ECE 111 - Homework #5:

Renewable Energy
Due Tuesday, September 26th
Please submit via email, via hard copy, or on BlackBoard

Solar Energy

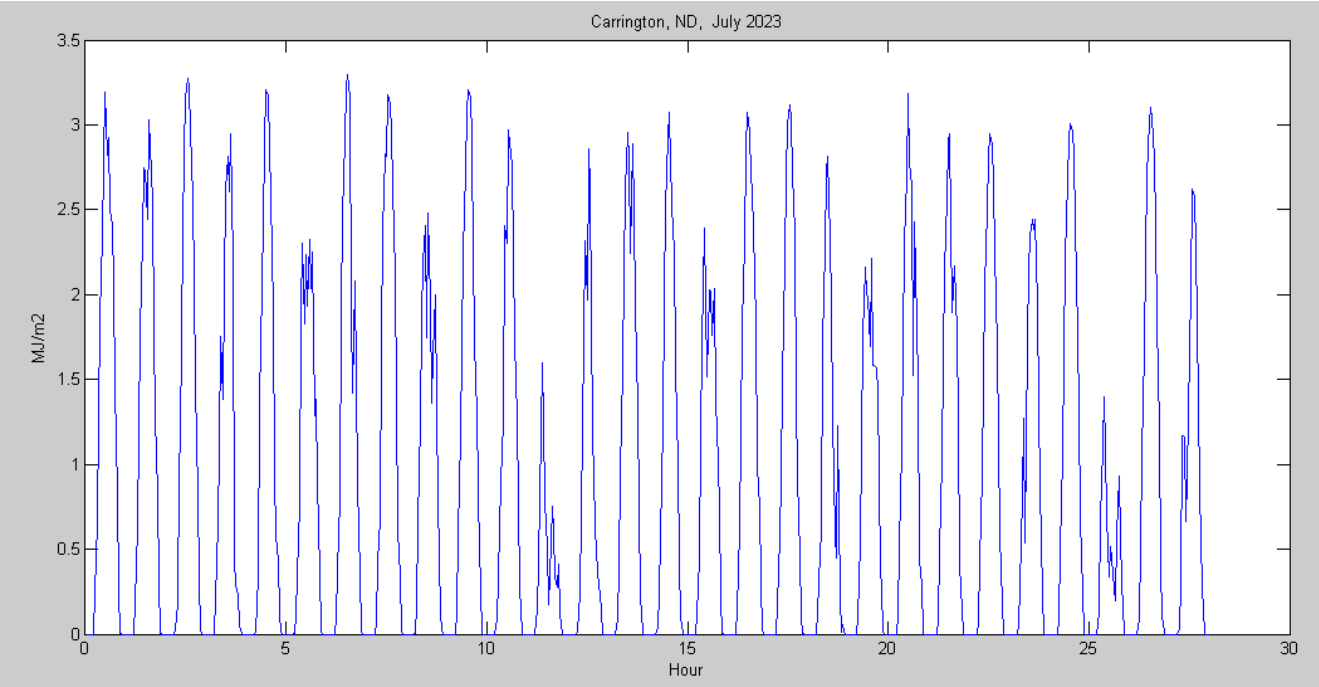
A 13kW split phase solar power system with a 20kWh battery sells on ebay for $18,905 (March 15, 2023). Is this a good buy?

1) Load 4-weeks worth of solar energy data from NDAWN. (close to your home town if you're from North Dakota). Plot this in MATLAB as wind speed vs hour.

- https://ndawn.ndsu.nodak.edu/
- Hourly Data
- Solar Radiation - Total (MJ/m2)
- August, 2022

Plot the solar ratiation vs. hour in Matlab

```
>> size(MJ)

ans =

   672     1

>> hr = [1:672]';
>> plot(hr/24,MJ)
>> xlabel('Hour');
>> ylabel('MJ/m2');
>> title('Carrington, ND,  July 2023')
```



2) Calculate the kW generated each hour for the array

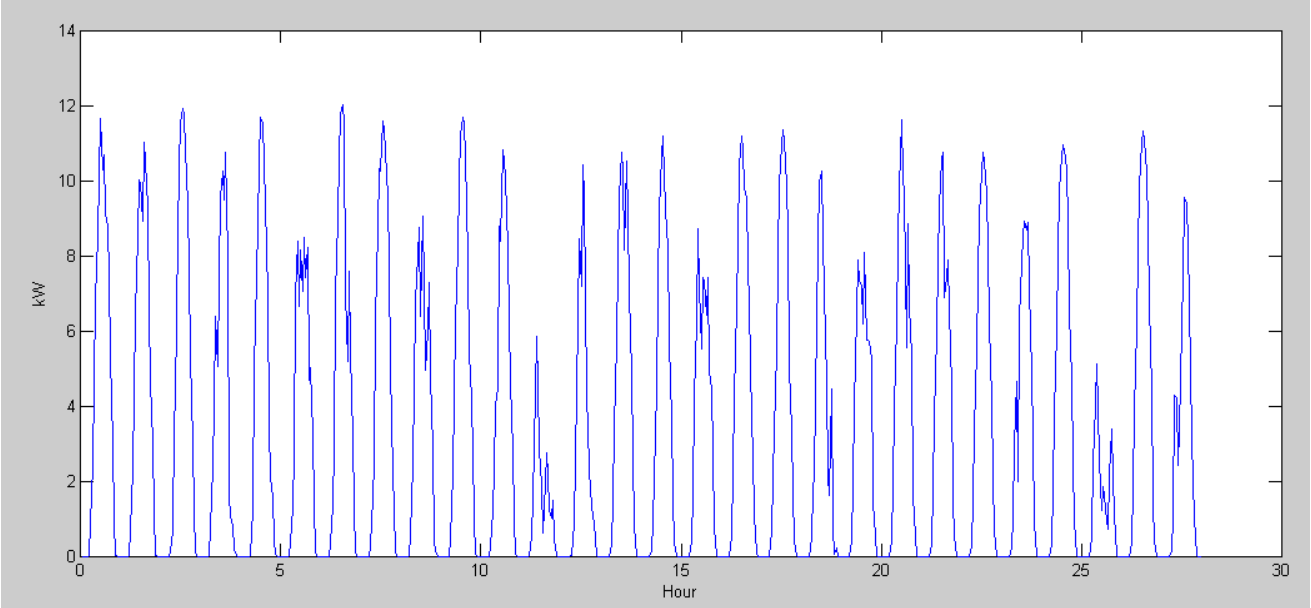
- 32 panels
- Each panel has an area of 2.00 square meters
- Panel efficiency = 20.5%

Plot the energy produced on an hourly basis for the month of August

First, convert MJ/m2 to kWh

$$\left(1\frac{MJ}{m^2}\right)(64m^2)\left(\frac{1{,}000{,}000J}{MJ}\right)\left(\frac{1Wh}{3600J}\right)\left(\frac{1kWh}{1000Wh}\right)(0.205) = 3.644kWh$$

```
>> kW = MJ * 3.644;
>> plot(hr/24,kW)
>> xlabel('Hour');
>> ylabel('kW')
```



3) Calculate

- The total energy produced over the month of August in kWh

```
>> kWh = sum(kW) * 1

kWh =  2.3136e+003
```

- The value of this energy, assuming Excel Energy's time-of-day metering and net-metering:
  - $0.15340 / kWh from 9am to 9pm
  - $0.02559 / kWh otherwise

```
>> Time = [1:672]';
>> hr = mod(Time, 24);
>> peak = 1*(hr>8).*(hr<21);
>> offpeak = 1-peak;
>> Dollars = sum(kW .* peak)*0.15340 + sum(kW .* offpeak)*0.02559

Dollars =  334.9638
```

In the month of July, 2023, these panels would generate $334.96 in revenue

- The number of pounds of coal this array offsets over this month (assuming 1.78 lb of coal = 1kWh)

```
>> Pounds = kWh * 1.78

Pounds =  4118.2
```

And offset 4118 pounds of coal

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

- Assume each month is like August (kind of iffy)
- How many months (or years) will it take to generate $18,905?

```
>> Weeks = 18905 / ( Dollars / 4)

Weeks =  225.7557

>> Years = Weeks / 52

Years =    4.3415
```

In Minnesota, these panels would pay for themselves in 4.34 years

Note:

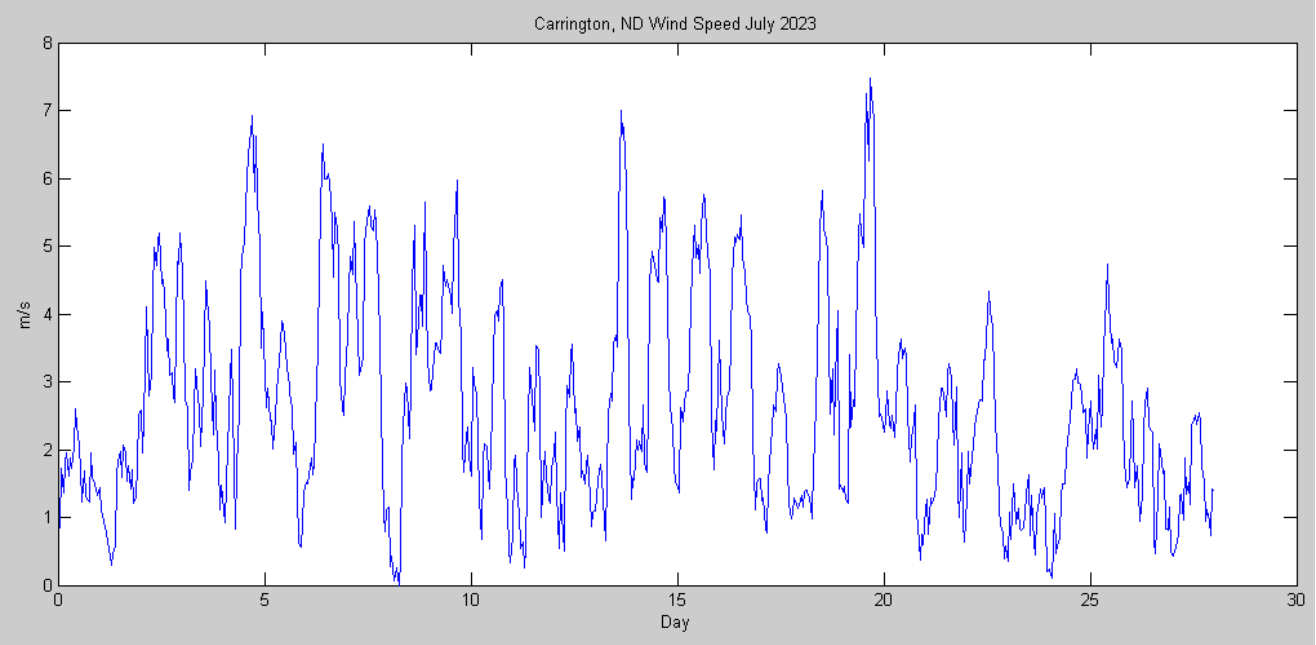
- If you include installation costs, this number will go up
- If you live in North Dakota, this number will go up
- If you do a full year (rather than saying all months are like July), this number will go up

Wind Energy

5) Load the 4-weeks worth of wind-speed data from NDAWN. (close to your home town if you're from North Dakota). Plot this in MATLAB as wind speed vs hour.

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

```
>> size(Wind)

ans =

   672     1

>> day = [1:672]' / 24;
>> plot(day,Wind)
>> xlabel('Day');
>> ylabel('m/s');
>> title('Carrington, ND Wind Speed July 2023');
```



6) Write a function in Matlab where you pass the wind speed at 180m (about 2.2x the wind speed at the ground) and it returns the power generated by a Vestas V163-4.5 MW

Wind Speed (m/s)	0..3	4	5	6	7	8	9	10	11	12	13+
kW	0	33	310	685	1,235	1,786	2,480	3,189	3,813	4,252	4,500

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

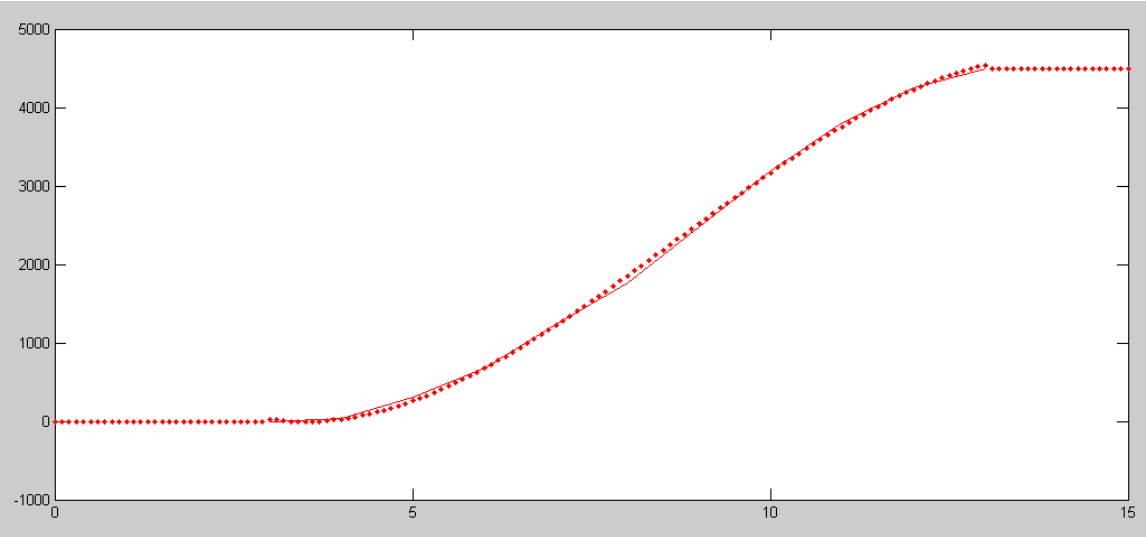
6a) Determine a function in Matlab to approximate this curve.

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

x = [3,4,5,6,7,8,9,10,11,12,13]';
y = [0,33,310,685,1235,1768,2480,3189,3813,4252,4500]';
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) = 4500;
    else
        kW(i) = [Wind(i)^3, Wind(i)^2, Wind(i), 1]*A;
    end
end

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

Check: Compare the function vs. the data from 0..15 m/s wind speed

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

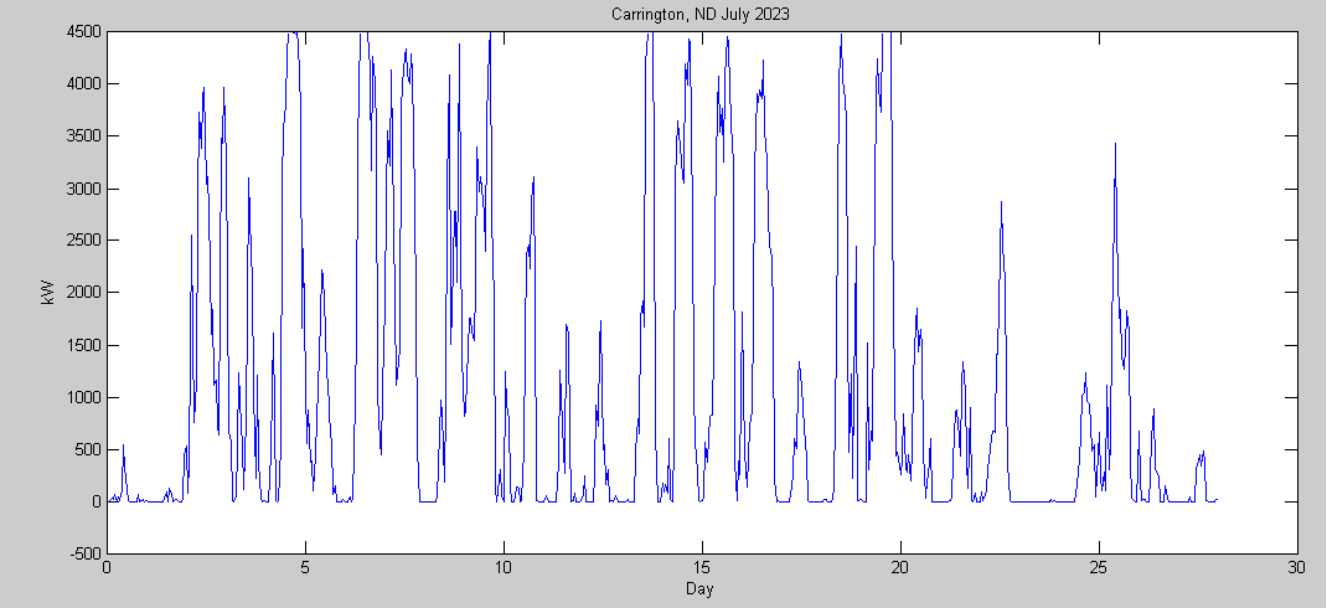
The dotted line (curve fit) matches the solid line (power curve) pretty well



6b) Use this function to compute how much power a Vestas V163-4.5MW wind turbine would produce from the wind data your found in problem 3.

```
>> kW = PowerCurve(Wind * 2.2);
>> plot(day, kW);
>> xlabel('Day');
>> ylabel('kW');
>> title('Carrington, ND July 2023');
>> kWh = sum(kW)

kWh =  7.2857e+005
```

Over this 4-week span, the wind turbine would produce 728,570 kWh of electricity



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 =  7.2857e+005

>> Pounds = kWh * 1.78

Pounds =  1.2968e+006
```

This wind turbine offsets 1,296,800 pounds of coal over this four-week span

8) Assume

- This wind turbine costs $5.85 million to build ($1300 / kW), and
- The value of this energy, assuming Excel Energy's time-of-day metering and net-metering:
  - $0.15340 / kWh from 9am to 9pm
  - $0.02559 / kWh otherwise

How long will it take for this wind turbine to pay for itself?

```
>> X = [1:672]';
>> hr = mod(X, 24);
>> peak = 1*(hr>8).*(hr<21);
>> offpeak = 1-peak;
>> Dollars = sum(kW .* peak)*0.15340 + sum(kW .* offpeak)*0.02559

Dollars =  9.1321e+004
```

This wind turbine generates $92,321 over these four weeks

```
>> Weeks = 5.85e6 / ( Dollars / 4)

Weeks =  256.2403

>> Years = Weeks / 52

Years =    4.9277
```

At this rate, it will take 4.92 years for the wind turbine to pay for itself.

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