Modelling and Control of Renewable Energy Project Report

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- ## The Site:

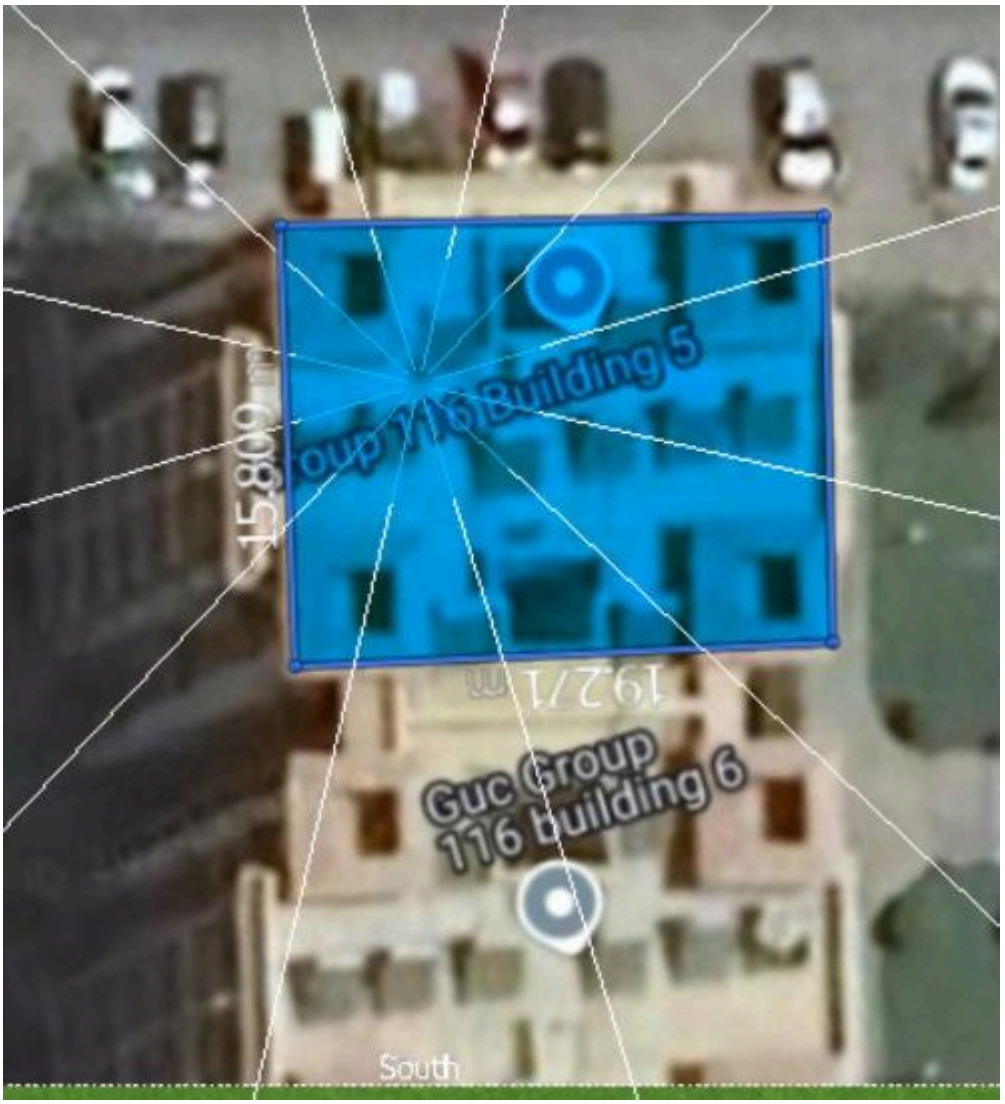
  Our Site will be the GIU Dorms in Rehab, which has these coordinates:
  latitude : 30 degree ,4 minutes ,24.72 sec.
  longitude : 31 degree ,30 minutes ,37.58 sec

- **The Loads of the house:**

Appliance	**No.**	**Average power/ appliance** (Watt)	**Daily use** (hours/day)	**Duration** (from … to …)	**Total energy** (Watt Hour)
Lamps	11	22	9.5	From 4pm to 11pm ,from 7am to 8am and two lamps from 11pm to 7am	2299
Chargers (for phones, laptops, headphones	9	95	1	From 4:30 to 5:30pm	855
AC	2	1500	5	From 4pm to 9pm	15000
Fridge	2	1730(per day)	24	All day long	3460
Router	2	12	24	All day long	576
Electric water heater	1	1125	2	From 7pm to 9pm	2250
Kettle	1	1100	0.5	From 5:30pm to 6pm	550
Microwave	1	1200	0.5	From 5pm to 5:30pm	600
Domestic appliances	1	500	0.5	From 8:30pm to 9pm	250
Washing machine	1	1100	3 washing cycles	From 1pm to 3pm	3000

-The Total number of Energy consumption throughout the day= 28841 Wh

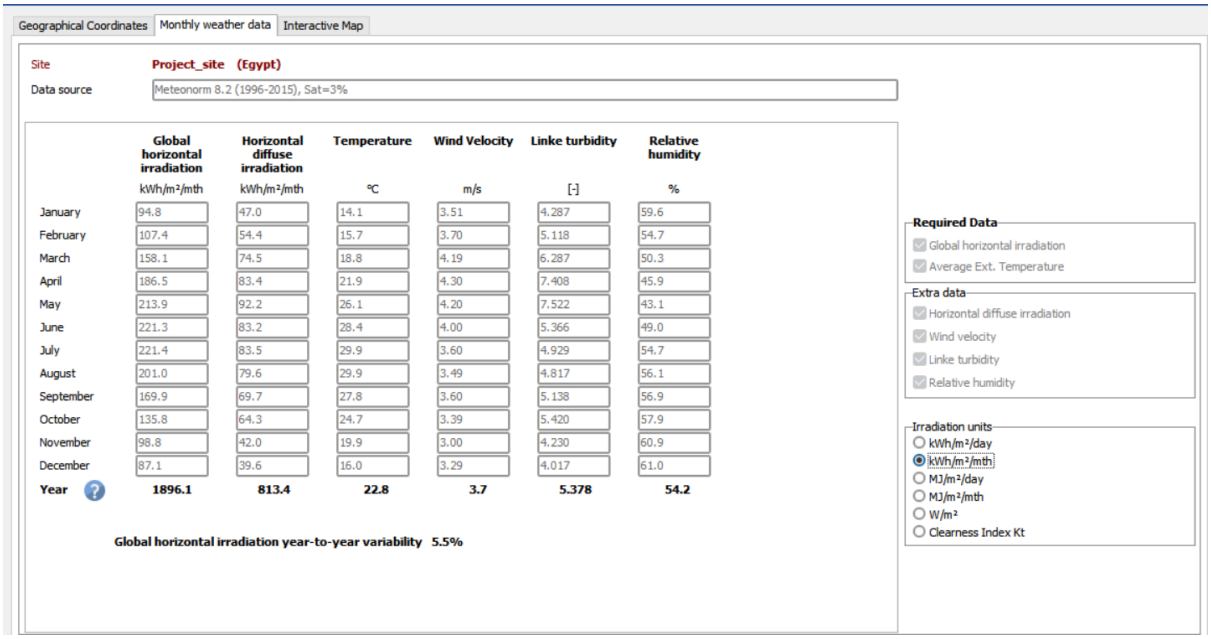
- **The Roof Dimensions:**

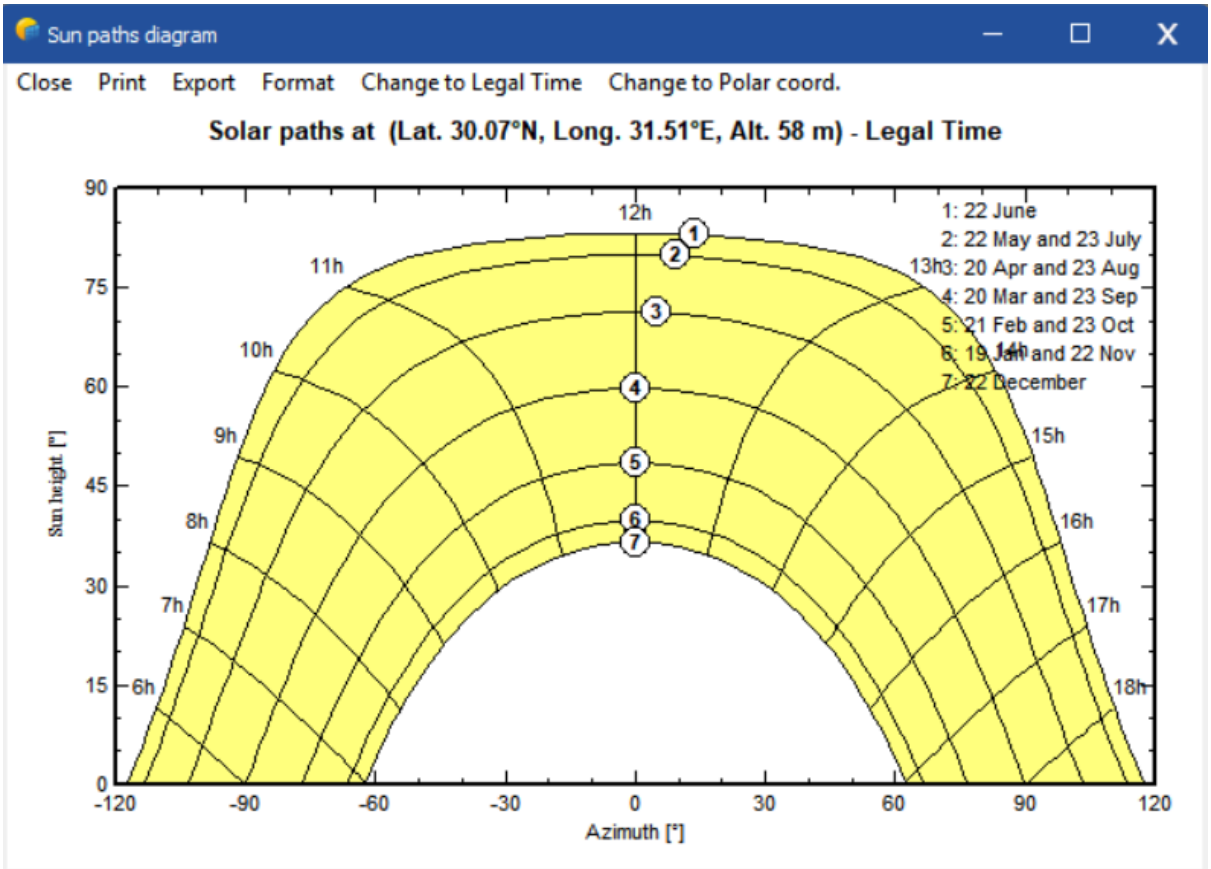


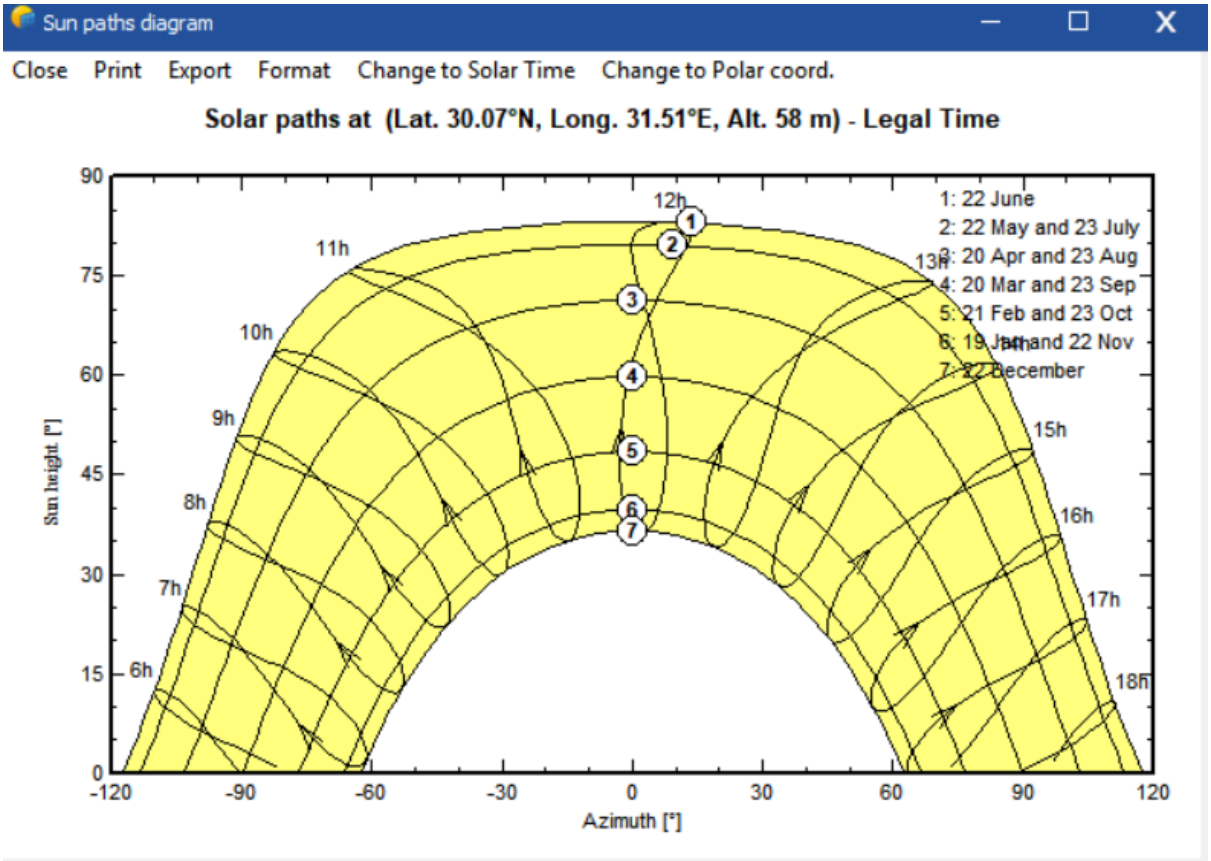
-The roof dimensions are 19.2 m by 15.8 m (Area of 303.36 m^2) according to PVSOL.

- **The Orientation of the PV Panels + info about site:**

- Here are the sun paths and the site data:-







- After some research on fixed tilt orientation, we found out that:-

= The best angles for summer are 10^{o} as tilt angle and 0^{o} as azimuth
This will result in a transposition factor(FT) of 1.01 and loss of optimum energy of 0%
Moreover the incident irradiation is 1230 kwh/m²

= While for winter, 46^{o} as tilt and no azimuth
Which will result in FT of 1.36 and 0% loss of optimum energy
And the incident irradiation is 930 kwh/m²

so,
We suggest doing a **seasonal tilt** (46 in winter and 10 in summer)
The azimuth will be set to 0^{o} throughout the year or **using a 2 axis tracker**.

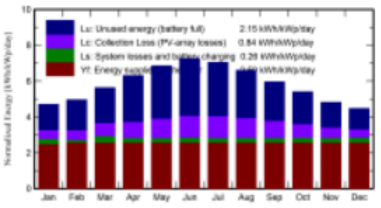
- Seasonal tilting

Main results

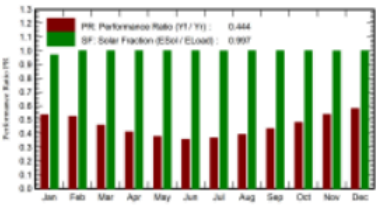
System Production

Useful energy from solar	10500 kWh/year	Perf. Ratio PR	44.37 %
Available solar energy	19757 kWh/year	Solar Fraction SF	99.74 %
Excess (unused)	8711 kWh/year		
Loss of Load		**Battery aging (State of Wear)**	
Time Fraction	0.0 %	Cycles SOW	96.9 %
Missing Energy	27 kWh/year	Static SOW	90.0 %

Normalized productions (per installed kWp)



Performance Ratio PR



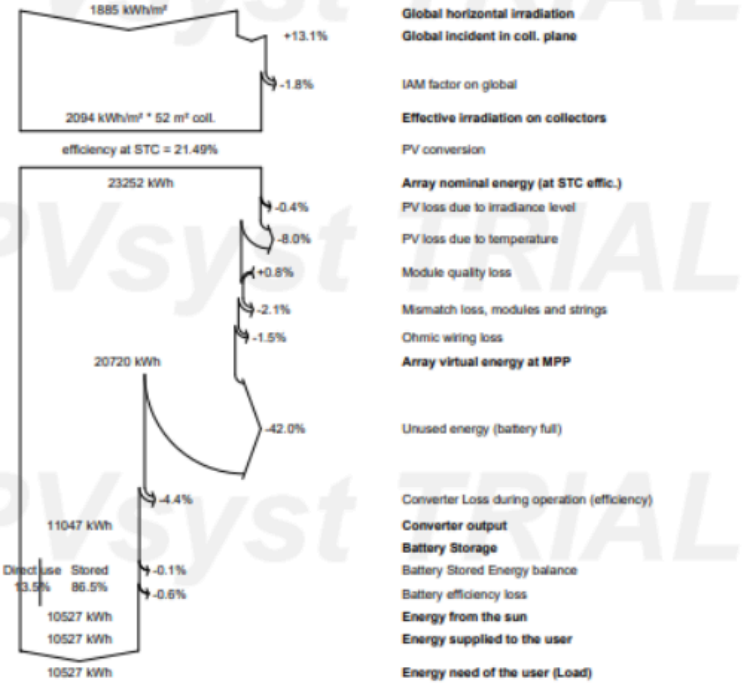
Balances and main results

	GlobHor	GlobEff	E_Avail	EUnused	E_Miss	E_User	E_Load	SolFrac
	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh	kWh	ratio
January	95.3	144.1	1408	485	27.1	867	894	0.970
February	106.7	136.9	1336	521	0.0	808	808	1.000
March	156.3	171.7	1644	670	0.0	894	894	1.000
April	183.1	185.5	1763	855	0.0	865	865	1.000
May	211.5	208.4	1943	1007	0.0	894	894	1.000
June	220.1	213.4	1969	1058	0.0	865	865	1.000
July	219.3	214.0	1961	1023	0.0	894	894	1.000
August	200.9	200.7	1851	912	0.0	894	894	1.000
September	168.5	174.7	1625	717	0.0	865	865	1.000
October	135.4	165.1	1555	613	0.0	894	894	1.000
November	100.2	143.0	1369	461	0.0	865	865	1.000
December	88.3	137.0	1333	391	0.0	894	894	1.000
Year	1885.5	2094.4	19757	8711	27.1	10500	10527	0.997

Legends

GlobHor	Global horizontal irradiation	E_User	Energy supplied to the user
GlobEff	Effective Global, corr. for IAM and shadings	E_Load	Energy need of the user (Load)
E_Avail	Available Solar Energy	SolFrac	Solar fraction (EUsed / ELoad)
EUnused	Unused energy (battery full)		
E_Miss	Missing energy		

Loss diagram



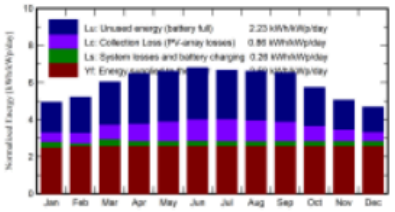
- 2-axis tilting:

Main results

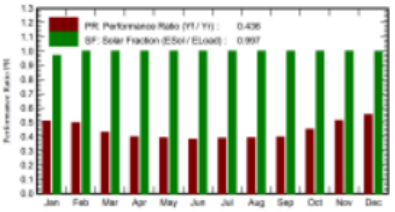
System Production

Useful energy from solar	10500 kWh/year	Perf. Ratio PR	43.57 %
Available solar energy	20077 kWh/year	Solar Fraction SF	99.74 %
Excess (unused)	9030 kWh/year		
Loss of Load		**Battery aging (State of Wear)**	
Time Fraction	0.0 %	Cycles SOW	96.9 %
Missing Energy	27 kWh/year	Static SOW	90.0 %

Normalized productions (per installed kWp)



Performance Ratio PR



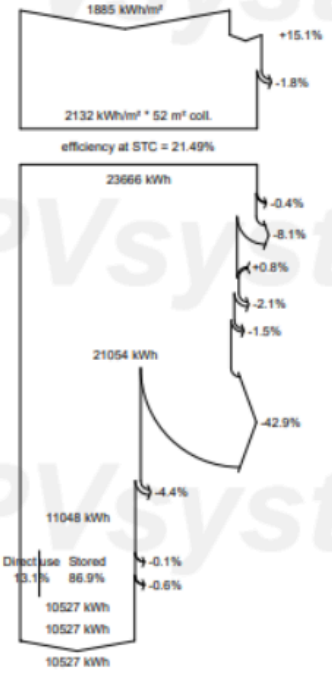
Balances and main results

	GlobHor kWh/m²	GlobEff kWh/m²	E_Avail kWh	EUnused kWh	E_Miss kWh	E_User kWh	E_Load kWh	SolFrac ratio
January	95.3	151.5	1479	554	27.1	867	894	0.970
February	106.7	143.9	1403	588	0.0	808	808	1.000
March	156.3	183.9	1757	784	0.0	894	894	1.000
April	183.1	191.2	1810	901	0.0	865	865	1.000
May	211.5	200.1	1863	924	0.0	894	894	1.000
June	220.1	198.4	1826	917	0.0	865	865	1.000
July	219.3	201.1	1840	901	0.0	894	894	1.000
August	200.9	200.4	1843	904	0.0	894	894	1.000
September	168.5	192.4	1778	870	0.0	865	865	1.000
October	135.4	175.4	1649	709	0.0	894	894	1.000
November	100.2	150.0	1434	525	0.0	865	865	1.000
December	88.3	143.4	1393	453	0.0	894	894	1.000
Year	1885.5	2131.8	20077	9030	27.1	10500	10527	0.997

Legends

GlobHor	Global horizontal irradiation	E_User	Energy supplied to the user
GlobEff	Effective Global, corr. for IAM and shadings	E_Load	Energy need of the user (Load)
E_Avail	Available Solar Energy	SolFrac	Solar fraction (EUsed / ELoad)
EUnused	Unused energy (battery full)		
E_Miss	Missing energy		

Loss diagram



Global horizontal irradiation
Global incident in coll. plane
IAM factor on global
Effective irradiation on collectors
PV conversion
Array nominal energy (at STC effic.)
PV loss due to irradiance level
PV loss due to temperature
Module quality loss
Mismatch loss, modules and strings
Ohmic wiring loss
Array virtual energy at MPP
Unused energy (battery full)
Converter Loss during operation (efficiency)
Converter output
Battery Storage
Battery Stored Energy balance
Battery efficiency loss
Energy from the sun
Energy supplied to the user
Energy need of the user (Load)

We did 2 simulations in each case of the 2 orientations (seasonal tilting and 2 axis tracking) , in the light of the given screenshots of some of the differences between the 2 orientations, we saw that for the 2 axis tracking

- Price of 1 tracker is 27,593.50egp
- The excess energy is 9030 kwh / year
- The available energy is 20077 kwh / year

While for the seasonal tilting

- Price of 1 support is 5619.55egp
- The excess energy is 8711 kwh / year
- The available energy is 19757 kwh / year

Also taking the power loss diagrams into consideration, we decided that it's not worth it to implement a 2 axis tracker as it is so costly and there is nearly no difference in both cases.
So, we will be using a seasonal tilt system.

● The inverter:

- Inverters have two parameters that define them:
    1. **The continuous power ratin**g: this must handle the steady state power of all the loads.
    2. **The surge power rating**: this must handle the momentary surge power during startup of some loads (like appliances with Motors, Compressors, Resistive heating elements).

-**The continuous power rating** : 4KW

-To estimate the surge power for the appliances, we will use typical surge multipliers for each type of load. Here are the multipliers commonly applied:

1. **Motors/Compressors (like AC, fridge, washing machine):** 3–5 times the steady-state power.
2. **Resistive Heating Elements (like water heater, kettle, microwave):** 1–1.5 times the steady-state power.
3. **Electronics (e.g., routers, chargers):** No surge multiplier; they operate at steady power.

Appliance	**No.**	**Surge Power** (Watt)	**Steady-State Power** (Watt)
Fridge	3	216	72
AC	3	4500	1500
Washing Machine	1	3300	1100
Microwave	1	1200	1200
Electric Heater	1	1125	1125
Kettle	1	1100	1100
Lamps	11	–	22
Router	2	–	12
Domestic	1	–	500
Chargers	9	–	95

-**The surge power rating:** the sum of surge power (of ones who have surge power) and steady-state power (for ones that don't have surge power)= 22.494 KWatt.

-To estimate the required input power supplied to the inverter from the battery, we will uses these rules:

Load	**Inverter**		
Total wattage of loads (Watt)	Output Power (Watt)	Efficiency (%)	Input Power (Watt) [(Output) / (Efficiency)]*100%
4000	4000	95	4210

-To estimate the system current based on the system voltage:

Total System Wattage (Watt)	System Voltage (V)	System Current (A) [System Wattage/System Voltage]
4210	48	87.7

-we agreed on a system voltage of 48V as recommended in the datasheet of the inverter click here to read the datasheet of the inverter

-the link of the inverter on AliExpress: https://de.aliexpress.com/item/3256803311690581.html?src=google&gateway Adapt=glo2deu

- **The Battery:**

-We will use a LiFePo4 battery, which has an average energy efficiency of 95%.

-The DOD of the battery will be 80% (which means that the battery SOC (State Of Charge) can not get below 20%).

-This battery should be able to supply the house with enough power for 2 days straight without any energy produced by the PV panels.

Load	**Battery**				
Total energy of loads (Wh/day)	no. of autonomy days	Efficiency (%)	DC controller efficiency (%)	DOD (%)	Total energy of the Battery (Wh)
30354.89	2	95	95	80	84096.8

module			**Battery pack**			**Cells configuration**
voltage (V)	capacity (Ah)	energy (KWh)	Total voltage (V)	Total capacity (Ah)	Total energy (KWh)	1S8P
48	200	9600	48	1600	76800	—

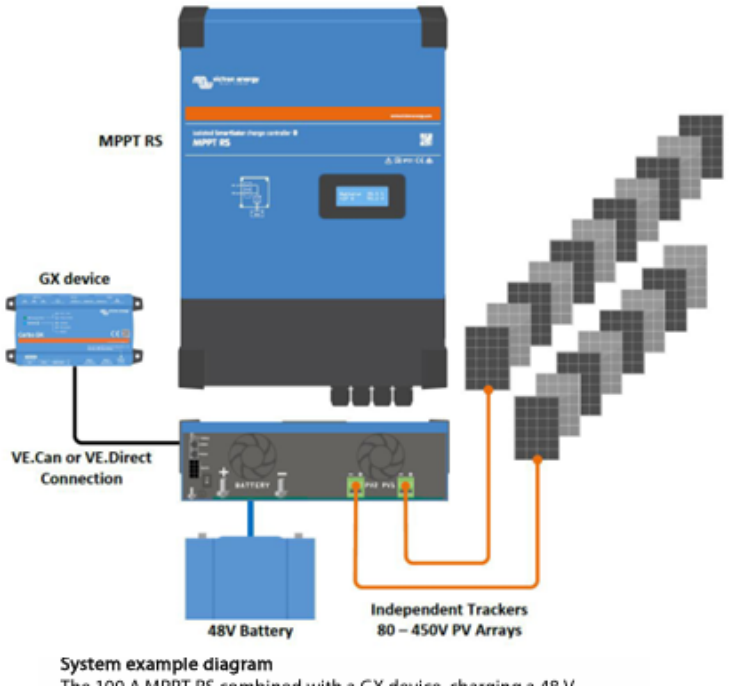
-we had a choice to make here, either have only 8 batteries in parallel and end up with a total energy capacity of 76800 (8% less than the desired energy capacity), or to connect 9 batteries in parallel and end up with a total energy capacity of 86400 (2.8% more than the desired capacity).

-We agreed on the design of having 8 batteries in parallel.

-The link for the battery on amazon:
[Sunpal Lifepo4 Solar Energy Storage Batteries 48V 100Ah 200Ah 5kWh 10kWh 15kWh Powerwall Lithium Ion Solar Storage Battery]

- **the charge controller**

-For the charger controller we need a charger controller which is able to operate with power range 10 to 11 kw and nominal voltage battery 48v. The best option for our system is the SmartSolar MPPT RS 450|200 - Isolated 11.52 kW Solar Charge Controller with 450V PV input.(we are going to use the one with charging current 200A)



System example diagram

Isolated SmartSolar MPPT RS	450|100	450|200
CHARGER		
Battery voltage	48 V	
Rated charge current	100 A	200 A
Maximum charge power	5.8 kW at 57.6 V	11.5 kW at 57.6 V
Charge voltage 'absorption'	Default setting: 57,6 V (adjustable)	
Charge voltage 'float'	Default setting: 55,2 V (adjustable)	
Programmable voltage range	Minimum: 36 V Maximum: 60 V [7]	
Charge algorithm	Multi-stage adaptive (adjustable)	
Battery temperature sensor	Included	
Maximum efficiency	96 %	
Self-consumption	15 mA	
SOLAR		
Maximum DC PV voltage	450 V	
Start-up voltage	120 V	
MPPT operating voltage range	65 – 450 V [1]	
Number of trackers	2	4
Max. PV operational input current	MC4 models: 16 A per tracker Tr models: 18 A per tracker	
Max. PV short circuit current [2]	20 A per tracker	
Max. DC output charging power	4000 W per tracker 5760 W total	4000 W per tracker 11520 W total
Maximum PV array size per tracker [3]	7200 Wp (450 V x 20 A) [3]	
PV Isolation fail level [4]	100 kΩ	
GENERAL		
Synchronised Parallel Operation	Yes, up to 25 units with VE.Can	
Programmable relay [5]	Yes	
Protection	PV reverse polarity Output short circuit Over temperature	
Data communication	VE.Direct port, VE.Can port & Bluetooth (6)	
Bluetooth frequency	2402 – 2480 MHz	
Bluetooth power	4dBm	
General purpose analogue/digital in port	Yes, 2x	
Remote on-off	Yes	
Operating temperature range	-40 to +60 °C (fan assisted cooling)	
Humidity (non-condensing)	max 95 %	
ENCLOSURE		
Material & Colour	steel, blue RAL 5012	
Protection category	IP21	
Battery-connection	M8 bolts	
Power terminals PV input (-Tr version)	16 mm²	
Power terminals PV input (MC4 version)	1 pair of male and female MC4 connectors per tracker	
Weight	7,9 kg	13,7 kg
Dimensions (h x w x d) in mm	440 x 313 x 126	487 x 434 x 146

-With a price of 76797 EGP.

-The link of the charge controller:
https://www.inutec-int.com/MPPT-RS-450-200-mc4

- **surge voltage protection**

-For lighting strikes we need to use a surge protection, we are going to use SLP-PV600.

No. of Poles	2
Rated Current	40kA
Brand	ARC Impulse inc / LPS
Voltage	600
Material	PA 06
Phase	3 pole DC
Model Name/Number	SLP40 PV6oo
Warranty	5 years
Mounting Type	Din Rail
Degree Of Protection	IP 20
I Deal In	New Only
Minimum Order Quantity	01 Piece

-With price 416 EGP.

-The link for the surge protection device:
2 SLP-PV-600 Surge Arrester at ₹ 700/piece in Ghaziabad | ID: 22660343130

- ## Circuit breakers and switches

-We are going to one circuit breaker one between the **inverter and the load** because it is the most common for fault and we chose circuit breaker over fuses because the difference in the price was not that big and the advantage of reuse the circuit breaker which can cost effective in the long term over the fuses.

-The circuit breaker should have a rating current of surge power/Vm=22000/220 sqrt(2)=141.4A

Gopact MCCB 200, 3 Poles 200A Circuit Breaker, 25kA at 415VAC

Out Of Stock Be The First To Review This Product

SKU G20B3A200

Brand Schneider Electric

EGP 7,234 ~~EGP 10,485~~

ADD TO WISH LIST ADD TO COMPARE

QUICK OVERVIEW

Range of product: GoPact MCCB
Product type: Circuit breaker
Device application Distribution
Poles 3P

-The link for circuit breaker:
Gopact MCCB 200, 3 Poles 200A Circuit Breaker, 25KA, G20B3A200|Gila Electric.

-regarding the switches we are going to use two switches:

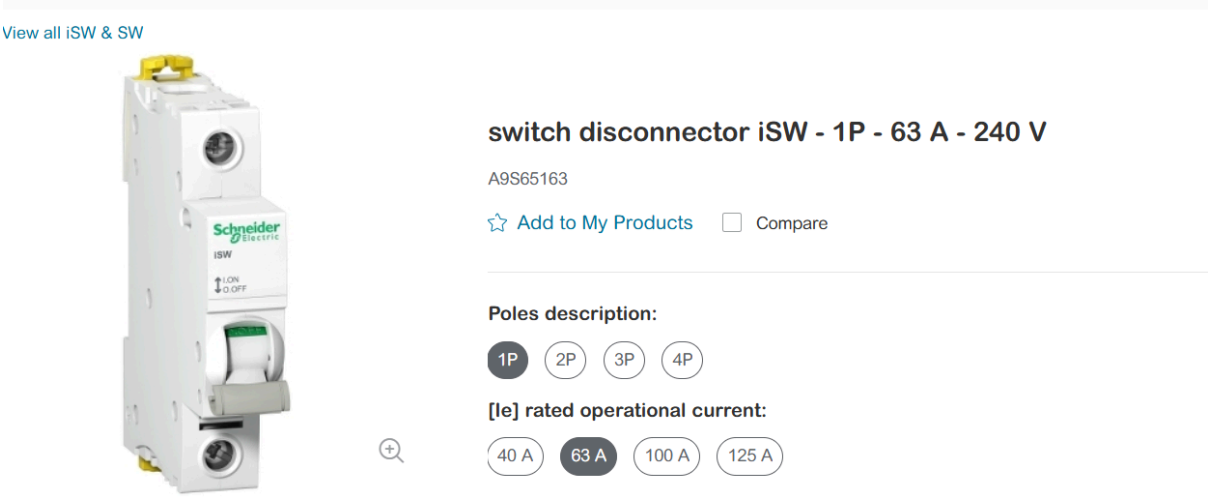
1. one for the battery.
2. one for the Pv panel.

-We decided to use these two switches at these exact locations to make the owners capable of shutting down the system whenever they want (e.g. travelling, …), or shutting down one or both of them for maintenance.

-The battery switch: which is selected according to the controller's max charging current which is 200A.
(we didn't find one with a single pole, so we will use only one pole of the 3 poles of the switch.)

-The link of the website that sells the switch:
https://gilaelectric.com.eg/en/compact-ins250-switch-disconnector-250a-standard-version-with-black-rotary-handle-3-poles.html

-The PV panel switch: we need one with rating 60A, but i can only find one with rating current 63A, which is not a problem because it is only used to disconnect the PV panel if we want.



-The price is about 1580egp.

- **Stand-Alone PV System**

  -Estimating the needed daily energy to be supplied by the PV module:

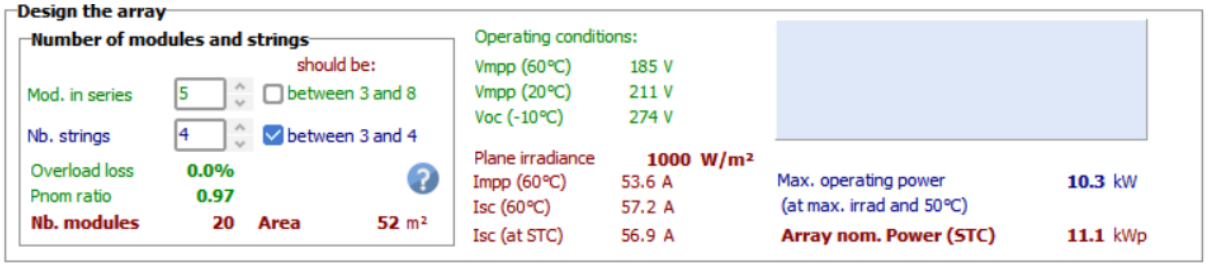
Loads	Inverter efficiency (%)	Battery efficiency (%)	Charger controller efficiency (%)	Output energy from SPV module (Wh)	de-rating factor (%)	Energy of SPV module (Wh)
28840	95	95	95	33634.2	92	36290

-Estimation of PV module power:
The total incident irradiance at our location during the worst day in winter was about 3400 wh/m^2 per day, which means total PSH is 3.4h.
(We chose winter to do our calculations as it has the least average irradiance during the day)

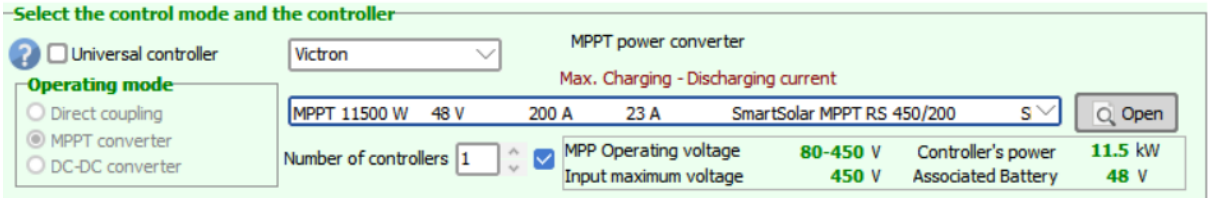
Energy of SPV module (Wh)	Equivalent daily sunshine hours (h)	SPV module wattage (W)/Wp
36290	3.4	10674

Total number of PV modules = Total module power / power of one module
Total number of PV modules = 10674/ 555
Total number of PV modules = 19.3 => 20 (4*5) array

-We are using a JinkoSolar 555Wp/35V module in a 4-string,5-series connection:



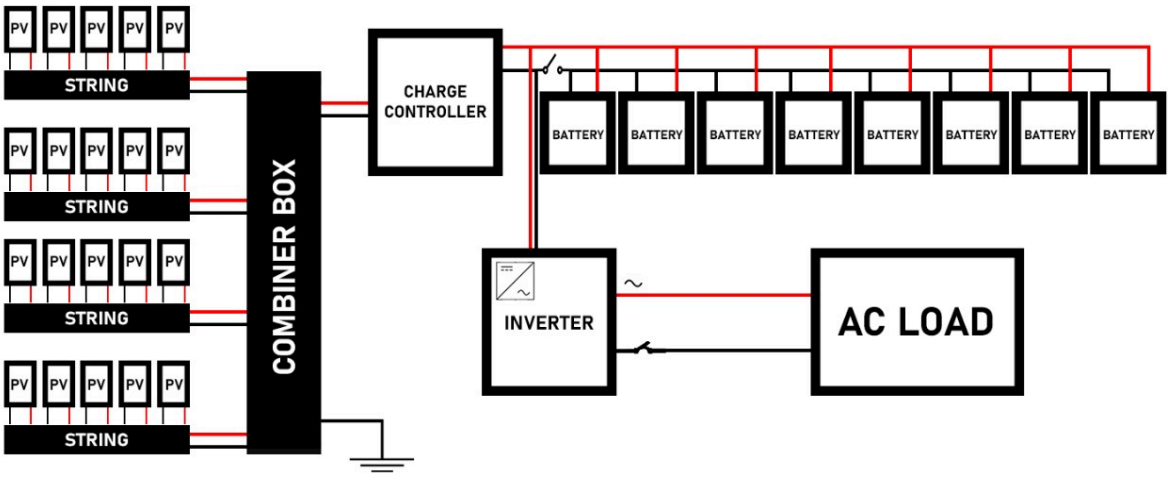
-Compatible with the charger controller:
Controller power is 11500W and PV power is about 10.3KW
PV SC current @ 60 degrees (57.2A) is less than PV rated current of the controller (200A)
Operating input voltage (274 Voc) is within range (max 450V)

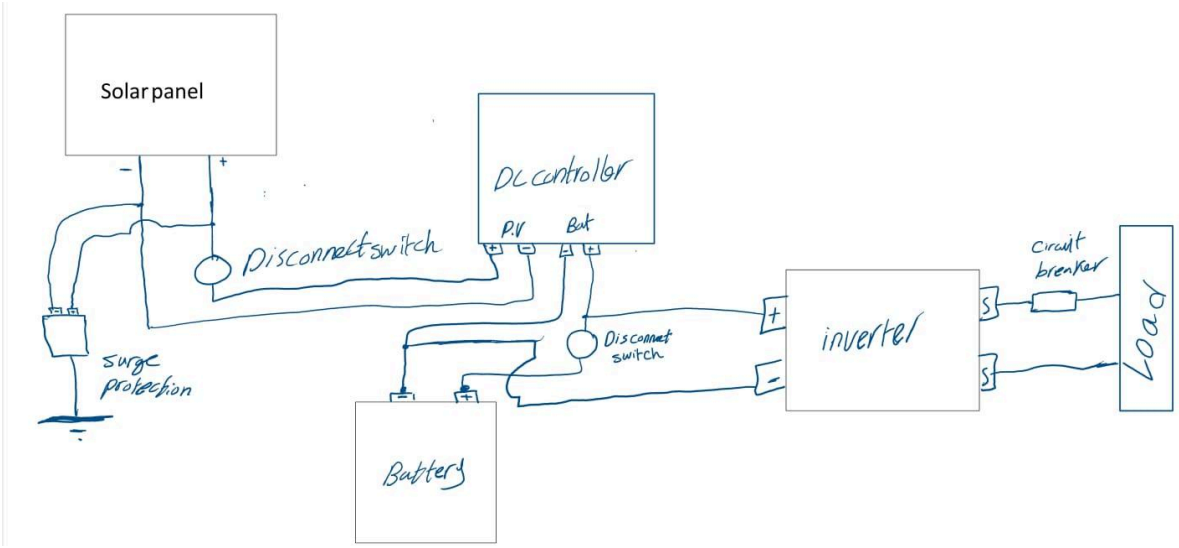


[Link to the PV module]

[Link to PV module datasheet]

- **The Wiring**





- **The Cost and Payback Period of the PV System**

- The cost analysis **with the batteries**:

The component	Quantity	Cost (egp)	Total cost (egp)
PV modules	20	4856.25	97125

Batteries	8	26263	210104
Charge controller	1	76797	76797
Inverter	1	51668.31	51668.31
Circuit breakers	2	7234	14468
Switches	2	9917+1580	22994
Surge protection	1	416	416
Support	1	5,619.55	5,619.55
Maintenance, installation	1	16000	16000
Wires	1	5000	5000
Total cost	-	-	500236.86

-In Egypt for our monthly consumption **910.7KWh/month** is **1.5 EGP/KWh**

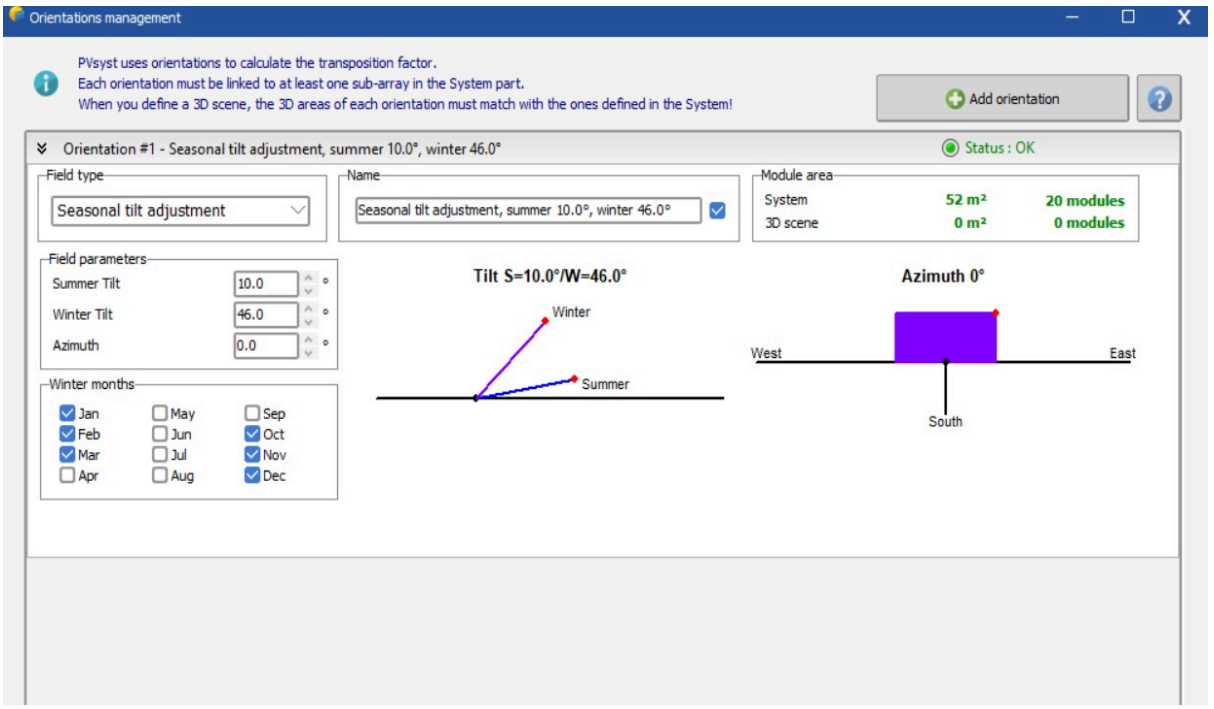
The yearly consumption	The price per KWh	The total cost for the PV system	The payback period
10928.4 KWh	1.5 EGP/KWh	500236.86 EGP	30.5 years

- The cost analysis **without the batteries**:

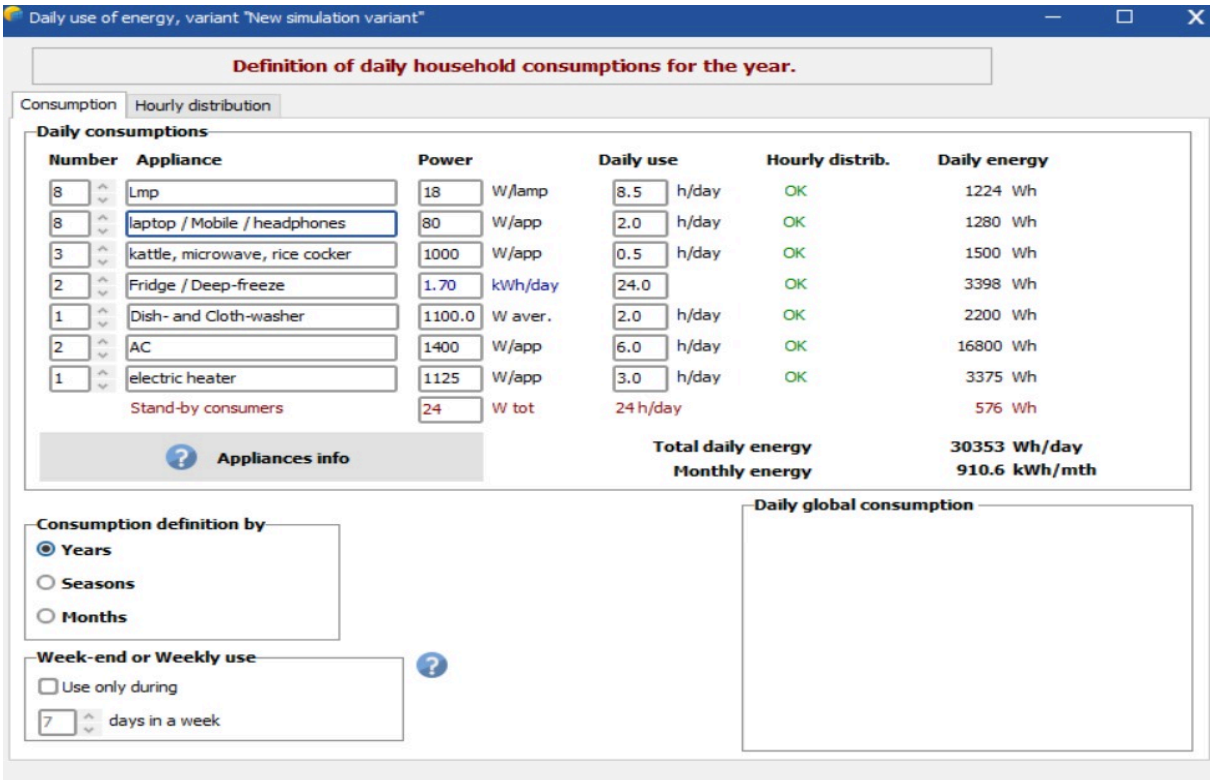
The yearly consumption	The price per KWh	The total cost for the PV system	The payback period
10928.4 KWh	1.5 EGP/KWh	290132.86 EGP	17.7 years

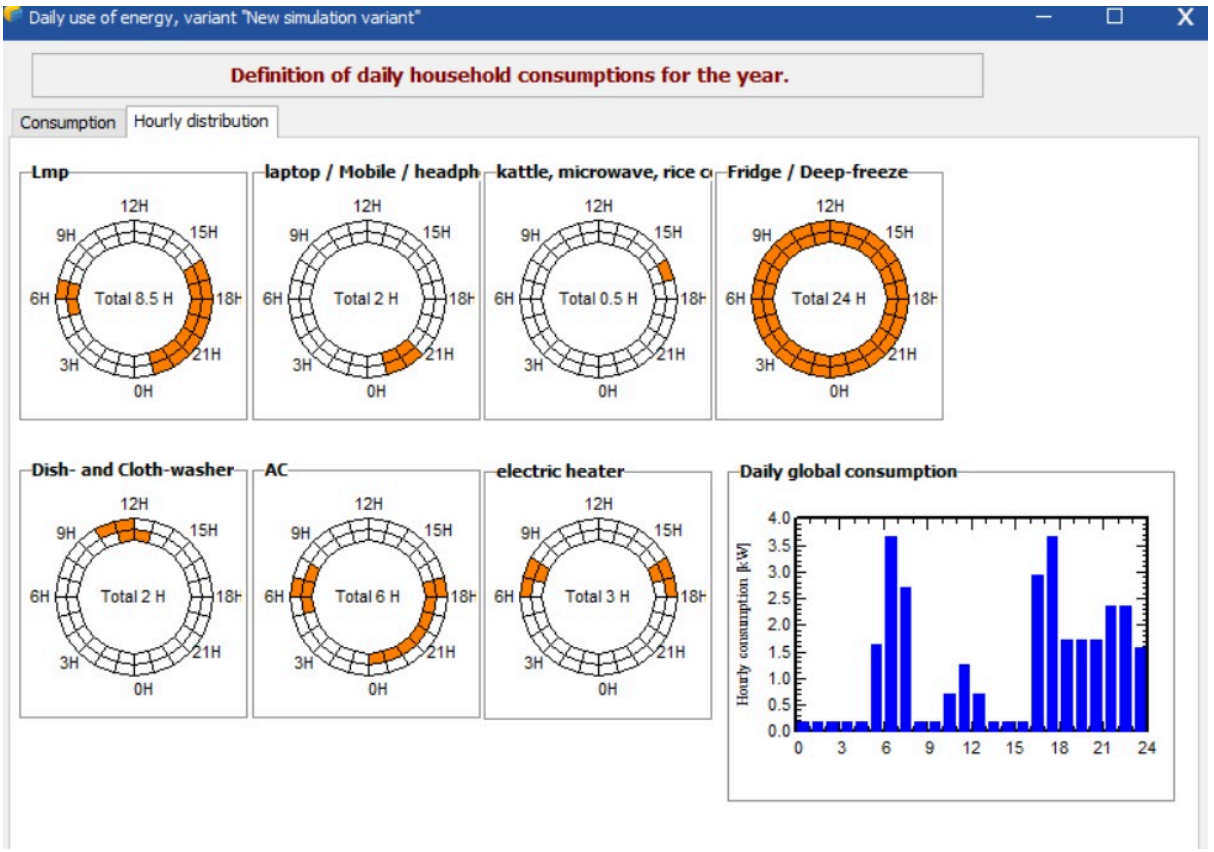
- ## The Simulation of The whole System on PVSyst

-The orientation of the PV panel:

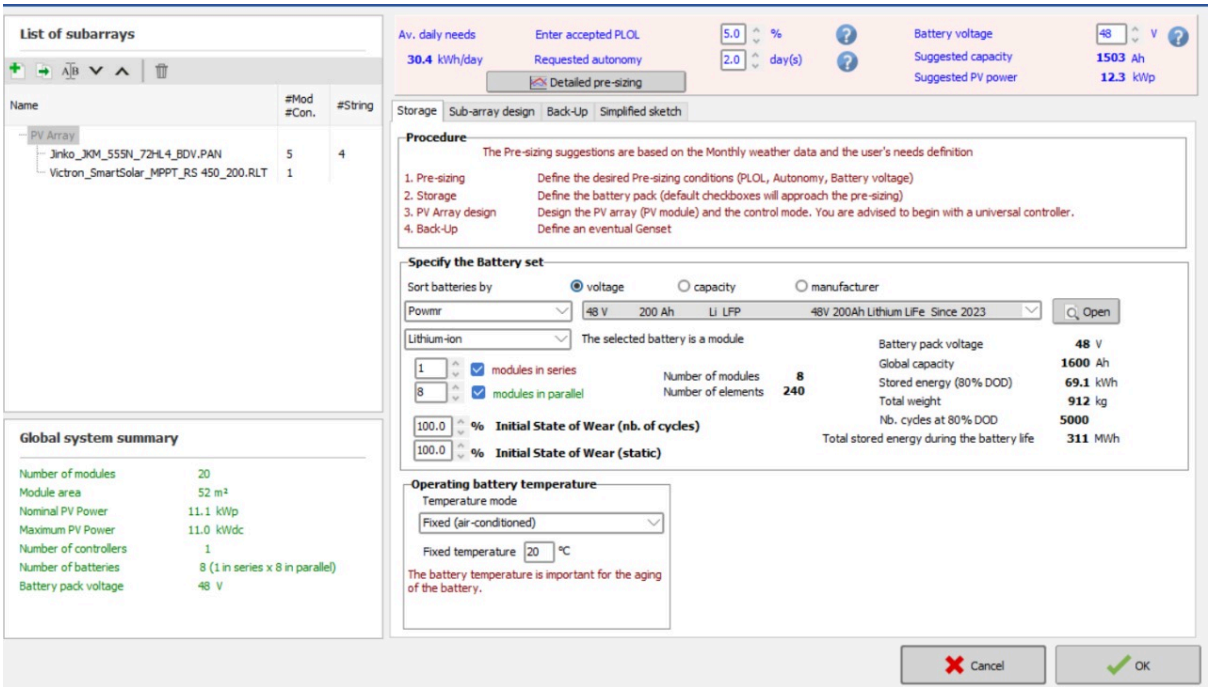


-The load specification, hourly consumption, and load profile:

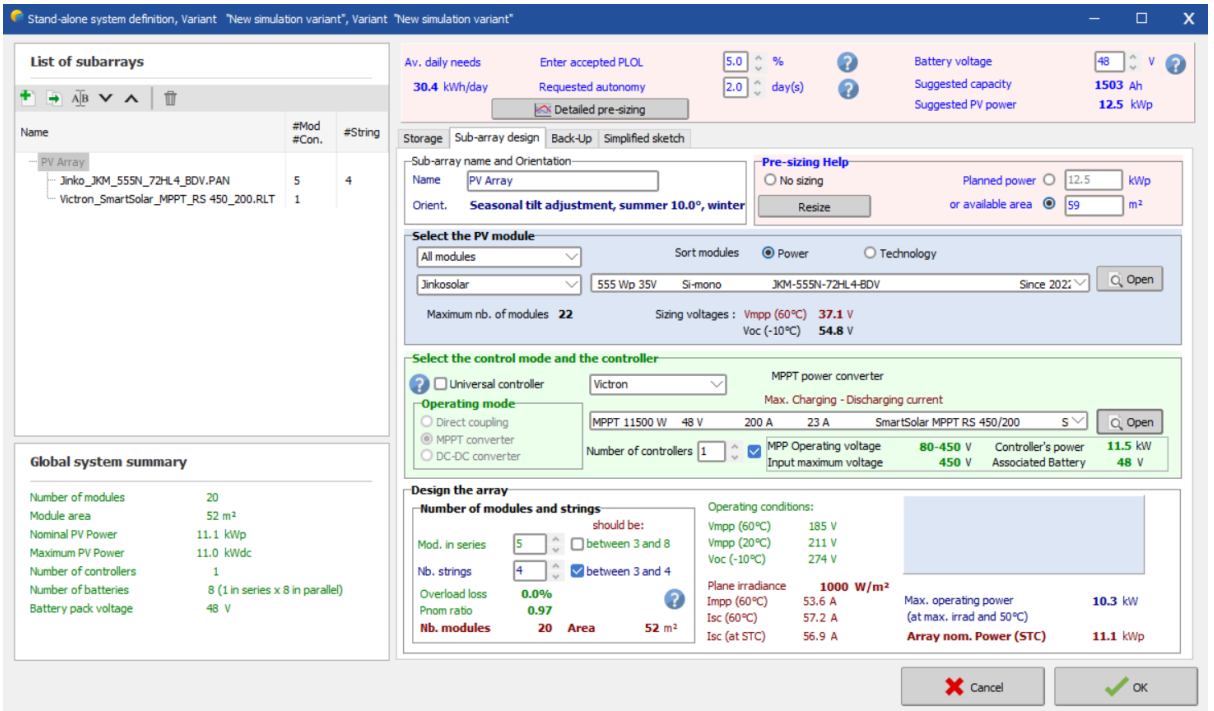




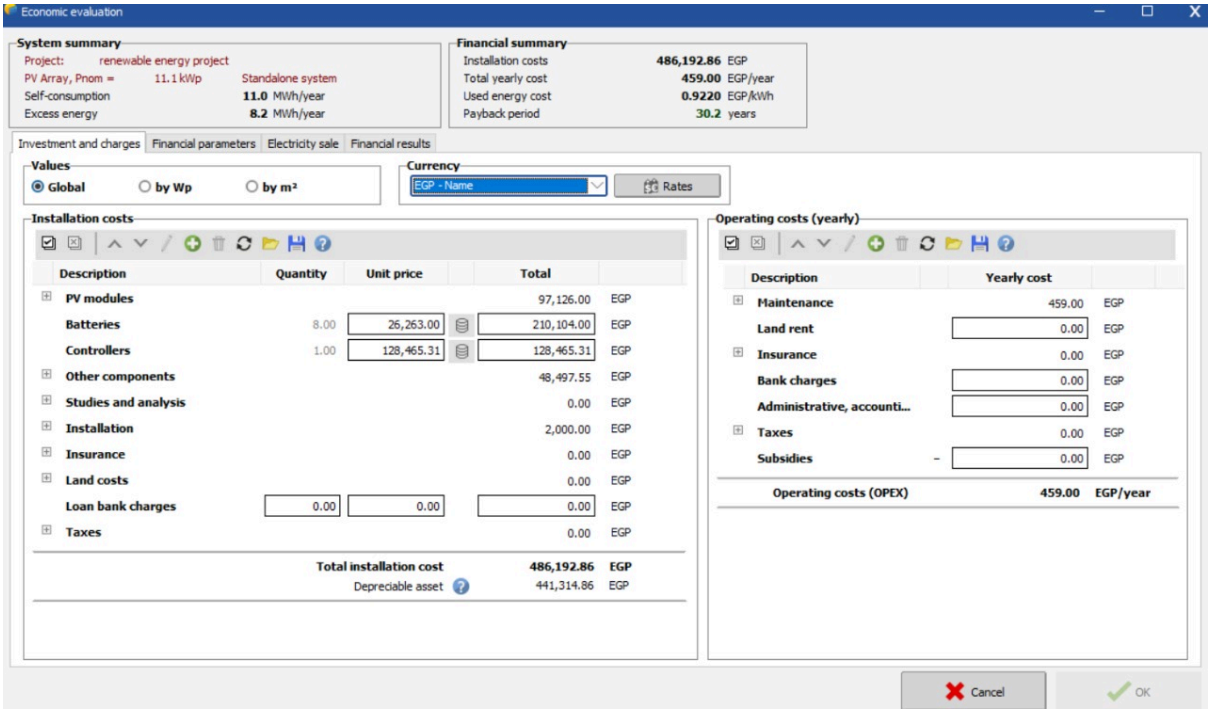
-The storage unit parameters:



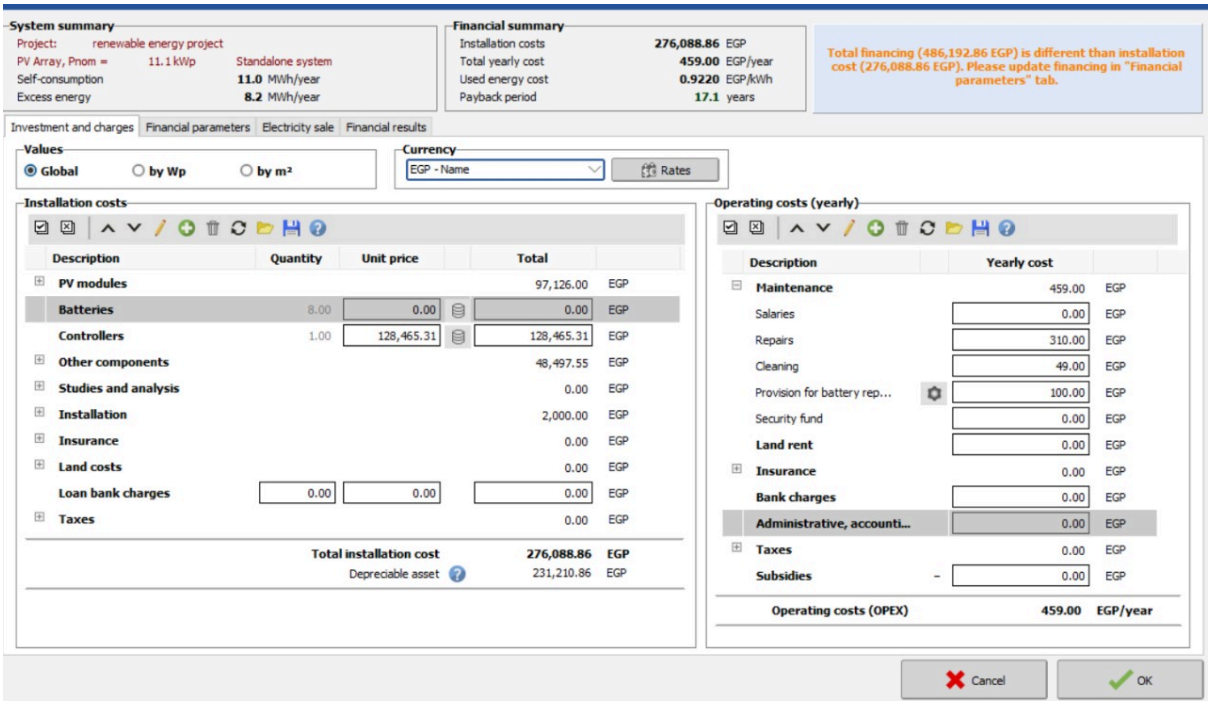
-The PV array parameters:



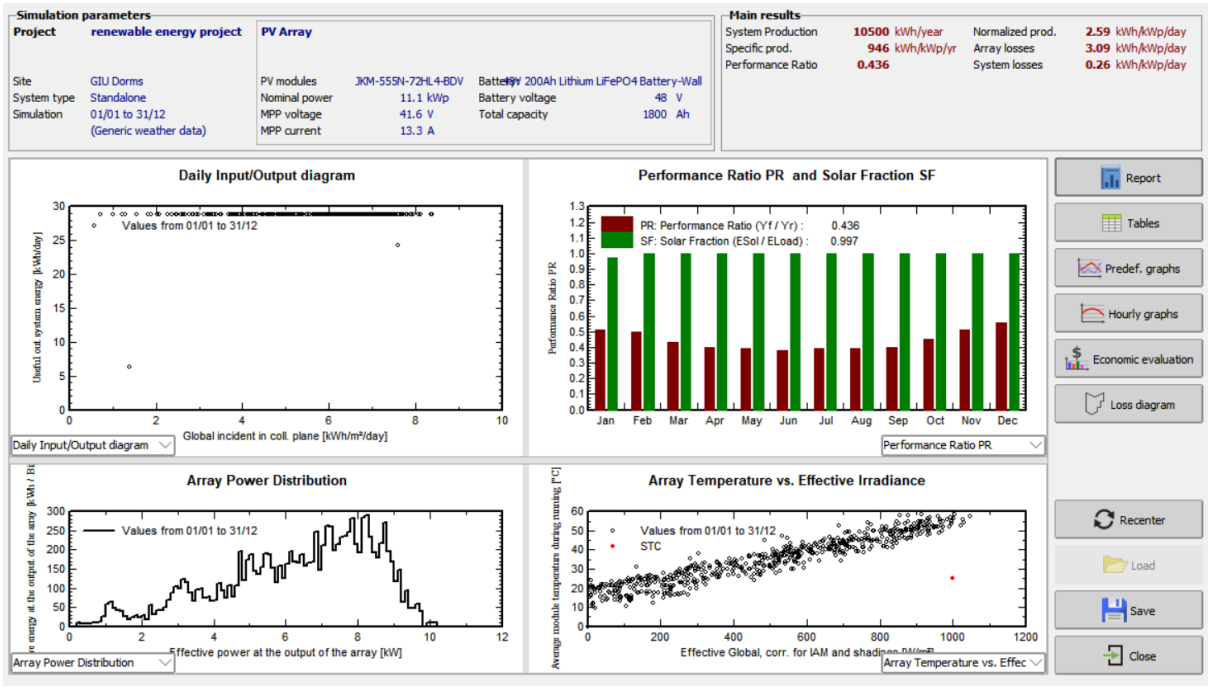
-The cost analysis with the batteries:



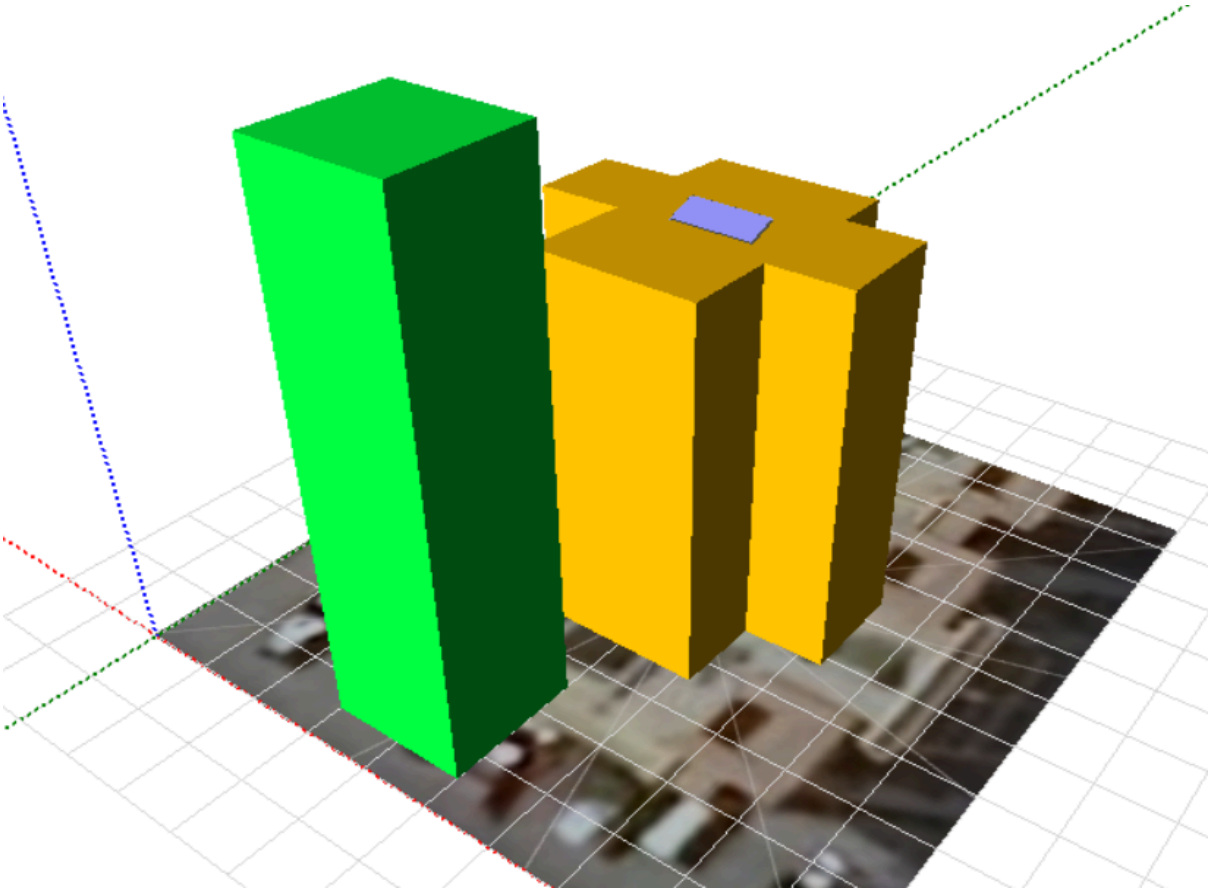
-The cost analysis without the batteries:



-After the decision to use seasonal tilting:



- **The Effect of Shading on the PV panel production**



-The image above is the exact scenery, i used an image from google maps to make a polygon the same shape as the building and extruded it.

Close Print Export Help

Recompute

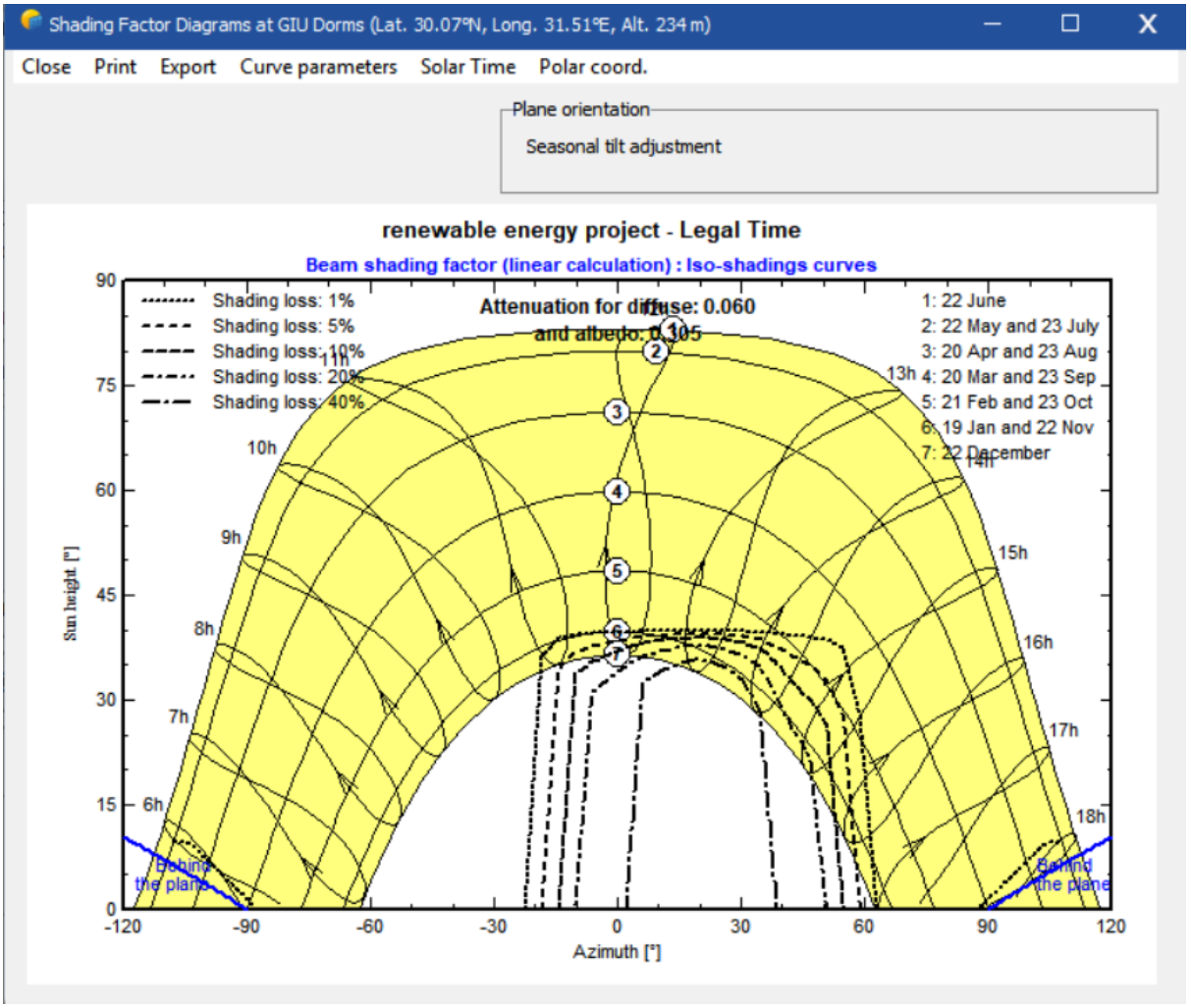
Plane orientation
Seasonal tilt adjustment

Shading factor table (linear), for the beam component, Orient. #1

Azimuth / Height	-180°	-160°	-140°	-120°	-100°	-80°	-60°	-40°	-20°	0°	20°	40°	60°	80°	100°	120°	140°	160°	180°
90°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30°	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.323	1.000	0.150	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20°	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.323	1.000	0.336	0.000	0.000	0.000	0.000	0.000	0.000	1.000
10°	Behind	Behind	Behind	Behind	0.000	0.000	0.000	0.000	0.000	0.323	1.000	0.336	0.000	0.000	0.000	Behind	Behind	Behind	Behind
0°	Behind	Behind	Behind	Behind	Behind	0.000	0.000	0.000	0.000	0.323	1.000	0.336	0.000	0.000	Behind	Behind	Behind	Behind	Behind

Shading factor for diffuse: 0.060 and for albedo: 0.305

-This is the table that illustrates the effect of shading of the tall building on the pv panels.



-This is the graph that shows the effects of shading, the dotted lines represent the azimuth angles at which the panels will be shaded because of the tall building. Each line represents how much area is shaded at each angle.

- **The inverter datasheet:**

PARAMETER:								
Model	SW 1KW	SW 1.5 KW	SWW 2KW	SW 3KW	SW 4KW	SW 5KW	SW 6KW	SW 8KW
battery voltage system	12V/24V		12V/24V/48V		24V/48V			48V
INVERTER OUTPUT:								
rated power	1000W	1500W	2000W	3000W	4000W	5000W	6000W	8000W
peak power (20 ms)	3000W	4500W	6000W	9000W	12000W	15000W	18000W	24000W
waveform	Pure sine wave							
AC Voltage Regulation (Battery Mode)	110Vac-220Vac/230Vac/240Vac							