*American Journal of Energy Research, 2021, Vol. 9, No. 1, 21-29*
Available online at http://pubs.sciepub.com/ajer/9/1/3
Published by Science and Education Publishing
DOI:10.12691/ajer-9-1-3

# Analytical Study of Power Generation Using PV System for Al-Shuaiba and Al-Shuqiq Regions in Saudi Arabia

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*Received May 27, 2021; Revised July 03, 2021; Accepted July 11, 2021*

**Abstract** This paper presents an analytical study of PV power generation of two regions in Saudi Arabia. Saudi Arabia need to expand its power generation capacity to meet expected rises in electricity demand. Saudi Arabia has good future to use the solar energy more extensively because of the availability of high solar radiation, large rainless area, and long sunlight. Saudi Arabia aims to increase solar power production to meet a significant portion of potential energy demand in the country. To achieve its solar power goals, various installations and research works are being undertaken nowadays in the Saudi Arabia. Therefore, the most recent updates of the solar industry in the country are important for further research investigation. This paper explores the present state of Saudi Arabia and the potential prospects of the solar industry. It also aims to discuss the possibility of connecting the photovoltaic (PV) system with the grid, while calculating the amount of reducing carbon dioxide ($CO_2$) emissions during the production of electricity through clean energy. In this work a simulation (***PVsyst 7.1***) software program to simulate the installation of PV cells on two regions of Saudi Arabia including Al-Shuaiba and Al-Shuqiq regions. Also, the possibility of using the tracker system to track the sunshine and generate more power from PV systems was discussed.

***Keywords:*** *PV, solar, cells, renewable, Saudi Arabia*

**Cite This Article:** Abdulwahab M. Bajawi, and Ahmed M. Nahhas, "Analytical Study of Power Generation Using PV System for Al-Shuaiba and Al-Shuqiq Regions in Saudi Arabia." *American Journal of Energy Research*, vol. 9, no. 3 (2021): 21-29. doi: 10.12691/ajer-9-1-3.

## 1. Introduction

In Saudi Arabia, the electric power generating aims to raise generating capacity to 120 GW through 2032 by fast growth of the country's economy over the last decade. There is strategy being developed to supply consumption from clean resources to meet the Saudi Arabia's increasing demand for electric power with a lower consumption of oil. The highest power demand is estimated to rise by 2032 between 55 GW and 122 GW with a different of 61 GW between the project output and the demand rate. The oil consumption in Saudi Arabia should be decreased. The usage of sun energy can support the electricity generation in Saudi Arabia and reduce the oil consumption.

The region between 40°N and 40°S latitudes is considered throughout the world to be the Sunbelt, and in the middle of this belt. Saudi Arabia has a good position in the map of world (latitudes 16°& 33°N) and (longitudes 34° and 56°E), it can use this location to generate electricity from sun. Solar power potential in this area is enormous because it is solar powered at approximately 5-9 kWh/m$^2$/day [1].

Indeed, the Arabian Peninsula has an average solar radiation of approximately 2200 kWh/m$^2$ per year [2] requiring just approximately 0.1 percent of the land [3] to meet the expected demand for electricity by 2050.

Therefore, King Abdullah City for Atomic and Renewable Energy (KACARE) has developed the goal of producing 54 GW of renewable energy by 2032, the agency responsible for developing renewable energy in the country. For the medium term, 24 GW are planned by 2020 [4,5]. Figure 1 shows the different energy sources for 2032, specifically, for PV&CSP, more than 108,900,000 Dollars are to be invested for 41 GW by 2030, which is one third of the national consumption.

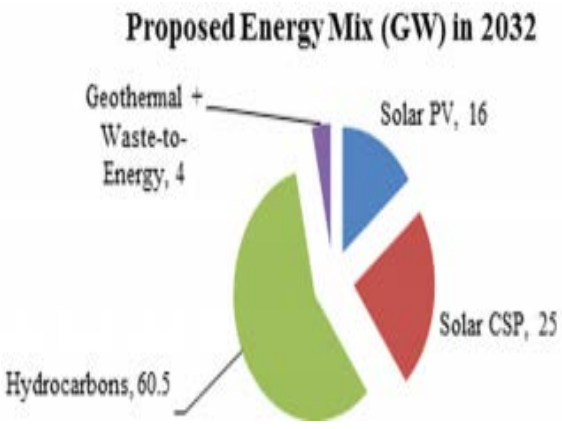



**Figure 1.** Proposed energy mix (GW) in 2032 [6]

Saudi Arabia's capability to produce, transmit and develop renewable energy sources is numerous. It ties Africa to Asia with an area of 2,150,000 $Km^2$. Saudi Arabia has a good area especially in GCC, also in Arab world it has second position of area [7]. Moreover, the economy of Saudi Arabia is growing up around 5.31%, with an average shift in real GDP.

Consequently, Saudi Arabia will be able to invest in renewable energy projects under all the geo-economic conditions.

In 2022 Saudi Arabia aims to introduce PV production with capacity of 11 GW to hit 40 GW in renewable energy by 2030. The rates of return for projects of renewable sources of energy are stepped up in capacity [8,9,10]. The experts suggest the most competitive production site for PV power can emerge in Saudi Arabia. The Institute for Energy of the European Commission has reported that 1/3 percent of light from the deserts of the GCC is adequate for Europe as a whole.

## 2. Sustainable Energy Outlook in SA

Saudi Arabia is one of Middle East Countries' most likely productive areas for solar energy production [11].

Saudi Arabia has an average of 8.89 hours of bright sunshine a day and a vast, rainless area with an average sun radiation of 5591 $Wh/m^2$ [12]. Though Saudi Arabia has the most solar capacity in the world.

Nearly 56% of national oil and 46% of national natural gas production are now consumed at homes. However, Saudi Arabia aims to produce energy from renewable resources to meet a significant part of the country's electricity demand, given the increase in global demand for oil and the impact of global warming, this number is predicted to nearly triple in the next 20 years [13]. Figure 2 shows the Sustainable energy outlook in Saudi Arabia.

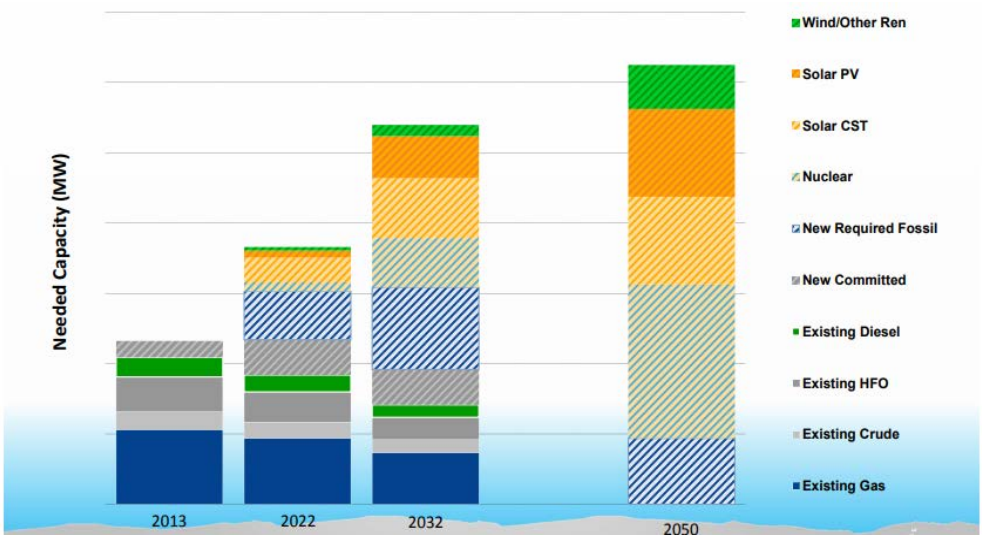



**Figure 2.** Sustainable energy outlook in Saudi Arabia [13]

## 3. Study of PV Energy Production in SA

In 2030, the expected studies indicate that the emissions will rise in Saudi Arabia, also these studies show that the emissions grow up four times between 1990 and 2015 (276%). GHG emissions per capita in Saudi Arabia is 20 tone $CO_2e$/capita which is a one of highest numbers for the G20 countries. Also, one of the highest effects on environment is the energy generation by fossil fuel [14].

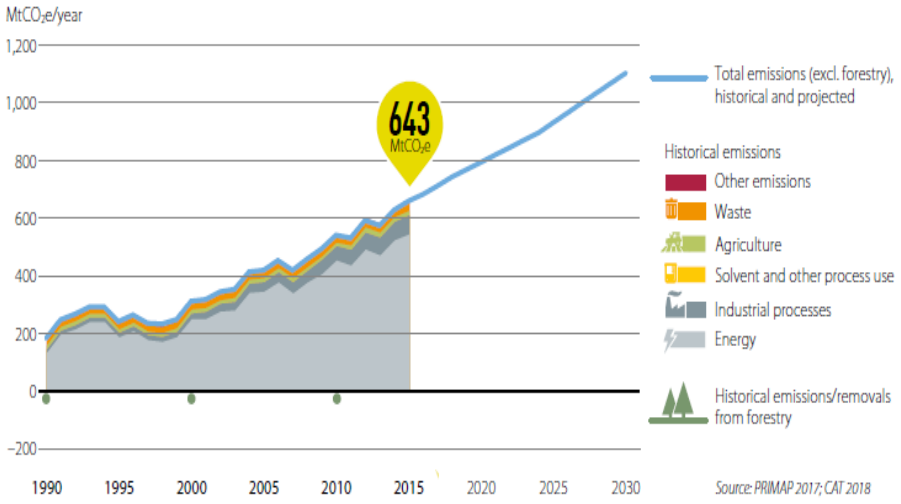



**Figure 3.** Saudi Arabia emissions [14]

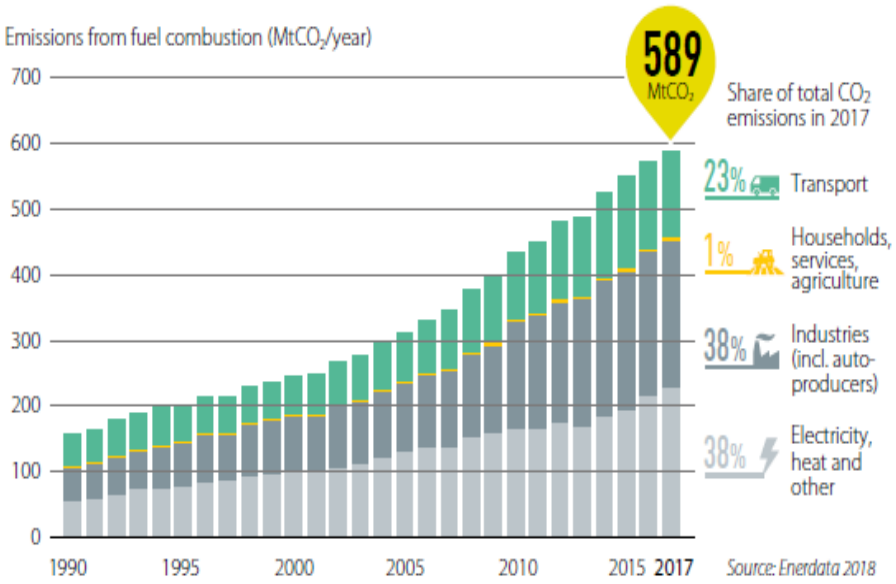



**Figure 4.** Saudi Arabia $CO_2$ emissions [14]

Saudi Arabia is working on reducing the GHG emissions, because of the bad effect on the climate. The $CO_2$ emissions which result from generating power is the largest contributor for overall GHG emissions [15]. Power generation and heat and industries are the biggest sources of emissions that grow up 22% between 2012 -2017 [14]. Figure 3 shows the Saudi Arabia emissions.

The solution of reducing the high $CO_2$ emissions is by using the PV energy. In this part the possibility of connecting the PV system with the grid is discussed. Moreover, calculating the amount of reducing $CO_2$ emissions during the production of electricity through clean energy using a simulation (***PVsyst 7.1***) program. A simulation of the installation of PV on two regions of the Saudi Arabia is discussed and presented. Also, the possibility to use the tracker system to track the sunshine and generate more power from PV systems.

## 3.2. Simulation of PV system in Saudi Arabia and results

The simulation was done on two locations which is near the power plants of Saudi Electricity Company. The reason of choosing these two locations is the ease to connect PV systems directly to the grid and with short distance of distribution lines. These two locations are in Al-Shuaiba and Al-Shuqiq. The calculations and simulation were accomplished by PVsyst 7.1 program and GLOBAL SOLAR ATLAS. Moreover, the reduction of the $CO_2$ emissions is shown. The estimated power generation for each site is 200 MWp. The first site in this study was Al-Shuaiba, the Coordinates are (Latitude 20.63°N, Longitude, 39.58°E) and Altitude is 8 m. Figure 5 shows the location map of Al-Shuaiba site [16]

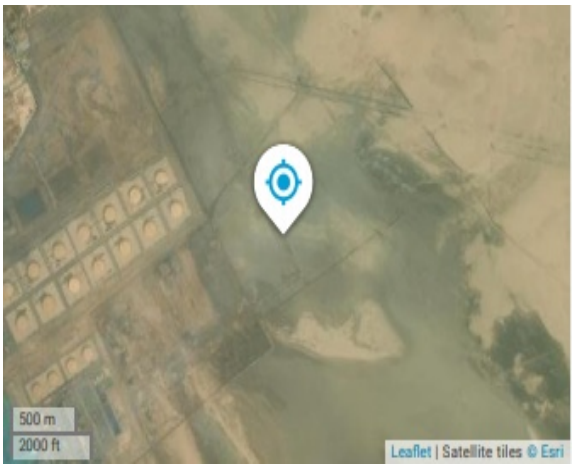



**Figure 5.** Location map of Al-Shuaiba site [16]

For Al-Shuaiba site, the best tilt angle is 21.2 degree with zero-degree Azimuth that give maximum power from PV panels. The data of sun path were collected from Metronome program, it is an unparalleled combination of reliable data and advanced calculation materials. From this data can be access to exact historical and information's for all time of year. In this system will use around (363636) PV modules with unit nominal power (550wp) that generate 200MWp, also the design connection of modules will be (25974 strings) *(14 series). Figure 6 shows the Daily input/output diagram (kwh/m2/day) & Daily system output Energy (kwh/day) of Al-Shuaiba PV project.

According of International Energy Agency (IEA) studies of $CO_2$ emission country factors, the $CO_2$ emissions saved from Al-Shuaiba project equal (234119.183) $tCO_2$ per year. The lifetime of photovoltaic system is between 25 to 30 years. For 25 years of lifetime the project can save around 5.85 million tons of $CO_2$ emissions as shown in Figure 7. Table 1 shows the total power generation of Al-Shuaiba project is 376488 MWh with performance ratio (81.8%).

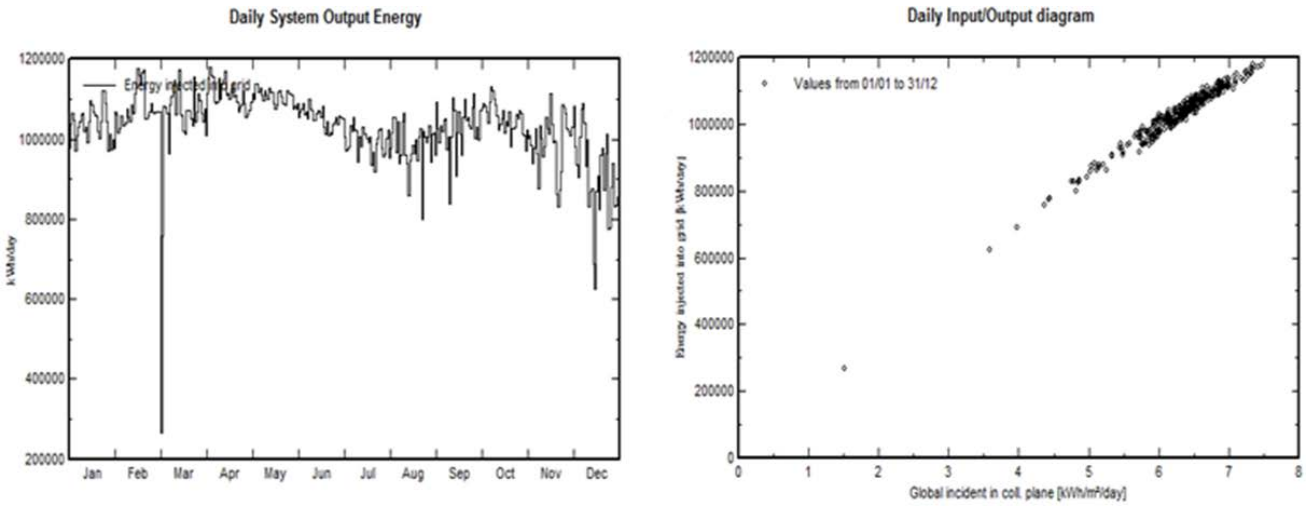


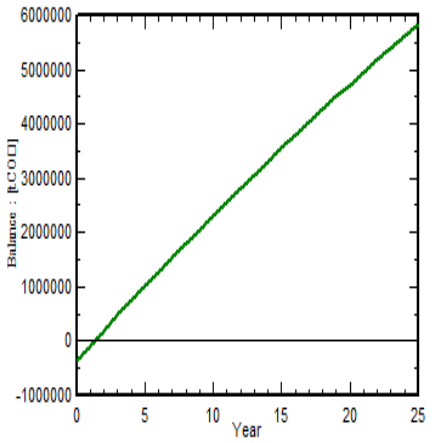

**Figure 6.** Daily input/output diagram (kwh/m$^2$/day) & Daily system output Energy (kwh/day) of Al-Shuaiba PV project

**Table 1. Total power generation of Al-Shuaiba project**

**New simulation variant**

**Balances and main results**

| | GlobHor kWh/m² | DiffHor kWh/m² | T_Amb °C | GlobInc kWh/m² | GlobEff kWh/m² | EArray MWh | E_Grid MWh | PR ratio |
|---|---|---|---|---|---|---|---|---|
| January | 150.9 | 40.0 | 22.47 | 192.5 | 190.4 | 32951 | 32138 | 0.835 |
| February | 155.5 | 54.2 | 23.84 | 183.4 | 181.0 | 30985 | 30238 | 0.824 |
| March | 180.9 | 76.1 | 26.41 | 195.0 | 192.0 | 32955 | 32166 | 0.825 |
| April | 205.7 | 76.8 | 29.41 | 205.9 | 202.7 | 34209 | 33363 | 0.810 |
| May | 228.0 | 87.4 | 32.64 | 213.3 | 209.5 | 35145 | 34283 | 0.803 |
| June | 214.1 | 99.1 | 33.61 | 195.6 | 191.9 | 32401 | 31617 | 0.808 |
| July | 205.3 | 101.6 | 35.00 | 190.3 | 186.8 | 31564 | 30803 | 0.810 |
| August | 193.4 | 102.1 | 34.71 | 188.5 | 185.4 | 31272 | 30501 | 0.809 |
| September | 181.8 | 80.6 | 32.52 | 190.2 | 187.4 | 31607 | 30836 | 0.811 |
| October | 176.7 | 64.4 | 30.64 | 201.7 | 199.2 | 33451 | 32625 | 0.809 |
| November | 144.4 | 50.5 | 27.20 | 179.0 | 176.6 | 30512 | 29779 | 0.832 |
| December | 129.8 | 51.4 | 24.48 | 165.5 | 163.2 | 28831 | 28138 | 0.850 |
| Year | 2166.4 | 884.4 | 29.44 | 2300.9 | 2266.1 | 385883 | 376488 | 0.818 |



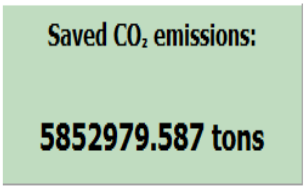




**Figure 7.** $CO_2$ emissions saved at Al-Shuaiba project

- Al-Shuaiba site with two axis tracking system.

This system will show the total energy production from the same amount or size photovoltaic farm by using the two-tracking axis of sun light and how much $CO_2$ emission saved. The best tilt and Azimuth angle for Al-Shuaiba site, the best tilt angle limits are (0/80) degree and Azimuth limits is (-120/120) degree that give maximum power from PV panels.

Figure 8 shows Daily input/output diagram (kwh/m$^2$/day) & Daily system output Energy (kwh/day) of Al-Shuaiba PV project with two axis tracking system. Table 2 shows the total power generation of Al-Shuaiba project is 473437 MWh with performance ratio (80.4%).

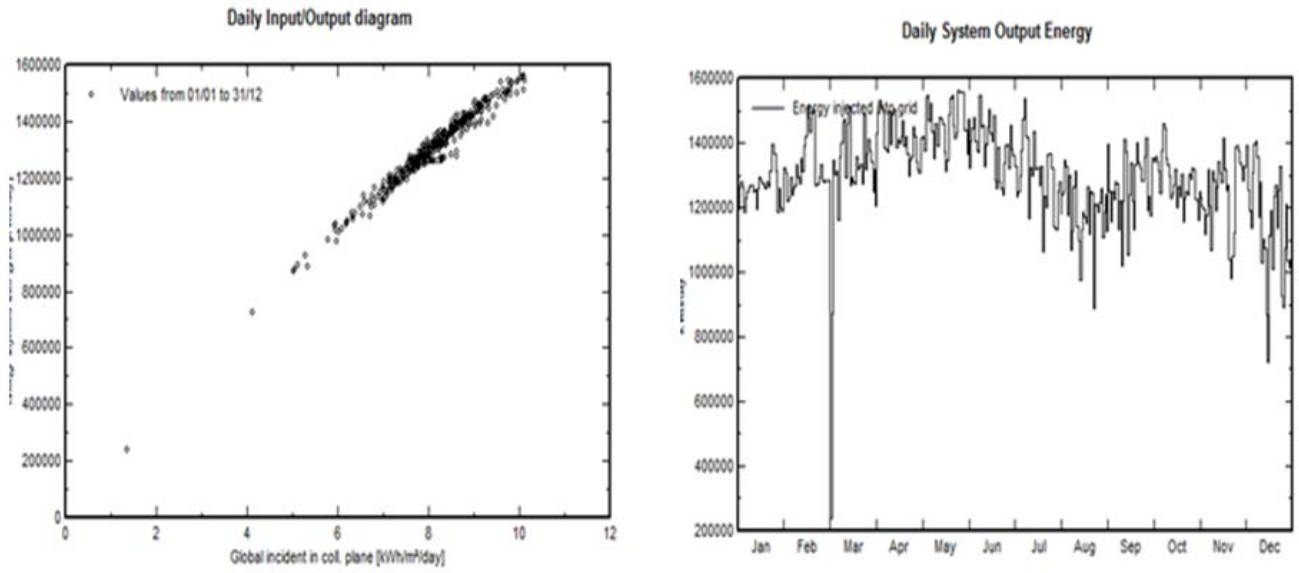


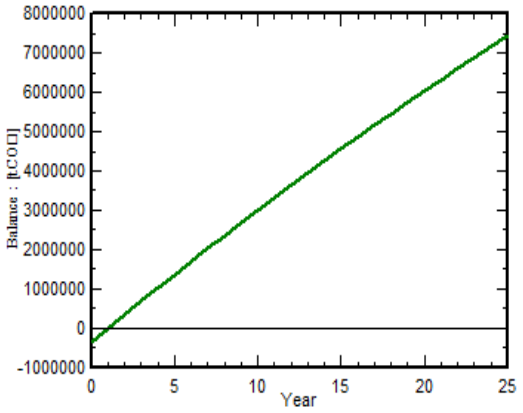

**Figure 8.** Daily input/output diagram & Daily system output Energy of Al-Shuaiba PV project

**Table 2. Total power generation of Al-Shuaiba project**

**New simulation variant**

**Balances and main results**

| | GlobHor kWh/m² | DiffHor kWh/m² | T_Amb °C | GlobInc kWh/m² | GlobEff kWh/m² | EArray kWh | E_Grid kWh | PR ratio |
|---|---|---|---|---|---|---|---|---|
| January | 150.9 | 40.0 | 22.47 | 248.7 | 247.9 | 40177467 | 39171061 | 0.787 |
| February | 155.5 | 54.2 | 23.84 | 231.8 | 230.8 | 38165242 | 37238420 | 0.803 |
| March | 180.9 | 76.1 | 26.41 | 244.4 | 243.2 | 41008930 | 40020878 | 0.819 |
| April | 205.7 | 76.8 | 29.41 | 266.2 | 265.1 | 43602228 | 42537998 | 0.799 |
| May | 228.0 | 87.4 | 32.64 | 286.9 | 285.7 | 46327556 | 45200648 | 0.788 |
| June | 214.1 | 99.1 | 33.61 | 260.6 | 259.2 | 42659759 | 41622281 | 0.799 |
| July | 205.3 | 101.6 | 35.00 | 248.7 | 247.3 | 41142481 | 40156814 | 0.807 |
| August | 193.4 | 102.1 | 34.71 | 227.7 | 226.2 | 37697913 | 36778150 | 0.808 |
| September | 181.8 | 80.6 | 32.52 | 234.1 | 232.9 | 38815219 | 37881376 | 0.809 |
| October | 176.7 | 64.4 | 30.64 | 250.3 | 249.2 | 40890584 | 39895935 | 0.797 |
| November | 144.4 | 50.5 | 27.20 | 230.7 | 229.7 | 38285413 | 37361048 | 0.810 |
| December | 129.8 | 51.4 | 24.48 | 214.4 | 213.4 | 36448248 | 35573122 | 0.830 |
| Year | 2166.4 | 884.4 | 29.44 | 2944.4 | 2930.7 | 485221041 | 473437731 | 0.804 |




**Saved $CO_2$ emissions:**

**7453421.084 tons**

**Figure 9.** $CO_2$ emissions saved from Al-Shuaiba site with two axis tracking system.

The $CO_2$ emissions saved from this project equal 298136.843 $tCO_2$ per year, and the lifetime of PV system is between 25 to 30 years. For 25 years of lifetime the project can save around 7.45 million tons of $CO_2$ emissions as shown in Figure 9.

- Al-Shuqiq site was the second location in the western coast, it is in the Jizan region. The coordinates are (Latitude 17.6339 °N, Longitude, 42.1382 °E) and Altitude is 8 m.

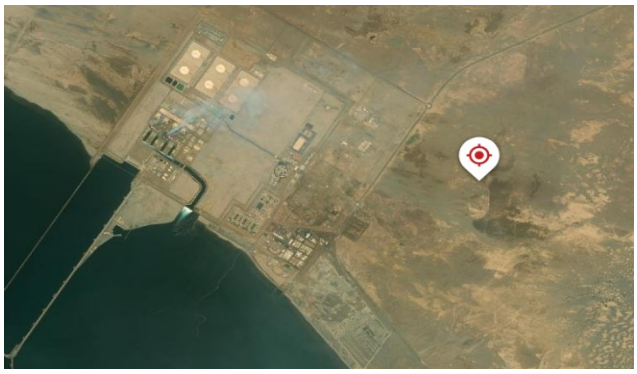


**Figure 9.** Location map of Al-Shuqiq site [16].

The best tilt and Azimuth angle for Al-Shuqiq site, the best tilt angle is 21 degrees with zero-degree Azimuth that give maximum power from PV panels. The data of sun path are collected from Metronome program, it is an unparalleled combination of reliable data and advanced calculation materials. From this data can be access to exact historical and information's for all time of year.

In this system will use around (363636) PV modules with unit nominal power (550 wp) that generate 200 MWp, also the design connection of modules will be (25974 strings) *(14 series). Figure 9 shows the daily input and output diagram, which is on x-axis is global incident coll. plan (kilowatt hour per meter square per day) and on Y-axis is energy injected into grid (kilowatt hour per day.

Table 3 shows the total power generation of Al-Shuqiq project is 387820 MWh with performance ratio (81.4%).

According of International Energy Agency (IEA) studies of $CO_2$ emission country factors, the carbon dioxide $CO_2$ emissions saved from Al-Shuqiq project equal (241600.928) $tCO_2$ per year, and the lifetime of PV system is between 25 to 30 years. For 25 years of lifetime the project can save around 6.04 million tons of $CO_2$ emissions as shown in Figure 10. The $CO_2$ emissions saved from Al-Shuqiq project is shown in Figure 11.

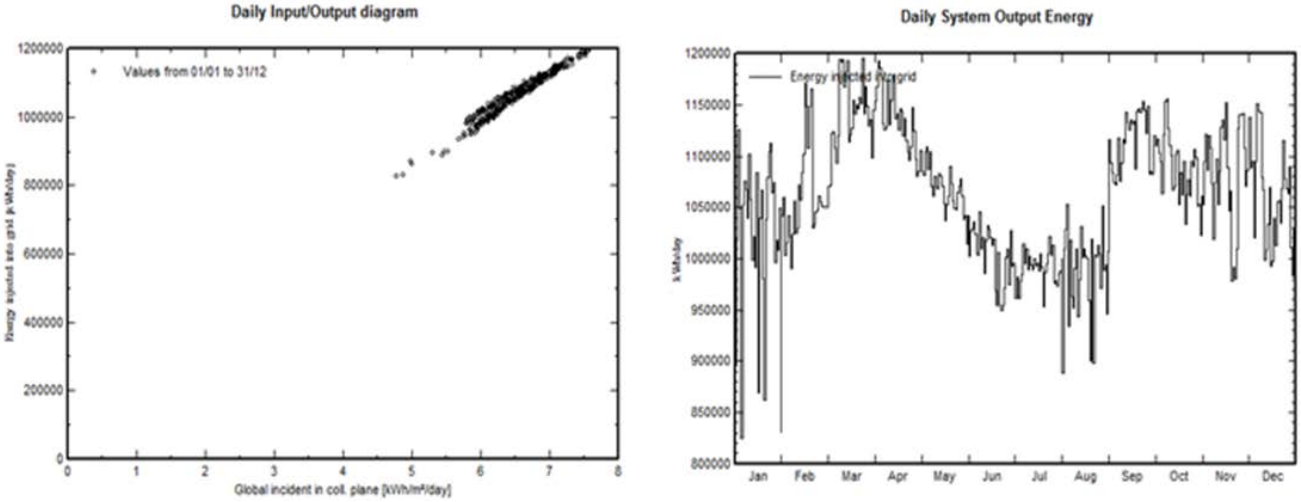



**Figure 10.** Daily input/output diagram & Daily system output Energy of Al-Shuqiq PV project

**Table 3. Total power generation of Al-Shuqiq project**

New simulation variant shuqiq

Balances and main results

| | GlobHor kWh/m² | DiffHor kWh/m² | T_Amb °C | GlobInc kWh/m² | GlobEff kWh/m² | EArray MWh | E_Grid MWh | PR ratio |
|---|---|---|---|---|---|---|---|---|
| January | 152.1 | 52.8 | 24.93 | 188.1 | 185.7 | 32385 | 31601 | 0.840 |
| February | 155.4 | 61.6 | 26.12 | 178.9 | 176.5 | 30478 | 29748 | 0.831 |
| March | 205.9 | 69.4 | 28.53 | 219.8 | 216.8 | 36292 | 35409 | 0.805 |
| April | 215.6 | 73.9 | 30.91 | 212.2 | 208.8 | 34943 | 34095 | 0.803 |
| May | 221.7 | 90.5 | 33.46 | 204.4 | 200.5 | 33903 | 33090 | 0.809 |
| June | 204.1 | 103.7 | 34.09 | 184.9 | 181.2 | 30830 | 30078 | 0.814 |
| July | 205.6 | 104.8 | 34.62 | 188.6 | 185.0 | 31476 | 30710 | 0.814 |
| August | 194.9 | 105.7 | 33.81 | 187.5 | 184.4 | 31327 | 30570 | 0.815 |
| September | 202.1 | 74.1 | 32.37 | 209.1 | 206.2 | 34288 | 33451 | 0.800 |
| October | 186.6 | 67.0 | 30.96 | 209.1 | 206.6 | 34569 | 33710 | 0.806 |
| November | 163.2 | 44.1 | 28.28 | 199.5 | 197.2 | 33303 | 32495 | 0.814 |
| December | 155.5 | 40.9 | 26.14 | 198.6 | 196.3 | 33675 | 32864 | 0.827 |
| Year | 2262.6 | 888.6 | 30.37 | 2380.8 | 2345.2 | 397468 | 387820 | 0.814 |

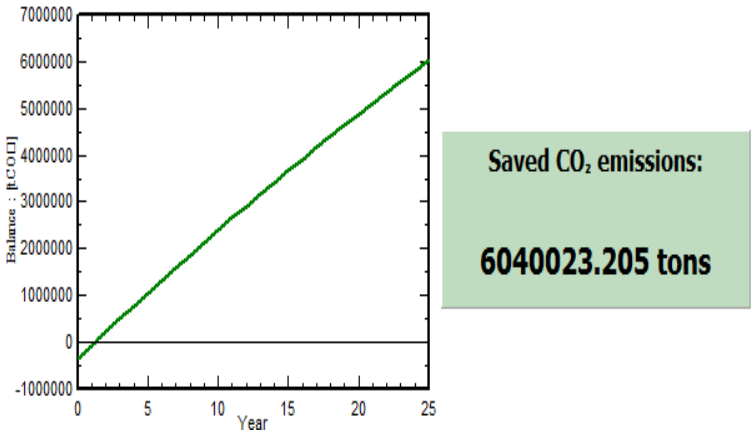



**Figure 11.** $CO_2$ emissions saved from Al-Shuqiq project

- Al-Shuqiq site with two axis tracking system.

This system will show the total energy production from the same amount or size PV System using the two-tracking axis of sun light and how much $CO_2$ emission saved. Figure 12 shows the best tilt and Azimuth angle for Al-Shuqiq site, the best tilt angle limits is (0/80) degree and Azimuth limits is (-120/120) degree that give maximum power from PV panels. Figure 13 shows the reference incident energy in collector plane of Al-Shuqiq site with two axis tracking system.

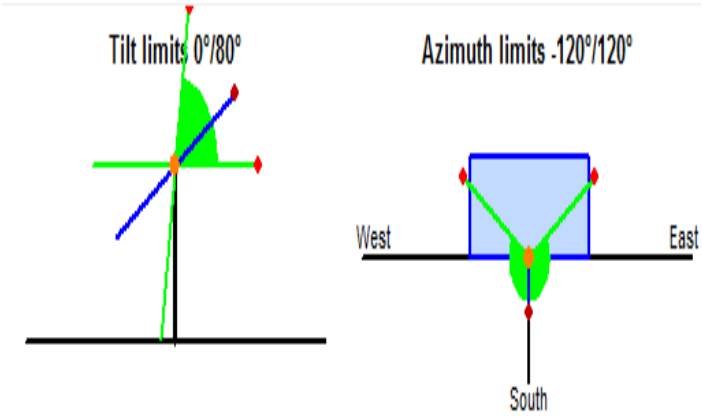



**Figure 12.** Tilt angle limits degree and Azimuth limits.

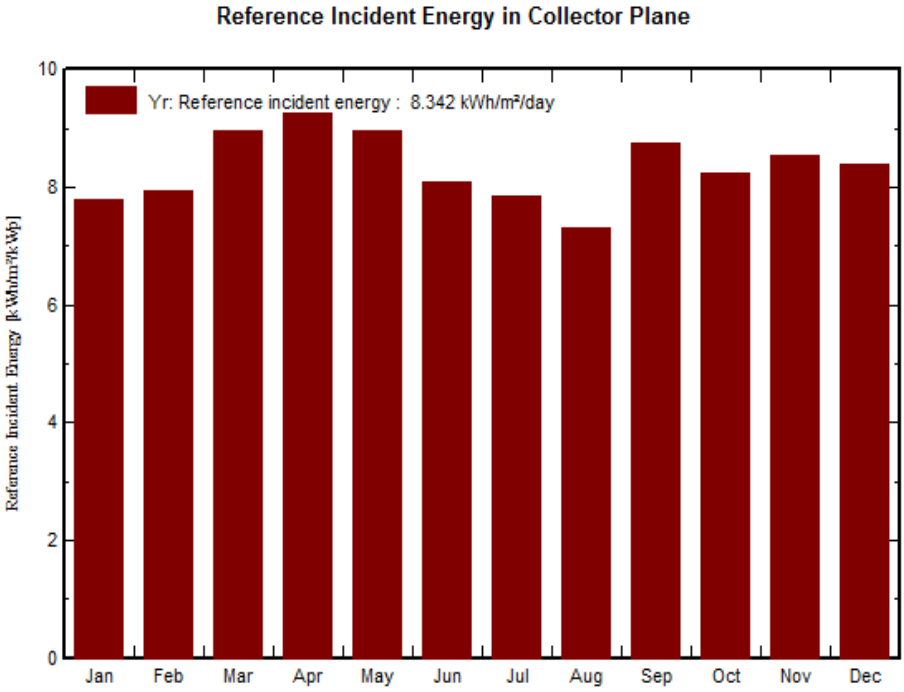



**Figure 13.** Reference energy in collector plane

**Table 4. Total power generation of Al-Shuqiq project**

New simulation variant shuqiq

Balances and main results

| | GlobHor kWh/m² | DiffHor kWh/m² | T_Amb °C | GlobInc kWh/m² | GlobEff kWh/m² | EArray kWh | E_Grid kWh | PR ratio |
|---|---|---|---|---|---|---|---|---|
| January | 152.1 | 52.8 | 24.93 | 241.7 | 240.7 | 40519796 | 39534002 | 0.818 |
| February | 155.4 | 61.6 | 26.12 | 222.7 | 221.7 | 37498423 | 36596931 | 0.822 |
| March | 205.9 | 69.4 | 28.53 | 277.5 | 276.4 | 45100647 | 44007490 | 0.793 |
| April | 215.6 | 73.9 | 30.91 | 278.1 | 277.1 | 44950379 | 43853037 | 0.788 |
| May | 221.7 | 90.5 | 33.46 | 277.7 | 276.4 | 45380767 | 44289688 | 0.798 |
| June | 204.1 | 103.7 | 34.09 | 242.5 | 241.0 | 40039436 | 39080867 | 0.806 |
| July | 205.6 | 104.8 | 34.62 | 243.7 | 242.3 | 40463935 | 39497710 | 0.810 |
| August | 194.9 | 105.7 | 33.81 | 226.9 | 225.4 | 37791551 | 36886481 | 0.813 |
| September | 202.1 | 74.1 | 32.37 | 262.6 | 261.6 | 42522905 | 41476551 | 0.790 |
| October | 186.6 | 67.0 | 30.96 | 255.3 | 254.2 | 41523839 | 40494298 | 0.793 |
| November | 163.2 | 44.1 | 28.28 | 256.2 | 255.4 | 41302913 | 40299533 | 0.786 |
| December | 155.5 | 40.9 | 26.14 | 260.2 | 259.3 | 42323108 | 41295346 | 0.794 |
| Year | 2262.6 | 888.6 | 30.37 | 3045.0 | 3031.4 | 499417699 | 487311933 | 0.800 |

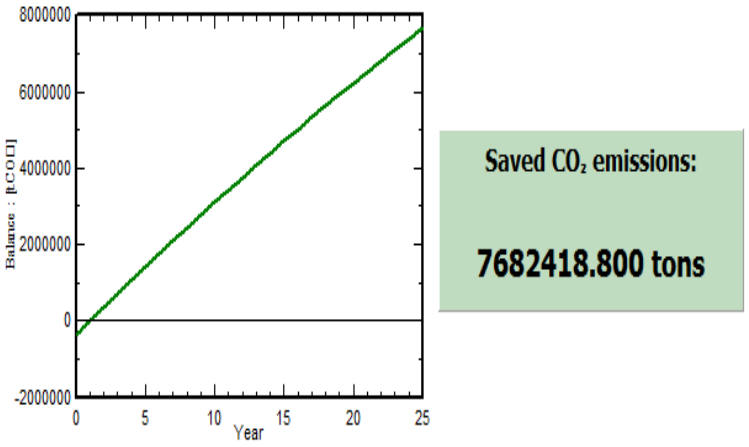



**Figure 14.** $CO_2$ emissions saved from Al-Shuqiq site with two axis tracking system

Table 4 shows the total power generation of Al-Shuqiq project is 487311 MWh with performance ratio (80.0%).

The $CO_2$ emissions saved from this project equal 307296.752 $tCO_2$ per year, and the lifetime of photovoltaic system is between 25 to 30 years. For 25 years of lifetime the project can save around 7.68 million tons of $CO_2$ emissions as shown in Figure 14. Ethe $CO_2$ emissions was determined to be decreased with an estimated power generation for each site is 200 MWp.

## 4. Conclusion

In this work, an analytical study of using PV system energy in two sites of Saudi Arabia was presented. The work discussed the possibility of connecting the PV system with the grid, while calculating the amount of reducing carbon dioxide emissions during the production of electricity through clean energy. a simulation program was used to simulate the installation of PV cells on two regions in Saudi Arabia. The possibility to use the tracker system to track the sunshine and generate more power from PV systems was discussed. The results of this study showed that the use of PV systems near the power plants in two locations in Saudi Ariba will be save the dependence of the oil. Moreover, it will reduce the $CO_2$ emissions. The expected total generated power from Al-Shuaiba PV station is 368 GW/h without the tracking system and 473 GW/h for the tracking system. The expected total generated power from Al-Shuqiq PV station is 388 GW/h without the tracking system and 488 GW/h for the tracking system.

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