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# Potential Assessment of a Residential Rooftop Grid-Connected PV System: Algiers and Tamanrasset Case Study

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## Abstract

Worldwide, the demand for electrical energy in the residential sector is increasing year after year due to demographic, economic and urban development. This is accompanied by an increase in fossils fuels resources consumption and consequently negative environment effect. Demand-side management approach (DSM), energy efficiency, and renewable energy is a set of concepts that can help to reduce electricity demand are the key and actual solutions. Recently, a rooftop photovoltaic system (RTPVS) is an attractive alternative electricity source for households, their potential at any given location can be evaluated through simulation software and tools. This paper deals with the potential assessment of the rooftop grid-connected PV system under the weather conditions of Algiers (36°45,2 N, 3°3,5 E) in the north and Tamanrasset (22°47,4 N, 5°31,2 E) in the south of Algeria. A system of 5 kWp is simulated under various tilts angle from 0 to 90 degrees to find the optimal tilt one. Assessment of system energy yield, performance ratio (PR), capacity utilization factor (CUF) and specific energy (SE) are carried out, calculated and analyzed. Simulation results show, that 30° and 15° are respectively the optimal tilt angle for Algiers and Tamanrasset, which gives the high values of analyzed parameters. As a comparative analysis, the potential of the rooftop PV system at the Tamanrasset area is higher than in the site of Algiers. The average annual energy, PR, CUF, and SE of the simulated system was found to be (9681 kWh-7251 kWh) (78%-80%), (22,1%-16,55%), and (1936,2 kWh/kWp-1450,2 kWh/kWp) for Tamanrasset and Algiers, respectively.

**Keywords:** Rooftop photovoltaic system (RTPVS), tilt angle, solar cell, performance ratio, capacity utilization factor, demand side management, energy efficiency.

## 1. Introduction

Fossil fuels such as coal, oil and natural gas are currently the world's main source of energy. They will continue to produce 80% of the world's energy until 2030. Successive oil shocks since the 1970s have demonstrated the risks of producing energy based on fossil fuel resources, as their growing consumption leads to the depletion of the world's resources in addition to environmental problems such as increasing CO<sub>2</sub> emissions and global warming. To this end, great attention has been given to the promotion of energy generation from renewable energy sources, in particular solar photovoltaic (PV) [1-3]. Because solar photovoltaic has a number of advantages such as it is clean, renewable, easy to maintain, scalable in size and reliable in operation [3].

Power generated from solar photovoltaic cells (PV) is an ideal option for generating renewable power which is suitable for various applications by directly converting incident solar radiation into electricity for households, villages electrification, grid supply, and water pumping, or by using concentrated solar power (CSP) [4], with one of these two

main traditional categories of connection: grid-connected without battery or also called grid-tied systems and stand-alone (off-grid) systems with storage (see Figure 1) [5, 6].

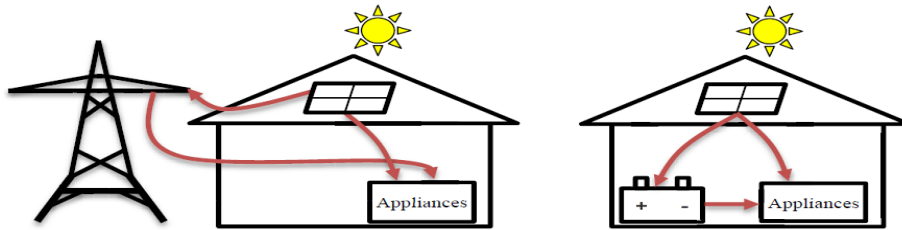


Figure 1. Schematic diagram of PV grid-connected and off-grid systems [6].

From the literature and worldwide, there are various applications of solar energy to meet energy needs such as in grid supply [3, 6], water pumping [8-10], domestic applications [11-13], industrial sector [14], university campus [15], building rooftop PV system [16, 17] and schools [18]. The performance study and feasibility analysis of these systems are carried out either on an experimental basis or by means of a simulation approach.

Based on the literature, and to the best of our knowledge, in Algeria, there are no detailed studies about rooftop PV systems feasibility assessment and analysis, especially for residential application. However, this paper focuses on and presents the feasibility analysis of 5 kW residential rooftop grid-connected photovoltaic systems based on the simulation approach is carried. Two sites in northern and southern of Algeria are examined as a case study, i.e. Algiers and Tamanrasset. As the performance of the solar power plant depends on several factors, energy production, tilt angle, performance ratio, and capacity utilization factor are addressed and analyzed.

Following the introduction of Section 1, the remainder of this paper is structured as follows: Section 2 presents the trend and penetration of photovoltaic energy in the world and in the Algerian context. Section 3 discusses the need for renewable energy and load management, as well as the residential application of a rooftop grid-connected PV system. Section 4 presents the case study, a methodology, selected areas description, and its solar resource assessment. Various parameters used in the analysis are also provided. The simulation results with the complete system analysis for both sites are presented in Section 5, and Section 6 gives the conclusion of this paper.

## 2. Photovoltaic Energy Trend and Penetration

Electricity is a daily necessity in various fields and applications, its consumption is increasing and evolving rapidly. According to the report of the International Energy Agency, in 2016 more than 25,000 TWh were produced worldwide compared to 15,500 TWh in 2000, noting that more than 60% of the world's electricity in the same year is generated from fossil fuels [19].

As mentioned above, population growth, the need for sustainable energy, concerns about CO<sub>2</sub> emissions, the benefits of green renewable technologies for the diversification of supply resources, all these lead to a rapid worldwide growth of solar PV system applications, and even for other types of renewable energy, but in 2016, PV solar energy increased faster than all other energy sources [20, 21]. According to the Statistical Review of World Energy and IEA agency, it is estimated that global solar electricity generation has grown exponentially from 7.9 TWh in 2007 to about 442.6 TWh in 2017, representing 1.3% of all electricity with 320,000 GWh in 2016 compared to 990 GWh only in the 2000 year [19, 22]. According to the International Energy Agency (IEA), in 2018 the global

cumulative solar energy capacity has seen the largest increase ever recorded, increased by 181 GW (added) to reach around 508 GWp, and will surpass 1100 GWp by the end of 2023 according to the same report, as shown between 2008 and 2018 in Figure 2 [8, 24].

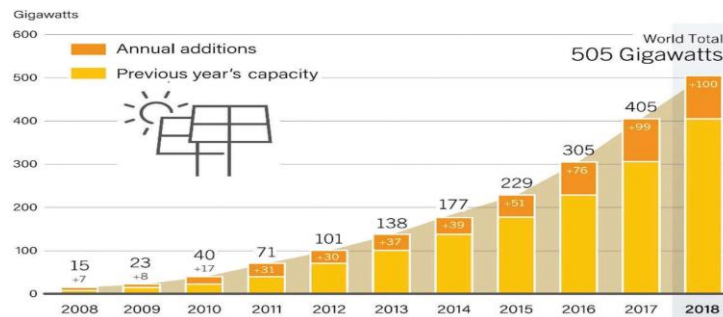


Figure 2. Trends of global solar energy capacity [24].

Regarding about photovoltaic energy in the Algerian context, as many countries in the world, Algeria with its large area and weather diversity has a high potential of solar energy particularly in the Saharan, i.e. the southern regions [25] is committed to the promotion of the renewable energy programs launched in 2011 by the Ministry of Energy and Mines to preserve its fossil resources for the future generations and also contribute to reducing CO<sub>2</sub> emissions [26]. The details of the Algerian potential in terms of the solar resource is given in Table 1 [27].

Table 1. Solar potential in Algeria [27].

| Areas  | Coastal area | High plains | Sahara    |
|--|--------------|-------------|-----------|
| Surface (%)  | 4            | 10          | 86        |
| Area (km <sup>2</sup> )                            | 95.27        | 238.147     | 2.048.297 |
| Mean daily sunshine duration (h)                   | 7.26         | 8.22        | 9.59      |
| Average duration of sunshine (h/year)              | 2650         | 3000        | 3500      |
| Received average energy (kWh/m <sup>2</sup> /year) | 1700         | 1900        | 2650      |
| Solar daily energy density ((kWh/m <sup>2</sup> )  | 4.66         | 5.21        | 7.26      |

The program of renewable energies in Algeria to reach a rate of 27% of the national production of electricity from renewable sources with the objective of installing a capacity of 22,000 MW by 2030 will be done in two phases as follows: 2015-2020 which aims to install 4,525 MW, and the second phase of 2021-2030 to achieve the rest. Environmentally, this program will lead to a reduction of more than 18% in CO<sub>2</sub> emissions by 2030. The evolution of the contribution of renewable sources to the national electricity production is shown in Figure 3, the program of renewable energy development in Algeria shared on the phases as are illustrated in Figure 4 [28, 29].

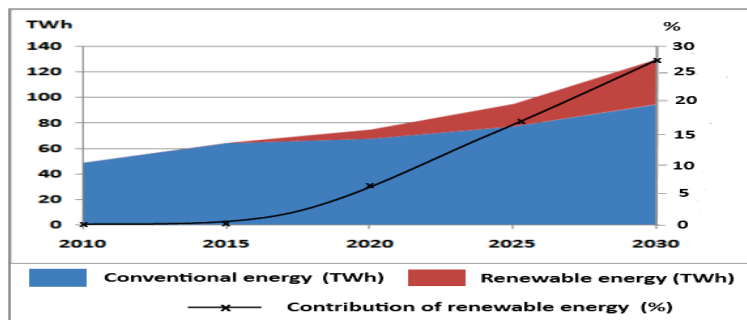


Figure 3. Trend to 2030-renewable energy contribution program in Algeria.

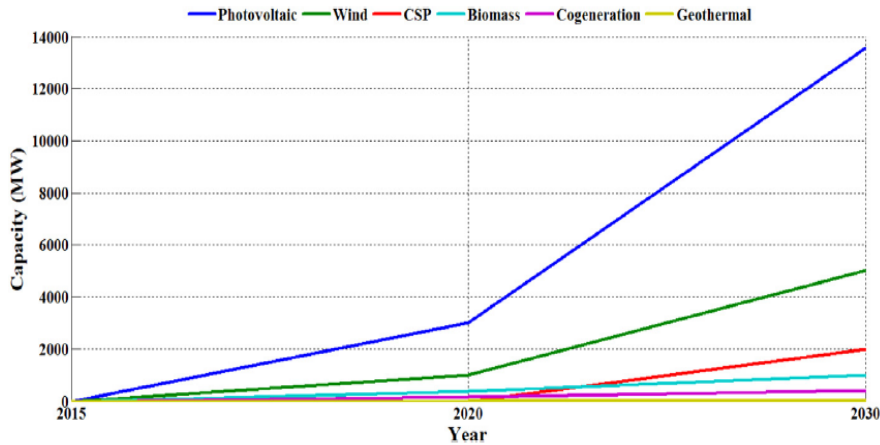


Figure 4. Phases of the Algerian renewable energy program by sector [29].

### 3. Rooftop Grid-Connected PV System for Residential Application

An increase in global energy demand has been observed as a result of economic activity development and certainly as a result of population growth. In the Algerian context, the residential sector is currently one of the major contributors to the national energy balance. According to the Algerian company of gas and electricity distribution Sonelgaz, electricity consumption grows very quickly in Algeria, i.e. was 64.6 TWh and is expected to reach at least 75 TWh in 2020 and 130 TWh in 2030 [30].

Following the increase in demand from Sonelgaz customers, particularly households, whose total number of subscribers exceeded 9.6 million at the end of 2018, compared with 9.2 million at the end of 2017 (+4.6%), which led to an increase in electricity consumption by 4.9% to reach 13.9 Mtep. In addition, a significant increase is observed in the consumption of the "Households and other" sector from 13.2% to 22.4 Mtep, driven by the residential sub-sector with 17.6% [31]. Algerian energy consumption by sector for the year 2019 is shown in Figure 5, where the household and other sector presents the highest percentage (46,6%), followed by the transport and industry sector with 31.7% and 21.7%, respectively.

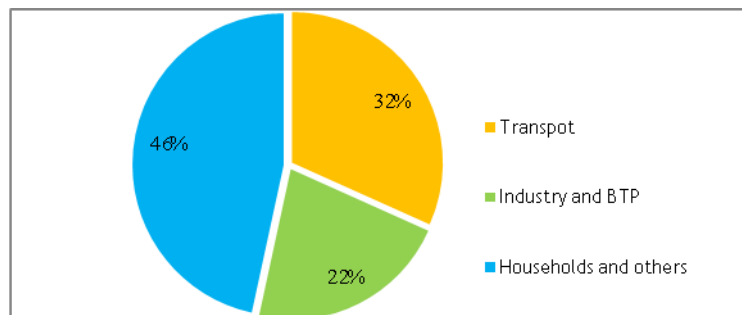


Figure 5. Electricity consumption by sector in Algeria in 2019.

In 2030, energy consumption will be 63 Mtep (growth of 3,5%), and in the case of energy control policy, the growth is only 2.6% (52 Mtep). However, Algeria's energy needs are covered almost exclusively by hydrocarbons, i.e. about 90% of electricity is produced mainly by power plants using natural gas [33]. So, for this sector, energy efficiency and demand side management activities (DSM) have significant potential in Algeria as shown in Figure 6. To minimize energy consumption, the implementation of demand side management, energy efficiency measures and the adoption of renewable energy sources are the two basic strategies according to the author in [34].

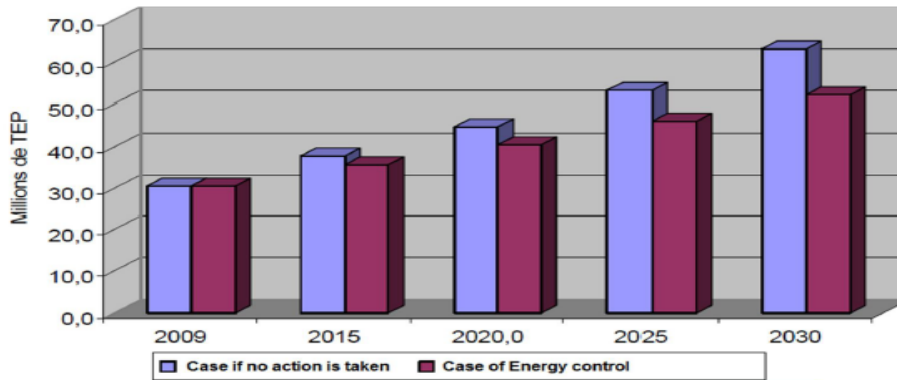


Figure 6. Energy consumption perspective in Algeria [32].

Nowadays and due to its positive characteristics (low maintenance cost, does not produce pollution and it is easy in terms of installation and use), photovoltaic (PV) systems are widely used to produce electricity in order to achieve an energetic mix that is adopted by various financial support programs such as feed-in tariffs policy and subsidies.

The integration of photovoltaic systems (PVs) at the low-voltage level (LV), such as in communities, on rooftops, in micro-grid applications and distributed generation systems is one of the most popular applications of this technology [34, 35]. More than 40% of the total PV capacity is integrated into the LV distribution grids as domestic rooftop systems [35]. Installing this type of solar PV system on residential roofs can make sound economic sense: offsets the need to purchase peak time electricity from the grid, it reduces carbon emissions and puts unused rooftop space to good use, and ensure their energy independence.

Demand side management (DSM) or load management represents all the actions that can lead the consumer to modify the volume of consumed energy and/or the time of its consumption, through improving energy efficiency and the optimal allocation of power sources for public service and consumer benefit. DSM is a solution that targets commercial, residential, and industrial customers, and is developed for demand reduction or demand shifting at a specific time for a specific duration [4].

As shown in Figure 7, six specific load objectives generally associated with DSM concept which are classified into two main objectives namely energy efficiency (EE) or strategic conservation which involves a reduction in overall energy consumption, and load management (LM) including load shifting strategies, peak shaving, and valley filling techniques [36].

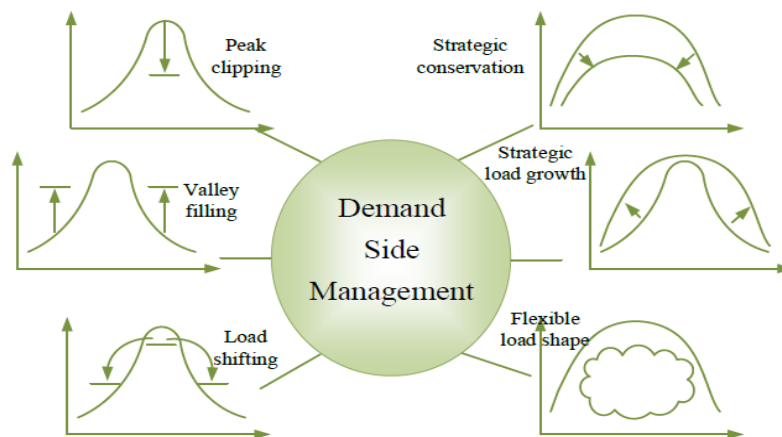


Figure 7. Typical load curves of demand side management concept [36].

Renewable energies (PV, wind, solar rooftop, etc), and PV self-consumption and on-site generation are some of the most used means in this concept. The energy exchange and interaction between the customer that uses the rooftop PV system and the utility grid are illustrated in Figure 8.

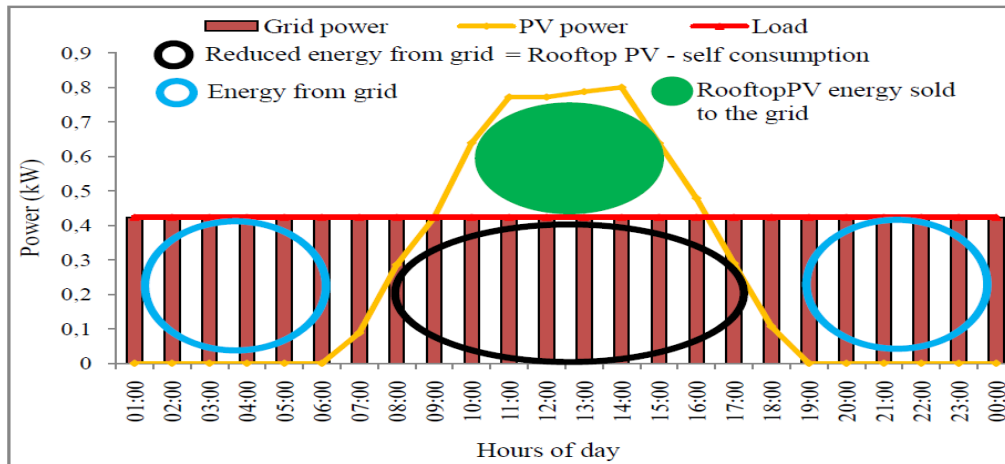


Figure 8. Energy consumption and generation from rooftop PV grid connected system.

#### 4. Case Study and Methodology

As already mentioned in the introduction, the objective of this paper is the investigation and analysis of the technical feasibility of a residential rooftop grid-connected solar energy system by means of the simulation approach. The system of 5 kW based amorphous silicon (a-Si) is simulated in two different weather conditions of Algeria, one in the north (Algiers) and the second one in the south area (Tamanrasset).

The configuration of the rooftop grid-connected PV system and its components, the system description, detailed information for both sites, and the parameters analyzed, including energy production, performance ratio, and capacity utilization factor, are presented in detail as follows. The design of the system under consideration, i.e. a rooftop grid-connected system, consists of four main components as follows.

- Solar PV array uses a specific technology of PV cells connected in series and parallel to absorb and convert sunlight directly into DC power.
- Grid-connected DC/AC inverter that converts direct current (DC) from PV generator to alternating current (AC) supplied to the load and/or to the utility grid with the ability to synchronize with the grid frequency.
- Protection devices, grid connection safety equipment, and energy monitoring system (net-metering, circuit breaker...).
- Distribution grid and customer electrical load.

The schematic of the rooftop grid-connected PV system is shown in Figure 9. In this configuration, the owner of the photovoltaic system can save money by producing and sending more electricity to the power grid and receives energy from the grid when there is no photovoltaic generation, such as at night or on cloudy days. Net metering is the process of calculating the amount of electricity sold and/or purchased into/from the utility grid.

##### 4.1. Description of study area

In this paper, two sites Algerian were selected as study locations, these cities include Algiers in the north and Tamanrasset in the south with a desert climate and higher solar

radiation. The specific information of the two sites and locations on the map of Algeria are shown in Table 2 and Figure 10, respectively. The detailed information of the simulated rooftop grid-connected PV system in terms of orientation used solar cell technology, system capacity, and tracking mode are summarized in Table 3. In addition, eight tilt angles (from 0 to 90 degrees) were compared to select the best one.

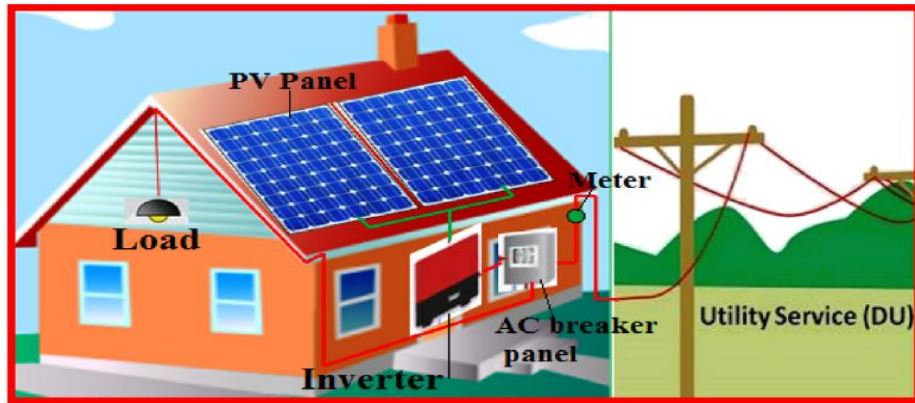


Figure 9. Rooftop grid connected PV system configuration.

Table 2. Detailed sites information.

|                                   | Locations                    |                               |
|-----------------------------------|------------------------------|-------------------------------|
| Country                           | Algeria                      |                               |
| Site name                         | Tamanrasset                  | Algiers                       |
| Coordinates (Latitude, Longitude) | 22°47,4 N, 5°31,2 E          | 36°45,2 N, 3°3,5 E            |
| Average solar irradiation         | 5.90 kWh/m <sup>2</sup> /day | 4.773 kWh/m <sup>2</sup> /day |
| Annual air temperature at 2 m     | 23.16 °C                     | 17.81°C                       |

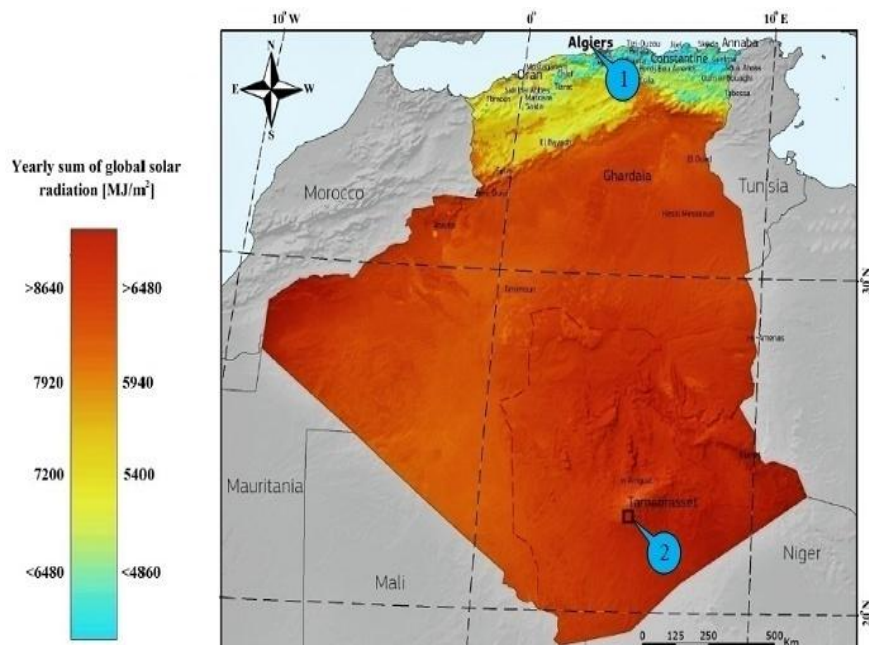


Figure 10. Sites locations on Algeria maps, (1) Algiers area, (2) Tamanrasset site.



Table 3. Technical details of the simulated system

|                             |  |
|-----------------------------|--|
| Installed power             | 5 kWp                                      |
| Installation type           | Rooftop grid connected                     |
| Type of modules             | Amorphous silicon (a-Si), Efficiency 14.9% |
| Mounting system             | Fixed mounting                             |
| Tilt angles                 | 0°, 15°, 30°, 45°, 60°, 75° and 90°.       |
| Orientation of PV generator | South (180°)                               |
| Customer type               | Residential                                |
| Availability                | 95.0%                                      |
| Albedo                      | 20%  |

#### 4.2. Solar resource assessment

The assessment of the solar potential on-site is a critical step in the development of a solar energy system. Meteorological data for the two locations (Algiers and Tamanrasset) including solar irradiation ( $\text{kWh/m}^2/\text{day}$ ), clearness index and ambient temperature ( $^{\circ}\text{C}$ ), are obtained from the National Aeronautics and Space Administration database (NASA) after providing the geographical coordinates of the selected sites (see Table 2) [37]. The average monthly solar radiation data for Algiers and Tamanrasset are illustrated in Figures 11 and 12, respectively. The monthly profile of ambient temperature is shown in Figure 12.

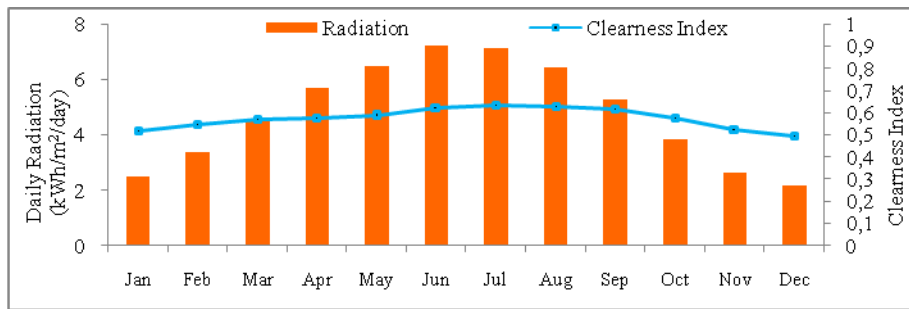


Figure 11. Monthly average global horizontal irradiance at Algiers location.

As shown in Figure 11, the solar irradiation for the Algiers region ranges between a minimum of  $2.15 \text{ kWh/m}^2/\text{day}$  (December) and a maximum of  $7.2 \text{ kWh/m}^2/\text{day}$  (July), whereas the annual average solar irradiation is  $4.773 \text{ kWh/m}^2/\text{day}$ . The clearness index varies from 0.492 to 0.632 with an annual average value of 0.573.

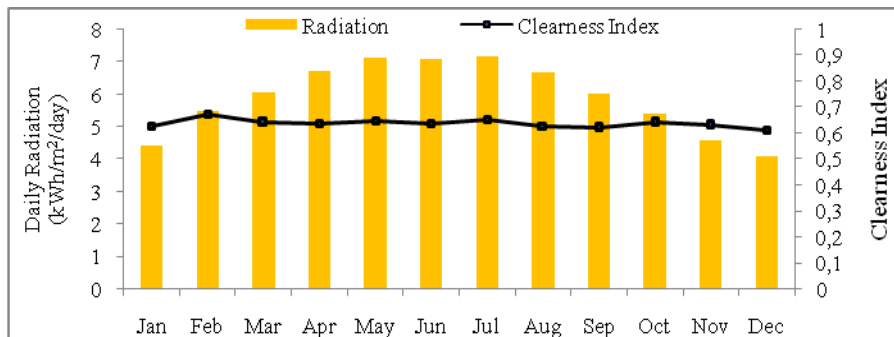


Figure 12. Monthly average global horizontal irradiance at Tamanrasset.

The same for Tamanrasset location, the highest irradiation is possible in July ( $7.18 \text{ kWh/m}^2/\text{day}$ ), and the lowest irradiation is seen in December month ( $4.09 \text{ kWh/m}^2/\text{day}$ ).

And 0.61, 0.652 are the minimum and maximum values of the clearness index in this region.

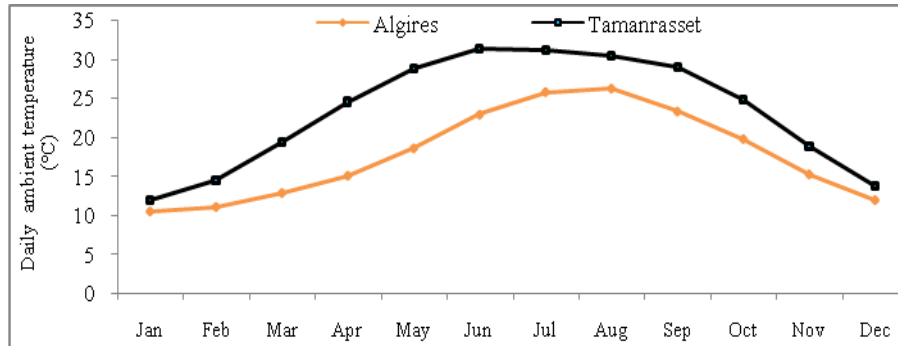


Figure 13. Monthly average ambient temperature data.

An average annual solar irradiation and clearness index is about 5.90 kWh/m<sup>2</sup>/day and 0.636, respectively. From Figure 13, the ambient temperature at Tamanrasset is higher than in the Algiers site, having the annual average is 23.16°C and 17.81°C, respectively.

### 4.3. Analyzed parameters

The electricity generation and rooftop solar photovoltaic system operation depend on a number of factors such as solar radiation, ambient temperature, tilt angle, solar cell technology used and shading, etc [38]. The objective of this analysis is summarized in these points:

- To assess the potential of solar resources in the north and south of Algeria country.
- Discussion of the role of the rooftop PV system as a means of load management in a residential application, its optimized design, advantages and influenced parameters on the system.
- Predict the performance of a 5 kW residential rooftop grid-connected solar PV system on two different sites (Algiers, Tamanrasset).
- The system performance comparison between the two locations based on a number of selected parameters including solar resource, energy production, performance ratio and capacity utilization factor of the system.

The simulation process followed during this research includes the following steps:

- Selection of study locations (Algiers and Tamanrasset).
- Monthly average global horizontal solar radiation estimation
- Determination of the PV generator size that is estimated in relation to the consumption of a residential application.
- Selection of the PV cell technology to be used in the system.
- The setting of system parameters (tilt angles, azimuth and tracking options, etc.).
- Defining the parameters to be analyzed (energy yield, PR, utilization factor).
- Run the simulation.
- Finally, obtain simulation results, then analysis and discussion.

#### 4.3.1. Tilt angle

In solar photovoltaic systems, the angle at which the PV generators are mounted is called the tilt angle, which is dependent on the geographical location of the system, seasonality, shade conditions, etc. The tilt angle has an important role in the system performance, must be calculated and maintained optimal to maximize the collection of

solar radiation. According to the literature, the tilt angle is optimal when it is equal or close to the latitude of the corresponding location [39]. In this paper, the system is simulated with different tilt angles from 0 to 90 degrees in order to see its effect and to determine the optimal one.

#### 4.3.2. Solar cell technology

In terms of solar cell technologies, there are three main categories in the solar energy market, namely crystalline silicon, thin-film solar cells, and multi-junction solar cells. The crystalline Silicon c-Si PV technology consists of two main types, polycrystalline silicon (poly c-Si) and mono crystalline silicon (mono c-Si) [40]. For the second generation, the two main types are and Copper Indium Gallium Deselenide (CIGS) and the cadmium telluride (CdTe) technologies. Silicon PV modules have the highest portion among the commercialized technologies and dominates the worldwide solar PV market, i.e. accounting for almost 95 % in 2017 according to Fraunhofer Institute for Solar Energy Systems (Fraunhofer Institute for Solar Energy Systems, 2018), however, the rest represents all thin-film technologies, i.e. 5% of the total annual production [23]. In this paper, amorphous silicon (a-Si) solar cell technology is used in this simulated rooftop PV system.

#### 4.3.3. System energy yield

The total alternative energy production ( $E_{AC}$ ) is defined as the amount of power generated by the rooftop PV system over a given period of time. The hourly, daily and monthly photovoltaic energy output can be calculated respectively as in the following equations [41].

$$E_{AC,h} = \sum_{t=1}^{60} E_{AC,t} \quad (1)$$

$$E_{AC,d} = \sum_{h=1}^{24} E_{AC,h} \quad (2)$$

$$E_{AC,m} = \sum_{d=1}^N E_{AC,d} \quad (3)$$

Where;  $E_{AC,t}$ ,  $E_{AC,h}$ ,  $E_{AC,d}$  and  $E_{AC,m}$  are the AC energy output at time t (in min), the hourly, daily and monthly AC energy output and N is the number of days in a month.

#### 4.3.4. Performance ratio (PR)

The performance ratio (PR) is one of the most important factors in the feasibility analysis of solar systems. The PR is defined as the ratio between the AC output power (monthly and/or yearly) and the maximum possible DC generated power at system rated capacity (nameplate capacity), i.e. also the ratio between the nominal installed rated power and the incident energy [3]. The PR formula is given by the Eq. (4).

$$PR (\text{month/year}) = \frac{EP (\text{month/year})}{P_{\text{rated}} * S (\text{month/year})} \quad (4)$$

Where; EP in (kWh) is the actual monthly or yearly produced energy, S is the equivalent sun hours of the month or year and  $P_{\text{rated}}$  is the nameplate capacity of PV system.

#### 4.3.5. Capacity utilization factor (CUF)

The capacity utilization factor is defined as the ratio between the two terms, the produced AC energy by the rooftop PV system over a given period of time and the energy that would have been generated if the system is operated at full capacity (nominal power) over during the same specific period. The CUF is given by the following equation (5) [42].

$$CUF = \frac{E_{AC}}{P * H} = \frac{E_{AC}}{P_{PV, rated} * 8760} * 100\% \quad (5)$$

Where; P is the capacity of rooftop PV system in (Wp) and H is the number of operating hours in on day/month/year.

#### 4.3.6. Specific energy [KWh/KWp]

The specific energy (SE) in [KWh/KWp] is an indicator of the energy generation from the PV system based on the available irradiation [43].

$$SE = \frac{E_{AC}}{P_{array, STC}} \quad (6)$$

Where;  $E_{AC}$  is the AC energy production,  $P_{array, STC}$  is the energy output (yield) of power plant.

In this configuration of the rooftop grid-connected PV system, there is an exchange of energy between the customer and the grid operator, i.e. purchase and sale of energy. The net energy purchased can be calculated using Eq. (66).

$$NEP = \sum_{i=1}^n Energy_{purchased, i} - \sum_{i=1}^n Energy_{sold, i} \quad (7)$$

Where,  $NEP_{kwh}$  in (kWh) is the net energy purchased,  $Energy_{purchased, i}$  and  $Energy_{sold, i}$  in (kWh) are respectively the energy purchased and the energy sold in the month i, and n is number of months.

## 5. Results and Discussions

Simulation results and discussions are given in this section for the two selected sites, Algiers and Tamanrasset in Algeria country. The results are analyzed with a focus on the system energy yield, performance ratio (PR), capacity utilization factors, the influence of the tilt angle on these indices is also examined.

### 5.1. Results for Tamanrasset location

The annual variation of the AC energy ( $E_{AC}$ ) produced by the system, the annual variation of PR and the capacity utilization factor as a function of tilt angles for the site of Tamanrasset are given in Figures 14, 15 and 16, respectively.

From Figure 14, the system energy yield is variable and increases with the variation of the tilt angles from 0 degree up to an angle of 30 degree, then it decreases with the other tilt angles, i.e. 45°, 60°, 75°, and 90°. The minimum energy yield of the system always corresponds to the tilt angle of 90 degree with 5088 kWh/year. On the other hand, the maximum annual energy output is generated when the PV panel is tilted at a tilt angle of 15°, i.e. 9681 kWh.

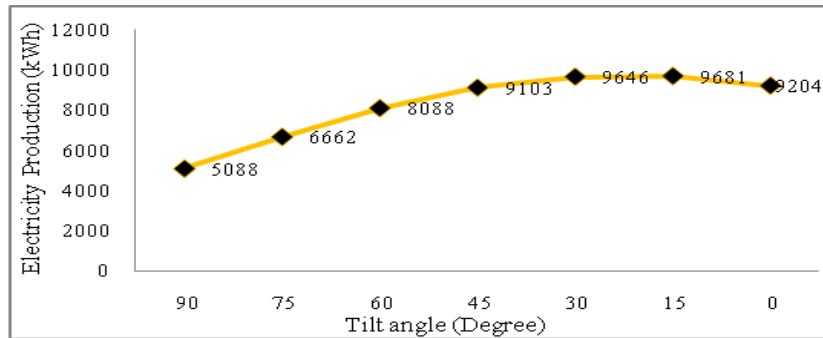


Figure 14. Annual system energy yield at Tamanrasset location.

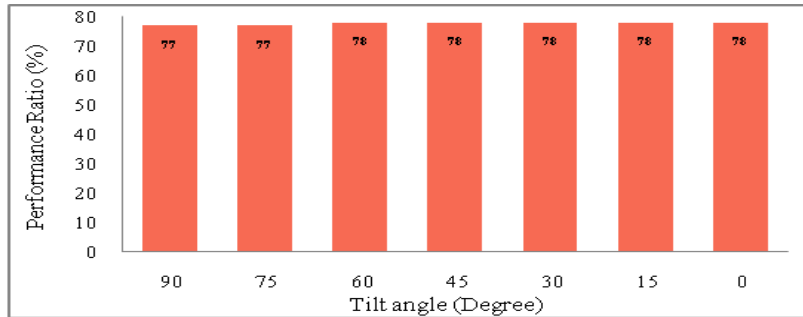


Figure 15. Performance ratio variation at Tamanrasset location.

The performance ratio (FR) at the Tamanrasset site has two values 77% and 78%, the maximum annual average performance ratio (PR) of 78% is seen for tilt angle of 0°, 15°, 30°, 45 and 60 degree.

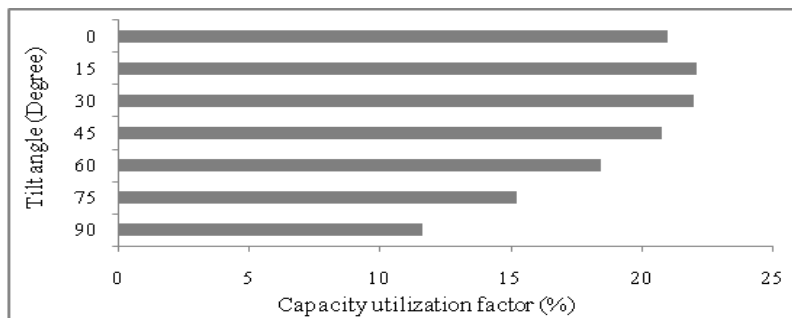


Figure 16. Capacity utilization factor for Tamanrasset site.

From Figure 16, we find that the tilt angles of 15 and 30 degrees gives a better results in term of capacity utilization factor with 22.1% and 22.01%, respectively. However, the minimum values of PR and CUF are observed when the system is tilted at an angle of 90 degree.

## 5.2. Results for Algiers location

Similarly, the results for the case of Algiers are about the same as those of Tamanrasset in term of tilt angle effect, the energy produced by the rooftop photovoltaic system varies as a function of the variation in the tilt angle, and ranges from a minimum of 4301 kWh to a maximum of 7251 kWh. As shown in both Figures 18 and 19, the same behavior is observed for PR and CUF. The average annual value of performance ratio of the rooftop PV system for this location varies between a minimum of 77% and a maximum of 80% for the tilt angles of 90 and 30 degrees, respectively.

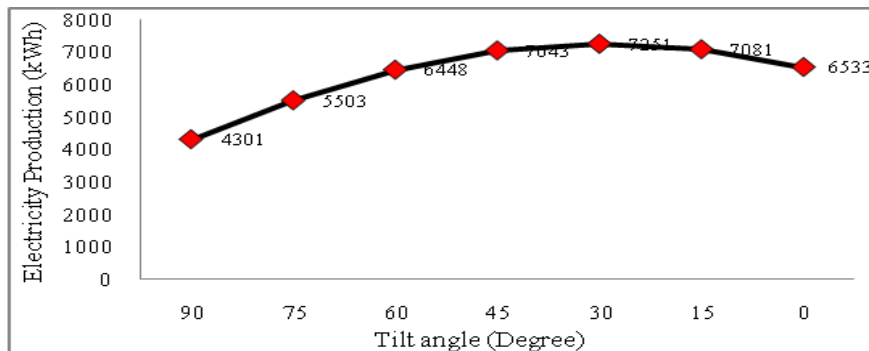


Figure 17. Results of energy production at Algiers location.

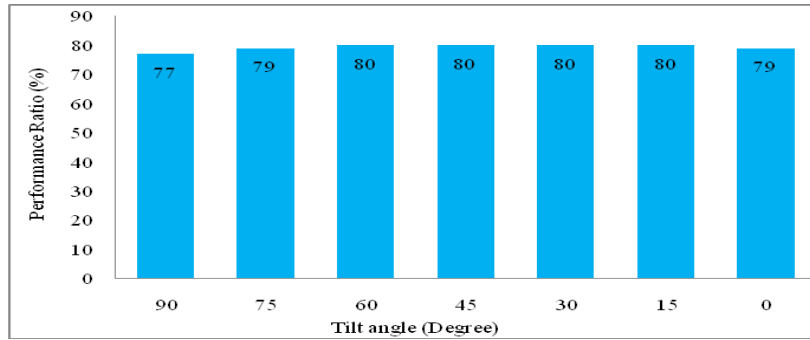


Figure 18. Performance ratio at Algiers location.

The same for CUF at this location, which varies depending on the tilt angle, between a minimum and maximum of 71% (90°) and 80% (30°), respectively. As a summary, for the site of Algiers in the north, the tilt angle of 30 degree gives the best results in terms of system productivity, performance ratio and capacity utilization factor, i.e. 7251 kWh, 80% and 16.55%, respectively. However, the minimum of all these parameters is achieved when the rooftop PV system is vertically mounted.

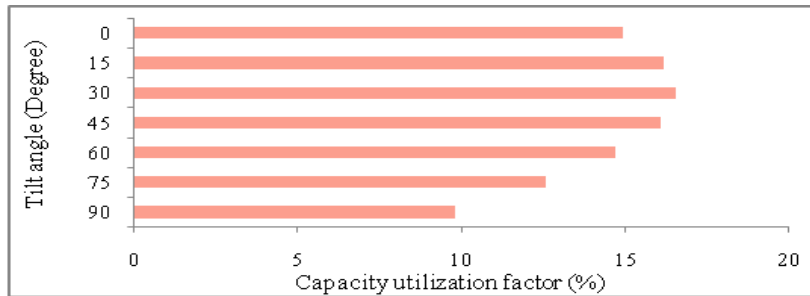


Figure 19. Average capacity utilization factor for different tilt angles.

### 5.3. Annual energy output comparison

Comparative performance analysis of the proposed rooftop PV system at Algiers and Tamanrasset is examined in this section based on the energy yields (kWh/year) and specific energy (kWh/kWp) as shown in Figures 20 and 21, respectively.

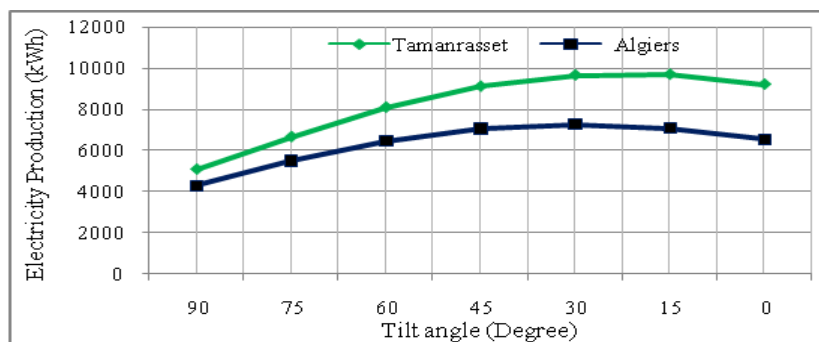


Figure 20. Energy yields comparison at Algiers and Tamanrasset.

From Figure 20, electricity production is always higher for the case of Tamanrasset compared to the Algiers site for different tilt angles, which is justified by the greater solar radiation potential in the south than in the north. The difference in electricity generation between the two sites is estimated at 2671 kWh/year, 2600 kWh/year, 2395 kWh/year,

2060 kWh/year, 1640 kWh/year, 1159 kWh/year and 787 kWh/year for the tilt angle 0°, 15°, 30°, 45°, 60°, 75°, and 90°.

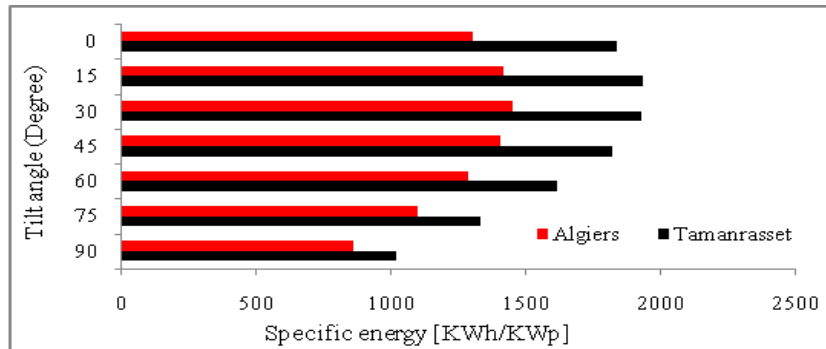


Figure 21. Results of specific energy for both locations.

The same is observed for the results of specific energy, it is higher in Tamanrasset than in Algiers, the maximum is found 1936.2 kWh/kWp and 1450.2 kWh/kWp for a tilt angle of 15 and 30 degrees, respectively for Tamanrasset and Algiers locations, while the minimum is obtained when the PV generator is vertically mounted with 1017.6 kWh/kWp and 860.2 kWh/kWp for Tamanrasset and Algiers, respectively.

## 6. Conclusion

With the continuous growth of electric energy consumption and the worldwide problem of climate change, load management, and renewable energy, especially solar energy has emerged as a better environmentally friendly option. In this paper, the technical feasibility analysis of a rooftop grid-connected PV system of 5 kWp based amorphous silicon (a-Si) technology for residential application is carried out through the simulation approach. The study requires a set of procedures starting with the site selection, availability of solar resources and their assessment, component selections, design and study of influencing parameters. Algiers and Tamanrasset are two sites in Algeria chosen as case studies. The proposed rooftop grid-connected PV system analyzed using several technical factors including, system energy yield, performance ratios, capacity utilization factor, and specific energy. Based on the simulation, the best results for the site of Tamanrasset are obtained at a tilt angle of 15 degrees with an energy yield, a performance ratio (PR) and a capacity utilization factor (CUF) of 9681 kWh, 78% and 22.1%, respectively.

For Algiers site, the annual average energy yield of the system is 2406 kWh, the annual average values of CUF and PR are 16,55% and 80%, respectively. Noted that the maximum of all these results is obtained at a tilt angle of 30 degrees. In terms of comparison between the two sites, Tamanrasset presents a higher result than Algiers thanks to its considerable solar potential.

Finally, given the solar potential at both selected sites and based on the simulation results of this proposed rooftop grid-connected photovoltaic system, this technology presents a feasible integrated solution for electricity supply and electric load management, particularly in the domestic application and then to diversify and create a clean energy mix in Algeria.

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