Economics Feasibility of 1 MW Solar Photovoltaics Project Case study of El Oued

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Abstract :

The purpose of this paper is to analyze the feasibility of economics and performance of a small-scale PV systems in the state of El Oued from Algeria Sahara region. Moreover, the selected locations are El Oued in the south of Algeria, considering that 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 addition, this study explores the current policies and conditions of the small-scale solar PV projects in Algeria, bringing significant benefits to the different entities, namely policy makers, investors and researchers working in the field of solar phototactic energy.

Furthermore, the feasibility of the solar photovoltaic project is analyzed considering the economic aspects such as the photovoltaic system, capital investment cost and the annual power generation cash flow. As well as giving a reliability and financial analysis, we have used the System Advisor Model, (SAM), which is a techno-economic model designed to makes performance predictions and cost of energy estimates for grid-connected power projects based on installation and operating costs and system design parameters that we specify as inputs to the model. to calculate principally the levelized cost of energy of the project, over the analysis period.

Keywords: *Solar Photovoltaics, Economics Feasibility, performance, the levelized cost of energy.*

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

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1 INTRODUCTION

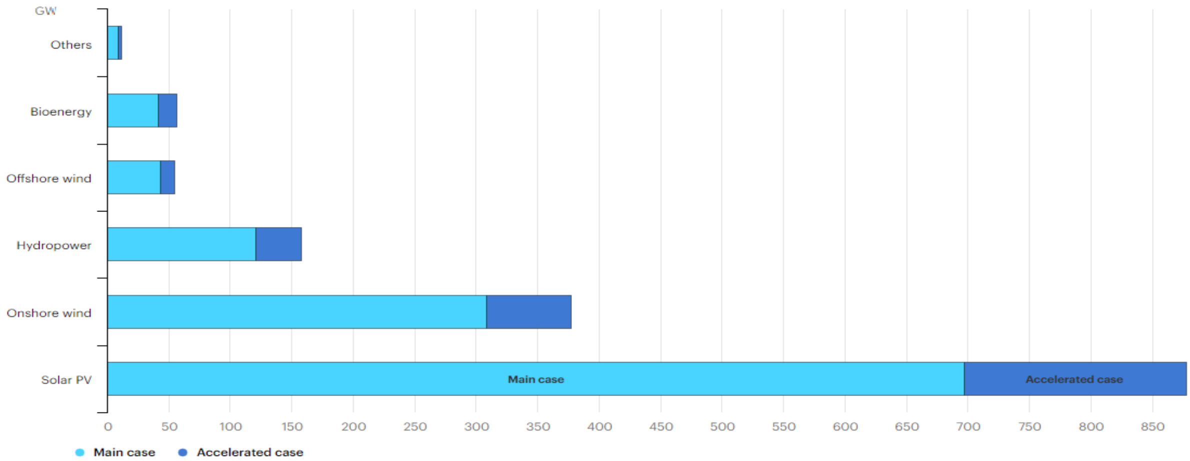
Significantly, it has been expected that Solar photovoltaic (PV) will play from the beginning of the century, one of the most important of these challenge keys, Due to its rapid technological development. (Co-operation & Development, 1998).

Consequently, a considerable effort is 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, 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)

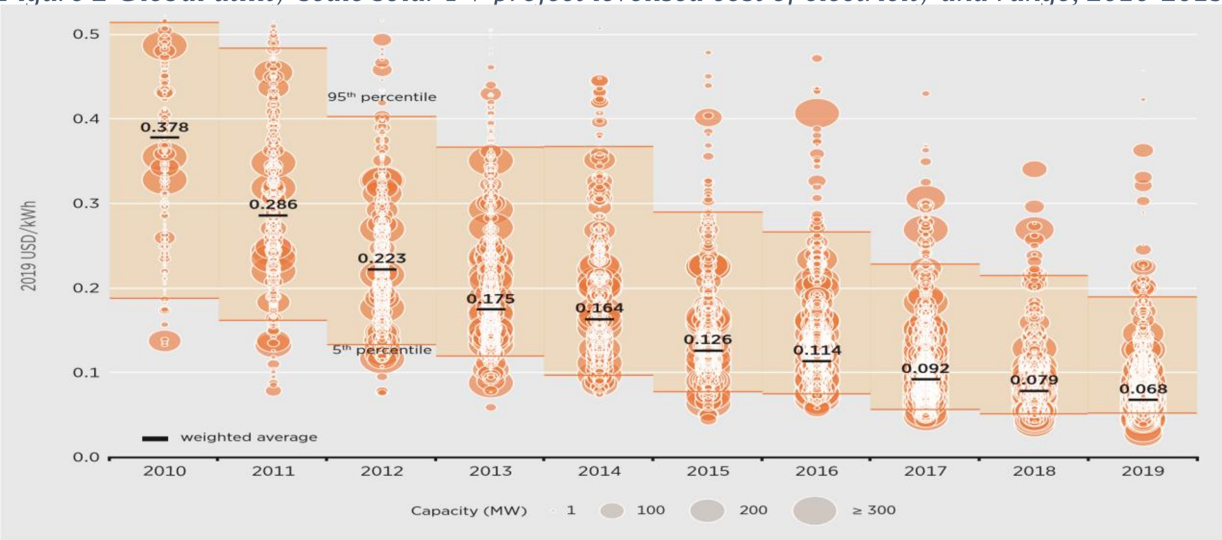


Source: IEA. (2019). Renewables 2019-Market analysis and forecast from 2019 to 2024. https://www.iea.org

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 groundmounted 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

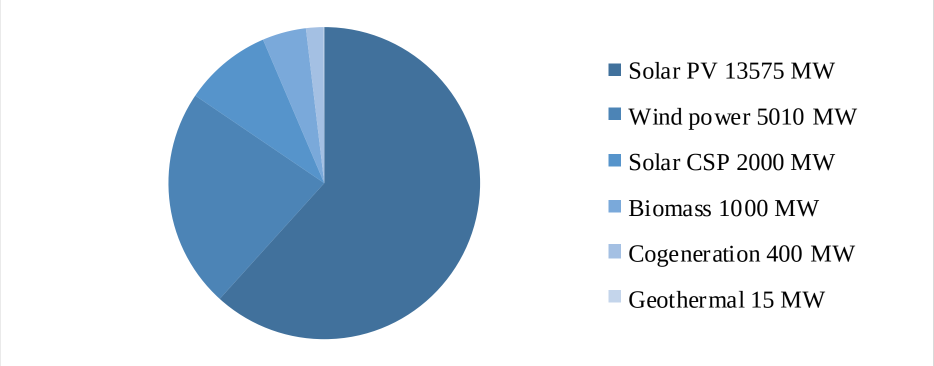
Furthermore, Solar panels have improved substantially in their efficiency and power output over the last few decades. In 2018, the efficiency of multi-crystalline PV reached 17%, while that of mono-crystalline reached 18%. This positive trend is expected to continue through to 2030. Yet, as the global 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 A REVIEW OF RENEWABLE ENERGIES IN ALGERIA

It is important to note that 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.[1] [2]

The Renewable Energy and Energy Efficiency Development Plan, launched with its first version in 2011 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 (€100.1bn) 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%. [3] 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.[4]

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



Source: Renewable energy development center - Algeria. CDER (2018). http://portail.cder.dz

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.[5]

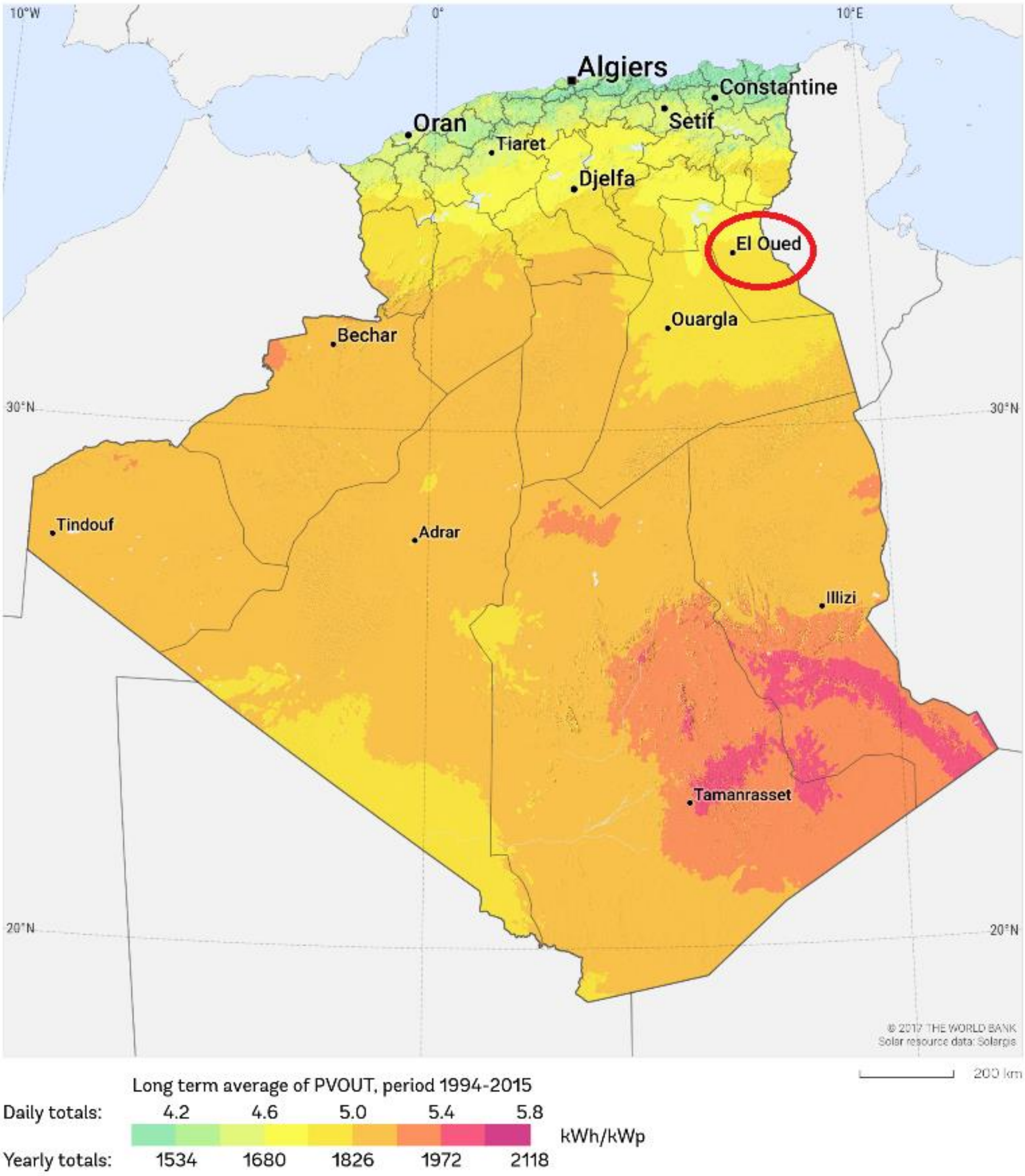
3 DESIGN OF THE PROPOSED PV PLANT

3.1 Site characteridtics

The selected location for this study is El oued, situated in the south of Algeria; weather data of this location, such as GHI and ambient temperature are taken from NREL database; an hourly timeframe is selected due to TMYx(2003-2017) standard format. TMYx files are derived from ISD (US NOAA's Integrated Surface Database) with hourly data through 2017.and files are created from NSRDB (National Solar Radiation Database from NREL: National Renewable Energy Laboratory).[6]

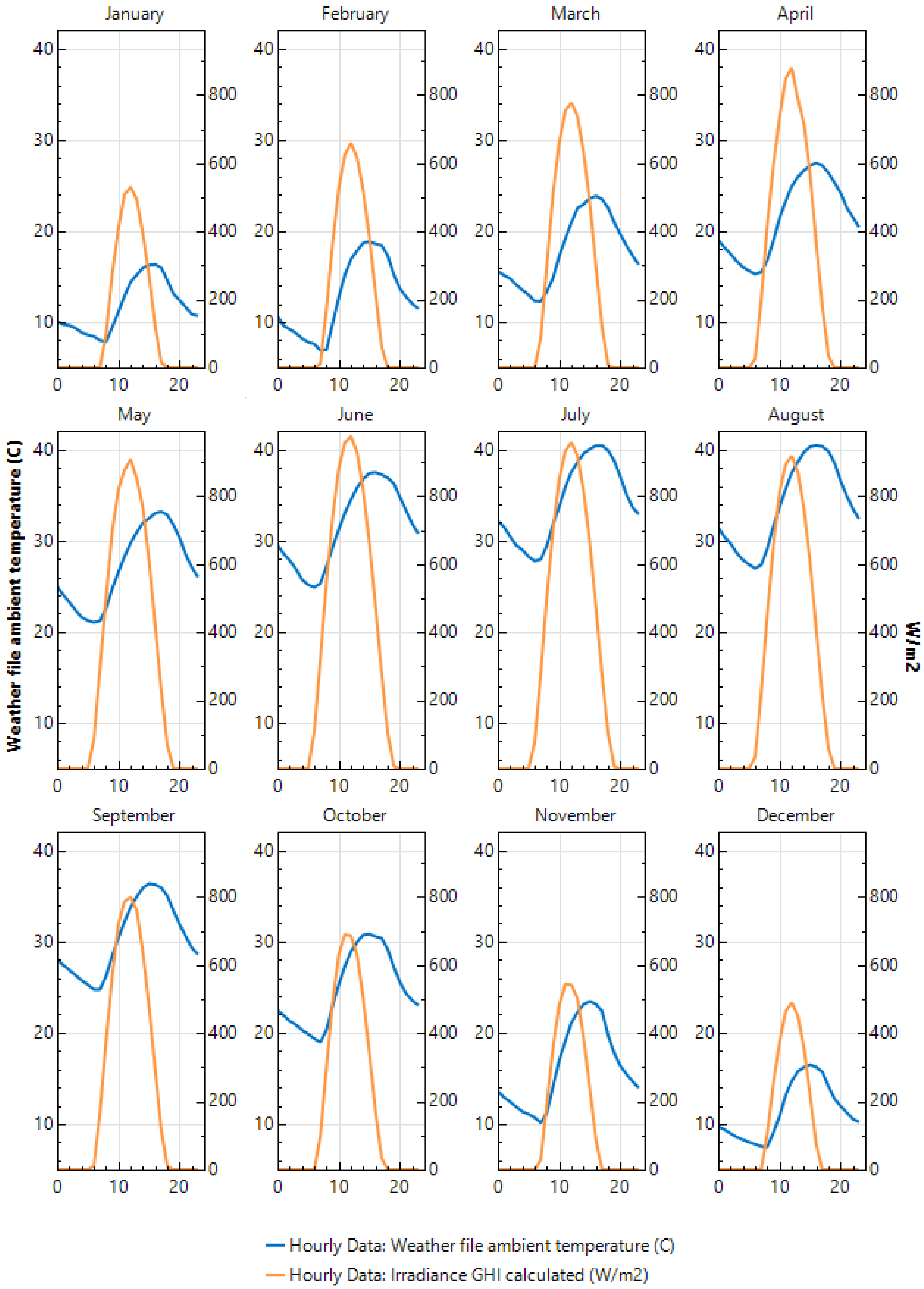
The location of El Oued is at, Latitude [°]: 33.5, Longitude [°]: 3E, Altitude [m]: 7.6. See *Figure* **,** which represents also the Algeria photovoltaic power potential. Moreover, the monthly Global horizontal irradiation and Ambient temperature for Eloued, are shown in *Figure 5 5*

Figure 4 Algeria photovoltaic power potential.



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

Figure 5 Monthly Global horizontal irradiation and temperature of El oued



Source: SAM (2018). Autor Simulation.

3.2 Selection Of Pv Modules And Inverters

- ***Selection Of Pv Modules***

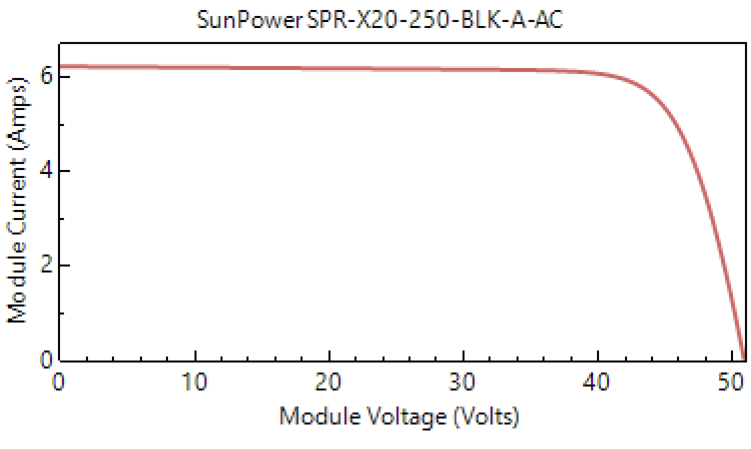
The selection of a PV module for grid connected systems are the object for the economic feasibility. As well as the site study El oued are full connected to the grid. It requires consideration regarding weighing costs against efficiencies. Since the cost has a higher importance due to the number of modules expected to be needed, mono-crystalline modules of considerably high efficiency are needed for or proposition of 1MW PV solar plant. 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-X20-250* shown in *Table 1* and *Figure*

Table 1 Electrical Data for Solar PV Panel SPR-X20-250

Nominal efficiency	20.0926	%
Maximum power (Pmp)	249.952	Wdc
Max power voltage (Vmp)	42.8	Vdc
Max power current (Imp)	5.8	Adc
Open circuit voltage (Voc)	50.9	Vdc
Short circuit current (Isc)	6.2	Adc

Source: NREL (2018).GO Solar California Data:
https://www.gosolarcalifornia.org/equipment/pv_modules.php

Figure 6 module characteristics at references condition for Solar PV SPR-X20-250.



Source: SAM (2018).Autor simulation.

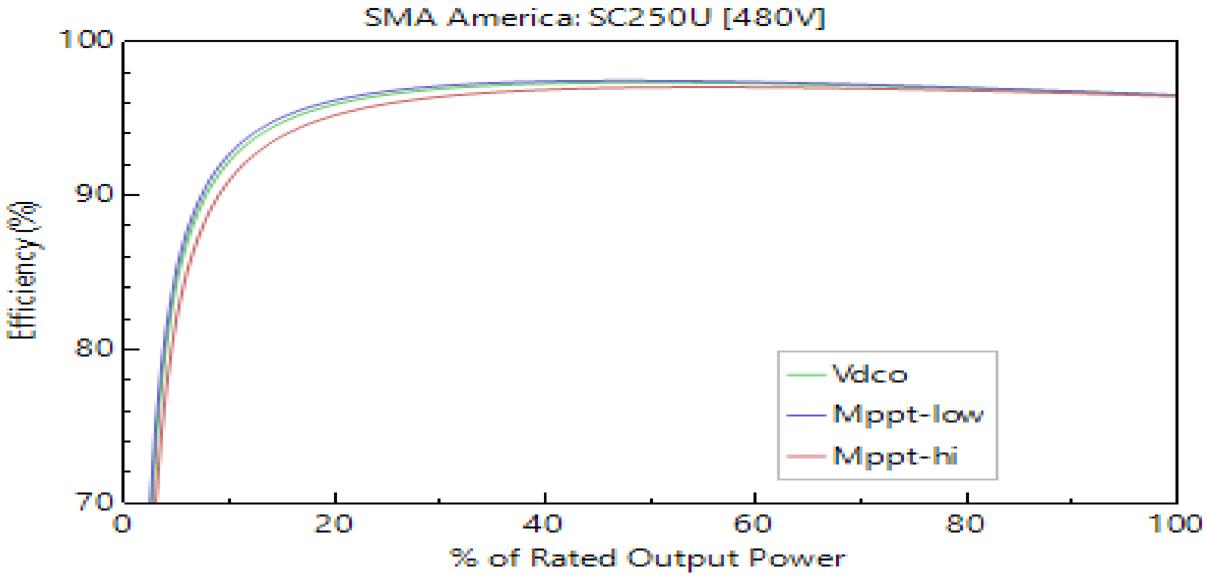
3.3 Selection Of Inverters

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 1MW.The selected inverter Specifications (*SMA SC 250U[480V]*), are shown in Table 2.

Table 2 ***Specifications SMA SC 250U[480V Inverter.***

Input data	
Max. PV power (recommended)	295 kW
DC voltage range MPPT	330 V – 600 V
PV start voltage (Configurable from 300 – 600 V)	400 V
Max. permissible DC voltage	600 V
Max. permissible DC current	800 A
Number of DC inputs / connection point	6 / DC fuse
Output data	
Nominal AC output power	250 kW
Operating grid voltage	480 V WYE / Δ*
Nominal AC current	300 A (@ 480 V)
AC frequency (nominal)	60 Hz
Power factor	> 0.99
Harmonic distortion of grid current	< 5%
Power consumption	
Internal consumption in operation	< 1000 W
Internal consumption in Standby	< 69 W
Mechanics	
Width / height / depth (in)	110 / 80 / 33
Weight	4200 lbs
Efficiency	
Peak efficiency	97.5%
CEC weighted efficiency	97.0%
Euro-Eta	96.6%
Permits	
Certificates	UL 1741, UL 1998, IEEE 1547
EMC	FCC Part 15 Class A
Ambient conditions	
Ambient temperature	-4 °F to 113 °F
Max. Temperature for $_{Pnom}$	113 °F
Enclosure	NEMA 3R
Rel. humidity	15% ... 95%
Interfaces	
Display	LCD
Communication (Sunny WebBox, optional)	Ethernet, analog, GSM
Connection Sunny String-Monitor U	RS485
System monitoring	Sunny Portal
*Quarter 1, 2010	
Type designation	SC 250U

Figure 7 Efficiency curves and characteristics for SMA SC 250U[480V] Inverter



Source: SAM (2018).Autor simulation.

4 RELIABILITY ANALYSIS

It is technically known, that a reliable power system is a generation system that has sufficient power to feed load demand in a period.[7] In other words, a reliability analysis of solar system, based on a wellbeing approach, which is a combination of probabilistic and deterministic techniques.[8] 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 Table 2

Table 2. ***Summary of proposed design calculations under SAM simulation***

System Overview	
peak power	1 MW
number of modules	4000
number of strings	500
Total modules area	4,976.0 m^2
Number of strings	500
Number of modules per string	9
inverter	Central inverter MPPT TL /3 phase
no of inverter	3
Area required	4.1 acres = 4,976.0 m^2

Source: Author calculation under SAM

For the analysis we choose the SAM simulator. (the System Advisor Model (SAM) developed by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL)). 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.[9] 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.[10] the Selected project will be granted a PPA with a duration ranging from 20 to 25 years, while solar PV 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.[11]

5 ECONOMIC ANALYSIS

5.1 Financial data

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

Table 3 Financing Parameters used in economic feasibility

Financing 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

5.2 Economic feasibility

Economic feasibility analyses for PV systems used in past years are Net Present Cost (NPC), Levelized Cost of Energy (LCOE), and Life Cycle Cost (LCC). Economic 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. [12] at an interest rate or internal rate of return (IRR). [13]

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.[14]

LCOE is calculated by dividing the produced electricity annualized cost on the total useful electrical energy generated.[15] The mathematical model used to calculate LCOE is as follows. [16]

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

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.

6 RESULTS AND DISCUSSIONS

Several parameters were considered in the analyze of the economic feasibility of 1 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 analyzing the potential of a photovoltaic system at a known location.

Table 3 SAM economic results *Figure 4* ***Monthly Energy Production***

Figure 3 shows a number of elements depicting the total potential energy that could be harvested for each month of the year totaling a potential of 187154MWh/year. The Energy injected into the grid per year also shown in this figure and is found to be about 39472006,00MWh. Moreover *Table 3* SAM economic results *Figure 4* ***Monthly Energy Production***

As well as depicts the effective energy at the output of the array, percentage efficiency of the array and percentage efficiency of the system, which is found to be 178154MWh, 16.69% and 16.19% respectively.

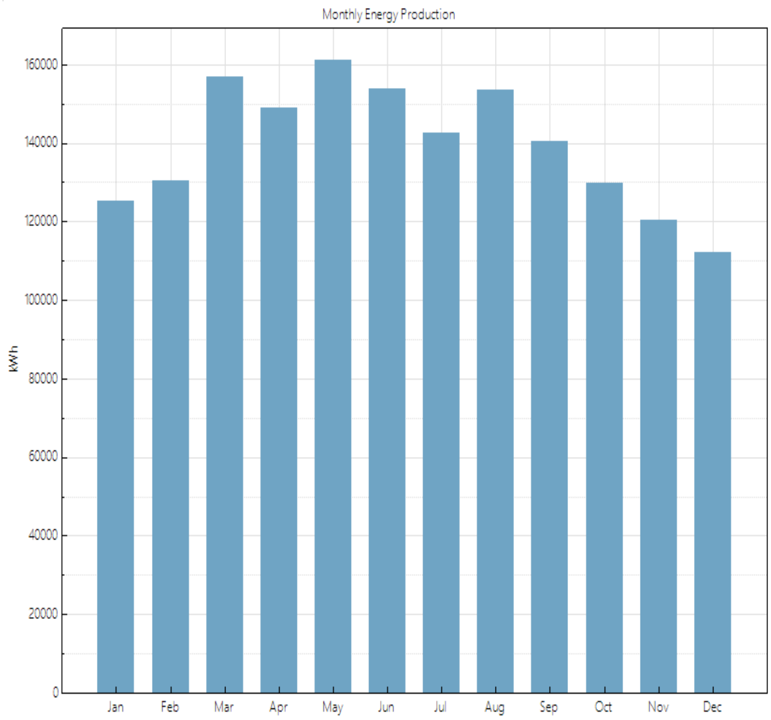
Moreover, the value of LCOE of the project is so Hight, taking into account the price of electricity in Algeria of about 4 cents, which is incomparable with other project in the world, we have to say that the projects for small solar photovoltaic need more enhance and financial facilities to improve its feasibility and performance

Table 3 SAM economic results

Metric	Value
Annual energy (year 1)	1,675,670 kWh
Capacity factor (year 1)	19.1%
Energy yield (year 1)	1,676 kWh/kW
Performance ratio (year 1)	0.75
PPA price (year 1)	12.20 ¢/kWh
PPA price escalation	0.00 %/year
Levelized PPA price (nominal)	12.20 ¢/kWh
Levelized PPA price (real)	6.79 ¢/kWh
Levelized COE (nominal)	11.89 ¢/kWh
Levelized COE (real)	6.62 ¢/kWh
Net present value	$43,072
Internal rate of return (IRR)	11.00 %
Year IRR is achieved	20
IRR at end of project	12.46 %
Net capital cost	$1,595,495
Equity	$671,895
Size of debt	$923,600

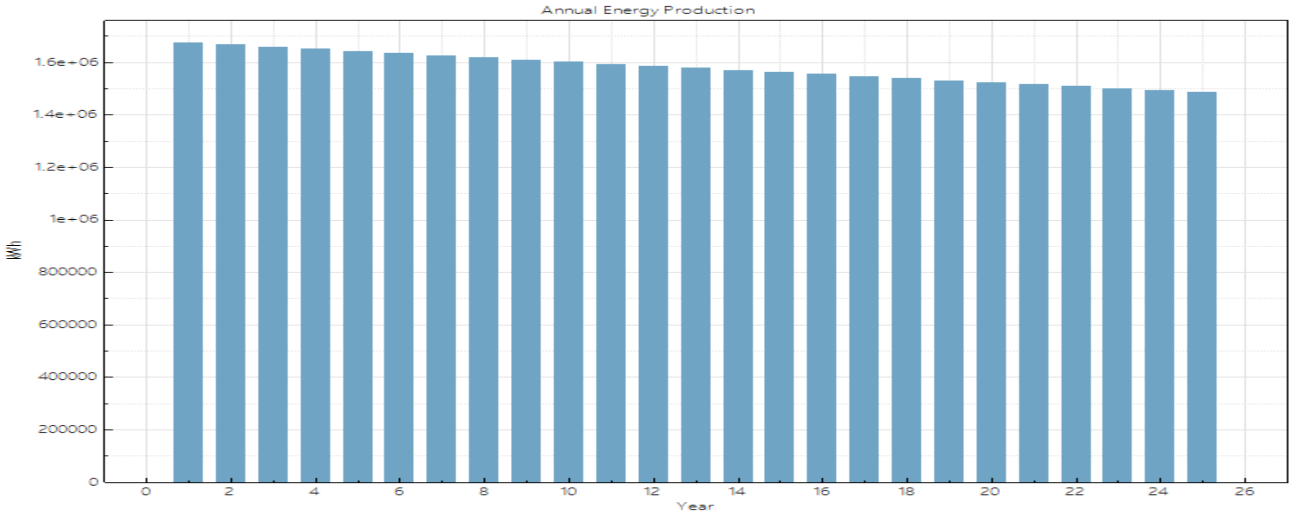
Source: Author calculation under SAM

Figure 4 ***Monthly Energy Production***



Source: Author calculation under SAM

Figure 5 *Monthly Energy Production*



Source: Author calculation under SAM

7 CONCLUSION

This paper presents design modelling and simulation as well as technical and economic potential of a small-scale solar PV grid-connected electricity generation plant of size capacity 1MW in El Oued state from 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 simulation clearly shows that the efficiency of photovoltaic panels decreases in summer season. 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.

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 75%. The simulation results show that annual electricity generation of the proposed solar PV plant is 1675670 Kh of useful AC electricity. This is sufficient energy to reduce for 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. As well as, the projects for small solar photovoltaic need more enhance and financial facilities from the Algerian government to improve its feasibility and performance

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