Economics Feasibility of Solar Photovoltaics project of 5 Mwh in El Oued university campus

Khalida Abi [1], Fateh serdouk [2*]

[1] El oued University (Algeria), *abi-khalida@univ-eloued.dz*
[2] El oued University (Algeria), *serdouk-fateh@univ-eloued.dz*

Received: 17-05-2021 Accepted: 06-06-2021 Published: 30-09-2021

Abstract:

The purpose of this paper is to analyze the feasibility of economics and performance of a utility-scale PV systems of 5 Mwh Proposal in the El Oued university campus from Algeria. Taking into consideration that Algeria, and especially the Algerian Sahara, is one of the regions with the most photovoltaic potential to generate electricity in the world

Moreover, the feasibility of the solar photovoltaic project proposed is analyzed considering the economic aspects under the System Advisor Model, (SAM), The study will be carried out in different phases: The first phase will be focused on towards the situation and potential for solar photovoltaic energy in Algeria. Then, understanding and analyzing the economic and reliability analysis of the proposed project. Finally, representing an analysis conclusion of the economic feasibility of the proposed plant.

Keywords: *Solar Photovoltaics; Economics Feasibility; Levelized Cost of Energy (LCOE); El Oued university campus.*

Jel Classification Codes**: :** *C63, Q29, Q21, D24*

1 INTRODUCTION

It is universally acknowledged that two of the key technological and economic challenges of the 21st century are energy and the environment. (Smalley, 2005), Significantly, it has been expected that Solar photovoltaic (PV) will play from the beginning of the century, one of the most important of these challenge keys, Due to its rapid technological development. (Co-operation & Development, 1998).

Consequently, considerable efforts are being made to affect a gradual transition from systems based on fossil fuels to those based on renewable energies. Electricity generation from solar energy is currently one of the main research areas in the field of renewable energy. (Mihoub, Chermiti, & Beltagy, 2017a)

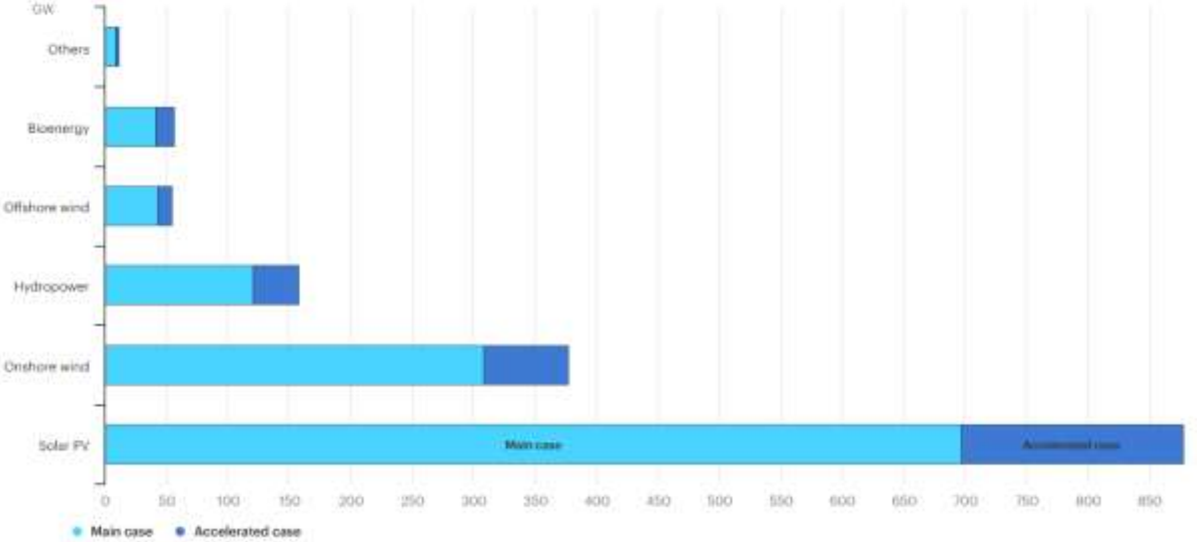
As outlines in IRENA'S report "Future of solar photovoltaic " that the growth in Solar photovoltaic (PV) power deployment that would be needed in the next three decades to achieve the Paris climate goals. (IRENA, 2019) (Klein, Carazo, Doelle,

* ***Corresponding author***

Bulmer, & Higham, 2017), which limits the rise in global temperature to well below 2 degrees and closer to 1.5 degrees, aligned within the envelope of scenarios presented in the 2018 report of the Intergovernmental Panel on Climate Change (IPCC). (Masson-Delmotte et al., 2018). in order to comply with the COP21 agreement. Solar photovoltaic (PV) offers excellent characteristics to play a major role in this energy transition.

Driven by cost reductions cost reductions, technological advancements, as well as strong business case of photovoltaic utility scale project, the world's total renewable-based power capacity will grow by 50% between 2019 and 2024. This increase of 1,200 gigawatts – equivalent to the current total power capacity of the United States. (IEA, 2019). Moreover, Solar PV accounts for 60% of the grow. The share of renewables in global power generation is set to rise from 26% in 2019 to 30% in 2024. See ***Figure*** 1

Figure 1 Renewable capacity growth between 2019 and 2024 by technology (Main case and accelerated case)

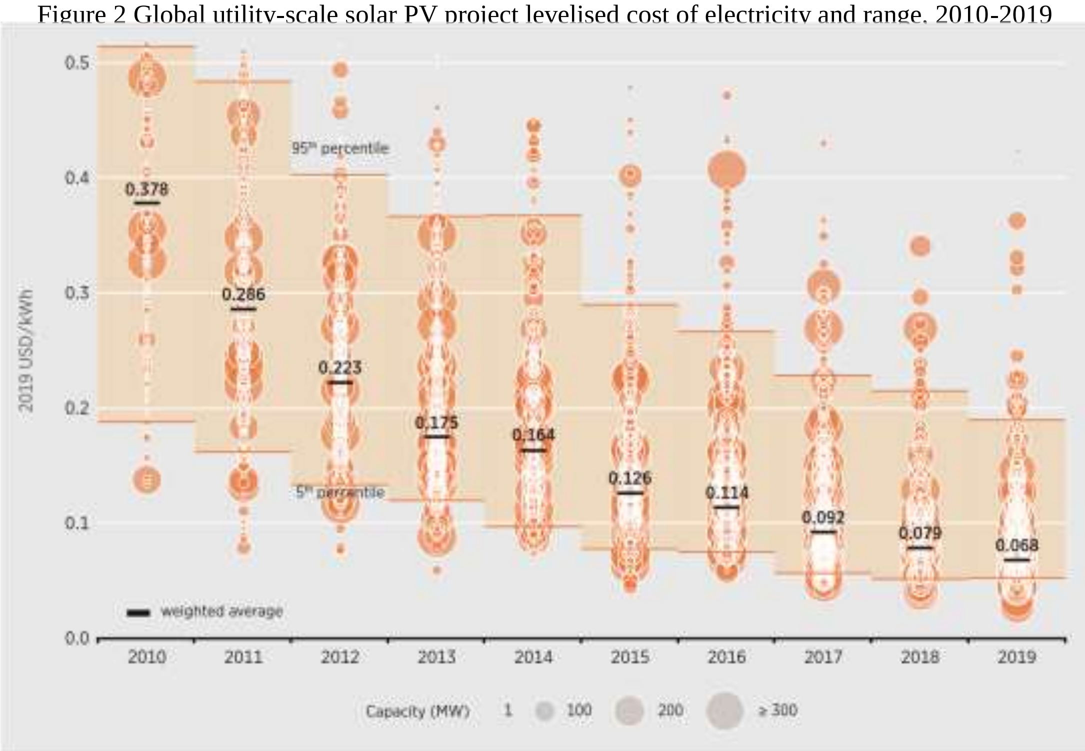


Source: IEA. (2019). Renewables 2019-Market analysis and forecast from 2019 to 2024. https://www.iea.org

From an unsubsidized cost of approximately 75 USD/ watt in 1976. to 75 USD/watt. (in 1985 dollars). (Callaghan & McDonald, 1986) solar photovoltaic (PV) modules have declined in price to below 0.50 USD/watt. In 2017, with the total installed costs for ground-mounted PV systems having recently fallen below 1 USD/watt. (Kabir, Kumar, Kumar, Adelodun, & Kim, 2018), Significantly, such cost reductions for solar photovoltaic (PV) modules are driven by continuous technological improvements, including higher solar PV module efficiencies. Yet alongside these developments, the chief driver of renewable energy is its strong business case, which offers increasingly exciting economic opportunities. Notably, after nearly a decade of steady cost decline for solar technologies, between 2010 and 2019, The global weighted-average LCOE of utility-scale PV plants declined by 82%, from around USD 0.378/kWh to USD 0.068/kWh in 2019, with a 13% reduction year-on-year in 2019.(IRENA, 2020b). See

Figure 2

Figure 2 Global utility-scale solar PV project levelised cost of electricity and range, 2010-2019



Source: IRENA. (2020b). Renewable power generation costs in 2019. Report. https://www.irena.org

For instance, Solar photovoltaics (PV) shows the sharpest cost decline over 2010-2019 at 82%, followed by concentrating solar power (CSP) at 47%, onshore wind at 40% and offshore wind at 29%. (IRENA, 2020b).

The fall in electricity costs from utility-scale solar photovoltaic (PV) projects since 2010 has been sustained, dramatic and remarkable. Driven by an 82% decrease in solar PV module prices since the end of 2009, along with reductions in balance of system (BoS) costs, the global weighted average LCOE of utility-scale solar PV fell 73% between 2010 and 2019, to USD 0.068/kWh in 2019. (IRENA, 2020b)

Increasingly, this technology is competing head to-head with conventional power sources and doing so without financial support. (Huang, Wang, Zheng, Li, & Liu, 2014b) (Mihoub, Chermiti, & Beltagy, 2017b) (IRENA, 2018) (Anuta, Ralon, Taylor, & La Camera, 2019)

While price declines of more than 80% on solar PV modules have been a major factor, balance-of-system costs have also fallen. Moreover, between 2010 and 2017, the global capacity weighted average total installed cost of newly commissioned utility-scale PV projects decreased by 68%, with a 10% decrease in 2017 from 2016 levels. See

Figure 2

Furthermore, Solar panels have improved substantially in their efficiency and power output over the last few decades. In 2018, the efficiency of multi-crystalline PV reached 17%, while that of mono-crystalline reached 18%. This positive trend is expected to continue through to 2030. Yet, as the global PV market increases, so will the need to prevent the degradation of panels and manage the volume of decommissioned PV panels leading to circular economy practices. This includes innovative and alternative ways to reduce material use and module degradation, and opportunities to reuse and recycle PV panels at the end of their lifetime. (IRENA, 2019) (Fong & Tippett, 2012)

2 THE LANDSCAPE FOR RENEWABLE ENERGY IN ALGERIA

As the biggest country on the continent and with the Sahara Desert occupying 75% of its territory, Algeria boasts undeniable potential for the development of solar energy, especially in the south, where insolation rates are as high as 2650 KWh per sq metre (DLR, 2009). As a result, Algeria expects to generate 37% of its electricity needs from solar by 2030, as outlined in the National Development Plan for Renewable Energies, which aims to achieve an installed renewable generation capacity of 22 GW by 2030, with solar accounting for 13.5 GW.

Globally, there are about 1700 TW of solar power theoretically available over land for PV. Whereas, the capture of even 1% of this power would supply more than the world's power needs. Algeria has the potential to be one of the major contributors in solar energy and become a role model to other countries in the world.(A. B. Stambouli et al., 2017) (A. Stambouli, Khiat, Flazi, & Kitamura, 2012) (DLR, 2009) (Fateh & Khalida, 2018), With an average annual sunshine 2000 h and assessed a territory composed of 86%of the Sahara desert, its solar power is estimated at about 1700KWh/m2/year in the north and 2650 KWh/m2/year in the south, which corresponds to a capacity 8 times higher than the natural gas reserves of the country, and the largest solar fields in the world.(Abada & Bouharkat, 2018)

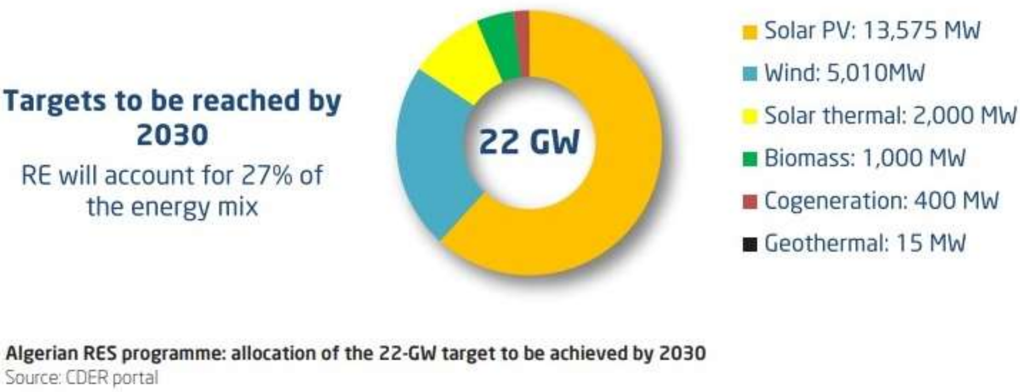
Algeria, being the largest country in Africa, in the Mediterranean and in the Arab world, has one of the highest solar area in the world, estimated to exceed five billion GWh/yr. The annual sunshine duration is estimated to be around 2 500 hours on average, and could exceed 3 600 hours in some parts of the country.(UNFCCC, 2015) (Trieb, O'Sullivan, Pregger, Schillings, & Krewitt, 2009) with a high level of radiation and the yearly average of daily solar irradiation ranges from 5kWh/m2.day to 7 kWh/m2.day. (Maafi, 2000)

The fiscal dependence of Algeria from the export of its massive oil and gas reserves, combined with the fact that over 90% of the country’s electricity generation is based on this resource, poses serious problems in facing the growing residential electricity demand. Moreover, the slump in prices of oil since the third quarter of 2014 has nearly halved Algeria’s foreign currency reserves. Moreover, Algeria’s oil reserves are projected to be depleted in 21 years and its gas reserves in 54 years. (BP, 2017).

In another side, around 85% of Algeria’s landmass is located in the Sahara Desert, and the country’s solar radiation potential is among the highest in the world, at an estimated 13.9 TWh per year. Especially for photovoltaic power potential. In light of this view, In 2016, Algeria launched a new economic growth model (2016–19) in order to avoid risks derived from fossil fuels price fluctuation, an ambitious set of reforms aimed at diversifying away from oil and boosting sectors in Algeria such as manufacturing, agriculture, renewable energy, information and communications technology (ICT) and tourism. (MF, 2016), (PMS, 2017).

The Renewable Energy and Energy Efficiency Development Plan, launched with its first version in 2011 (Burger, 2012) and updated in 2015, has put greater focus on deployment of large scale solar photovoltaic installations. The updated version of the Program in 2015 aims to install 4,500 MW of new projects until 2020 and overall, of 22,000 MW in which 13500 MW of solar photovoltaic, until 2030. The Algerian program is expected to mobilize $120bn in investment and significantly boost the share of renewable energy to the country's energy mix from 2% to 27% by 2030. Out of the planned 22 GW, solar photovoltaic will account for 61.7% of projects, followed by wind with 22.7%, thermal solar 9%, biomass 4.5%, co-generation 1.8% and geothermal 0.07%. (OBG, 2017) See ***Figure** 3*

Figure 3 Algeria's program for renewable energy development by 2030



Source: Renewable energy development center - Algeria. CDER (2020). http://portail.cder.dz

In addition to satisfying local demand, boosting alternative sources of energy should also allow Algeria to increase exports to markets in Africa and Europe. Indeed, exports of both renewable and conventional energy are expected to receive a boost under the REEEDP. Of the 22-GW total, 10 GW will be allocated for export, mainly to Europe, with another 300bn cu meters of natural gas per year to be preserved for export by 2030. (OBG, 2017)

Furthermore, the producer of renewable energy in Algeria enjoys purchase tariffs which are guaranteed for a period of 20 years for photovoltaic installations. The sectors not covered by the guaranteed purchase price will be financed by FNERC for 50% to 90% of the investment cost according to the selected technology and industry. (Fateh & Khalida, 2018). As of end-2019, non-hydro renewables capacity in Algeria stood at under 500MW. Overall, the government aim to install 22GW of renewable energy by 2030, which includes 13.6GW of solar photovoltaic capacity. (IRENA, 2020a)

3 METHODS AND MATERIALS

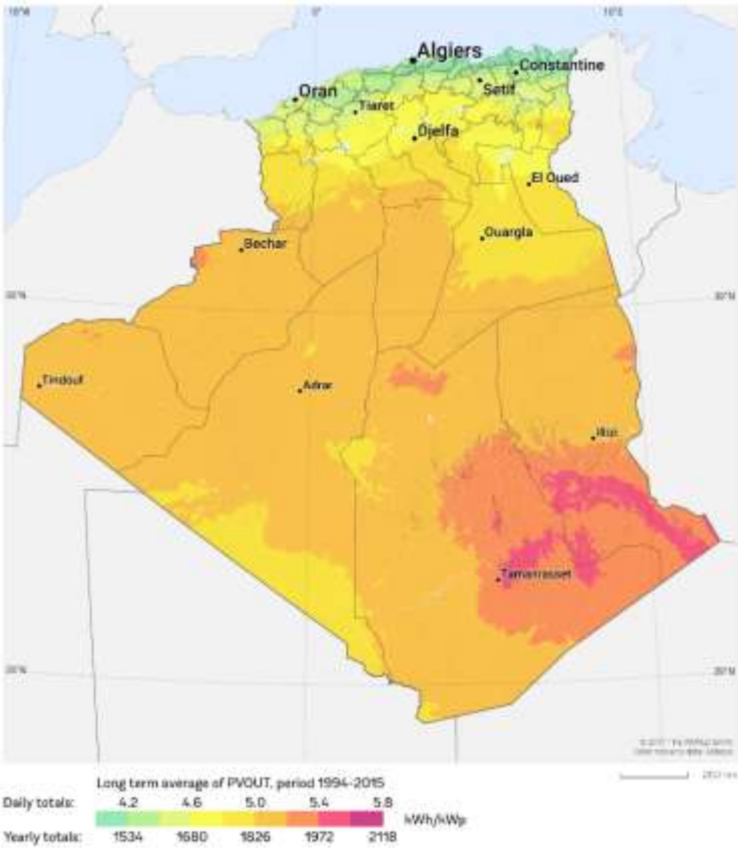
3.1 DESIGN OF THE PROPOSED PV PLANT

3.1.1 Site characteristics

In order to study the energy production, a PV system of 5MWp installed capacity was considered. Monthly Global horizontal irradiation and temperature used as input. In this study, the selected location is El oued, from the east south of Algeria; weather data of this location, such as GHI and ambient temperature are taken from (Photovoltaic geographical information system) PVGIS database.(PVGIS, 2020) As well as, an hourly timeframe is selected due to TMYx (2007-2016) standard format. PVGIS provides a geographical assessment of solar resource and performance of photovoltaic technology. It was originally developed for Europe but now has been extended to Africa and Asia.(Sengupta et al., 2015). Notably, Our choice for the Eloued university campus, are driven by the free land presented in the campus, and the Hight consumption of electricity.

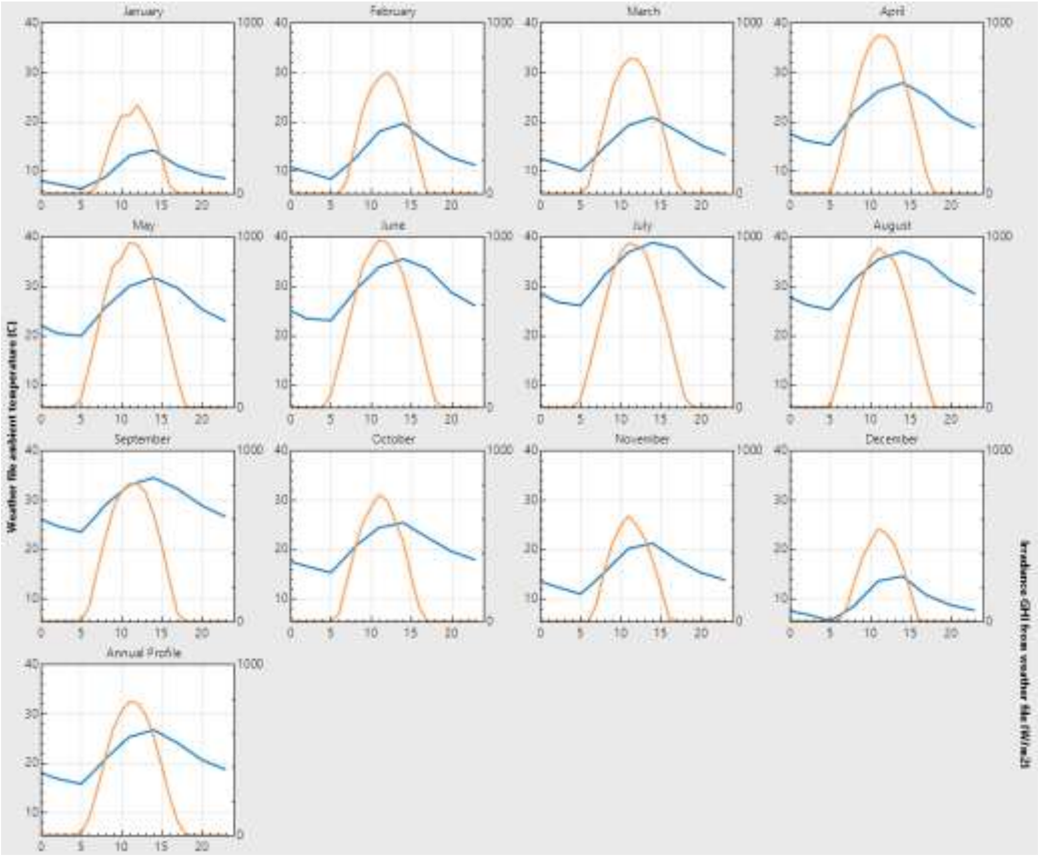
The location of El Oued is at, Latitude [°]: 33.5, Longitude [°]: 3E, Altitude [m]: 7.6. See ***Figure** 4*, which represents also the Algeria photovoltaic power potential. Moreover, the monthly Global horizontal irradiation and Ambient temperature for Eloued, are shown in ***Figure** 5*

Figure 4 Algeria photovoltaic power potential.



Source: The World Bank (2017). Solar Resource Data: Solargis. Http://Globalsolaratlas.Info

Figure 5 Monthly and annual Global horizontal irradiation and temperature of El oued



Source: SAM (2020). Autor simulation.

3.1.2 Selection Of PV Modules And Inverters

The photovoltaic module and the inverter are the two fundamental components of a photovoltaic system; the former enables the power generation and the latter enables the conversion to standard AC power.

3.1.2.1 Selection Of PV Modules

The selection of a PV module for grid connected systems are the object for the economic feasibility. As well as the site study El oued are full connected to the grid. It requires consideration regarding weighing costs against efficiencies. Since the cost has a higher importance due to the number of modules expected to be needed, mono-crystalline modules of considerably high efficiency are needed for or proposition of 5 MW PV solar plant.

Projects in Algeria are expected to have a power range of 5 MW to 10 MW, and to be spread across more than 15 preselected sites in different regions. (Emiliano, 2018). in the line of these trends, the capacity chosen for the proposed plant is 5Mwh.

For this design, a large variety of PV panel options are studied in terms of type, power, cost and warranty using Electrical Data for Sunpower Panel (*SPR-E19-310-COM)* shown in ***Table*** *1* and

Table 1 Electrical Data for Solar PV Panel SPR-E19-310-COM

Nominal Power (Pnom)	310 W
Power Tolerance	+5/–3%
Avg. Panel Efficiency	19.3%
Rated Voltage (Vmpp)	54.7 V
Rated Current (Impp)	5.67 A
Open-Circuit Voltage (Voc)	64.4 V
Short-Circuit Current (Isc)	6.05 A
Max. System Voltage	1000 V UL & 1000 V IEC
Maximum Series Fuse	15 A
Power Temp Coef.	–0.35% / °C
Voltage Temp Coef.	–176.6 mV / °C
Current Temp Coef.	2.6 mA / °C

Source: SUNPOWER (2020). Solar Data: https://us.sunpower.com

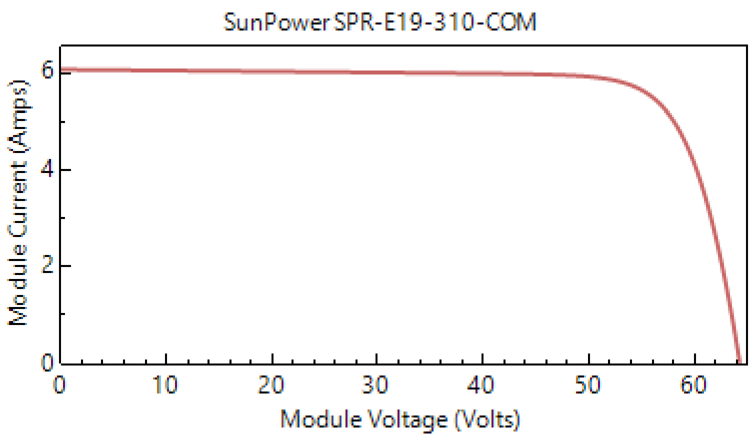
Figure 6

Table 1 Electrical Data for Solar PV Panel SPR-E19-310-COM

Nominal Power (Pnom)	310 W
Power Tolerance	+5/–3%
Avg. Panel Efficiency	19.3%
Rated Voltage (Vmpp)	54.7 V
Rated Current (Impp)	5.67 A
Open-Circuit Voltage (Voc)	64.4 V
Short-Circuit Current (Isc)	6.05 A
Max. System Voltage	1000 V UL & 1000 V IEC
Maximum Series Fuse	15 A
Power Temp Coef.	–0.35% / °C
Voltage Temp Coef.	–176.6 mV / °C
Current Temp Coef.	2.6 mA / °C

Source: SUNPOWER (2020). Solar Data: https://us.sunpower.com

Figure 6 module characteristics at references condition for Solar PV Panel ***SPR-E19-310-COM****.*



Source: SAM (2018). Autor simulation.

3.1.2.2 Selection Of Inverters

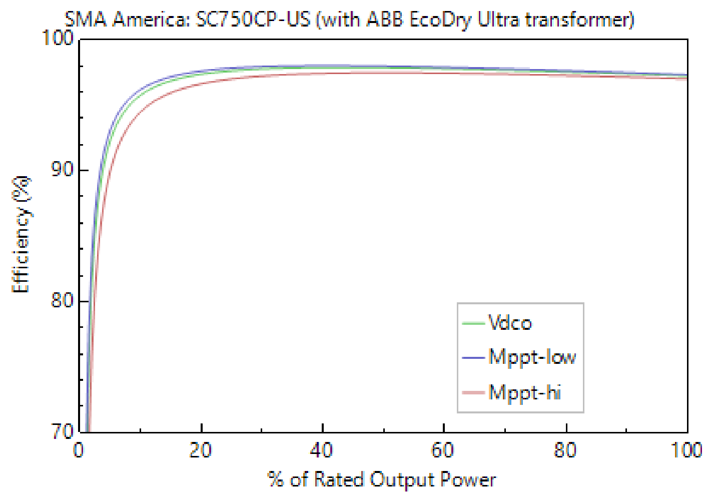
Inverters has been sized such expected power level, as compatibility with the specifications on the grid side. The calculated number of panels under our choice is 4000. These are considered to generate the desired energy of 5MW.The selected inverter Specifications (*SMA SC 2500-EV-US [550V]*), are shown in Table 2.

Table 2 Specifications for SC 750CP-US Inverter.

Input Data	
MPP voltage range	545 V_{DC} to 820 V_{DC}
Maximum DC voltage	1,000 V_{DC}
Maximum DC current	1,600 A_{DC}
Max. array short circuit current	2,596 A_{DC}
Number of DC inputs*	9
Output Data	
Continuous AC power at (+50°C)	750 kVA
Continuous AC power at (+40°C)	780 kVA
Continuous AC power at (+25°C)	825 kVA
AC current at (+50°C)	1,266 A_{AC}
AC current at (+40°C)	1,317 A_{AC}
AC current at (+25°C)	1,393 A_{AC}
Nominal AC voltage ± 10%	342 V_{AC}
Nominal power frequency	60 Hz [50 Hz]
Power frequency range	59.3 Hz to 60.5 Hz [49.3 Hz to 50.5 Hz]
Power factor cos φ	0.8 to 1
Current total harmonic distortion	< 5% (with respect to IEEE 1547)
Power Consumption	
Self-consumption in operation	< 1,800 W
Standby consumption	< 150 W
Dimensions and Weight	
Width x height x depth	(2,562 mm x 2,272 mm x 956 mm)
Weight	(1,870 kg)
Efficiency	
Maximum efficiency	98.62%
Operating temperature range	(− 25°C to +50°C)

Source: Sunpower (2020). PV Module Data: https://www.sma.de

Figure 7 *Efficiency curve of SMA SC 750CP-US Inverter.*



Source: SMAAMERICA (2020). Inverter Data: https://www.sma.de/

3.2 Reliability Analysis

A reliable power system is a generation system that has sufficient power to feed load demand in a period. In other words, a reliability analysis of solar system, based on a wellbeing approach, which is a combination of probabilistic and deterministic techniques. (Ghaedi, Abbaspour, Fotuhi-Friuzabad, & Parvania, 2014) (Huang, Wang, Zheng, Li, & Liu, 2014a).
Based on the selected inverter size the total number of inverters for the plant is 3 inverters. The calculated number of panels 4000 are divided by the number of obtained inverters i.e.3. Notably, some changes have been done for the technical and industrial characteristics, under the simulation with the System Advisor Model (SAM). See **Erreur ! Source du renvoi introuvable.**

Table 3.Summary of proposed design calculations under SAM simulation

System Overview	
peak power	5 MW
number of modules	16116
number of strings	1343
Total modules area	21.7 acres = 26,285.2 m^2
Number of strings	500
Number of modules per string	12
inverter	Central inverter MPPT TL /3 phase
no of inverter	5

Source: Author calculation under SAM

For the analysis we have adopted the SAM simulator. The System Advisor Model (SAM) developed by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL). Where it was the result of a partnership between NREL, Sandia National Laboratory, and the DOE Solar Energy Technologies Program (NREL 2010).(Gifford, Grace, & Rickerson, 2011). Generally, SAM is a performance and financial model as well as a techno-economic computer model designed to facilitate decision making for investors and researchers involved in the renewable energy: -Project managers and engineers-Financial and policy analysts-Technology developers -Researchers. (Freeman et al., 2018), (Gilman, 2015)

Furthermore, our research focus is in the financial models for projects that either buy or sell electricity at retail rates for sell electricity at a price determined in a power purchase agreement (PPA). Which is the case of latest Algeria trends launched in 2017 and 2018. with an expected price of 0.04USD. (EMW, 2017). However, in 2019 The Algerian Electricity and Gas Regulation Commission (CREG) had set a ceiling price of DZD10.24/kWh (0.079USD) for the Biskra allocation. The Ghardaïa region, which was set to have 50 MW of new solar, should have paid no more than DZD10.8/kWh (0.084USD) and Ouargla's planned 30 MW should have supplied solar electricity for no more than DZD11.16 (0.087USD). The region of El Oued expected for 10 MW facilities established at each of Tendala and Nakhla. As well as, no ceiling price was disclosed for those allocations. Notably, the Selected project will be granted a (power purchase agreement) PPA, with a duration ranging from 20 to 25 years.

3.3 Economic Analysis

3.3.1 Project Costs :

The total cost incurred in the generation of energy comprises of the initial CAPEX and annual O&M costs.

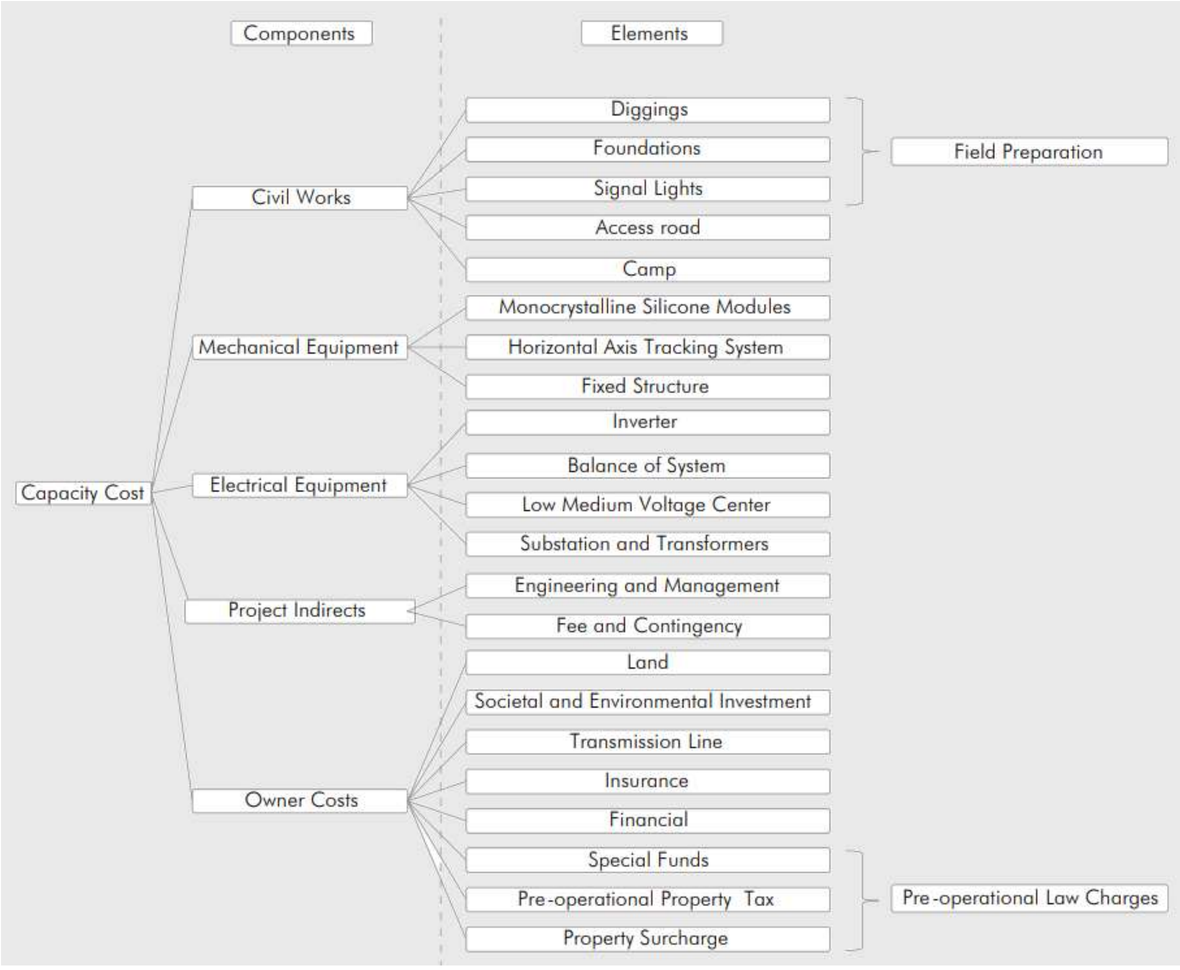
The capital costs is defined as all costs to engineer, procure, construct, and commission all equipment within the plant facility fence line. (EIA, 2016). As well as, the initial CAPEX can be separated into hardware and soft costs. Hardware costs refer to equipment and materials, civil engineering, power generation equipment, and annex buildings, while soft costs include design, permits and authorizations, and construction supervision services. Moreover, capital costs represent the total cost a developer would expect to incur during the construction of a project, excluding financing costs. (EIA, 2020)

O&M costs cover annual operations and maintenance costs of the power plant and financial services fees, such as insurance premiums. (Lee & Ahn, 2020)

3.3.2 Investment cost structure

The component cost is adapted from EIA (2013). The subsequent level is based on a 22-element structure as depicted in ***Figure*** 8 . (Castillo-Ramírez, Mejía-Giraldo, & Muñoz-Galeano, 2017), (U. Eia, 2013)

Figure 8 Investment cost structure PV large scale



Source: Castillo-Ramírez, A., Mejía-Giraldo, D., & Muñoz-Galeano, N. (2017). Large-scale solar PV LCOE comprehensive breakdown methodology. CT&F-Ciencia, Tecnología y Futuro, 7(1), 117-126.

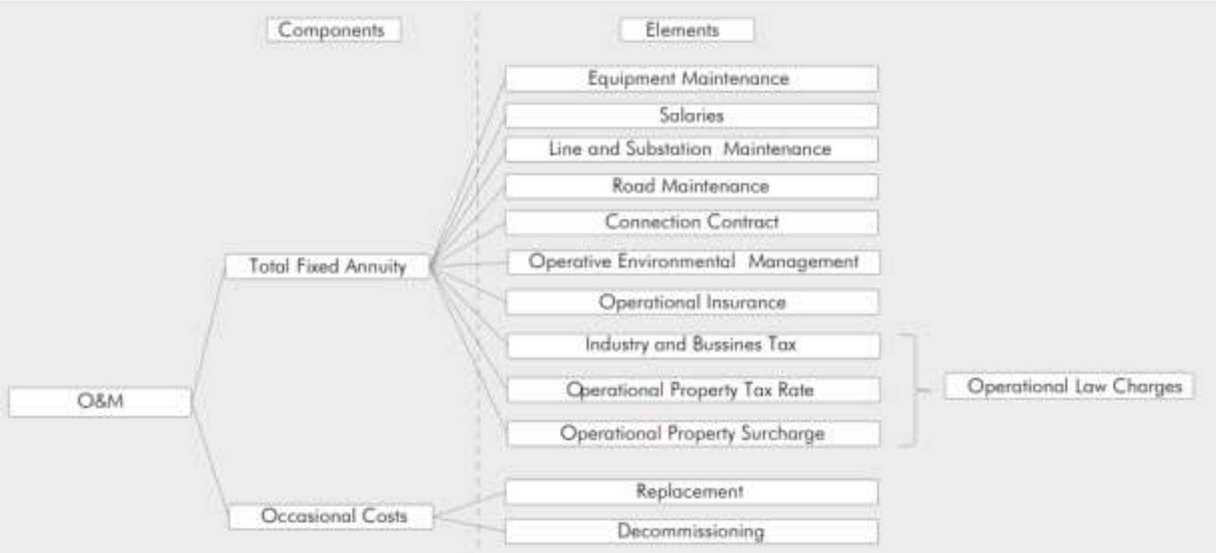
3.3.3 Operating and maintenance costs structure

The components and elements of a photovoltaic O&M costs are classified into two main categories as shown in

Figure 9 : as below

- Total Fixed Annuity (TFA), which comprises both, the equipment maintenance and complementarity costs (operational insurance and environmental management); and
- Occasional Costs (OC), such as replacement and decommissioning costs, which are expenses that must be counted in a particular period. Variable O&M costs are not considered in this study since they are negligible. (Castillo-Ramírez et al., 2017)

Figure 9 Operating and maintenance costs structure PV large scale



Source: Castillo-Ramírez, A., Mejía-Giraldo, D., & Muñoz-Galeano, N. (2017). Large-scale solar PV LCOE comprehensive breakdown methodology. CT&F-Ciencia, Tecnología y Futuro, 7(1), 117-126.

3.3.4 Financial data

The fixed financing parameters for the proposed PV plant used in simulation are given in ***Table** 4*

Table 4 Financial Parameters used in economic feasibility study

Financial data	Analysis Period	Loan Term	Loan Rate	Inflation Rate	Real Discount Rate	Nominal Discount Rate	Minimum Required IRR	Assessed Percent	Insurance Rate	Sales Tax	State Income Tax Rate
value	25	20	8	6.4	3.75	10.39	11	80	0.3	5	15

Source: (Bank of Algeria, 2020), (IRENA, 2020b)

The Equity flip structure for the proposes plant is shown in ***Table** 5*

Table 5 Equity Flip Structure for the project

Equity Flip Structure	
Tax investor share of equity (%)	80.00
Tax investor share of project cash pre-flip (%)	98.00
Tax investor share of project cash post-flip (%)	10.00
Tax investor share of tax benefits pre-flip (%)	98.00
Tax investor share of tax benefits post-flip (%)	10.00

Source: Author calculation under SAM

3.4 Levelized Cost of Energy (LCOE)

Reliability analysis generally based to attempt acceptable investment. However, economic analysis was used sometime after reliability analysis, in order to propose a system with high reliability and lowest cost. (Zhang, Zhao, Smith, Xu, & Yu, 2012) For the purpose of this study, the LCOE analysis of solar PV, the major variables that determine the economics of power generation are the generation amount of power and cost. However, these two variables fluctuate significantly and contain uncertain factors related to the solar radiation amount, technological advancement, and market conditions. The LCOE ($/kWh) defined as the average cost per kWh of useful electrical energy produced by the system when a lifetime, investment cost, replacement, operation and maintenance, and capital cost is considered. (Hengevoss, Baumgartner, Nisato, & Hugi, 2016), (Darling, You, Veselka, & Velosa, 2011).

In another word the LCOE The PV LCOE here includes all the costs and profit margins of the whole value chain including manufacturing, installation, project development, operation and maintenance (O&M), and inverter replacement. (Vartiainen, Masson, Breyer, Moser, & Román Medina, 2020). Moreover, Residual value of the PV system and dismantling cost is set as zero here. For the time being, there is no agreed price neither for the value of second-hand modules not for the income from recycling.

LCOE is calculated by dividing the produced electricity annualized cost on the total useful electrical energy generated. (Dale, 2013) The mathematical model used to calculate LCOE is as follows. (Alsadi & Khatib, 2018)

$$\mathrm{LCOE} = \frac{\sum_{n=1}^{N} \frac{I_n + O_n}{(1+r)^n}}{\sum_{n=1}^{N} \frac{P_n}{(1+r)^n}}$$

where N is economical lifetime of the system, I_n is the investment cost in year n, O_n is the maintenance and operational cost (O&M) in year n, P_n is the electricity production in year n, and r is the discount rate.

Furthermore, The LCOE is affected by construction costs, operations and maintenance costs, the lifespan of the power plant, power generation technology, energy efficiency, system degradation rates, inflation and interest rates, and corporate taxes. The formula for calculating the LCOE may be defined as follows: (Clauser & Ewert, 2018),

$$LCOE_t = \frac{CAPEX_t + \sum_{n=1}^{T} \frac{OM_n + FC_n}{(1+r)^n}}{\sum_{n=1}^{T} \frac{(1-d)^n \times CF \times 365(days) \times 24(hours) \times Capacity}{(1+r)^n}}$$

In the above formula, $CAPEX_t$ refers to initial investment, which include equipment and materials, the construction of structures, grid connection, permits, design, supervision, and inspection at time t. Indirect costs, OM_n, are the O&M costs at time n; FC_n, the finance costs at time n; r, the discount rate; d, the degradation rate; CF, the capacity factor; capacity, the energy generating capacity of the power plant; and T, the operation period of the power plant. that is interest cost due to debt.

4 RESULTS AND DISCUSSIONS

Several parameters were considered in the analyse of the economic feasibility of 5 MW PV system. These include the total investment cost, the fixed operating costs, of maintenance, repair and use, the price of guaranteed purchase offered by the government and the increase in energy price.

The final system design is performed using the System Advisor Model (SAM) simulation software. for analysing the potential of a photovoltaic system at the chosen location. El Oued university campus. **Erreur ! Source du renvoi introuvable.***Table 6*

Table 6 *SAM economic results for the 5Mw PV project*

Metric	Value
Annual energy (year 1)	9,047,248 kWh
Capacity factor (year 1)	20.70%
Energy yield (year 1)	1,810 kWh/kW
Performance ratio (year 1)	0.78
PPA price (year 1)	10.00 ¢/kWh
PPA price escalation	1.00 %/year
Levelized PPA price (nominal)	10.76 ¢/kWh
Levelized PPA price (real)	5.98 ¢/kWh
Levelized COE (nominal)	9.88 ¢/kWh
Levelized COE (real)	5.49 ¢/kWh
Investor IRR in flip year	25.23%
Flip year	1
Investor IRR at end of project	29.37%
Investor NPV over project life	$271,609
Developer IRR at end of project	67.39%
Developer NPV over project life	$544,618
Net capital cost	$6,772,522
Equity	$1,773,721
Debt	$4,998,801
Minimum DSCR	0.58

Source: Author calculation under SAM

Furthermore, ***Figure** 10* shows a total potential energy that could be harvested for each month of the year totalling a potential of 9,047,248 kWh MWh/year. The Energy injected into the grid per year also shown in ***Table* 7** For the year 1.

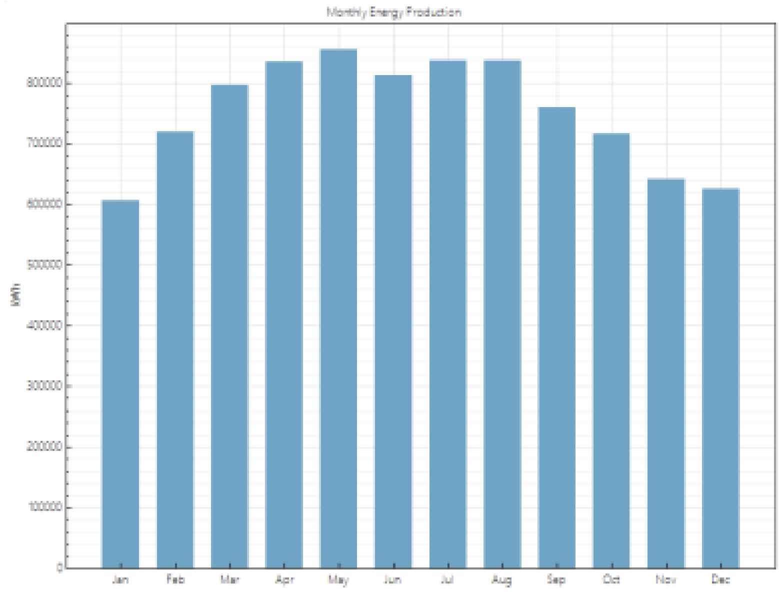
Table 7 System AC and DC energy production

Time stamp	System AC energy | (kWh/mo)	PV array DC energy | (kWh/mo)
Jan	606190	635347
Feb	720483	777638
Mar	797249	857474
Apr	835969	886557
May	855559	896258
Jun	813067	843946
Jul	836914	867225
Aug	837475	869550
Sep	759881	788238
Oct	716692	746645
Nov	641569	668668
Dec	626200	652320

Source: Author calculation under SAM

The simulation clearly shows that the efficiency of photovoltaic panels decreases in summer season. (June for example), This is explained by the fact that the solar cells lose energy through heat. In fact, that part of energy of solar cells is lost i.e. Consumed by cells instead of producing energy.

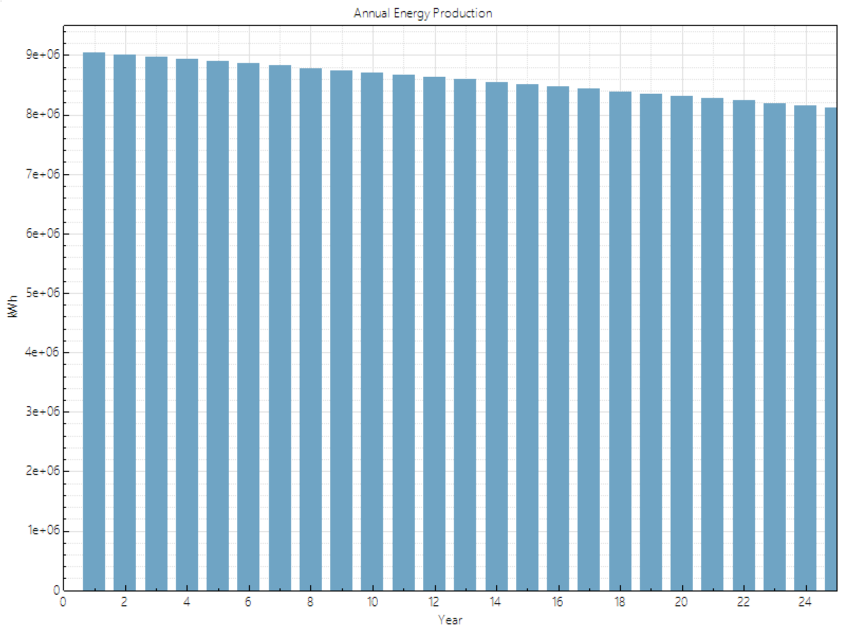
Figure 10 Monthly Energy Production



Source: Author calculation under SAM

***Figure** 11* also depicts the effective energy at the output of the plant per year, with a percentage efficiency of the system, which is found to be 20.70%.

Figure 11 Annual Energy Production



Source: Author calculation under SAM

5 CONCLUSION

This paper has presented a design modelling and simulation as well as technical and economic potential of utility-scale of solar PV grid-connected electricity generation plant of 5MW in El Oued state (southern east of Algeria). Simulations of the designed system is performed with SAM. It is used to obtain information on energy production, efficiency of system and energy loss by PV grid connected system.

The Levelized COE (real), found to be 5.49 ¢/kWh, As well as, the Levelized COE (nominal) 9.88 ¢/kWh, coupled with a positive net present value for the investor and the developer. Above all, we can say that the project is economically feasible referring to the latest tenders launched by the Algerian authorities, in different sites, with LCOE of 7.9 ¢/kWh and 8.4 ¢/kWh.

The PV grid connected system operates and demonstrates that how much energy is produced and what are the losses, as a way forward to indicate the profitability of the system.

Finally, the study demonstrates that the plant's annual performance is 78%. The simulation results show that annual electricity generation of the proposed solar PV plant is 9,047,248 kWh of useful AC electricity. This is sufficient energy to reduce load shedding or to power water distillation plant capable of producing drinking water for el Oued inhabitants.

In addition, the overall annual CO_2 reduction in the lifecycle of System It is obvious that PV system as a future candidate is an effective tool to replace the conventional power generation and capable to combat climate change. Taking into account the simulation results and the actual price of renewable energy equipment, the system has very high cost and still unfeasible without the incentives of the competent authorities. Turning to solar power would help Algeria meet the growing demand for electricity and save gas production for export purposes.

6 BIBLIOGRAPHY

1. Abada, Z., & Bouharkat, M. (2018). Study of management strategy of energy resources in Algeria. *Energy Reports, 4*, 1-7.
2. Alsadi, S., & Khatib, T. (2018). Photovoltaic power systems optimization research status: A review of criteria, constrains, models, techniques, and software tools. *Applied sciences, 8*(10), 1761.
3. Anuta, H., Ralon, P., Taylor, M., & La Camera, F. (2019). Renewable power generation costs in 2018. *International Renewable Energy Agency, Abu Dhabi*.
4. BP. (2017). *BP Statistical Review of WorldEnergy 2016*. Retrieved from London, UK: https://www.bp.com/
5. Burger, S. (2012). Desertec: A Fata Morgana? *Africa Policy Journal, 8*, 52-53.
6. Callaghan, W., & McDonald, R. (1986). *Flat-Plate Solar Array Project: Final report: Volume 1, Executive summary*. Retrieved from
7. Castillo-Ramírez, A., Mejía-Giraldo, D., & Muñoz-Galeano, N. (2017). Large-scale solar PV LCOE comprehensive breakdown methodology. *CT&F-Ciencia, Tecnología y Futuro, 7*(1), 117-126.
8. Clauser, C., & Ewert, M. (2018). The renewables cost challenge: Levelized cost of geothermal electric energy compared to other sources of primary energy–Review and case study. *Renewable and Sustainable Energy Reviews, 82*, 3683-3693.
9. Co-operation, O. f. E., & Development. (1998). *21st century technologies: promises and perils of a dynamic future*: OECD Publishing.
10. Dale, M. (2013). A comparative analysis of energy costs of photovoltaic, solar thermal, and wind electricity generation technologies. *Applied sciences, 3*(2), 325-337.
11. Darling, S. B., You, F., Veselka, T., & Velosa, A. (2011). Assumptions and the levelized cost of energy for photovoltaics. *Energy & environmental science, 4*(9), 3133-3139.
12. DLR. (2009). *Characterisation of Solar Electricity Import Corridors from MENA to Europe - Potential, Infrastructure and Cost*. Retrieved from Germany https://www.dlr.de/tt/Portaldata/41/Resources/dokumente/institut/system/publications/Solar_import_DLR_2009_07.pdf
13. EIA. (2016). *Capital cost estimates for utility scale electricity generating plants*. Retrieved from https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capcost_assumption.pdf

14. EIA. (2020). *Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generating Technologies*. Retrieved from Washington, DC 20585: https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capital_cost_AEO2020.pdf
15. Eia, U. (2013). Updated capital cost estimates for utility scale electricity generating plants. *US Energy Inf. Adm, 524*.
16. Emiliano, B. (2018). Algeria set to resume plans for large-scale solar with strong local content commitment. *PV MAGAZINE*. Retrieved from https://www.pv-magazine.com/2020/05/29/algeria-plans-4-gw-of-solar-tenders/
17. EMW. (2017, 05/06/
18. 2017 May 06). Algerian government expects reference price of $0.04/kWh for 4 GW solar tender. *Energy Monitor Worldwide*.
19. Fateh, S., & Khalida, A. (2018). *Analitycal review of renewable energies framework in Algeria: Financing schemes and funds.* Paper presented at the 2018 9th International Renewable Energy Congress (IREC).
20. Fong, A., & Tippett, J. (2012). *Project development in the solar industry*: CRC Press.
21. Freeman, J. M., DiOrio, N. A., Blair, N. J., Neises, T. W., Wagner, M. J., Gilman, P., & Janzou, S. (2018). *System Advisor Model (SAM) General Description (Version 2017.9. 5)*. Retrieved from
22. Ghaedi, A., Abbaspour, A., Fotuhi-Friuzabad, M., & Parvania, M. (2014). Incorporating Large Photovoltaic Farms in Power Generation System Adequacy Assessment. *Scientia Iranica, 21*(3), 924-934.
23. Gifford, J. S., Grace, R. C., & Rickerson, W. H. (2011). *Renewable Energy Cost Modeling: A Toolkit for Establishing Cost-Based Incentives in the United States; March 2010--March 2011*. Retrieved from
24. Gilman, P. (2015). *SAM photovoltaic model technical reference*. Retrieved from
25. Hengevoss, D., Baumgartner, C., Nisato, G., & Hugi, C. (2016). Life Cycle Assessment and eco-efficiency of prospective, flexible, tandem organic photovoltaic module. *Solar Energy, 137*, 317-327.
26. Huang, K., Wang, X., Zheng, Y. H., Li, L. X., & Liu, Y. L. (2014a). *Reliability Analysis of Distribution Network with Integrated Photovoltaic Power Generation.* Paper presented at the Applied Mechanics and Materials.
27. Huang, K., Wang, X., Zheng, Y. H., Li, L. X., & Liu, Y. L. (2014b). Reliability Analysis of Distribution Network with Integrated Photovoltaic Power Generation. *Applied Mechanics and Materials, 672-674*, 956-960. doi:http://dx.doi.org/10.4028/www.scientific.net/AMM.672-674.956
28. IEA. (2019). *Renewables 2019-Market analysis and forecast from 2019 to 2024*. Retrieved from Paris: https://www.iea.org/reports/renewables-2019
29. IRENA. (2018). *Renewable power generation costs in 2017*. Retrieved from Abu Dhabi: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_2017_Power_Costs_2018.pdf
30. IRENA. (2019). FUTURE OF SOLAR PHOTOVOLTAIC Deployment, investment, technology, grid integration and socio-economic aspects. (International Renewable Energy Agency (IRENA), Abu Dhabi).
31. IRENA. (2020a). *Renewable capacity statistics 2020*. Retrieved from Abu Dhabi: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Mar/IRENA_RE_Capacity_Statistics_2020.pdf
32. IRENA. (2020b). *Renewable power generation costs in 2019. Report*
33. Retrieved from
34. Kabir, E., Kumar, P., Kumar, S., Adelodun, A. A., & Kim, K.-H. (2018). Solar energy: Potential and future prospects. *Renewable and Sustainable Energy Reviews, 82*, 894-900.
35. Klein, D., Carazo, M. P., Doelle, M., Bulmer, J., & Higham, A. (2017). *The Paris Agreement on climate change: Analysis and commentary*: Oxford University Press.
36. Lee, C.-Y., & Ahn, J. (2020). Stochastic Modeling of the Levelized Cost of Electricity for Solar PV. *Energies, 13*(11), 3017.
37. Maafi, A. (2000). A survey on photovoltaic activities in Algeria. *Renewable Energy, 20*(1), 9-17.
38. Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P., . . . Pidcock, R. (2018). *Global Warming of 1.5 OC: An IPCC Special Report on the Impacts of Global Warming of 1.5° C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*: World Meteorological Organization Geneva, Switzerland.
39. MF. (2016). *Le nouveau modele de croissance (synthese)*. algerie: Ministère des Finances Retrieved from http://www.mf.gov.dz/article_pdf/upl-be15d6d0e0ffa387bfb08d8f5d8698ab.pdf.
40. Mihoub, S., Chermiti, A., & Beltagy, H. (2017a). Methodology of determining the optimum performances of future concentrating solar thermal power plants in Algeria. *Energy, 122*, 801-810.
41. Mihoub, S., Chermiti, A., & Beltagy, H. (2017b). Methodology of determining the optimum performances of future concentrating solar thermal power plants in Algeria. *Energy, 122*, 801.

42. OBG. (2017). *The Report : Algeria 2017*. Retrieved from https://oxfordbusinessgroup.com/
43. PMS. (2017). *Government action plan for the implementation work of the president of the republic's program*. Algeria prime minister's services Retrieved from http://www.premier-ministre.gov.dz/ressources/front/files/pdf/plans-d-actions/plan-d-action-du-gouvernement-2017-fr.pdf.
44. PVGIS. (2020). Retrieved from https://ec.europa.eu/jrc/en/pvgis
45. Sengupta, M., Habte, A., Kurtz, S., Dobos, A., Wilbert, S., Lorenz, E., . . . Myers, D. (2015). Best practices handbook for the collection and use of solar resource data for solar energy applications.
46. Smalley, R. E. (2005). Future global energy prosperity: the terawatt challenge. *Mrs Bulletin, 30*(6), 412-417.
47. Stambouli, A., Khiat, Z., Flazi, S., & Kitamura, Y. (2012). A review on the renewable energy development in Algeria: Current perspective, energy scenario and sustainability issues. *Renewable & Sustainable Energy Reviews, 16*(7), 4445-4460. doi:http://dx.doi.org/10.1016/j.rser.2012.04.031
48. Stambouli, A. B., Benmessaoud, M. T., Flazi, S., Yamaguchi, S., Itaka, K., Sumiya, M., & Koinuma, H. (2017). The prospect of the sahara solar energy research centre in algeria as the first stage of the sahara solar breeder initiative and a proposal for the second stage *. *Current Politics and Economics of Africa, 10*(4), 419-449.
49. Trieb, F., O'Sullivan, M., Pregger, T., Schillings, C., & Krewitt, W. (2009). Characterisation of solar electricity import corridors from MENA to Europe.
50. UNFCCC. (2015). *Intended nationally determined contribution INDC-Algeria*. Retrieved from https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Algeria/1/Algeria%20-%20INDC%20(English%20unofficial%20translation)%20September%2003,2015.pdf
51. Vartiainen, E., Masson, G., Breyer, C., Moser, D., & Román Medina, E. (2020). Impact of weighted average cost of capital, capital expenditure, and other parameters on future utility‐ scale PV levelised cost of electricity. *Progress in Photovoltaics: Research and Applications, 28*(6), 439-453.
52. Zhang, X., Zhao, X., Smith, S., Xu, J., & Yu, X. (2012). Review of R&D progress and practical application of the solar photovoltaic/thermal (PV/T) technologies. *Renewable and Sustainable Energy Reviews, 16*(1), 599-617.