This algorithm computes the solar apex and azimuth edges in the period from the year - 2000 to 6000, with vulnerabilities of +/ - 0.0003 degrees taking into account the date, time, and area on Earth. (Reference: Reda, I.; Andreas, A., Solar Position Algorithm for Solar Radiation Applications, Solar Energy. Vol. 76(5), 2004; pp. 577-589). The software has not been tried on an assortment of stages and is not ensured to take a shot at yours. It is given here as an accommodation [29].

CONCLUSION

In this paper general introduction on solar energy was discussed, followed by the technologies of solar energy in which PV and CSP technologies were discussed. In this paper the advancement of solar energy technology in which the various area in which advancement is needed such as PV and CSP, Systems combination, soft costs and Technology to market were discussed

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C. REFERENCES

[1] E. F. Camacho, T. Samad, M. Garcia-Sanz, and I. Hiskens (2012). Control for Renewable Energy and Smart Grids. Retrived 4/29/2016 from http://ieeecss.org/sites/ieeecss.org/files/documents/IoCT-Part1-06RESG.pdf

[2] M. Garcia-Sanz and C.H. Houpis. Wind Energy Systems: Control Engineering Design. Boca Raton, FL: Taylor & Francis, 2011.

[3] U.S. Department of Energy (DOE). (2011). Critical Materials Strategy. http://energy.gov/sites/prod/files/DOE_CMS2011_FINAL_Full.pdf.

[4] Quadrennial Technology Review (2015), Chapter 4: Advancing Clean Electric Power Technologies. Retrieved 4/29/2016 from: http://energy.gov/sites/prod/files/2015/12/f27/QTR2015-4P-Solar-Power.pdf

[5] International Energy Agency (IEA) (2014). "Technology Roadmap: Solar Photovoltaic Energy" (PDF). *http://www.iea.org*. IEA. Archived from the original on 7 October 2014. Retrieved 7 October 2014.

[6] L. Fraas, L. Partain, Wiley, Solar Cells and their Applications Second Edition, 2010, ISBN 978-0-470-44633-1 , Section10.2.

[7] Concentrating Solar Power in 2001 – An IEA/SolarPACES Summary of Present Status and Future Prospects" (PDF). International Energy Agency – SolarPACES. Retrieved 2 July 2008.

[8] L. Julia (2008, 5 November). "What is a luminescent solar concentrator?". Science.howstuffworks.com. Retrieved 19 April 2011.

[9] D. Feldman, G. Barbose, M. Margolis, M. Bolinger, D. Chung, R. Fu, J. Seel, C. Davidson, R. Wiser (2015). Photovoltaic System Pricing Trends: Historical, Recent, and Near-Term Projections 2015 Edition. National Renewable Energy Laboratory. Golden, CO. http://www.nrel.gov/docs/fy15osti/64898.pdf.

[10] U.S. Department of Energy (DOE). (2012). SunShot Vision Study. Washington, DC: U.S. DOE.

[11] National Renewable Energy Laboratory (NREL) (2016), Solar Resource Information. Retrived 4/29/2016 from: http://www.nrel.gov/rredc/solar_resource.html

[12] National Renewable Energy Laboratory (NREL) (2016), Solar Resource data. Retrieved 4/29/2016 from: http://www.nrel.gov/rredc/solar_data.html

[13] National Renewable Energy Laboratory (NREL) (2016), Solar Radiation Monitoring Network. Retrieved 4/29/2016 from: http://rredc.nrel.gov/solar/old_data/hbcu/

[14] National Renewable Energy Laboratory (NREL) (2016), India Solar Resource Maps & Data. Retrieved 4/29/2016 from: http://www.nrel.gov/international/ra_india.html

[15] National Renewable Energy Laboratory (NREL) (2016), NREL's Spectral Solar Radiation Data Base. Retrieved 4/29/2016 from: http://rredc.nrel.gov/solar/old_data/spectral/

[16] National Renewable Energy Laboratory (NREL) (2016), Solar Resource Variability. Retrieved 4/29/2016 from: http://rredc.nrel.gov/solar/new_data/variability

[17] National Renewable Energy Laboratory (NREL) (2016), Circumsolar Radiation Data: The Lawrence Berkeley Laboratory Reduced Data Base. Retrieved 4/29/2016 from: http://rredc.nrel.gov/solar/old_data/circumsolar/

[18] R. E. Bird, and R. L. Hulstrom, *Simplified Clear Sky Model for Direct and Diffuse Insolation on Horizontal Surfaces*, Technical Report No. SERI/TR-642-761, Golden, CO: Solar Energy Research Institute, 1981.

[19] R. E. Bird, and C. Riordan, Simple Solar Spectral Model for Direct and Diffuse Irradiance on Horizontal and Tilted Planes at the Earth's Surface for Cloudless Atmospheres, Technical Report No. SERI/TR-215-2436, Golden, CO: Solar Energy Research Institute, 1984

[20] R. E. Bird, and Riordan, C. J. (1986). "Simple Simple Solar Spectral Model for Direct and Diffuse Irradiance on Horizontal and Tilted Planes at the Earth's Surface for Cloudless Atmospheres." *Journal of Climate and Applied Meteorology*. Vol. 25(1), January 1986; pp. 87-97.

[21] E. L. Maxwell, A Quasi-Physical Model for Converting Hourly Global Horizontal to Direct Normal Insolation, Technical Report No. SERI/TR-215-3087, Golden, CO: Solar Energy Research Institute, 1987.

[22] A. Skartveit, J. A. Olseth, and M.E. Tuft. *An Hourly Diffuse Fraction Model with Correction for Variability and Surface Albedo*. Solar Energy, Vol 63 #2, pp 173-183, 1998.

[23] National Renewable Energy Laboratory (NREL) (2016), PVWatts® Calculator. Retrieved 4/29/2016 from: http://pvwatts.nrel.gov/

[24] National Renewable Energy Laboratory (NREL) (2016), PVWatts® Calculator. Retrieved 4/29/2016 from: http://pvwatts.nrel.gov/

[25] National Renewable Energy Laboratory (NREL) (2016), System Advisor Model (SAM). Retrieved 4/29/2016 from: https://sam.nrel.gov/

[26] National Renewable Energy Laboratory (NREL) (2016), Simple Model of the Atmospheric Radiative Transfer of Sunshine (SMARTS). Retrieved 4/29/2016 from: http://www.nrel.gov/rredc/smarts/

[27] National Renewable Energy Laboratory (NREL) (2016), Solar and Moon Position Algorithm (SAMPA). Retrieved 4/29/2016 from: http://www.nrel.gov/midc/sampa/

[28] National Renewable Energy Laboratory (NREL) (2016), Solar and Moon Position Algorithm (SAMPA). Retrieved 4/29/2016 from: http://www.nrel.gov/midc/sampa/

[29] National Renewable Energy Laboratory (NREL) (2016), Solar Position Algorithm (SPA). Retrieved 4/29/2016 from: http://www.nrel.gov/midc/spa/