An-Najah National University

Faculty of Engineering & Information Technology

Energy and Environment Department

Graduation Project 2

“Design of a large PV grid connected-pumping system: A grid and environment impact studies “

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Abstract:

In this project we will design a PV system to install in a 0.25- acre farm near the city of Nablus, so we have three possible systems to do so:

1- On grid system.
2- Off grid system.
3- Off and on grid system.

The aim of the first graduation project is to analysis the first option (on grid system) , and to study it from an economical point of view to determine its feasibility .

The software packages PVSYS and RETSCREEN will be used for determining the components of the PV systems and the output power of each estimation. The system design will include the power of the PV generator, the ratings of the inverter and its number, the wiring of the system and the protection features.

We will discuss in details, the amount of PV's required and how to orient them to give us the maximum power, number of inverters needed, number and sizing of cables, find the cost of the first analysis and how feasible it is on the land.

Then we will design a 199.24kW for true-south and 266.9kw and 69.36 KW south oriented off grid system for the horizontal PV system to cover the load that the farm needs to operate during peak months.

Moreover, a techno economical study will be done for this system including environmental impact assessment.

Discussion

The farm has an area of 110 acres implanted with different kinds of crops that is locally used, the farm has a high consumption of water that is pumped over the whole area of the farm which makes the electricity bill very high for the farmers. Furthermore, the electricity is supplied from Tubas distribution company and it faces many blackouts during the peak times on the grid.

The Farm's owner faces many losses of the crops due to these blackouts and so he wants a reliability of providing electricity and also as well, he wants saving in his electricity bill by doing a PV system in a small area of the farm that can't be used for agriculture which equals 2.5 acres ($2500m^2$), divided into two parts; the land ($2000m^2$) and building roof on the top of the well area which is ($500m^2$).

We have studied the possibilities of the methods that would fit in with the constrains that we have such in order to install our system on the ground, so we came out with these three solutions.

1- On-grid, True south oriented installed PV's. On both (land and well).
2- On-grid, Horizontal oriented installed PV's. On both (land and well).
3- Off-grid, True south oriented installed PV's. only on the well.

Furthermore, we will discuss each solution in details in the coming chapters and each solution will be provided with a Retscreen report for the financial issue and how feasible the solution is and also an environmental impact has been done to see the impact of installing the PV system on the around environment.

Literature review

A large number of national and international studies have been conducted to study the opportunities of reducing electricity consumption and improving energy efficiency. These studies show that, it is quite possible to limit the increase in energy use without having negative effects.

This chapter provides a literature review about previous work. The survey includes the following aspects:

- Design and sizing of on-grid PV systems.
- Design and sizing of hybrid PV systems.

Review of Related Work

Many researches on the design and sizing approaches of grid-connected PV systems, and power quality of grid-connected PV systems have been investigated.

Samimi et al. (1997), analyzed the optimal tilt angle and other aspects of PV modules in various climates. However, an economic optimization design tool for optimal PV size based on technology information, current tariffs and policy has not yet been developed.

Haas et al. (1999), investigated the socioeconomic aspects about an Austrian 200 kWp-rooftop program (100 PV systems with an average capacity of 2.28 kWp) to promote small grid-connected PV systems in Austria.

Gong, and Kulkarni (2005), suggested an optimization method for a grid-connected PV system based on maximizing the utilization of the array output energy and minimizing the electricity power sold to the grid.

Li et al. (2009), dealt with the sizing optimization problem of stand-alone PVPS using hybrid energy storage technology. The three hybrid power systems, i.e., PV/Battery system, PV/fuel cell (PV/FC) system, and PV/FC/Battery system, are optimized, analyzed and compared. The proposed PV/FC/Battery hybrid system was found to be the configuration with lower cost, higher efficiency, and less PV modules as compared with single storage system.

Al-Salaymeh et al. (2010), proposed a design of PV system to produce energy for basic domestic needs. The proposed design studied the feasibility of utilizing PV systems in a standard residential apartment in Amman city in Jordan to conduct energy and economic calculations. It was found that the calculated payback period high in a stand-alone system, to decrease payback period a grid-connected PV system was suggested. The output results of this study show that installation of PV system in a residential flat in Jordan may not be economically rewarding owing to the high cost of PV system compared to the cost of grid electricity.

Techno-economic evaluation of off-grid hybrid photovoltaic–diesel–battery power systems for rural electrification in Saudi Arabia—A way forward for sustainable development Techno-economic viability of hybrid photovoltaic diesel battery power systems for residential loads in Saudi Arabia has been presented.

Economic viability of stand-alone solar photovoltaic system in comparison with diesel-powered system for India Mohanlal Kolhea,, Sunita Kolhea , J.C. Joshib,1(2002). The economic feasibility of standalone PV system in comparison to the most likely conventional alternative system has been analyzed for energy demand through sensitivity analysis and the analysis shows that PV-powered systems are the lowest cost option at a daily energy demand of up to 15kWh

Methodology:

In our proposed project we divided the land that the PV system will be installed into two areas, one called the land with an area of $2000m^2$ and the other is called the well which will be a roof topping with an area of $500m^2$.

The first thing we studied the area which the PV will be installed on, we designed the installations of the panels and taking into considerations the shading analysis between the arrays. And designed the proposed solutions which are the on-grid; true south 199.26KWp and 266.9KWp. and the hybrid solution, PV/Battery storage with the grid 69.36 KWp.

The next step was to do the electrical diagram of each system, as each system consists of solar modules, inverters, DC and AC protection and earthing system. In each component of the system the ratings of each device are calculated to select the correct rating device in order to give the protection from over current production.

After this process we gathered all of the components needed for each system and build a bill of quantity. We investigated the prices of the components in the Palestinian market so we can have a very close estimation of the cost of each proposal solution.

At the end of our project and as we have all of the prices needed for each system we used Retscreen software application to do the economical analyzing, as the software has database of all of the locations around the world with the solar radiation for that location, we can expect the income savings of each system and thus we are able to know the simple payback period and the cost of energy and as well as the cost of the KWp of each system.

CHAPTER 1: INTRODUCTION TO SOLAR ENERGY

Chapter 1: Introduction to Solar energy

Introduction

Renewable energy is the key to a sustainable future, all other forms of energy will be eventually run out, whether it is oil within the next century or coal within the next several hundred, at some point in the future, we will need to be totally reliant in renewable forms or else we will have nothing left to "burn".

Renewable energy is also a key to a sustainable future in that it has a much smaller environmental impact. The largest impact for many renewable forms is the damage done in getting the materials to make the machinery to harvest the energy.

However, the overall impact in much smaller than the fossil fuels or nuclear energy, which has large extraction and waste problems, the drawbacks to use the renewable energy are availability and economics.

Renewable energy sources contribute approximately 25% of the human energy use worldwide; the prime source of renewable energy is solar radiation, i.e. sunlight.

Mankind's traditional uses of wind, water, and solar power are widespread in developed and developing countries, but the mass production of energy (electrical, thermal,……etc.), using renewable energy source has become popular only recently, reflecting the major threats if climate change due to pollution, concerns about exhaustion of fossil fuels, and the environmental, social and political of fossil fuels and nuclear power, many counters and organization promote renewable energies through taxes and subsidies. [1]

1.1 Electricity in Palestine (Challenges and difficulties)

The energy sector acts as a key enabler across all industries. Access to a stable and reasonably priced energy supply is an important driver of economic growth: wastewater treatment plants, manufacturing sites, high tech-hubs, hotels, and many other facilities require reliable power in order to operate effectively. In addition, households require electricity for families to lead a comfortable life, schools need it to create a functional learning environment, and hospitals depend on it to provide a consistent quality of care for patients. [2]

1.2 Energy supply gaps are constraining economic growth

The Palestinian economy is heavily dependent on energy imports with 90% of electricity currently. The remainder is generated by the Gaza Power Plant (GPP), which is fueled by imported gasoil. The majority of the imported electricity comes from Israel. [2]

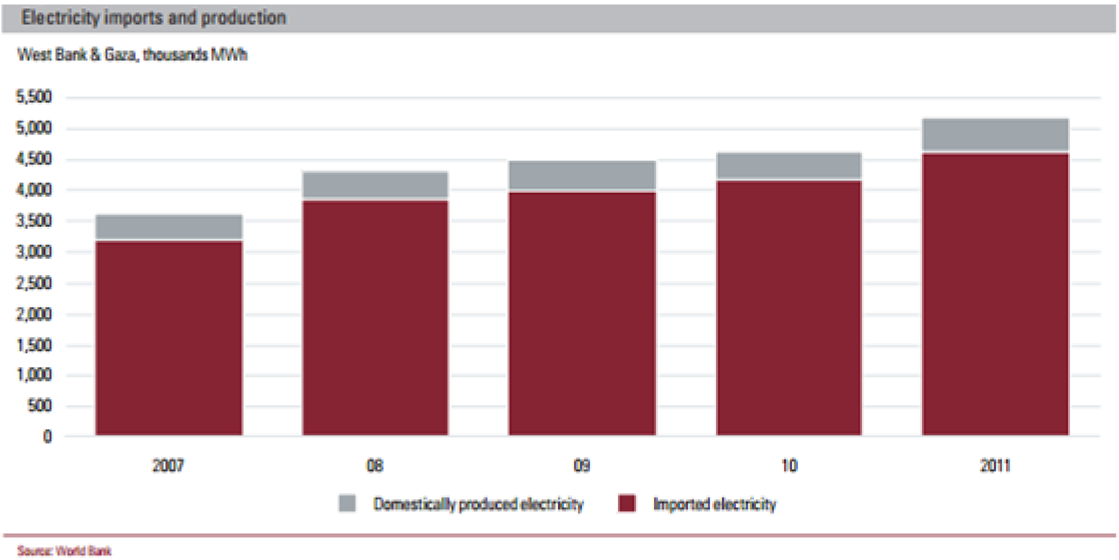


Figure 1: electricity imports and production

Dependence on imports combined with the high cost of domestic production has led to a significant gap between supply and demand. According to interviews, in 2010, the annual electricity needed in the West Bank and Gaza was estimated to be around 6,200 GWh, while supply was only 4,300 GWh. As a result of structural supply shortages in 2008 the majority of Gazan households suffered power cuts of at least eight hours per day, with some having no electricity for up to 12 hours per day. While less of an issue in the West Bank, major energy supply issues continue to affect Gaza. A second problem is inadequate infrastructure. The world Bank estimates losses during distribution to be around 25%: Jordan experiences half this rate of loss and Israel's losses are around 3%.

By reducing dependence on energy imports and increasing utilization of renewable energy, ensuring resilient and sustainable energy supply, our analysis suggests that the Palestinian economy has an opportunity to produce up to 70% of its electricity needs domestically, with as much as 50% of production coming from renewable sources by 2030. If achieved, this could result in more than 17,000 new jobs (from less than 1,000 in 2012) and directly add up to $2.2 B to GDP.[2]

1.3: solar energy:

Solar energy can be a major contributor to the future Palestinian energy supply, with its high potential in the area. Palestine receives about 3,000 hours of sunshine per year

Domestic solar water heating (SWH) is widely used in Palestine where almost 70% of houses and apartments have such system. In fact, Palestine is one of the leading countries in the field of SWH for domestic purpose.

Solar power has many types of technology to exploitation sunlight to produce energy. The following are used in Palestine.[3]

a) Domestic solar water heater.
b) Solar drying.
c) Solar desalination and cooling.
d) Photovoltaic.

1.4: addressing constraints in growth of the sector:

There are four internal constraints that are largely within Palestinian control, which could be therefore feasibly addressed[3]:

1- insufficient energy storage and domestic electricity production facilities, such as gas-freed power plants. This results in the high level of dependence on imports.
2- A lack of incentives to encourage investment in renewable energy
3- Electricity policies do not encourage small-scale generation.
4- High rates of electricity theft, transmission losses and poor billing can result in extra cost being passed on to consumers who do regularly pay, driving up their prices

1.5 Solar radiation in Palestine

Energy from sun travels to the earth in the form of electromagnetic radiation similar to radio waves, but in a different frequency range. Available solar energy is often expressed in units of energy per time per unit area, such as watts per square meter (W/m^2). The amount of energy available from the sun outside the earth's atmosphere is approximately 1367.7 W/m^2; some of the solar energy is absorbed as it passes through the earth's atmosphere. As a result, on a clear day the amount of solar energy available at the earth's surface in the direction of the sun is typically about 1000 W/m^2. at any particular time, the available solar energy is primarily dependent on time and current cloud conditions. Furthermore, useable solar energy is depended upon available solar energy, other weather conditions, the technology used, and the application, the Mean monthly and annual daily global radiations (MJ/m2/day) in Jerusalem shown is the next table[3].

Month	32°N outside atmosphere	Mean Radiation	µ	%
January	20.2	12.02	0.8	60
February	25.0	15.25	1.38	61
March	30.8	19.5	1.13	63
April	35.8	24.09	0.63	67
May	39.5	28.02	0.67	71
June	40.8	30.24	0.34	74
July	40.0	29.76	0.34	74
August	37.2	27.35	0.50	74
September	32.6	23.68	0.50	73
October	26.8	18.49	0.71	69
November	21.4	13.99	0.63	65
December	18.7	11.3	0.67	60
Annual	**30.7**	**21.14**	**0.8**	**69**

Table 1: mean monthly and annual daily global radiation

The Daily Average Global Solar Radiation (kWh/m².day) is given below

	Allud	**Bet Dagan**	**Jerusalem**	**Jericho**	**Bethlehem**	**Gaza**	**PT Average**
Location	**3200N 345E**	**3200N 344E**	**3146N 3511E**	**3151N 352E**	**3151N 3507E**	**3131N 3426E**	
Jan	3.19	2.85	3.06	2.78	2.93	2.78	**2.97**
Feb	4.36	3.76	3.71	3.28	3.28	3.89	**3.73**
Mar	5.44	4.85	5.03	4.85	4.89	4.86	**5.03**
Apr	6.76	6.01	6.35	6.61	6.61	5.83	**6.24**
May	7.92	7.07	7.55	6.89	6.89	6.94	**7.24**
Jun	8.48	7.69	8.42	8.06	8.06	7.78	**8.13**
Jul	8.31	7.45	8.31	8.12	8.12	7.5	**7.9**
Aug.	7.49	6.91	6.91	7.3	7.3	7.22	**7.30**
Sept.	6.49	5.85	6.66	6.36	6.36	6.25	**6.26**
Oct.	5.06	4.51	4.99	4.93	4.93	4.72	**4.81**
Nov.	3.77	3.34	3.8	3.25	3.25	3.61	**3.51**
Dec.	3.05	2.61	3	2.61	2.61	2.5	**2.74**
Average	**5.86**	**5.24**	**5.70**	**5.45**	**5.45**	**5.33**	**5.46**

Table 2The daily average global solar radiation (kWh/m2.day)

CHAPTER 2: WATER PUMPING SYSTEM

Chapter 2:
Water Pumping system

Introduction

The farm has an area of 110 acres implanted with different kinds of crops that is locally used, the farm has a high consumption of water that is pumped over the whole area of the farm, as the pumping system removes water from a well into a water distribution network to cover the whole area of the farm. The pumping system consist of 3 pumps (120HP, 50HP and 70HP).

Thus, makes the electricity bill very high. There is a utility grid connected to the farm with a transformer of 6.6 kv in order to feed it with electricity

Figure 2:the pumping system

Site view

The farm that we are working on is oriented at **Latitude** 32.16 **/ Longitude** 35.21 given below some tables defining exactly the parameters of our location.

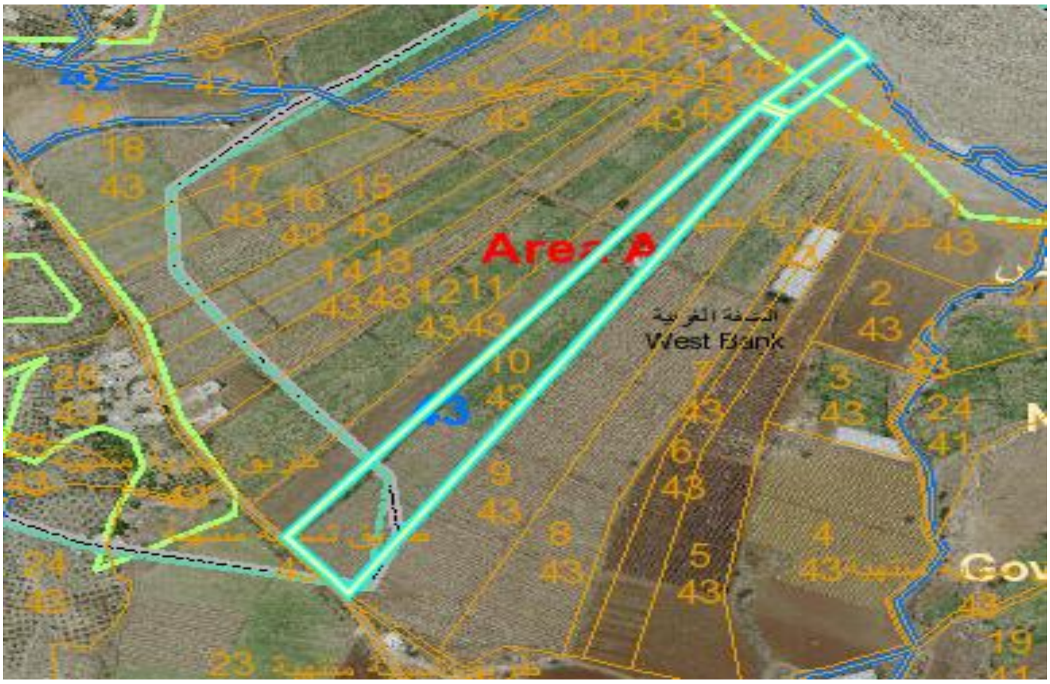


Figure 3: The plan of the farm

Lat 32.16 Lon 35.21	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	1.04	1.33	1.63	1.86	1.92	1.86	1.82	1.70	1.45	1.27	1.05	0.96	1.49
Minimum	0.93	1.12	1.30	1.64	1.67	1.73	1.64	1.56	1.28	1.09	0.98	0.82	1.31
Maximum	1.07	1.36	1.77	2.03	2.19	2.08	1.98	1.83	1.56	1.42	1.15	0.99	1.62
22-year Average K	0.48	0.49	0.54	0.59	0.64	0.67	0.67	0.65	0.64	0.58	0.53	0.48	0.58
Minimum K	0.44	0.35	0.45	0.53	0.57	0.63	0.64	0.62	0.61	0.51	0.43	0.40	0.52
Maximum K	0.56	0.60	0.65	0.65	0.69	0.70	0.70	0.68	0.68	0.64	0.57	0.58	0.64

Table 3:: Monthly Averaged Diffuse Radiation Incident on A Horizontal Surface (kWh/m2/day)

Lat 32.16 Lon 35.21	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
22-year Average	3.84	4.15	5.29	6.45	7.81	8.71	8.55	7.83	7.18	5.79	4.62	3.71	6.17

Table 4:: Monthly Averaged Direct Normal Radiation (kWh/m2/day)

Lat 32.16 Lon 35.21	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	0950	0954	0948	0940	0936	0939	0946	0944	0935	0926	0924	0932

Table 5:Monthly Averaged Solar Noon (GMT time)

Lat 32.16 Lon 35.21	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	10.3	11.0	11.9	12.9	13.8	14.2	14.0	13.3	12.4	11.4	10.5	10.1

Table 6:Monthly Averaged Daylight Hours (hours)

Lat 32.16 Lon 35.21	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	6.02	6.19	6.26	5.65	5.28	5.36	5.45	5.18	4.73	4.67	4.80	5.57	5.42

Table 7:Monthly Averaged Wind Speed At 50 m Above The Surface Of The Earth (m/s)

Lat 32.16 Lon 35.21	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Minimum	-11	-14	-10	-9	-8	-9	-7	-5	-5	-8	-12	-14	-9
Maximum	13	19	12	12	9	7	6	5	5	10	10	15	10

Table 8: Minimum and Maximum Difference From Monthly Averaged Wind Speed At 50 m (%)

Given below an aerial view of the farm. The farm is located in Taloza village – block number 43 – parcel number 10.

We have divided the working area into two categories as follows:

1- The farm:

Figure 4: the selected land to install PV

The empty area above the meadow is our working area where we wish to install our system, this area is approximately 2 acres.

2- The water well:

The farm consists of a water well to help irrigate the crops during drought seasons like summer, So the fact that some crops require constant irrigation led to a high electricity bill which is why the owner of the farm wishes to install PV system that helps him reducing his bill.

Figure 5: the plan of the well

In order to use the area of the well to we will consider building a structural frame to install our system on.

Problem statement:

The farm has an area of 110 acres implanted with different kinds of crops that is locally used, the farm has a high consumption of water that is pumped over the whole area of the farm which makes the electricity bill very high for the farmers. Furthermore, the electricity is supplied from Tubas distribution company and it faces many blackouts during the peak times on the grid.

The Farm's owner faces many losses of the crops due to these blackouts and so he wants a reliability of providing electricity and also as well, he wants saving in his electricity bill by doing a PV system in a small area of the farm that can't be used for agriculture which equals 2.5 acres ($2500m^2$), divided into two parts; the land ($2000m^2$) and building roof on the top of the well area which is ($500m^2$).

We have studied the possibilities of the methods that would fit in with the constrains that we have such in order to install our system on the ground, so we came out with these three solutions.

4- On-grid, True south oriented installed PV's. On both (land and well).
5- On-grid, Horizontal oriented installed PV's. On both (land and well).
6- Off-grid, True south oriented installed PV's. only on the well.

Furthermore, we will discuss each solution in details in the coming chapters and each solution will be provided with a Retscreen report for the financial issue and how feasible the solution is and also an environmental impact has been done to see the impact of installing the PV system on the around environment.

Energy Bill:

The energy bill for the farm is relatively a very high bill due to the pumping system to an open area of the farm. As can be noticed the peak of energy consumption from March to May each year. The farmer provided us, the energy bill for the whole year of 2017 as following in the table below. Taking in consideration the rate of KWH is 0.65NIS/KWH (0.184$/kwh)

Month	Energy Consumption	Money Paid
January	1494	971.3
February	13407	8714.84
March	20094	13061.18
April	67189	43673.35
May	94417	61371.14
June	16097	10463.61
July	15384	10000
August	15692	10200
September	16154	10500.5
October	16357	10632.5
November	15579	10126.5
December	7692	5000
Total	299562	194715

Table 9: Energy bill of the farm

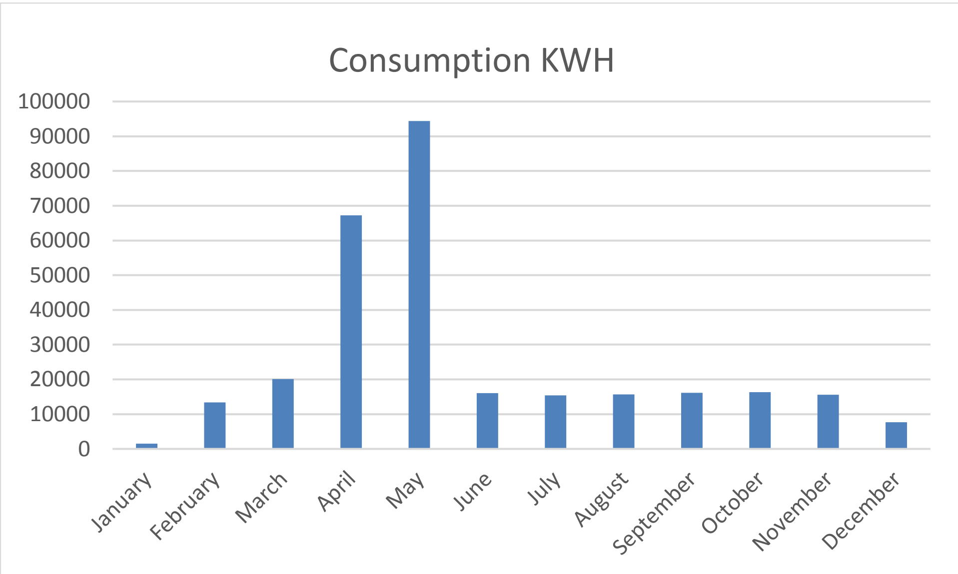


Figure 6: Energy Consumption of the farm

CHAPTER 3: COMPONENTS OF SOLAR SYSTEM

Chapter 3:
Components of Solar System

3.1 Solar module

In the early 1950s, photovoltaic (PV) cells were developed as a spin-off of transistor technology. Very thin layers of pure silicon are impregnated with tiny amounts of other elements. When exposed to sunlight, small amounts of electricity are produced. Originally this technology was a costly source of power for satellites but it has steadily come down in price making it affordable to power homes and businesses [1].

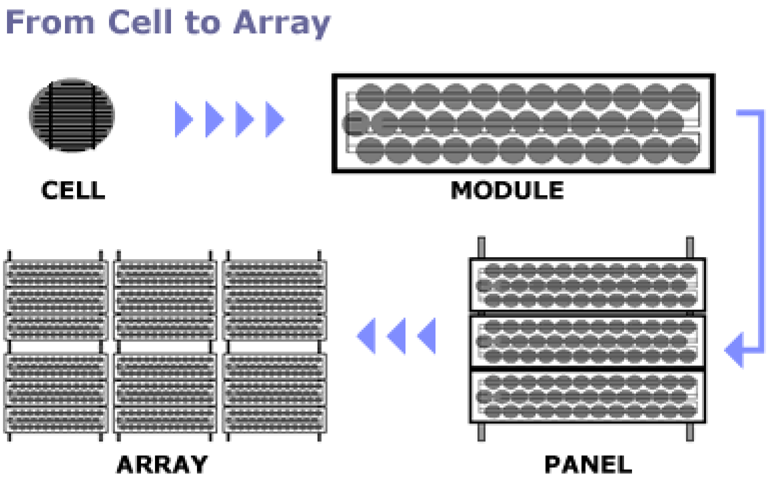


Figure 7 from cell to array

Cells	Semiconductor device that converts sunlight into direct current (DC) electricity
Modules	PV modules consist of PV cell circuits sealed in an environmentally protective laminate and are the fundamental building block of PV systems
Panels	PV panels include one or more PV modules assembled as a pre-wired, field-installable unit
Array	A PV array is the complete power-generating unit, consisting of any number of PV modules and panels

There are currently three commercial production technologies for PV Modules, the selection of solar modules should be based on various properties:

Single Crystalline
this is the oldest and more expensive production technique, but it's also the most efficient sunlight conversion technology available. Module efficiency averages about 10% to 12%.

Polycrystalline or Multicrystalline
this has a slightly lower conversion efficiency compared to single crystalline but manufacturing costs are also lower. Module efficiency averages about 10% to 11%.

Amorphous or Thin Film
Silicon material is vaporized and deposited on glass or stainless steel. The cost is lower than any other method. Module efficiency averages 5% to 7%.

3.2 inverters

An inverter is an electrical circuit capable of turning DC power into AC power , while at the same time regulating the voltage , current, and frequency of the signal.

A **solar inverter**, or converter or PV **inverter**, converts the variable direct current (DC) output of a photovoltaic (PV) **solar** panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network [1].

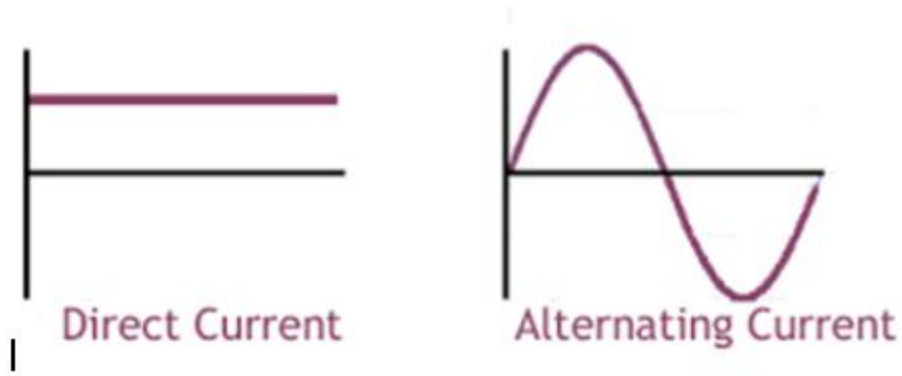


Figure 8: DC and AC current waveform

Working of Solar Inverter:

Solar panels produce direct electricity with the help of electrons that are moving from negative to positive direction. Most of the appliances that we use at home work on alternative current. This AC is created by the constant back and forth of the electrons from negative to positive. In AC electricity the voltage can be adjusted according to the use of the appliance. As solar panels only produce Direct current the solar inverter is used to convert the DC to AC.

An inverter produces square waves or a sine wave which can be used for running lights, televisions, lights, motors etc. However, these inverters also produce harmonic distortion. Expensive inverters make use of lots of steps to produce a sine wave and thus are found in residential solar inverters. Basically, inverters should be a large one so that it supplies enough power to all the necessary appliances.

The wires attached on the silicon catch hold of these neutrons and while connecting to the circuit, current is formed. This then gives space for direct electricity and for converting that into alternate electricity an inverter is used so that the house appliances can run. As mentioned before major of the house appliances work on alternate current hence an inverter is used to convert DC to AC [1].

3.3 monitoring

The Net Monitoring technology allows to monitor as many inverters as we wish, without the need of special communication cards that are usually required by the inverter manufacturers and you also don't need to pay for the online monitoring, no matter what size of system you have.

The monitoring system provides:

1- Real time energy information.
2- Renewable Energy monitoring.
3- Measurement and Verification of essential equipment (M&V)
4- Operations and Maintenance of asset portfolio (O&M)
5- Data export via push or pull with an open data API.
6- Lower energy cost.
7- Lower emission associated with fossil fuel energy.
8- Establish building energy benchmark and LEED points.
9- Peak Demand analysis.
10- Energy Efficiency projects and commissioning.

3.4 Protection:

The selection of circuit protection devices for solar energy circuits is one area where designers pay a lot of attention for. These circuits may be used in systems ranging from residential-scale applications to those intended for large industrial facilities and grid-connected solar farms. Most of Protection parts get along with standards of International Electrotechnical Commission (IEC). For example, IEC 60364-7-712:2017 applies to the electrical installation of PV systems intended to supply all or part of an installation [4].

3.4.1 Fuses:

The most common first line of defense is fuses, a fuse, it must be selected to protect a PV source circuit operating at its short-circuit current rating, and also protect it in case of a fault on that circuit. Fuses, which are inherently passive devices, can be designed to be less costly than circuit breakers with the same performance characteristics. These PV system fuses and their testing are described in UL Standard 2579, Low-Voltage Fuses for Photovoltaic Systems, and IEC standard 60269-6[5+6]

3.4.2 circuit breakers

DC circuit breaker

DC string circuit-breaker in large systems prevent regeneration from intact modules to modules with a short-circuit. Their advantage over fuses is that they are immediately ready for use after a trip, and when the cause of the trip has been remedied.

For the correct dimensioning of a circuit-breaker in a direct current network some electrical parameters which characterize the device itself must be evaluated.[5+6]

1. Rated operational voltage Ue

It represents the value of voltage which determines the application of the equipment and to which all the other parameters typical of the equipment are referred.

2. Rated uninterrupted current Iu

It represents the value of current which the equipment can carry for a indefinite time (uninterrupted duty). This parameter is used to define the size of the circuit-breaker.

3. Rated current In

It represents the value of current which characterizes the protection trip unit mounted on the circuit-breaker and determines the protection characteristic of the circuit-breaker itself according to the available settings of the trip unit. This current is often referred to the rated current of the load protected by the circuit-breaker itself. [5+6]

AC circuit breaker

To protect the inverter, both DC input and AC output need to be protected. So AC Circuit Breakers are installed with different rates that suits the passing current through the AC wires to prevent any faults could occur. [5+6]

3.4 cables

DC Cables

A solar cable is the interconnection cable used in photovoltaic power generation. Solar cables interconnect solar panels and other electrical components of a photovoltaic system. Solar cables are designed to be UV resistant and weather resistant. They can be used within a large temperature range and are generally laid outside.

Individual modules are connected using cables to form the PV generator. The module cables are connected into a string which leads into the generator junction box, and a main DC cable connects the generator junction box to the inverter. In order to eliminate the risk of ground faults and short circuits, the positive and negative cables, each with double insulation, are laid separately. [5+6]

3.5 lighting protection system.

Lightning protection is a common cause of failures in photovoltaic (PV). A damaging surge can occur from lightning that strikes a long distance from the system, or even between clouds. But most lightning damage is preventable. for preventing these effects, lighting protection is a must to install in solar systems.[7]

A lighting protection system consist of:

1- One or more air termination

2- Earthing conductor
3- Separate electrode

The earth-termination system of the PV system is designed as a ring earth electrode (surface earth electrode); whilst the earth-termination system of the operation building should be designed as a foundation earth electrode.

The metal supporting frames, onto which the PV modules are fixed, must be connected to the earth-termination Lightning and surge protection for PV systems on solar plants By A Bar wise, DEHN Protection South Africa Measures to protect the sensitive electronic system components from failure due to lightning flashes and surges are essential. The earth-termination system of the PV system and the one of the operation building, have to be connected to each other via at least one conductor. [7]

Surge lighting equipotential bonding in principle, all conductive systems entering the operation building from outside have to be generally included into the lightning equipotential bonding. The requirements of lightning equipotential bonding are fulfilled by the direct connection of all metal systems and by the indirect connection of all live systems via lightning current arresters. Lightning equipotential bonding should be performed preferably near the entrance of the structure in order to prevent partial lightning currents from penetrating the building. The conductor in lighting protection is 70 mm2 standard to carry the very high current come from the lighting.[7]

Surge protection Powerful surge Protection Devices used for installations and buildings with high lighting strike risk. They contribute to the safety of equipment. Surge Arresters ensure continuity of service of installation and divided into two categories; DC surge arresters and AC surge Arresters. [7]

DC surge arresters

It is connected to each string of the inverters after the fuses and placed in the DC protection panel that is near the inverter input. An Earth wire in the surge arrester is connected to the DC Earthing Base bare.

AC surge arresters

It is connected to each AC wire comes out from the inverter and placed in the AC protection panel that is near the inverter output. An Earth wire in the surge arrester is connected to the AC Earthing Base bare.

3.6 Earthing

Ground defines as "the earth," these words can mean connected, or connecting, to the earth. More often they mean connected, or connecting, to a conductive device that is connected to the earth. The electric potential of the earth is assumed to be zero. [7]

We need the ground system to discharge the high current in the earth if the system is ungrounded the current will reverse then may be causes fires and the same thing when open circuit happen.

In AC systems, the grounded conductor is also known as the neutral conductor. DC systems can be negatively or positively grounded—based on the polarity of the grounded conductor—or ungrounded. The DC system grounding connection is accomplished through the main bonding jumper or, in the case of separately derived systems, via the system bonding jumper. System grounding on the DC side of a PV system generally occurs via a ground-fault protection circuit that is internal to a listed inverter. [7]

When install the earthing we must be careful to:

- provided that earthing conductors shall have a minimum size of 6.0 mm2 copper, 10 mm2 aluminum or 70 mm2 hot dip galvanized steel. Unprotected aluminum or copper-clad aluminum conductors shall not be used for final underground connections to earth electrodes.
- A minimum of two separate dedicated and interconnected earth electrodes must be used for the earthing of the solar PV system support structure with a total earth resistance not exceeding 5 Ohm.
- When install the earthing we must do that after any ampere carry in the system.

The output of the PV module is DC but the output of the invertor is AC so we have two grounded system to the DC and AC but when we install it we must use one of three methods: [7]

(1) Separate Direct-Current Grounding Electrode System Bonded to the Alternating-Current Grounding Electrode System. A separate DC grounding electrode or system shall be installed, and it shall be bonded directly to the ac grounding-electrode system. The size of any bonding jumper(s) between ac and dc systems shall be based on the larger size of the existing ac grounding electrode conductor or the size of the dc grounding electrode conductor. The dc grounding electrode system conductor(s) or the bonding jumpers to the ac grounding electrode system shall not be used as a substitute for any required ac equipment grounding conductors.

(2) Common Direct-Current and Alternating-Current Grounding Electrode. A dc grounding electrode conductor, shall be run from the marked DC grounding electrode connection point to the AC grounding electrode. Where an AC grounding electrode is not accessible, the DC grounding electrode conductor shall be connected to the AC grounding electrode conductor. This DC grounding electrode conductor shall not be used as a substitute for any required ac equipment grounding conductors.

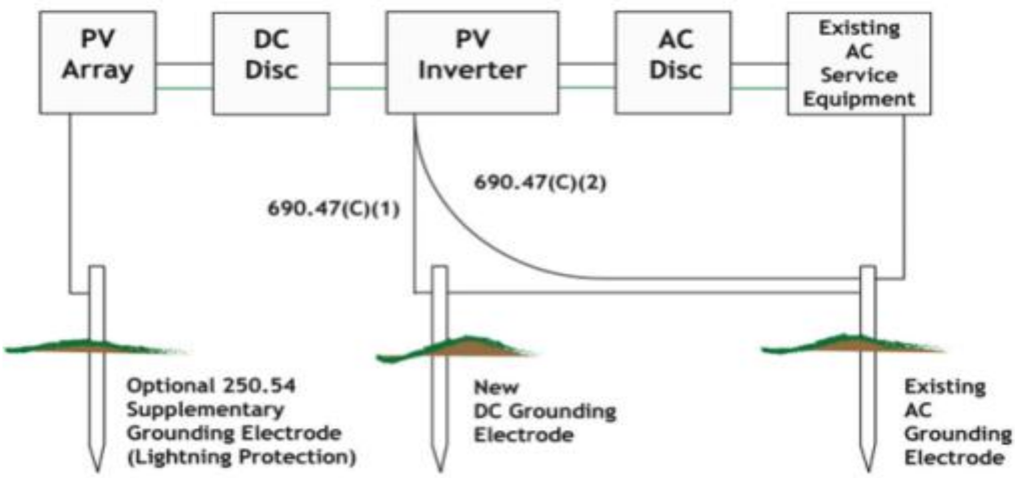


Figure 9:Common DC and AC Grounding Electrode

(3) Combined DC Grounding-Electrode Conductor and AC Equipment Grounding Conductor. An unspliced, or irreversibly spliced, combined grounding conductor shall be run from the marked DC grounding electrode conductor connection point along with the AC circuit conductors to the grounding busbar in the associated ac equipment. This combined grounding conductor shall be the larger.

Although any of the three methods of making connections to the inverter grounding electrode terminal may be used, there are advantages and disadvantages to each. [7]

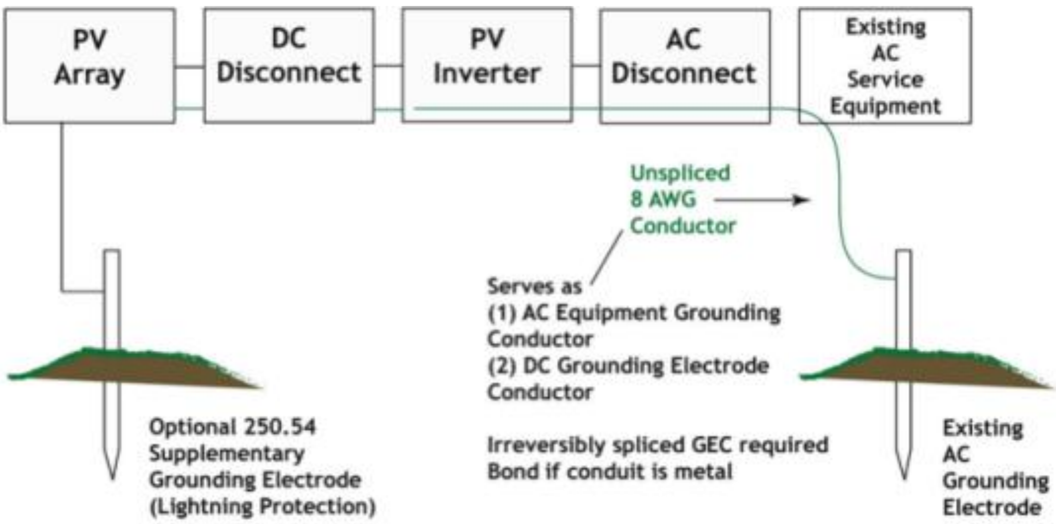


Figure 10: Combined DC Grounding-Electrode Conductor and AC Equipment Grounding Conductor

3.7 RCD protection

An RCD, or residual current device, is a life-saving device which is designed to prevent you from getting a fatal electric shock if you touch something live, such as a bare wire. It can also provide some protection against electrical fires. RCDs offer a level of personal protection that ordinary fuses and circuit-breakers cannot provide. [7]

CHAPTER 4: TRUE SOUTH ORIENTED DESIGN

Chapter 4:
True South Oriented Design

Introduction:

In this solution we used both areas that can PV installed on; the land and well, an overall area of 2500m^2. This system will be connected with grid in net metering tariff which is a method designed to accelerate investments in renewable energy by allowing energy producers to be compensated for the energy they feed back into the grid.

Tubas electricity distribution company takes 10% as services of the energy produced from the PV system and the other 90% of generated electricity will be discounted from the electricity bill, and if the production of energy exceeds of the energy consumed, the bi-directional net-metering will save the credits of the excess energy for the coming months and so on till the end of year, if any energy is consumed more then money should be paid and if the annual energy production exceeds then in this case no money returns to the producer.

In this case 199.24 KWp will be connected into the grid divided as 127.84KWp (17 ˚ tilted angle) installed on the land and 71.4 KWp (27˚ tilted angle) installed as roof toping of the well.

4.1 Solar Modules

For our design we are going to use the module from Hanwha Q cell, named as: Q. plus-L-G4.2,330-340 with the following specifications

PV module specification	
Type	Q. plus-L-G4.2,330-340
Maximum power (P max)	**340 Wp**
Maximum voltage (V max)	**37.63 V**
Maximum current (I max)	**9.03 A**
Short circuit current (I s.c)	**9.59 A**
Open circuit voltage (V o.c)	**47.07 V**
Efficiency	**17.4%**

Table 10: PV Module specification

The total number of PV modules is 586. With a power of 340w for each, deliever a power of 199.24 KWp distributed as following.

	True South	Tilt Angle
Land	376	17˚
Well	210	27˚
Total	586	

Table 11: PV modules in south oriented

The below picture is an overview of the whole farm without installing anything.

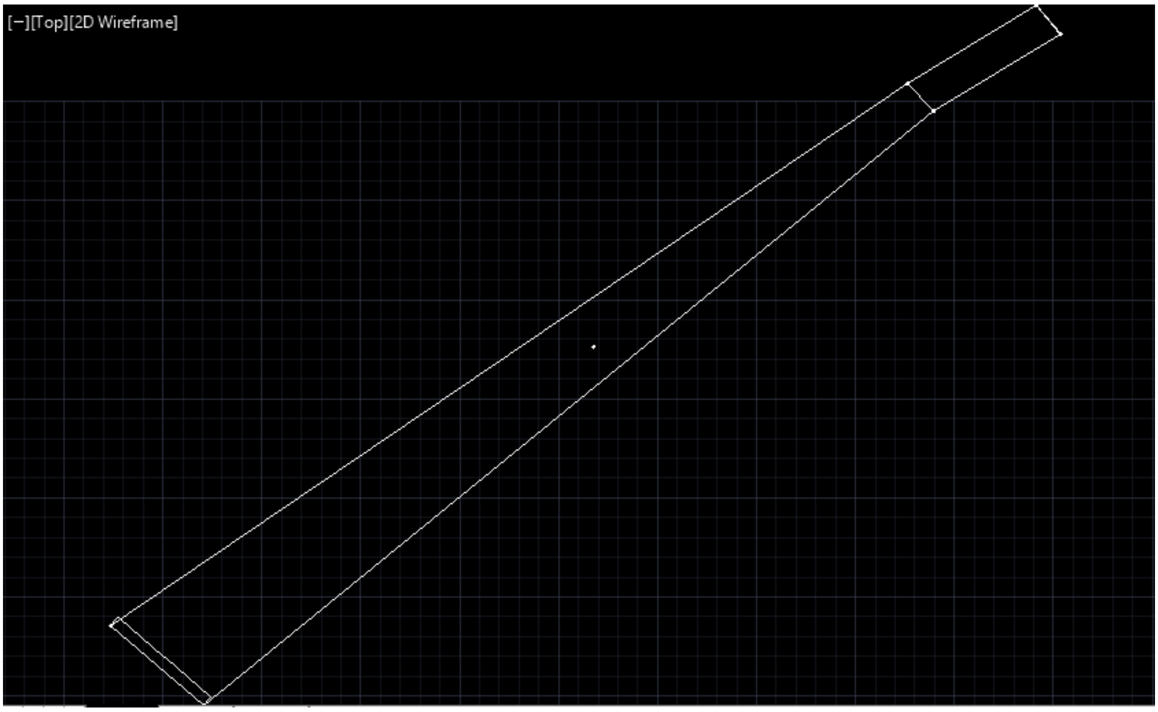


Figure 11:The plan of the farm

we took a 3-m space from the fence in the farm to the PV's so the fence won't cause any shading to the PV'S plus it is a space for any working or maintenance that would be held in the future and in the south east of the farm a service room will be built to have the land system connections and inverters.

We took 1.5-m as shading between the PV's the calculation of shading as following

4.2 Shading analysis

Shading analysis is one of the most essential steps in phase of solar energy system design or analysis. In photovoltaic it is important to analyze shading caused by surrounding objects and/or vegetation. The availability of Photovoltaic (PV) and increased interest in using and installing this system encourages the need to review the methodologies and assumptions used to develop.

Shading Calculations:

Depending on J.K Copper's method to calculate array spacing of Photovoltaic systems using vector analysis.

The proposed values are:

* Tilt angle = 17°

An array consists of three PV modules (three rows)

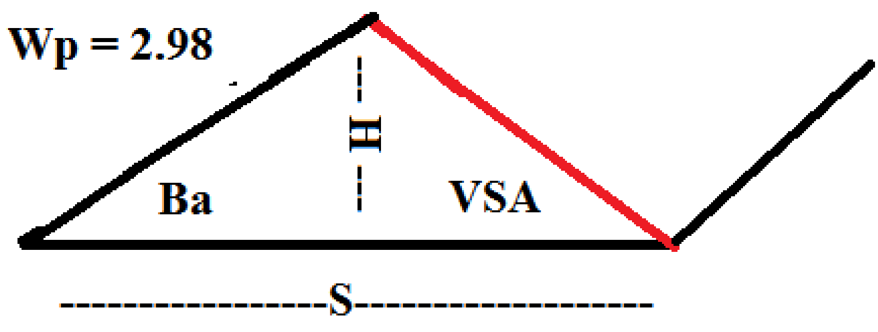


Figure 12: shading analysis

Eq 1 : $S = \frac{H}{tan\, VSA}$

Eq 2 $H = Sin\, Ba * Wp$

Eq 3 :$\tan \text{VSA} = \frac{\tan \alpha s}{\cos \phi}$ As:

:s : Altitude angle.

ϕs : Azimuth angle of the sun.

ϕc : Azimuth angle of the collector .

Ba : Tilt angle

Wp : PV width

S : Shading distance

considering the maximum self-shading on the 21st of December at 14:00 ,

αs at 14:00 = 25.07

ϕs at 14:00 = 215.87

ϕc = 180 ° from North

then:

$$\tan \text{VSA} = \frac{\tan 25.07}{\cos (215.87 - 180)}$$

$$\tan \text{VSA} = \frac{0.47}{0.81}$$

Tan VSA = 0.5775

$$H = Sin\, 17 * 2.98$$

H = 0.8713

Back to Eq 1 :

$$S = \frac{0.8713}{0.5775}$$

S = 1.51 meter

PV modules distribution for the land area

The following figure descirbes the destribution of the PV modules in the land after taking cosideration of both the service road and the shading area between the modules arrays.

We used Autocad software inorder to sketch the following plan.

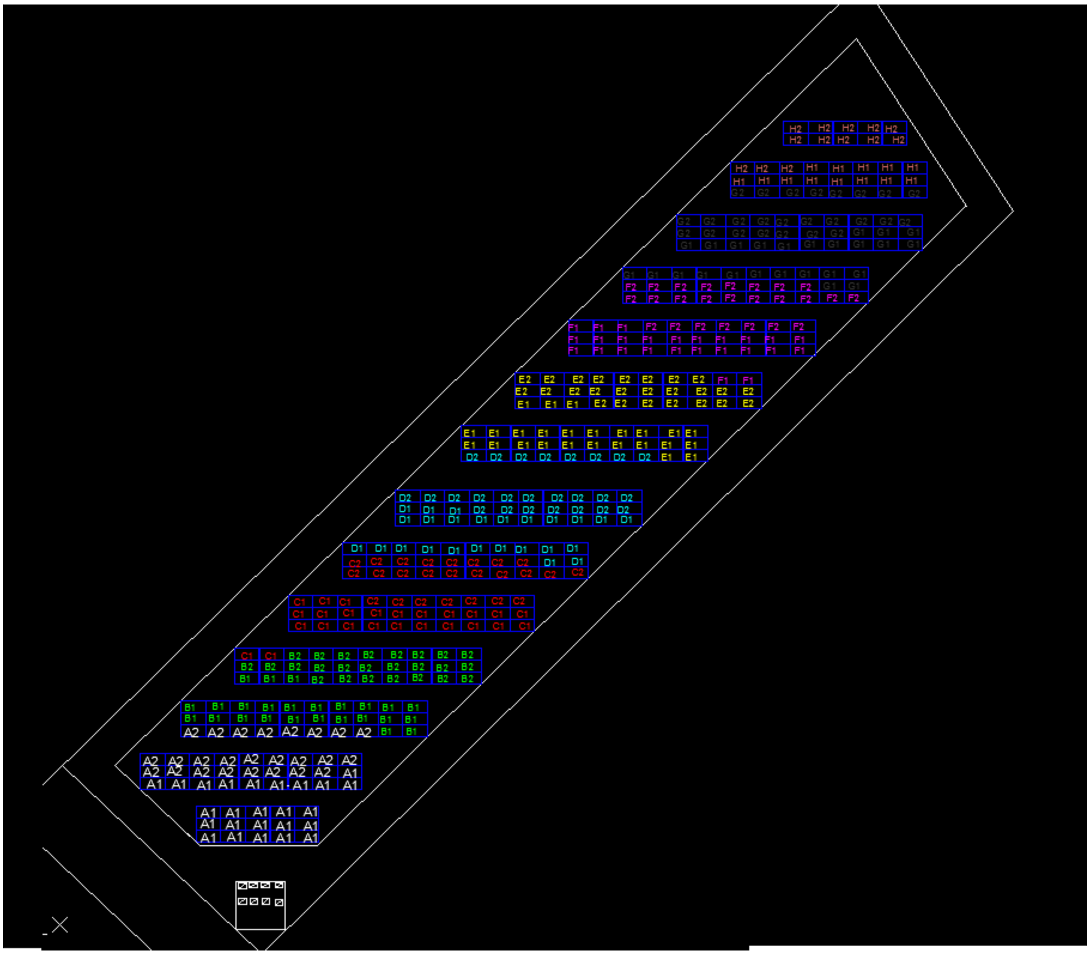


Figure 13: PV modules distributed in the land

PV modules distribution for the well roofing area:

The area of the well is $(500m^2)$ and we need to get as much as we can of this area in order to get the max power of the modules installed, thus we used the same method as for the land with Tilt angle =27˚, but without doing separated arrays here we have smaller. Thus these modules will be installed on a tough roof (27˚ tilted to south) in order to have the max number of modules on that roof, so no shading between arrays should be calculated.

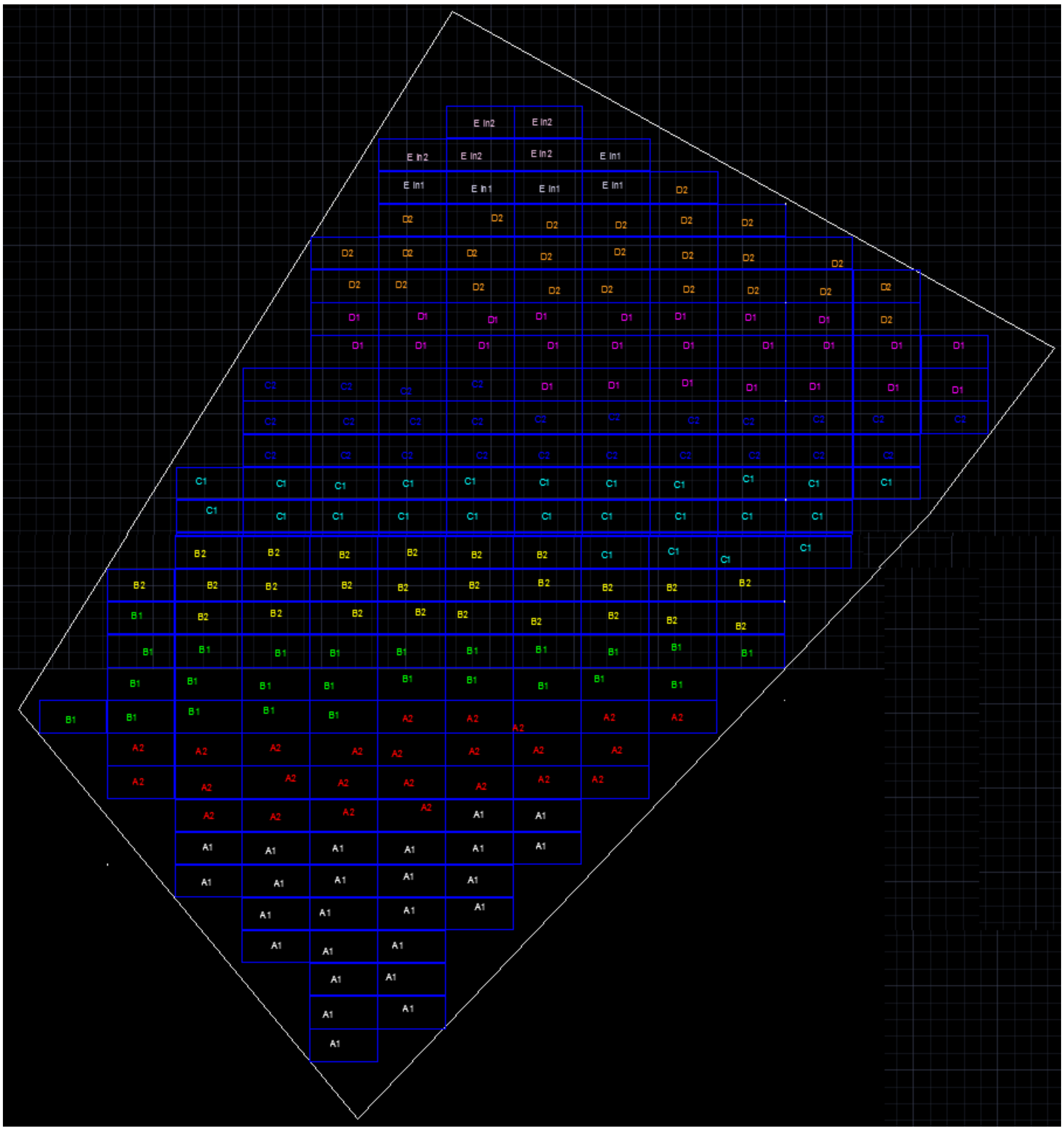


Figure 14: PV modules distributed on the roof of the well

4.3 Inverters

For our design we have selected ABB module TRIO inverter, named as: TRIO-20.0/27-Tl-OULT, PVI-10/12 and TRIO 5.8/8.5

The following table shows the specifications of these inverters then following them with the calculations to size the inverters that are needed for the true south oriented solution.

Inverter specification type	20Kw	10KW	5.8 Kw
Max abs DC input	**1000v**	**1000v**	**1000v**
Number of mppt	**2**	**2**	1
DC input volt range (mppt)	**440-800**	**300-750**	**320-800**
DC max input current (mppt)	**30A**	**22A**	**24A**
DC rated power	**20750w**	**10300w**	**5950w**
AC voltage range	**400V**	**400V**	**400V**
AC Max current	**33A**	**16A**	**10A**
Max. efficiency	**98.2%**	**97.3%**	**98%**

Table 12: ABB inverters specifications

1- size the inverters for the land:

total number of panels for the land = 376 panels

for the panels: Imppt=9.03 Vmppt=37.63

for each inverter MPPT

15(panels)*37.63(vmppt)= 564.45 (in range of 20KW inverter)

2(arrays of panels) *9.03= 18.06A (less than the max current for mppt of the inverter)

Number of panels for each MPPT = 15*2 = 30 Panels

Number of panels for 2 MPPTs (one inverter 20KW) = 30*2 = 60 panels

Total number of panels for the land design = 376 panels

Number of (20 KW inverters) = 6 inverters (6*20 = 120 KW)

Total number of panels = 6*60 = 360 panels (360*0.34KW/Panel = 122.4KW)

But total number of the land design = 376

16 panels need another inverter so (16*0.34KW) = 5.44 so we choose 5.8KW

Number of mppt for 5.8 inverter is 2 but we use one mppt

16panels * 37.63 v/panel = 602.08 V (in range)

2- size the inverters for the well:

total number of panels for the well = 210 panels

for the panels: Imppt=9.03 Vmppt=37.63

for each inverter MPPT

15(panels)*37.63(vmppt)= 564.45 (in range of 20KW inverter)

2(arrays of panels) *9.03= 18.06A (less than the max current for mppt of the inverter)

Number of panels for each MPPT = 15*2 = 30 Panels

Number of panels for 2 MPPTs (one inverter 20KW) = 30*2 = 60 panels

Total number of panels for the land design = 210 panels

Number of (20 KW inverters) = 3 inverters (3*20 = 60KW)

Total number of panels = 3*60 = 180 panels (180*0.34KW/Panel = 61.2KW)

But total number of the land design = 210

30 panels need another inverter so (30*0.34KW) = 10.2Kw so we choose 10KW inverter

Number of mppt for 10KW inverter is 2

For each MPPT:

15panels * 37.63 v/panel = 564.45 V (in range)

1(arrays of panels) * 9.03 = 18.06A (less than the Imax of each mppt)

So total number of panels connected to the inverter = 15panels*2mppt = 30 panels

	20KW	10KW	5.8
Land	6	0	1
Well	3	1	0
total	9	1	1

Table 13: total number of inverters for the south oriented

4.4 Mentoring system

The Net Monitoring technology allows to monitor as many inverters as we wish, without the need of special communication cards that are usually required by the inverter manufacturers and you also don't need to pay for the online monitoring, no matter what size of system you have.

The monitoring system provides:

1- Real time energy information.
2- Renewable Energy monitoring.
3- Measurement and Verification of essential equipment (M&V)
4- Operations and Maintenance of asset portfolio (O&M)
5- Data export via push or pull with an open data API.
6- Lower energy cost.
7- Lower emission associated with fossil fuel energy.
8- Establish building energy benchmark and LEED points.
9- Peak Demand analysis.
10- Energy Efficiency projects and commissioning.

We used eGauge Systems EG3000 Meter ANSI C12.1 - 1% Compliance w/ Ethernet. Table below shows the characteristics of EG3000 meter.

Mfr. Part #:	A000-ETH-016
CS Part #:	cs-300351
Dimensions:	6.94 × 3.25 × 1.3 in
Weight:	0.5 lb

Table 14:eGauge mentoring system specifications

4.5 Cables

1- DC cables

We used two ratings for DC cables, which are ($4mm^2$ and $6\ mm^2$) depending on the location of the DC side, for each string we use $4mm^2$ and when it delivers to the combined box where 2 strings join together to go to the inverter, then $6mm^2$ will be used as following:

Before DC combined box, I=9.03A – DC cables $4mm^2$

After DC combined box, I=18.06A – DC cables $6mm^2$

2-AC cables

The following table shows the cross-section areas of the AC cables after the inverters until the bi-directional metering

	AC cable	AC current	Location
AC CB's (40 A)	AC cables (4*16 mm)	30 A	The output of each inverter
AC CB's (150 A)	AC cables (70 mm)	144 A	the AC cable goes from land`s room to the largest AC Base Bare in well`s room and the cable from AC Base Bare of well`s inverters to the largest AC Base Bare.
AC CB's (250 A)	AC cables (150 mm)	234 A	the AC cable goes from the largest AC base bare to the bi-directional metering.

Table 15: cross section area of AC cables and their location

4.5 Protection

1- DC side

Circuit Breakers

We used DC Circuit Breakers (20A/10 A &1000 volt) as each MPPT of the inverters has a current value of 9.03 A, one for every string and connected in the protection panel.

Fuse

It is connected to each string of the inverters and the used one in our project is 15 A that is recommended in the inverter`s data sheet. And it comes along with a Fuse Holder; which is a mechanical part used for connecting two fuses.

AC Surge Arresters

It is connected to each string of the inverters after the fuses and placed in the DC protection panel that is near the inverter input. An Earth wire in the surge arrester is connected to the DC Earthing Base bare, the rating of the surge arrester is (1000v 40KA)

	NO. Invertors	NO. fuses	NO. fuse holders	NO. DC C.B 10A	No. DC C.B 20A	NO. DC Surge Arresters
Land	7	25	25	1	12	25
Well	4	18	18	2	8	18

Table 15: DC protection of south oriented design

2- AC side

AC Circuit Breakers

We used AC Circuit Breakers (40A/15 A &1000 volt) as each inverter has a max current value of 9.03*2*0.9*2 A=32.5 and also as well AC protection is needed after the bass bare of gathering the output of the AC side after the inverters such as (100A/250A AC CB).

	NO. Invertors	NO. AC C.B (40 A)	No. AC C.B (15A)	NO. AC C.B (100 A)	NO. AC C.B (250 A)
Land	7	6	1	0	1
Well	4	3	1	1	0

Table 16: AC protection of South oriented design

AC surge arresters

It is connected to each AC wire comes out from the inverter and placed in the AC protection panel that is near the inverter output. An Earth wire in the surge arrester is connected to the AC Earthing Base bare. We used AC surge arrester of 40 A and 1000 volt

RCD

An RCD, or residual current device, is a life-saving device which is designed to prevent you from getting a fatal electric shock if you touch something live, such as a bare wire. It can also provide some protection against electrical fires. RCDs offer a level of personal protection that ordinary fuses and circuit-breakers cannot provide.

	NO. AC Surge Arrester	NO. of RCD
Land	8	1
well	5	1

Table 17: AC protection of south oriented design

4.6 Bill of Quantity

A bill of quantity has been made which itemized list of the materials and components with their prices that are required to install the PV for the south oriented design, and it is important to expect the costs of the installations.

4.6.1 BOQ for land

type	# of units	unit cost	total cost	
PV	127.84	450	57528	$
Inveter 20KW	6	3488	20928	$
Inveter 5.8KW	1	1000	1000	$
Internet connected Monitoring system	1	1700	1700	NIS
steel mounting structure	376	238	89488	NIS
DC PROTECTION				
fuse 15A	25	32	800	NIS
fuse holder	25	32	800	NIS
DC CCT breaker 10A	1	246	246	NIS
DC CCT breaker 20A	12	250	3000	NIS
surge protection	25	285	7125	NIS
DC combiner Box	8	71	568	NIS
DC base bar	12	25	300	NIS

AC PROTECTION				
AC CCT breaker 40A	6	185	1110	NIS
AC CCT breaker 20A	1	150	150	NIS
Surge protection	8	335	2680	NIS
AC combiner boxes	7	2000	14000	NIS
AC cables (16mm)/meter	16	7	112	NIS
AC cables (150mm)/meter	215	253	54395	NIS
RCD 400mA	1	400	400	NIS
AC base bar	1	25	25	NIS
Earth base bar	1	25	25	NIS
AC CB 250A	1	746	746	NIS

Table 18: BOQ of land in south oriented design

4.6.2 Well BOQ

type	# of units	unit cost	total cost	
PV	71.4	450	32130	$
Inveter 20KW	3	3488	10464	$
Inveter 10KW	1	1744	1744	$
Internet connected Monotring system	1	1700	1700	NIS
Roofing	490	50	24500	NIS
DC PROTECTION				
fuse 15A	18	32	576	NIS
fuse holder	18	32	576	NIS
DC CCT breaker 10A	2	246	492	NIS
dC CCT breaker 20A	8	250	2000	NIS
surge protection	18	285	5130	NIS
DC combiner Box	4	71	284	NIS
DC Passbar	4	25	100	NIS
AC PROTECTION				
AC CCT breaker 40A	3	185	555	NIS
AC CCT breaker 20A	1	150	150	NIS
Surge protection	4	335	1340	NIS
AC combiner boxes	4	2000	8000	NIS
AC cables (16mm)/meter	10	7	70	NIS
AC cables (70mm)/meter	5	118	590	NIS
RCD 400mA	1	400	400	NIS
AC Passbar	1	25	25	NIS
Earth Passbar	1	25	25	NIS
MCB 150A	1	150	150	NIS

Table 19: BOQ of well in south oriented design

4.6.3 combination of land and well BOQ

TYPE	# OF UNITS	COST OF UNIT	TOTAL COST	
DC CABLES (6MM)/METER	2500	3.6	9000	NIS
AC CCT BREAKER 400A	2	746	1492	NIS
RCD 400MA	1	400	400	NIS
KWH GENERTATION METERING	1	91	91	NIS
BI-DIRECTIONAL METER	1	196	196	NIS
COMBINATION BOX	1	1600	1600	NIS
AC CABLE (150MM)/METER	3	253	759	NIS
UNCOVERED CABLE 25MM/METER	18	12	216	NIS
EARTHING BIT DC	6	54	324	NIS
EARTHING BIT AC	6	54	324	NIS
ELECTRODES	6	280	1680	NIS
LIGHTING PROTECTION	1	7000	7000	NIS
EARTH CABLE(30MM)/METER	1130	13.2	14916	NIS
EARTH BASE BARE	4	25	100	NIS
CONNECTORS	6	45	270	NIS
ACCESOARIES	1	1500	1500	NIS

Table 20:BOQ of the combination of the well and land for the south oriented design

The sum of these costs is used in Retscreen to do the financial report as following in the next section.

4.7 Restscreen

The RetScreen Clean Energy Project Analysis Software is a tool that helps with decision making allowing engineers, architects, and financial planners to model and analyze any clean energy project.

The technologies included in RetScreen's project models are all-inclusive and include both traditional and non-traditional sources of clean energy as well as conventional energy sources and technologies.

In this project, RetScreen was used to help us make a detailed study for a photovoltaic power plant in Talloza used to pump water from three different pumps used for irrigation.

The Following files are for the south oriented, both the well and land separately.

Natural Resources Canada Ressources naturelles Canada Canada

RETScreen® International
www.retscreen.net

Clean Energy Project Analysis Software

Project information

See project database

Project name	water pumping - 199.24kW - on grid
Project location	Talluza – The LAND
Prepared for	power plant
Prepared by	, bahaa majadleh, mohammed ateri
Project type	Power
Technology	Photovoltaic
Grid type	Central-grid
Analysis type	Method 2
Heating value reference	Higher heating value (HHV)
Show settings	
Language - Langue	English - Anglais
User manual	English - Anglais
Currency	$
Units	Metric units

Site reference conditions

Select climate data location

Climate data location	Jericho
Show data	

	Unit	Climate data location	Project location
Latitude	˚N	31.9	31.9
Longitude	˚E	35.5	35.5
Elevation	m	-275	-275
Heating design temperature	°C	5.0	
Cooling design temperature	°C	32.9	
Earth temperature amplitude	°C	23.1	

Month	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	10.6	58.7%	2.80	96.3	4.5	11.7	229	19
February	11.4	54.0%	3.50	96.2	4.6	13.3	185	39
March	14.2	50.8%	4.60	96.0	4.7	17.5	119	129
April	18.9	41.7%	6.00	95.8	4.4	23.9	0	266
May	22.2	41.2%	7.10	95.8	4.1	28.3	0	378
June	24.3	45.5%	7.90	95.6	4.1	31.2	0	428
July	26.0	46.9%	7.80	95.4	4.1	33.7	0	496
August	26.4	49.1%	7.20	95.5	3.9	33.8	0	508
September	25.0	49.3%	6.00	95.8	3.6	31.2	0	451
October	21.7	52.8%	4.70	96.0	3.7	25.5	0	363
November	17.0	52.0%	3.40	96.2	3.7	18.8	30	210
December	12.3	56.5%	2.60	96.3	4.1	13.3	175	73
Annual	19.2	49.9%	5.31	95.9	4.1	23.6	738	3,359
Measured at (m)					10.0	0.0		

Complete Energy Model sheet

RETScreen4 2012-06-01 NRCan/CanmetENERGY

RETScreen Energy Model - Power project Show alternative units

Proposed case power system

Technology		Photovoltaic	
Analysis type		○ Method 1 ⊙ Method 2	
Resource assessment			
Solar tracking mode		Fixed	
Slope	°	17.0	
Azimuth	°	0.0	

☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate $/MWh	Electricity exported to grid MWh
January	2.80	3.50	166.2	12.84
February	3.50	4.05	166.2	13.30
March	4.60	5.03	166.2	17.94
April	6.00	6.19	166.2	20.75
May	7.10	6.96	166.2	23.64
June	7.90	7.54	166.2	24.43
July	7.80	7.53	166.2	25.00
August	7.20	7.30	166.2	24.17
September	6.00	6.49	166.2	21.03
October	4.70	5.51	166.2	18.87
November	3.40	4.27	166.2	14.63
December	2.60	3.33	166.2	12.12
Ann	**5.31**	**5.65**	**166.20**	**228.72**

Annual solar radiation - horizontal	MWh/m²	1.94		
Annual solar radiation - tilted	MWh/m²	2.06		
Photovoltaic				
Type		poly-Si		
Power capacity	kW	127.84		*See product database*
Manufacturer		hanwha		
Model		Q.Plus L-G4.2 330-340	1 unit(s)	
Efficiency	%	17.1%		
Nominal operating cell temperature	°C	45	°F	113.0
Temperature coefficient	% / °C	0.40%		
Solar collector area	m²	748	ft²	8,047
Miscellaneous losses	%	3.0%		
Inverter				
Efficiency	%	98.2%		
Capacity	kW	35.8		
Miscellaneous losses	%	2.0%		
Summary				
Capacity factor	%	20.4%		
Electricity exported to grid	MWh	228.72		
			$/kWh	0.166

Settings				
Method 1	Notes/Range			
Method 2	Second currency	Notes/Range	None	
	Cost allocation			

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Site investigation	p-d			$ -	
Resource assessment	project			$ -	
Environmental assessment	p-d			$ -	
Preliminary design	p-d			$ -	
Detailed cost estimate	p-d			$ -	
GHG baseline study & MP	project			$ -	
Report preparation	p-d			$ -	
Project management	p-d			$ -	
Travel & accommodation	p-trip	1	$ 641	$ 641	
User-defined	cost			$ -	
				$ -	
Subtotal:				**$ 641**	0.4%
Development					
Contract negotiations	p-d			$ -	
Permits & approvals	p-d	1	$ 234	$ 234	
Site survey & land rights	p-d			$ -	
GHG validation & registration	project			$ -	
Project financing	p-d			$ -	
Legal & accounting	p-d	2	$ 300	$ 600	
Project management	p-d			$ -	
Travel & accommodation	p-trip			$ -	
User-defined	cost			$ -	
				$ -	
Subtotal:				**$ 834**	0.5%
Engineering					
Site & building design	p-d	1	$ 5,000	$ 5,000	
Mechanical design	p-d	1	$ 1,828	$ 1,828	
Electrical design	p-d	1	$ 10,969	$ 10,969	
Civil design	p-d	1	$ 5,484	$ 5,484	
Tenders & contracting	p-d			$ -	
Construction supervision	p-d			$ -	
civil work	cost	1	$ 16,500	$ 16,500	
employees		6	$ 856	$ 5,133	
Subtotal:				**$ 44,914**	24.5%
Power system					
Photovoltaic	kW	127.84	$ 450	$ 57,528	
Road construction	km			$ -	
Transmission line	km			$ -	
Substation	project			$ -	
Energy efficiency measures	project			$ -	
User-defined	cost			$ -	
				$ -	
Subtotal:				**$ 57,528**	31.4%
Balance of system & miscellaneous					
Specific project costs		Photovoltaic			
Inverter	kW	126	$ 174	$ 21,940	
Collector support structure	m²			$ -	
Installation	project	1	$ 57,253	$ 57,253	
Building & yard construction	m²			$ -	
Spare parts	%			$ -	
Transportation	project			$ -	
Training & commissioning	p-d			$ -	
User-defined	cost	0	$ -	$ -	
Contingencies	%		$ 183,110	$ -	
Interest during construction		2 month(s)	$ 183,110	$ -	
Subtotal:				**$ 79,193**	43.2%
Total initial costs				**$ 183,110**	100.0%

Annual costs (credits)	Unit	Quantity	Unit cost	Amount
O&M				
Land lease & resource rental	project			$ -
Property taxes	project			$ -
Insurance premium	project			$ -
Parts & labour	project			$ -
GHG monitoring & verification	project			$ -
Community benefits	project			$ -
General & administrative	%		$ -	$ -
User-defined	cost	1	$ 380	$ 380
Contingencies	%		$ 380	$ -
Subtotal:				**$ 380**

Periodic costs (credits)	Unit	Year	Unit cost	Amount
User-defined	cost			$ -
				$ -
End of project life	cost			$ -

Financial parameters

General		
Fuel cost escalation rate	%	
Inflation rate	%	1.0%
Discount rate	%	
Project life	yr	25
Finance		
Incentives and grants	$	
Debt ratio	%	0.0%
Income tax analysis		☑
Effective income tax rate	%	
Loss carryforward?		No
Depreciation method		Declining balance
Half-year rule - year 1	yes/no	Yes
Depreciation tax basis	%	
Depreciation rate	%	
Tax holiday available?	yes/no	No

Annual income

Electricity export income		
Electricity exported to grid	MWh	229
Electricity export rate	$/MWh	166.20
Electricity export income	$	38,014
Electricity export escalation rate	%	
GHG reduction income		☑
Net GHG reduction	tCO2/yr	0
Net GHG reduction - 25 yrs	tCO2	0
GHG reduction credit rate	$/tCO2	
Customer premium income (rebate)		☑
Electricity premium (rebate)	%	
Other income (cost)		☑
Energy	MWh	
Rate	$/MWh	
Other income (cost)	$	0
Duration	yr	
Escalation rate	%	
Clean Energy (CE) production income		☑
CE production	MWh	229
CE production credit rate	$/kWh	
CE production income	$	
CE production credit duration	yr	
CE production credit escalation rate	%	
Fuel type	**Energy delivered (MWh)**	
Solar	229	Yes

Project costs and savings/income summary

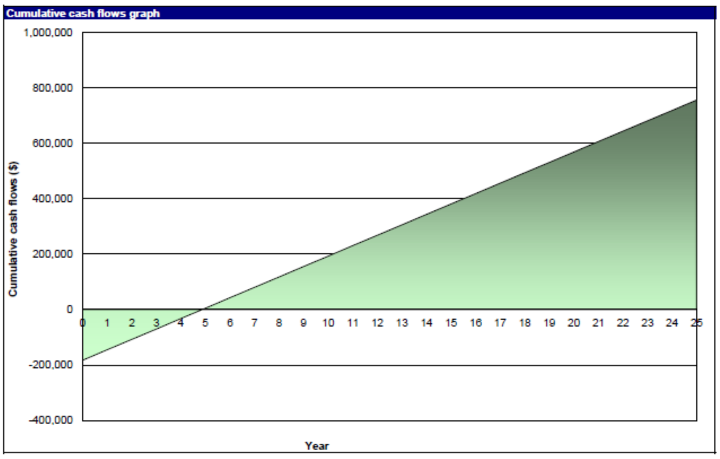
Initial costs			
Feasibility study	0.4%	$	641
Development	0.5%	$	834
Engineering	24.5%	$	44,914
Power system	31.4%	$	57,528
Balance of system & misc.	43.2%	$	79,193
Total initial costs	100.0%	$	183,110
Annual costs and debt payments			
O&M		$	380
Fuel cost - proposed case		$	0
Total annual costs		$	380
Periodic costs (credits)			
Annual savings and income			
Fuel cost - base case		$	0
Electricity export income		$	38,014
Total annual savings and income		$	38,014

Financial viability

Pre-tax IRR - equity	%	20.3%
Pre-tax IRR - assets	%	20.3%
After-tax IRR - equity	%	20.3%
After-tax IRR - assets	%	20.3%
Simple payback	yr	4.9
Equity payback	yr	4.9
Net Present Value (NPV)	$	756,400
Annual life cycle savings	$/yr	30,256
Benefit-Cost (B-C) ratio		5.13
Energy production cost	$/MWh	33.92
GHG reduction cost	$/tCO2	No reduction

Yearly cash flows

Year	Pre-tax	After-tax	Cumulative
#	$	$	$
0	-183,110	-183,110	-183,110
1	37,630	37,630	-145,479
2	37,626	37,626	-107,853
3	37,622	37,622	-70,231
4	37,619	37,619	-32,612
5	37,615	37,615	5,002
6	37,611	37,611	42,613
7	37,607	37,607	80,220
8	37,602	37,602	117,822
9	37,598	37,598	155,420
10	37,594	37,594	193,015
11	37,590	37,590	230,605
12	37,586	37,586	268,190
13	37,581	37,581	305,772
14	37,577	37,577	343,349
15	37,573	37,573	380,922
16	37,568	37,568	418,490
17	37,564	37,564	456,054
18	37,559	37,559	493,614
19	37,555	37,555	531,169
20	37,550	37,550	568,719
21	37,546	37,546	606,265
22	37,541	37,541	643,806
23	37,536	37,536	681,342
24	37,531	37,531	718,873
25	37,527	37,527	756,400



Project information

See project database

Project name	water pumping well
Project location	talluza - well
Prepared for	power plant
Prepared by	Bahaa Majadleh Mohammed ateri
Project type	Power
Technology	Photovoltaic
Grid type	Central-grid
Analysis type	Method 2
Heating value reference	Higher heating value (HHV)
Show settings	
Language - Langue	English - Anglais
User manual	English - Anglais
Currency	$
Units	Metric units

Site reference conditions

Select climate data location

Climate data location	Jericho
Show data	

	Unit	Climate data location	Project location
Latitude	˚N	31.9	31.9
Longitude	˚E	35.5	35.5
Elevation	m	-275	-275
Heating design temperature	°C	5.0	
Cooling design temperature	°C	32.9	
Earth temperature amplitude	°C	23.1	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		10.6	58.7%	2.80	96.3	4.5	11.7	229	19
February		11.4	54.0%	3.50	96.2	4.6	13.3	185	39
March		14.2	50.8%	4.60	96.0	4.7	17.5	119	129
April		18.9	41.7%	6.00	95.8	4.4	23.9	0	266
May		22.2	41.2%	7.10	95.8	4.1	28.3	0	378
June		24.3	45.5%	7.90	95.6	4.1	31.2	0	428
July		26.0	46.9%	7.80	95.4	4.1	33.7	0	496
August		26.4	49.1%	7.20	95.5	3.9	33.8	0	508
September		25.0	49.3%	6.00	95.8	3.6	31.2	0	451
October		21.7	52.8%	4.70	96.0	3.7	25.5	0	363
November		17.0	52.0%	3.40	96.2	3.7	18.8	30	210
December		12.3	56.5%	2.60	96.3	4.1	13.3	175	73
Annual		19.2	49.9%	5.31	95.9	4.1	23.6	738	3,359
Measured at	m					10.0	0.0		

Complete Energy Model sheet

RETScreen Energy Model - Power project Show alternative units

Proposed case power system

Technology		Photovoltaic
Analysis type		Method 1 Method 2

Resource assessment

Solar tracking mode		Fixed
Slope	°	27.0
Azimuth	°	0.0

☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate $/MWh	Electricity exported to grid MWh
January	2.80	3.81	166.2	7.755
February	3.50	4.26	166.2	7.771
March	4.60	5.14	166.2	10.205
April	6.00	6.12	166.2	11.453
May	7.10	6.70	166.2	12.722
June	7.90	7.15	166.2	12.977
July	7.80	7.18	166.2	13.348
August	7.20	7.13	166.2	13.202
September	6.00	6.57	166.2	11.873
October	4.70	5.81	166.2	11.067
November	3.40	4.65	166.2	8.843
December	2.60	3.65	166.2	7.389
Ann	**5.31**	**5.69**	**166.18**	**128.605**

Annual solar radiation - horizontal	MWh/m²	1.94
Annual solar radiation - tilted	MWh/m²	2.08

Photovoltaic

Type		poly-Si	
Power capacity	kW	71.40	*See product database*
Manufacturer		hanwha	
Model		Q.Plus L-G4.2 330-340	1 unit(s)
Efficiency	%	17.1%	
Nominal operating cell temperature	°C	45	
Temperature coefficient	% / °C	0.40%	
Solar collector area	m²	418	
Miscellaneous losses	%	3.0%	

Inverter

Efficiency	%	98.2%
Capacity	kW	35.8
Miscellaneous losses	%	2.0%

Summary

Capacity factor	%	20.6%
Electricity exported to grid	MWh	128.605

Settings				
Method 1	Notes/Range			
Method 2	Second currency	Notes/Range	None	
	Cost allocation			

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Site investigation	p-d			$ -	
Resource assessment	project			$ -	
Environmental assessment	p-d			$ -	
Preliminary design	p-d			$ -	
Detailed cost estimate	p-d			$ -	
GHG baseline study & MP	project			$ -	
Report preparation	p-d			$ -	
Project management	p-d			$ -	
Travel & accommodation	p-trip	1	$ 358	$ 358	
User-defined	cost			$ -	
				$ -	
Subtotal:				$ 358	0.3%
Development					
Contract negotiations	p-d			$ -	
Permits & approvals	p-d	5	$ 156	$ 780	
Site survey & land rights	p-d			$ -	
GHG validation & registration	project			$ -	
Project financing	p-d			$ -	
Legal & accounting	p-d	1	$ 300	$ 300	
Project management	p-d			$ -	
Travel & accommodation	p-trip			$ -	
User-defined	cost			$ -	
				$ -	
Subtotal:				$ 1,080	1.0%
Engineering					
Site & building design	p-d			$ -	
Mechanical design	p-d	1	$ 1,021	$ 1,021	
Electrical design	p-d	1	$ 1,126	$ 1,126	
Civil design	p-d	1	$ 3,063	$ 3,063	
Tenders & contracting	p-d			$ -	
Construction supervision	p-d			$ -	
Civil work	cost	0	$ -	$ -	
employees		6	$ 478	$ 2,867	
Subtotal:				$ 8,077	7.8%
Power system					
Photovoltaic	kW	71.40	$ 450	$ 32,130	
Road construction	km	0	$ -	$ -	
Transmission line	km			$ -	
Substation	project			$ -	
Energy efficiency measures	project			$ -	
User-defined	cost			$ -	
				$ -	
Subtotal:				$ 32,130	30.9%
Balance of system & miscellaneous					
Specific project costs		Photovoltaic			
Inverter	kW	70	$ 174	$ 12,208	
Collector support structure	m²			$ -	
Installation	project	1	$ 50,063	$ 50,063	
Building & yard construction	m²			$ -	
Spare parts	%			$ -	
Transportation	project			$ -	
Training & commissioning	p-d			$ -	
User-defined	cost			$ -	
Contingencies	%		$ 103,916	$ -	
Interest during construction		2 month(s)	$ 103,916	$ -	
Subtotal:				$ 62,271	59.9%
Total initial costs				$ 103,916	100.0%

Annual costs (credits)	Unit	Quantity	Unit cost	Amount
O&M				
Land lease & resource rental	project			$ -
Property taxes	project			$ -
Insurance premium	project			$ -
Parts & labour	project			$ -
GHG monitoring & verification	project			$ -
Community benefits	project			$ -
General & administrative	%		$ -	$ -
User-defined	cost	1	$ 220	$ 220
Contingencies	%		$ 220	$ -
Subtotal:				$ 220

Periodic costs (credits)	Unit	Year	Unit cost	Amount
User-defined	cost			$ -
				$ -
End of project life	cost			$ -

Financial parameters

General		
Fuel cost escalation rate	%	
Inflation rate	%	1.0%
Discount rate	%	
Project life	yr	25
Finance		
Incentives and grants	$	
Debt ratio	%	
Income tax analysis		☑
Effective income tax rate	%	
Loss carryforward?		No
Depreciation method		Declining balance
Half-year rule - year 1	yes/no	Yes
Depreciation tax basis	%	
Depreciation rate	%	
Tax holiday available?	yes/no	No

Annual income

Electricity export income		
Electricity exported to grid	MWh	129
Electricity export rate	$/MWh	166.18
Electricity export income	$	21,372
Electricity export escalation rate	%	
GHG reduction income		☐
Net GHG reduction	tCO2/yr	0
Net GHG reduction - 25 yrs	tCO2	0
Customer premium income (rebate)		☐
Other income (cost)		☑
Energy	MWh	
Rate	$/MWh	
Other income (cost)	$	0
Duration	yr	
Escalation rate	%	
Clean Energy (CE) production income		☑
CE production	MWh	229
CE production credit rate	$/kWh	
CE production income	$	
CE production credit duration	yr	
CE production credit escalation rate	%	
Fuel type	**Energy delivered (MWh)**	
Solar	229	Yes

Project costs and savings/income summary

Initial costs			
Feasibility study	0.3%	$	358
Development	1.0%	$	1,080
Engineering	7.8%	$	8,077
Power system	30.9%	$	32,130
Balance of system & misc.	59.9%	$	62,271
Total initial costs	**100.0%**	**$**	**103,916**
Annual costs and debt payments			
O&M		$	220
Fuel cost - proposed case		$	0
Total annual costs		**$**	**220**
Periodic costs (credits)			
Annual savings and income			
Fuel cost - base case		$	0
Electricity export income		$	21,372
Total annual savings and income		**$**	**21,372**

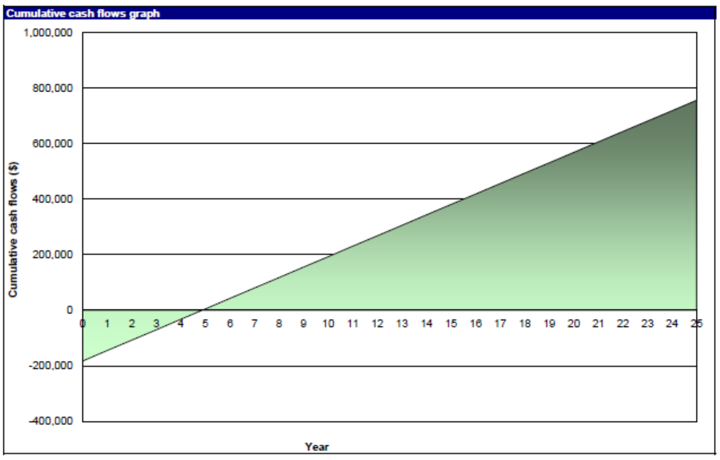
Financial viability

Pre-tax IRR - equity	%	20.1%
Pre-tax IRR - assets	%	20.1%
After-tax IRR - equity	%	20.1%
After-tax IRR - assets	%	20.1%
Simple payback	yr	4.9
Equity payback	yr	4.9
Net Present Value (NPV)	$	424,097
Annual life cycle savings	$/yr	16,964
Benefit-Cost (B-C) ratio		5.08
Energy production cost	$/MWh	34.27
GHG reduction cost	$/tCO2	No reduction

Yearly cash flows

Year	Pre-tax	After-tax	Cumulative
#	$	$	$
0	-103,916	-103,916	-103,916
1	21,149	21,149	-82,767
2	21,147	21,147	-61,620
3	21,145	21,145	-40,475
4	21,143	21,143	-19,332
5	21,140	21,140	1,808
6	21,138	21,138	22,946
7	21,136	21,136	44,082
8	21,133	21,133	65,215
9	21,131	21,131	86,346
10	21,129	21,129	107,474
11	21,126	21,126	128,600
12	21,124	21,124	149,724
13	21,121	21,121	170,845
14	21,119	21,119	191,964
15	21,116	21,116	213,080
16	21,114	21,114	234,194
17	21,111	21,111	255,305
18	21,108	21,108	276,413
19	21,106	21,106	297,519
20	21,103	21,103	318,622
21	21,100	21,100	339,722
22	21,098	21,098	360,820
23	21,095	21,095	381,915
24	21,092	21,092	403,007
25	21,089	21,089	424,097

Cumulative cash flows graph



CHAPTER 5: HORIZONTAL ORIENTED DESIGN

Chapter 5:
Horizontal Oriented Design

Introduction:

In this solution we used both areas that can PV installed on; the land and well, an overall area of 2500m^2. This system will be connected with grid in net metering tariff which is a method designed to accelerate investments in renewable energy by allowing energy producers to be compensated for the energy they feed back into the grid.

Tubas electricity distribution company takes 10% as services of the energy produced from the PV system and the other 90% of generated electricity will be discounted from the electricity bill, and if the production of energy exceeds of the energy consumed, the bi-directional net-metering will save the credits of the excess energy for the coming months and so on till the end of year, if any energy is consumed more than money should be paid and if the annual energy production exceeds then in this case no money returns to the producer.

In this case 266.9 KWp will be connected into the grid divided as 195.5 KWp installed on the land and 71.4 KWp installed as toping of the well.

5.1 Solar Modules

For our design we are going to use the module from Hanwha Q cell, named as: Q. plus-L-G4.2,330-340 with the following specifications

PV module specification	
Type	Q. plus-L-G4.2,330-340
Maximum power (P max)	**340 Wp**
Maximum voltage (V max)	**37.63 V**
Maximum current (I max)	**9.03 A**
Short circuit current (I s.c)	**9.59 A**
Open circuit voltage (V o.c)	**47.07 V**
Efficiency	**17.4%**

Table 19: PV Module specification

The total number of PV modules is 785. With a power of 340w for each, deliver a power of 199.24 KWp distributed as following.

	True South	Tilt Angle
Land	575	0
Well	210	0
Total	785	

Table 21: PV modules in south oriented

The below picture is an overview of the whole farm without installing anything.

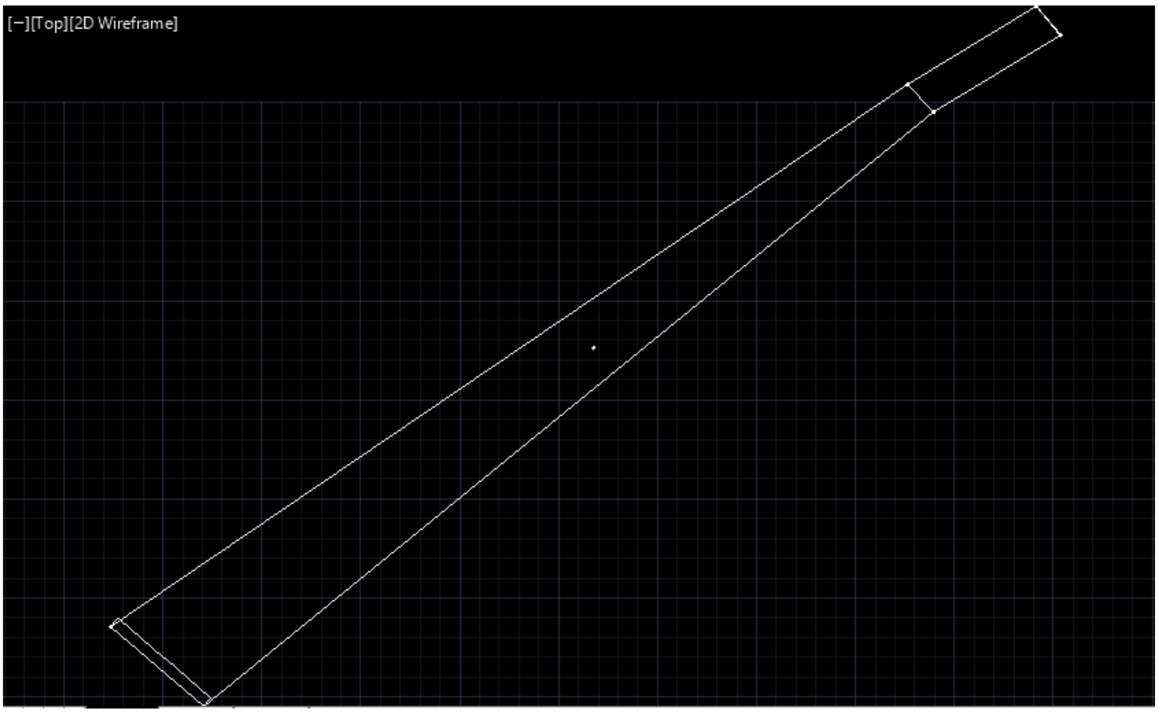


Figure 15:The plan of the farm

we took a 3-m space from the fence in the farm to the PV's so the fence won't cause any shading to the PV'S plus it is a space for any working or maintenance that would be held in the future and in the south east of the farm a service room will be built to have the land system connections and inverters. And there is no shading as all of the modules are 0 tilted.

PV modules distribution for the land area

The following figure descirbes the destribution of the PV modules in the land after taking cosideration of both the service road. We used Autocad software inorder to sketch the following plan.

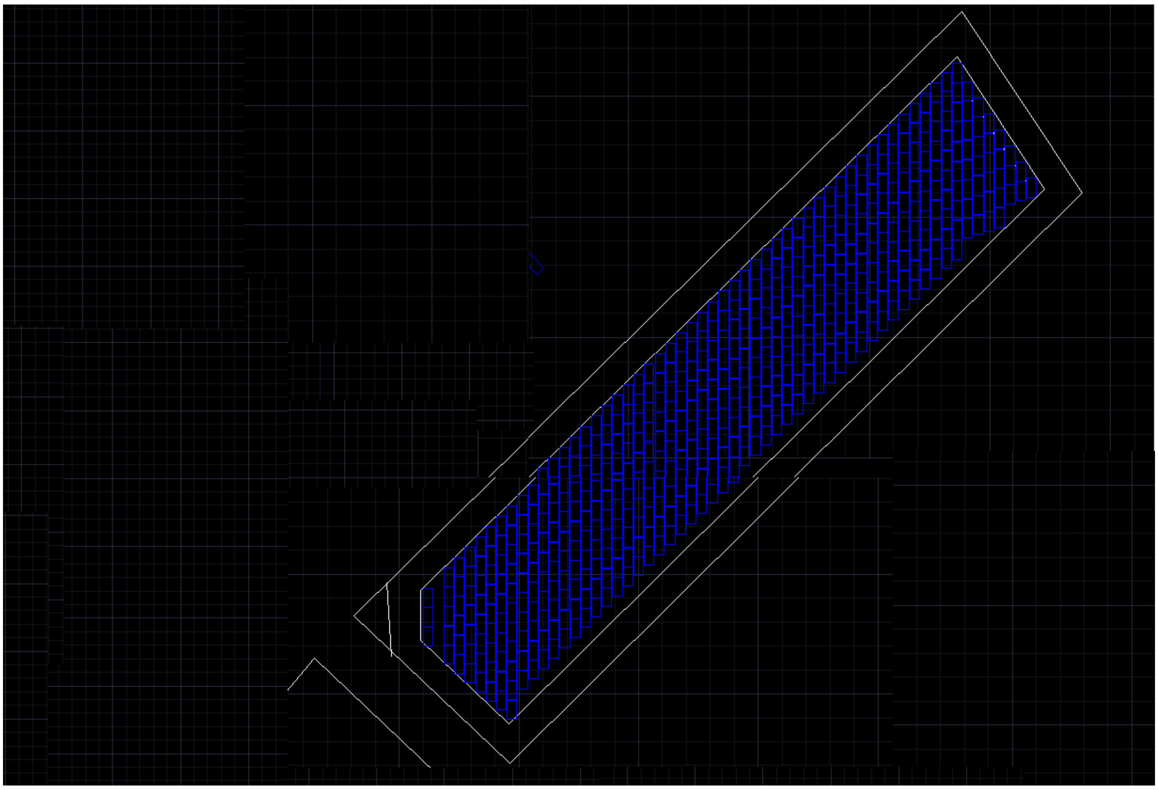


Figure 16:PV modules horizontal distributed in the land

PV modules distribution for the well roofing area:

The area of the well is $(500m^2)$ and we need to get as much as we can of this area in order to get the max power of the modules installed, thus we used the same method as for the land with Tilt angle $=0^{\circ}$, but Thus these modules will be installed on a tough roof in order to have the max number of modules on that roof, so no shading between arrays should be calculated.

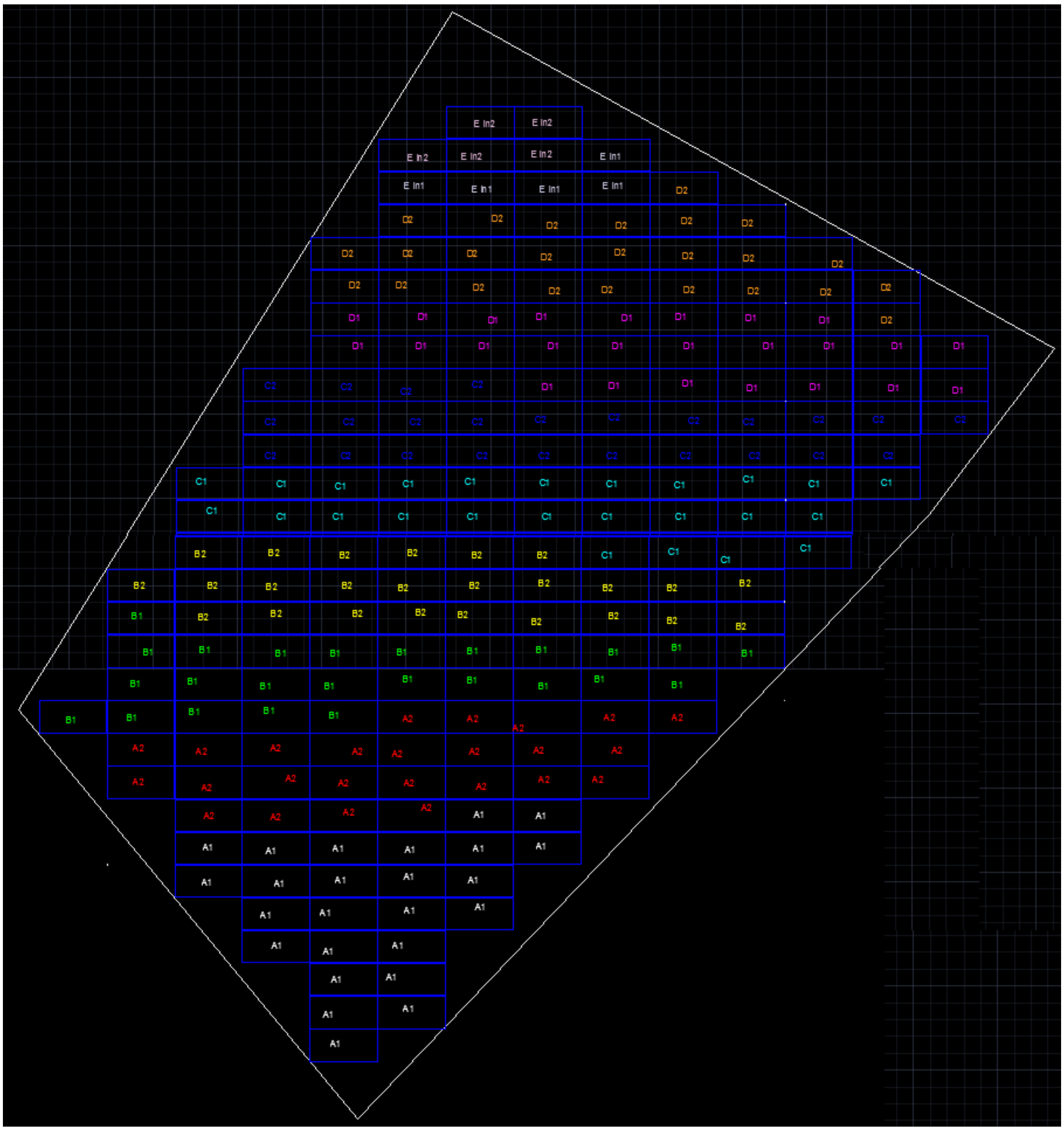


Figure 17:PV modules distributed on the roof of the well

5.3 Inverters

For our design we have selected ABB module TRIO inverter, named as: TRIO-20.0/27-Tl-OULT, PVI-10/12 and TRIO 5.8/8.5

The following table shows the specifications of these inverters then following them with the calculations to size the inverters that are needed for the true south oriented solution.

Inverter specification	type	20Kw	10KW	5.8 Kw
Max abs DC input		**1000v**	**1000v**	**1000v**
Number of mppt		**2**	**2**	1
DC input volt range (mppt)		**440-800**	**300-750**	**320-800**
DC max input current (mppt)		**30A**	**22A**	**24A**
DC rated power		**20750w**	**10300w**	**5950w**
AC voltage range		**400V**	**400V**	**400V**
AC Max current		**33A**	**16A**	**10A**
Max. efficiency		**98.2%**	**97.3%**	**98%**

Table 21: ABB inverters specifications

3- size the inverters for the land:

total number of panels for the land = 575 panels

for the panels: Imppt=9.03 Vmppt=37.63

for each inverter MPPT

15(panels)*37.63(vmppt)= 564.45 (in range of 20KW inverter)

2(arrays of panels) *9.03= 18.06A (less than the max current for mppt of the inverter)

Number of panels for each MPPT = 15*2 = 30 Panels

Number of panels for 2 MPPTs (one inverter 20KW) = 30*2 = 60 panels

Total number of panels for the land design = 575 panels

Number of (20 KW inverters) = 9inverters (9*20 = 180 KW)

Total number of panels = 9*60 = 540 panels (540*0.34KW/Panel = 183.6KW)

But total number of the land design = 575

15 panels need another inverter so (15*0.34KW) = 5.1 so we choose 5.8KW

Number of mppt for 5.8 inverter is 2 but we use one mppt

15panels * 37.63 v/panel = 564.45 V (in range)

4- size the inverters for the well:

total number of panels for the well = 210 panels

for the panels: Imppt=9.03 Vmppt=37.63

for each inverter MPPT

15(panels)*37.63(vmppt)= 564.45 (in range of 20KW inverter)

2(arrays of panels) *9.03= 18.06A (less than the max current for mppt of the inverter)

Number of panels for each MPPT = 15*2 = 30 Panels

Number of panels for 2 MPPTs (one inverter 20KW) = 30*2 = 60 panels

Total number of panels for the land design = 210 panels

Number of (20 KW inverters) = 3 inverters (3*20 = 60KW)

Total number of panels = 3*60 = 180 panels (180*0.34KW/Panel = 61.2KW)

But total number of the land design = 210

30 panels need another inverter so (30*0.34KW) = 10.2Kw so we choose 10KW inverter

Number of mppt for 10KW inverter is 2

For each MPPT:

15panels * 37.63 v/panel = 564.45 V (in range)

1(arrays of panels) * 9.03 = 18.06A (less than the Imax of each mppt)

So total number of panels connected to the inverter = 15panels*2mppt = 30 panels

	20KW	10KW	5.8
Land	9	0	1
Well	3	1	0
total	12	1	1

Table 22: total number of inverters for the south oriented

4.4 Mentoring system

The Net Monitoring technology allows to monitor as many inverters as we wish, without the need of special communication cards that are usually required by the inverter manufacturers and you also don't need to pay for the online monitoring, no matter what size of system you have.

The monitoring system provides:

1- Real time energy information.
2- Renewable Energy monitoring.
3- Measurement and Verification of essential equipment (M&V)
4- Operations and Maintenance of asset portfolio (O&M)
5- Data export via push or pull with an open data API.
6- Lower energy cost.
7- Lower emission associated with fossil fuel energy.
8- Establish building energy benchmark and LEED points.
9- Peak Demand analysis.
10- Energy Efficiency projects and commissioning.

We used eGauge Systems EG3000 Meter ANSI C12.1 - 1% Compliance w/ Ethernet. Table below shows the characteristics of EG3000 meter.

Mfr. Part #:	A000-ETH-016
CS Part #:	cs-300351
Dimensions:	6.94 × 3.25 × 1.3 in
Weight:	0.5 lb

Table 23: eGuage monitoring system specifications

5.5 Cables

1- DC cables

We used two ratings for DC cables, which are (4mm^2 and 6 mm^2) depending on the location of the DC side, for each string we use 4mm^2 and when it delivers to the combined box where 2 strings join together to go to the inverter, then 6mm^2 will be used as following:

Before DC combined box, I=9.03A – DC cables 4mm^2

After DC combined box, I=18.06A – DC cables 6mm^2

2-AC cables

The following table shows the cross-section areas of the AC cables after the inverters until the bi-directional metering

Table 24:cross section area of AC cables and their location

	AC cable	AC current	Location
AC CB's (40 A & 3poles)	AC cables (4*16 mm)	30 A	The output of each inverter
AC CB's (90 A)	AC cables (25 mm)	90 A	To protect the AC the cable from AC Base Bare of well`s inverters to the largest AC Base Bare.
AC CB's (250 A)	AC cables (120 mm)	216 A	To protect the AC cable goes from land`s room to the largest AC Base Bare in well`s room

5.6 Protection

1- DC side

Circuit Breakers

We used DC Circuit Breakers (20A/10 A &1000 volt) as each MPPT of the inverters has a current value of 9.03 A, one for every string and connected in the protection panel.

Fuse

It is connected to each string of the inverters and the used one in our project is 15 A that is recommended in the inverter`s data sheet. And it comes along with a Fuse Holder; which is a mechanical part used for connecting two fuses.

AC Surge Arresters

It is connected to each string of the inverters after the fuses and placed in the DC protection panel that is near the inverter input. An Earth wire in the surge arrester is connected to the DC Earthing Base bare, the rating of the surge arrester is (1000v 40KA)

	NO. Inverters	NO. fuses	NO. fuse holders	NO. DC C.B 10A	No. DC C.B 20A	NO. DC Surge Arresters
Land	10	38	38	1	18	38
Well	4	18	18	2	8	18

Table 25:DC protection of south oriented design

3- AC side

AC Circuit Breakers

We used AC Circuit Breakers (40A/15 A &1000 volt) as each inverter has a max current value of 9.03*2*0.9*2 A=32.5 and also as well AC protection is needed after the bass bare of gathering the output of the AC side after the inverters such as (100A/250A AC CB).

	NO. Invertors	NO. AC C.B (40 A)	No. AC C.B (15A)	NO. AC C.B (100 A)	NO. AC C.B (250 A)
Land	10	9	1	0	1
Well	4	3	1	1	0

Table 26: AC protection of South oriented design

AC surge arresters

It is connected to each AC wire comes out from the inverter and placed in the AC protection panel that is near the inverter output. An Earth wire in the surge arrester is connected to the AC Earthing Base bare. We used AC surge arrester of 40 A and 1000 volt

RCD

An RCD, or residual current device, is a life-saving device which is designed to prevent you from getting a fatal electric shock if you touch something live, such as a bare wire. It can also provide some protection against electrical fires. RCDs offer a level of personal protection that ordinary fuses and circuit-breakers cannot provide.

	NO. AC Surge Arrester	NO. of RCD
Land	11	1
well	5	1

Table 27: AC protection of south oriented design

5.7 Bill of Quantity

A bill of quantity has been made which itemized list of the materials and components with their prices that are required to install the PV for the south oriented design, and it is important to expect the costs of the installations.

Item description	Unit	Quantity	Unit Price ($)	Total price($)	Unit Price(NIS)	Total price(NIS)
PV Module (340Wp)	No.	785	156	122460	546	428610
Grid Connected Inverters(20 Kw)	No.	15	4882	73230	17098.33	256474.95
Grid Connected Inverters(10 Kw)	No.	1	2441	2441	8543.5	8543.5
Grid Connected Inverters(5.8 Kw)	No.	1	1415	1415	4952.5	4952.5
Internet connected Monotring system	L.S	1	487	487	1704.5	1704.5
steel mounting structure	for one module	575	68	39100	238	136850
DC cables solar type	meter	2679.5	1.02	2733.09	3.57	9565.815
DC cables(10 mm)				0		0
AC cables(PG36, 16 mm)	meter	120	7	840	24.5	2940
DC CB's(10 A &1000 volt)	No.	34	70.28	2389.52	246	8364
DC fuse holders	No.	17	9.14	155.38	32	544
DC fuses(15A)	No.	34	9.14	310.76	32	1088
DC Surge arresters(40A, 1000V)	No.	34	81.4	2767.6	285	9690
DC protection panels(plastic)(well)	No.	1	20.35	20.35	71.25	71.25
DC protection panels(plastic)(land)	No.	1	11.3	11.3	39.58	39.58
AC protection panels (plastic) land	No.	1	571.4	571.4	2000	2000
AC protection panels (plastic) well	No.	2	571.4	1142.8	2000	4000
AC cables(25 mm)	meter	2	10.93	21.86	38.28	76.56
AC cables(120 mm)	meter	180.32	52.5	9466.8	183.75	33133.8
AC cables(240 mm)	meter	20.52	105	2154.6	367.5	7541.1
AC CB's(40 A & 3poles)	No.	17	52.85	898.45	185	3145
AC CB's(90 A)	No.	1	76.5	76.5	268	268
AC CB's (250 A)	No.	1	213.09	213.09	745.83	745.83
AC CB's(400 A)	No.	1	340	340	1193.33	1193.33
AC Surge arresters(40A, 1000V)	No.	17	95.71	1627.07	335	5695
مرابط	No.	6	12.85	77.1	45	270
earthing bit DC	No.	6	15.42	92.52	54	324
system grounding electrodes	No.	6	80	480	280	1680
lighting protection system(ABB bulser 60)	No.	1	342.85	342.85	1200	1200
complete system installation & operation(as specified above)	person	20	100	2000	350	7000
generation kWh meter panel	L.S	1	26	26	91	91
Bidirectional kWh meter panel	L.S	1	56	56	196	196
كابل معرى 25 mm	meter	18	3.42	61.56	12	216
system grounding electrodes	No.	6	80	480	280	1680
earthing bit AC	No.	6	15.42	92.52	54	324
مرابط earth electrodes	No.	6	12.85	77.1	45	270
MAIN BD	No.	1	457.14	457.14	1600	1600
Earth cable (30 mm)	meter	1282	3.77	4833.14	13.2	16922.4
Earth base bare	unit	4	7.14	28.56	25	100
Accesoaries		1	257.14	257.14	700	700
لوح الزينكو مع الاعمدة	squared meter	486.76	14.28	6950.9328	50	24338
AC Base bare 1X2/ 5cm	No.	2	7.14	14.28	25	50
AC Base bare 1X2/ 5cm	No.	1	14.28	14.28	50	50

Table 28:Boq of horizontal design

The sum of these costs is used in Retscreen to do the financial report as following in the next section.

5.8 Restscreen

The RetScreen Clean Energy Project Analysis Software is a tool that helps with decision making allowing engineers, architects, and financial planners to model and analyze any clean energy project.

The technologies included in RetScreen's project models are all-inclusive and include both traditional and non-traditional sources of clean energy as well as conventional energy sources and technologies.

In this project, RetScreen was used to help us make a detailed study for a photovoltaic power plant in Talloza used to pump water from three different pumps used for irrigation.

The Following files are for the horizontal oriented, both the well and land in the same report.

Project information

See project database

Project name	water pumping - 266.9kW Horizontal
Project location	talluza
Prepared for	power plant
Prepared by	Bahaa Majadleh, Mohammed Ateri
Project type	Power
Technology	Photovoltaic
Grid type	Central-grid
Analysis type	Method 2
Heating value reference	Higher heating value (HHV)
Show settings	
Language - Langue	English - Anglais
User manual	English - Anglais
Currency	$
Units	Metric units

Site reference conditions

Select climate data location

Climate data location	Jericho
Show data	

	Unit	Climate data location	Project location
Latitude	˚N	31.9	31.9
Longitude	˚E	35.5	35.5
Elevation	m	-275	-275
Heating design temperature	°C	5.0	
Cooling design temperature	°C	32.9	
Earth temperature amplitude	°C	23.1	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		10.6	58.7%	2.80	96.3	4.5	11.7	229	19
February		11.4	54.0%	3.50	96.2	4.6	13.3	185	39
March		14.2	50.8%	4.60	96.0	4.7	17.5	119	129
April		18.9	41.7%	6.00	95.8	4.4	23.9	0	266
May		22.2	41.2%	7.10	95.8	4.1	28.3	0	378
June		24.3	45.5%	7.90	95.6	4.1	31.2	0	428
July		26.0	46.9%	7.80	95.4	4.1	33.7	0	496
August		26.4	49.1%	7.20	95.5	3.9	33.8	0	508
September		25.0	49.3%	6.00	95.8	3.6	31.2	0	451
October		21.7	52.8%	4.70	96.0	3.7	25.5	0	363
November		17.0	52.0%	3.40	96.2	3.7	18.8	30	210
December		12.3	56.5%	2.60	96.3	4.1	13.3	175	73
Annual		19.2	49.9%	5.31	95.9	4.1	23.6	738	3,359
Measured at	m					10.0	0.0		

Complete Energy Model sheet

RETScreen Energy Model - Power project

Show alternative units

Proposed case power system

Technology		Photovoltaic
Analysis type		○ Method 1 ⊙ Method 2
Resource assessment		
Solar tracking mode		Fixed
Slope	°	0.0
Azimuth	°	0.0

☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate $/MWh	Electricity exported to grid MWh
January	2.80	2.80	184.6	21.71
February	3.50	3.50	184.6	24.26
March	4.60	4.60	184.6	34.52
April	6.00	6.00	184.6	42.19
May	7.10	7.10	184.6	50.42
June	7.90	7.90	184.6	53.43
July	7.80	7.80	184.6	54.10
August	7.20	7.20	184.6	50.02
September	6.00	6.00	184.6	40.98
October	4.70	4.70	184.6	34.07
November	3.40	3.40	184.6	24.68
December	2.60	2.60	184.6	20.07
Ann	**5.31**	**5.31**	**184.60**	**450.46**

Annual solar radiation - horizontal	MWh/m²	1.94	
Annual solar radiation - tilted	MWh/m²	1.94	
Photovoltaic			
Type		poly-Si	
Power capacity	kW	266.90	*See product database*
Manufacturer		hanwha	
Model		Q.Plus L-G4.2 330-340	1 unit(s)
Efficiency	%	17.1%	
Nominal operating cell temperature	°C	45	
Temperature coefficient	% / °C	0.40%	
Solar collector area	m²	1,561	
Miscellaneous losses	%	3.0%	
Inverter			
Efficiency	%	98.2%	
Capacity	kW	35.8	
Miscellaneous losses	%	2.0%	
Summary			
Capacity factor	%	19.3%	
Electricity exported to grid	MWh	450.46	

Settings					
Method 1	Notes/Range				
Method 2	Second currency	Notes/Range	None		
	Cost allocation				

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Site investigation	p-d			$ -	
Resource assessment	project			$ -	
Environmental assessment	p-d			$ -	
Preliminary design	p-d			$ -	
Detailed cost estimate	p-d			$ -	
GHG baseline study & MP	project			$ -	
Report preparation	p-d			$ -	
Project management	p-d			$ -	
Travel & accommodation	p-trip	1	$ 1,000	$ 1,000	
User-defined	cost			$ -	
				$ -	
Subtotal:				**$ 1,000**	0.2%
Development					
Contract negotiations	p-d			$ -	
Permits & approvals	p-d	5	$ 200	$ 1,000	
Site survey & land rights	p-d			$ -	
GHG validation & registration	project			$ -	
Project financing	p-d			$ -	
Legal & accounting	p-d	1	$ 300	$ 300	
Project management	p-d			$ -	
Travel & accommodation	p-trip			$ -	
User-defined	cost			$ -	
				$ -	
Subtotal:				**$ 1,300**	0.3%
Engineering					
Site & building design	p-d			$ -	
Mechanical design	p-d	1	$ 3,817	$ 3,817	
Electrical design	p-d	1	$ 22,900	$ 22,900	
Civil design	p-d	1	$ 11,450	$ 11,450	
Tenders & contracting	p-d			$ -	
Construction supervision	p-d			$ -	
User-defined	cost			$ -	
				$ -	
Subtotal:				**$ 38,167**	8.0%
Power system					
Photovoltaic	kW	266.90	$ 450	$ 120,105	
Road construction	km	1	$ 5,000	$ 5,000	
Transmission line	km			$ -	
Substation	project			$ -	
Energy efficiency measures	project			$ -	
User-defined	cost			$ -	
				$ -	
Subtotal:				**$ 125,105**	26.2%
Balance of system & miscellaneous					
Specific project costs		Photovoltaic			
Inverter	kW	36	$ 8,670	$ 310,386	
Collector support structure	m²			$ -	
Installation	project	20	$ 100	$ 2,000	
Building & yard construction	m²			$ -	
Spare parts	%			$ -	
Transportation	project			$ -	
Training & commissioning	p-d			$ -	
User-defined	cost			$ -	
Contingencies	%		$ 477,958	$ -	
Interest during construction		2 month(s)	$ 477,958	$ -	
Subtotal:				**$ 312,386**	65.4%
Total initial costs				**$ 477,958**	100.0%

Annual costs (credits)	Unit	Quantity	Unit cost	Amount
O&M				
Land lease & resource rental	project			$ -
Property taxes	project			$ -
Insurance premium	project			$ -
Parts & labour	project			$ -
GHG monitoring & verification	project			$ -
Community benefits	project			$ -
General & administrative	%		$ -	$ -
User-defined	cost	1	$ 300	$ 300
Contingencies	%		$ 300	$ -
Subtotal:				**$ 300**

Periodic costs (credits)	Unit	Year	Unit cost	Amount
User-defined	cost			$ -
				$ -
End of project life	cost			$ -

Financial parameters

General		
Fuel cost escalation rate	%	
Inflation rate	%	1.0%
Discount rate	%	
Project life	yr	25
Finance		
Incentives and grants	$	
Debt ratio	%	
Income tax analysis		☑
Effective income tax rate	%	
Loss carryforward?		No
Depreciation method		Declining balance
Half-year rule - year 1	yes/no	Yes
Depreciation tax basis	%	
Depreciation rate	%	
Tax holiday available?	yes/no	No

Annual income

Electricity export income		
Electricity exported to grid	MWh	450
Electricity export rate	$/MWh	184.60
Electricity export income	$	83,154
Electricity export escalation rate	%	
GHG reduction income		☐
Net GHG reduction	tCO2/yr	0
Net GHG reduction - 25 yrs	tCO2	0
Customer premium income (rebate)		☐
Other income (cost)		☑
Energy	MWh	
Rate	$/MWh	
Other income (cost)	$	0
Duration	yr	
Escalation rate	%	
Clean Energy (CE) production income		☑
CE production	MWh	450
CE production credit rate	$/kWh	
CE production income	$	
CE production credit duration	yr	
CE production credit escalation rate	%	
Fuel type	**Energy delivered (MWh)**	
Solar	450	Yes

Project costs and savings/income summary

Initial costs			
Feasibility study	0.2%	$	1,000
Development	0.3%	$	1,300
Engineering	8.0%	$	38,167
Power system	26.2%	$	125,105
Balance of system & misc.	65.4%	$	312,386
Total initial costs	**100.0%**	**$**	**477,958**
Annual costs and debt payments			
O&M		$	300
Fuel cost - proposed case		$	0
Total annual costs		**$**	**300**
Periodic costs (credits)			
Annual savings and income			
Fuel cost - base case		$	0
Electricity export income		$	83,154
Total annual savings and income		**$**	**83,154**

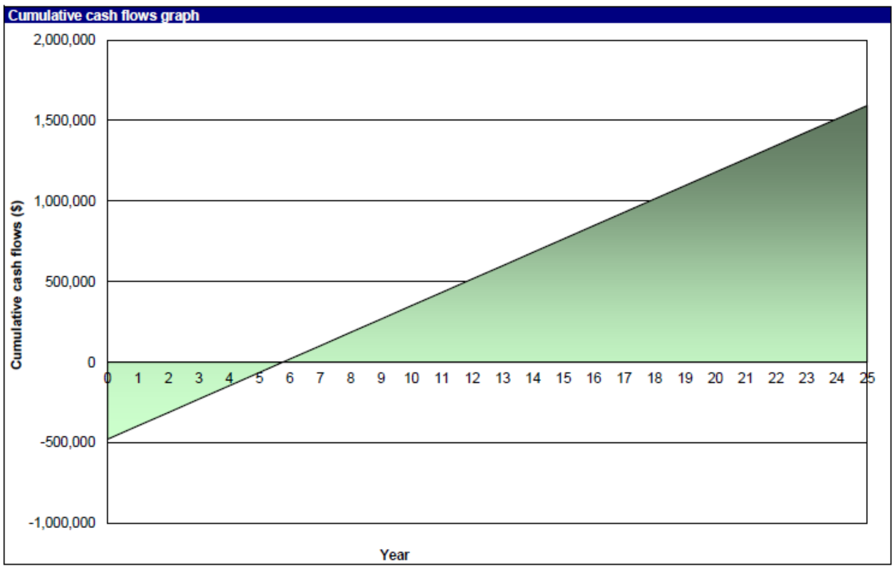
Financial viability

Pre-tax IRR - equity	%	17.0%
Pre-tax IRR - assets	%	17.0%
After-tax IRR - equity	%	17.0%
After-tax IRR - assets	%	17.0%
Simple payback	yr	5.8
Equity payback	yr	5.8
Net Present Value (NPV)	$	1,592,340
Annual life cycle savings	$/yr	63,694
Benefit-Cost (B-C) ratio		4.33
Energy production cost	$/MWh	43.20
GHG reduction cost	$/tCO2	No reduction

Yearly cash flows

Year	Pre-tax	After-tax	Cumulative
#	$	$	$
0	-477,958	-477,958	-477,958
1	82,851	82,851	-395,106
2	82,848	82,848	-312,258
3	82,845	82,845	-229,413
4	82,842	82,842	-146,571
5	82,839	82,839	-63,732
6	82,836	82,836	19,103
7	82,833	82,833	101,936
8	82,829	82,829	184,765
9	82,826	82,826	267,591
10	82,823	82,823	350,414
11	82,820	82,820	433,234
12	82,816	82,816	516,050
13	82,813	82,813	598,863
14	82,809	82,809	681,672
15	82,806	82,806	764,478
16	82,802	82,802	847,280
17	82,799	82,799	930,079
18	82,795	82,795	1,012,875
19	82,792	82,792	1,095,666
20	82,788	82,788	1,178,455
21	82,784	82,784	1,261,239
22	82,781	82,781	1,344,020
23	82,777	82,777	1,426,797
24	82,773	82,773	1,509,570
25	82,769	82,769	1,592,340

Cumulative cash flows graph



CHAPTER 6: OFF-GRID DESIGN

Chapter 6: Off grid Design

Introduction:

In this solution we used the well roof toping that can PV installed on, an overall area of $500m^2$. This system will be an off grid (battery capacity) during night load and in the blackouts, during the day the load will be dependent on the grid to get electricity and during night from the energy storage.

In this case 69.36 KWp will be connected into batteries through an inverter. This system will be installed on the well as roof toping (27° tilted angle) so no shading analysis is required.

in time with the energy demand from the connected loads, additional storage systems (batteries) are generally used. The power output of a solar array deviates with weather conditions; the rewarding activity of the PV system is therefore to find out the optimal size of a solar array and battery to meet load demand. With rising fuel cost, concern for climate change and need to find alternative energy source solar PV technology is seen as a solution to energy supply in remote area.

6.1 Load estimation

The daily load of the pumping system will be calculated as an average daily from the electricity bill as following.

Month	Daily energy consumption KWH	Hourly energy consumption KWH
January	48.2	2
February	478	19.9
March	648.2	27
April	2239	93.3
May	3045	126.8
June	536	22.3
July	496	20.6
August	506	21
September	538	22.4
October	527	22
November	519	21.6
December	248	10.3

Table 29: avg daily and hourly energy consumption

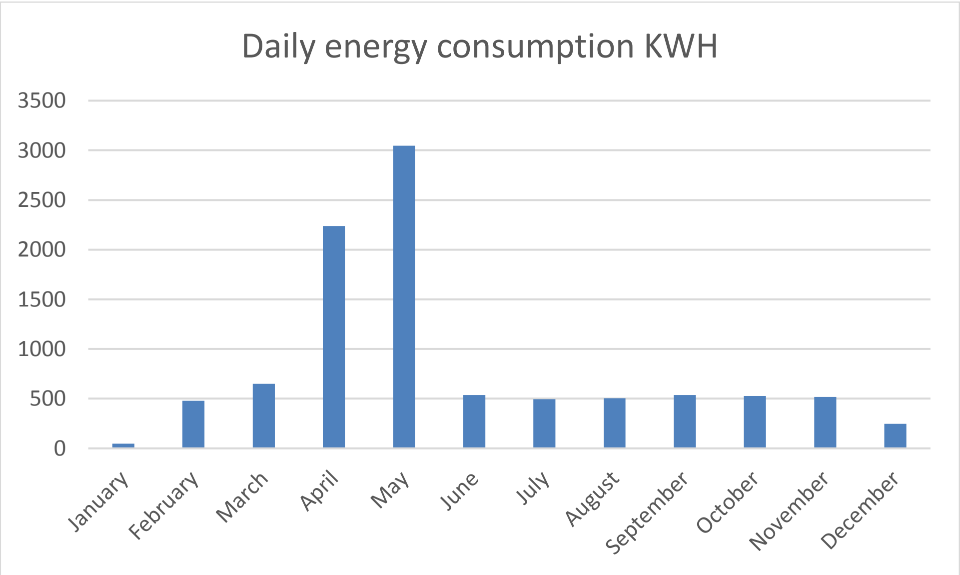


Figure 18: Avg daily and hourly energy consumption

6.2 Solar source:

Solar radiation data are often presented as an average daily for each month. Of course, on any given day the solar radiation continuously from sunup to sundown. The maximum irradiance is available at solar noon which is defined as the midpoint, in time, between sunrise and sunset. The term peak sun hours are defined as the equivalent number of hours per day, with solar irradiance equaling 1,000 w m^{-2}, that would give the same amount of energy. [8]

at any particular time, the available solar energy is primarily dependent on time and current cloud conditions. Furthermore, useable solar energy is depended upon available solar energy, other weather conditions, the technology used, and the application, Therefore, peak sun hours correspond directly to average daily insolation in kwh m^{-2}.[8]

month	PSH (average daily peak sun hours) h/day
January	2.818
February	3.68
March	5.24
April	6.319
May	7.084
June	8.106
July	7.908
August	7.2316
September	6.0963
October	4.297
November	2.7276
December	2.589

Table 30: avg daily peak sun hours

6.3 system sizing

By taking September to design the capacity needed for the whole year, as September daily consumption is relatively more than the other daily consumption expect the very high months of energy consumptions that will take into consideration by adding more battery capacity to cover their loads for few hours.

The daily consumption of Septembers is 538KWh/day. As was mentioned above the off-grid solution will be providing energy up t0 12hrs depending on the season and on the load. Providing 12 hours is about 269Kwh.

Battery

stores energy for supplying to electrical appliances when there is a demand. Battery bank, which is involved in the system to make the energy available at night or at days of autonomy (sometimes called no-sun-days or dark days), when the sun is not providing enough radiation. These batteries, usually lead-acid, are designed to gradually discharge and recharge 80% of their capacity hundreds of times. [9]

Battery specification	
Type	Lead acid and patented Gel electrolyte
Model	DG12-200
Chemical Composition	Lead Acid, AGM
Voltage	12 V
Amp Hours	200AH
Depth of discharge (DOD)	60%
Efficiency	85%

Table 31: Battery specifications

Daily consumption = 538kwh, 12hrs consumption=269Kwh

In Ah, $\frac{wh}{volt*pf*\sqrt{3}} = \frac{269000}{400*0.9*\sqrt{3}} = 434Ah$

Required storage = $\frac{total\ Ah}{DoD*eff} = \frac{434}{0.6*0.85} = 851Ah \ \cong 1000Ah$

Battery bank sizing:

Number of batteries in parallel = $\frac{Required\ battery\ storage}{rated\ battery\ capacity} = \frac{1000Ah}{200Ah} = 5\ batteries$

Number of batteries in series = $\frac{Total\ battery\ bank\ volt}{rated\ battery\ volt} = \frac{360}{12} = 30\ batteries$

Total number of battery needed = 30*5 = 150 battery

Solar Modules

This sizing method is designed to generate enough energy during the design month to meet the load and cover all losses in the system. This means that in an average year the load will be met and the battery state-of-charge will be the same on the last day of the design month as on the first day.

In our design as we are taking September as an ideal month, the following sample of calculation to provide 12 hours of energy taking into consideration the solar radiation on September near Tubas, and for the other months the same method is used to expect the hours of storage depending on each month's solar radiation. The design method uses current (amperes) instead of power (watts) to describe the load requirement because it is easier to make a meaningful comparison of PV module performance. [9]

For this design we are going to use the module from Hanwha Q cell, named as: Q. plus-L-G4.2,330-340 with the following specifications

PV module specification	
Type	Q. plus-L-G4.2,330-340
Maximum power (P max)	**340 Wp**
Maximum voltage (V max)	**37.63 V**
Maximum current (I max)	**9.03 A**
Short circuit current (I s.c)	**9.59 A**
Open circuit voltage (V o.c)	**47.07 V**
Efficiency	**17.4%**

Table 32: PV Module specification

$$I\max = \frac{total\ Ah}{PSH\ for\ sept} = \frac{851}{6.09} = 140A$$

Number of modules in Parallel = $\frac{I\ max}{I\ s.c*0.9} = \frac{140}{9.59*0.9} = 17\ modules$

Number of modules in series = = $\frac{Battery\ Volt}{V\ max} = \frac{360}{37.63} = 12\ modules$

Total Number of modules = 12*17 = 204

Total power of the system = 204*0.34= 69.36Kwp

As september considered an ideal month, the system is going to be 69.36KWp with 150 batteries (total Ah 1000Ah) and as the previous method done for september, the other months will be calculated with 69.36kwp and charge 150 batteries with (1000ah) as the following sample of calculation done for march. Total ah is to be calculated as well as estimation time to consume the storage. [9]

$$\frac{I\ max}{I\ s.c*0.9} = NO.modules\ in\ parallel,\ then\ Imax = Is.c * 0.9 * NO.modules\ in\ Parallel$$

$$Imax = 9.59 * 0.9 * 17 = 138.16A$$

$$I\max = \frac{total\ Ah}{PSH\ for\ march}\quad then,\ total\ Ah = Imax * PSH\ for\ march$$

$$total\ Ah = 138.16 * 5.24 = 724\ Ah\ \ (required\ storage)$$

$$Ah\ in\ AC\ provided = total\ Ah * DOD * eff$$

$$Ah = 724 * 0.85 * 0.6 = 369Ah$$

$$in\ KWh = total\ Ah * voltage * PF * \sqrt{3}$$

In Kwh = 369 * 400 *0.9 * 1.72 = 228.62 KWh

Hourly energy consumption in march = 27kwh

The storage capacity is enough to provide the daily load in march as

$$\frac{total\ kwh\ produced}{kwh} = \frac{228.6}{27} = 8\ hrs$$

month	Hourly energy consumption (kwh)	Daily energy sotrage (kwh)	Ah delivered to load (daily)	Hrs provided from the system	NO. of battery needed
January	2	120	198.5	2days/12hrs	60
February	19.9	195.2	259	8 hrs	90
March	27	229.5	369	8 hrs	120
April	93.3	280	455.2	3 hrs	150
May	126.8	317	500	2.5 hrs	150
June	22.3	312	571.16	14 hrs	150
July	20.6	309	557	15 hrs	150
August	21	315	509	15 hrs	150
September	22.4	269	434	12 hrs	150
October	22	187	302.7	8.5 hrs	90
November	21.6	119	192	5.5 hrs	60
December	10.3	114	183	11 hrs	60

Table 33: avg daily energy storage

As can be noticed from the table above, the storage is not the same for each month, due to the changing in solar radiation from season to season, and also as well can be noticed that the hours to be providing from the energy storage varies from month to month due to the load needed. The system will not be using the whole battery capacity as some months need 60 batteries and other need 150 battery. In such months that need 60 batteries or 90 batteries or 120 batteries, the other batteries will be disconnected from the system to protect them from the charging and discharging current, to keep the life cycle as high as possible and also due to the Imax produced from the PV system in such months is not enough to charge these batteries.

Inverter

Inverters are necessary in any stand-alone PV system with ac loads. All requirements that the ac load will place on variation in voltage, frequency, and waveform can be tolerate. On the input side, the dc voltage, surge capacity, and acceptable voltage variation must be specified. [9]

In our design we used Zigor, HITC (three phase hybrid) inverter for solar, batteries and grid.

Inverter specifications	
input (DC)	**100KW**
Recommended PV	**105 KW**
Max AC Rated power	**100 kW**
AC voltage	**400 V**
AC max current output for each phase	**152A**
Max. efficiency	**96%**
Battery nominal voltage/range	**350/ 300-420**
Charge max current	**100A**
Discharge max current	**335A**
MPPT voltage range	**420-700 Vdc**
MPPT max Current	**250A**

Table 34: Zigor, hybrid inverter specification

Number of modules in parallel = 17,

I = I mppt current (module) * NO. of modules in parallel

$I = 9.03 * 17 = 153.1A$ (less than MPPT max current of the inverter)

Number of modules in series = 12,

V = V mppt (module) * NO. of modules in series

V =37.63 * 12 = 451.56 Vdc (within voltage range)

6.4 Charge controller system

According to its function it controls the flow of current from PV to charge the batteries and to protect them from the overcharging case and also as well to control the discharging current from the batteries to the load. In our case the charge controller is already built in, as it comes with the inverter.

So there is no need to get a charge controller as separated part to connect from the PV to the batteries directly, firstly the PV should be connected directly into the inverter PV input and the batteries should be connected with the inverter into the Battery Input. In this cycle the inverter does not make any conversions between DC/AC and AC/DC to charge the batteries, the Inverter works as a charge controller to pass the current in DC into batteries directly with controlling the charging and discharging cycles.

6.5 Cables

1- DC cables

We used three ratings for DC cables, which are (4mm^2 and 25 m$m^2$and 23 mm^2) depending on the location of the DC side, for each string we use 4mm^2 and when it delivers to the combined box where 2 strings join together to go to the inverter, then 25mm^2 and 23 mm^2will be used to connect between batteries and with the inverter as following:

Before DC combined box, I=9.03A – DC cables 4mm^2

After DC combined box, I=153.51A – DC cables 25mm^2

After Inverter with Battery capacity, Imax=200A – DC cables 35mm^2

2-AC cables

After the inverter the only AC cable is required to connect the system with the pump, the max current delivered is 150A with a cable rating of 70 mm^2

6.6 Protection

1- DC side

Circuit Breakers

We used DC Circuit Breakers (250 A &1000 volt) as one MPPT of the inverters has a current value of 151.51A, one for every string and connected in the protection panel.

And we used DC circuit breakers (630A, 500Vdc) for battery protection

Fuse

It is connected to each string of the inverters and the used one in our project is 15 A that is recommended in the inverter`s data sheet. And it comes along with a Fuse Holder; which is a mechanical part used for connecting two fuses.

AC Surge Arresters

It is connected to each string of the inverters after the fuses and placed in the DC protection panel that is near the inverter input. An Earth wire in the surge arrester is connected to the DC Earthing Base bare, the rating of the surge arrester is (1000v 40KA)

	NO. Invertors	NO. fuses	NO. fuse holders	NO. DC C.B 250A	No. DC C.B 630A 500vdc	NO. DC Surge Arresters
Well	1	17	17	1	6	17

Table 35: DC protection for off grid system

2- AC side

AC Circuit Breakers

We used AC Circuit Breakers (150 A &1000 volt) as one inverter has a max current value of 17*9.03*0.9*=138.2 the location of this CB is after the inverter before going to the pump.

AC surge arresters

It is connected to each AC wire comes out from the inverter and placed in the AC protection panel that is near the inverter output. An Earth wire in the surge arrester is connected to the AC Earthing Base bare. We used AC surge arrester of 40 KA and 1000 volt

RCD

An RCD, or residual current device, is a life-saving device which is designed to prevent you from getting a fatal electric shock if you touch something live, such as a bare wire. It can also provide some protection against electrical fires. RCDs offer a level of personal protection that ordinary fuses and circuit-breakers cannot provide.

	NO. AC Surge Arrester	NO. of RCD
well	1	1

Table 366: AC protection for off grid

6.7 Bill of Quantity

A bill of quantity has been made which itemized list of the materials and components with their prices that are required to install the PV for the off-grid design, and it is important to expect the costs of the installations.

type	**# of units**	**unit cost**	**total cost**	**currency**
PV	69.36	450	31212	$
Inverter 100KW	1	35000	35000	$
Batteries	150	330	49500	$
Mentoring	1	1700	1700	NIS
Roofing	490	50	24500	NIS
DC Protection	**# of units**	**unit cost**	**total cost**	**currency**
Fuse 15A	17	32	544	NIS
Fuse holder	17	32	544	NIS
DC surge protection	17	285	4845	NIS
DC combined Box	2	700	1400	NIS
DC base bar	2	250	500	NIS
DC CB 250A	1	800	800	NIS
MC4	34	17	578	NIS
DC cables 4mm	480	3.5	1680	NIS
DC cables 25 mm	200	21	4200	NIS
DC cables 35 mm	15	30	450	NIS
DC CB 630A (500vdc)	6	1100	6600	NIS
AC	**# of units**	**unit cost**	**total cost**	**currency**
AC CB 150A	1	450	450	NIS
AC cable 70 mm	10	118	1180	NIS
RCD 400mA	1	400	400	NIS
combination box	1	1600	1600	NIS
Earthing	**# of units**	**unit cost**	**total cost**	**currency**
uncovered cable 25mm/meter	18	12	216	NIS
earthing bit DC	6	54	324	NIS
earthing bit AC	6	54	324	NIS
electrodes	6	280	1680	NIS
lighting protection	1	7000	7000	NIS
earth cable(30mm)/meter	1130	13.2	14916	NIS
earth base bare	4	25	100	NIS
connectors	6	45	270	NIS

Table 377: BOQ for the off-grid design

6.8 Restscreen

The RetScreen Clean Energy Project Analysis Software is a tool that helps with decision making allowing engineers, architects, and financial planners to model and analyze any clean energy project.

The technologies included in RetScreen's project models are all-inclusive and include both traditional and non-traditional sources of clean energy as well as conventional energy sources and technologies.

In this project, RetScreen was used to help us make a detailed study for a photovoltaic power plant in Talloza used to pump water from three different pumps used for irrigation.

Natural Resources Canada Ressources naturelles Canada

Canada

RETScreen® International

www.retscreen.net

Clean Energy Project Analysis Software

Project information

See project database

Project name	water pumping well
Project location	talluza
Prepared for	Power plant
Prepared by	Bahaa Majadleh, Mohammed ateri
Project type	Power
Technology	Photovoltaic
Grid type	Off-grid
Analysis type	Method 2
Heating value reference	Higher heating value (HHV)
Show settings	☐

Site reference conditions

Select climate data location

Climate data location	Jericho
Show data	☐

Complete Energy Model sheet

RETScreen4 2013-08-27

NRCan/CanmetENERGY

Base case power system

Grid type		Off-grid		
Technology		Grid electricity		
Fuel rate	$/kWh	0.184		
Capacity	kW	89.50		
Annual O&M cost	$	0		
Electricity rate - base case	$/kWh	0.184		
Total electricity cost	$	70,015		

Load characteristics

Method 1

Method 2

	Unit	Base case	Proposed case	
Electricity - daily - DC	kWh	221.800	221.800	
Electricity - daily - AC	kWh	820.710	820.710	
Intermittent resource-load correlation			Negative	

Percent of month used

		Base case	Proposed case	Energy saved
Electricity - annual - DC	MWh	80.957	80.957	0%
Electricity - annual - AC	MWh	299.559	299.559	0%
Peak load - annual	kW		89.50	

Proposed case power system

Inverter

Capacity	kW	100.0	Peak load - annual - AC
Efficiency	%	98%	
Miscellaneous losses	%	2%	

Battery

Days of autonomy	d	1.0	
Voltage	V	12.0	
Efficiency	%	85%	
Maximum depth of discharge	%	80%	
Charge controller efficiency	%	80%	
Temperature control method		Ambient	
Average battery temperature derating	%	3.1%	
Capacity	Ah	200	121,351
Battery	kWh	2	

Technology Photovoltaic

Resource assessment

Solar tracking mode		Fixed
Slope	°	27.0
Azimuth	°	0.0

Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity delivered to load MWh
January	2.80	3.81	5.32
February	3.50	4.26	5.33
March	4.60	5.14	7.00
April	6.00	6.12	7.85
May	7.10	6.70	8.72
June	7.90	7.15	8.90
July	7.80	7.18	9.15
August	7.20	7.13	9.05
September	6.00	6.57	8.14
October	4.70	5.81	7.59
November	3.40	4.65	6.06
December	2.60	3.65	5.07
Annual	**5.31**	**5.69**	**88.18**

Annual solar radiation - horizontal	MWh/m²	1.94
Annual solar radiation - tilted	MWh/m²	2.08

Photovoltaic

Type		poly-Si		
Power capacity	kW	69.36	77.5%	*See product database*
Manufacturer		hanwha		
Model		Q. Plus L-G4.2 330-340	10 unit(s)	
Efficiency	%	17.2%		
Nominal operating cell temperature	°C	45		
Temperature coefficient	% / °C	0.40%		
Solar collector area	m²	403.3		
Control method		Maximum power point tracker		
Miscellaneous losses	%	2.0%		

Summary

Capacity factor	%	21.6%	
Electricity delivered to load	MWh	88.18	23.2%

Peak load power system

Technology		Grid electricity		
Fuel rate	$/kWh	0.184		
Charger efficiency	%	85.0%		
Suggested capacity	kW	89.5		
Capacity	kW	90	100.0%	*See product database*
Electricity delivered to load	MWh	292.3	76.8%	

.

RETScreen Financial Analysis - Power project

Financial parameters

General

Fuel cost escalation rate	%	
Inflation rate	%	1.0%
Discount rate	%	
Project life	yr	25

Finance

Incentives and grants	$	
Debt ratio	%	

Income tax analysis ☐

Annual income

Electricity export income

GHG reduction income ☐

Net GHG reduction	tCO2/yr	7
Net GHG reduction - 25 yrs	tCO2	180

Customer premium income (rebate) ☐

Other income (cost) ☐

Clean Energy (CE) production income ☐

Project costs and savings/income summary

Initial costs

Feasibility study	0.3%	$	358
Engineering	3.6%	$	5,210
Power system	21.8%	$	31,212
Balance of system & misc.	74.3%	$	106,319
Total initial costs	**100.0%**	**$**	**143,099**

Annual costs and debt payments

O&M	$	220
Fuel cost - proposed case	$	63,281
Total annual costs	**$**	**63,501**

Periodic costs (credits)

Annual savings and income

Fuel cost - base case	$	70,015
Total annual savings and income	**$**	**70,015**

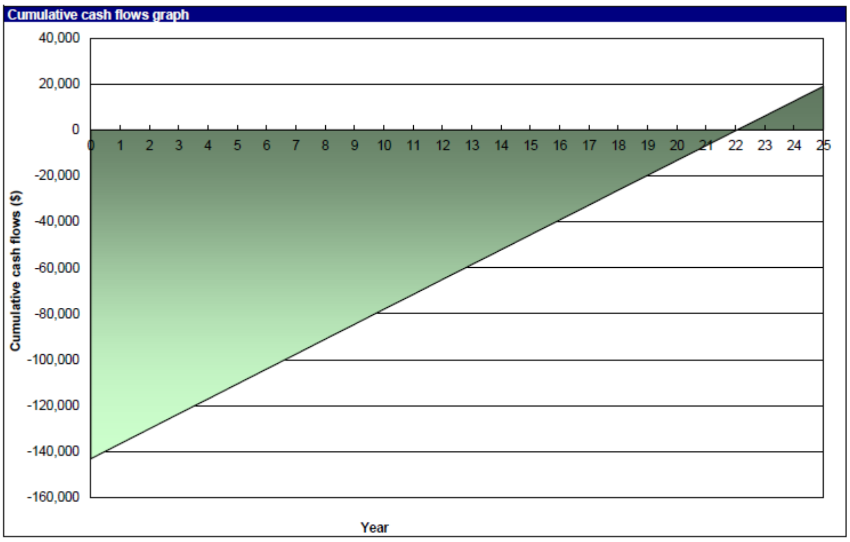
Financial viability

Pre-tax IRR - equity	%	1.0%
Pre-tax IRR - assets	%	1.0%
After-tax IRR - equity	%	1.0%
After-tax IRR - assets	%	1.0%
Simple payback	yr	22.0
Equity payback	yr	22.1
Net Present Value (NPV)	$	18,966
Annual life cycle savings	$/yr	759
Benefit-Cost (B-C) ratio		1.13
GHG reduction cost	$/tCO2	(106)

Yearly cash flows

Year	Pre-tax	After-tax	Cumulative
#	$	$	$
0	-143,099	-143,099	-143,099
1	6,511	6,511	-136,588
2	6,509	6,509	-130,078
3	6,507	6,507	-123,571
4	6,505	6,505	-117,067
5	6,502	6,502	-110,564
6	6,500	6,500	-104,064
7	6,498	6,498	-97,566
8	6,495	6,495	-91,071
9	6,493	6,493	-84,578
10	6,491	6,491	-78,087
11	6,488	6,488	-71,599
12	6,486	6,486	-65,114
13	6,483	6,483	-58,630
14	6,481	6,481	-52,150
15	6,478	6,478	-45,671
16	6,476	6,476	-39,196
17	6,473	6,473	-32,723
18	6,470	6,470	-26,252
19	6,468	6,468	-19,784
20	6,465	6,465	-13,319
21	6,462	6,462	-6,857
22	6,460	6,460	-397
23	6,457	6,457	6,060
24	6,454	6,454	12,514
25	6,451	6,451	18,966

Cumulative cash flows graph



CHAPTER 7: ENVIRONMENTAL IMPACT ASSESSMENT

Chapter 7:
Environmental Impact Assessment

7.1 EXECUTIVE SUMMARY

7.1.1 Introduction

The owner of the farm intends to develop a 199.24 kWp Solar Photovoltaic Power Plant in Taloza-Palestine. The proposed project is expected to contribute to providing daytime power supply to the farm. In fulfillment of the International Finance Corporation (IFC)/ World Bank Standards, in compliance with statutory requirements and in line with good environmental management practices in Palestine together to sustainable project development, an Environmental and Social Impact Assessment (ESIA) of the proposed utility scale PV based solar power plant project has been carried out.

7.1.2 Study area

The PV system is located in Taloza village within the territory of Taloza-Far'a –Nablus. (Basin 43 pieces 10). It is 1 km away from localities, 11 km away from Nablus. The land of the farm has a total area of 110 acres, 2.5 acres are being used to establish the project. The factory is located with latitude 32.16 and longitude 35.21.

Located on an under-construction street, width 16 m and this street is privet for this project.

7.1.3 Objectives of the Study

The objectives of the ESIA for the proposed project are to;

• obtain all necessary information/data to satisfy regulatory requirements of , state and local authorities on environmental matters, and stakeholders;
• show that a systematic assessment of the impacts of the proposed project have been carried out using standard procedures;
• develop an Environmental and Social Management Plan (ESMP) for all phases of the proposed project's life cycle; and
• provide necessary information and evidence for developing an Environmental Impact Statement (EIS) for the proposed project in its entirety

7.1.4 ESIA Methodology

The methodology adopted basically follows the following steps and flowchart:

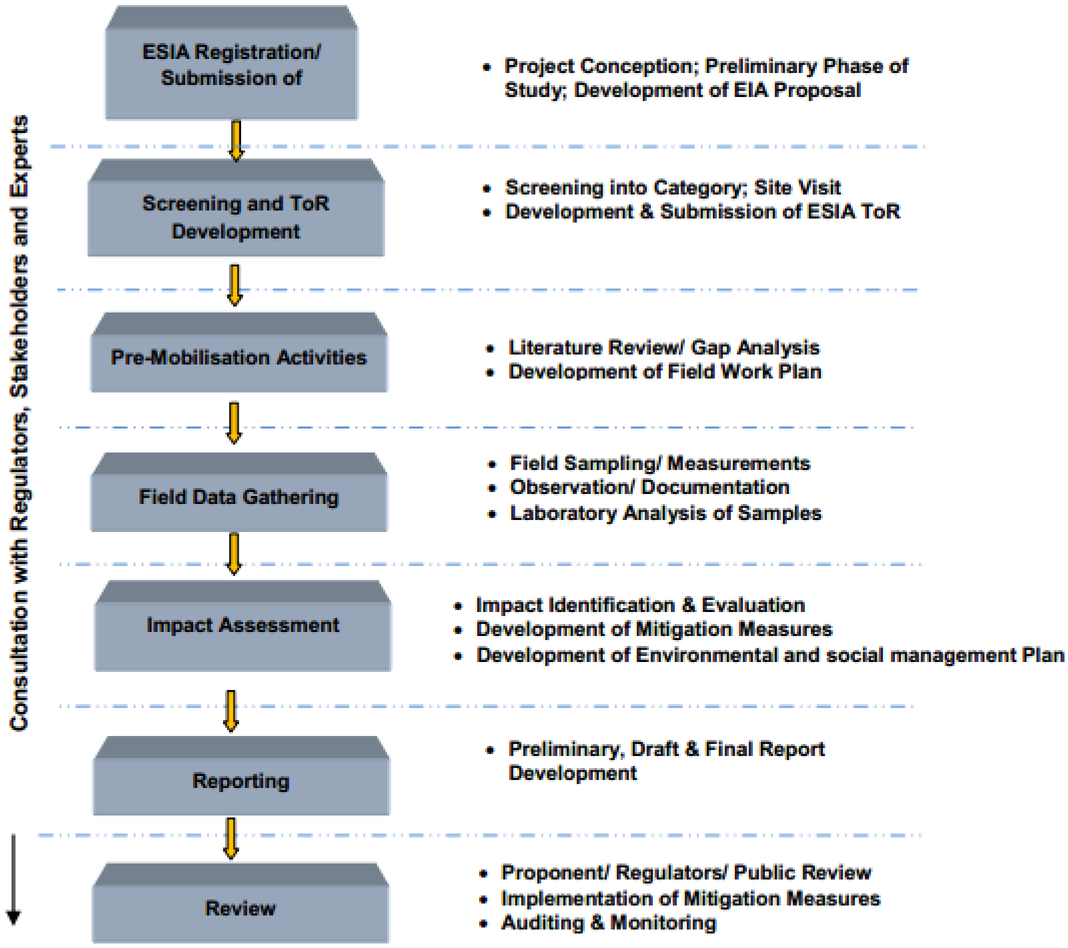


Figure 19: ESIA methodology

7.1.5 Administrative and Legal Framework

The study has been undertaken in line with guidelines/standards of national agencies responsible for environmental management and saddled with enforcing existing statutes and regulations in Palestine on power generation industries as well as with those of international organization concerned with environmental matters. These bodies include the Overseas Private Investment Corporation (OPIC), the International Finance Corporation (IFC) and Palestinian Environment Authority.

International Best Practice Standards and Guidelines used include:

• Equator Principles;
• IFC Performance Standards;
• Environmental, Health and Safety (EHS) Guidelines;
• Convention on International Trade in Endangered Species (CITES); and
• Basel convention on the control of transboundary movement of hazardous wastes and their disposal.

7.1.6 Benefits of the Proposed Project

The most significant accruable benefit is the expected improvement in power supply. Other benefits are to:

• At the national level, construction of the proposal will result in an increase in grid based power generation capacity. At the local level, it directly contributes to development of Taloza area (through the employment opportunities it will directly create and through multiplier effects that will flow from the increased availability of power within the region.

• Reduce the amount of the electricity bill that the farm produce per month due to the utilization of three water pumps.

• Decrease environmental emissions associated with private power generators and other thermal fossil fuel-based power plants, thereby encouraging renewable energy form as better option to sustainable power sector development.

7.1.7 Envisaged Sustainability

7.1.7.1 Economic and Commercial Sustainability

The project is envisaged to be economically and commercially sustainable throughout its designed life span because of:

• Availability of constant sunlight at the site of the proposed Independent Power Plant.

• The close proximity of the proposed power plant to existing electricity grid connection

.• project site is accessible by good road network for delivery of bulky plant parts for initial installation and maintenance.

• The revenue that would accrue from power distribution. [11+15]

7.1.7.2 Technical Sustainability

The proponent of the proposed 199.24 kWp photovoltaic solar power plant plans to carry out the development activities using best available technology. The technology to be applied would be International Standard that has been tested.

Photovoltaic (PV) is a method of converting solar energy into current electricity using semiconducting materials that exhibit the photovoltaic effect. The direct conversion of sunlight to electricity occurs without any moving parts or environmental emissions during operation. It possesses required skills, experience and requisite expertise and financial capability to develop and operate utility-scale PV Based Solar Power Plant Projects. The proposed power plant will be an outdoor installation. [11+15]

7.1.7.3 Environmental Sustainability

Construction of the 199.24 kWp photovoltaic Solar Farm shall be executed in line with the best environmentally acceptable techniques/methods to ensure minimal negative impacts on the environment. The Environment Authority guidelines and standards for EIA as well as and other International standards shall guide the project. The incorporation of the findings and recommendations of this EIA at the various stages of the project activity will ensure environmental sustainability. Furthermore, the fact that the project source is renewable energy makes the project environmentally sustainable. The project will be environmentally sustainable because of the inherent environmental advantages of the mitigation measures that would be designed into the project as documented in this EIA. The monitoring and management programs to be implemented as recommended in the EMP will help ensure environmental sustainability of the project. [11+15]

7.1.8 ANTICIPATED ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

Environmental impacts assessment was carried out considering present environmental setting of the project area, and nature and extent of the proposed activities. Potential environmental impacts associated with the proposed project activities are classified as:

(i) Impacts during pre-construction phase
(ii) Impacts during construction phase
(iii) Impacts during operation and decommissioning phase.

7.1.8.1 Impacts during construction phase :

This includes on site action activities which will be undertaken by the contractor ,This mainly includes preparing the detailed design and layout of the project , transportation of the project,as well as on site preparation and construction activities for the installation of PV arrays and other project's component.

7.1.8.2Impacts during operation phase :

This includes activities to be undertaken by the project operator which mainly include the daily operation of the PV plant and maintenance activities (e.g: PV module cleaning)

7.1.8.3 Impacts during decommissioning phase

It is not clear now what will happen during this phase , given that the PV module lifetime is 25 years , in case of full decommissioning of the PV project, decommissioning could include the disconnection of the various project components (PV arrays, inverters,…etc) for final disposal. In Addition gates and fences will be removed.

To minimize/mitigate the impacts the developer should follow the Environmental Management Plan (EMP) properly.

This will be headed by a Project Director (PD), supported by technical staff including Design and Supervision Consultants (DSC), who will design the infrastructure, manage selection of Contractors, and supervise construction.

Mitigation is the responsibility of the PV installer company. The EPC contractor engaged by the project authority will implement the EMP along with mitigation measures, as part of the contractual obligation, and the DSC will supervise the work.

7.1.9 ENVIRONMENTAL MANAGEMENT AND MONITORING PLAN

Environmental Management Plan has been developed for addressing all adverse impacts pertaining to the implementation of the project. The plan presented in tabular form includes impacts, their sources of occurrence, their mitigation measures, actors responsible for implementation of mitigation measures and their responsibilities.
Environmental Monitoring Plan has incorporated key environmental components and parameters to be monitored their indicators, frequency, timing and locations of monitoring and also the actors responsible for carrying out such monitoring.

7.2 Existing environment descriptions:

7.2.1 Meteorological condition

Meteorological information relevant to the factory site is available from the Palestinian Meteorology. The average rainfall in 2017-2018 was 601.1 (mm) which equals to 74%. The relative humidity is between 60-70%. The maximum temperature is 38 °C in July and the lowest is 4 °C in January. The available data on wind directions and speeds indicate that, the wind blows from East to West. The wind speed is about 12 km/h and rarely exceeds this number so mostly the wind is calm. [16]

7.2.3 Noise

The project area is noiseless, as there is no activity other than agricultural in the area.

7.2.4 Soil quality

It is a plain land with no rocks, the soil used in this land is the Red pink petrosa soil that covers most of the lands in the west bank, It consists of limestone, dolomite, organic matter and phosphate.

7.2.5 Present cropping practice and wild life

The site is classified as an Agriculture land. It’s implemented with different types of crops, such as: cucumber, sweet pepper, corn and cauliflower. There is no wild life in that area so there will be no hazards to animal chain area. The land is only used for planting it is not considered as touristic to historical spot.

7.2.6 Economic baseline data

The average price of lands in that area per acre is between 7000-8000JOD. There is an utility gird connected to the land that is 6.6kw. In that area exists a well, water is pumped from the well by 3 pumps: 120hp, 70hp, and 50hp, that feed the farm and nearby farms with water.

7.3 ANALYSIS OF PROJECT ALTERNATIVES

7.3.1 Site Alternatives

Relocation option to a different site is an option available for the project implementation. At the moment, there are no alternative sites for the proposed development. This means that the proponent has to look for the land if relocation is proposed and land is not available and if available it will be too expensive for the proponent to achieve his dream.

Looking for the land to accommodate the scale and size of the project and completing official transaction on it may take a long period. In addition, it is not a guarantee that such land would be available. It's also worth noting that the said project is already underway in terms of seeking development approvals in various government departments.

The project proponent would spend another long period of time on design and approvals of the plans by the relevant government departments.

This would also lead to a situation like No Action Alternative. In consideration of the above concerns and assessment of the current proposed site, relocation is not a viable option.

7.4 Public Participation

7.4.1 General

Public Consultation is a tool for managing two-way communication between the project sponsor and the public. Its goal is to improve decision-making and build understanding by actively involving individuals, groups and organizations with a stake in the project. This involvement will increase a project's long-term viability and enhance its benefits to locally affected people and other stakeholders.

7.4.2 Objectives

The objective of stakeholder consultation is to ensure that a participatory approach takes place, which in turn documents concerns of all stakeholder groups and makes sure that such concerns are considered, responded to, and incorporated into the decision-making process of the development. Stakeholder consultation needs to be a two-way communication process that imparts information to stakeholders, but also obtains additional and on-the-ground information from them. Stakeholder consultation and engagement must take place at the inception phase of the EIA process and implemented all through the study period.

7.4.3 Taking actions

Our consultant, firstly, met with the head of the municipality of Taloza, and took a general idea about their first opinions. Their opinions vary between acceptance and rejection. We wanted to discuss the project with the inhabitants of Taloza briefly, to give them a clear idea about our projects. Considering this, we organized a meeting and invited all the stockholders from Taloza, Ministry of local government, Ministry of Agriculture, Ministry of Health, Authority of Energy and the water authority. During the meeting, as we took notes of their opinions. Air pollution and water consumption were their main concerns. We perfectly understood their concerns as our project will take place in an agricultural zone,

So, we discussed the projects impacts and our mitigations plans with them. Which showed them that our project won't ruin their corps or mess with their lands and the agricultural life in the area, then we also showed them how this project will rise the economic conditions in Palestine by hiring workers, also how it will increase Palestinians' environmental awareness. By the end of the meeting, we could successfully achieve high acceptance for the project and without the need for any compensations, since the area we have is sufficient for the project

7.5 screening

In this stage we decide whether the PV project requires an EIA or not, and what level of details is required.

As this project could make several effects on the environmental, social and economic life and It was clear that the project needs a full EIA. The main components that will be studied are water, air, and land use these parameters are the most effected by the project and needs mitigating processes. In addition, other parameters are going to be discussed some have positive impacts and others have negative ones. Climate, water quality and recourses, topography, air quality and noise, crops and biodiversity are affected negatively in this project. By contrast, education, employment, economic considerations, and culture are the parameters that are affected positively.

7.5.1 Terms of references

The terms of references serve as a road map for EIA preparation and should ideally encompass the issues and impacts that have been identified during the scoping process.

<u>The TOR includes:</u>

- Description of the location and the design of the proposed project.
- The material that is used during operation and methods of disposal.
- Determination of the environmental impacts that may affect the surrounding
- Environments, and the mitigation measures that should be taken.

The authorities and ministries that gave the approvals and licenses before starting the project:

1- Ministry Of Local Government.

2- Ministry Of Agriculture.

3- Ministry Of Energy .

4- Water Authority of Palestine (PWA).

5- Ministry of Health.

6- The nearby farms owners

7- Ministry of Economics

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7.6 Scoping

After the site assessment, a risk assessment was undertaken to characterize the likely environmental risks associated with the construction, operation and decommissioning of the Solar Plant. The aim of the risk assessment was to ensure that all relevant risks were investigated and mitigated as part of the project submission, relative to the degree of environmental risk they represent.

7.6.1 Environmental issues of the project: -

(Biophysical, Resource and Land Use Components)

7.6.1.1 Noise:

Noise levels are measured in decibels, and maximum decibel levels considered protective of human hearing are identified for various activities and pieces of equipment. As appropriate, hearing protection would be required for workers under Occupational Safety and Health Administration regulations during the installation or removal of the solar array. There are no noise sources on site or from immediately adjacent areas. The combination of area vegetation and topography blocks general noise sources, such as motor vehicles on area roads. The short-term activities and equipment related to the installation of the solar array would not likely result in noticeable noise impacts to off-site areas. PV systems do not generate noise once they are installed. Consequently, the presence of a solar array on the Durango disposal site would not introduce a source of noise to the area.

The following table shows the sound levels of the machines and confirms that the sound level is rather normal and within the allowable limit.

Machine type	Sound power measured from 15m
Generator	79 db
Concrete pump	82-94 db
Air hammer	85 db
Drill	88 db
Bulldozer	82-92 db

Table 388: sound levels

7.6.1.2 Land Use

The Project site location does not conflict with any of the relevant governmental planning context. The project initiator owns the land so there is no conflict in land use for the project purpose. In addition, the project site does not provide any major value to local communities. Therefore, there are no anticipated impacts. However, the proposed solar power plant will be in the agricultural land which might ultimately degrade surrounding agricultural land as well. There will be some major impacts due to land-filling: The proposed project site it needs about 1-m concrete filling.

7.6.1.3Air Quality

The main impacts associated with construction activities will be:

1) Dust generation: resulting from earthworks such as levelling, grading, excavation works and movement of vehicles across dirt/unpaved roads, especially during windy conditions.

2) Exhaust emissions: Exhaust emissions of SO2, NOx, CO, CO2, and PM10, PM2.5 will be attributed predominantly to the operation of the construction plant and road vehicles such as movement of vehicles during construction works. These emissions will be limited to the project area and are anticipated to be generated in small concentrations and dispersed rapidly within the area leading to an impact of low significance. This means that these effects are localized and temporary which implies that any deterioration in air quality at project location is unlikely to be significant and is expected to be transient.

No emissions are expected to be released during the operation phase, due to the fact that solar PV power plants do not release greenhouse gases or any toxic pollutants during their operation, as a result, no impacts on ambient air quality are anticipated during the operation phase.

There will be environmental impacts of emission of greenhouse gas, Ozone depletion, photochemical smog, and acidification and also health effects on people due to battery maintenance. [11+14+15]

It is worth mentioning that solar power plants have very low air emissions of air pollutants such as sulfur dioxide, nitrogen oxides, carbon monoxide, volatile organic compounds, and the greenhouse gas carbon dioxide during operations compared to fossil fuel power generation facilities, since solar power plants do not involve combustion processes.

Similar to construction, the decommissioning phase is anticipated to generate dust and exhaust emissions. Decommissioning activities will involve site preparation, dismantling and disassembling of the components of the solar power plant facility, clearance of the site, and rehabilitation if needed. [10+12+14+15]

7.6.1.4 Biodiversity (Flora and Fauna)

Site preparation activities which will take place on site for the installation of the PV arrays and the various project components are expected to include land clearing activities, levelling and excavation.

Such construction activities could result in the alteration of the site's habitat and thus potentially distribute existing habitats (flora and fauna) and results in the displacement of exclusion of species particularly threatened or endangered which might be presents within the project's site and surrounding areas.

Other impacts on the biodiversity of the site are mainly from improper management of the site which could include improper practices by the workers.

In addition, as shown in the baseline the project site is not located within or near areas of critical environment concerns.

Given all of the above, the potential impacts on biodiversity created during the construction phase would of a long-term duration as they would result in a permanent change in the natural biodiversity of the site. Such impact is considered of negative impacts and of a medium magnitude given that the change in the natural biodiversity of the site will be noticeable. However, as the site is considered of low ecological significance, the receiving environment is determined to be at low sensivity. Given all of the above, such impact is considered to be of minor significance.[10+11+13+14]

7.6.1.5 Soil

Construction activities are expected to result in significant soil loss. The excavation, leveling and other earthworks are the possible source to disturb the soil due to the removal of top soil, which could trigger soil erosion process.

Another most significant source of soil pollution is the damage of battery and PV panels in case of major accidents. These contain chemicals and may be harmful for soil quality.

During the decommissioning phase, the decommissioning activities are anticipated to have an impact of medium significance to soil. This is due to possible accidental leakage of chemicals during demolition activities. [14+15]

7.6.1.6 Water resources

The fact that there is a well in the area to supply the crops makes it essential to prevent any major impacts to the water, which might be affected during construction stage due to disposal of solid wastes, dredged materials, accidental spillage of products, cement, concrete and noxious chemicals.

7.6.1.7 Waste Generation

Improper management of non-hazardous and hazardous waste generated during construction may lead to impacts on soil, water, visual environment, in addition to health and safety of workers.

Non-hazardous waste includes plastic, metals and glass.

Hazardous waste includes absorbent material, concrete, rocks, etc.

Battery: One of the most important components of solar power plant is battery. Improper disposal and recycling of storage batteries result in lead sulfate contamination in lands and water bodies. Through percolation, lead sulfate can contaminate groundwater and transfer up the food chain.

Waste generation during the operation phase is considered part of daily operations, therefore, it is not considered to have any significant impacts to the environment or health of personnel present on site. And will be limited to wastewater from maintenance and cleaning activities in addition to domestic waste (due to workers domestic activities).

PV modules: PV modules wastes are the other waste besides the battery and few other solid wastes generated during the operational stage. These include end-of-life solar PV modules, electrical wastes, metallic wastes and stationary wastes of office works etc. [14+15]

7.6.2 Economic Components

7.6.2.1 Direct employment and income:

Economy can be affected at different stages (during construction and operation process). Construction activities (excavation, building the site, roads… etc.) are one of the sources that affect the economy, where we employ a number of employees in the construction phase of the plant, thus increasing the income of workers and During the operation phase will be employing others, including staff engineers and other workers, thus also we need drivers for trucks, and thus contribute to increasing the income of citizens within the city, and improve the national economy. [15]

7.6.2.2 Transportation requirements:

The project will have a positive impact on the transportation sector and transportation, in terms of the need for trucks in addition to drivers for driving trucks and the need to buy the needed materials which affects the economy.

Despite the impact on the streets to increase the number of vehicles, but not a significant increase mentioned.

7.6.3 Health component

7.6.3.1 Health and safety

The construction activities include site preparation, infrastructure utilities installation, building structures. Therefore, there will be potential impacts on workers' health and safety due to exposure to risks through construction activities that lead to accidents causing injuries and death. Construction works and activities bear frequent accident and health risks for both the laborers and the public general, with varying direct and indirect consequences. Therefore, the project authority needs to make provision for specific medical services, workers insurance policies and indemnities, emergency provisions and a rescue/evacuation plans in case of major accidents. [10+11]

There are many hazards associated with a solar PV power plant if sufficient precautions are not taken during the operation stages. The impact origins are in the following sectors:

1. Entering of lead (Pb) into human body from the battery
2. Acid hazard during battery handling
3. Leaching of materials from broken or fire damaged PV modules
4. Emergency Fire Hazard
5. Electrocution of workers
6. Electromagnetic radiation from PV modules

7.6.3.2 Employment opportunities

Positive benefits of the project may arise either from short-term job opportunities during construction, or long-term job opportunities during operation. It is important that construction and operation jobs to be targeted to the local people.

7.7 Leopold matrix

The given figure is a summary of the environmental impacts of our project. The impact varies between negative to positive.

activities		Pre construction			Construction				Operation and decommissioning				
Environmental Items		Generation of waste	Dust from movement	Leveling	Risk of injury	Installation of the system	excavation,	Fencing	Cleaning	Reduced power generation	Maintenance	Project disposal	Total
Physical	Climate	-3 / 7	-1 / 4				-3 / 6					-2 / 10	-7 / 27
	Transportation	-4 / 7	-4 / 4			4 / 11		1 / 2					-3 / 24
	Water quality	-3 / 7	-3 / 4			-2 / 11	-3 / 6		-3 / 8		-2 / 9	-3 / 10	-19 / 55
	Air quality	-3 / 7	-3 / 4			-2 / 11	-3 / 6		-2 / 8		-3 / 9	-3 / 10	-19 / 5
	Geology/soils	-4 / 7	-2 / 4	-4 / 5		-2 / 11		-2 / 2	-2 / 8		-3 / 9	-3 / 10	6 / 56
	topography			4 / 5									4 / 5
	Noise and dust	-3 / 7	-6 / 4	-1 / 5		-1 / 11	-4 / 6	-2 / 2					-17 / 35
Biological	Crops	-4 / 7	-2 / 4	-2 / 5		-1 / 11	-3 / 6	-3 / 2	-3 / 8		-3 / 9	-5 / 10	-4 / 35
	Wildlife	-3 / 7	-2 / 4				-2 / 6		-2 / 8		-1 / 9		-4 / 44
	Biodiversity	-4 / 7	-2 / 4			-1 / 11	-4 / 6		2 / 8		-2 / 9	-5 / 10	-2 / 55
Socio-economic	Employment			3 / 5	-3 / 3	5 / 11		3 / 2	2 / 8		4 / 9	4 / 10	18 / 48
	Education	-2 / 7				6 / 11			8 / 8		3 / 9	6 / 10	21 / 45
	Economy					7 / 11			7 / 8	-4 / 1	4 / 9	7 / 10	21
	Population		-2 / 4										-2 / 4
	Health	-3 / 7	-4 / 4	-3 / 5	-4 / 3	3 / 11						7 / 10	-4 / 40
	Land Use			-2 5		-4 11		-2 2					-8 / 18

Table 39: Leopold matrix

7.8 Mitigation measures

7.8.1 Noise

The following identifies the mitigation measures to be applied by the Contractor during the construction phase and which include:

1- Apply adequate general noise suppressing measures. This could include the use of well-maintained mufflers and noise suppressants for high noise generating equipment and machinery, developing a regular maintenance schedule of all vehicles, machinery, and equipment for early detection of issues to avoid unnecessary elevated noise level, etc
.

2- If noise levels were found to be excessive, construction activities should be stopped until adequate control measures are implemented.

7.8.2 Land use

The project developer is to take responsibility of minimizing environmental impact on the surroundings by following the project's environmental management plan (EMP). For example, the developer should advise contractor to must fenced the proposed area so that the surrounding agricultural land will not be disturbed. Since these activities are to be performed temporarily the minimum impact is expected to be acceptable

7.8.3 Air quality

The following identifies the mitigation measures to be applied by the Contractor during the construction phase (to prevent impacts caused by their construction activities and which are within their control) and which include:

▪Comply with the Occupational Safety and Health Administration (OSHA) requirements and the Bangladesh Codes to ensure that for activities associated with high dust levels, workers are equipped with proper Personal Protective Equipment (e.g. masks, eye goggles, breathing equipment, etc.);

▪Apply basic dust control and suppression measures which could include:
▪Regular watering of all active construction areas.
▪Proper planning of dust causing activities to take place simultaneously in order to reduce the dust incidents over the construction period.
▪Proper management of stockpiles and excavated material (e.g. watering, containment, covering, bunding).
▪Proper covering of vehicles transporting aggregates and fine materials
▪Develop a regular inspection and scheduled maintenance program for vehicles, machinery, and equipment to be used throughout the construction phase for early detection of issue to avoid unnecessary pollutant emissions.

▪If dust or pollutant emissions were found to be excessive, construction activities should be stopped until the source of such emissions have been identified and adequate control measures are implemented.

During the operation phase, service and maintenance is very important as to have a battery system to run efficiently and with least possible replacement of batteries and related environmental impacts. Only purchase batteries from a source that can ensure that used batteries can be returned for environmental friendly recycling.

Photovoltaic (PV) is now a proven technology which is inherently safe as opposed to somedangerous electricity generating technologies. Photovoltaic systems make no air pollution and cause no pollution in operation. PV panel should be clean and maintenance regularly for dust free. The supplier will collect wastage PV panels for maintenance and destroy and they will be responsible for management of PV panels and battery [12+13+14]

7.8.4 Biodiversity (Flora and Fauna)

The following identifies the mitigation measures to be applied by the contractor during the construction phase which include:

- Before construction commences, undertake a flora survey to identify the presence of any key faunal species of importance . of any key species exist within the project site then it should be relocated outside of the construction active areas.
- Ensure that the fencing constructed for the project site allows the natural movement of faunal species within the areas.
- Implement improper management measures to prevent damage to the biodiversity of the site. This could include a proper code of conduct , awareness raising and training of personnel such as :
  - Prohibit hunting at any time and under any condition by workers on site.
  - Ensure proper storage, collection and disposal of waste generated.
  - Restrict activities to allocated construction areas only, including movement of workers and vehicles to roads within the site and prohibit off-roading to minimize disturbance

Following the implantation of these mitigation measures, the significance of these impacts is categorized as not significant [15]

7.8.5 Soil

Assuming that spill response plans shall be in place by the contractor, it is anticipated that impacts to soil resulting from these activities will be likely, with a marginal consequence, yielding medium impact significance.

The filling material should be collected from the approved source dredging location with proper care so that no spillage will be happen. Retention wall or water proof boundary with plastic material should be constructed before the dredged material placement to prevent the spillage from site to adjacent agricultural land.

Through implanting spill response procedures, and proper storage and handling of any chemicals on site, the impact probability will be reduced. The project proponent should check these devices regularly and have to replace the damaged and expired or bad devices. However, if possible, the damaged and expired devices should be maintained properly and recycled. [13+15]

7.8.6 Water resources

In order to minimize the adverse impact on water quality, the following mitigation measures are proposed:

▪ The contractor will dispose of the debris material to a designated disposal site.

▪ All reasonable measures will be taken to prevent the wastewater produced in construction from entering into creek and stream.

▪ Contractor's camp will be provided with sanitary latrines that do not pollute surface waters.

▪ The ground water in the project area has been used for different purposes like drinking and irrigation, hence proper mitigation measures must be ensured at construction site to avoid any spillage and leakage of oil. All the staffs at construction areas must be refrained of discharge any liquid wastes on the ground.[14]

7.8.7 Water generation

All waste generated at construction site will be managed as per Contractor's Waste Management procedures. Domestic wastewater generated at site will be collected in septic tanks. These shall be transported to the nearest approved municipal wastewater handling facility, and solid wastes shall be disposed of in a secured area for trash

7.9 Environmental Monitoring Plan

7.9.1 General

An Environmental Monitoring Plan will be prepared to provide during the construction and operation phases of the solar power plant. The environmental components that will be monitored are those that will be positively or negatively affected, or expected to be affected, by construction activity. Environmental management is a sustainable way of planning, arranging, supervising, organizing, and developing the environment for the maintenance of the preservation of natural resources and the prevention or reduction of damage to the environment. The major environmental impact, monitoring method, responsible organization, and expense for each environmental item in the construction and operation phases for the proposed development are listed in the below table.

7.9.2 Objectives

The objective of environmental monitoring during the construction and operation phases is to compare the monitored data against the baseline condition collected during the study period to assess the effectiveness of the mitigation measures and the protection of the ambient environment based on national standards. The main objectives of the pre-construction, construction and operation phase monitoring plans will be to:

- Monitor the actual impact of the works on physical, biological and socioeconomic receptors within the project area for indicating the adequacy of the EIA;
- Recommend mitigation measures for any unexpected impact or where the impact level exceeds that anticipated in the EIA;
- Ensure compliance with legal and community obligations including safety on construction sites;
- Ensure the safe disposal of excess construction materials

- Evaluate the effectiveness of the mitigation measures proposed in the EMP and recommend improvements, if and when necessary

Activity	Source	Impact	Mitigation measure	Monitoring action	Monitoring responsibility
Installation of the system+ excavation	installing excavation	Dust, Noise, water quality, air quality	Water spray, Ear protection,	Daily water spray, regular check, Time Scheduling	Monitor Engineer
Waste	Installing and maintenance	Dust, Waste	1-Check storage, disposal and handling of hazards waste. 2-Waste to be collected and disposed safely	Weekly check up on the correct disposal methods	Monitor Engineer
Health and safety	All phases	Risk of injury	1-Check safe water supply, hygienic toilet at camp. 2-First aid box with required tools and medicines. 3-Heavy materials at the location to be handled safely. 4-Check of personal protective equipment for workers at site.	1-regular check up on workers health and safety 2-provide medical insurance to workers on site.	Monitor Engineer
Biodiversity	Construction and decommissi oning	Dust and leakage of chemicals	1-Regually check on leakage 2-Use correct methods of waste disposal 3-use correct methods of decommissioning the system.	Regularly check up on leakages and waste treatment	Monitor engineer
Water Source and quality	Construction and decommissi oning	Leakage of waste into water	1-carefully install the system 2-use the right waste disposal method 3-use correct method in decommissioning the system	Check up while construction and while decommissionin g	Monitor engineer

Table 390:Monitoring plan

7.10 Conclusion

According to the above analysis, we can conclude that, if the recommended mitigation measures and environmental management processes are adopted properly, the project will be environmentally sound and sustainable.
Primarily the national economy will be benefitted by the project. Benefits in the project area will be in significant except for some short terms employment and business opportunities during the construction phase. However, the needs of the solar photovoltaic power plan are obvious and for that the livelihood of the area will be developed. Developed livelihood will directly influence the growth of economy of the area.

During the construction stage, there will be some negative impacts of the project. There are no significant cumulative adverse impacts during operation that are identifiable at this stage. The construction impacts should be very predictable and manageable, and with appropriate mitigation few residual impacts are likely.

The project is expected to have a small "environmental footprint". No endangered or protected species of flora or fauna are reported at the project site. The proposed project activities have no significant adverse environmental impact so far as a time bound execution program with application of advanced construction technology is ensured. The mitigation measures are well within such codes and practices of construction and operation of the proposed project.

Results:

We had designed 3 solutions for the farm, in the results section we will be talking about the total cost of each solution and the cost unit of KW and the cost of energy produced.

1-True south (199.24KWp):

Total initial cost of land = 183110$

Total intial cost of well = 103916$

As these two installations are suggested to be combined then,

Total initial cost of true south = 287026 $

With a SPBP of 4.9 years

Cost of KWp unit = $\frac{287026}{199.24} = 1440.6$ $

Cost of energy = $\frac{Initial\ cost}{Energy\ prodcued\ \ for\ the\ lifetime\ of\ the\ project\ (KWH)} = \frac{287026}{7178092} = 0.04\$\ (0.14 NIS)$

2-Horizontal (266.9KWp):

As land and well installations are suggested to be combined then,

Total initial cost of horizontal = 477958 $

With a SPBP of 5.8 years

Cost of KWp unit = $\frac{477958}{266.9} = 1770.2$ $

Cost of energy = $\frac{Initial\ cost}{Energy\ prodcued\ \ for\ the\ lifetime\ of\ the\ project\ (KWH)} = \frac{477958}{1863292.5} = 0.25\$\ (0.9 NIS)$

3- Off-grid (69.36KWp):

As well installations are suggested to be combined with energy storage then,

Total initial cost of true south = 143100 $

With a SPBP of 22 years

Cost of KWp unit = $\frac{143100}{69.36} = 2063$ $

Cost of energy = $\frac{Initial\ and\ running\ cost}{Energy\ prodcued\ \ for\ the\ lifetime\ of\ the\ project\ (KWH)} = \frac{192600}{880843} = 0.21\$\ (0.76 NIS)$

Conclusion:

In our graduation project 1, we designed true south and horizontal oriented system to find a good solution to the problem that the owner of the farm faces, these two solutions were to solve the problem of the high electricity bill that they pay yearly which makes the benefits back from the farm to be less than it supposed to be. In graduation project 2, we edited some parts of true south design and the total initial cost got reduced due to over designing in Inverters.

And also, in graduation project2, we designed an off - grid system as a roof topping of the well to be the solution that the owner of the farm is looking for, which is reliability, as the reliability of the electricity provided from Tubas electricity distribution company is bad and it effects the crops when there's no water pumped, this solution will fit as the off - grid system will be providing the pump with the energy needed during nights and in blackouts.

Moreover, in graduation project 2 we did Environmental impact assessment to check the impacts that the system will do on the near environment during and after the installations. This study was required to be done.

As can be noticed in the results section, the most economical benefits come with the true south design as the unit cost of KWp is 1440 $ which is in the range of the Palestinian PV installation market, and the cost of kwh generated is 0.14NIS with simple pay back period of 4.9years. This solution will be connected in net-metering tariff with bi-directional meter which means the reliability will stay the same.

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APPENDIX