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# Exploring The Feasibility Of Residential Solar Panel Adoption In Algeria's Arid And Hot Regions: A Cost-Benefit Analysis Of An On-Grid System

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**Abstract**. This research aims to explore the economic and technical feasibility of residential solar panel adoption in Algeria, specifically in its arid and hot regions. By analyzing the potential for solar energy generation and assessing the economic viability of solar panel systems, this study aims to evaluate the financial impact on energy bill savings and the economic feasibility of solar panel adoption. A case study of a residential building located in the city of Biskra is used as a representation of the potential for solar energy in these specific areas, along with real data of energy consumption over the last five years. A simulation of an on-grid system using Skelion plugin and PVsyst software was performed to evaluate the financial impact on energy bill savings. The study also evaluated the economic feasibility through the calculation of costs and benefits, including the payback period, net present value (NPV), and the internal rate of return (IRR). Results showed that solar energy has great potential in Algeria and that residential solar panel systems can provide a positive net present value and internal rate of return, indicating that they are economically viable. Additionally, the payback period for these systems was found to be reasonable. Homeowners who install solar panels on their roof can reduce their dependence on the traditional electricity grid by generating their own electricity, which can lead to significant savings on energy bills and reduce their carbon footprint.

**Keywords**. Residential solar panels, On-grid system, Economic feasibility, Dynamic Simulation, Energy bill savings, hot & arid climate of Algeria

## 1. Introduction

Algeria is a country where the population and economy are expanding rapidly[1],[2], and as a result, energy usage has been increasing in recent years. The country relies severely on fossil fuels, such as natural gas and oil, as its primary source of energy[3],[4],. This dependence on fossil fuels has led to a number of environmental and economic challenges. For example, the high level of greenhouse gas emissions that result from the burning of fossil fuels contribute to climate change and have a negative impact on air quality and public health[4].To ensure environmental preservation and sustainability, it is important for Algeria to diversify its energy mix. By diversifying the energy mix and developing alternative sources of energy, such as solar,

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wind, and hydro, the country can reduce its dependence on fossil fuels and ensure a more reliable and sustainable energy supply. furthermore, diversifying the energy mix can help to mitigate the environmental and economic challenges associated with the reliance on fossil fuels.

Algeria has a great potential for solar energy due to its location, as it is located in the north of Africa and it has a high level of solar radiation throughout the year, thus making it an ideal location for solar energy projects. The solar radiation levels in the country are among the highest in the world, with an average of about 6.5 kWh/m2 per day[5]. This high solar radiation level makes it an ideal location for solar power generation. Assessing the economic and technical feasibility of residential solar panel adoption is important in order to support the widespread adoption of solar energy in Algeria. Residential solar panel systems are becoming increasingly popular as a way for homeowners to generate their own electricity and reduce their dependence on the traditional electricity grid. However, the adoption of these systems can be influenced by a variety of factors, such as the costs and benefits of the systems, the availability of government incentives and subsidies, and the level of consumer awareness and education about solar energy.

In recent years, there has been a growing interest in the use of solar energy in Algeria's cities[4],[6],[7],[8],[9]. Researchers have been studying the potential for solar energy adoption in these urban areas and have found that there is a significant opportunity for the country to connect the power of the sun to meet its energy needs. Benelkadi & al [10],zebbar & all [11] studies have shown that the high solar radiation levels in Algeria, combined with the increasing costs of traditional energy sources, make solar energy a cost-effective and sustainable solution for the country.

Despite that, few researches have concentrated on the economic and technical feasibility of residential solar panel in hot and arid regions of Algeria by analyzing the potential for solar energy generation and assessing the economic viability of solar panel systems. The objective of the research is to investigate the practicality and cost-effectiveness of incorporating solar panels in residential buildings, specifically in the arid and hot regions of Algeria to promote the widespread use of solar energy in the country.

## 2. Methodology

### *2.1. Case study and data collection*

#### *2.1.1. The residential building case study*

The building used as a case study in this work is located in the western region of Biskra, Algeria. It is a two-story structure with a roof area of 53 $m^2$. It is part of a larger complex of 177 buildings. The building's orientation is south-west facing. The building is home to a family of five, consisting of parents and three children. The building has three bedrooms, a living room, a kitchen, a garage, a bathroom and terraces. The family uses the building as their primary residence and they are living in it. Figure 01 illustrates the architectural layout of four building structures, with the highlighted area in red indicating the chosen case.

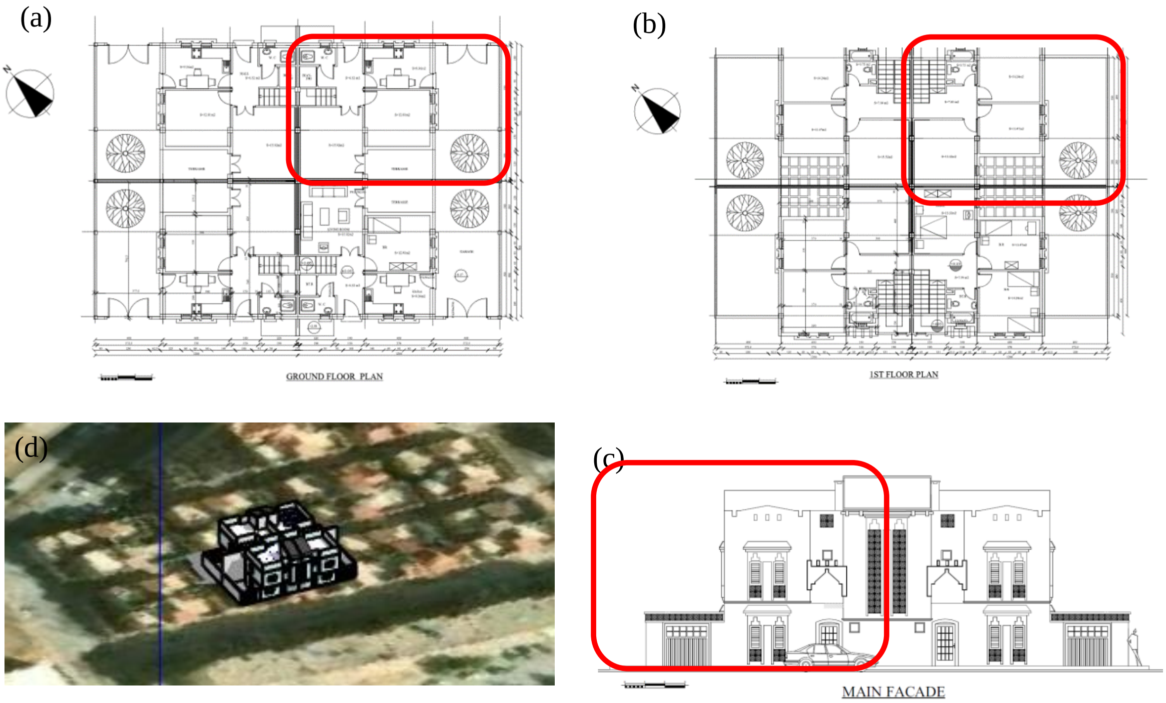


Figure 01: (a) the ground floor plan, (b) the first-floor plan, (c) main façade of the building, (d) 3d view,

### *2.1.2. Solar irradiation in the region of study*

Figure (02) shows the annual values of global horizontal irradiation and horizontal diffuse irradiation generated fom a TMY file. The city of Biskra receives a significant amount of solar radiation throughout the year. The global horizontal irradiation sum of 1798 kwh/m2 and the horizontal diffuse irradiation sum of 795 kwh/m2 indicate that the area receives a large amount of direct and indirect solar radiation on a horizontal surface. These values emphasize that this city is an area with high solar potential.

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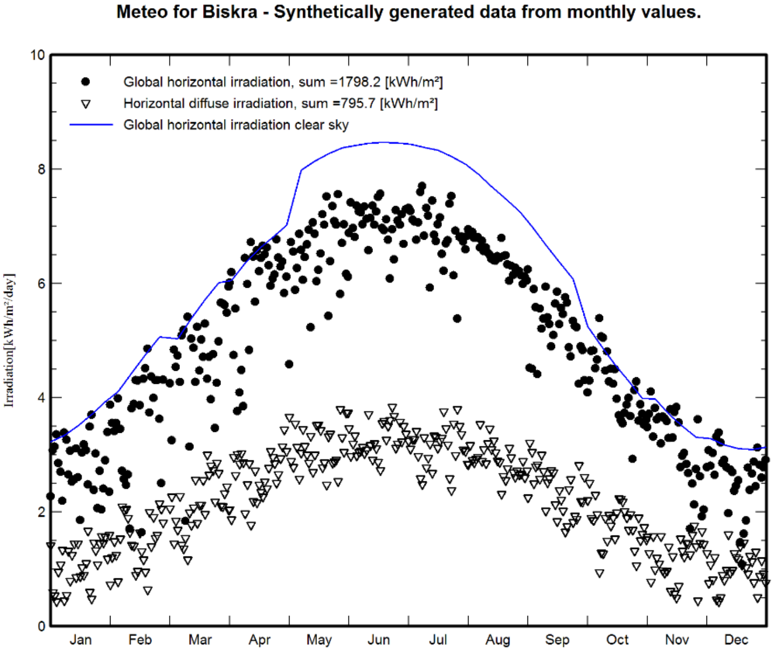

Figure 2 : Solar irradiation in Biskra

### *2.1.3. Electricity data collection*

The method used to collect data on the energy consumption of the last five years involved obtaining bills, provided from the electricity supplier, from the building's owner. The bills include detailed information such as the amount of gas and electricity used, the dates of consumption, taxes and the cost of the gas and electricity. This information was organized in a table (table01) in order to analyze and understand the building's electricity consumption patterns over time.

| **Year** | **2022** | **2021** | **2020** | **2019** | **2018** |
|---|---|---|---|---|---|
| First semester (kwh) | 375 | 475 | 402 | 396 | 385 |
| second semester (kwh) | 614 | 519 | 605 | 591 | 576 |
| third semester (kwh) | 2767 | 3391 | 3211 | 2847 | 2912 |
| fourth semester (kwh) | 3161 | 2914 | 3022 | 2955 | 3084 |
| **Annual consumption (kwh)** | **6917** | **7299** | **7240** | **6789** | **6957** |
| **Annual cost (Euro)** | **230,55** | **245,53** | **242,61** | **225,66** | **232,19** |

Table 1 : semesterly electricity usage and cost from billing statements

The electricity usage in this house varies significantly throughout the year, it is between 6789 kwh and 7299 kwh. The lowest usage is during the winter, 375 to 475 kwh. Usage increases in the spring to 519 to 614 kwh and then significantly increases in the summer to 2767 to 3391 kwh. Usage then 2914 to 3161 kwh in the fall. This variation in electricity usage could be due to different factors such as weather conditions, occupancy, and air conditioning usage.

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*2.2. The model and the method of analysis*

*2.2.1. Skelion plugin and PVsyst software*

PVsyst is a software tool for the design, simulation, and financial analysis of photovoltaic energy systems. It includes a database of PV modules and inverters, as well as tools for climate data analysis and energy yield calculation. It allows users to model and analyze different scenarios, including the effects of shading and weather conditions on the performance of the system. Whereas, Skelion is a plugin for Sketchup that allows users to design and analyze photovoltaic systems in 3D, when used in conjunction with PVsyst, adds advanced 3D shading and design capabilities to the software.

The diagram bellow describes the framework used in this study using both skelion and PVsyst.

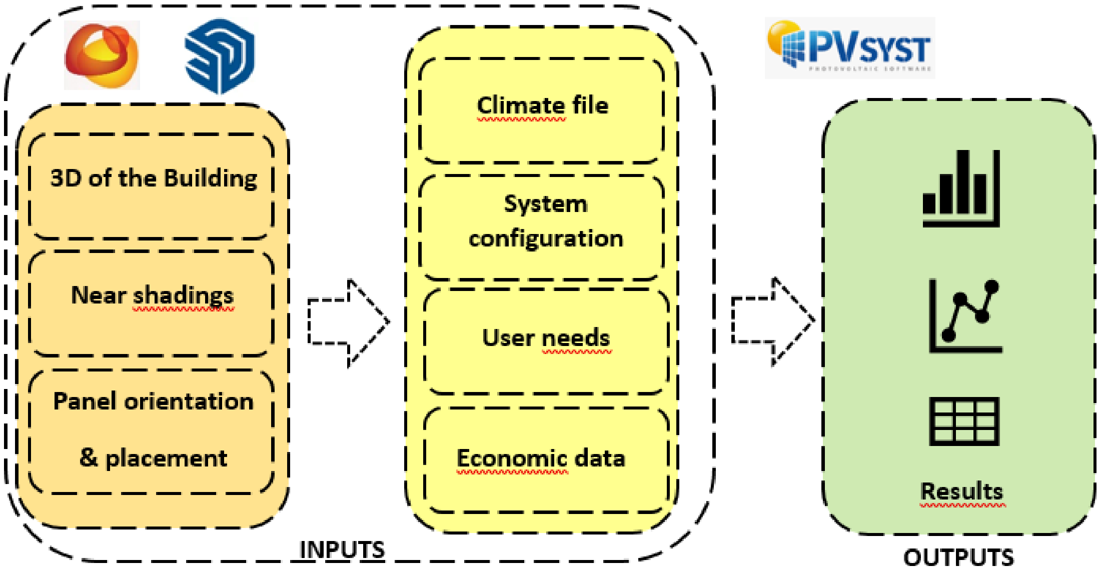


Figure 03: modelling process

*2.2.2. The solar panel system model*

*a) Climate file*

The coordinates of Biskra city, Algeria are 34.85°, 5.7333°. These geographic coordinates were used to generate information about the city climate using a TMY (Typical Meteorological Year) file provided by Meteonorm 8.1 database in PVsyst software.

*b) 3D, near shading and PV Panel orientation*

The building's shape and solar components were created using SketchUp and the Skelion plugin. The process began by identifying the building's location using a Google Map image as a reference, which provided the coordinates, including longitude and latitude (Fig. 1 (d)). Next, Skelion was utilized to place solar components based on various factors such as the roof area, PV modules, orientation, and pitch. A summary of the parameters used can be found in the table (02).

| **Roof area** | **Orientation** | | **Pv modules** | | | | | | **Pitch** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Azimuth In Skelion | Tilt | Model | Dimensions | | | Weight | Power | PSH interval | |
| | | | | length | width | thickness | | | Hour | Hour |
| 53 $m^2$ | 0 | 30 | Condor mono 72 cells | 1956 mm | 992 mm | 50 mm | 23 kg | 320 w | 10 :00 | 14:00 |

Table 02: A summary of Skelion parameters

It is worth noting that the PVsyst optimization tool is used to determine the optimal tilt, and azimuth of a panel based on site coordinates. In our case, the panels were facing southwest, exactly 26° from south, which is not the best orientation according to the calculations. This has resulted in a loss of -1.7% in panel performance (fig 4).

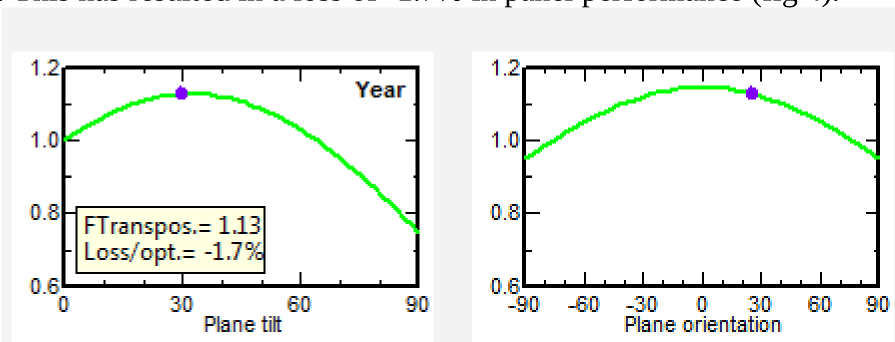


Figure 04: the orientation losses to the optimum

*c) Systems*

The solar panel system in this model has a planned power output of 2 kW. It includes 6 panels, with a total module area of 12 square meters. The PV module used in this project is Alex_Solar_ALM_320w which is similar to the Algerian condor's PV panels characteristics. While the inverters model was 2.0kw 50-90v 50Hz APS_DS3D-H_Europe that convert the DC power generated by the panels into AC power. The array design consists of a total of 3 rows (strings), with 2 panels in each row, arranged in a south-west facing orientation at a tilt angle of 25 degrees. The panels were connected in series to provide optimal performance, with a nominal power ratio ratio of 0.96. for more details about the system design see the figure in appendix (1)

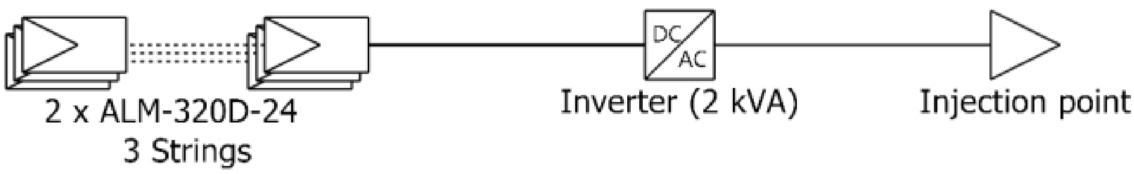


Figure 05: single-line diagram of the solar panel system

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*d) User needs*

The user needs section of the PVsyst model for this family was created by analyzing their energy consumption patterns throughout the year. Factors such as daily usage and seasonal changes, as well as the use of AC systems during summer and fall, were taken into consideration. Based on this information, an average daily energy demand of 18.5 kwh was used as the target for the model. The hourly distribution of use is illustrated in the figure below.

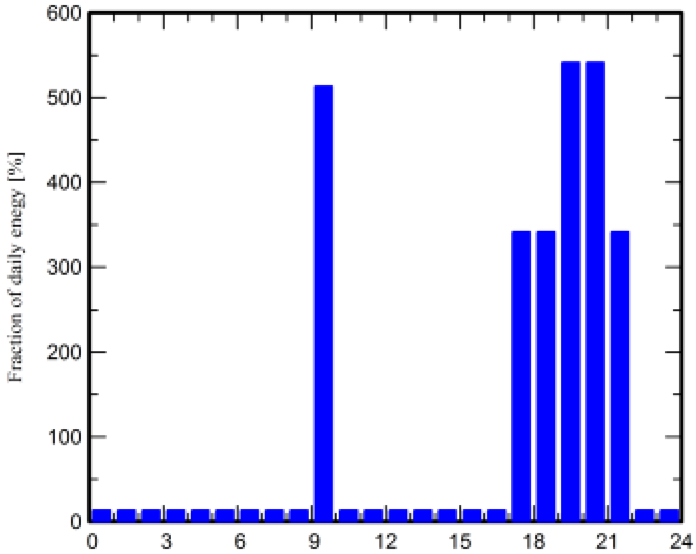

Figure 06: hourly distribution of use

*1.3. The economic evaluation*

The financial analysis of the photovoltaic system, including the cost of the equipment and installation, as well as the projected revenue from the generated electricity over the lifetime of the system. It also includes the calculation of financial indicators such as the internal rate of return (IRR), the net present value (NPV) and payback period to evaluate the financial feasibility of the project.

▪ The net present value (NPV) is used to calculate the present value of future cash flows generated by an investment, taking into account the time value of money and a specified discount rate. The formula for NPV is as follows:

$NPV = \sum_{t=0}^{n} \frac{Rt}{(1+i)t}$ Initial Investment …………………… (01)

Where:

- Rt= net cash inflow – outflow during a single period t
- ti=discount rate or return that could be earned in alternative investments
- t=number of time periods.

▪ The internal rate of return (IRR) is used to calculate the rate at which the net present value (NPV) of an investment equals zero. The IRR is the discount rate that makes the NPV of the investment equal to zero. The formula for IRR is:

$0 = NPV = \sum_{t=1}^{T} \frac{\mathrm{Ct}}{(1+IRR)t} - C_0$ …………………….(02)

Where

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- Ct= Net cash inflow during the period t
- C0=Total initial investment costs
- IRR= The internal rate of return
- t= The number of time periods

▪ Payback period is an important metric when considering the economic viability of a system, as it can help determine how long it will take for the system to start generating a return on investment. Payback time is typically measured in years, and is calculated by dividing the total cost of the system by the annual savings generated by the system. The shorter the payback time, the more quickly the system will start generating a return on investment. The formula for the payback period is as follows:

$$\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Annual Savings}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(03)$$

Where

- Initial Investment: The initial cost of the investment.
- Annual Savings: The annual savings or cash flows generated by the investment.

Regarding the installation cost of the panel system components used in this study, it is given in the table below according to the information provided in the Condor catalogue [12], and other researches [13],[10],[9] :

| Item | Quantity units | Cost EUR | Total EUR |
|---|---|---|---|
| PV modules | | | |
| ALM-320D-24 | 6 | 289.00 | 1 734.00 |
| Supports for modules | 6 | 20.00 | 120.00 |
| Inverters | | | |
| DS3D-H?Europe? | 1 | 585.00 | 585.00 |
| Other components | | | |
| Accessories, fasteners | 1 | 200.00 | 200.00 |
| Studies and analysis | | | |
| Engineering | 1 | 200.00 | 200.00 |
| Installation | | | |
| Global installation cost per module | 6 | 150.00 | 900.00 |
| Taxes | | | |
| VAT | 1 | 0.00 | 400.00 |
| | | Total | 4 139.00 |
| | | Depreciable asset | 2 639.00 |

Figure 07: installation cost

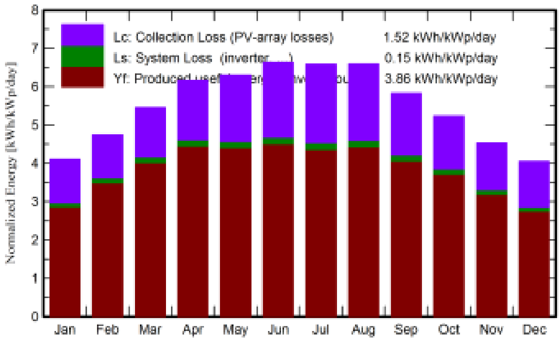
## 3. Discussions of Results

### *3.1. System production*

The designed solar system produced approximately 40% of the required energy over a year, with a specific production of 1408 kWh/kWp/year. The system's performance was measured using the performance ratio (PR), which is a measure of the efficiency of the system. The PR of 0.7 (fig.09) indicates that the system was not operating at optimal efficiency. One factor that contributed to this inefficiency was the solar factor of 21.54. This value represents the fraction of total available solar energy that is converted into usable electricity by the system. Ideally, the solar factor should be as high as possible, but in this case, the system was not performing at its best due to various factors such as shading from buildings and misalignment of panels. These issues negatively impacted the system's performance, By optimizing the rooftop design for panel installation, the building could potentially benefit from a higher performance ratio and solar factor. Despite these limitations, the system is still capable of producing a significant amount of energy and contributing to the reduction of the family's overall energy consumption.

Table 03: PVsyst main results

| Produced energy | Used energy | Specific production | Performance ratio | Solar fraction |
|---|---|---|---|---|
| 2704 kwh/year | 6770kwh/year | 1408kwh/kwp/year | 70 % | 21.54 |



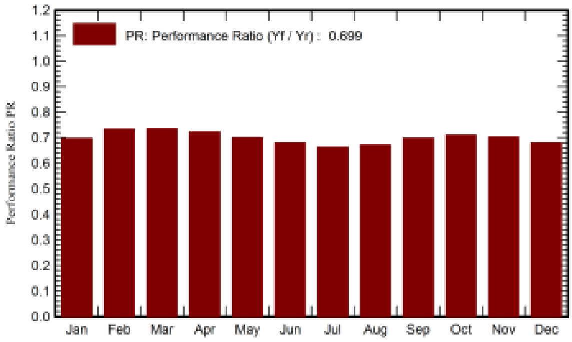




Figure 08: normalized production (per installed kwp). Figure 09: performance ratio PR

### *3.2. Economic evaluation*

Based on the given results, the family's photovoltaic system investment has a project lifetime of 25 years. The family has invested 4139 euro in this project, and the payback period is expected to be 09 years, which is relatively short. The net present value (NPV) of the investment is 5450.31 euro, which is positive and indicates that the investment is expected to generate positive returns over its lifetime. The internal rate of return (IRR) of 9.80% is relatively high and indicates a strong rate of return on the investment. The return on investment (ROI) of 131% is even higher, indicating that the family is expected to see a return on their investment that is more than their original investment. In conclusion, based on these results, this photovoltaic system investment appears to be economically favorable for the family. The short payback period, high IRR, and positive NPV all point to a strong potential for financial returns on the investment.

Table 04: PVsyst financial results

| Project life time | Own funds | Electricity sell | | Self-consumption | Payback period | NPV | IRR | ROI |
|---|---|---|---|---|---|---|---|---|
| | | Peak tariff | Off peak tariff | | | | | |
| 25 years | 4139 euro | 0.55 euro | 0.55 euro | 0.01 euro | 09 years | 5450.31 euro | 9.80% | 131.1% |

## 4. Conclusion

In this work we tried to examine the economic and technical feasibility of residential solar panel adoption in the city of Biskra, Algeria. the results of this study indicate that the photovoltaic system investment appears to be economically favorable for the family. The system produced approximately 40% of the required energy over a year. The performance ratio (PR) of 0.7 indicates that the system was not operating at optimal efficiency, which was due to various factors such as shading from buildings and misalignment of panels. However, the family's investment has a project lifetime of 25 years, with an investment of 4139 euro and a payback period of 09 years, which is relatively short. The net present value (NPV) indicates that the investment is expected to generate positive returns over its lifetime. The internal rate of return (IRR) of 9.80% is relatively high and indicates a strong rate of return on the investment. The return on investment (ROI) of 131% is even higher, indicating that the family is expected to see a return on their investment that is more than their original investment. In terms of residential solar panel adoption in Algeria, these results highlight the potential for solar energy to contribute to energy sustainable development in the country. Solar panels can provide clean, renewable energy and reduce dependence on fossil fuels, which is essential for a sustainable future. By promoting residential solar panel adoption in Algeria, the country can take a step towards a more sustainable and secure energy future.

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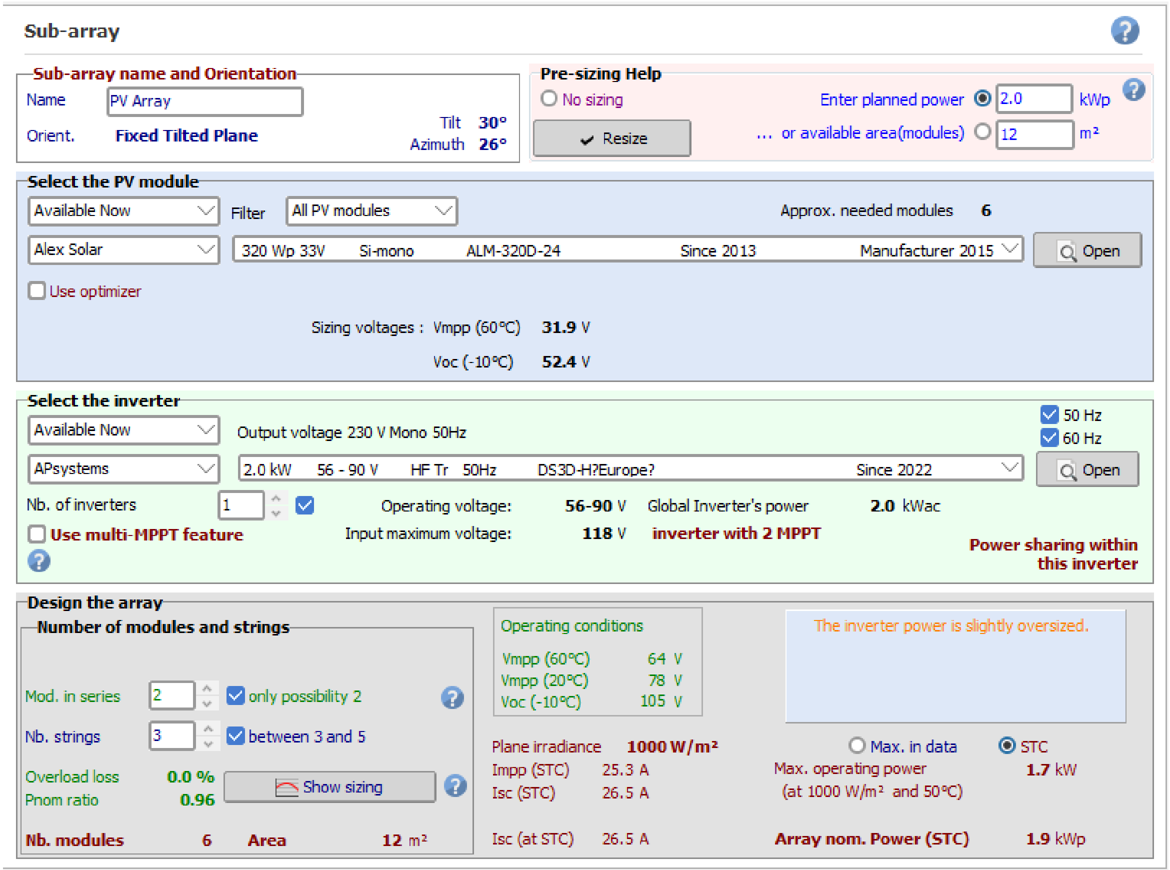
## Appendices




Appendix 01: the main parameters of the system.

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**Detailed User's needs**

Daily household consumers, Seasonal modulation, average = 18.5 kWh/day

**Summer (Jun-Aug)**

| | Nb. | Power | Use | Energy |
|---|---|---|---|---|
| | | W | Hour/day | Wh/day |
| Lamps (LED or fluo) | 6 | 18/lamp | 3.5 | 378 |
| TV / PC / Mobile | 2 | 110/app | 5.5 | 1210 |
| Domestic appliances | 2 | 200/app | 1.0 | 400 |
| Fridge / Deep-freeze | 1 | | 24 | 300 |
| Dish- and Cloth-washer | 1 | | 1 | 500 |
| AC | 2 | 1200 tot | 13.0 | 31200 |
| Stand-by consumers | | | 24.0 | 24 |
| Total daily energy | | | | 34012 |

**Autumn (Sep-Nov)**

| | Nb. | Power | Use | Energy |
|---|---|---|---|---|
| | | W | Hour/day | Wh/day |
| Lamps (LED or fluo) | 6 | 18/lamp | 5.0 | 540 |
| TV / PC / Mobile | 2 | 110/app | 5.5 | 1210 |
| Domestic appliances | 2 | 200/app | 1.0 | 400 |
| Fridge / Deep-freeze | 1 | | 24 | 300 |
| Dish- and Cloth-washer | 1 | | 1 | 500 |
| AC | 2 | 1200 tot | 13.0 | 31200 |
| Stand-by consumers | | | 24.0 | 24 |
| Total daily energy | | | | 34174 |

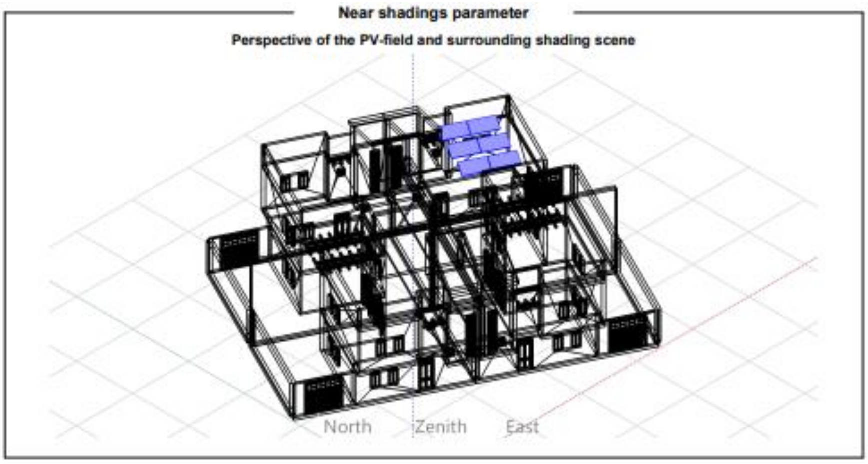
**Winter (Dec-Feb)**

| | Nb. | Power | Use | Energy |
|---|---|---|---|---|
| | | W | Hour/day | Wh/day |
| Lamps (LED or fluo) | 6 | 18/lamp | 5.0 | 540 |
| TV / PC / Mobile | 2 | 110/app | 5.0 | 1100 |
| Domestic appliances | 2 | 200/app | 1.0 | 400 |
| Fridge / Deep-freeze | 1 | | 24 | 300 |
| Dish- and Cloth-washer | 1 | | 1 | 500 |
| Stand-by consumers | | | 24.0 | 24 |
| Total daily energy | | | | 2864 |

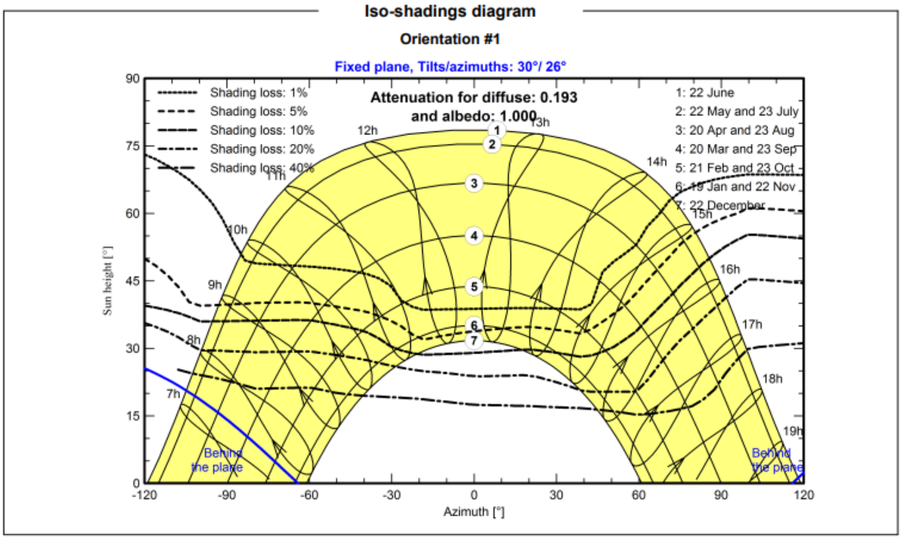
**Spring (Mar-May)**

| | Nb. | Power | Use | Energy |
|---|---|---|---|---|
| | | W | Hour/day | Wh/day |
| Lamps (LED or fluo) | 6 | 18/lamp | 5.0 | 540 |
| TV / PC / Mobile | 2 | 110/app | 5.5 | 1210 |
| Domestic appliances | 2 | 200/app | 1.0 | 400 |
| Fridge / Deep-freeze | 1 | | 24 | 300 |
| Dish- and Cloth-washer | 1 | | 1 | 500 |
| Stand-by consumers | | | 24.0 | 24 |
| Total daily energy | | | | 2974 |

Appendix 02: detailed user's needs.




Appendix 03: 3D view of near shading parameter.




Appendix 04: iso shadings diagram.

| | GlobHor kWh/m² | DiffHor kWh/m² | T_Amb °C | GlobInc kWh/m² | GlobEff kWh/m² | EArray kWh | E_User kWh | E_Solar kWh | E_Grid kWh | EFrGrid kWh |
|---|---|---|---|---|---|---|---|---|---|---|
| **January** | 87.0 | 33.78 | 11.13 | 127.3 | 100.4 | 177.1 | 89 | 11.4 | 159.2 | 77.4 |
| **February** | 100.7 | 41.52 | 12.82 | 132.9 | 112.8 | 194.7 | 80 | 15.7 | 171.8 | 64.5 |
| **March** | 144.3 | 65.91 | 17.71 | 169.2 | 148.0 | 248.3 | 92 | 24.1 | 215.4 | 68.1 |
| **April** | 176.2 | 78.78 | 21.69 | 184.8 | 162.4 | 265.9 | 89 | 26.6 | 229.7 | 62.6 |
| **May** | 202.0 | 97.15 | 26.86 | 195.2 | 170.1 | 272.4 | 92 | 29.4 | 233.1 | 62.8 |
| **June** | 211.7 | 97.98 | 31.73 | 199.1 | 174.0 | 269.8 | 1020 | 237.4 | 22.4 | 783.0 |
| **July** | 213.7 | 97.07 | 35.81 | 204.2 | 178.8 | 270.1 | 1054 | 240.1 | 19.9 | 814.3 |
| **August** | 200.5 | 89.68 | 34.61 | 204.4 | 180.9 | 273.9 | 1054 | 246.6 | 17.4 | 807.7 |
| **September** | 156.9 | 71.80 | 29.13 | 174.9 | 153.7 | 242.9 | 1025 | 221.8 | 12.6 | 803.4 |
| **October** | 129.3 | 55.20 | 24.21 | 162.3 | 141.1 | 229.8 | 1059 | 212.8 | 8.9 | 846.6 |
| **November** | 95.0 | 35.88 | 16.40 | 136.0 | 111.7 | 190.6 | 1025 | 180.7 | 3.0 | 844.6 |
| **December** | 81.1 | 30.91 | 12.13 | 125.6 | 96.4 | 170.4 | 89 | 11.9 | 152.2 | 76.9 |
| **Year** | 1798.2 | 795.68 | 22.91 | 2016.0 | 1730.1 | 2805.9 | 6770 | 1458.4 | 1245.5 | 5311.9 |

**Legends**

| | | | |
|---|---|---|---|
| GlobHor | Global horizontal irradiation | EArray | Effective energy at the output of the array |
| DiffHor | Horizontal diffuse irradiation | E_User | Energy supplied to the user |
| T_Amb | Ambient Temperature | E_Solar | Energy from the sun |
| GlobInc | Global incident in coll. plane | E_Grid | Energy injected into grid |
| GlobEff | Effective Global, corr. for IAM and shadings | EFrGrid | Energy from the grid |

Appendix 05: Balances and main results.

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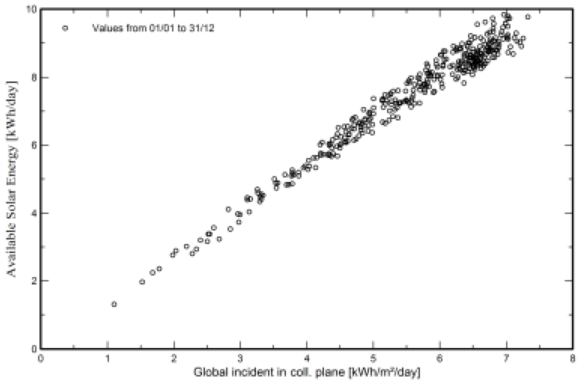
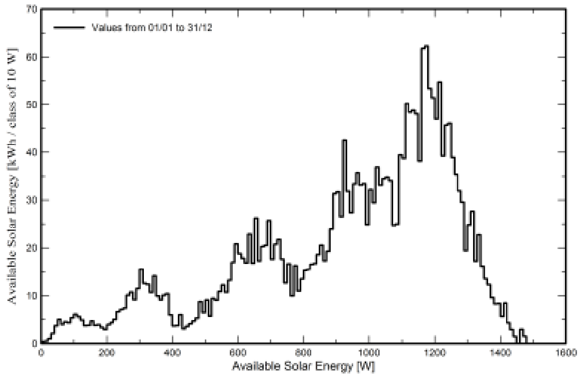
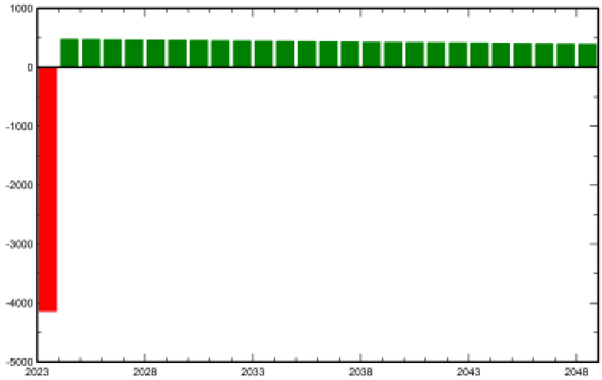
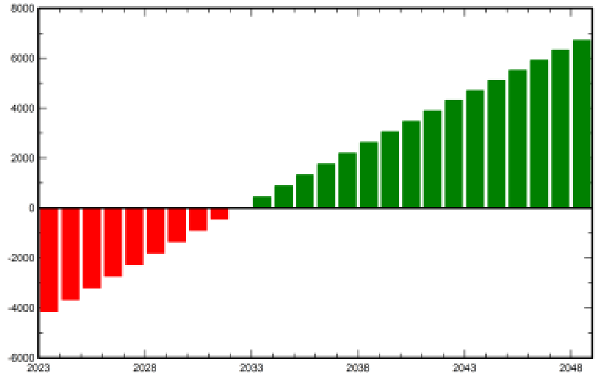


Appendix 06: system output power distribution.



Appendix 07: daily input /output diagram.


Appendix 08: yearly net profit (euro )


Appendix 09: cumulative cashflow (euro)

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**Financial analysis**

**Detailed economic results (EUR)**

| Year | Electricity sale | Own funds | Run. costs | Deprec. allow. | Taxable income | Taxes | After-tax profit | Self-cons. saving | Cumul. profit | % amorti. |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 4 139 | 0 | 0 | 0 | 0 | 0 | 0 | -4 139 | 0.0% |
| 1 | 685 | 0 | 147 | 108 | 430 | 65 | 473 | 1 | -3 669 | 11.4% |
| 2 | 681 | 0 | 148 | 108 | 426 | 64 | 470 | 2 | -3 207 | 22.5% |
| 3 | 678 | 0 | 148 | 108 | 422 | 63 | 466 | 2 | -2 754 | 33.5% |
| 4 | 674 | 0 | 149 | 108 | 418 | 63 | 463 | 2 | -2 307 | 44.3% |
| 5 | 671 | 0 | 150 | 108 | 413 | 62 | 459 | 2 | -1 869 | 54.8% |
| 6 | 668 | 0 | 151 | 108 | 409 | 61 | 456 | 2 | -1 438 | 65.3% |
| 7 | 664 | 0 | 151 | 108 | 405 | 61 | 452 | 2 | -1 015 | 75.5% |
| 8 | 661 | 0 | 152 | 108 | 401 | 60 | 449 | 2 | -599 | 85.5% |
| 9 | 658 | 0 | 153 | 108 | 397 | 60 | 445 | 2 | -190 | 95.4% |
| 10 | 654 | 0 | 154 | 108 | 393 | 59 | 442 | 2 | 212 | 105.1% |
| 11 | 651 | 0 | 155 | 108 | 389 | 58 | 438 | 2 | 607 | 114.7% |
| 12 | 648 | 0 | 155 | 108 | 385 | 58 | 435 | 2 | 995 | 124.0% |
| 13 | 645 | 0 | 156 | 108 | 381 | 57 | 431 | 2 | 1 376 | 133.2% |
| 14 | 641 | 0 | 157 | 108 | 377 | 57 | 428 | 3 | 1 750 | 142.3% |
| 15 | 638 | 0 | 158 | 108 | 373 | 56 | 425 | 3 | 2 118 | 151.2% |
| 16 | 635 | 0 | 158 | 108 | 369 | 55 | 421 | 3 | 2 480 | 159.9% |
| 17 | 632 | 0 | 159 | 108 | 365 | 55 | 418 | 3 | 2 835 | 168.5% |
| 18 | 629 | 0 | 160 | 108 | 361 | 54 | 414 | 3 | 3 184 | 176.9% |
| 19 | 626 | 0 | 161 | 108 | 357 | 54 | 411 | 3 | 3 527 | 185.2% |
| 20 | 622 | 0 | 162 | 108 | 353 | 53 | 408 | 3 | 3 864 | 193.4% |
| 21 | 619 | 0 | 162 | 98 | 359 | 54 | 403 | 4 | 4 194 | 201.3% |
| 22 | 616 | 0 | 163 | 98 | 355 | 53 | 400 | 4 | 4 518 | 209.2% |
| 23 | 613 | 0 | 164 | 98 | 351 | 53 | 396 | 4 | 4 836 | 216.9% |
| 24 | 610 | 0 | 165 | 98 | 348 | 52 | 393 | 4 | 5 149 | 224.4% |
| 25 | 607 | 0 | 166 | 98 | 344 | 52 | 390 | 4 | 5 456 | 231.8% |
| **Total** | **16 126** | **4 139** | **3 904** | **2 639** | **9 583** | **1 437** | **10 784** | **65** | **5 456** | **231.8%** |

Appendix 10: detailed financial analysis results

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**Financial analysis**

**Simulation period**

| | | | |
|---|---|---|---|
| Project lifetime | 25 years | Start year | 2024 |

**Income variation over time**

| | |
|---|---|
| Inflation | 0.50 %/year |
| Production variation (aging) | -0.50 %/year |
| Discount rate | 1.00 %/year |

**Income dependent expenses**

| | |
|---|---|
| Income tax rate | 10.00 %/year |
| Other income tax | 5.00 %/year |
| Dividends | 0.00 %/year |

**Depreciable assets**

| Asset | Depreciation method | Depreciation period (years) | Salvage value (EUR) | Depreciable (EUR) |
|---|---|---|---|---|
| PV modules | | | | |
| ALM-320D-24 | Straight-line | 25 | 0.00 | 1 734.00 |
| Supports for modules | Straight-line | 25 | 0.00 | 120.00 |
| Inverters | | | | |
| DS3D-H?Europe? | Straight-line | 25 | 0.00 | 585.00 |
| Accessories, fasteners | Straight-line | 20 | 0.00 | 200.00 |
| | | Total | 0.00 | 2 639.00 |

**Financing**

| | |
|---|---|
| Own funds | 4 139.00 EUR |

**Electricity sale**

| | | | |
|---|---|---|---|
| Feed-in tariff | Peak tariff | 0.5500 EUR/kWh | |
| | Off-peak tariff | 0.4500 EUR/kWh | 20:00-07:00 |
| Duration of tariff warranty | | 20 years | |
| Annual connection tax | | 0.00 EUR/kWh | |
| Annual tariff variation | | 0.0 %/year | |
| Feed-in tariff decrease after warranty | | 0.00 % | |

**Self-consumption**

| | |
|---|---|
| Consumption tariff | 0.0010 EUR/kWh |
| Tariff evolution | +5.0 %/year |

**Return on investment**

| | |
|---|---|
| Payback period | 9.5 years |
| Net present value (NPV) | 5 456.31 EUR |
| Internal rate of return (IRR) | 9.80 % |
| Return on investment (ROI) | 131.8 % |

Appendix 11: detailed financial analysis results

**Cost of the system**

**Installation costs**

| Item | Quantity units | Cost EUR | Total EUR |
|---|---|---|---|
| PV modules | | | |
| ALM-320D-24 | 6 | 289.00 | 1 734.00 |
| Supports for modules | 6 | 20.00 | 120.00 |
| Inverters | | | |
| DS3D-H?Europe? | 1 | 585.00 | 585.00 |
| Other components | | | |
| Accessories, fasteners | 1 | 200.00 | 200.00 |
| Studies and analysis | | | |
| Engineering | 1 | 200.00 | 200.00 |
| Installation | | | |
| Global installation cost per module | 6 | 150.00 | 900.00 |
| Taxes | | | |
| VAT | 1 | 0.00 | 400.00 |
| | | Total | 4 139.00 |
| | | Depreciable asset | 2 639.00 |

**Operating costs**

| Item | Total EUR/year |
|---|---|
| Maintenance | |
| Provision for inverter replacement | 117.00 |
| Repairs | 30.00 |
| Total (OPEX) | 147.00 |
| Including inflation (0.50%) | 156.17 |

**System summary**

| | |
|---|---|
| Total installation cost | 4 139.00 EUR |
| Operating costs (incl. inflation 0.50%/year) | 156.17 EUR/year |
| Unused energy | 1458 kWh/year |
| Energy sold to the grid | 1245 kWh/year |
| Cost of produced energy (LCOE) | 0.135 EUR/kWh |

Appendix 12: cost of the system

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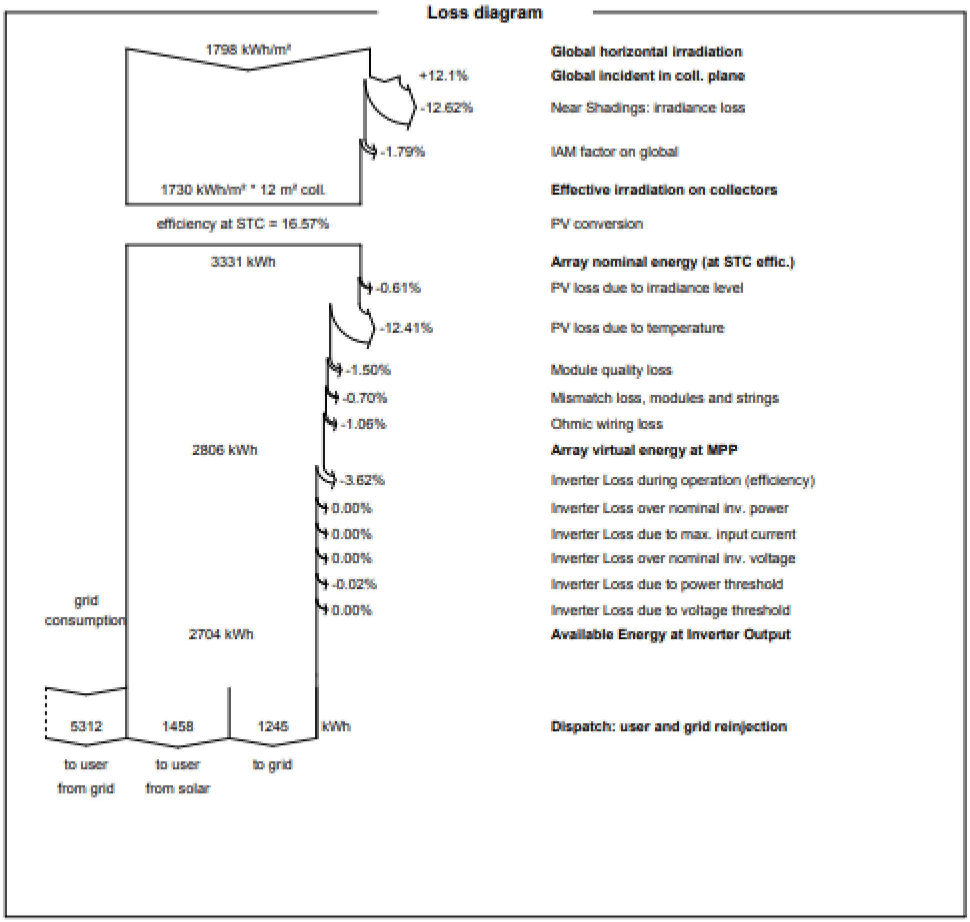
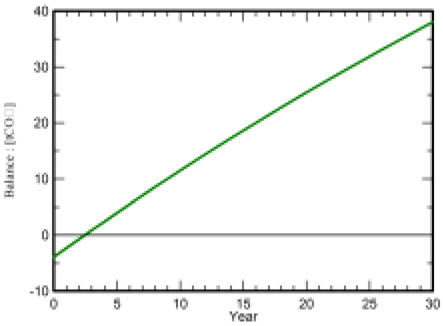



Appendix 13: loss diagram

**$CO_2$ Emission Balance**

| | |
|---|---|
| Total: | 38.0 $tCO_2$ |
| **Generated emissions** | |
| Total: | 3.92 $tCO_2$ |
| Source: | Detailed calculation from table below: |
| **Replaced Emissions** | |
| Total: | 48.3 $tCO_2$ |
| System production: | 2703.84 kWh/yr |
| Grid Lifecycle Emissions: | 596 $gCO_2$/kWh |
| Source: | IEA List |
| Country: | Algeria |
| Lifetime: | 30 years |
| Annual degradation: | 1.0 % |

**Saved $CO_2$ Emission vs. Time**




**System Lifecycle Emissions Details**

| Item | LCE | Quantity | Subtotal [$kgCO_2$] |
|---|---|---|---|
| Modules | 1713 kgCO2/kWp | 1.92 kWp | 3288 |
| Supports | 3.98 kgCO2/kg | 60.0 kg | 239 |
| Inverters | 394 kgCO2/units | 1.00 units | 394 |

Appendix 14: $CO_2$ emission balance