An-Najah National University

Faculty of Engineering

Dpt. of Environment & Energy Engineering

Analysis and Evaluation of PV Grid Connected Systems in Palestine

Authors:

Amin A. Bazyan

Hiba B. Assi

Sura B. Malhis

Supervisor:

Dr. Tamer Khatib

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Acknowledgments

We would like to thank God for helping us complete this study.

To our family, specially our parents and siblings, the ones who knew we were going to make it, even when we did not.

To our friends, who brought joy and happiness during the past years.

To our teachers, who taught us well. To Dr. Tamer Khatib, who had helped us very much during this study and everything else.

Abstract

Investing of grid connected PV systems for many Palestinian utilities has spread widely due to the decreasing price of the PV components and the supportive governmental policies that encourages stakeholders to invest in the renewable energy sector. A number of schools, municipality buildings and private firms have also built such PV systems. A sample of 15 schools was chosen to be evaluated technically and economically. These systems are rated at a range of 6-35 kWp. Furthermore, the systems were technically evaluated by calculating the yield factor, capacity factor and the performance ratio, the resulted numbers were compared to reference values from other researches. Finally, the ten sites were evaluated economically using simple pay-back period and IRR.

This paper deals with the problem of economical and performance evaluation of the solar photovoltaic systems, based on the available operation data measurements. The main goal is to find out the most significant cause-effect relationships between the available measured inputs and the output power of the system. The problem is not easy one, because quite often the available measurements are correlated and in addition, they have an indirect influence on the final output of the system - the output power.

The resulted data varied from one school to another, some sites had a good average values while others were far below the expected range. The main causes of these problems will be discussed specifically in the second part of our research. We will explain them from policy, behavior and technical points of view.

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1. Introduction

a. Background

Not all Palestinian people have access to electricity the whole day. However, there are unusual constraints on energy development in West Bank. Palestine has not developed domestic energy resources and relies heavily on imports from Israel. Furthermore, energy insecurity is further reinforced by the fact that Israel controls the quantity and condition of energy imported into Palestine. For example, the Israeli control of Palestinian borders prevents open trade in electricity and petroleum products between Palestine and other countries. Israel is therefore able to impose non-competitive energy prices and tariffs on Palestine. Due these socio-political conditions, RE's play special importance for this country [1].

Solar energy is the only secured and viable energy source in Palestine and it has a high potential. This high solar energy potential is demonstrated in an annual average solar radiation of 5.4 kWh/m^2.day and a sunshine duration amounting to about 3000 h/year [2, 3]

b. Purpose of the project

Our project is a study of the installed PV grid connected systems in Palestine, an analysis of the energy production and the economic feasibility of these systems. We also aim to discuss the things that lowers the efficiency of these systems.

c. Description of the area

The study consists of the west bank in Palestine. The sites for PVS installation are located at Different Latitude and Longitude nearby According to their locations shown in table (1.1).

Table 1: PV systems sites location and coordinates

Site No.	Location	Longitude	Latitude
1	South of Nablus	32◦15’33” N	35◦27’63” E
2	North of Jerusalem	32◦18’46” N	35◦25’79” E
3	South East of Jenin	32◦25’55” N	35◦20’40” E
4	West of Tubas		
5	South of Nablus	32◦18’43” N	”34’84◦35E
6	North West of Salfeet	32◦06’87” N	35◦15’96” E
7	East of Jenin		
8	North East of Jenin	32◦48’33” N	35◦58’33” E
9	Middle of Salfeet	32◦06’65” N	”39’08◦35E
10	West East of Nablus	32◦05’01” N	35◦21’46” E
11	Tubas Dynamometer	32◦32’83” N	35◦37’42” E
12	Tubas Storage	32◦32’56” N	35◦36’94” E
13	Tubas Municipality Building	32◦32’30” N	35◦36’89” E
14	Parking lot	32◦32’22” N	35◦36’92” E
15	Cafeteria	32◦32’24” N	35◦36’97” E

d. Solar radiation and hours of sunshine

Palestine has high solar energy potential about 3000 sunshine hours per year, and the solar radiation on horizontal surface varies from 2.63 kW h/m2 /day in December to 8.4 kW h/m2 /day in June.

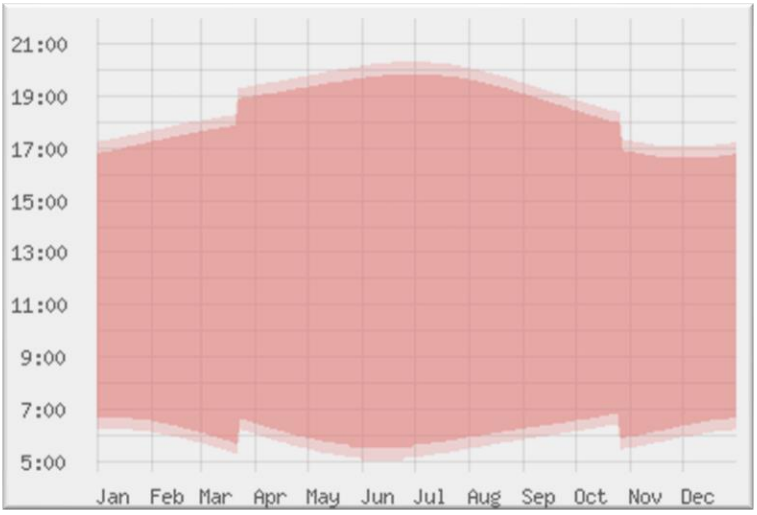

Figure 1: Average monthly sunshine hours in Palestine

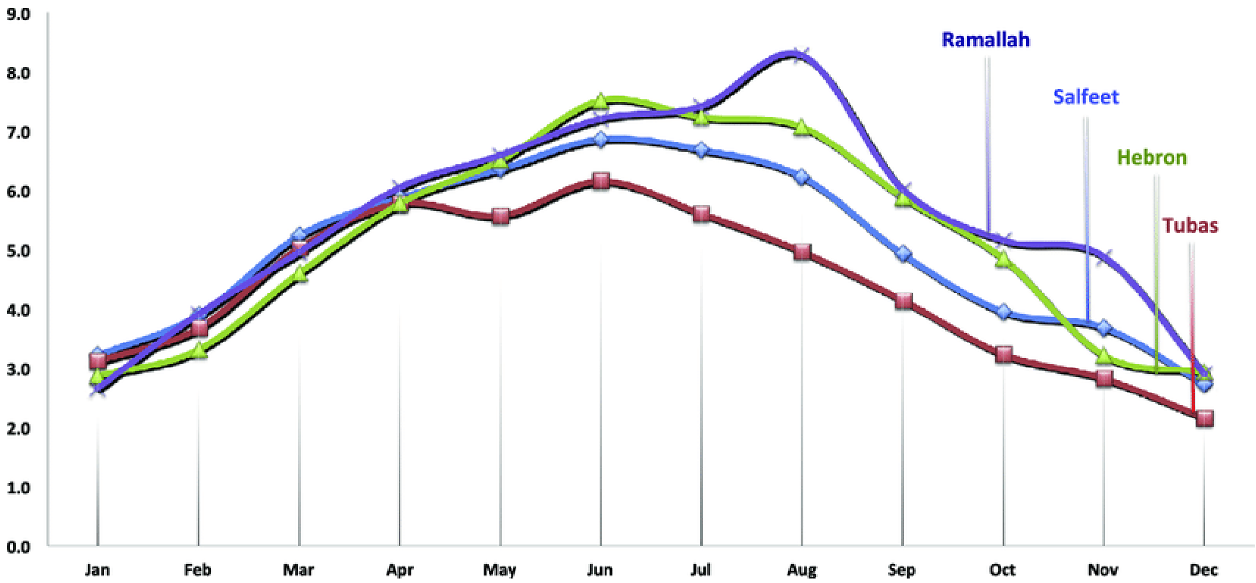

Figure 2: Monthly average solar radiation in different cities in the West Bank [7]

e. Systems specifications

Each system has the following capacities as shown in table:

Table 2: Peak power for all the studied PV systems

System No.	Capacity (kW)
1	7
2	10
3	7
4	8
5	6
6	7
7	7
8	8
9	7
10	7
11	14.3
12	6.8
13	22.3
14	34.7
15	5

f. Net metering

The PV generated electricity supply the house and the excess energy is injected into the grid and sold at different price amounting to 0.75 of the original consumer tariffs. The net metering is an incentive mechanism for renewable energy use and permits the consumer unit to subtract the self-produced energy from its measured kWh consumption. In times of overproduction, the electrical energy is injected into the grid which serves as 'electricity storage'. When a consumer unit's electricity consumption is higher than the production, the consumer unit is allowed to use the electricity supplied by the grid. The produced and injected energy is subtracted from the amount of electricity consumed from the grid in the form of electricity credits (in kWh). If the production of energy is higher than the consumption during the accounting period, the over production is credited to the next month. The credits are valid for 36 months. In the case of higher consumption than self-production, the negative balance has to be paid by the consumer unit in the form of the prevailing electricity tariff. The monthly electricity bill provides the consumer unit with the balance information [4, 5].

g. PV system components

1) **PV Modules:** Poly crystalline Tier one modules (Hanwha L-G5, 330Wp). The Module is the production from Hanwha, which is one of the largest photovoltaic module manufacturers. The proposed module is characterized by high yield and outstanding protection against degradation effects, which enables the module to offer reliable returns and thus be the most cost efficient among its peers. The module is guaranteed to generate superior yield based on High power output, it is also guaranteed long-term durability due to verified resistance against PID effects (verified by TÜV SÜD),

Withstands 5400 Pa snow and 4000 Pa wind loads, and certified protection in harsh environments (salt-mist, ammonia corrosion). With Module efficiency not less than 17%. The Module is warranted for 12 Year Workmanship and 25 Years Linear Performance. For further details, please see the submitted data sheet of the module. Finally, PID Certificate and Test reports will be delivered before procurement.

2) **DC/AC Solar Inverter:** SMA 10000 is the ideal inverter for low-scale residential plants. Not only does it deliver extraordinarily high yields with an efficiency of 98%, but it also offers enormous design flexibility and compatibility with many PV modules thanks to its multistring capabilities and wide input voltage range which allows the inverter to regulate reactive power at the point of common coupling. Separate controllers are no longer needed, lowering system costs.

3) **Communication System:** ABB Cluster Controller is ideal for data-logging ABB inverters and acting as an internet gateway when analog inputs for weather sensors or digital inputs for pulse counting meters and status inputs are also needed. Cluster Controller is built in display enabling easy configuration of inputs, outputs, and communications; in addition to quick review of energy and power. Cluster Controller Collects performance information such as energy harvest, power, and voltage and inverter status.

4) **DC-Side Connections & Protection Devices:** The DC-side of the system is designed to ensure maximum protection levels and optimum design, while conforming to the international standards. All connections between modules, DC protection devices and inverters are done using top quality. In addition, connection points are combined using top quality connectors, especially designed for solar applications. Each PV String is protected individually with a fuse or CB, and each MPPT Input of the inverter is protected with a 2-pole Breaker with rated current depend on the design, DC Circuit Breaker, in addition to a DC Surge Arrestor (if the inverter not have DC Surge Arrestor & DC switch inside it) to make sure the system is protected against any lightning strikes or over-voltage faults.

5) **DC Cable:** The DC-Cable of the system is designed to transfer the electricity from the PV panel to the inverter with cross section depend on the current that transfer inside it which are of top quality and chosen to withstand the maximum output current of the Panels according to the specification and drawing. The cables offered are extremely robust and resist high mechanical load and abrasion, endure high temperatures & fire performance and have weather-proof characteristics.

6) **AC-Side Connections & Protection Devices:** The AC-side of the system is designed to ensure maximum protection levels with minimum power line losses, while conforming to the international standards. With ratings suitable to the parameters of each component ‟s connection point. All protection devices and assembly bus bars are held in custom made, durable, weather-proof cabinets positioned appropriately on site, ensuring easier regular access during preventive maintenance procedures, and technical checking.

7) **AC Cable:** The AC-Cable of the system is designed to transfer the electricity from the inverter to the AC system with cross section, which are chosen to withstand the maximum output current of the inverter according to the specification and drawing. The cables offered are extremely robust and resist high mechanical load and abrasion, endure high temperatures.

8) **The grounding system:** It is designed to ensure that each PV module is individually grounded using a 16-mm2 Earthing cable connecting the modules between each other for 1st Row in table & other cable for the 2nd panel's row in table. Moreover, a cable with 16mm2 frame and the mounting structure. In addition to that, the mounting structure is grounded using 16-mm2 Earthing cables, while all other system components are grounded using appropriately sized earthling cables. The main earthing busbar is connected to Electrode or to the existing Earthing system of the same building using earthing cable according to the specification and drawings to get a resistivity with not more than 5 Ohms.

2. Technical evaluation methodologies.

In each PV-Grid connected system, we need to evaluate the parameters which describe the energy quantities in order to judge the feasibility of the project. In this paper, the following technical criteria should be applied.

a. Yield factor (YF)

The yield factor in the general definition is set to compare the regular energy production of the project to its total peak power. An exact definition would be 'The ratio of energy produced by a PV system, either annually, monthly or daily, over the peak power of that system. [6]
This factor can be calculated manually by the following equation:

$$YF = \frac{Energy_{Generated}\ (kWh)}{System\ Power_{Peak}\ (kW_p)}$$

There are many factors that can affect the value of the yield factor. First of all, it mainly depends on the annual irradiation that is incidence to the collector since this parameter is directly connected to the annual energy production. Second, the module's sensitivity to high temperatures and low light levels. Finally, the losses occurring in the system and its efficiency [7].

The following tables represent the value of monthly yield factor for each site followed by the annual yield factor for all the sites.

Table 3: Monthly yield factor (YF) for sites 1 to 5 in kWh/kWp

	Site 1	Site 2	Site 3	Site 4	Site 5
Jan	7.07	100.1	100.71	0	96.33
Feb	0	168	109.71	0	78.17
Mar	0	164.5	163.43	0	128.17
April	0	172.8	166.71	147.75	48.33
May	154.57	168.3	161.43	146.5	84.67
Jun	177.57	177.9	166.29	158	176.33
July	168	186.1	168	159.75	80.67
Aug	161.43	186.1	156.57	154.13	29.67
Sep	86.86	164.4	149.43	144.38	172.33
Oct	0	131.9	130.29	0	112.5
Nov	86.14	107.9	112	90.38	88
Dec	36.14	87.7	85.43	0	36.67

Table 4: Monthly yield factor (YF) for sites 6 to 10 in kWh/kWp

	Site 6	Site 7	Site 8	Site 9	Site10
Jan	82.71	98.29	87.63	98.86	75.43
Feb	81.29	105.43	101.13	110.71	91.71
Mar	142.3	160.29	162.75	161.71	148.9
April	145.4	164.57	169.25	82.71	171.4
May	158	161.43	165	0	173.1
Jun	12.71	165.57	174.5	0	187.3
July	85.43	166.86	175.38	0	189.9
Aug	169.1	150.43	165.38	0	182.7
Sep	3.714	156.86	164	124.29	157.3
Oct	123.6	135	136.25	107.14	37.71
Nov	105	112.43	86.38	0	0
Dec	93.86	87.71	0	0	0

Table 5: Monthly yield factor (YF) for sites 11 to 15 in kWh/kWp

	Site 11	Site 12	Site 13	Site 14	Site 15
Jan	91.85	66.21	96.83	59.93	66.45
Feb	95.91	103.28	98.93	64.62	94.44
Mar	115.46	152.06	114.93	30.62	121.28
April	149.10	172.01	144.51	123.74	147.96
May	174.14	166.50	169.07	165.65	160.03
Jun	150.86	178.78	150.8	163.73	44.97
July	166.41	176.54	162.41	145.29	0.00
Aug	161.01	144.66	149.09	127.35	0.00
Sep	112.87	122.74	102.57	125.85	0.00
Oct	114.46	106.39	94.92	106.47	5.37
Nov	91.53	84.67	16.69	80.04	88.96
Dec	63.40	83.49	67.63	68.53	76.28

Table 6: Annual yield factor (YF) for all sites in kWh/kWp

Site No.	Annual Yield Factor
1	950.94
2	1,967.01
3	1,809.17
4	1,084.28
5	1,226.15
6	1,303.40
7	1,803.60
8	1,719.93
9	742.55
10	1,533.38
11	1,610.91
12	1,687.11
13	1,482.39
14	1,366.98
15	872.88

The following figures represent the values in the tables above.

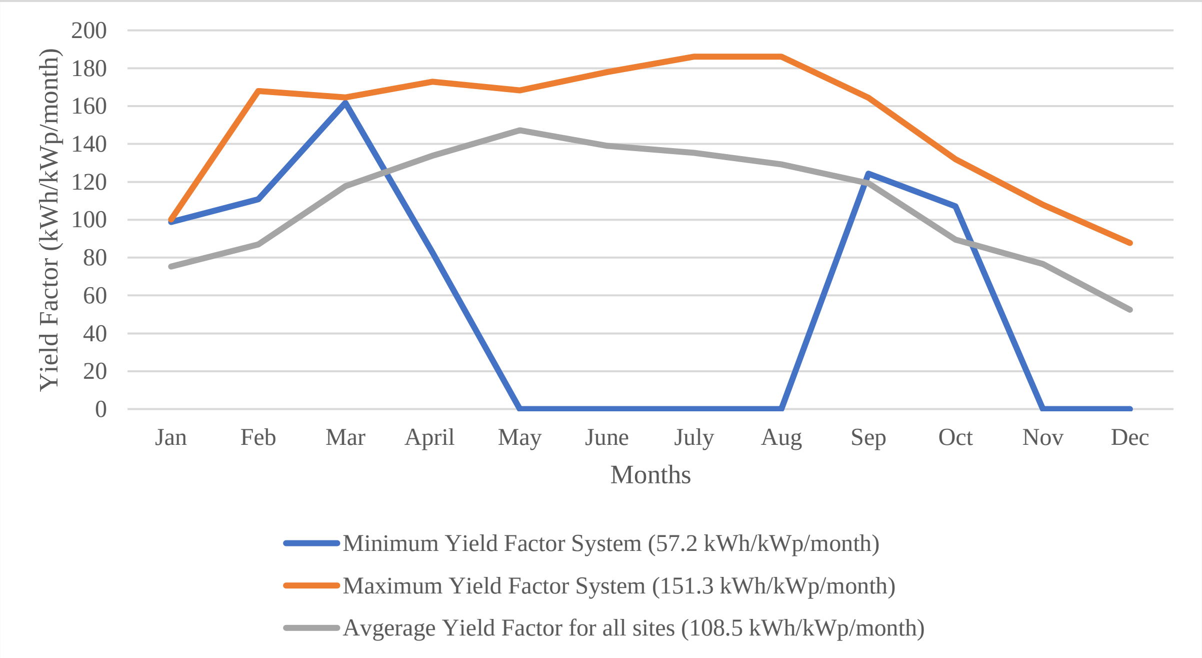

Figure 3: Monthly yield factor (YF) for all sites

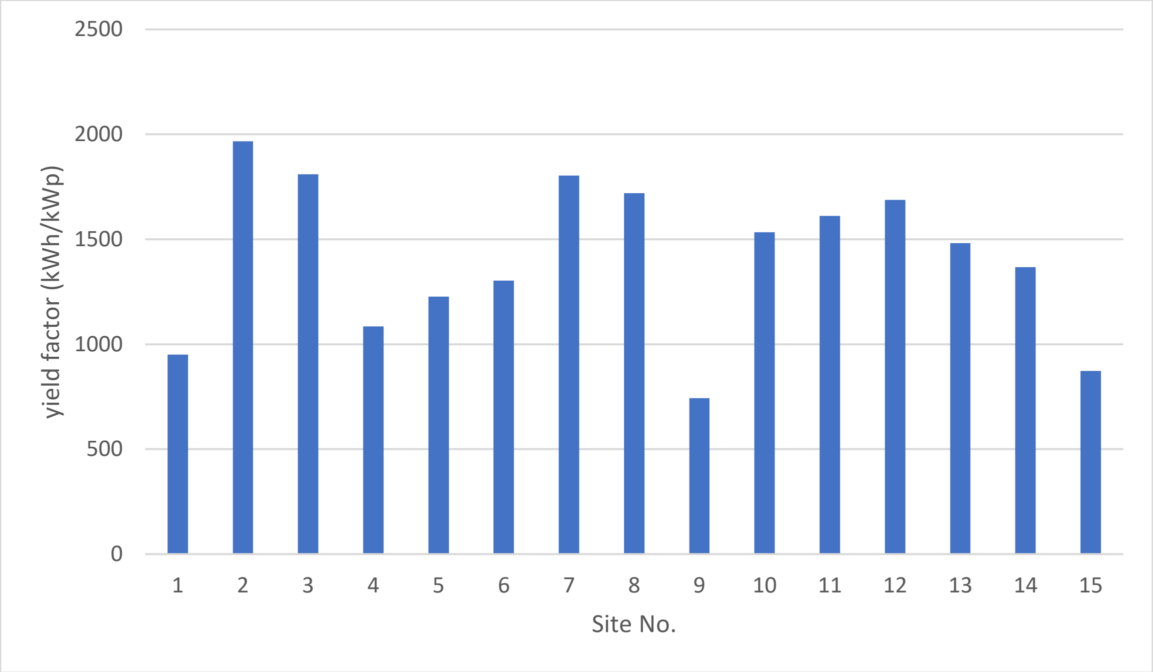

Figure 4: Annual yield factor (YF) for all sites

b. Performance Ratio

The performance ratio is a very important measure of PV projects since it evaluates the quality of the PV system only without considering the incident solar irradiation or the orientation of the solar panels. Therefore, this variable is independent of environmental conditions surrounding the project.

It's agreed to define the performance ratio as 'the ratio of the actual energy output of the PV system to the expected energy output'. This factor will give an indication of the percentage of energy that is available to being utilized by the grid after subtracting the losses of the system, this value varies between zero and one, and it is expressed as a percentage.

The following formula is used for manual calculation of the performance ratio:

$$PR = \frac{Energy_{Generated}(kWh)}{Theoratical\ Energy_{Generated}(kWh)}$$

Many factors would affect the value of the performance factor. The first thing is the temperature of the PV module, when the PV panels are cold, their efficiency would be relatively high. Second, the power dissipation and the conduction losses through the system plus the efficiency value of the inverter and the PV modules. Third, the degradation of the PV panels will definitely lower the P.F value by time, monocrystalline and polycrystalline PV panels usually age up to 20 years.

The following tables represent the values of monthly performance factors for each site.

Table 7: Monthly performance ratio (PR) for sites 1 to 5

	Site 1	Site 2	Site 3	Site 4	Site 5
Jan	4.85%	68.64%	69.06%	0.00%	66.06%
Feb	0.00%	115.20%	75.23%	0.00%	53.60%
Mar	0.00%	112.80%	112.07%	0.00%	87.89%
April	0.00%	118.49%	114.32%	101.31%	33.14%
May	105.99%	115.41%	110.69%	100.46%	58.06%
Jun	121.76%	121.99%	114.02%	108.34%	120.91%
July	115.20%	127.61%	115.20%	109.54%	55.31%
Aug	110.69%	127.61%	107.36%	105.69%	20.34%
Sep	59.56%	112.73%	102.47%	99.00%	118.17%
Oct	0.00%	90.45%	89.34%	0.00%	77.14%
Nov	59.07%	73.99%	76.80%	61.97%	60.34%
Dec	24.78%	60.14%	58.58%	0.00%	25.14%

Table 8: Monthly performance ratio (PR) for sites 6 to 10

	Site 6	Site 7	Site 8	Site 9	Site10
Jan	56.72%	67.40%	60.09%	67.79%	51.72%
Feb	55.74%	72.29%	69.34%	75.92%	62.89%
Mar	97.57%	109.91%	111.60%	110.89%	102.07%
April	99.72%	112.85%	116.06%	56.72%	117.55%
May	108.34%	110.69%	113.14%	0.00%	118.73%
Jun	8.72%	113.53%	119.66%	0.00%	128.42%
July	58.58%	114.42%	120.26%	0.00%	130.19%
Aug	115.98%	103.15%	113.40%	0.00%	125.29%
Sep	2.55%	107.56%	112.46%	85.22%	107.85%
Oct	84.73%	92.57%	93.43%	73.47%	25.86%
Nov	72.00%	77.09%	59.23%	0.00%	0.00%
Dec	64.36%	60.15%	0.00%	0.00%	0.00%

Table 9: Monthly performance ratio (PR) for sites 11 to 15

	Site 11	Site 12	Site 13	Site 14	Site 15
Jan	62.98%	45.40%	67.01%	41.10%	45.57%
Feb	65.77%	70.82%	68.47%	44.31%	64.76%
Mar	79.17%	104.27%	79.54%	21.00%	83.16%
April	102.24%	117.95%	100.01%	84.85%	101.46%
May	119.41%	114.17%	117.01%	113.59%	109.74%
Jun	103.45%	122.59%	104.37%	112.28%	30.84%
July	114.11%	121.06%	112.40%	99.63%	0%
Aug	110.41%	99.20%	103.18%	87.33%	0%
Sep	77.39%	84.17%	70.99%	86.30%	0%
Oct	78.49%	72.95%	65.69%	73.00%	3.68%
Nov	62.76%	58.06%	11.55%	54.89%	61.00%
Dec	43.48%	57.25%	46.81%	46.99%	52.31%

Table 10: Annual performance ratio (PR) for all sites

Site No.	Annual Performance Ratio
1	50.16%
2	103.75%
3	95.43%
4	57.19%
5	64.68%
6	68.75%
7	95.13%
8	90.72%
9	39.17%
10	80.88%
11	84.97%
12	88.99%
13	78.92%
14	72.11%
15	46.04%

The following figures represent the values in tables above.

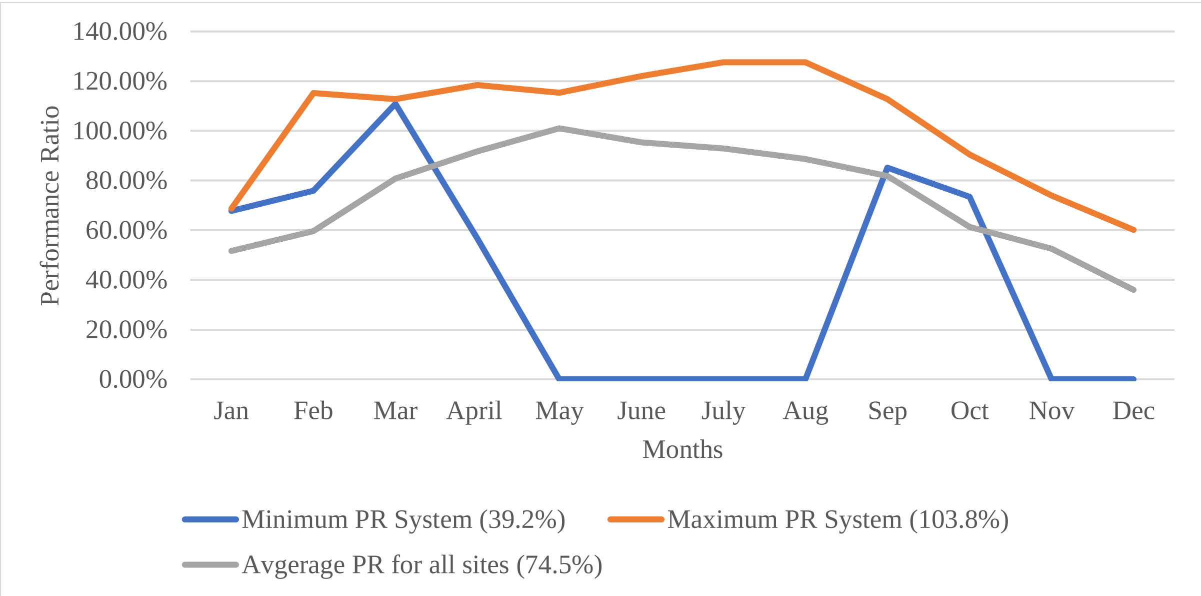

Figure 5: Monthly performance ratio (PR) for all sites

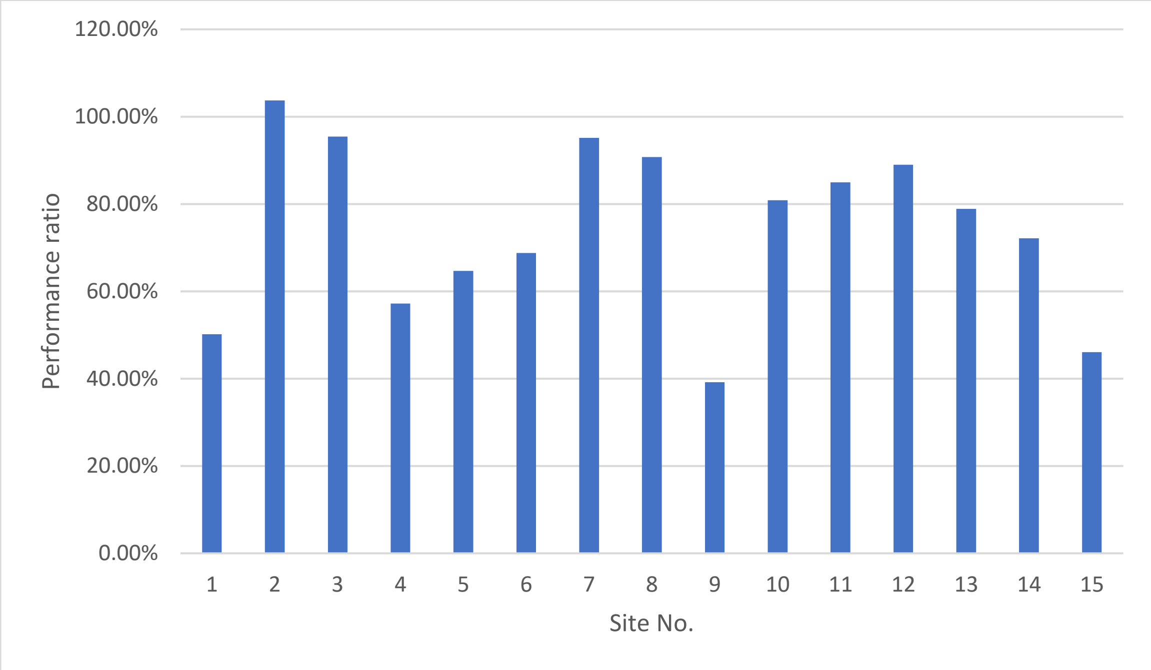

Figure 6: Annual performance ratio (PR) for all sites

c. Capacity factor

The capacity factor indicates the relation between the output energy of a system at a specific period, to the energy of that system at its maximum power potential. Meaning that it is the actual power generated divided by the theoretical maximum power. [6]

$$CF = \frac{Energy_{Generated}(kWh/month)}{System\ Power_{Peak}(kWp) \times 12 \times 30}$$

The capacity factor depends on the operating time and power output, so if we have a low ratio then that means the system is not operating either due to no solar radiation or due to a break down in the plant. On the other hand, is not operating because of a low operating time so the power output is below its maximum [8].

The following tables represent the value of capacity factor for each site.

Table 11: Monthly capacity factor (CF) for sites 1 to 5

	Site 1	Site 2	Site 3	Site 4	Site 5
Jan	1.90%	26.91%	27.07%	0.00%	25.90%
Feb	0.00%	50.00%	32.65%	0.00%	23.26%
Mar	0.00%	44.22%	43.93%	0.00%	34.45%
April	0.00%	48.00%	46.31%	41.04%	13.43%
May	41.55%	45.24%	43.39%	39.38%	22.76%
Jun	49.33%	49.42%	46.19%	43.89%	48.98%
July	45.16%	50.03%	45.16%	42.94%	21.68%
Aug	43.39%	50.03%	42.09%	41.43%	7.97%
Sep	24.13%	45.67%	41.51%	40.10%	47.87%
Oct	0.00%	35.46%	35.02%	0.00%	30.24%
Nov	23.93%	29.97%	31.11%	25.10%	24.44%
Dec	9.72%	23.58%	22.96%	0.00%	9.86%

Table 12: Monthly capacity factor (CF) for sites 6 to 10

	Site 6	Site 7	Site 8	Site 9	Site10
Jan	22.24%	26.42%	23.56%	26.57%	20.28%
Feb	24.19%	31.38%	30.10%	32.95%	27.30%
Mar	38.25%	43.09%	43.75%	43.47%	40.02%
April	40.40%	45.71%	47.01%	22.98%	47.62%
May	42.47%	43.39%	44.35%	0.00%	46.54%
Jun	3.53%	45.99%	48.47%	0.00%	52.02%
July	22.96%	44.85%	47.14%	0.00%	51.04%
Aug	45.47%	40.44%	44.46%	0.00%	49.12%
Sep	1.03%	43.57%	45.56%	34.52%	43.69%
Oct	33.22%	36.29%	36.63%	28.80%	10.14%
Nov	29.17%	31.23%	23.99%	0.00%	0.00%
Dec	25.23%	23.58%	0.00%	0.00%	0.00%

Table 13: Monthly capacity factor (CF) for sites 11 to 15

	Site 11	Site 12	Site 13	Site 14	Site 15
Jan	24.69%	17.80%	26.03%	16.11%	17.86%
Feb	25.78%	27.76%	26.59%	17.37%	25.39%
Mar	31.04%	40.88%	30.90%	8.23%	32.60%
April	40.08%	46.24%	38.85%	33.26%	39.77%
May	46.81%	44.76%	45.45%	44.53%	43.02%
Jun	40.55%	48.06%	40.54%	44.01%	12.09%
July	44.73%	47.46%	43.66%	39.06%	0.00%
Aug	43.28%	38.89%	40.08%	34.23%	0.00%
Sep	30.34%	32.99%	27.57%	33.83%	0.00%
Oct	30.77%	28.60%	25.51%	28.62%	1.44%
Nov	24.60%	22.76%	4.49%	21.52%	23.91%
Dec	17.04%	22.44%	18.18%	18.42%	20.50%

Table 14: Annual capacity factor (CF) for all sites

Site No.	Annual Capacity Factor
1	19.93%
2	41.54%
3	38.12%
4	22.82%
5	25.90%
6	27.35%
7	38.00%
8	36.25%
9	15.77%
10	32.31%
11	33.31%
12	34.89%
13	30.65%
14	28.27%
15	18.05%

The following figures represent the values in tables above.

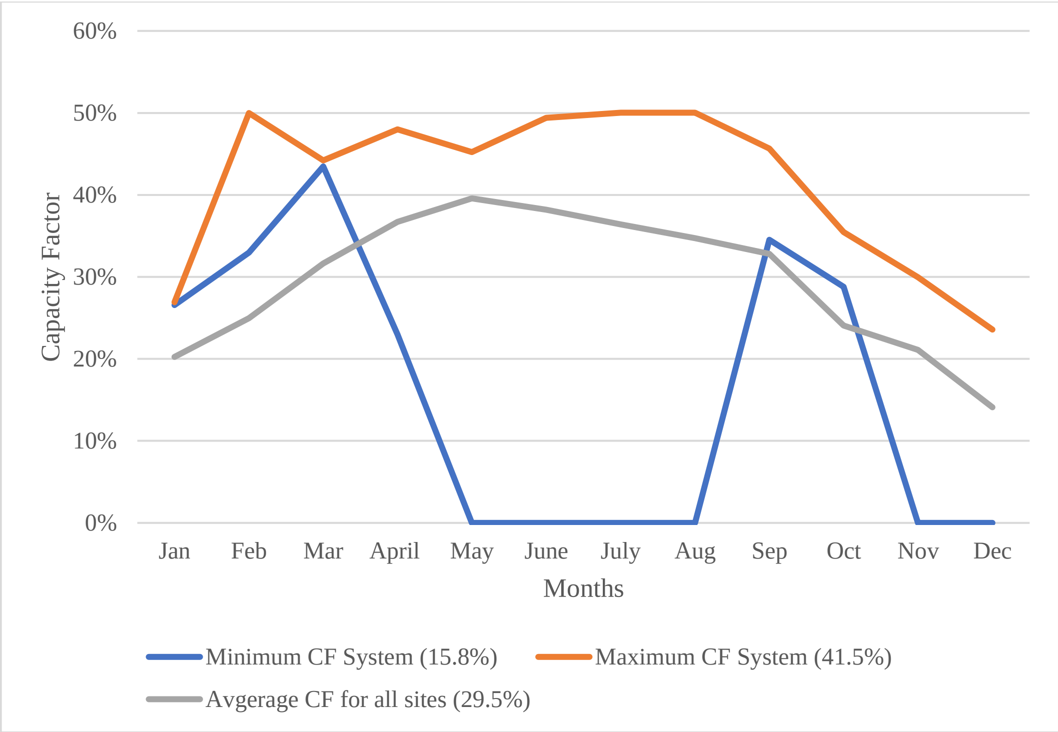

Figure 7: Monthly capacity factor (CF) for all sites

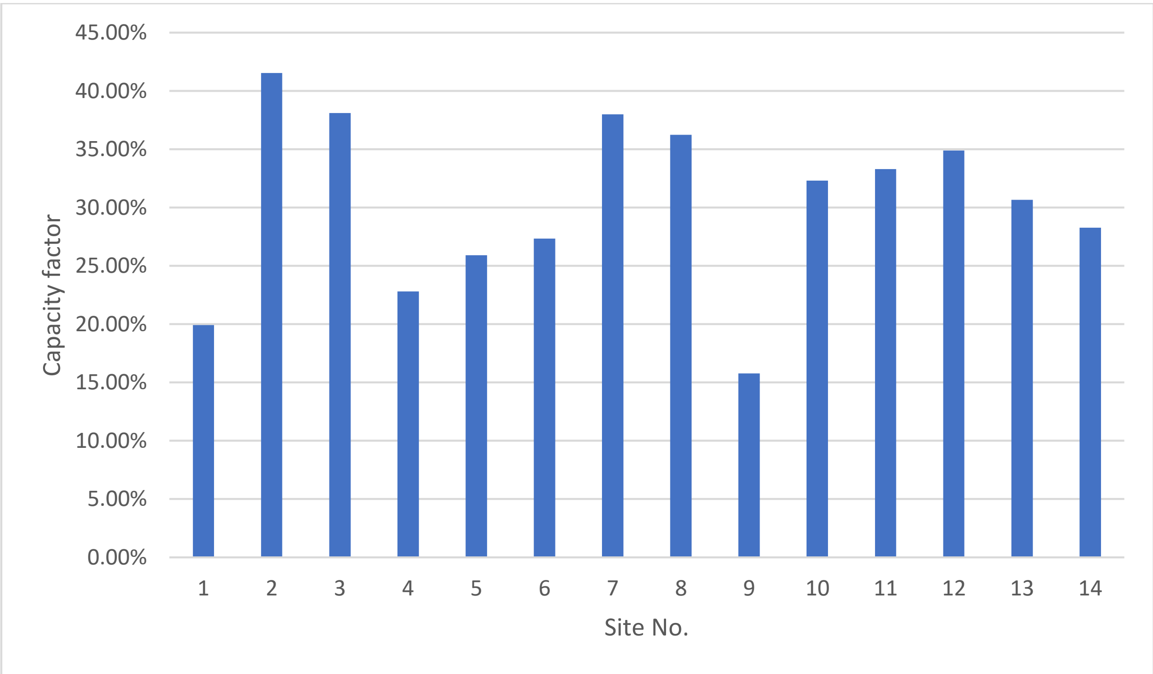

Figure 8: Annual capacity factor (CF) for all sites

3. Economical Evaluation Methodologies.

Once the technical requirements of a PV application have been stated and a PV system design completed, the economic analysis can be carried out. The economic assessment includes both costs and benefits of the system. The economical evaluation methodology is important for evaluating real outcomes of investments. To reach this result the proposed methodology follows the following economic aspects like:

- Evaluation of costs of the PV systems (investment costs and costs for maintenance), and an estimation of yearly income.
- Analysis of cash flows.
- Estimation of economical parameters.

This project gets its annual revenues from the net-metering system.

a. Net metering:

Net metering is a policy that forces companies to buy from solar owners any excess electricity they may generate and do not need at that instance. If a consumer with a solar PV system connected to the grid for net metering generates more electricity than they use, the electricity meter will run backwards to provide credits. The consumer is then billed only net electricity usage each month.

The tables below will show the monthly production of energy for each site:

Table 15: Monthly energy yield for sites 1 to 5 in kWh

	Site 1	Site 2	Site 3	Site 4	Site 5
Jan	50	1,001	705	0	578
Feb	0	1,680	768	0	469
Mar	0	1,645	1,144	0	769
April	0	1,728	1,167	1,182	290
May	1,082	1,683	1,130	1,172	508
Jun	1,243	1,779	1,164	1,264	1,058
July	1,176	1,861	1,176	1,278	484
Aug	1,130	1,861	1,096	1,233	178
Sep	608	1,644	1,046	1,155	1,034
Oct	0	1,319	912	0	675
Nov	603	1,079	784	723	528
Dec	253	877	598	0	220

Table 16: Monthly energy yield for sites 6 to 10 in kWh

	Site 6	Site 7	Site 8	Site 9	Site10
Jan	579	688	701	692	528
Feb	569	738	809	775	642
Mar	996	1,122	1,302	1,132	1,042
April	1,018	1,152	1,354	579	1,200
May	1,106	1,130	1,320	0	1,212
Jun	89	1,159	1,396	0	1,311
July	598	1,168	1,403	0	1,329
Aug	1,184	1,053	1,323	0	1,279
Sep	26	1,098	1,312	870	1,101
Oct	865	945	1,090	750	264
Nov	735	787	691	0	0
Dec	657	614	0	0	0

Table 17: Monthly energy yield for sites 11 to 15 in kWh

	Site 11	Site 12	Site 13	Site 14	Site 15
Jan	1,310	452	2,161	2,081	330
Feb	1,368	704	2,208	2,244	468
Mar	1,646	1,037	2,565	1,063	602
April	2,126	1,173	3,225	4,296	734
May	2,483	1,136	3,774	5,751	794
Jun	2,151	1,219	3,366	5,685	223
July	2,373	1,204	3,625	5,044	0
Aug	2,296	987	3,328	4,422	0
Sep	1,609	837	2,289	4,370	0
Oct	1,632	726	2,119	3,696	27
Nov	1,305	577	372	2,779	441
Dec	904	569	1,510	2,379	378

Table 18: Annual energy yield for all sites in kWh

Site No.	Annual Energy Generation
1	6,145
2	18,157
3	11,690
4	8,007
5	6,791
6	8,422
7	11,654
8	12,701
9	4,798
10	9,908
11	21,204
12	10,621
13	30,542
14	43,811
15	3,996

The following figures represent the values in tables above.

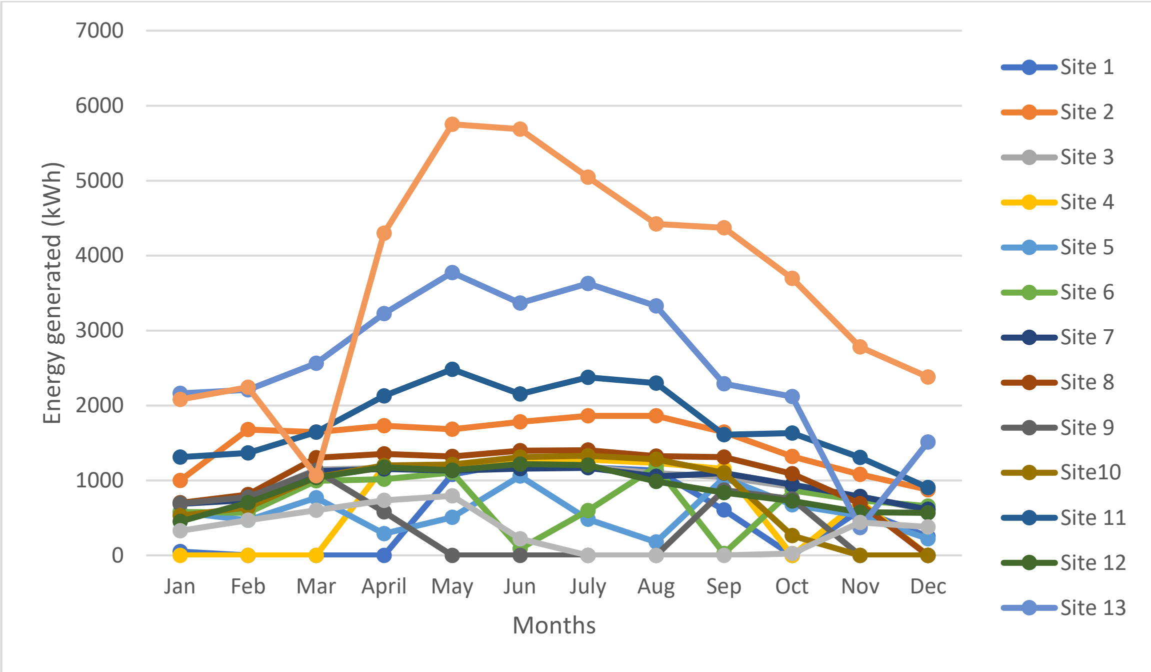

Figure 9: Monthly energy generation for all sites

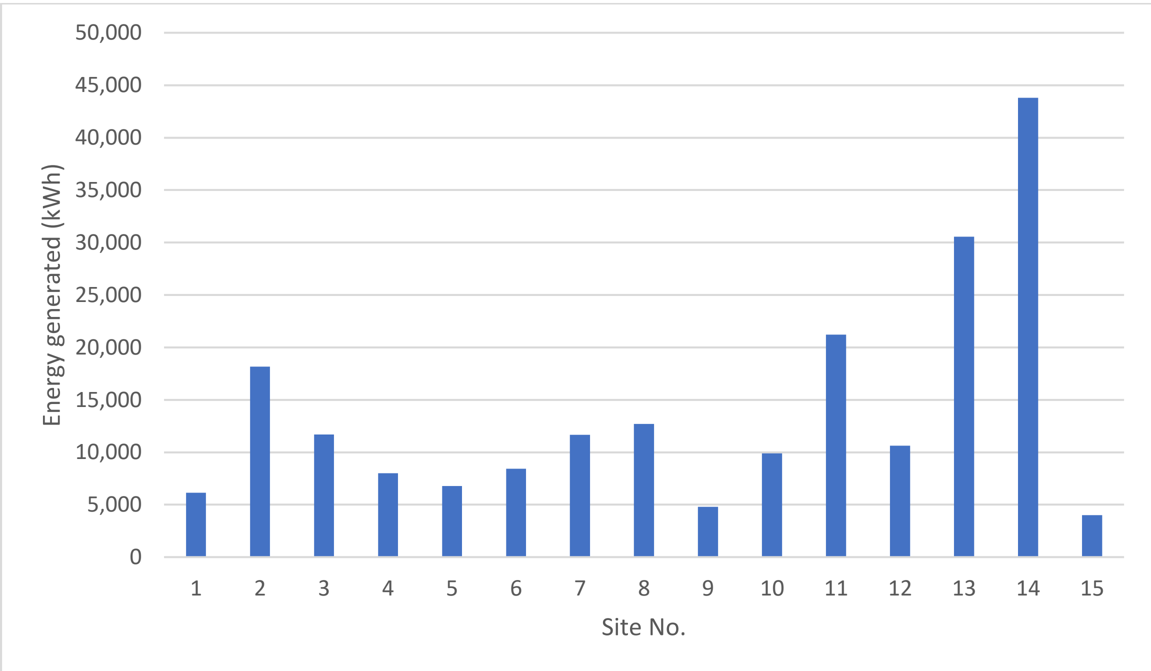

Figure 10: Annual energy generation for all sites

Now, we need to evaluate the system using economical parameters like the internal rate of return (IRR), the simple payback period and the degradation factor that effects the cash flow.

b. Simple payback period

The payback-period is one of the simplest methods that are used for the economical evaluation of PV projects, it tells the time needed for the project to payback itself. In other words, it expresses the time taken to cover the cash outflow.

Simple payback period is simply defined as 'The time taken for the revenues from the solar panels to equal the capital cost that is spent in the project's investment'. And it can be directly calculated by dividing the investment over revenues.

$$SPP = \frac{Investment\ (ILS)}{Revenues\ (ILS)}$$

It is mainly needed to calculate the installation expenditure, which refers to the gross cost of installing the PV solar panels, and the cost of its components as mentioned before. Then it is essential to specify the value of the yearly savings, which is found by the following equation.

$$Revenues = Energy\ tariff_{avg} \times Energy_{Generated}$$

The cost of selling electricity to the grid in Palestine is 0.620 ILS/KWH.

The following table shows detailed economic data of each site, and it also shows the value of SPBP that will be discussed later.

Table 19: Economical evaluation for sites 1 to 5

Site Number	Site 1	Site 2	Site 3	Site 4	Site 5
Type of the system	ABB	ABB	ABB	ABB	ABB
Project Capacity (kWp)	7	10	7	8	6
Yearly production(kwh)	6144	18157	11690	8007	6791
Production unit (kWh/KWp/year)	877.71	1816	1670	1000.9	1132
Currency	ILS	ILS	ILS	ILS	ILS
Price/kWp (ILS/kWp)	6300	6300	6300	6300	6300
Total Price	44100	63000	44100	50400	37800
Tariff Rate	0.62	0.62	0.62	0.62	0.62
Yearly Income (ILS)	3809.3	11257	7248	4964.3	4210
Simple Pay-Back Period (SPBP)	11.577	5.596	6.085	10.152	8.978

Table 20: Economical evaluation for sites 6 to 10

Site Number	Site 6	Site 7	Site 8	Site 9	Site10
Type of the system	ABB	ABB	ABB	ABB	ABB
Project Capacity (kWp)	7	7	8	7	7
Yearly production(kwh)	8422	11654	12701	4798	9908
Production unit (kWh/KWp/year)	1203.1	1665	1588	685.4	1415.4
Currency	ILS	ILS	ILS	ILS	ILS
Price/kWp (ILS/kWp)	6300	6300	6300	6300	6300
Total Price	44100	44100	50400	44100	44100
Tariff Rate	0.62	0.62	0.62	0.62	0.62
Yearly Income (ILS)	5221.6	7225	7875	2975	6143
Simple Pay-Back Period (SPBP)	8.4456	6.103	6.4	14.82	7.1789

Table 21: Economical evaluation for sites 11 to 15

Site Number	Site 11	Site 12	Site 13	Site 14	Site 15
Type of the system	SMA	SMA	SMA	SMA	SMA
Project Capacity (kWp)	14.26	6.82	22.32	34.72	4.96
Yearly production(kwh)	21,205	10,621	30,542	43,811	3,996
Production unit (kWh/KWp/year)	1,487	1,557	1,368	1,262	806
Currency	ILS	ILS	ILS	ILS	ILS
Price/kWp (ILS/kWp)	6300	6300	6300	6300	6300
Total Price	89,838	42,966	140,616	218.736	31,248
Tariff Rate	0.62	0.62	0.62	0.62	0.62
Yearly Income (ILS)	13,147	6,585	18,936	27,163	2,478
Simple Pay-Back Period (SPBP)	6.83	6.52	7.43	8.05	12.61

c. Performance degradation rate

The ability to predict accurately power delivery over the course of time is of vital importance to the growth of the photovoltaic (PV) industry. Two key cost drivers are the efficiency with which sunlight converted into power and how this relationship changes over time. An accurate quantification of power decline over time, also known as degradation rate, is essential to all stakeholders—utility companies, integrators, investors, and researchers alike. Financially, degradation of a PV module or system is equally important, because a higher degradation rate

translates directly into less power produced and, therefore, reduces future cash flows. Furthermore, inaccuracies in determined degradation rates lead to increased financial risk.
In our economical estimations, we selected the value of the performance degradation rate as 0.7% [9].
This factor mainly affects the energy produced yearly from the system, and its total cash flow. The following tables will show detailed numbers of cash flows for each site studied. These tables can be seen individually in the upcoming pages.

Table 22: Cashflow for site No. 1

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	6,144	0.62	3,809	0	-40,291
2	6,101	0.62	3,783	0	-36,508
3	6,058	0.62	3,756	0	-32,752
4	6,015	0.62	3,729	0	-29,023
5	5,972	0.62	3,703	0	-25,320
6	5,929	0.62	3,676	0	-21,644
7	5,886	0.62	3,649	0	-17,995
8	5,843	0.62	3,623	0	-14,372
9	5,800	0.62	3,596	0	-10,776
10	5,757	0.62	3,569	0	-7,207
11	5,714	0.62	3,543	0	-3,664
12	5,671	0.62	3,516	0	-149
13	5,628	0.62	3,489	0	3,341
14	5,585	0.62	3,463	0	6,803
15	5,542	0.62	3,436	0	10,239
16	5,499	0.62	3,409	0	13,649
17	5,456	0.62	3,383	0	17,031
18	5,413	0.62	3,356	0	20,387
19	5,370	0.62	3,329	0	23,717
20	5,327	0.62	3,303	0	27,019
21	5,284	0.62	3,276	0	30,295
22	5,241	0.62	3,249	0	33,545
23	5,198	0.62	3,223	0	36,767
24	5,155	0.62	3,196	0	39,963
25	5,112	0.62	3,169	0	43,133
Total	140,698				

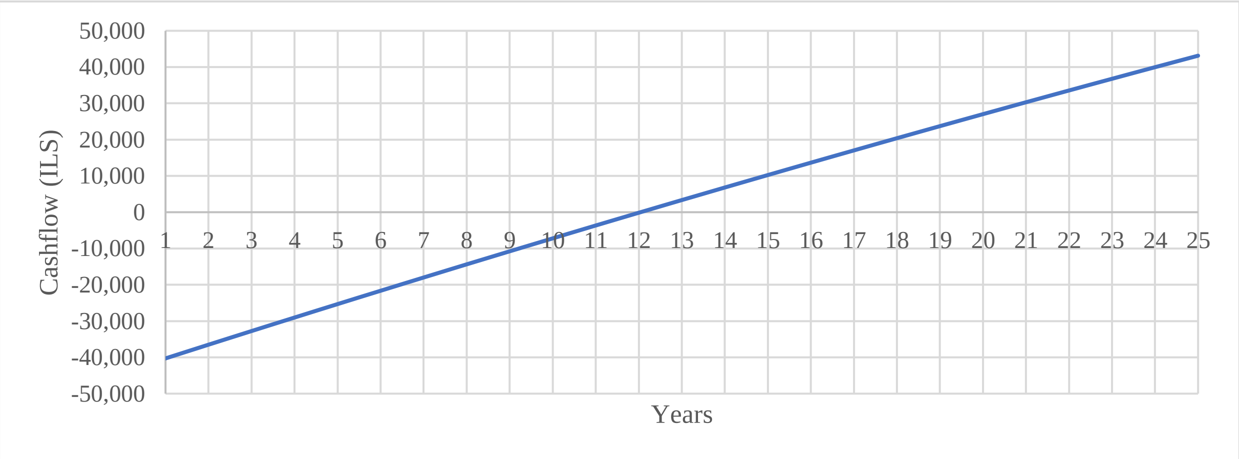

Figure 11: Cumulative cashflow and break-even point for site No. 1

Table 23: Cashflow for site No. 2

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	18,157	0.62	11,257	0	-51,743
2	18,030	0.62	11,179	0	-40,564
3	17,903	0.62	11,100	0	-29,464
4	17,776	0.62	11,021	0	-18,443
5	17,649	0.62	10,942	0	-7,501
6	17,522	0.62	10,863	0	3,362
7	17,394	0.62	10,785	0	14,147
8	17,267	0.62	10,706	0	24,852
9	17,140	0.62	10,627	0	35,479
10	17,013	0.62	10,548	0	46,027
11	16,886	0.62	10,469	0	56,497
12	16,759	0.62	10,391	0	66,887
13	16,632	0.62	10,312	0	77,199
14	16,505	0.62	10,233	0	87,432
15	16,378	0.62	10,154	0	97,586
16	16,251	0.62	10,075	0	107,661
17	16,123	0.62	9,997	0	117,658
18	15,996	0.62	9,918	0	127,576
19	15,869	0.62	9,839	0	137,414
20	15,742	0.62	9,760	0	147,175
21	15,615	0.62	9,681	0	156,856
22	15,488	0.62	9,603	0	166,458
23	15,361	0.62	9,524	0	175,982
24	15,234	0.62	9,445	0	185,427
25	15,107	0.62	9,366	0	194,793
Total	415,795				

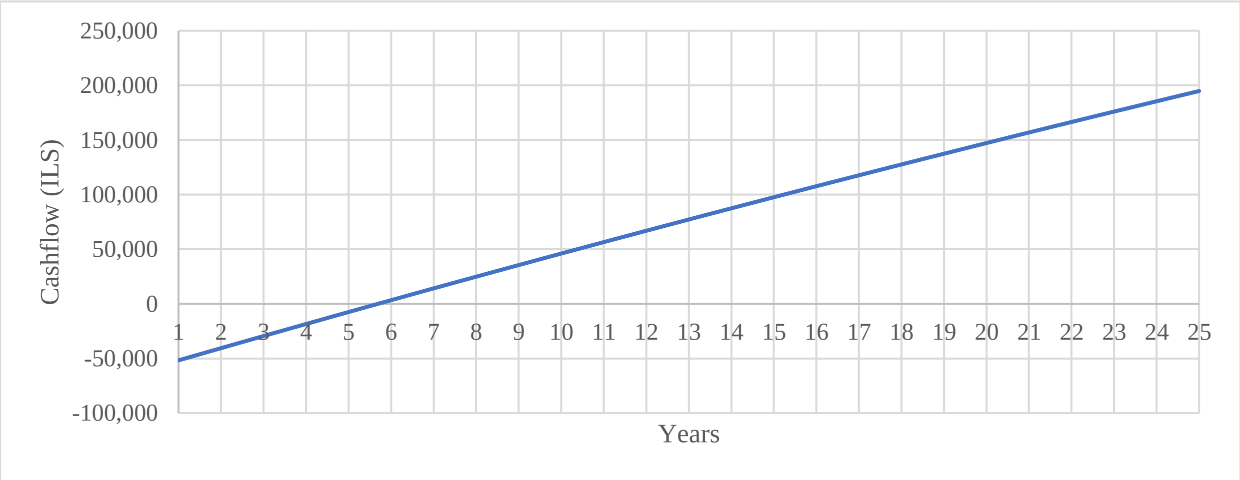

Figure 12: Cumulative cashflow and break-even point for site No. 2

Table 24: Cashflow for site No. 3

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	11,690	0.62	7,248	0	-36,852
2	11,608	0.62	7,197	0	-29,655
3	11,526	0.62	7,146	0	-22,509
4	11,445	0.62	7,096	0	-15,413
5	11,363	0.62	7,045	0	-8,368
6	11,281	0.62	6,994	0	-1,374
7	11,199	0.62	6,943	0	5,569
8	11,117	0.62	6,893	0	12,462
9	11,035	0.62	6,842	0	19,304
10	10,954	0.62	6,791	0	26,095
11	10,872	0.62	6,740	0	32,835
12	10,790	0.62	6,690	0	39,525
13	10,708	0.62	6,639	0	46,164
14	10,626	0.62	6,588	0	52,752
15	10,544	0.62	6,538	0	59,290
16	10,463	0.62	6,487	0	65,777
17	10,381	0.62	6,436	0	72,213
18	10,299	0.62	6,385	0	78,598
19	10,217	0.62	6,335	0	84,933
20	10,135	0.62	6,284	0	91,216
21	10,053	0.62	6,233	0	97,450
22	9,972	0.62	6,182	0	103,632
23	9,890	0.62	6,132	0	109,764
24	9,808	0.62	6,081	0	115,844
25	9,726	0.62	6,030	0	121,875
Total	267,701				

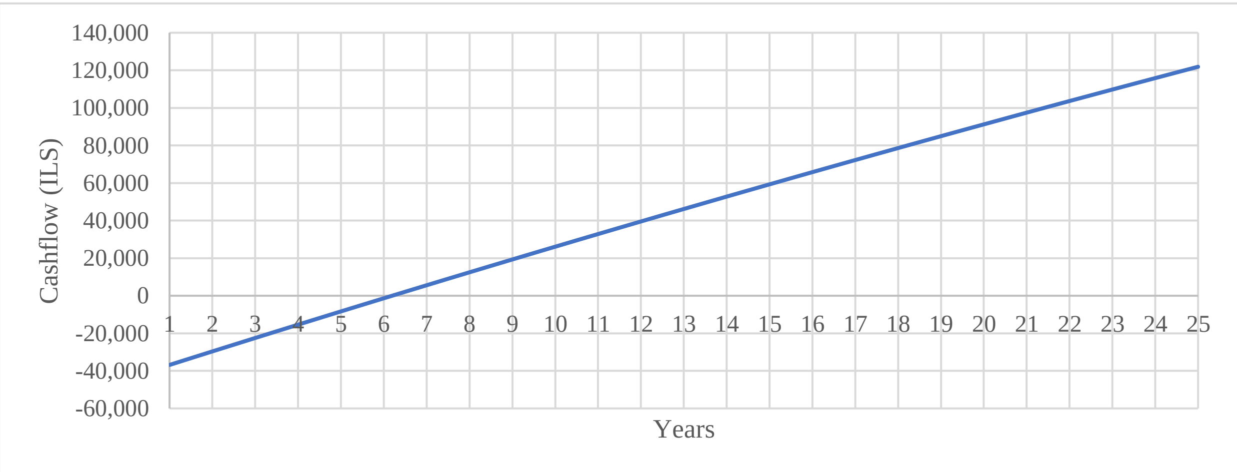

Figure 13: Cumulative cashflow and break-even point for site No. 3

Table 25: Cashflow for site No. 4

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	8,007	0.62	4,964	0	-45,436
2	6,101	0.62	3,783	0	-41,653
3	6,058	0.62	3,756	0	-37,897
4	6,015	0.62	3,729	0	-34,168
5	5,972	0.62	3,703	0	-30,465
6	5,929	0.62	3,676	0	-26,789
7	5,886	0.62	3,649	0	-23,140
8	5,843	0.62	3,623	0	-19,517
9	5,800	0.62	3,596	0	-15,921
10	5,757	0.62	3,569	0	-12,352
11	5,714	0.62	3,543	0	-8,809
12	5,671	0.62	3,516	0	-5,293
13	5,628	0.62	3,489	0	-1,804
14	5,585	0.62	3,463	0	1,658
15	5,542	0.62	3,436	0	5,094
16	5,499	0.62	3,409	0	8,504
17	5,456	0.62	3,383	0	11,886
18	5,413	0.62	3,356	0	15,242
19	5,370	0.62	3,329	0	18,572
20	5,327	0.62	3,303	0	21,874
21	5,284	0.62	3,276	0	25,150
22	5,241	0.62	3,249	0	28,400
23	5,198	0.62	3,223	0	31,622
24	5,155	0.62	3,196	0	34,818
25	5,112	0.62	3,169	0	37,988
Total	142,561				

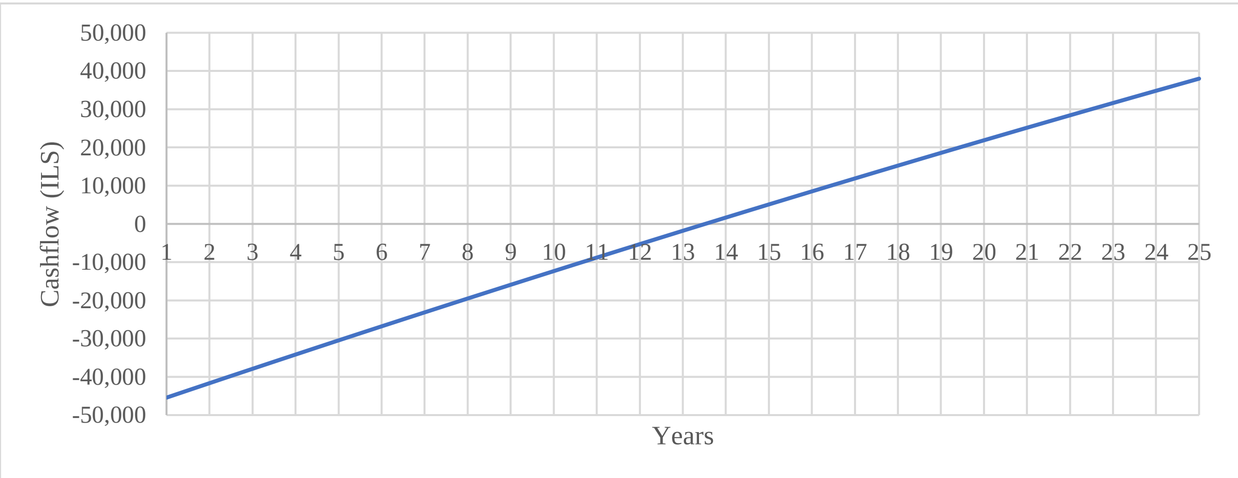

Figure 14: Cumulative cashflow and break-even point for site No. 4

Table 26: Cashflow for site No. 5

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	6,791	0.62	4,210	0	-33,590
2	6,743	0.62	4,181	0	-29,409
3	6,696	0.62	4,151	0	-25,257
4	6,648	0.62	4,122	0	-21,135
5	6,601	0.62	4,093	0	-17,043
6	6,553	0.62	4,063	0	-12,980
7	6,506	0.62	4,034	0	-8,946
8	6,458	0.62	4,004	0	-4,942
9	6,411	0.62	3,975	0	-967
10	6,363	0.62	3,945	0	2,978
11	6,316	0.62	3,916	0	6,894
12	6,268	0.62	3,886	0	10,780
13	6,221	0.62	3,857	0	14,637
14	6,173	0.62	3,827	0	18,464
15	6,125	0.62	3,798	0	22,262
16	6,078	0.62	3,768	0	26,030
17	6,030	0.62	3,739	0	29,769
18	5,983	0.62	3,709	0	33,478
19	5,935	0.62	3,680	0	37,158
20	5,888	0.62	3,650	0	40,809
21	5,840	0.62	3,621	0	44,430
22	5,793	0.62	3,591	0	48,021
23	5,745	0.62	3,562	0	51,583
24	5,698	0.62	3,533	0	55,116
25	5,650	0.62	3,503	0	58,619
Total	155,514				

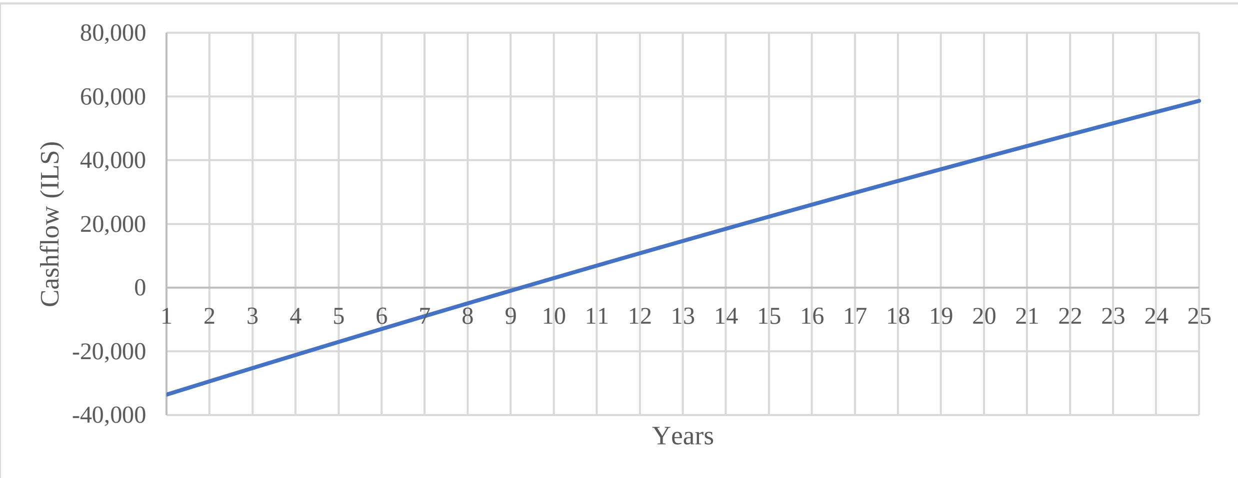

Figure 15: Cumulative cashflow and break-even point for site No. 5

Table 27: Cashflow for site No. 6

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	8,422	0.62	5,222	0	-38,878
2	8,363	0.62	5,185	0	-33,693
3	8,304	0.62	5,149	0	-28,545
4	8,245	0.62	5,112	0	-23,433
5	8,186	0.62	5,075	0	-18,357
6	8,127	0.62	5,039	0	-13,318
7	8,068	0.62	5,002	0	-8,316
8	8,009	0.62	4,966	0	-3,350
9	7,950	0.62	4,929	0	1,579
10	7,891	0.62	4,893	0	6,472
11	7,832	0.62	4,856	0	11,328
12	7,774	0.62	4,820	0	16,147
13	7,715	0.62	4,783	0	20,930
14	7,656	0.62	4,746	0	25,677
15	7,597	0.62	4,710	0	30,387
16	7,538	0.62	4,673	0	35,060
17	7,479	0.62	4,637	0	39,697
18	7,420	0.62	4,600	0	44,297
19	7,361	0.62	4,564	0	48,861
20	7,302	0.62	4,527	0	53,388
21	7,243	0.62	4,491	0	57,879
22	7,184	0.62	4,454	0	62,333
23	7,125	0.62	4,418	0	66,750
24	7,066	0.62	4,381	0	71,131
25	7,007	0.62	4,344	0	75,476
Total	192,864				

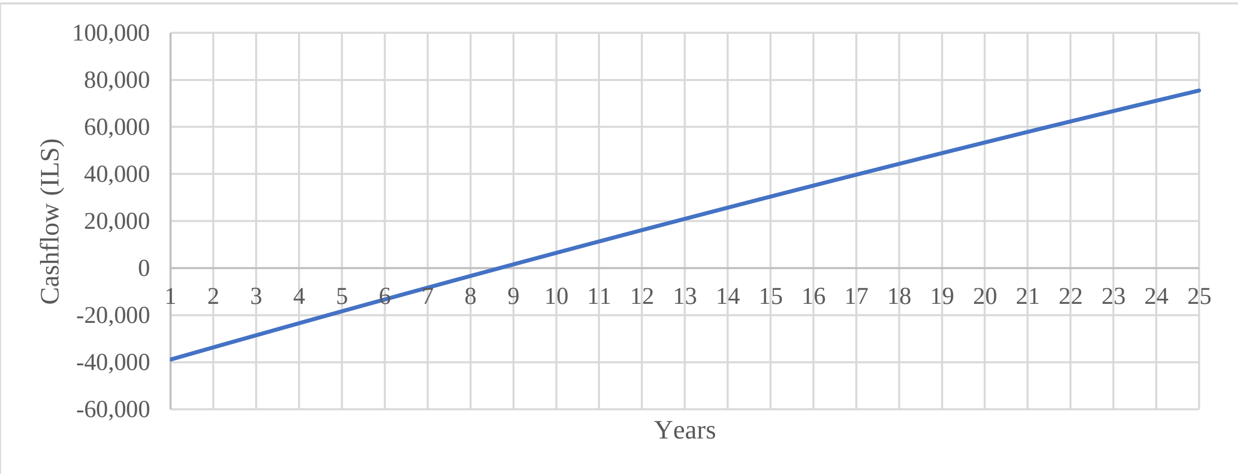

Figure 16: Cumulative cashflow and break-even point for site No. 6

Table 28: Cashflow for site No. 7

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	11,654	0.62	7,225	0	-36,875
2	11,572	0.62	7,175	0	-29,700
3	11,491	0.62	7,124	0	-22,575
4	11,409	0.62	7,074	0	-15,502
5	11,328	0.62	7,023	0	-8,478
6	11,246	0.62	6,973	0	-1,506
7	11,165	0.62	6,922	0	5,416
8	11,083	0.62	6,871	0	12,288
9	11,001	0.62	6,821	0	19,108
10	10,920	0.62	6,770	0	25,879
11	10,838	0.62	6,720	0	32,598
12	10,757	0.62	6,669	0	39,268
13	10,675	0.62	6,619	0	45,886
14	10,593	0.62	6,568	0	52,454
15	10,512	0.62	6,517	0	58,971
16	10,430	0.62	6,467	0	65,438
17	10,349	0.62	6,416	0	71,855
18	10,267	0.62	6,366	0	78,220
19	10,186	0.62	6,315	0	84,535
20	10,104	0.62	6,264	0	90,800
21	10,022	0.62	6,214	0	97,014
22	9,941	0.62	6,163	0	103,177
23	9,859	0.62	6,113	0	109,290
24	9,778	0.62	6,062	0	115,352
25	9,696	0.62	6,012	0	121,363
Total	266,877				

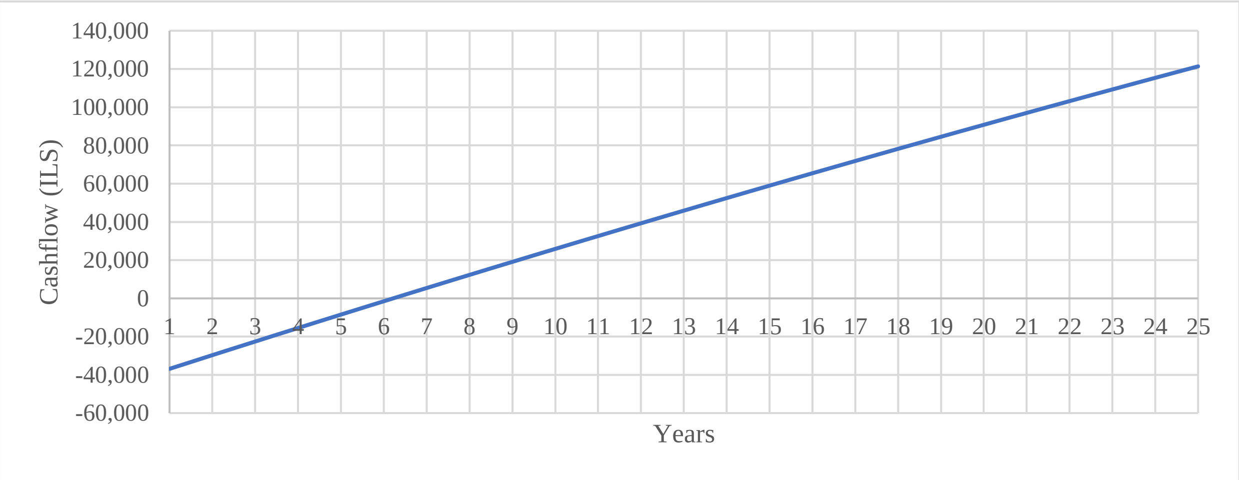

Figure 17: Cumulative cashflow and break-even point for site No. 7

Table 29: Cashflow for site No. 8

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	12,701	0.62	7,875	0	-42,525
2	12,612	0.62	7,819	0	-34,706
3	12,523	0.62	7,764	0	-26,942
4	12,434	0.62	7,709	0	-19,232
5	12,345	0.62	7,654	0	-11,578
6	12,256	0.62	7,599	0	-3,979
7	12,168	0.62	7,544	0	3,565
8	12,079	0.62	7,489	0	11,054
9	11,990	0.62	7,434	0	18,487
10	11,901	0.62	7,379	0	25,866
11	11,812	0.62	7,323	0	33,189
12	11,723	0.62	7,268	0	40,457
13	11,634	0.62	7,213	0	47,671
14	11,545	0.62	7,158	0	54,829
15	11,456	0.62	7,103	0	61,931
16	11,367	0.62	7,048	0	68,979
17	11,278	0.62	6,993	0	75,972
18	11,190	0.62	6,938	0	82,909
19	11,101	0.62	6,882	0	89,792
20	11,012	0.62	6,827	0	96,619
21	10,923	0.62	6,772	0	103,391
22	10,834	0.62	6,717	0	110,108
23	10,745	0.62	6,662	0	116,770
24	10,656	0.62	6,607	0	123,377
25	10,567	0.62	6,552	0	129,929
Total	290,853				

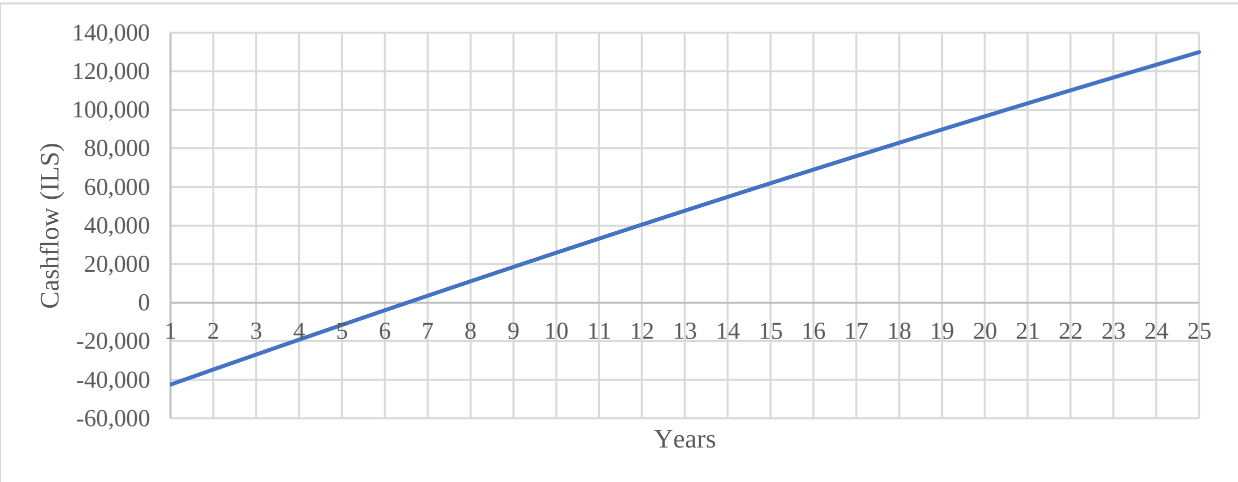

Figure 18: Cumulative cashflow and break-even point for site No. 8

Table 30: Cashflow for site No. 9

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	4,798	0.62	2,975	0	-41,125
2	4,764	0.62	2,954	0	-38,171
3	4,731	0.62	2,933	0	-35,238
4	4,697	0.62	2,912	0	-32,326
5	4,664	0.62	2,891	0	-29,434
6	4,630	0.62	2,871	0	-26,564
7	4,596	0.62	2,850	0	-23,714
8	4,563	0.62	2,829	0	-20,885
9	4,529	0.62	2,808	0	-18,077
10	4,496	0.62	2,787	0	-15,289
11	4,462	0.62	2,767	0	-12,523
12	4,429	0.62	2,746	0	-9,777
13	4,395	0.62	2,725	0	-7,052
14	4,361	0.62	2,704	0	-4,348
15	4,328	0.62	2,683	0	-1,665
16	4,294	0.62	2,662	0	997
17	4,261	0.62	2,642	0	3,639
18	4,227	0.62	2,621	0	6,260
19	4,193	0.62	2,600	0	8,860
20	4,160	0.62	2,579	0	11,439
21	4,126	0.62	2,558	0	13,997
22	4,093	0.62	2,537	0	16,535
23	4,059	0.62	2,517	0	19,051
24	4,026	0.62	2,496	0	21,547
25	3,992	0.62	2,475	0	24,022
Total	109,874				

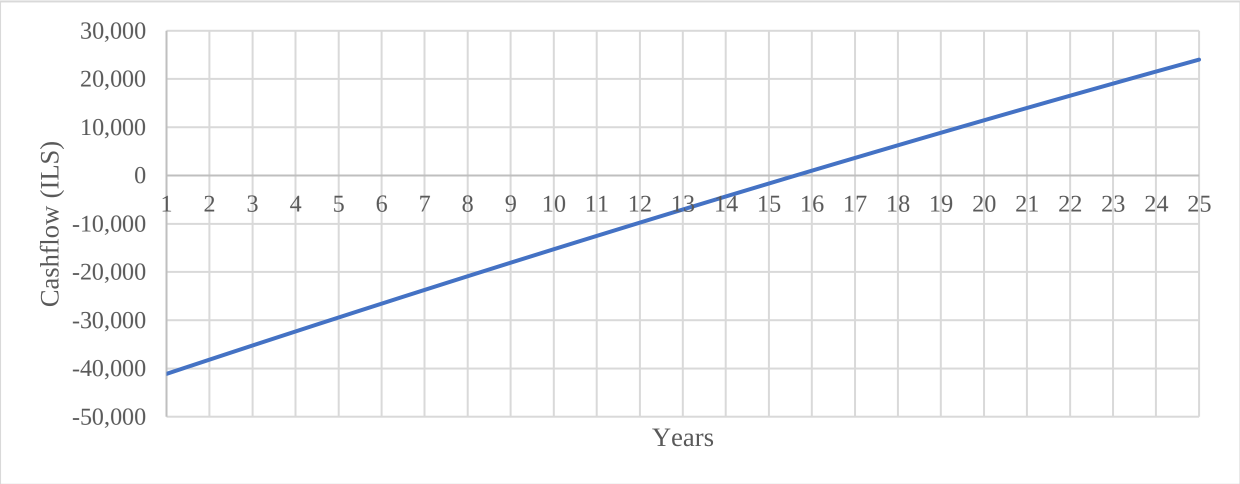

Figure 19: Cumulative cashflow and break-even point for site No. 9

Table 31: Cashflow for site No. 10

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	9,908	1	6,143	0	-37,957
2	9,839	1	6,100	0	-31,857
3	9,770	1	6,057	0	-25,800
4	9,701	1	6,015	0	-19,785
5	9,633	1	5,973	0	-13,812
6	9,566	1	5,931	0	-7,881
7	9,499	1	5,889	0	-1,992
8	9,433	1	5,848	0	3,856
9	9,367	1	5,807	0	9,664
10	9,301	1	5,767	0	15,430
11	9,236	1	5,726	0	21,156
12	9,171	1	5,686	0	26,843
13	9,107	1	5,646	0	32,489
14	9,043	1	5,607	0	38,096
15	8,980	1	5,568	0	43,663
16	8,917	1	5,529	0	49,192
17	8,855	1	5,490	0	54,682
18	8,793	1	5,451	0	60,133
19	8,731	1	5,413	0	65,547
20	8,670	1	5,375	0	70,922
21	8,609	1	5,338	0	76,260
22	8,549	1	5,300	0	81,560
23	8,489	1	5,263	0	86,824
24	8,430	1	5,226	0	92,050
25	8,371	1	5,190	0	97,240
Total	227,968				

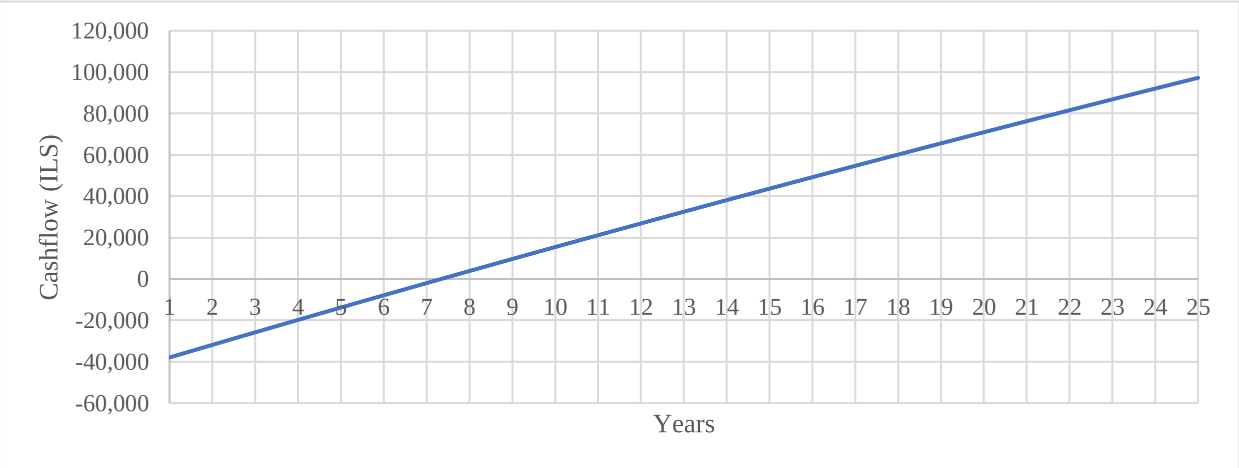

Figure 20: Cumulative cashflow and break-even point for site No. 10

Table 32: Cashflow for site No. 11

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	21,205	1	13147	0	-76,691
2	21,057	1	13055	0	-63,636
3	20,909	1	12964	0	-50,672
4	20,763	1	12873	0	-37,799
5	20,617	1	12783	0	-25,016
6	20,473	1	12693	0	-12,323
7	20,330	1	12604	0	281
8	20,188	1	12516	0	12,798
9	20,046	1	12429	0	25,226
10	19,906	1	12342	0	37,568
11	19,767	1	12255	0	49,823
12	19,628	1	12169	0	61,993
13	19,491	1	12084	0	74,077
14	19,354	1	12000	0	86,077
15	19,219	1	11916	0	97,992
16	19,084	1	11832	0	109,825
17	18,951	1	11749	0	121,574
18	18,818	1	11667	0	133,241
19	18,686	1	11586	0	144,827
20	18,556	1	11504	0	156,331
21	18,426	1	11424	0	167,755
22	18,297	1	11344	0	179,099
23	18,169	1	11265	0	190,364
24	18,041	1	11186	0	201,549
25	17,915	1	11107	0	212,657
Total	487,895				

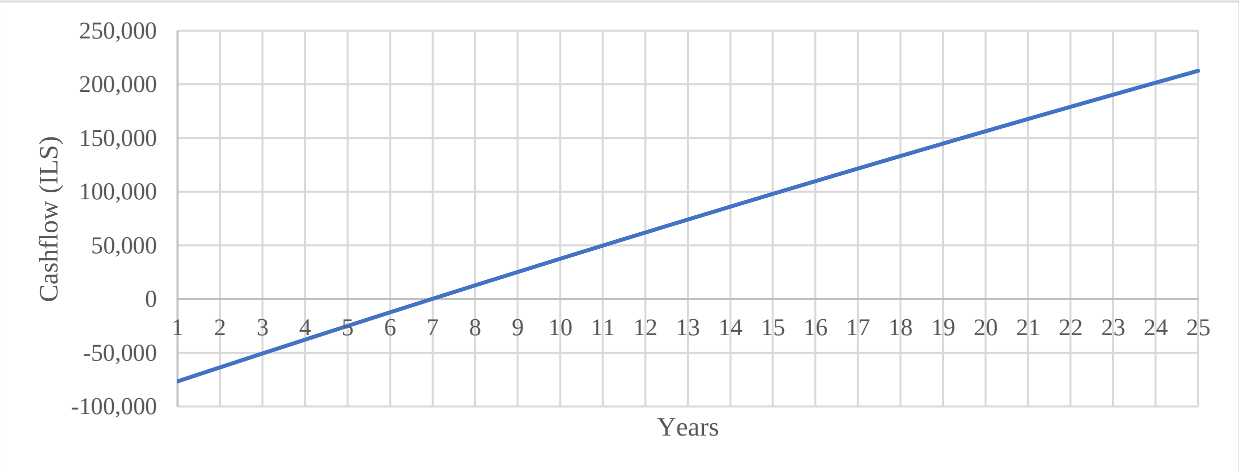

Figure 21: Cumulative cashflow and break-even point for site No. 11

Table 33: Cashflow for site No. 12

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	10,621	1	6,585	0	-36,381
2	10,547	1	6,539	0	-29,842
3	10,473	1	6,493	0	-23,349
4	10,400	1	6,448	0	-16,901
5	10,327	1	6,403	0	-10,499
6	10,254	1	6,358	0	-4,141
7	10,183	1	6,313	0	2,172
8	10,111	1	6,269	0	8,441
9	10,041	1	6,225	0	14,667
10	9,970	1	6,182	0	20,848
11	9,901	1	6,138	0	26,986
12	9,831	1	6,095	0	33,082
13	9,762	1	6,053	0	39,135
14	9,694	1	6,010	0	45,145
15	9,626	1	5,968	0	51,113
16	9,559	1	5,926	0	57,040
17	9,492	1	5,885	0	62,925
18	9,425	1	5,844	0	68,768
19	9,359	1	5,803	0	74,571
20	9,294	1	5,762	0	80,333
21	9,229	1	5,722	0	86,055
22	9,164	1	5,682	0	91,737
23	9,100	1	5,642	0	97,379
24	9,036	1	5,603	0	102,982
25	8,973	1	5,563	0	108,545
Total	244,373				

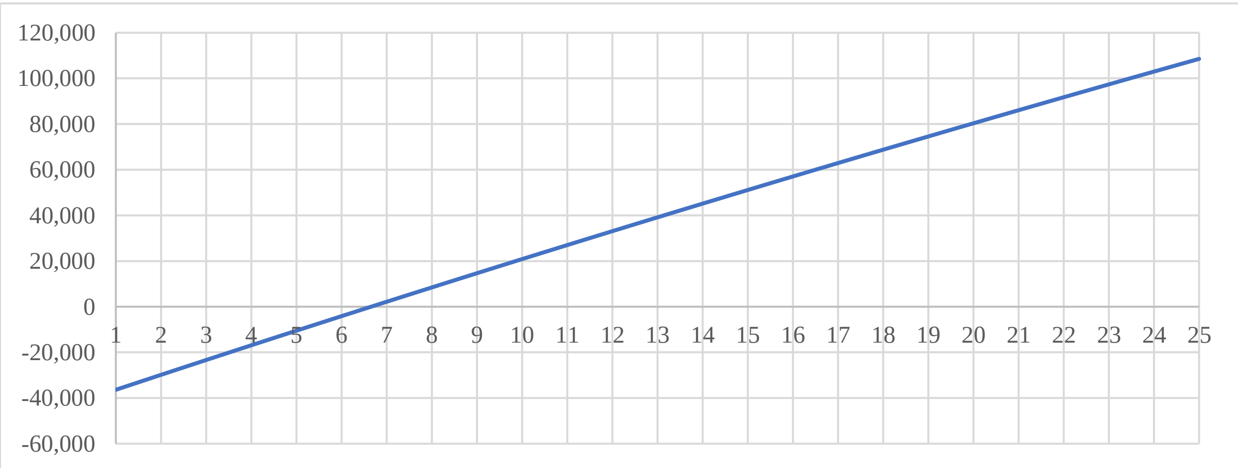

Figure 22: Cumulative cashflow and break-even point for site No. 12

Table 34: Cashflow for site No. 13

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	30,542	1	18936	0	-121,680
2	30,328	1	18,803	0	-102,876
3	30,116	1	18,672	0	-84,205
4	29,905	1	18,541	0	-65,663
5	29,696	1	18,411	0	-47,252
6	29,488	1	18,282	0	-28,970
7	29,281	1	18,155	0	-10,815
8	29,077	1	18,027	0	7,212
9	28,873	1	17,901	0	25,114
10	28,671	1	17,776	0	42,890
11	28,470	1	17,652	0	60,541
12	28,271	1	17,528	0	78,069
13	28,073	1	17,405	0	95,474
14	27,876	1	17,283	0	112,758
15	27,681	1	17,162	0	129,920
16	27,488	1	17,042	0	146,962
17	27,295	1	16,923	0	163,885
18	27,104	1	16,805	0	180,690
19	26,914	1	16,687	0	197,377
20	26,726	1	16,570	0	213,947
21	26,539	1	16,454	0	230,401
22	26,353	1	16,339	0	246,740
23	26,169	1	16,225	0	262,964
24	25,985	1	16,111	0	279,075
25	25,804	1	15,998	0	295,074
Total	702,725				

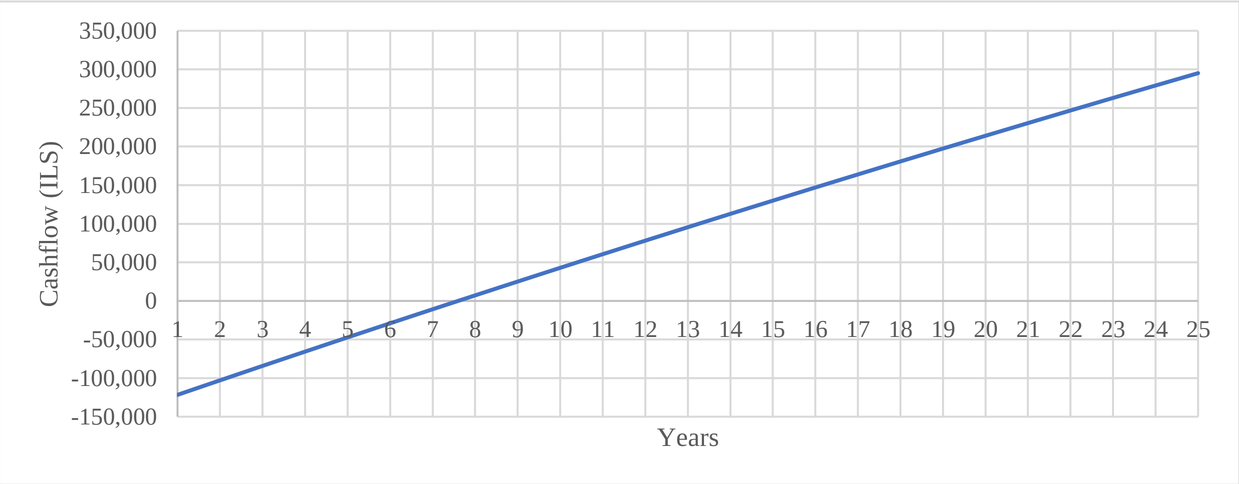

Figure 23: Cumulative cashflow and break-even point for site No. 13

Table 35: Cashflow for site No. 14

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	43,811	1	27,163	0	-191,573
2	43,504	1	26,973	0	-164,600
3	43,200	1	26,784	0	-137,817
4	42,897	1	26,596	0	-111,220
5	42,597	1	26,410	0	-84,810
6	42,299	1	26,225	0	-58,585
7	42,003	1	26,042	0	-32,543
8	41,709	1	25,859	0	-6,683
9	41,417	1	25,678	0	18,995
10	41,127	1	25,499	0	44,494
11	40,839	1	25,320	0	69,814
12	40,553	1	25,143	0	94,957
13	40,269	1	24,967	0	119,924
14	39,987	1	24,792	0	144,716
15	39,708	1	24,619	0	169,335
16	39,430	1	24,446	0	193,781
17	39,154	1	24,275	0	218,056
18	38,879	1	24,105	0	242,161
19	38,607	1	23,937	0	266,098
20	38,337	1	23,769	0	289,867
21	38,069	1	23,603	0	313,470
22	37,802	1	23,437	0	336,907
23	37,538	1	23,273	0	360,180
24	37,275	1	23,110	0	383,291
25	37,014	1	22,949	0	406,239
Total	1,008,025				

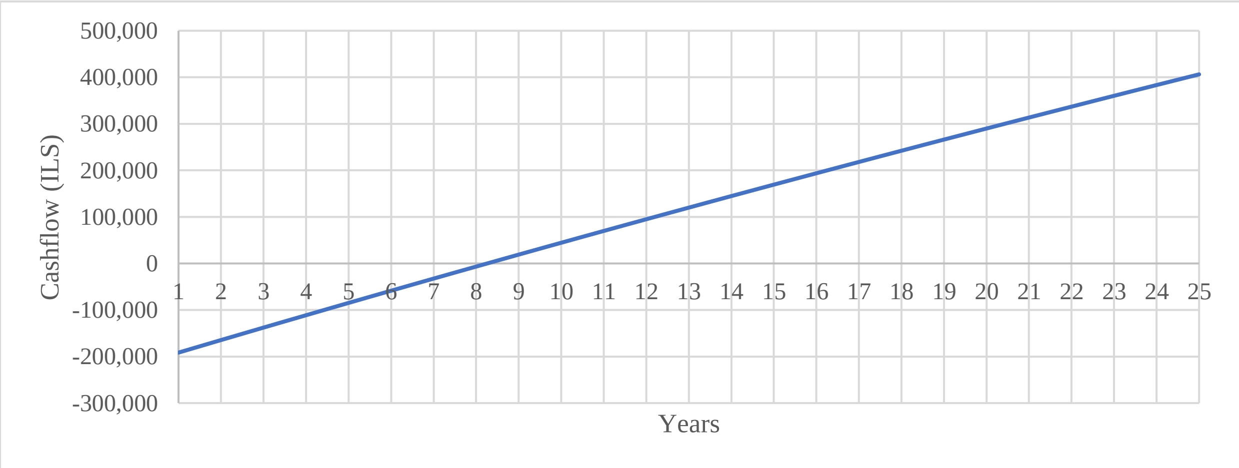

Figure 24: Cumulative cashflow and break-even point for site No. 14

Table 36: Cashflow for site No. 15

Year	Energy (kWh)	Tariff (ILS/kWh)	Yearly Income (ILS)	Maintenance (ILS)	Cumulative Cashflow (ILS)
1	3,996	1	2,478	0	-28,770
2	3,968	1	2,460	0	-26,310
3	3,940	1	2,443	0	-23,867
4	3,913	1	2,426	0	-21,441
5	3,885	1	2,409	0	-19,033
6	3,858	1	2,392	0	-16,641
7	3,831	1	2,375	0	-14,265
8	3,804	1	2,359	0	-11,907
9	3,778	1	2,342	0	-9,565
10	3,751	1	2,326	0	-7,239
11	3,725	1	2,309	0	-4,929
12	3,699	1	2,293	0	-2,636
13	3,673	1	2,277	0	-359
14	3,647	1	2,261	0	1,902
15	3,622	1	2,245	0	4,148
16	3,596	1	2,230	0	6,378
17	3,571	1	2,214	0	8,592
18	3,546	1	2,199	0	10,790
19	3,521	1	2,183	0	12,974
20	3,497	1	2,168	0	15,142
21	3,472	1	2,153	0	17,294
22	3,448	1	2,138	0	19,432
23	3,424	1	2,123	0	21,555
24	3,400	1	2,108	0	23,663
25	3,376	1	2,093	0	25,756
Total	91942				

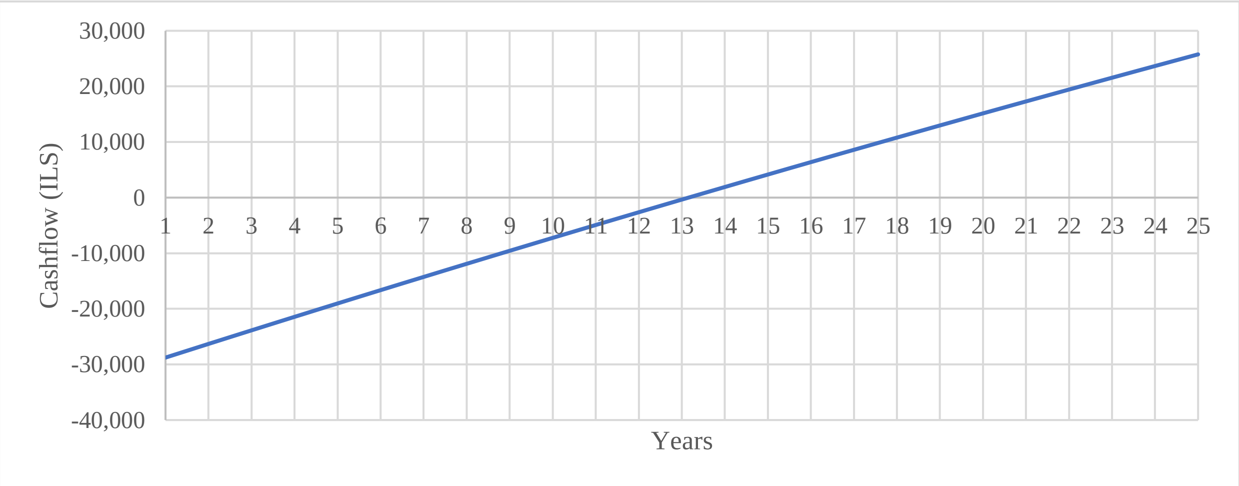

Figure 25: Cumulative cashflow and break-even point for site No. 15

d. Internal Rate of Return (IRR):

It is the value of the cost of the capital Ccfor which the NPV is equal to null and it represents the profitability of the investment whose suitability is being evaluated. If the IIR exceeds the value of Cc taken for the calculation of the NPV, the considered investment shall be profitable. On the contrary, if the IIR resulted to be lower than the return R, the investment would have to be avoided. Besides, when choosing among possible alternatives of investment with equal risk, that one with the higher IRR must be chosen.

The following table shows the values of the IRR of each site:

Table 37: Internal rate of return (IRR) for each site

Site No.	IRR
1	8%
2	20%
3	17%
4	5%
5	8%
6	9%
7	17%
8	16%
9	-5%
10	13%
11	14%
12	15%
13	12%
14	10%
15	-1%

4. Conclusion

In a nutshell, PV systems have high potential in Palestine due to many environmentally-supporting factors. However, many problems had been noted that affected the systems technically and financially, for instance, the lack of systems' monitoring which resulted in multiple days/months with zero generations. On the other hand, it was noted that there are many myths surrounding such systems which are generally adopted by contractors as they are in favor. These myths mainly reference to the fast payback period of such systems, which can be explained by not including the maintenance expenses, energy output reductions due to soiling and electricity blackouts … etc.

5. References

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