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Peak Sun Hour Analysis of Energy Systems

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Basic concepts for Peak Solar Hours (PSH)

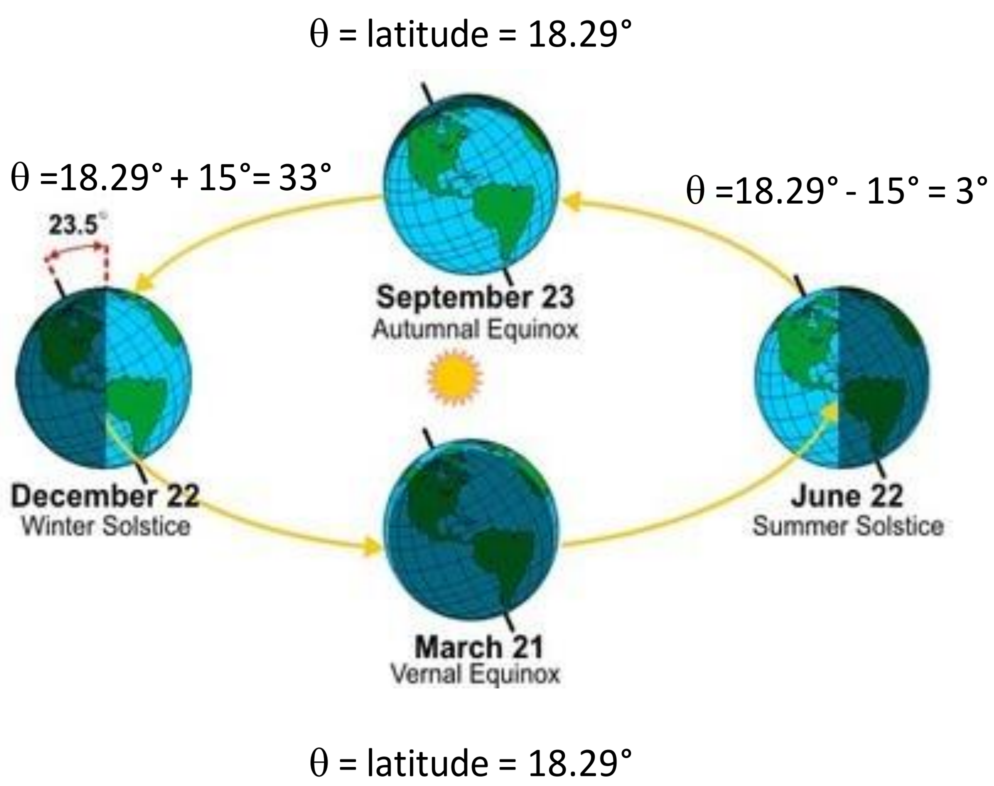
- Overview

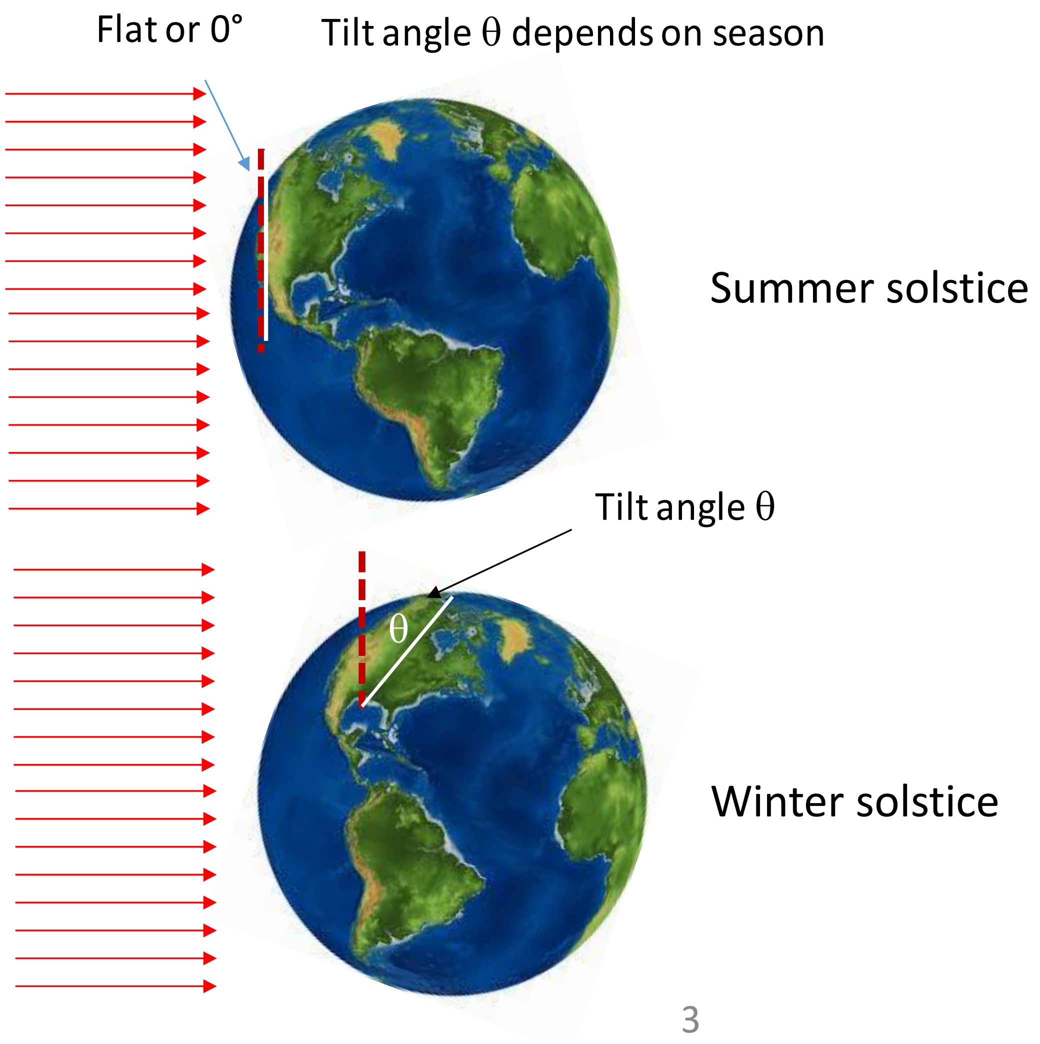
  - **Energy =** Power x time
  - **kWh =** kW x hours
  - **Power =** Energy/time

  Peak solar hours (PSH) have units of time.

  - **Energy =** Power x PSH
  - PSH is the basis for design of PV energy systems

The panel tilt angle depends on the season



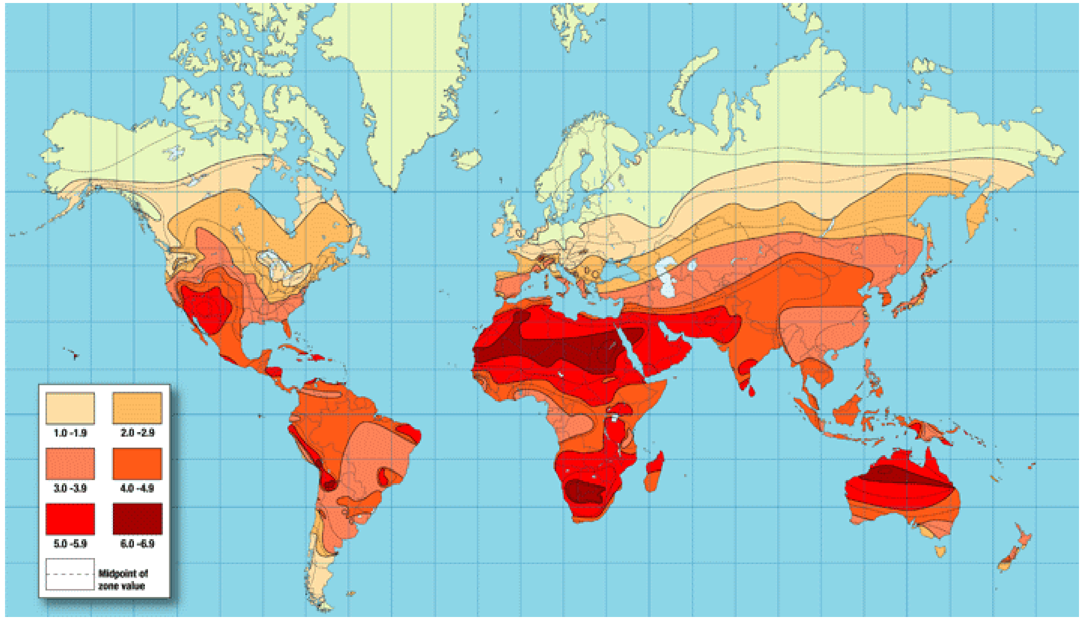


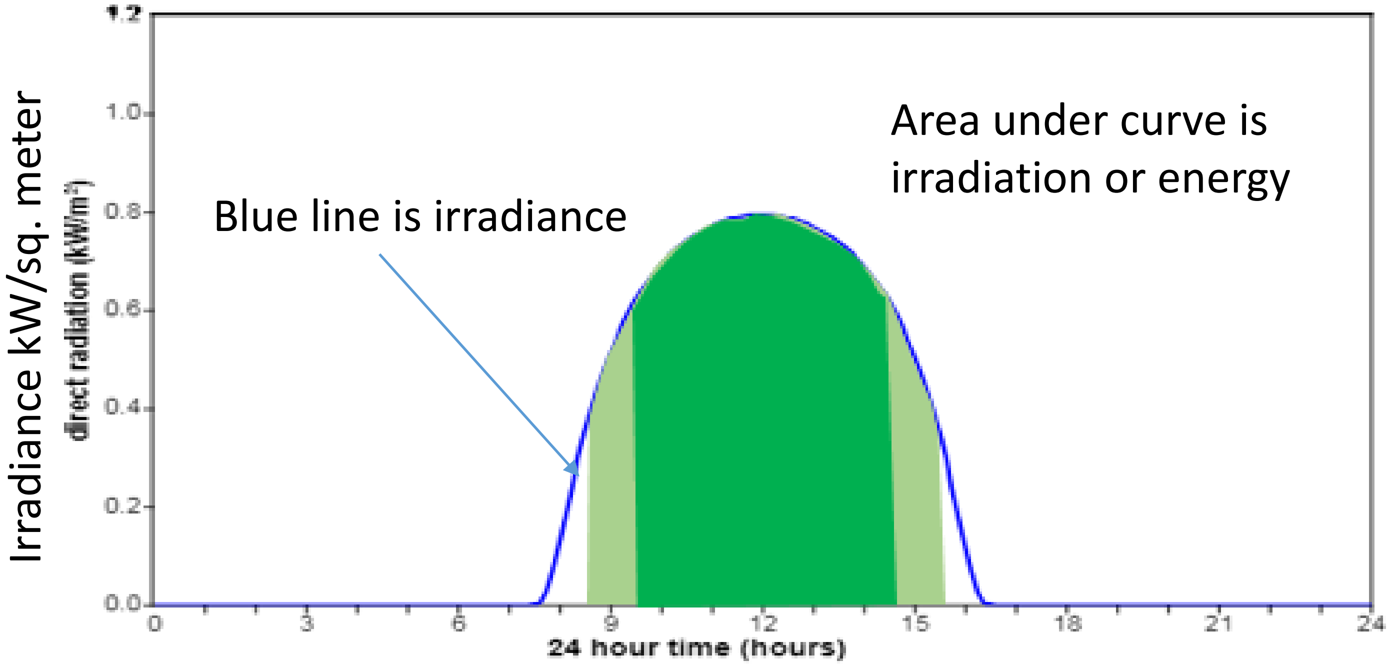
Best tilt angle (θ) for fixed array is latitude (18.29°)

Solar irradiance (power) and irradiation (energy)

Power x time = **Energy**

Irradiance x time = **irradiation** (area under curve)





When time under the curve is a full day, the irradiation is called the insolation.

At 5.4 hrs (green): lowest irradiance: 0.60 kW/m^2

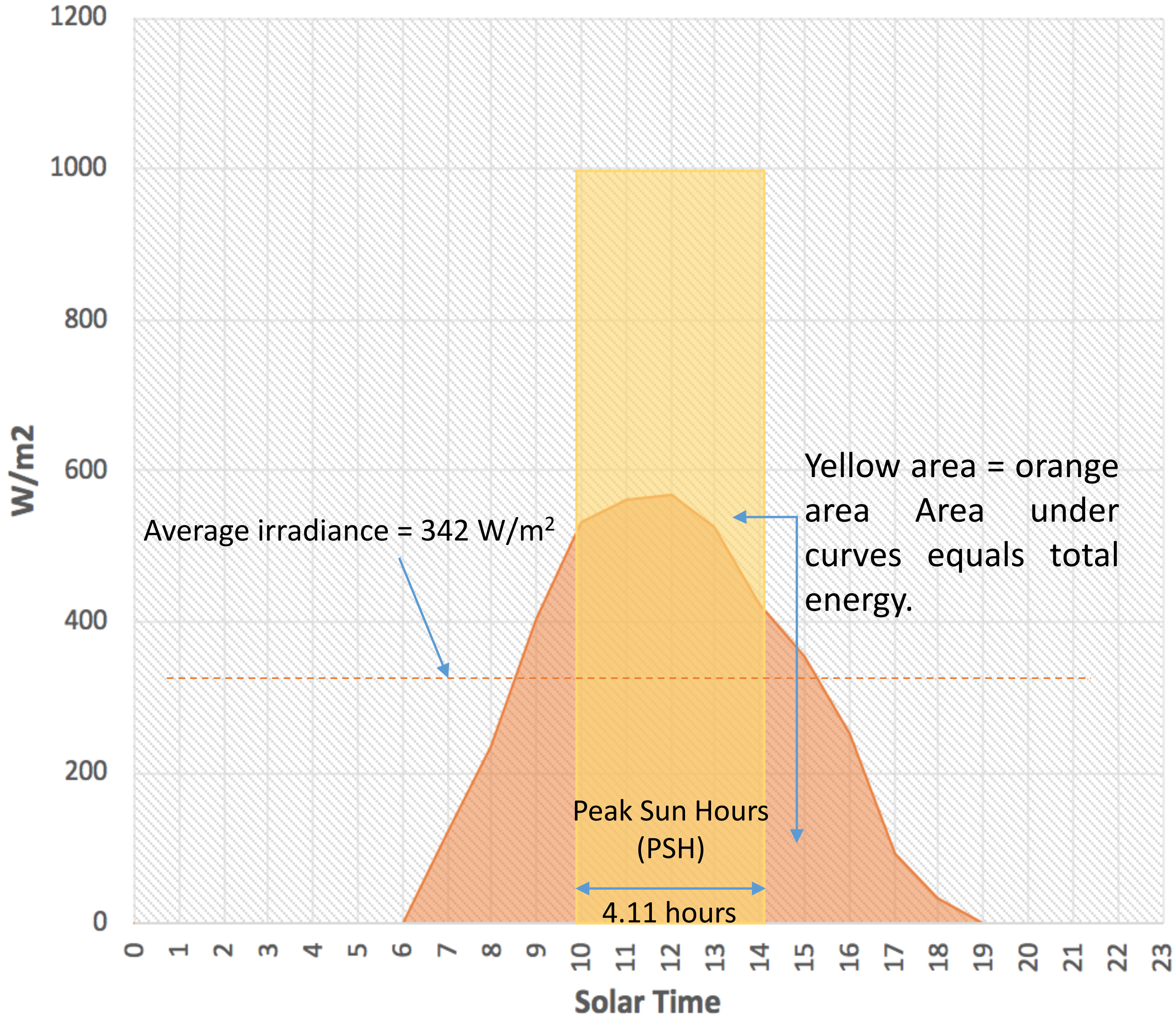
At 7.8 hrs (light green): lowest irradiance: 0.40 kW/m^2. More energy but at low power.

Derivation of Peak Sun Hours

Las Cruces, PR
Location= 18.29°N, 66.2°W
Panel tilt = 18.29°
Design month= November

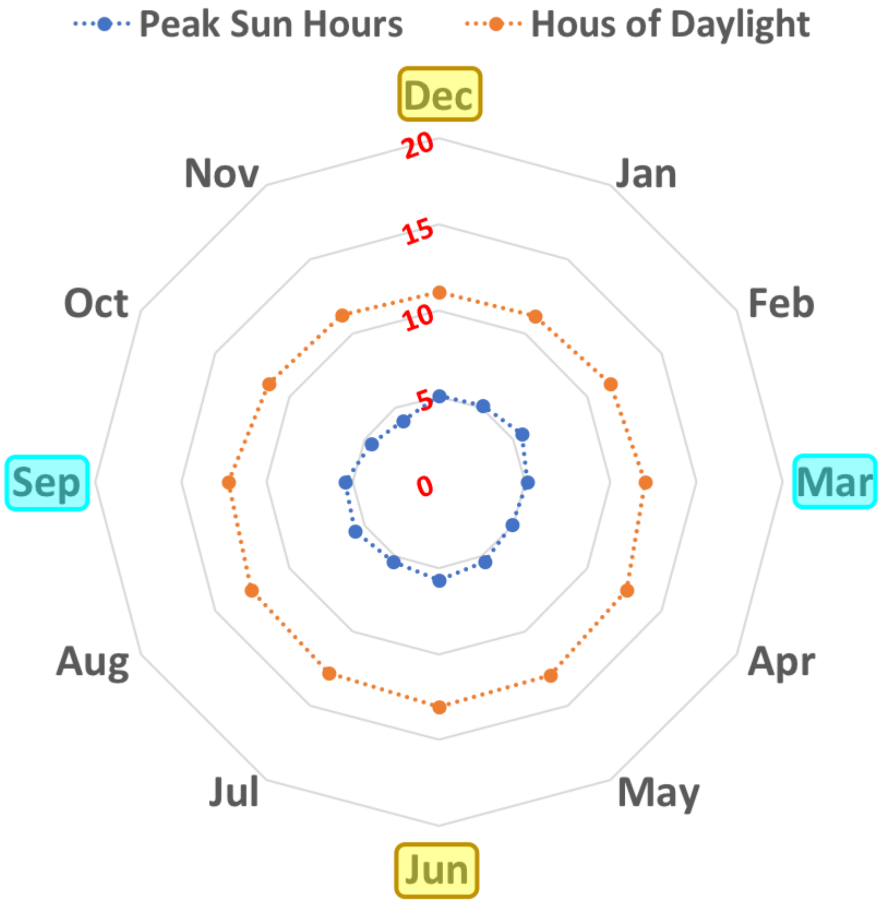
Peak sun hours is # hours at 1 kW/m^2 that provides equal energy as one day of solar irradiance over the same area.

Data from National Solar Radiation Database (NSRDB). Realtime data from site positioned meters.

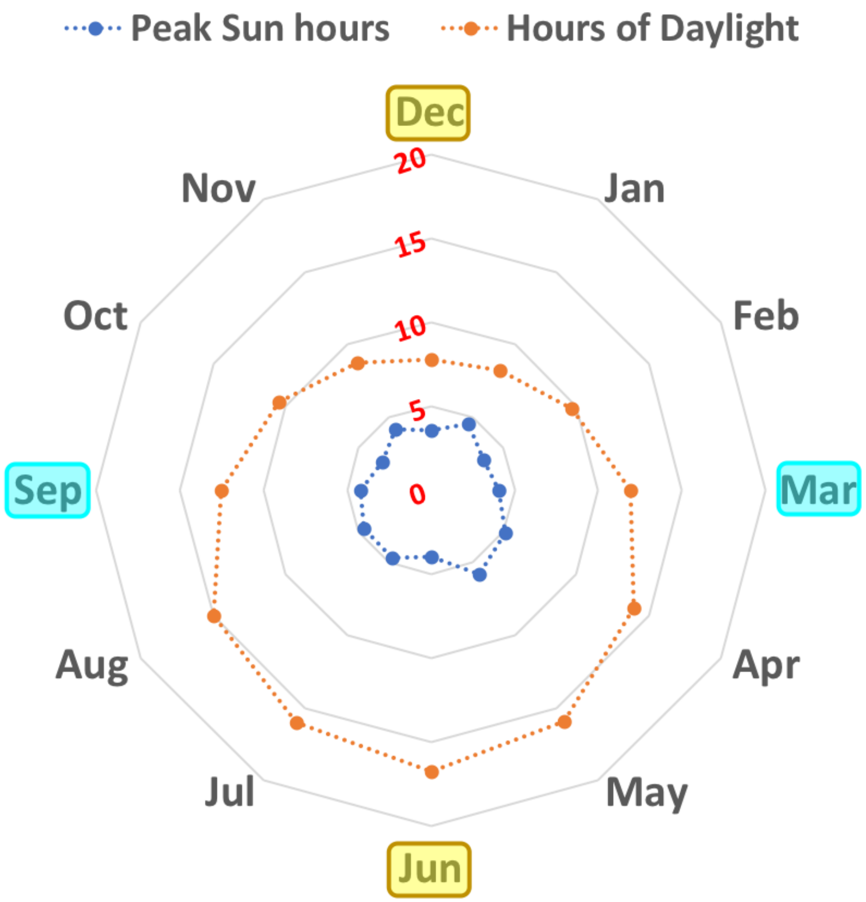


Peak Sun Hours vs Hours of Daylight

Las Cruces, PR
Location= 18.29°N, 66.2°W
Panel tilt = 18.29° = latitude



Goose Bay, Canada
Location= 53.29°N, 60.3°W
Panel tilt = 55.29° = latitude



Solstice

Equinox

Solar Data – San Juan, PR

San Juan, PR				Location: 18.47° N, 66.10° W, 6 Meters									
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Latitude Tilt -15													
Fixed array	5.22	5.85	6.84	7.06	6.41	7.03	7.39	6.62	6.29	5.78	5.07	5.19	6.23
Tracking Array	5.97	6.99	8.50	9.06	8.38	9.15	9.58	8.59	7.98	7.04	5.90	6.24	7.78
Latitude Tilt°													
Fixed array	6.00	6.42	7.08	6.89	6.00	6.44	6.82	6.36	6.36	6.21	5.74	6.08	6.37
Tracking Array	6.90	7.73	8.92	9.00	7.98	8.52	9.01	8.39	8.21	7.66	6.74	7.32	8.03
Latitude Tilt +15													
Fixed array	6.46	6.65	6.96	6.40	5.35	5.58	5.96	5.80	6.12	6.32	6.11	6.64	6.19
Tracking Array	7.36	7.95	8.72	8.33	7.03	7.31	7.83	7.62	7.87	7.75	7.12	7.90	7.73
Two Axis Tracking	7.40	7.96	8.94	9.12	8.40	9.23	9.63	8.61	8.22	7.79	7.15	7.99	8.37

- Equinox   - Solstice   - Tracking mechanism

Solar Data – San Juan, PR

San Juan, PR				Location: 18.43° N				19 Meters					
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Latitude Tilt -15													
Fixed array	4.5	5.1	5.8	6.1	5.7	6.0	6.0	6.0	5.6	5.0	4.5	4.1	5.4
Tracking Array	5.8	6.5	7.5	7.8	7.2	7.5	7.6	7.5	7.0	6.4	5.7	5.2	6.8
Latitude Tilt°													
Fixed array	5.1	5.6	6.1	6.1	5.4	5.5	5.6	5.8	5.7	5.4	5.1	4.8	5.5
Tracking Array	6.3	6.9	7.7	7.8	6.9	7.2	7.3	7.4	7.1	6.7	6.1	5.7	6.9
Latitude Tilt +15													
Fixed array	5.5	5.8	6.0	5.7	4.9	4.8	5.0	5.3	5.5	5.5	5.4	5.2	5.4
Tracking Array	6.6	7.1	7.6	7.5	6.5	6.7	6.8	7.0	7.0	6.7	6.3	6.0	6.8
Two Axis Tracking	6.6	7.1	7.7	7.9	7.2	7.7	7.7	7.6	7.1	6.7	6.4	6.1	7.2

- Equinox - Solstice - Tracking mechanism

Peak sun hours (PSH) govern PV power requirements for grids of any size.

A household grid

Panels only

Energy (kWh) = (PV power) x time
Assume household requires 8 kWh per day and you have 5.5 PSH.
Energy/time **= PV power**

$$\frac{8\ kWh}{5.5\ PSH} = 1.45 \text{ kW array}$$

Assume 300 watt panels: 1450/300 = 4.8. If you bundle all efficiency losses (e.g., 70% efficiency) the number increases to 4.8/0.7 = 6.9 panels. Purchase 7 panels.

7 X 300 X 0.7 = 1.470 kW. 1.47 kW X 5.5 hours = 8.085 kWh

365 X 8.085 = 2951 kWh at $0.20 each is $590/year.

7 panels @ $250/each is $1,750. A tax write-off.

Base amortization is $<$ 3 years.

Addition of batteries

Batteries that deliver 8kWh are optimal to match surge/peak power demand

To maintain the cycle life of the battery, A maximum depth of discharge of 40% is preferred.

8kWh/0.4 = 20kWh

Revised cost of lead acid battery = $2,720

Revised total costs = $4,470.

Revised base amortization is $<$ 8 years.

Water pump

Panels only

Gallons per day (GPD): 27,000
Peak sun hours (PSH): 4.11 hours
Calculate gallons per minute (GPM):

$$\textbf{GPM} = \frac{\text{GPD}}{\underbrace{\text{PSH X 60}}} = \frac{27{,}000}{4.11*60} = 109\ \text{GPM}$$

A standard formula

After some research you find that you need a 10 kW pump.

10 kW X 4.11 PSH = 41.1 kWh/per day.

41.1 X 365 = 15,001 kWh at 20 cents each is $3000 per year

10 kW/(0.3 kW/panel) = 33 panels at $250 each = $8,250.

The amortization period is 3 years

Addition of batteries

A battery pack *that can deliver* 41.1 kWh is optimal to match the power demand.

To maintain the cycle life of the battery, A maximum depth of discharge of 40% is preferred.

41.1/0.4 = 103 kWh

Lead acid battery costs $ 14,000

This increases total costs to $22,250

The amortization period is 7.5 years

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Go to www.TECRE.org for uploads

Thanks