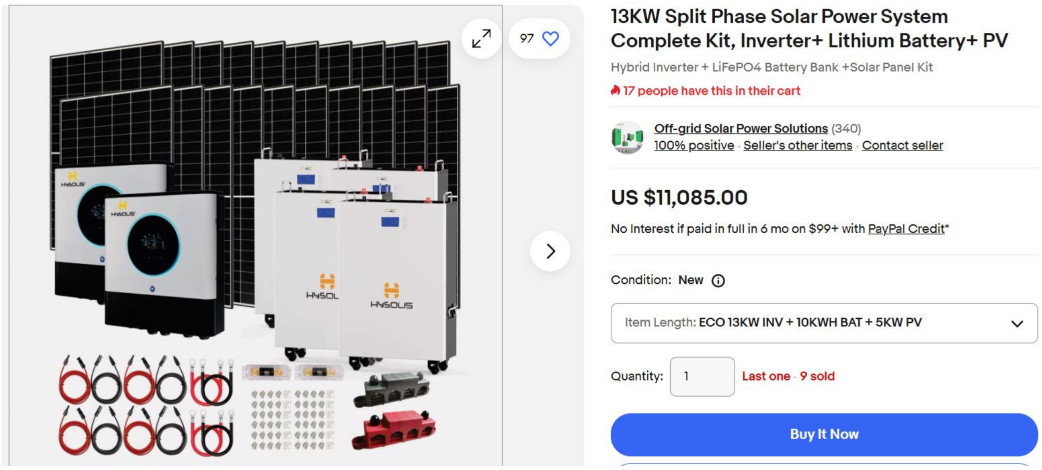
ECE 111 - Homework #5:

Renewable Energy

Due Monday, February 17th. Please submit via email or on BlackBoard

Solar Energy

A 13kW split phase solar power system with a 20kWh battery sells on ebay for $11,085 (January 5, 2025). Is this a good buy?



1) Load 4-weeks worth of solar energy data from NDAWN. (any town in North Dakota or Minnesota). Plot this in MATLAB as wind speed vs hour.

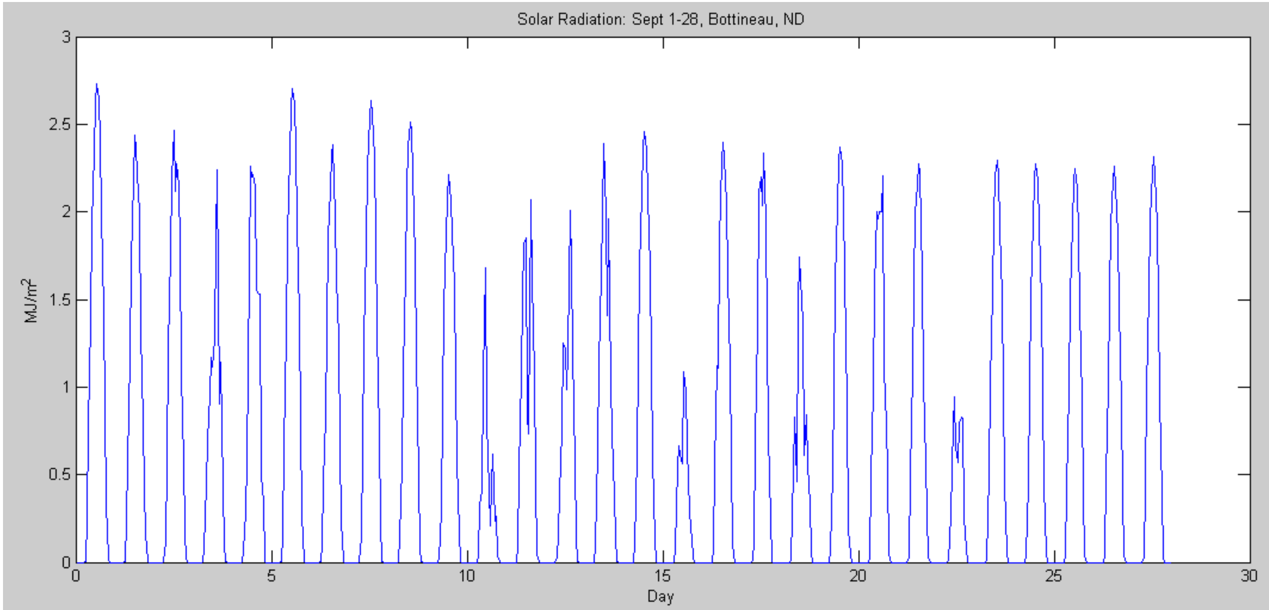
- Month = September or March (around the equinox - kind of a fair date)
- https://ndawn.ndsu.nodak.edu/
- Hourly Data
- Solar Radiation - Total (MJ/m2)

Plot the solar ratiation vs. hour in Matlab

Picking Boteneau, ND for the month of Septemper, 2024

Go to NDAWN, list the average solar radition for Septemper 1 to 28, 2024, and copy into Matlab

```
>> time = Data(:,1);
>> MJ = Data(:,2);
>> size(MJ)

   672      1

>> hr = [1:672]';
>> plot(hr/24, MJ)
>> xlabel('Day');
>> ylabel('MJ/m^2');
>> title('Solar Radiation: Sept 1-28, Bottineau, ND')
```


Solar Radiation: Sept 1-28, Bottineau, ND
MJ/m2
Day
0
0.5
1
1.5
2
2.5
3
0
5
10
15
20
25
30

2) Calculate the kW generated each hour for the array

- 32 panels
- Each panel has an area of 2.00 square meters
- Panel efficiency = 20.5%

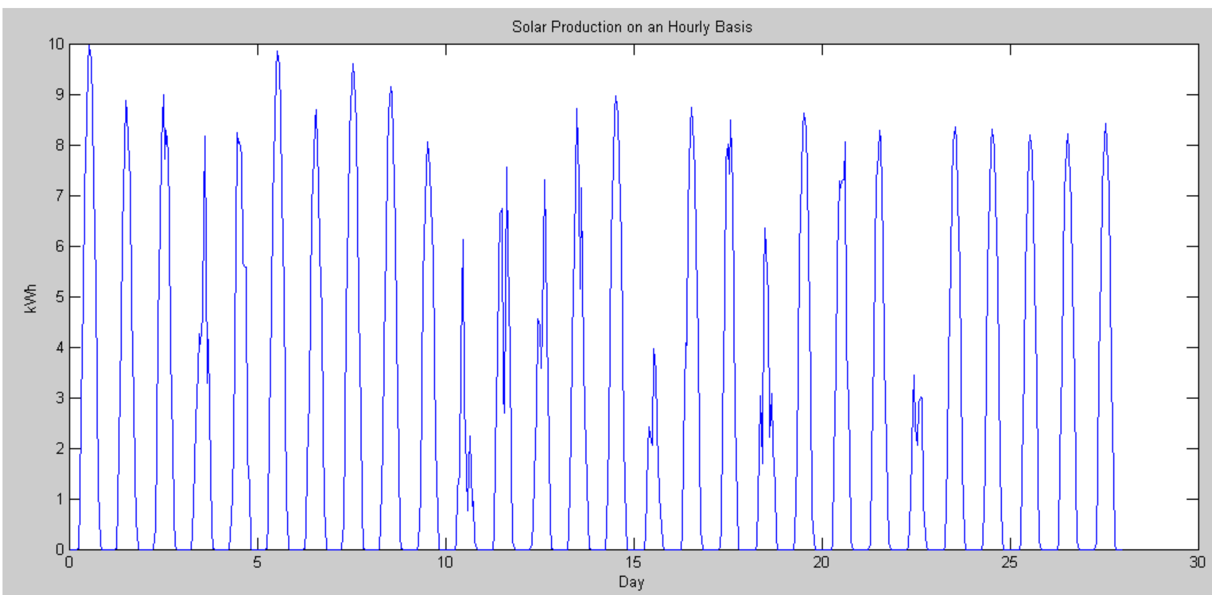
Plot the energy produced on an hourly basis for the month

The conversion from MJ/m^2 to kW is

$$\left(1\frac{MJ}{m^2}\right)\left(\frac{2m^2}{panel}\right)(32\text{ panels})\left(\frac{1{,}000{,}000J}{MJ}\right)\left(\frac{1Wh}{3600J}\right)\left(\frac{1kWh}{1000Wh}\right)(20.5\%) = 3.644kWh$$

In Matlab

```
>> kWh = MJ*3.644;
>> plot(hr/24, kWh)
>> xlabel('Day');
>> ylabel('kWh')
>> title('Solar Production on an Hourly Basis')
```



3) Calculate

- The total energy produced over the month in kWh
- The value of this energy, assuming 11 cents per kWh
- The number of pounds of coal this array offsets over this month (assuming 1.78 lb of coal = 1kWh)

In Matlab: The total energy produced

```
>> % Total Energy
>> kWh = sum(kW)

kWh =  1567.0
```

The total energy produced over these four weeks is 1567.0kWh

The value of the electricity at 11 cents per kWh

```
>> dollars = kWh * 0.11

dollars =   172.37
```

These solar panels would produce $172.37 in electricity over these 28 days

Pounds of coal:

```
>> pounds = sum(kWh) * 1.78

pounds = 2789.2
```

These solar panels would offset 2789 pounds of coal over these 28 days.

4) How many years will it take for this solar panel array to pay for itself?

- Assume each month is the same (kind of iffy)
- How many months (or years) will it take to generate $11,085?

In Matlab, the revenue generated each year would be:

```
>> years = 11085 / (dollars*365/28)

years =  4.9333
```

Based upon this data, it would take 4.933 years for the solar panels to pay for themselves.

- More if you live in North Dakota and you don't use 100% of the energy your produce
- More if you include the installation costs.
- Less if you include the 30% tax credit for solar panels

From a strictly financial standpoint, solar panels are a good investment.

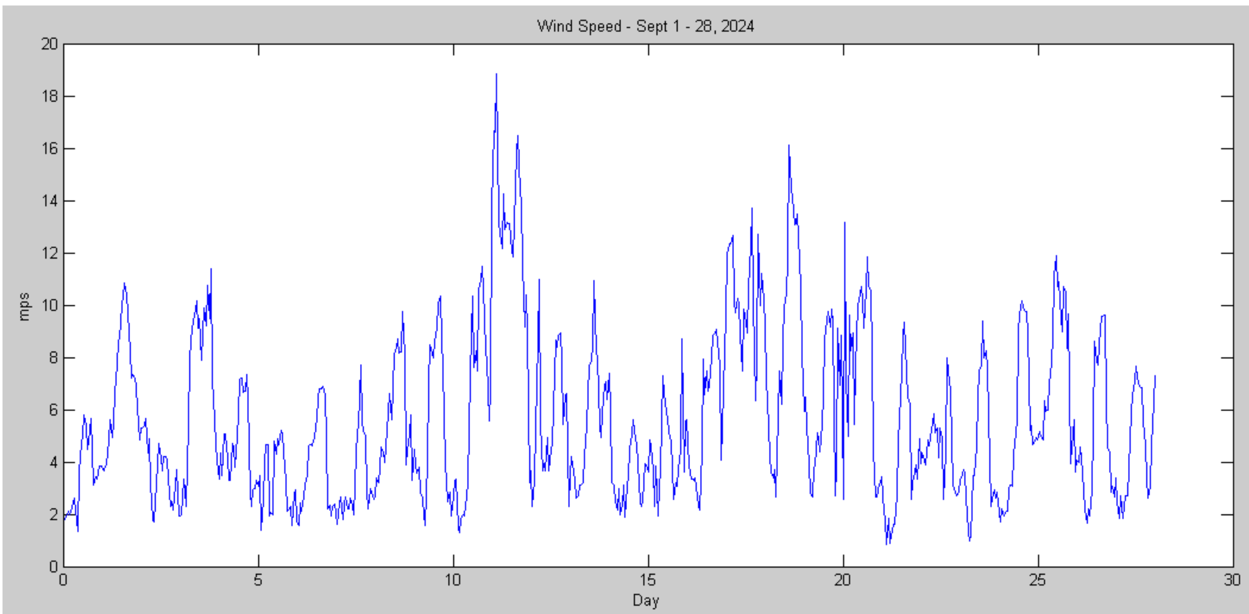
- As solar prices drop, it will be an even better investment in the future

Wind Energy

5) Load the 4-weeks worth of average wind-speed data from NDAWN. (any town in North Dakota or Minnesota). Plot this in MATLAB as wind speed vs hour.

https://ndawn.ndsu.nodak.edu/

```
>> time = Data(:,1);
>> mps = Data(:,2);
>> hr = [1:length(mps)]';
>> plot(hr/24, mps)
>> xlabel('Day');
>> ylabel('mps')
>> title('Wind Speed - Sept 1 - 28, 2024')
```



6) Write a function in Matlab where you pass the wind speed at 136m (about 1.8x the wind speed at the ground) and it returns the power generated by a Vestas V136-3.45 MW

Wind Speed (m/s)	0..3	4	5	6	7	8	9	10	11	12	13+
kW	0	25	238	525	947	1,369	1,901	2,445	2,923	3,260	3,450

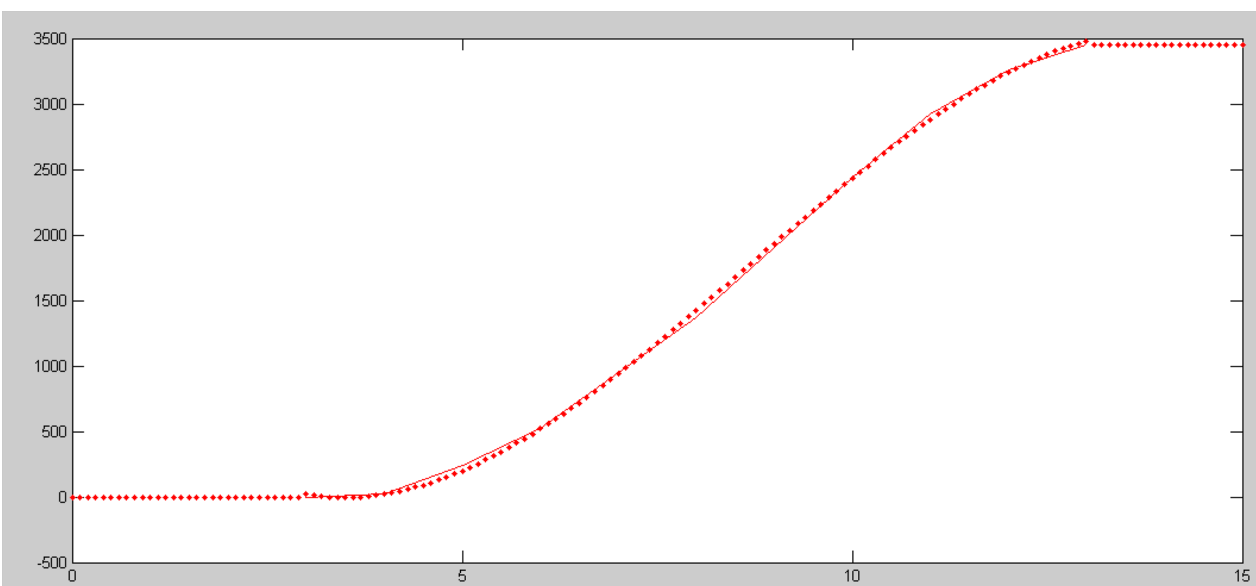
https://nozebra.ipapercms.dk/Vestas/Communication/4mw-platform-brochure/?page=1

6a) Determine a function in Matlab to approximate this curve.

```
function [kW] = PowerCurve( Wind )

x = [3,4,5,6,7,8,9,10,11,12,13]';
y = [0,25,238,525,947,1369,1901,2445,2923,3260,3450]';

B = [x.^3, x.^2, x, x.^0];
A = inv(B'*B)*B'*y;

kW = 0*Wind;
for i=1:length(Wind)
    if(Wind(i) < 3)
        kW(i) = 0;
    elseif(Wind(i) > 13)
        kW(i) = 3450;
    else
        kW(i) = [Wind(i)^3, Wind(i)^2, Wind(i), 1]*A;
    end
end

plot(x,y,'r',Wind,kW,'r.')
end
```

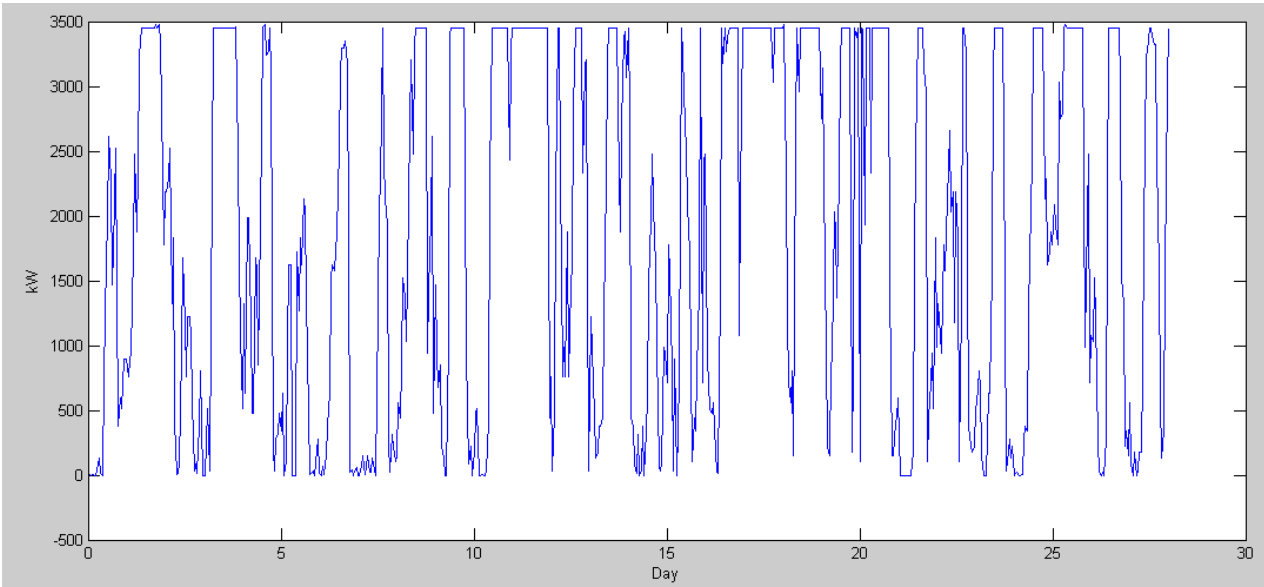
Checking this function from the command window:

```
>> Wind = [0:0.1:15]';
>> kW = PowerCurve(Wind);
```



6b) Use this function to compute how much power a Vestas V136-3.45MW wind turbine would produce from the wind data your found in problem 5.

```
>> kW = PowerCurve(mps*1.8);
>> plot(hr/24, kW)
>> xlabel('Day');
>> ylabel('kW')
```



7) It takes 1.78 pounds of North Dakota lignite coal to produce 1kWh of electricity. How many pounds of coal does this wind turbine offset over 4 weeks?

```
>> kWh = sum(kW)

kWh =   1.2469e+006

>> pounds = 1.78 * kWh

pounds =   2.2195e+006
```

A single wind turbine offsets 2.219 million pounds of coal

8) Assume

- This wind turbine costs $4.48 million to build ($1300 / kW), and
- The value of this energy, assuming 11 cents per kWh
- How long will it take for this wind turbine to pay for itself?

In Matlab

```
>> dollars = kWh * 0.11

ans =  137159
```

Over these 28 days, the wind turbine generates $137,159 in electricity.

The number of years it takes for the wind turbine to pay for itself:

```
>> years = 4.48e6 / (dollars*365/28)

years =     2.5056
```

From a financial standpoint, at 11 cents per kWh, wind energy is a really good investment.

- Even better at 15 cents per kWh (national average price of electricity)