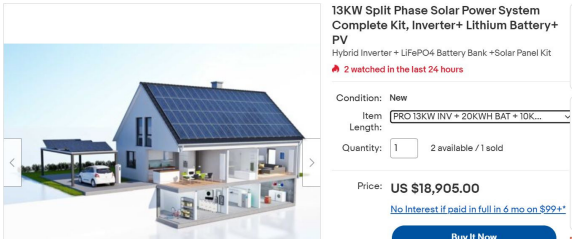
ECE 111 - Homework #5:

Renewable Energy

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?

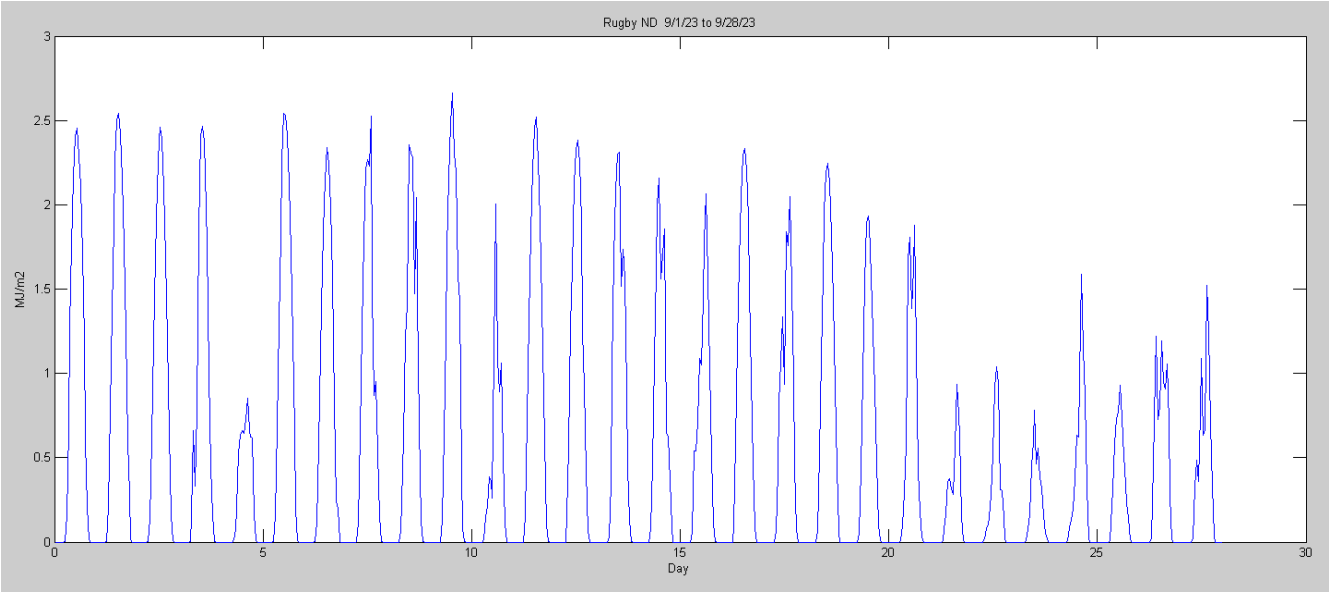


1) Load 4-weeks worth of solar energy data from NDAWN. (any town in North Dakota or Minnesota). Plot this in MATLAB as wind speed vs hour.

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

Plot the solar ratiation vs. hour in Matlab

```
>> SUN = [  <paste>  ];
>> length(SUN)

   672

>> plot(hr/24, MJ)
>> xlabel('Day');
>> ylabel('MJ/m2');
>> title('Rugby ND  9/1/23 to 9/28/23')>>
```



2) Calculate the kW generated each hour for the array

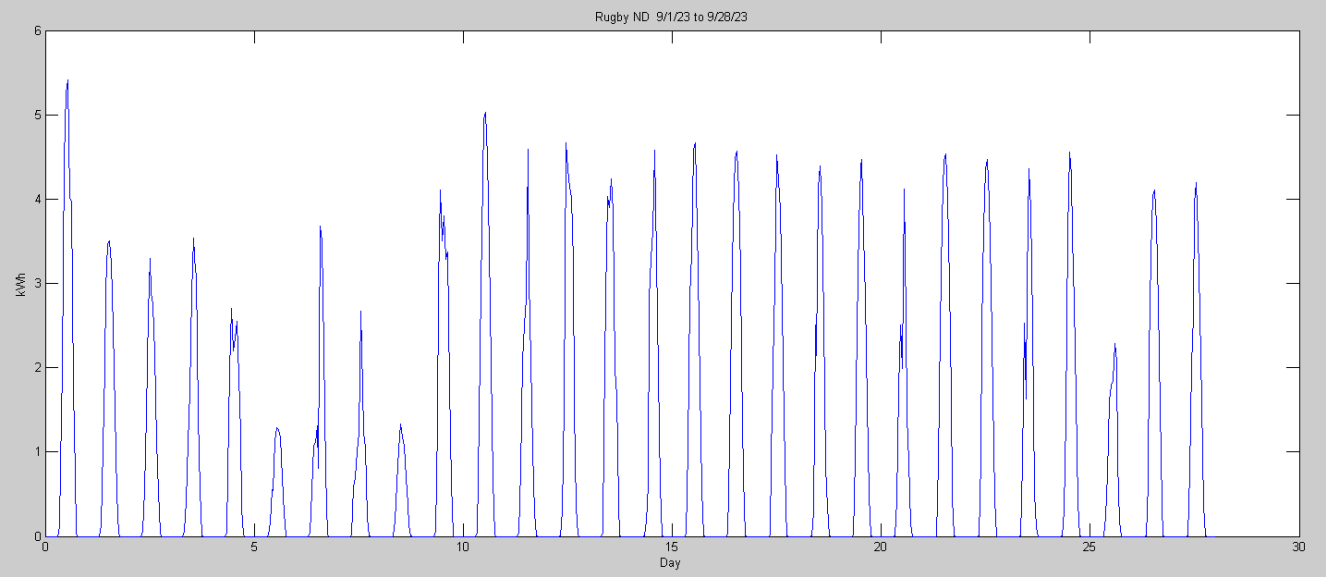
- 32 panels
- Each panel has an area of 2.00 square meters
- Panel efficiency = 20.5%

Plot the energy produced on an hourly basis for the month

Converting MJ/m2 to kWh

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

```
>> MJ = SUN;
>> kW = MJ * 3.6444;
>> plot(hr/24, kW)
>> xlabel('Day');
>> ylabel('kWh');
>> title('Rugby ND  9/1/23 to 9/28/23')
```



3) Calculate

The total energy produced over the month in kWh

```
>> kW = MJ * 3.6444;
>> kWh = sum(kW)

kWh =  1.3563e+003
```

Over the month of September, the array produces 1,356.3 kWh

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

```
>> hr24 = mod(hr,24);
>> peak = 1*(hr24>=9).*(hr24<21);
>> offpeak = 1 - peak;
>> Dollars = 0.15340*sum(kW .* peak) + 0.02559*sum(kW .* offpeak)

Dollars =   201.6269
```

Having the solar array on your house would reduce your utility bill by $201.62

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

```
>> Pounds = 1.78 * kWh

Pounds =  2414.2
```

Over the month of November, the array's energy output offsets 2,414.2 pounds of coal

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 $18,905?

```
>> years = 18905 / (Dollars * 365 / 28)

years =   7.1927
```

Assuming every month is like September, it will take 7.19 years for the solar array to pay for itself.

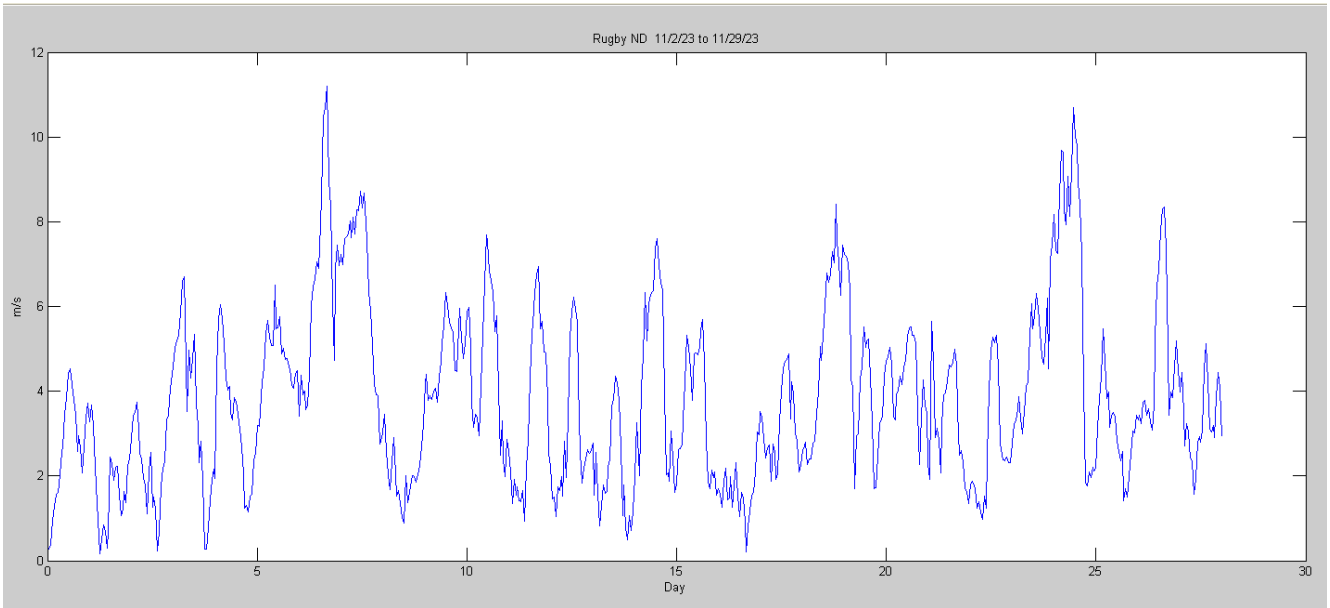
- Less if you take into account the 30% tax credit you get for installing the panels
- More if you include installation costs

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/

```
>> Wind = [  <paste>  ];
>> size(Wind)

   672     1

>> hr = [1:672]';
>> plot(hr/24, Wind)
>> xlabel('Day');
>> ylabel('m/s');
>> title('Rugby ND  11/2/23 to 11/29/23')
```



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

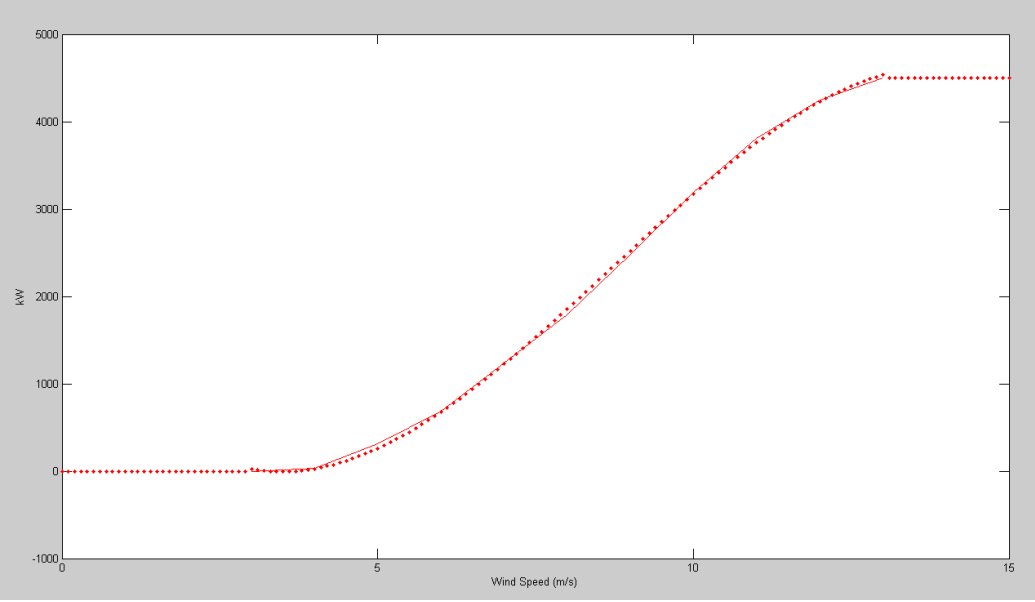
https://nozebra.ipapercms.dk/Vestas/Communication/4mw-platform-brochure/?page=1

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 = [0,33,310,685,1235,1786,2480,3189,3813,4252,4500]';
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 for wind speeds from 0 to 15 m/s

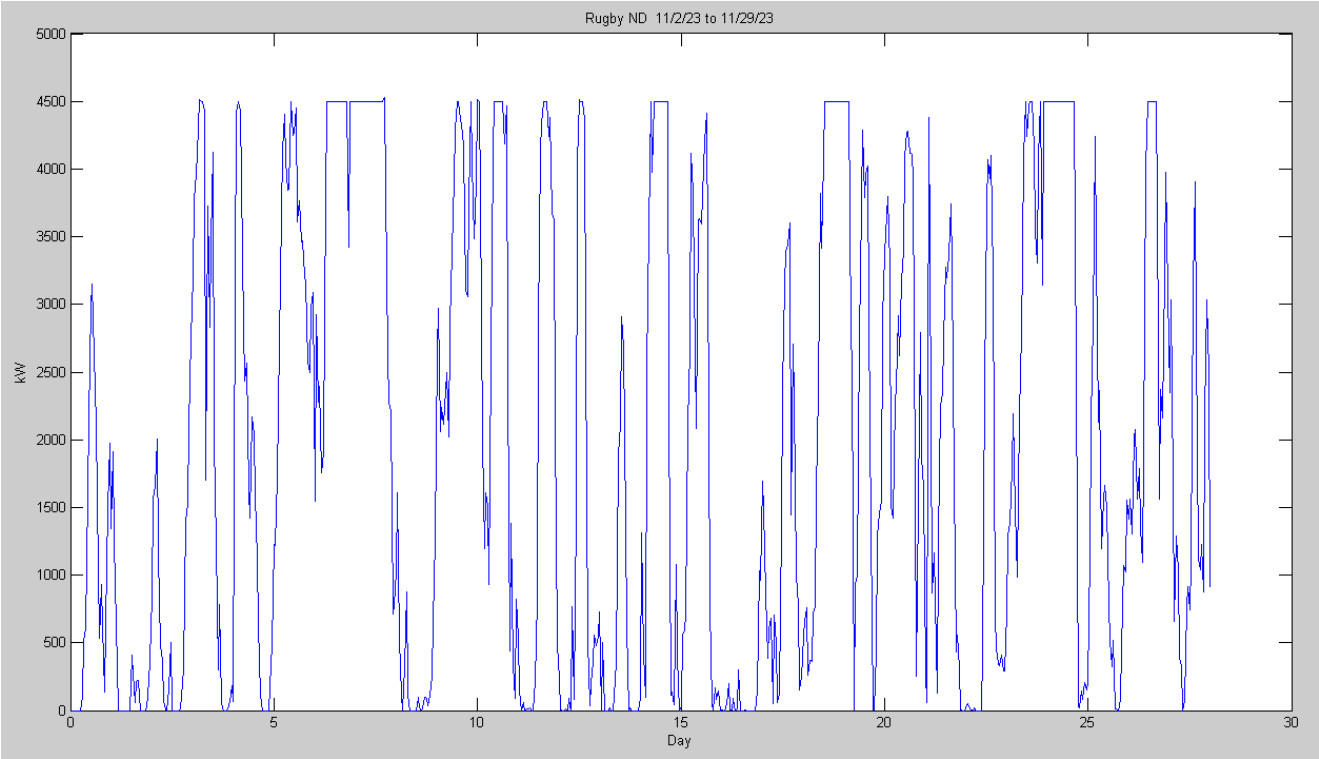
```
>> X = [0:0.1:15]';
>> kW = PowerCurve(X);
>> xlabel('Wind Speed (m/s)');
>> ylabel('kW');
```



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(hr/24, kW)
>> xlabel('Day');
>> ylabel('kW');
>> ylim([0,5000]);
>> title('Rugby ND  11/2/23 to 11/29/23')
>> kWh = sum(kW)

kWh =  1.3460e+006
```

Over these 28 days, a Vestas V163-4.5 wind turbine would produce 1,3460,000 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 =  1.3460e+006

>> Pounds = kWh * 1.78

Pounds =  2.3958e+006
```

Over these 28 days, a single Vestas wind turbine would offset 2,395,800 pounds of coal (!!)

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?

```
>> hr24 = mod(hr,24);
>> peak = 1*(hr24>=9).*(hr24<21);
>> offpeak = 1 - peak;
>> Dollars = 0.15340*sum(kW .* peak) + 0.02559*sum(kW .* offpeak)

Dollars =  1.3465e+005

>> years = 5.85e6 / (Dollars * 365 / 28)

years =    3.3328
```

A single wind turbine would generate $134,650 in revenue

- assuming you're getting time-of-day metering

At this rate, it would take 3.33 years for the wind turbine to pay for itself

- it's a good investment from a purely economic standpoint
- less if you take into account tax credits for renewable energy

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