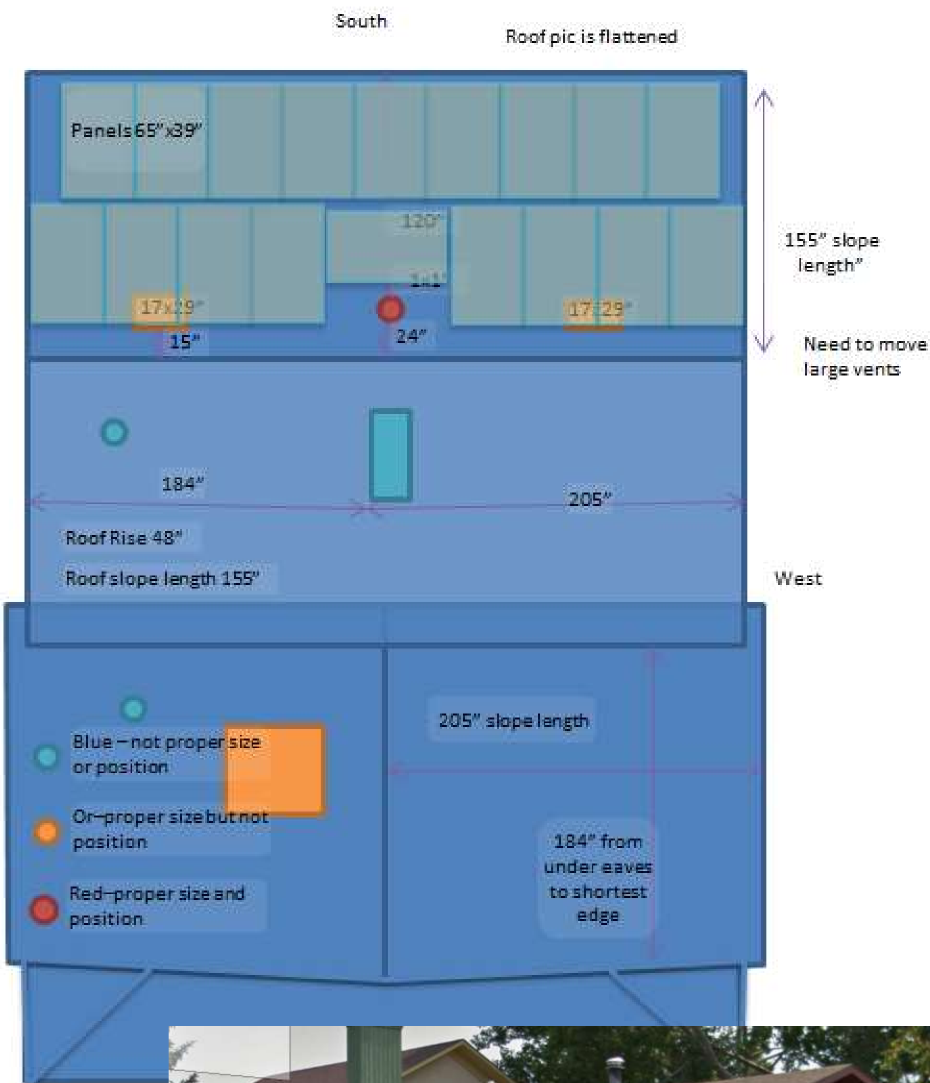
Solar Panels on the Roof?

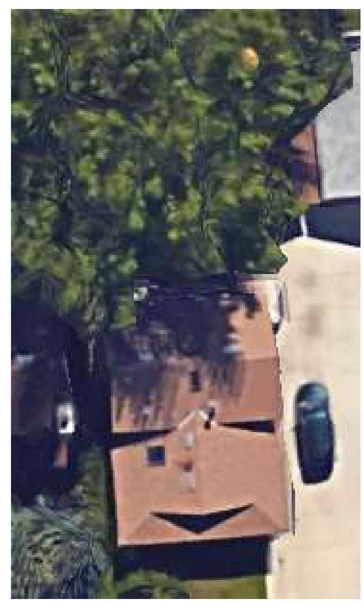
This paper is to simlpy use the calcs in the Solar Handbook, with a few missing peices added in so that we can use ANYONE's house and angles etc. and figure things out. I live in Calgary, which is 50 degrees N and the Solar Handbook's examples are London England which is 51 degress N . There are a lot more sources used, but the Solar Handbook is close to all of them.

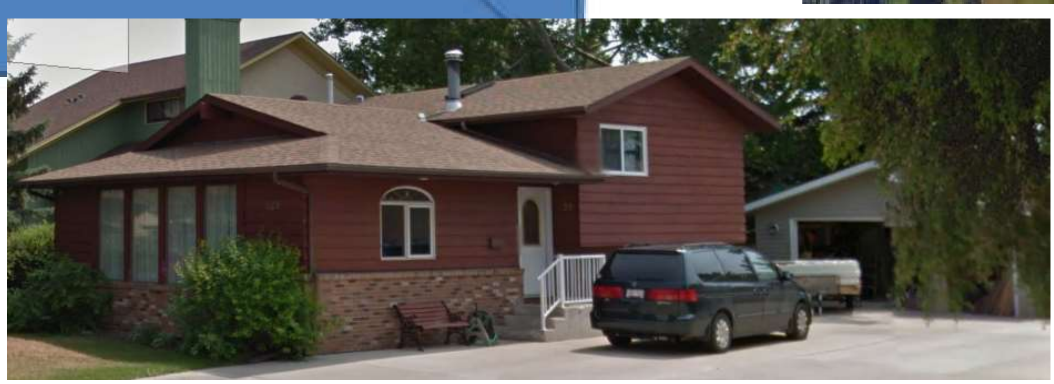
You can see my roof (flattened so w can see things better) drawn pretty much to scale with the eventual solar panels on the roof. The number of panels is what this whole paper is about. (TODO: malabel long rect. skylights, whirly gigs and rect. & pipe vents on roof.)

This paper calculates the amount of $$ made, and I have to still add the $$ spent to see how much money this will cost and how long it will take to pay back. All amounts are in Canadian dollars.



The tree is obviously an issue, but it is a poplar and has SINCE HAS BEEN TAKEN DOWN.
IT IS NOT THERE ANY MORE.





Input Variables

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The cost of electricity at my fixed rate is $CperKwH := 5.999$

The solar panels sizes are $l := 65\ in$ $w := 39\ in$ w. area $l \cdot w = 1.6355\ m^2$

The main roof size: $lroof := 155\ in$ $wroof := 184\ in + 205\ in$ $wroof = 389\ in$

I climbed the roof, but you could use atan(rise/run) where run is dist ALONG THE GROUND from peak of the roof to the gutter end. Because I went ON the roof, I am using the formula below.

vertical roof rise: $r := 48\ in$ which is 6 peices of siding at 8" per piece

$$\Theta roof := 90\ deg - acos\left(\frac{r}{lroof}\right) \qquad \Theta roof = 18.0398\ deg$$

At the end of the day, lets figure out the overall efficiency for all the parts

Solar Array Up/Down inefficiency

Using the spreadsheet provided, the worst efficiency is in the winter at

$$\eta ra := .80$$

Solar Array East/West facing inefficiency

In the Solar Handbook, they say the angle degrades linearly, but really, it is a formula that is based on a cosine. Lets take the data given and make a cosine function that represents the same data.

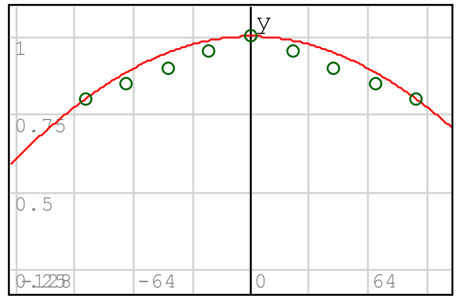
$$xv := -90, -90 + \frac{45}{2} .. 90 \cdot 1 \qquad yv := \begin{bmatrix} 80 \\ 85 \\ 90 \\ 95 \\ 100 \\ 95 \\ 90 \\ 85 \\ 80 \end{bmatrix} \%$$

```
plotG(x, y, char, size, color) := | plot := augment(x_1, y_1, char, size, color)
                                  | for i ∈ 2 .. length(x)
                                  |   plot := stack(plot, augment(x_i, y_i, char, size, color))
                                  | plot
```

plotA := plotG(xv, yv, "o", 10, "dark green")

$A := 1$ $B := .0072$

$few(x) := A \cdot cos(B \cdot x)$ Efficiency factor of panels not being due south



plotA
few(x)

$\eta ew := few(5)$ My solar panels face a little east - but a lot south

$\eta ew = 99.9352\ \%$

Solar Array power point efficiencies

Are you using MPPT controler / inverter? If so, then another inefficiency is 90%.
We will be using a grid tie inverter - so it will be this value.

$\eta ctrlr := 90\ \%$

Solar Array temperature effects

In Canada this is not an issue.

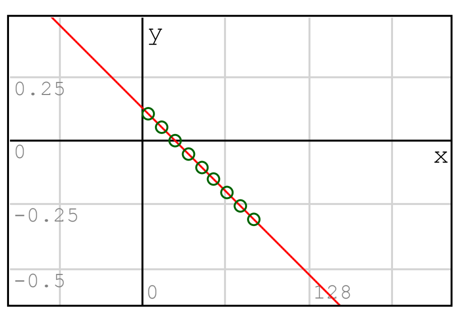
$xt := 5, 15 .. 85$

$yt := \begin{bmatrix} 10 \\ 5 \\ 0 \\ -5 \\ -10 \\ -15 \\ -20 \\ -25 \\ -30 \end{bmatrix} \%$

plotT := plotG(xt, yt, "o", 10, "dark green")

$mm := -.005 \quad b := 0.125$

$ftemp(x) := (mm) \cdot x + b$ Efficiency factor of panels on Temperature



plotT
ftemp(x)

Efficiency factor of panels on Temperature - we assume 25deg C for Calgary

$$\eta temp := 1 + ftemp\left(25 \cdot 1.4\right)$$

$$\eta temp = 0.95$$

As the book says, ensure 7-10cm of air below the panels is maintained for cooling

So putting it all together,

$$\eta total := \eta ctrlr \cdot \eta ew \cdot \eta ra \cdot \eta temp$$

$$\eta total = 0.6836$$

So, I am planning on maxing out my panel wattage allowed, so my solar panels will be about which means, we need to make our Solar Array

$$ftotal := \frac{1}{\eta total} = 1.4629$$

this much bigger than the amount we need.

If we estimate the costs of the Solar Panels, lets talk in general terms as per the handboo, then use real $ figures.

we can have this many panels

$\frac{lroof}{l} = 2.3846$ panels up $\frac{wroof}{w} = 9.9744$ panels accross

We have 2 panels up / down and 9 accross or 18 panels acting like

$PanelsUp := 2$

$PanelsAcc := 9$

If each panel can ideally provide

$Ppanel := 265\ W$

$Ppanel\eta := Ppanel \cdot \eta total$

In our installation, it only provides

$Ppanel\eta = 181.1426\ W$

and totals

$Ppanel\eta \cdot 2 \cdot 9 = 3260.566\ W$

Now if we tilt the top row of panels to the optimal, we take out ηra (TODO: Calc shadow overlap)

$$Ppanel\eta 1 := Ppanel \cdot \frac{\eta total}{\eta ra} \cdot 9 + Ppanel\eta \cdot 9 = 3668.1368\ W$$

The costs at solarwholesaler.ca (CDN$)

Panel Cost

$Pcost := 18 \cdot 279 = 5022$

Micro inverter cost

$MiCost := \frac{18}{2} \cdot 350 = 3150$

$RailCost := 2 \cdot 994 = 1988$

$CableCost := 500 = 500$

$TotalCost := Pcost + MiCost + RailCost + CableCost = 10660$

Or they sell a kit ... 4770W NEP 500W Micro Inverter Gridtie Kit (Poly)

$KitCost := 8936$ for 18 panels at 265W each

How much money will the panels make at our rate?

$$CostPower := \frac{\frac{CperKwH}{100}}{1\,hr \cdot 1\,kW}$$

each month from ... we get the following hours every month

$$hours1 := \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} \cdot 30.4$$

$$hours1 = \begin{bmatrix} 30.4 & 30.4 & 30.4 & 30.4 & 30.4 & 30.4 & 30.4 & 30.4 & 30.4 & 30.4 & \ldots \end{bmatrix}$$

$$hhours2 := hours1 \cdot 18 \cdot w \cdot l \cdot \frac{1}{m} \cdot \frac{1}{m}$$

Two axis tracking (ideal) from https://www.nrcan.gc.ca/18366

Ideal insolation...

$$insolation := \begin{bmatrix} 4 \\ 5.39 \\ 6.75 \\ 8.07 \\ 8.34 \\ 9.26 \\ 9.58 \\ 8.36 \\ 7.13 \\ 5.94 \\ 4.11 \\ 3.38 \end{bmatrix}$$ kwH/m^2 /day

Over 1 year, we make this many dollars ideally...

$$Tideal := hhours2 \cdot insolation \cdot 1\,kW \cdot 1\,hr \cdot CostPower = \begin{bmatrix} 4311.615 \end{bmatrix}$$

because things are not ideal, we will derate the money by our efficiency factor because things are not ideal, we will deflate the money by our efficiency factor

top array of 9 $\quad Ttop := \frac{Tideal}{2} \cdot \frac{\eta total}{\eta ra} = \begin{bmatrix} 1842.0211 \end{bmatrix}$ dollars

bottom array of 9 $\quad Tbot := \frac{Tideal}{2} \cdot \eta total = \begin{bmatrix} 1473.6169 \end{bmatrix}$ dollars

$Trealistic := Tbot + Ttop = \begin{bmatrix} 3315.638 \end{bmatrix}$ dollars

But we consume this much power according to the bill...

Last 12 months			
Date	12259		734.3141
9-Jun	728	0.0599	43.6072
11-Jul	710	0.0599	42.529
10-Aug	706	0.0599	42.2894
11-Sep	880	0.0599	52.712
13-Oct	863	0.0599	51.6937
9-Nov	606	0.0599	36.2994
9-Dec	852	0.0599	51.0348
9-Jan	878	0.0599	52.5922
8-Feb	909	0.0599	54.4491
9-Mar	825	0.0599	49.4175
9-Apr	820	0.0599	49.118
8-May	824	0.0599	49.3576
7-Jun	852	0.0599	51.0348
11-Jul	1806	0.0599	108.1794
31-Aug		0.0599	0

Still to be finished ... and proofed.