Solar Pumping

Introduction to the Technology and practical considerations for its deployment

Expert Workshop on Solar Pumping: An emerging market and Major Driver for sustainable Energy and Jobs

By:

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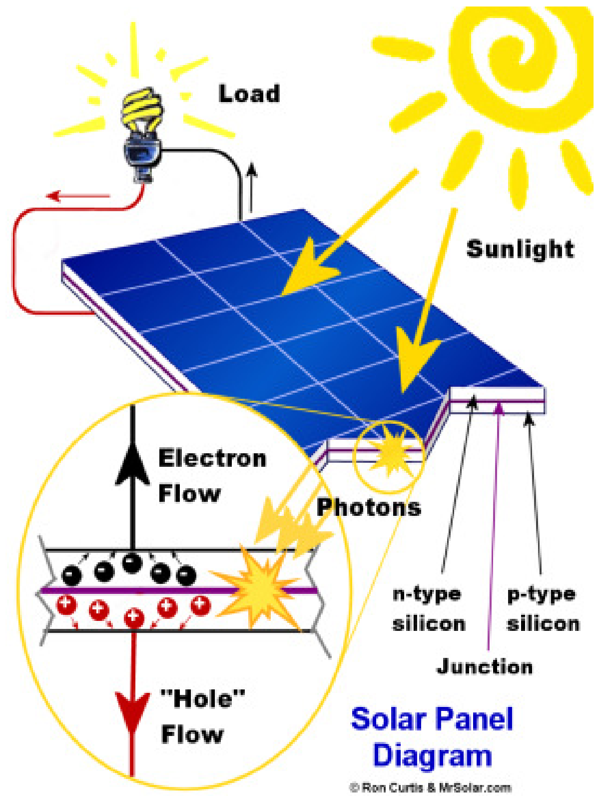
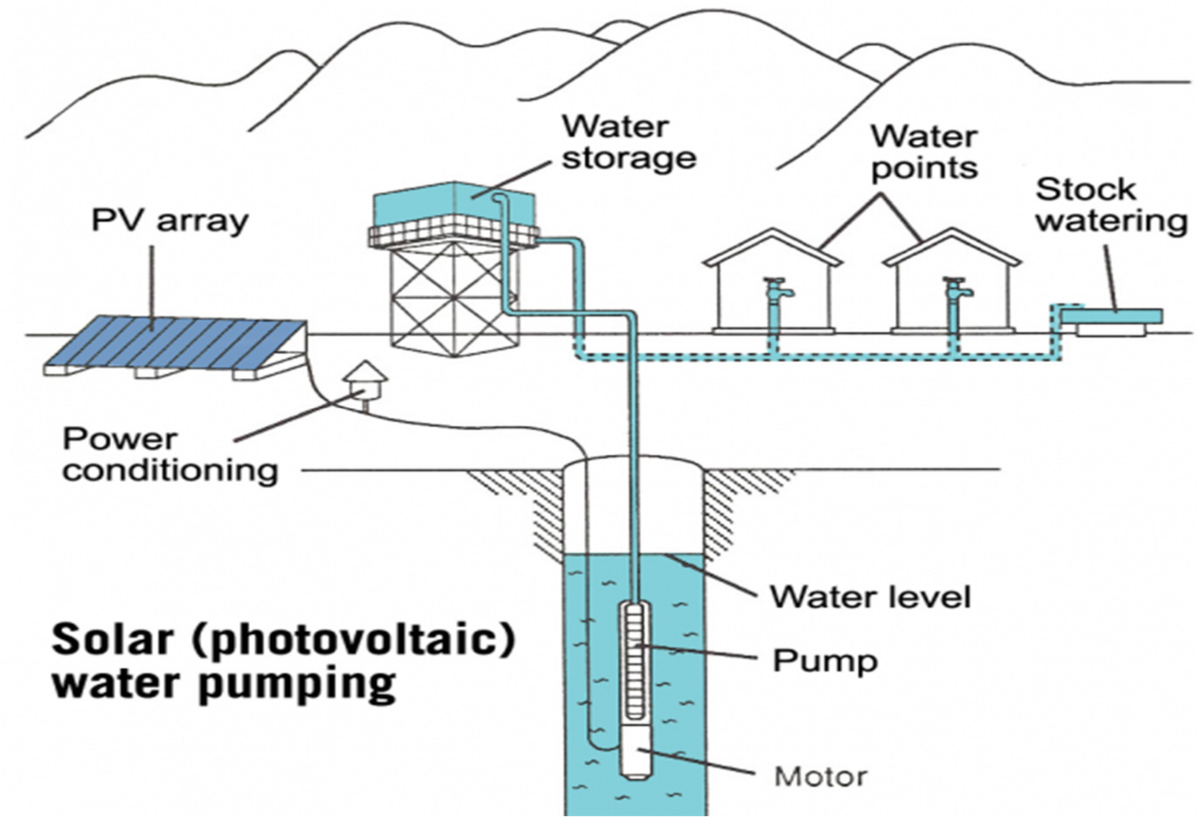
How Does it Work?

PV modules converts sunshine into electricity in the form of Direct Current (DC).

As long as we have a DC , we can convert it to whatsoever form of electricity we can imagine, boosting the voltage, converting it into Alternating current (AC), changing the frequency .. etc



System Configuration



Main System Components:

1) PV Array

2) Power Conditioner (Inverter or DC Controller)

3) Electric driven Pump

4) Storage Tank (Optional)
shall be discussed in Good Practices

5) Mounting Structure
(Fixed, Single Axis Tracker and Dual Axis Tracker)

6) BOS (DC, AC cables, MC4, Conduits, Fuses, Circuit breakers, Combiner boxes .. Etc)

Types of Pumps

Deep well Submersible pumps

Surface centrifugal pumps

Small Fountain pumps

Any electrically driven pump

We run an electric motor after all

Types of Pumps

DC Motor Pump Vs AC Motor Pump

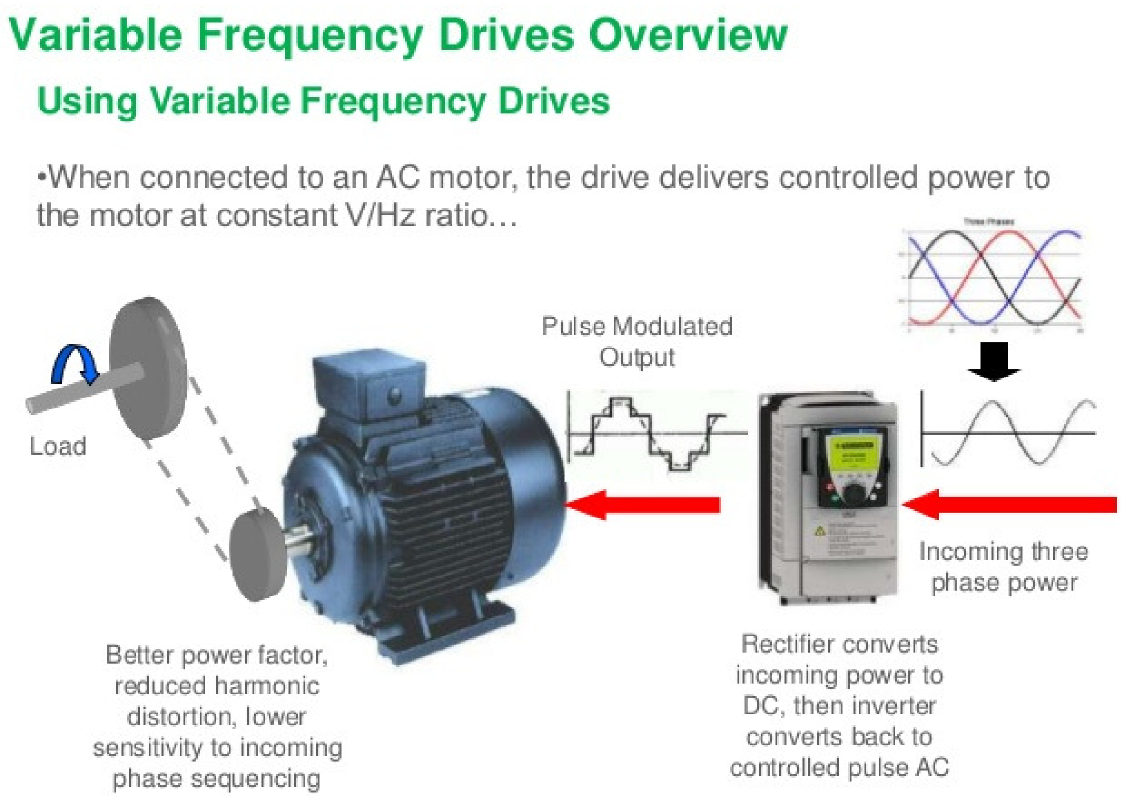
Advantages:
- Higher efficiency due to less conversion.
- DC motors are usually higher in efficiency

Disadvantages:
- Limited capacity due to market availability (usually from very little watts up to 7.5 HP)
- Higher initial price for DC motor itself (could be compensated by the higher efficiency)
- DC motors are usually harder to maintain and cost more for repair and maintenance

Advantages:
- Broader range of products from ½ HP up to 750 HP
- More common for farmers and irrigation applications, and its maintenance and repair is a common practice for them.
- Cheaper motor price.

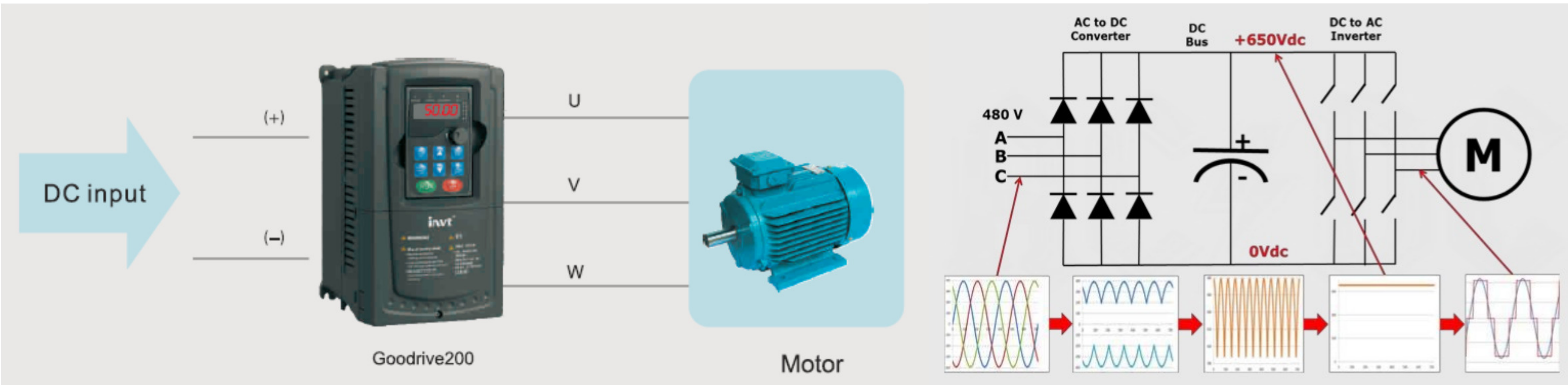
Disadvantages:
- More losses due to energy conversion from DC to AC.
- AC motor are usually less efficient than their DC motor counterpart.

VFD Technology



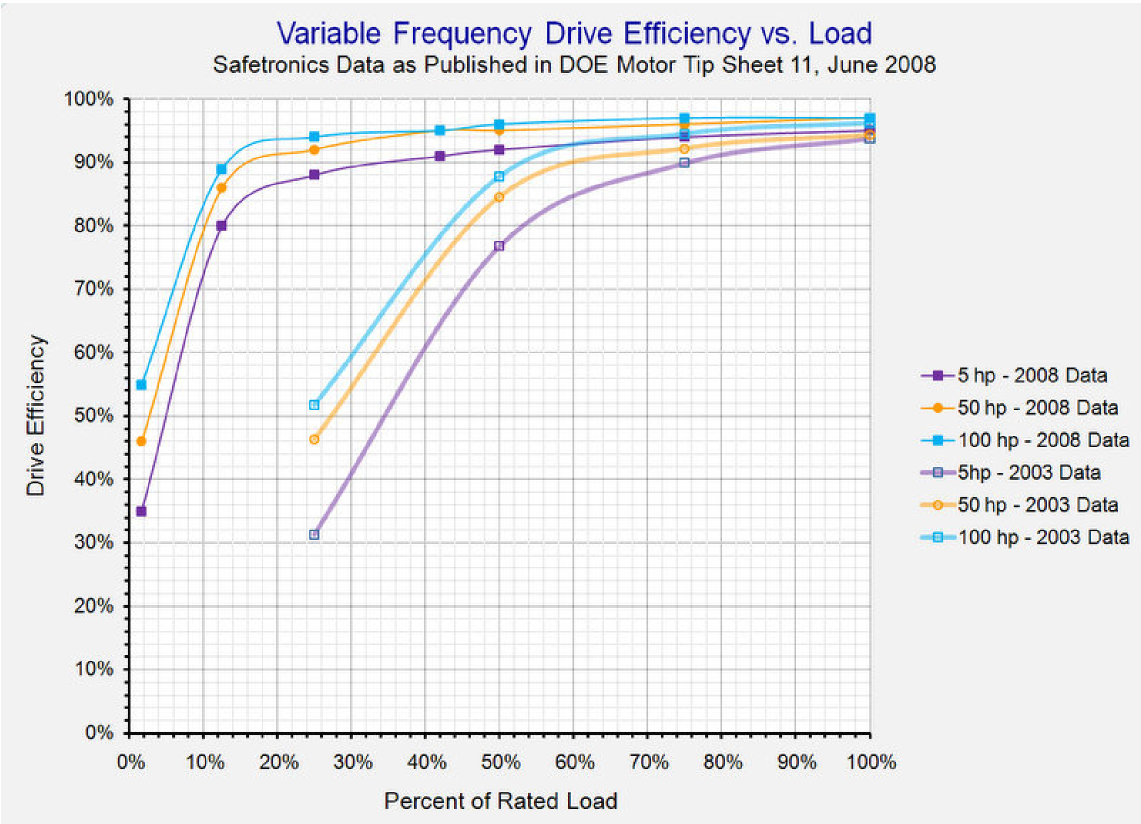
Driving an AC motor by DC power coming from the PV array is achieved by applying the VFD technology.
The main difference between normal VFD and Solar Pump Inverters is that, the solar pump inverter has a unique algorithm or method to control the output frequency based on the input power.
Also most of the solar pump inverters have another algorithm dedicated to track the PV maximum power point (MPPT) as it varies all through the day and from season to season depending on temperature and sunshine irradiance.

VFD Technology



VFD's could be supplied directly with DC to convert the DC power into controlled pulse AC power with the required Frequency (Hz)

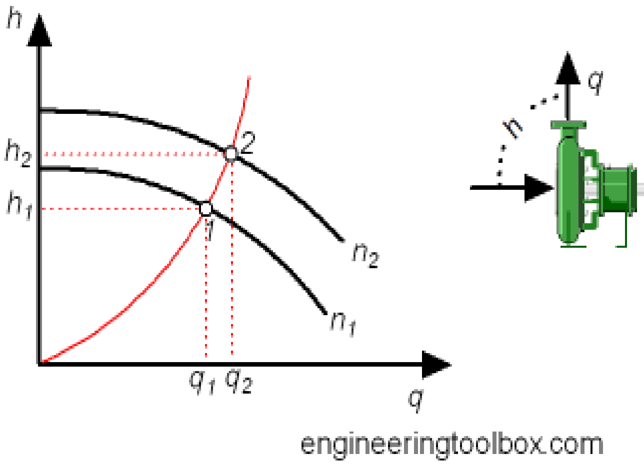
VFD Technology

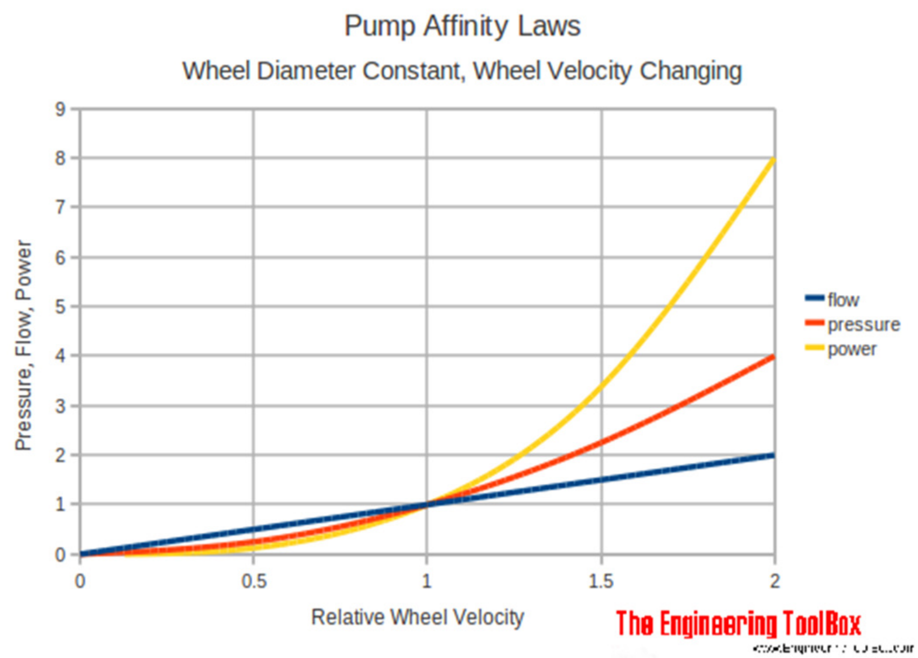


VFD is a mature enough technology, it has many applications in HVAC, Industrial Automation, Cranes, Elevators, escalators ..etc. and it has a benefit of energy saving when applied to applications with variable load / torque like fans and pumps.

Conversion efficiency has improved a lot during the past decade, now it reaches up to 98% for AC Powered VFD, i.e: near 99% for DC Powered VFD.

Variable speed Pump performance





A. $\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$

B. $\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2$

C. $\frac{BHP_1}{BHP_2} = \left(\frac{N_1}{N_2}\right)^3$

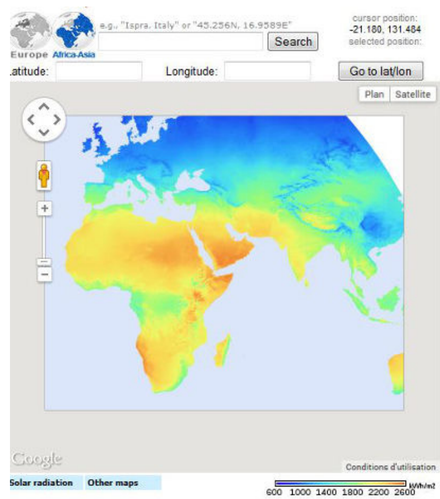
Q = Flow rate
H = Head (pressure)
BHP = Brake Horse Power

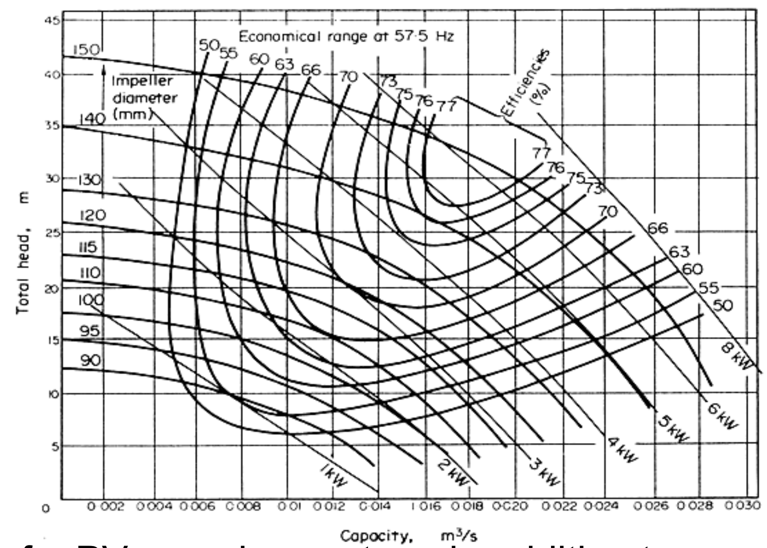
At **80%** of the motor rated speed, we get **80%** of the rated flow while using only **51.2%** of the nominal power.

http://www.engineeringtoolbox.com/affinity-laws-d_408.html

Performance calculations

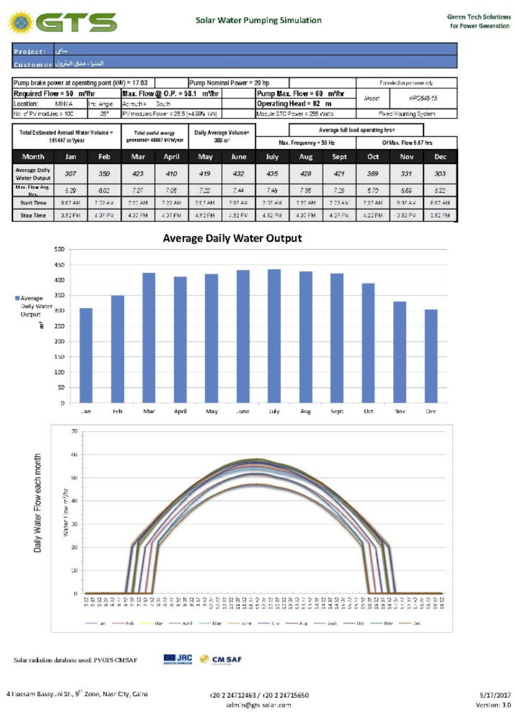
Daily pumped volume of water could be predicted based on solar irradiance databases for specific locations to estimate the hourly generated power from a PV system and the hydraulic pump curves and published performance data.





Many companies have developed their own tool to estimate the output of a PV pumping system, in addition to many international software developers like PVSYST and other inverter manufacturers.

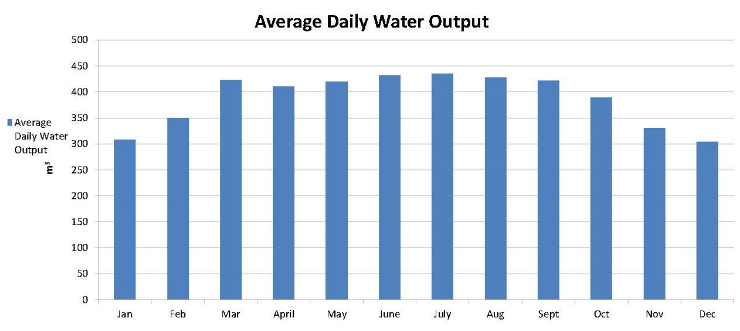
Output Sample



Pump brake power at operating point (kW) = 17.83		Pump Nominal Power = 29 hp		For selection purposes only:	
Required Flow = 50 m³/hr	Max. Flow @ O.P. = 58.1 m³/hr		Pump Max. Flow = 60 m³/hr	Model:	KPS646-15
Location: MINYA	Inc. Angle	Azimuth = South	Operating Head = 92 m		
No. of PV modules = 100	25°	PV modules Power = 26.5 (+4.99% kW)	Module STC Power = 265 Watts	Fixed Mounting System	

Total Estimated Annual Water Volume = 141447 m³/year	Total useful energy generated= 48887 kWh/year	Daily Average Volume= 388 m³	Average full load operating hrs=	
			Max. Frequency = 50 Hz	Of Max. Flow 6.67 hrs

Month	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Average Daily Water Output	307	350	423	410	419	432	435	428	421	389	331	303
Max. Flow Avg. Hrs.	5.29	6.02	7.27	7.06	7.22	7.44	7.48	7.36	7.25	6.70	5.69	5.22
Start Time	8:07 AM	7:52 AM	7:22 AM	7:22 AM	7:07 AM	7:07 AM	7:07 AM	7:22 AM	7:22 AM	7:37 AM	8:07 AM	8:07 AM
Stop Time	3:52 PM	4:07 PM	4:37 PM	4:37 PM	4:52 PM	4:52 PM	4:52 PM	4:37 PM	4:37 PM	4:22 PM	3:52 PM	3:52 PM



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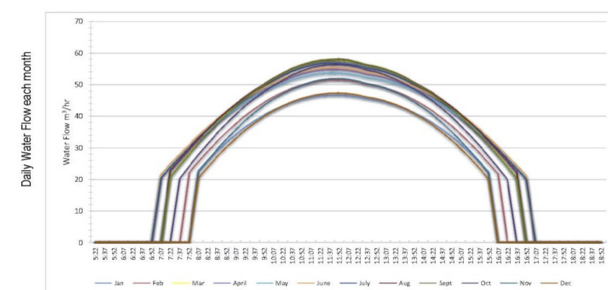
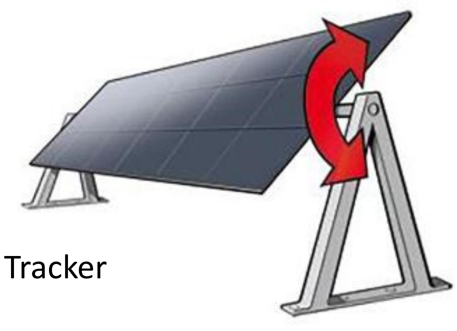


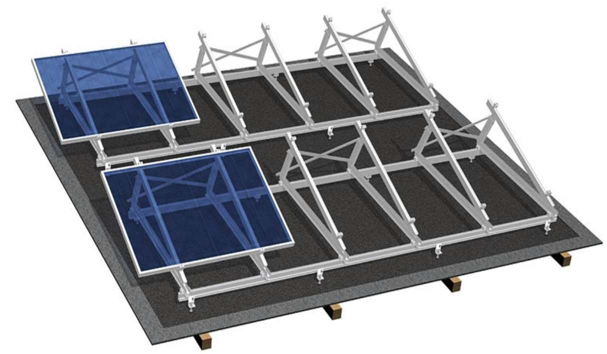
We need to show how would a specific pump perform under some certain conditions when powered by certain amount of PV modules

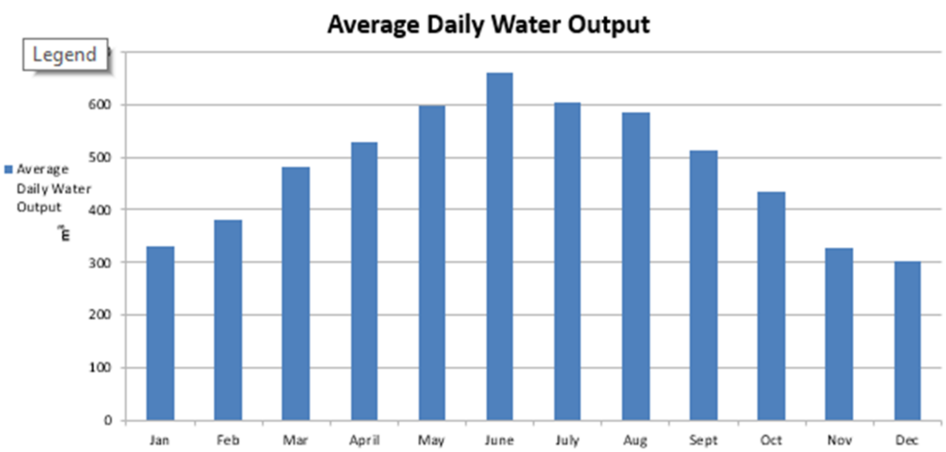
Mounting Structure

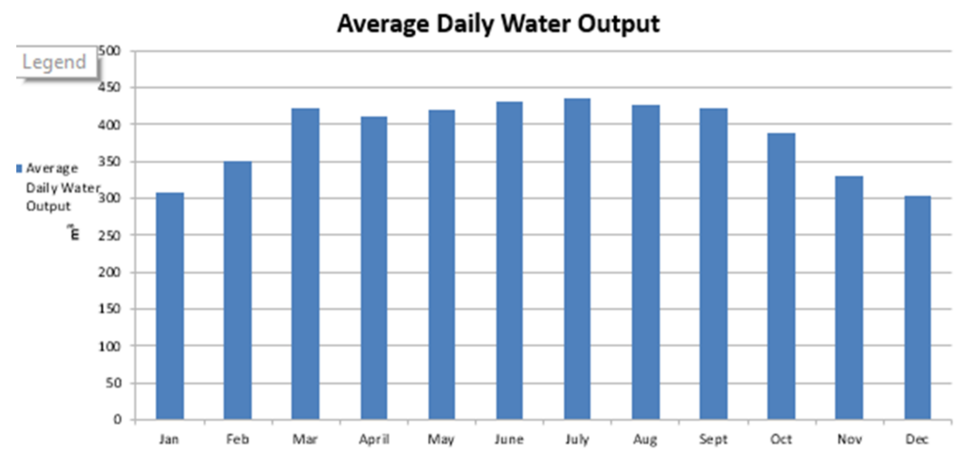


Horizontal Single Axis Tracker
(HSAT)

Fixed



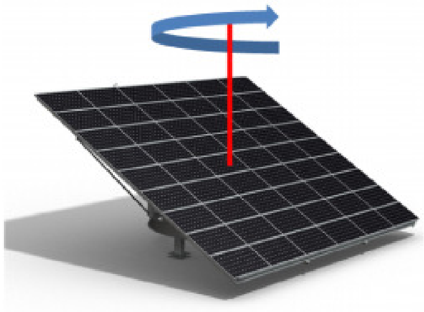


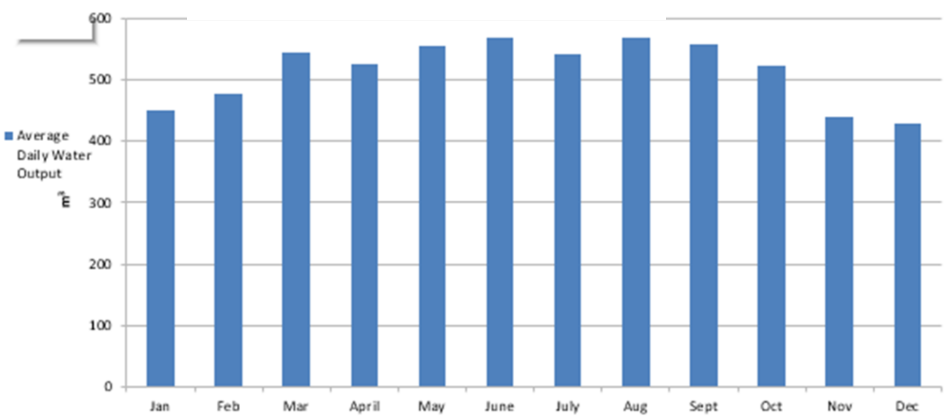


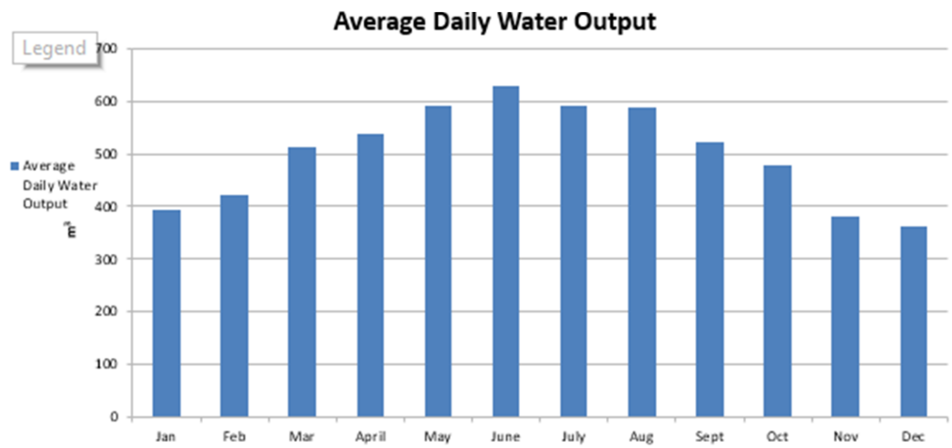
Mounting Structure

Inclined Single Axis Tracker

Vertical Axis Rotating Structure





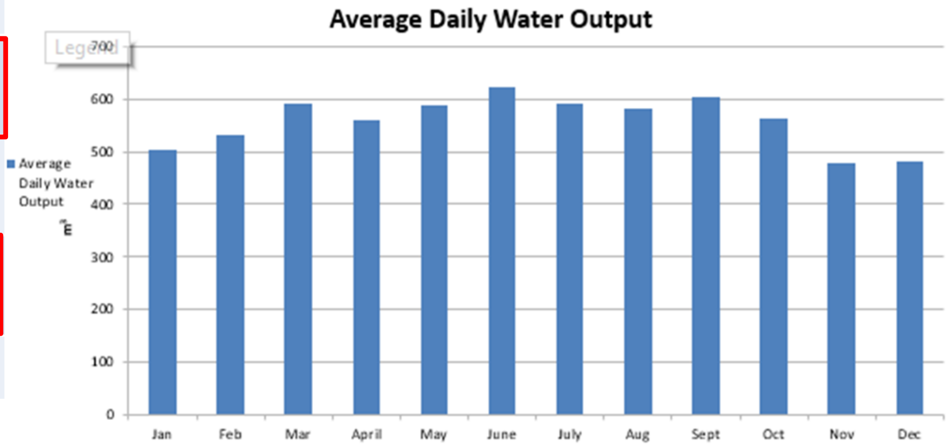


Mounting Structure

Comparison between different structures

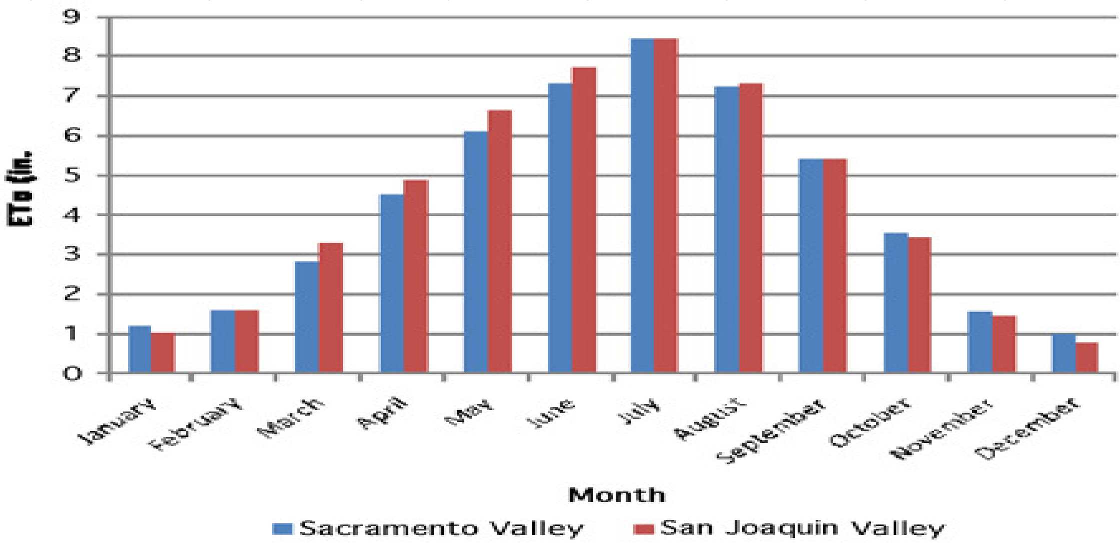
Structure Type	Annual Average	Peak (In June)	Cost	Remarks
	Water Volume m³/day			
Fixed	388	435	Low	
Horizontal Single Axis Tracker	480	630	Moderate	
Inclined Single Axis Tracker	515	565	High	
Vertical Axis Rotating Structure	501	625	Moderate - High	Suitable for manual tracking
Dual Axis Tracker	558	635	Highest	

Dual Axis Tracker



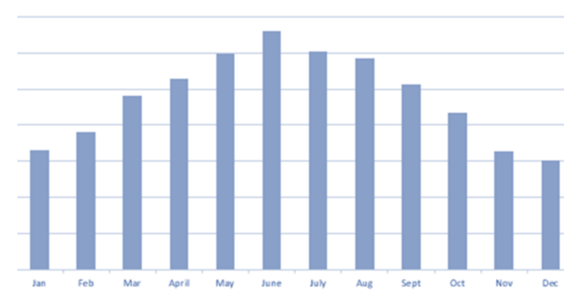
Daily Water Needs for irrigation (Olives Tree as an Example)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sacramento Valley	inches/ month	0.92	1.22	2.14	3.41	4.60	5.51	6.36	5.47	4.07	2.69	1.19	0.75
	gal/acre/day	801	1178	1872	3089	4027	4983	5571	4789	3686	2352	1079	657
San Joaquin Valley	inches/ month	0.78	1.22	2.49	3.68	5.00	5.81	6.35	5.51	4.09	2.60	1.12	0.60
	gal/acre/day	683	1186	2181	3333	4375	5261	5564	4822	3700	2280	1011	526



Source: University of California.
http://ucmanagedrought.ucdavis.edu/Agriculture/Crop_Irrigation_Strategies/Olives/

Average daily water output for HSAT



Storage Tank (Optional)

Advantages:

1- Enable farmers to irrigate any time, day or night.

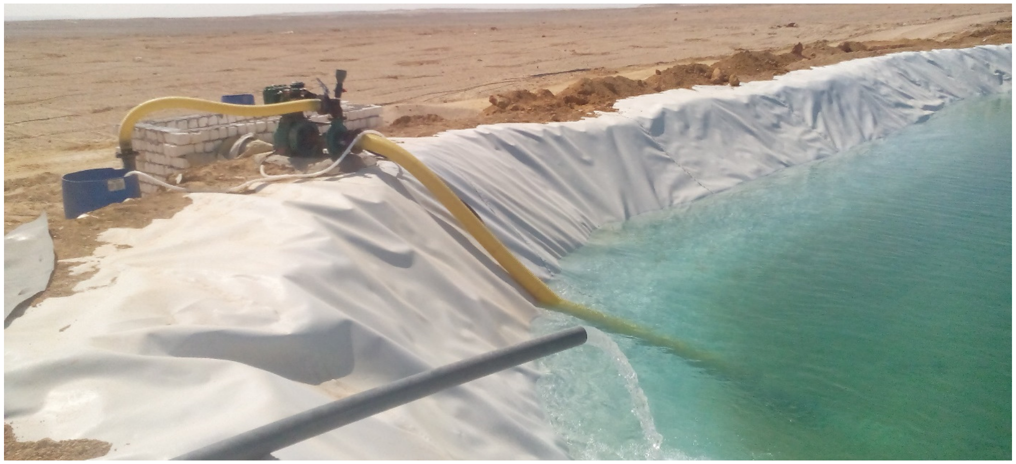
2- Can store reserve amount of water for irrigation during cloudy days or in case of emergency.

3- More water output due to lower head pressure on the solar pump.

4- Longer pump lifetime due to lower operating pressure and less friction and wear of the pump moving parts

5- Makes it possible to control the flow and pressure by using a smaller pump to pressurize the dripping network

6- Can be used to grow fish which creates an additional source of income for the farm and the waste of the fishes would create natural fertilizer for the plants

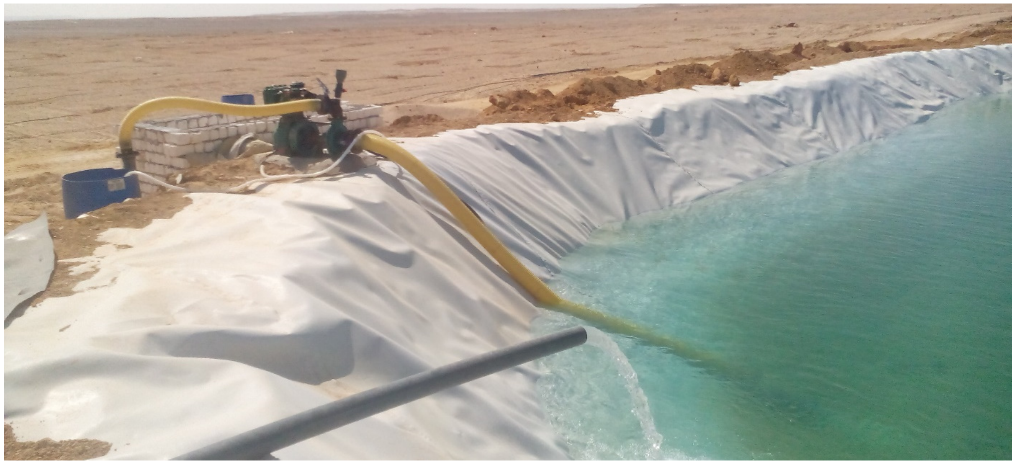


Storage Tank (Optional)

Disadvantages:

1- Extra initial cost

2- Needs another source of energy, usually a smaller surface pump running by diesel genset to run it at night



Advantages of Solar Pumping

Energy Independence

Can be applied Wherever the Sun shines

Energy Security

No Price hikes, no inflation, no supply shortage

Environmental Friendly

No pollution, no CO_2 emissions, low carbon footprint

More profitable for serious investors

Reasonable payback period and the more your system gets older, the lower the cost of the energy you get.

Easier to operate and maintain

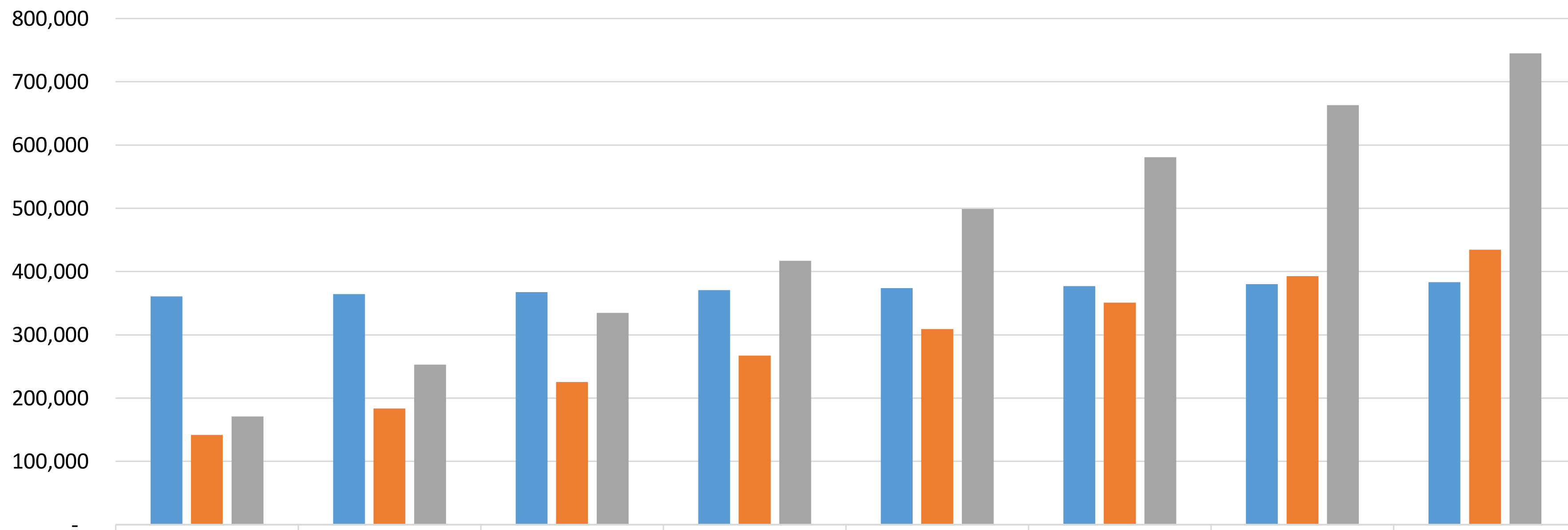
Automatic and manual running mode, could be monitored and controlled over the internet or GPRS, very low maintenance work needed

Comparison of the economics of 25 kW Solar System vs Diesel Genset and Utility electricity for 25 HP Solar Pump

Energy Source	Solar Pumping	Utility Electricity Medium Voltage Subscriber	Diesel Genset	Unit
Initial Cost (LE)	357,750	100,000	89,000.00	LE
Running Cost Calculations				
Diesel Oil (Today's Price)		2.35		LE/Litre
Diesel Oil (No Subsidy - Estimated)		6		LE/Litre
Electricity (Today's Price)		0.52 + 45 LE/kW Peak Power		LE/kWh
Electricity (No Subsidy - Estimated)		1.85		LE/kWh
Average running Hrs / day		8.61		Hours
Power Consumption				
Diesel Oil		8.10		Liters/Hr
Electricity		17.83		kW
Daily Running Cost from Energy Consumption perspective				
With Subsidies		106.58	163.99	LE/Day
W/O Subsidies		284.01	418.69	LE/Day
Annual Running Cost				
With Subsidies		38,820.4	59,732.4	LE/year
W/O Subsidies		103,451.5	152,508.4	LE/year
Expected Annual Maintenance and Repair Cost				
O&M Cost	3,219.8	3,000.0	22,250.0	LE/year

1st Scenario – Prices will not change

Accumulated expenses in Best Case Scenario

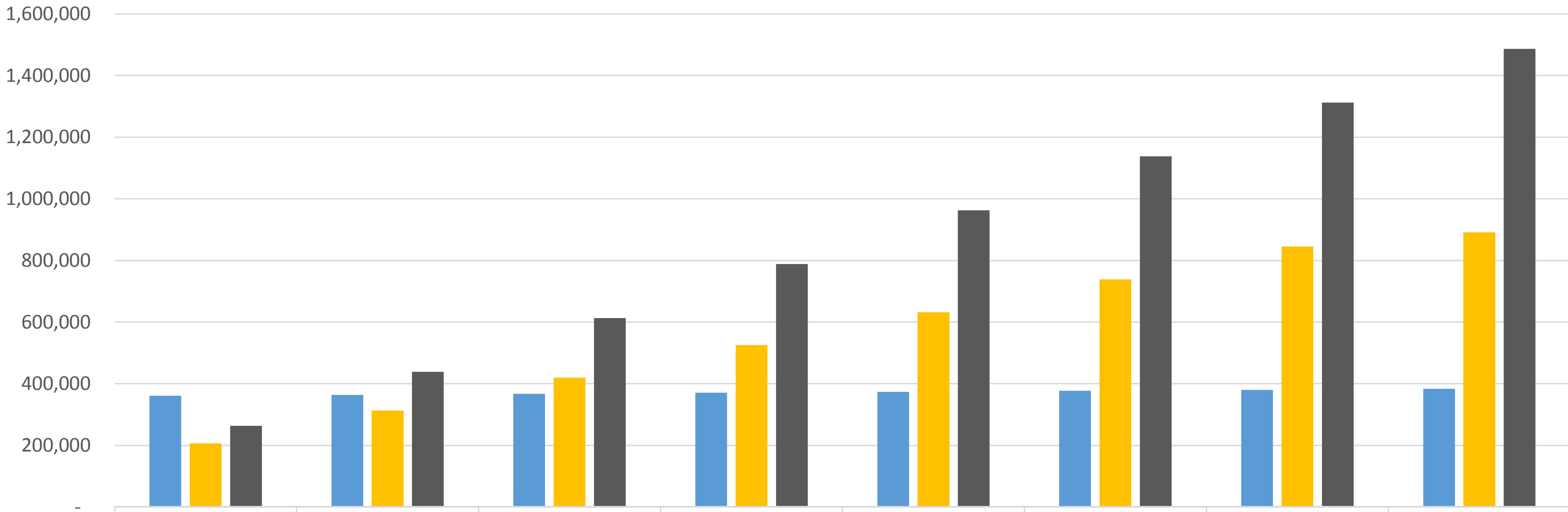


	1st Year Expenses	2nd Year Expenses	3rd Year Expenses	4th Year Expenses	5th Year Expenses	6th Year Expenses	7th Year Expenses	8th Year Expenses
Solar Power	360,970	364,190	367,409	370,629	373,849	377,069	380,288	383,508
Utility Electricity	141,820	183,641	225,461	267,282	309,102	350,922	392,743	434,563
Diesel Genset	170,982	252,965	334,947	416,930	498,912	580,895	662,877	744,860

Solar Power   Utility Electricity   Diesel Genset

2nd Scenario – No subsidies

Accumulated expenses over next 8 years

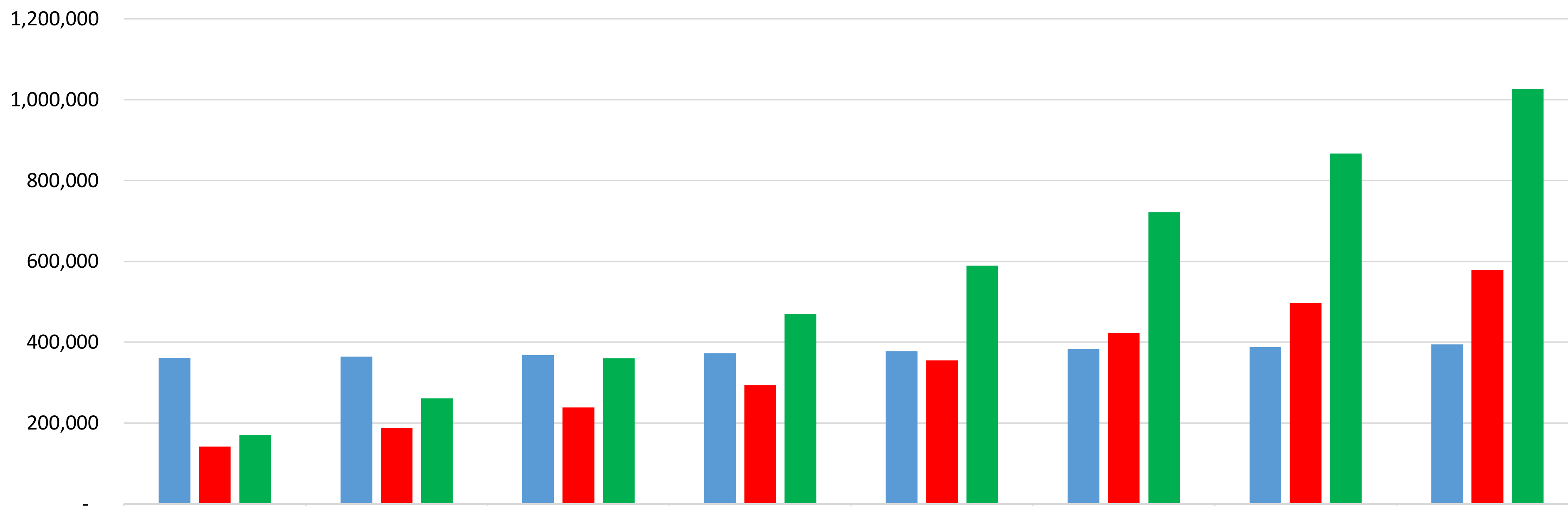


	1st Year Expenses	2nd Year Expenses	3rd Year Expenses	4th Year Expenses	5th Year Expenses	6th Year Expenses	7th Year Expenses	8th Year Expenses
Solar Power	360,970	364,190	367,409	370,629	373,849	377,069	380,288	383,508
Utility Electricity	206,452	312,903	419,355	525,806	632,258	738,709	845,161	891,455
Diesel Genset	263,758	438,517	613,275	788,034	962,792	1,137,550	1,312,309	1,487,067

Solar Power   Utility Electricity   Diesel Genset

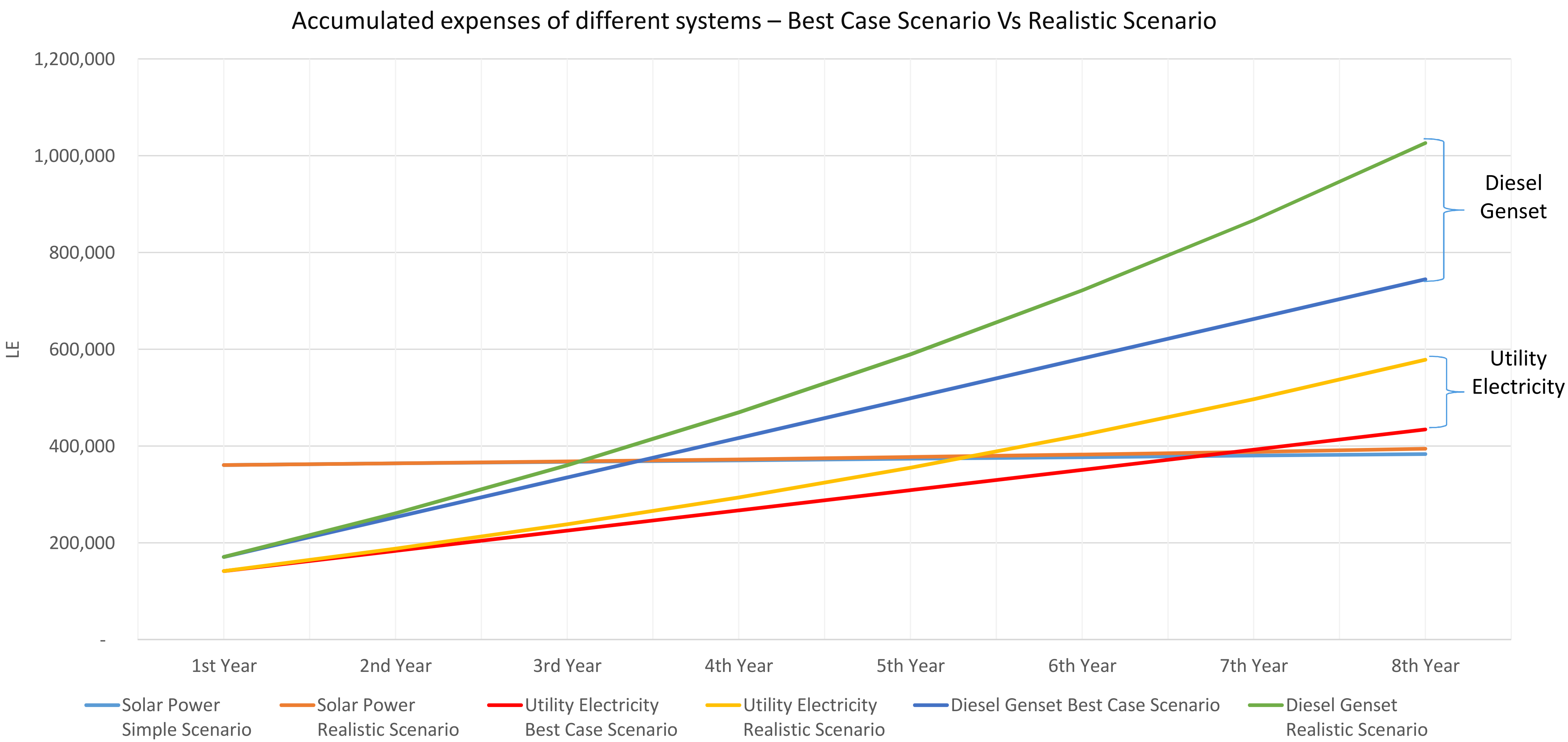
3rd Scenario – Today's prices with 10% annual increase

Accumulated Expenses - More Relastic Approach

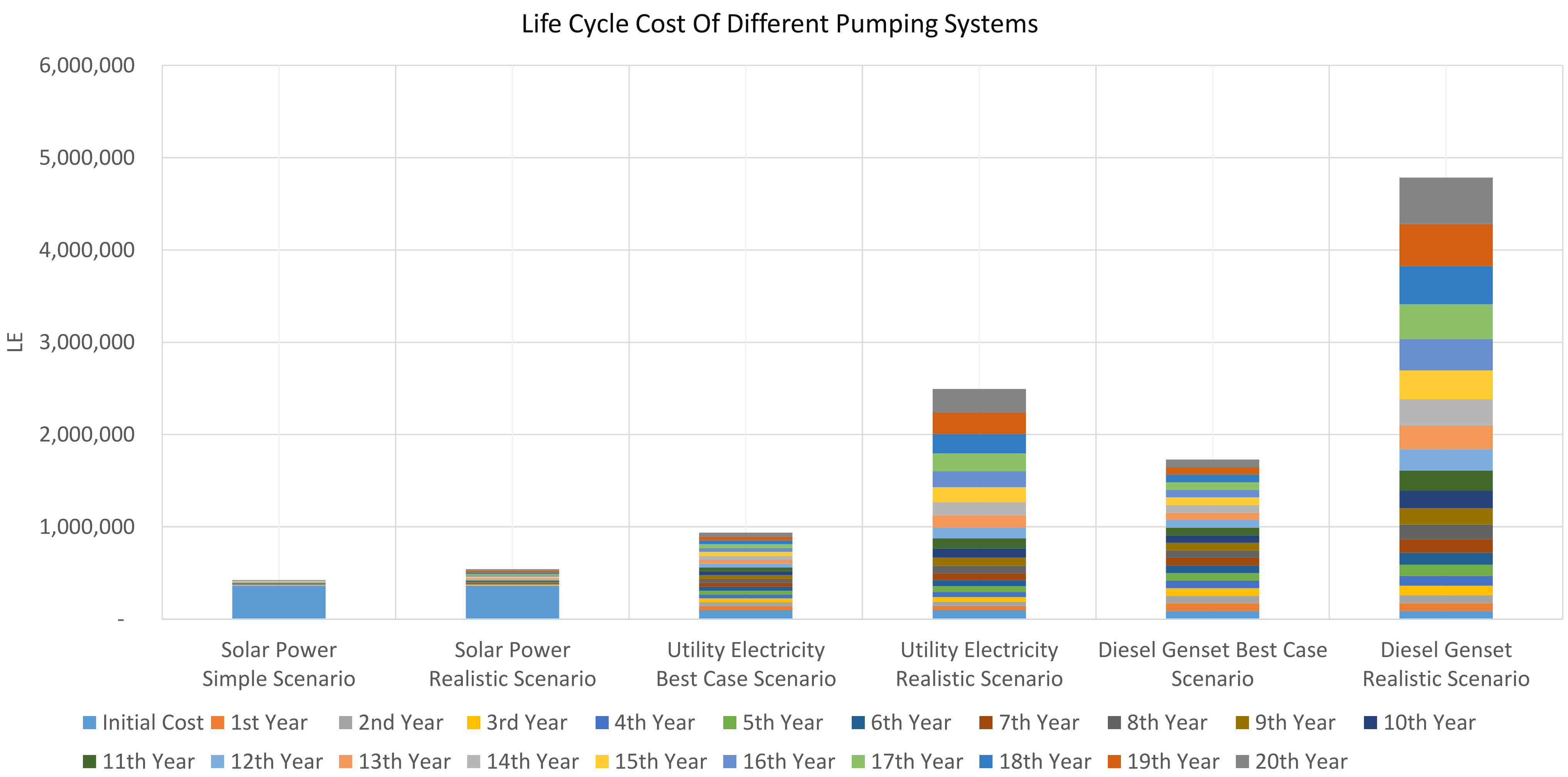


	1st Year Expenses	2nd Year Expenses	3rd Year Expenses	4th Year Expenses	5th Year Expenses	6th Year Expenses	7th Year Expenses	8th Year Expenses
Solar Power	360,970	364,511	368,407	372,693	377,407	382,592	388,296	394,571
Utility Electricity	141,820	187,823	238,425	294,088	355,318	422,670	496,757	578,253
Diesel Genset	170,982	261,163	360,362	469,481	589,511	721,545	866,781	1,026,542

Solar Power Utility Electricity Diesel Genset



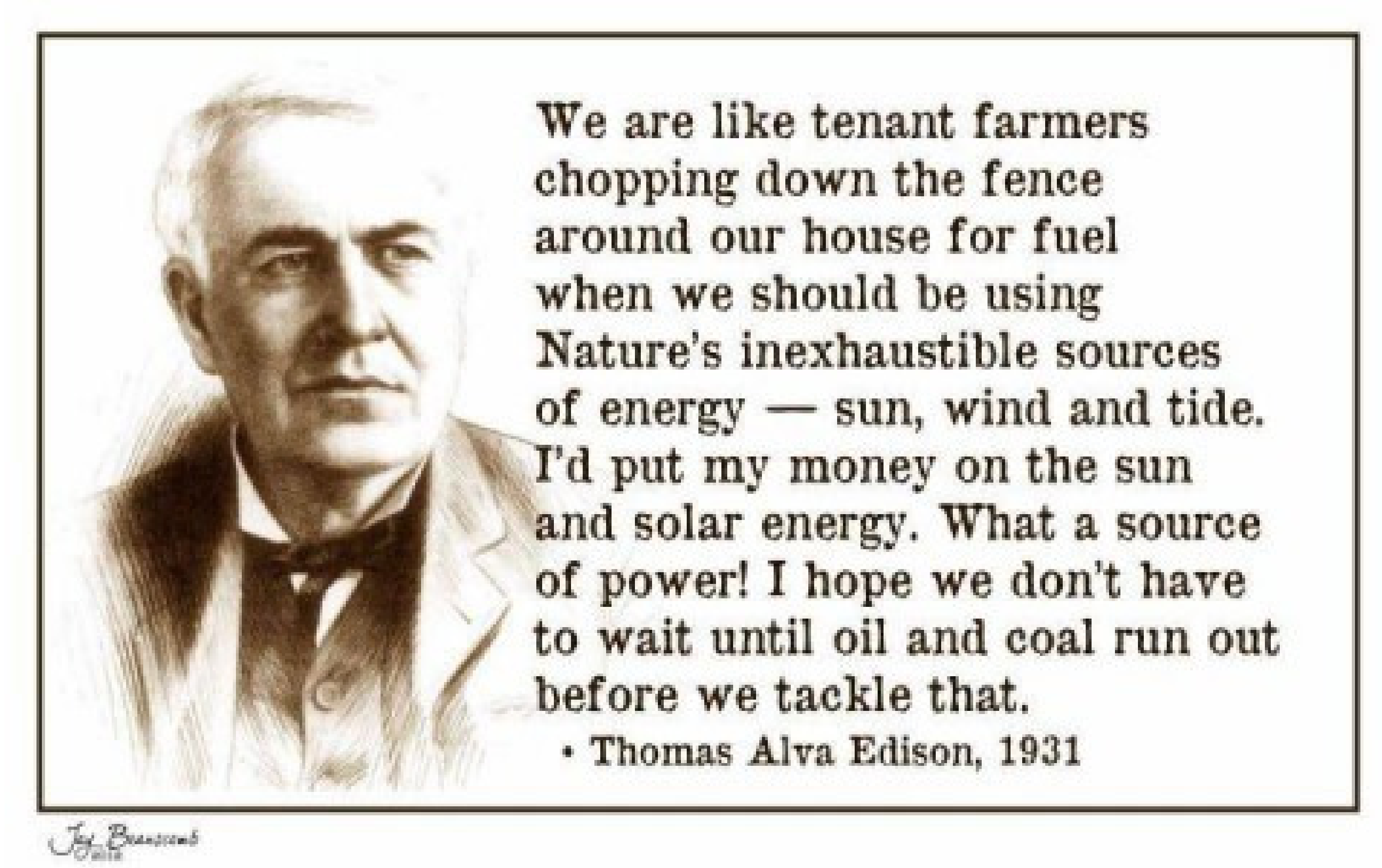
Accumulated expenses of different systems – Best Case Scenario Vs Realistic Scenario
1,200,000
1,000,000
800,000
600,000
400,000
200,000
-
LE
1st Year
2nd Year
3rd Year
4th Year
5th Year
6th Year
7th Year
8th Year
Diesel Genset
Utility Electricity
Solar Power Simple Scenario
Solar Power Realistic Scenario
Utility Electricity Best Case Scenario
Utility Electricity Realistic Scenario
Diesel Genset Best Case Scenario
Diesel Genset Realistic Scenario


Life Cycle Cost Of Different Pumping Systems
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
-
LE
Solar Power Simple Scenario
Solar Power Realistic Scenario
Utility Electricity Best Case Scenario
Utility Electricity Realistic Scenario
Diesel Genset Best Case Scenario
Diesel Genset Realistic Scenario
Initial Cost
1st Year
2nd Year
3rd Year
4th Year
5th Year
6th Year
7th Year
8th Year
9th Year
10th Year
11th Year
12th Year
13th Year
14th Year
15th Year
16th Year
17th Year
18th Year
19th Year
20th Year

Solar Pumping Applications in Egypt and the Potential

Current Situation in Egypt

More than 2000 pump running by solar power ranging from 1 or 2 HP up to 125 HP.
Desert land reclamation became much easier than before.
Hundreds of installers spread all around the country, many of them are from local communities of targeted areas.
The main barrier against spreading of solar pumping is the initial cost and the lack of financing facilities for small farmers, keeping in mind that most of them fear to deal with banks.


We are like tenant farmers
chopping down the fence
around our house for fuel
when we should be using
Nature's inexhaustible sources
of energy — sun, wind and tide.
I'd put my money on the sun
and solar energy. What a source
of power! I hope we don't have
to wait until oil and coal run out
before we tackle that.
• Thomas Alva Edison, 1931


Thank You