Impact of PV System Tracking on Energy Production and Climate Change

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Abstract: Green energy by PV systems reduces the dependence on fossil fuel-based power plants. Maximizing green energy to meet the demand reduces the burden on conventional power plants, hence lesser burning and greenhouse gases (GHG) emissions. For this purpose, this study draws a relationship between tracking schemes of the PV systems to GHG mitigation potential. The best fit location for detailed analyses is selected among the 15 most populous cities of Australia. The solar radiation potential is increased to 7.78 kWh/m²/d through dual axes tracking compared to 7.54, 6.82, 5.94, 5.73 kWh/m²/d through the one axis, azimuth based, fixed-tilted, and fixed-horizontal surface schemes, respectively. Through the dual axes tracking scheme, a 1 MW PV system per annum energy output avoids the burning of 796,065.3 L of gasoline, 4308.7 barrels of crude oil which is equal to the mitigation of 1852.7 tCO2 equivalent GHGs. Concisely, the PV system, through its green energy output, can avoid the release of greenhouse gases from fossil-fuel plants to tackle climate change more effectively.

Keywords: tracking schemes; PV system; GHG; climate change

1. Introduction

Man has been credited with global warming [1]. Digitalization of the world at the cost of energy production by burning fossil fuels releases greenhouse gases (GHG). GHGs trap the radiated energy received on the Earth from the Sun and leads to global warming, which results in the significant degradation of the environment, such as climate change. For reference, energy production and utilization accounts for 80% of CO2 and two-thirds of global GHG emissions [1–3]. India accounts for 7%, and the US for 15% of total global emissions [4]. However, natural factors, such as the carbon cycle, volcanic eruption, the Sun’s radiations, etc., affect the Earth’s natural balance as well. [1]. However, due to human actions, GHG concentration has constantly increased since the 1700s. GHGs has polluted air, the temperature rise in air and oceans, played a role in the depletion of the ozone layer, acid rain, global warming, i.e., frequent heat waves, floods, droughts, the risk to wildlife, scarcity of water resources, precipitation, and an 8-inch rise in sea level since 1880, while the list goes on [1,2,5]. Concisely, climate-related disasters have cost us hundreds of billions in terms of annual economic losses [5].

Digitalization based on energy needs green alternative energy resources. One of the promising solutions includes solar photovoltaic (PV) systems due to the Sun’s unlimited potential, availability, and 4–7 kWh/m²·solar radiation range across the globe on a daily average [3,6]. Earth receives 3 × 1024 joules per year of solar energy, which is much higher than human needs [7]. However, extracting energy from solar radiation through PV panels is a challenging task since it is limited to multiple factors, which include PV material, geographical constraints, temperature, pollution, humidity, wind speed, cleanliness, hotspots, and orientation angle of PV systems, etc. [3,6,8–12]. For instance, pollution, i.e., dust accommodation on PV panels, causes losses in PV system output by limiting the PV
panel’s ability to absorb radiation [12–14]. However, in the literature, there are different methods to increase the PV output, such as selection of appropriate absorbing material, Maximum power point tracking (MPPT), tracking, etc. [15–17]. MPPT extracts the maximum output from the system at a given irradiance and temperature.

Among multiple factors, the PV system output is mainly dependent upon the number of solar radiation intercepts on the PV panel surface [18], which is dependent on the incident angle of the solar radiation received on the PV panel’s surface, which is further dependent on the Earth’s movement on its both axes [8]. The Earth’s movement on both axes requires constant adjustment of the PV panel’s orientation angles to maximize the incident solar radiation intercept [8]. Maximum intercept is possible at the Cosine angle of incidence, panel’s perpendicular position to radiation. [8,18–20]. Therefore, to maximize the PV system potential, the importance of solar tracking is inevitable [4].

The continuous movement of Earth varies the solar radiation, hence PV output [19]. A solar PV system tracker follows the Sun’s movement to increase the intercept as high as possible by keeping the perpendicular angle between PV surface and incoming radiation [7,21]. Solar radiation, tilt, azimuth, inclination, declination, and zenith angle determine the optimal position of the tracking system [20]. PV panels with tracker schemes compared to fixed PV panels follow the Sun’s path to increase the solar radiation intercept [15]. The more precise the determination of optimal orientation angle, the more the yield of PV panels [3,22]. Therefore, to harvest maximum energy, there are mainly three types of trackers in terms of the degree of freedom are available, fixed surface, single-axis, and dual axes PV systems [18]. Moreover, based on the method of power supply tracking, PV systems are divided into active (require external power supply) and passive systems (do not require external power supply) [15].

In a fixed PV system, tilt, and azimuth angle play an important role by exposing the PV surface for solar radiation intercept [3,13]. Since the output depends on the Sun’s movement with respect to the PV panel location, which has no degree of freedom to follow the Sun, there is an optimal orientation angle (tilt and azimuth) with respect to yearly Sun movement and location of the PV panel [22]. In a single-axis tracking scheme, PV panels are moved from east to west or from north to south while fixing their tilt angle, freedom of only one degree [20,23]. This approach results in greater efficiency compared to the fixed surfaces [23]. And in dual axes, the tracker tracks the Sun’s movement in both directions.

Moreover, control of tracking system which requires drive trains there are mainly two approaches used, closed-loop (sensors based) and open-loop control (mathematical algorithm based) systems [15]. However, issues with the PV panels’ radiation intercept maximization are that tracking approaches are costly, and fixed approach limits PV output [21,24]. Techno-economic-based analysis of PV systems with different tracking schemes, such as two-axis tracking, vertical-axis, and horizontal axis, with different time adjustments, fixed-tilt azimuth tracking, etc., are widely discussed in the literature [25, 26].

PV systems cause environmental degradation during the manufacturing phase and produce hazardous contaminates, cause air pollution, and pollute water resources, etc. [27]. However, energy production by PV systems has no stack emissions, hence no GHG emissions. Therefore, higher the PV system output, lower burning of fossil fuels to meet the demand, and higher GHG emissions’ mitigation [3,12]. PV system carbon footprint (14–73 g CO2-eq/kWh) is up to 53 times less than emissions by burning of oil (742 g CO2-eq/kWh) [27]. PV system green energy can be increased by employing different tracking schemes, which increase the PV system GHG mitigation potential. This theoretical study follows a generic approach and draws a relationship between GHG mitigation potential, energy production, and different tracking schemes of the PV system. It presents the results of fixed-horizontal surface, fixed-tilted, one-axis tracking, azimuth tracking, and dual axes tracking after selecting a populated city of Australia among the top 15 cities based on the highest per annum average daily solar radiation potential on the fixed-horizontal surface.
The rest of the paper is structured as follows; Section II discusses the geographical location selection, Section III presents the PV system, while Section IV presents results, followed by Section V discussion, and finally, Section VI concludes the research.

2. Geographical Location Selection

Geographical locational parameters play a crucial role in PV system green energy output [21]. For this purpose, the fifteen most populous cities of Australia [28] were analyzed; geographical parameters (annual average) are provided in Table 1, which were fetched from the NASA Meteorological database and Ground through RETScreen Expert [29]. Based on the daily solar radiation average per annum on a horizontal surface, a single ideal location was selected to investigate the PV tracking scheme’s role in energy and GHG mitigation. Other geographical parameters, such as wind speed/direction, and temperature, play a role in the PV system output as well [10,11]. However, the most prominent factor is solar radiation [3,18].

Table 1. Geographical parameters of 15 most populous cities of Australia [29].

| City              | Population | Coordinates | Air Temperature (C) | Relative Humidity (%) | Precipitation (mm) | Daily Solar Radiation-Horizontal (kWh/m²/d) | Atmospheric Pressure (kPa) | Earth Temperature (C) |
|-------------------|------------|-------------|---------------------|-----------------------|--------------------|---------------------------------------------|---------------------------|----------------------|
| Sydney            | 4,778,044  | −33.8 N 151.2 E | 18                  | 68.2                  | 1005.57            | 4.54                                        | 101.6                     | 18.7                 |
| Melbourne         | 4,749,274  | −37.8 N 145.0 E | 15.5                | 64.4                  | 705.95             | 4.10                                        | 99.9                      | 13.9                 |
| Brisbane          | 2,252,122  | −27.6 N 153.0 E | 19.9                | 71.5                  | 1268.44            | 4.81                                        | 105.7                     | 21.8                 |
| Perth             | 2,159,065  | −31.9 N 116.0 E | 18.1                | 63.4                  | 676.59             | 5.22                                        | 104.9                     | 19.9                 |
| Adelaide          | 1,230,728  | −35.0 N 138.5 E | 16.3                | 63.3                  | 480.93             | 4.95                                        | 101.6                     | 16.5                 |
| Gold Coast        | 611,169    | −27.9 N 153.4 E | 20.6                | 72.7                  | 1268.44            | 4.81                                        | 100.7                     | 21.8                 |
| Canberra          | 343,835    | −35.3 N 149.2 E | 13                  | 68.1                  | 777.22             | 4.81                                        | 95                        | 12.5                 |
| Newcastle         | 336,881    | −32.9 N 151.8 E | 18.2                | 74.6                  | 1058.3             | 4.64                                        | 100.5                     | 18.5                 |
| Central Coast     | 318,109    | −33.3 N 151.6 E | 18.1                | 72.3                  | 1053.01            | 4.44                                        | 101.3                     | 19.6                 |
| Sunshine Coast    | 2,83,052   | −26.6 N 153.1 E | 20.2                | 78.5                  | 1408.97            | 5.15                                        | 101                       | 22.3                 |
| Wollongong        | 278,885    | −34.0 N 150.7 E | 16.3                | 72                    | 1077.94            | 4.47                                        | 98.6                      | 16.3                 |
| Hobart            | 185,332    | −42.9 N 147.3 E | 12.5                | 66.7                  | 882.68             | 3.71                                        | 97.8                      | 10.6                 |
| Townsville        | 180,474    | −19.3 N 146.8 E | 24.4                | 69.9                  | 960.39             | 5.73                                        | 101.2                     | 25.3                 |
| Geelong           | 172,249    | −38.2 N 144.3 E | 13.6                | 76.5                  | 732.26             | 4.17                                        | 100.6                     | 14.7                 |
| Cairns            | 156,444    | −16.9 N 145.8 E | 24.4                | 75                    | 2104.98            | 5.43                                        | 98.7                      | 24.4                 |

3. PV System

Solar panels are a green energy source that converts the recipient photons directly into electricity. The PV system can produce more energy by increasing its capacity and vice versa. However, for this research study, a 1 MW PV system was defined to increase the green energy penetration in the main grid; details are provided in Table 2.

Table 2. PV system specifications.

| PV Panels Efficiency | 19.15% |
|----------------------|--------|
| Inverter Efficiency  | 99%    |
| Temperature Coefficient | Pmax: −0.37 |
| PV Panel Life        | 30 years |

Electrical components, such as PV panels, age over time with an impact on panel efficiency and performance. Aging is defined by the electrical component manufacturers, reflected in datasheets [30]. Therefore, a proportion of loss is considered in the PV system right from the very first year due to electrical components aging and due to vicinal minute pollution accommodation on PV panels surface.
4. Results

The PV system tracking schemes’ impact was studied on RETScreen Expert developed by the Ministry of Natural Resources, Canada. It allows multiple analyses, such as GHG, financial, risk, and sensitivity, etc., of power plants, commercial, individual measures, transportation, industry, etc. More details are provided in [29]. Moreover, results were based on geographical parameters’ data provided by NASA and ground data through RETScreen Expert. Results may differ from the real-time data extracted and analyzed after the experimental setup on the specific location. However, due to the unavailability of real-time data, the NASA dataset was used, and results were produced using RETScreen Expert.

Solar radiation, i.e., photons, raises the energy level of valence electrons, and energetic electrons jump to the conduction band, which makes the current flow [7]. Therefore, the higher the solar radiation, the more load driving current. Solar radiation intercepted by PV panels varies throughout the day and with respect to season because of Earth’s movement on both axes. Therefore, different tracking schemes of PV systems and their impact on solar radiation potential, energy production, and GHG emissions in the case of fuel mix used to generate equivalent energy are provided in Table 3. Moreover, RETScreen provides an equivalent annual amount of CO2 emissions to total emissions by translating emitted gases’ global warming potential to CO2 as per IPCC standards [31].

Table 3. Solar Radiations, Energy Production, and GHG Emissions in the case of fuel mix.

| Location | -19.25 N 146.77 E |
|----------|------------------|
| Climate Zone and Elevation | Very hot—Humid, 9 m |
| Air Temperature (Annual Average) | 24.4 °C |
| Daily Solar Radiations Average (kWh/m2/d) and Energy Production Potential (kWh)—For a Single Year (1MW PV System) | |
| Month | Fixed—Horizontal. kWh/m2/d | kWh | kWh/m2/d | kWh | kWh/m2/d | kWh | kWh/m2/d | kWh |
|       | (19 tilt, 180 Azimuths) | kWh | kWh/m2/d | kWh | kWh/m2/d | kWh | kWh/m2/d | kWh |
| January | 6.33 | 152,986,777 | 5.88 | 142,469,798 | 7.19 | 174,414,805 | 7.63 | 184,973,587 | 8.04 | 194,333,267 |
| February | 6.19 | 135,131,114 | 5.97 | 130,610,437 | 6.96 | 152,145,015 | 7.40 | 161,801,694 | 7.56 | 165,051,726 |
| March | 5.78 | 140,408,545 | 5.89 | 142,717,501 | 6.68 | 161,759,061 | 7.36 | 178,336,603 | 7.37 | 178,563,674 |
| April | 5.47 | 129,607,424 | 6.02 | 141,473,612 | 6.72 | 157,833,548 | 7.74 | 181,747,214 | 7.80 | 183,090,5908 |
| May | 4.53 | 113,120,527 | 5.32 | 131,331,169 | 5.83 | 143,721,534 | 6.81 | 167,845,815 | 7.07 | 173,662,673 |
| June | 4.39 | 107,335,764 | 5.32 | 128,264,495 | 5.70 | 137,365,011 | 6.44 | 155,212,737 | 6.86 | 164,213,209 |
| July | 4.64 | 117,287,960 | 5.55 | 138,440,245 | 5.97 | 148,770,093 | 6.74 | 167,989,189 | 7.11 | 176,192,392 |
| August | 5.14 | 128,877,967 | 5.83 | 144,672,079 | 6.46 | 160,334,68 | 7.52 | 186,579,127 | 7.66 | 189,790,247 |
| September | 6.22 | 147,975,270 | 6.56 | 155,108,694 | 7.47 | 176,626,074 | 8.51 | 201,414,734 | 8.52 | 201,443,215 |
| October | 6.56 | 159,568,065 | 6.44 | 156,630,674 | 7.52 | 182,819,070 | 8.19 | 199,265,943 | 8.29 | 201,547,749 |
| November | 6.92 | 161,728,216 | 6.46 | 151,578,920 | 7.81 | 183,278,879 | 8.18 | 191,848,213 | 8.54 | 199,547,698 |
| December | 6.64 | 160,274,239 | 6.08 | 147,042,261 | 7.60 | 183,842,755 | 8.01 | 193,797,297 | 8.54 | 206,037,265 |
| Annual | 5.73 | 1,654,301,869 | 5.94 | 1,710,339,910 | 6.82 | 1,962,910,527 | 7.54 | 2,170,812,127 | 7.78 | 2,233,591,546 |
| Energy Reduced (kWh) | 579,289,678 | 523,251,639 | 520,681,019 | 62,779,418 | 0 |
| GHG Emissions—All types of fuel are used to generate equivalent energy-tons of CO2 equivalent | 1372.2159 | 1418.6986 | 1628.2017 | 180.6526 | 1852.7271 |
| GHG Reduced Potential (tCO2 eq) | 480.5112 | 434.0285 | 224.5254 | 52.0745 | 0 |
| Reduced Potential Energy and GHG (%) | 74.06 | 76.57 | 87.88 | 97.19 | 100 |
| Common Losses | Aging and Minute Pollution | |
| GHG Emission factor of Australia (excluding Transmission and Distribution) [29] | 0.823kgCO2/kWh |
| Australia Transmission and Distribution Losses [32] | 4.7796% |
| PV System Transmission and Distribution Losses [Assumed] | 4% |
Energy users dependent on the fossil fuel-based main grid to meet their energy demand emit GHG in the atmosphere at the plant level. Energy user dependence on green energy by PV system reduces the dependence and burden on conventional power plants, hence mitigation of GHGs. The PV system GHG mitigation potential increases with an increase in PV green output, which is directly dependent upon solar radiation intercept on PV panel surface, which is maximized using different tracking schemes. Equivalent cases of GHG mitigation potential for a single year are provided in Table 4, which provides information on the PV system tracking schemes’ potential. However, losses in the transmission and distribution sector for Australia were 4.7796% [32], and for the proposed PV system, 4% losses are considered.

| Equivalent Cases                  | Fixed—Horizontal | Fixed—Tilted  | Azimuth     | One Axis | Dual Axis |
|-----------------------------------|------------------|--------------|-------------|----------|----------|
| Cars and light trucks not used    | 251.3216         | 259.8349     | 298.2054    | 329.7899 | 339.3273 |
| Litres of gasoline not consumed   | 589,602.992      | 609,575.2826 | 699,592.9474| 773,690.3103| 796,065.2673|
| Barrels of crude oil not consumed | 3191.1998        | 3299.299     | 3786.5156   | 4187.5642| 4308.6677 |
| People reducing energy use by 20% | 1372.2159        | 1418.6986    | 1628.2017   | 1800.6526| 1852.7271 |
| Acres of forest absorbing carbon  | 311.8673         | 322.4315     | 370.0458    | 409.2392 | 421.0743 |
| Hectares of forest absorbing carbon| 126.2082         | 130.4834     | 149.7522    | 165.6132 | 170.4027 |
| Tons of waste recycled            | 473.1779         | 489.2064     | 561.4489    | 620.9147 | 638.8714 |

5. Discussion

The solar PV system has approximately infinite potential due to the availability of the Sun for the next hundreds of years, with no GHG emissions and no running cost. However, PV system’s potential can be maximized by exposing its surface for longer periods of time, such as by the utilization of PV tracker schemes. Trackers increase the solar radiation and PV panel’s intercept, which results in higher green energy output, hence lesser dependence on the fossil-fuel-based main grid, which is a major source of GHGs, global warming, and climate change. In addition, in the PV system literature, the active tracker’s role is discussed extensively from energy output and economic perspectives. However, a fixed-size PV system with different tracker schemes in relation to GHG mitigation potential, global warming, and climate change is somehow underestimated. Therefore, this study aimed to highlight the potential of tracking schemes on climate change and its biggest cause, GHG.

Results validated that a 1 MW PV system located in a populated city with high solar radiation potential, Townsville, Australia, had a per annum 1,654,301.9kWh energy potential at fixed- horizontally placed PV panels, which was increased to 1,710,339.9kWh by tilting the fixed PV system equivalent to location latitude and 180 azimuths. Moreover, PV green energy output was further increased by the utilization of azimuth-based tracking, one-axis tracking, and dual-axis tracking to 1,962,910.5, 2,170,812.1, and 2,233,591.5 kWh, respectively, which is equivalent to 1372.2, 1418.7, 1628.2, 1800.7, and 1852.7 tons of CO2 equivalent greenhouse gases mitigation, respectively, without any increase in PV system capacity.

6. Conclusions

Green renewable energy systems have tremendous potential. The solar PV system has the potential to phase out fossil fuel-based power generation methodologies and deal effectively with GHG emissions and climatic concerns associated with it. However, the PV system’s potential is limited to many factors involving technological, environmental,
and orientational, i.e., its proper adjustment with respect to the Sun’s movement, etc. However, PV system adjustment, i.e., tracking schemes, can improve its solar radiation intercept, energy production, and GHG mitigation potential even in the presence of technological and environmental limitations. For better understanding, a 1 MW dual-axis tracking scheme-based PV system located at Townsville has the equivalent potential to avoid 1852.7 tons CO2 per annum, which takes 421.1 acres of forest or 170.4 hectares of forest to absorb. It is equivalent to recycling 638.9 tons of waste. Tracking schemes of a PV system have the potential to mitigate GHG emissions with a direct impact on energy production. Future work involves practical justification of the PV system’s tracking impacts on energy and GHG mitigation potential and life cycle analysis of the PV system for complete direct and indirect GHG emission in all phases, materials extraction to disposal.

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**References**

1. What Are the Trends in Greenhouse Gas Emissions and Concentrations and Their Impacts on Human Health and the Environment? Available online: https://www.epa.gov/report-environment/greenhouse-gases (accessed on March 2021).
2. Mahmud, M.A.; Huda, N.; Farjana, S.H.; Lang, C. Environmental impacts of solar-photovoltaic and solar-thermal systems with life-cycle assessment. *Energies* 2018, 11, 2346.
3. Ahmed, W.; Sheikh, J.A.; Ahmad, S.; Farjana, S.H.; Mahmud, M.P. Impact of PV system orientation angle accuracy on greenhouse gases mitigation. *Case Stud. Therm. Eng.* 2021, 23, 100815.
4. Awasthi, A.; Shukla, A.K.; Manohar, S.R.M.; Dondariya, C.; Shukla, K.N.; Porwal, D.; Richhariya, G. Review on sun tracking technology in solar PV system. *Energy Rep.* 2020, 6, 392–405.
5. UN SDG Goal 13: Climate Action. Available online: https://www.sustainabledevelopmentgoals.org/gd/goal13-climate-action.html (accessed on March 2021).
6. Nadia, A.R.; Is, N.A.M.; Desa, M.K.M. Advances in solar photovoltaic tracking systems: A review. *Renew. Sustain. Energy Rev.* 2018, 82, 2548–2569.
7. Edward, A.; Dewi, T. The effectiveness of Solar Tracker Use on Solar Panels to The Output of The Generated Electricity Power. In *IOP Conference Series: Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2019; Volume 347, p. 012130.
8. Asiabapour, B.; Almusaid, Z.; Aslan, S.; Mitchell, M.; Leake, E.; Lee, H.; Fuentes, J.; Rainosek, K.; Hawkes, N.; Bland, A. Fixed versus sun tracking solar panels: An economic analysis. *Clean Technol. Environ. Policy* 2017, 19, 1195–1203.
9. Mehdi, G.; Ali, N.; Hussain, S.; Zaidi, A.A.; Shah, A.H.; Azem, M.M. Design and fabrication of automatic single axis solar tracker for solar panel. In Proceedings of the 2019 2nd International Conference on Computing, Mathematics and Engineering Technologies (iCoMET), Sukkur, Pakistan, 30–31 January 2019; pp. 1–4.
10. Vasel, A.; Iakovidis, F. The effect of wind direction on the performance of solar PV plants. *Energy Convers. Manag.* 2017, 153, 455–461.
11. Kawajiri, K.; Oozeki, T.; Genchi, Y. Effect of temperature on PV potential in the world. *Environ. Sci. Technol.* 2011, 45, 9030–9035.
12. Ahmed, W.; Sheikh, J.A.; Farjana, S.H.; Mahmud, M.A.P. Defects Impact on PV System GHG Mitigation Potential and Climate Change. *Sustainability* 2021, 13, 7793, https://doi.org/10.3390/su13147793.
13. Ullah, A.; Imran, H.; Maqsood, Z.; Butt, N.Z. Investigation of optimal tilt angles and effects of soiling on PV energy production in Pakistan. *Renew. Energy* 2019, 139, 830–843.
14. Lu, J.; Hajimirza, S. Optimizing sun-tracking angle for higher irradiance collection of PV panels using a particle-based dust accumulation model with gravity effect. *Sol. Energy* 2017, 158, 71–82.
15. Seme, S.; Srpič, G.; Kavšek, D.; Božičnik, S.; Letnik, T.; Prunseis, Z.; Štumberger, B.; Hadžiselimović, M. Dual-axis photovoltaic tracking system—Design and experimental investigation. *Energy* 2017, 139, 1267–1274.
16. Li, Z.; Cheng, Z.; Si, J.; Zhang, S.; Dong, L.; Li, S.; Gao, Y. Adaptive Power Point Tracking Control of PV System for Primary Frequency Regulation of AC Microgrid with High PV Integration. In *IEEE Transactions on Power Systems*; IEEE: Toulouse, France, 2021.
17. Eltamaly, A.M. A novel musical chairs algorithm applied for MPPT of PV systems. *Renew. Sustain. Energy Rev.* 2021, 146, 111135.
18. Abdollahpour, M.; Golzarian, M.R.; Rohani, A.; Zarchi, H.A. Development of a machine vision dual-axis solar tracking system. *Sol. Energy* 2018, 169, 136–143.
19. Racharla, S.; Rajan, K. Solar tracking system—a review. *Int. J. Sustain. Eng.* 2017, 10, 72–81.
20. Amelia, A.R.; Irwan, Y.M.; Safwati, I.; Leow, W.Z.; Mat, M.H.; Rahim, M.S.A. Technologies of solar tracking systems: A review. In *IOP Conference Series: Materials Science and Engineering*; IOP Publishing: Bristol, UK, 2020; Volume 767, p. 012052.

21. Alkaff, S.A.; Shamdasania, N.H.; Li, G.Y.; Venkiteswaran, V.K. A Study on implementation of PV Tracking for Sites proximate and Away from The Equator. *Process. Integr. Optim. Sustain.* 2019, 3, 375–382.

22. Akhlaghi, S.; Sarailoo, M.; Rezaeiahari, M.; Sangrody, H. Study of sufficient number of optimal tilt angle adjustment to maximize residential solar panels yield. In Proceedings of the 2017 IEEE Power and Energy Conference at Illinois (PECI), Champaign, IL, USA, 23–24 February 2017; pp. 1–5.

23. Batayneh, W.; Bataineh, A.; Soliman, I.; Hafees, S.A. Investigation of a single-axis discrete solar tracking system for reduced actuations and maximum energy collection. *Autom. Constr.* 2019, 98, 102–109.

24. Sharma, M.K.; Kumar, D.; Dhundhara, S.; Gaur, D.; Verma, Y.P. Optimal Tilt Angle Determination for PV Panels Using Real Time Data Acquisition. *Glob. Chall.* 2020, 4, 1900109.

25. Shabani, M.; Mahmoudimehr, J. Techno-economic role of PV tracking technology in a hybrid PV-hydroelectric standalone power system. *Appl. Energy* 2018, 212, 84–108.

26. Al Garni, H.; Awasthi, A. Techno-economic feasibility analysis of a solar PV grid-connected system with different tracking using HOMER software. In Proceedings of the 2017 IEEE International Conference on Smart Energy Grid Engineering (SEGE), Oshawa, ON, Canada, 14–17 August 2017; pp. 217–222.

27. Tawalbeh, M.; Al-Othman, A.; Kafiah, F.; Abdelsalam, E.; Almomeni, F.; Alkasrawi, M. Environmental impacts of solar photovoltaic systems: A critical review of recent progress and future outlook. *Sci. Total Environ.* 2020, 759, 143528.

28. Source: Population of Cities in Australia. 2021. Available online: https://worldpopulationreview.com/countries/cities/australia (accessed on June 2021).

29. RETScreen International. *RETScreen Software Online User Manual*; CANMET Energy Technology Centre: Varennes, QC, Canada, 2005. Available online: http://www.nrcan.gc.ca/energy/software-tools/7465 (accessed on Feb 2021).

30. mono-Si-CS3U-380MS-FG—KuDymond. Available online: https://www.energysage.com/solar-panels/canadian-solar-inc/1611/cs3u-380ms-fg/ (accessed on July 2021).

31. Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Changes in Atmospheric Constituents and in Radiative Forcing, 2013. Available online: https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter2-1.pdf (accessed on March 2021).

32. Australia—Electric Power Transmission and Distribution Losses (% of Output). Available online: https://tradingeconomics.com/australia/electric-power-transmission-and-distribution-losses-percent-of-output-wb-data.html (accessed on June 2021).