Solar Home Report

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Executive Summary

The designer was given a task to turn the client's home into a solar home where they will be able to go off the grid during the winter months. After much research, calculations, and modeling the team made it possible. With a total of 19 monocrystalline solar panels and 4 lithium-ion batteries, our client will have no problem getting the energy that they will need. With no budget in mind, we wanted our client to get the best products they possibly could. This ended up costing around $36,000 in total. There were also cons that came with this setup. The NPV for our client's solar home came out to be a negative number, meaning every 10 years the system is losing value. If this is a major issue for our client, we would be more than happy to redesign the system with a new goal in mind and that is to decrease the NPV and possibly make it positive.

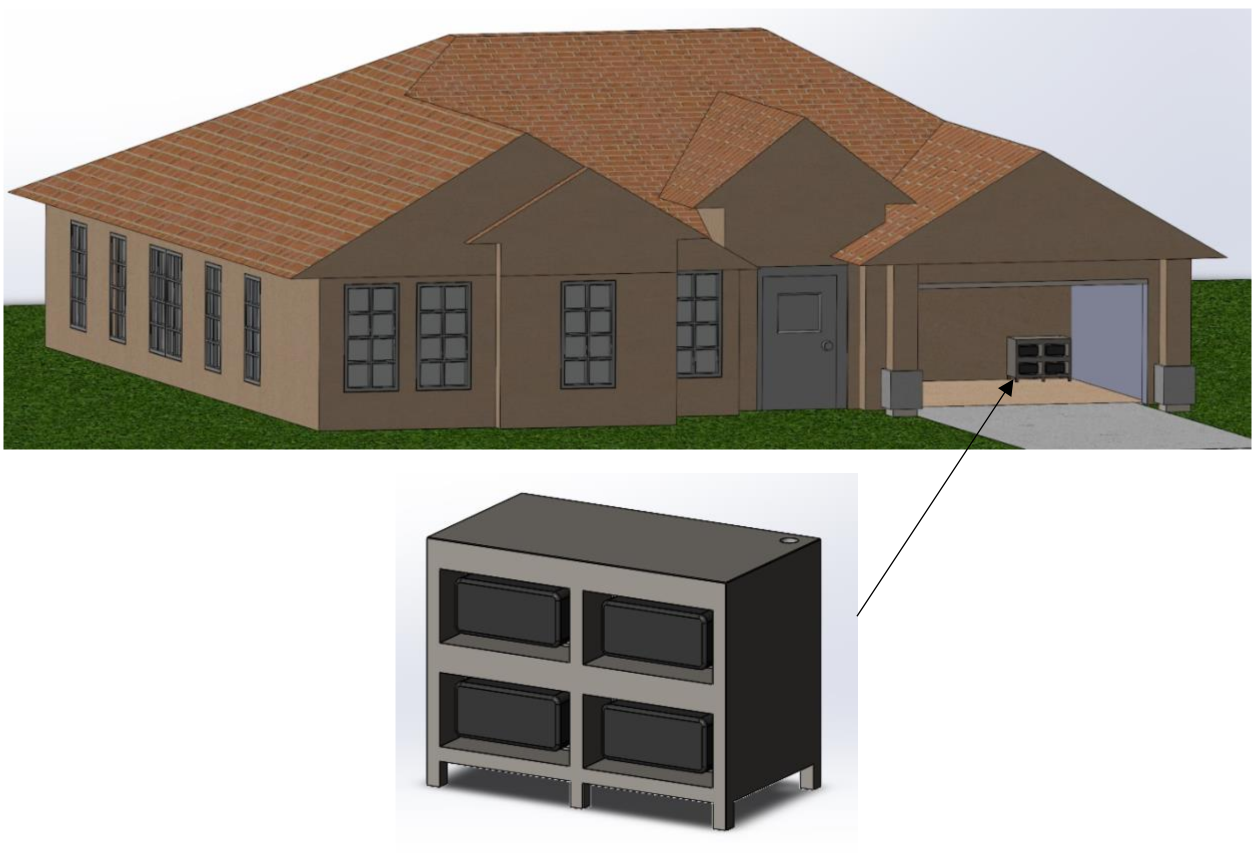
Our Design

When a client tells us that they want to go fully off the grid during the winter months, many big decisions must be made. After looking at the client's home and seeing the house's location, our team must choose a part of the roof that gets the most sun exposure. Once we decided on that, our team researched different types of solar panels and batteries that would work best for what our client wants. For these products, our team chose a monocrystalline solar panel by Canadian Solar that generate 300W of energy each and the LG Chem RESU10M lithium battery. Both products are top of the line and will exceed our client's expectations. The below tables show the main specs of both products.

LG Chem RESU10M Battery	
Energy Capacity	9.8 kWh
Voltage Range	126.0 V to 176.4 V
Nominal Voltage	155.5 V
Battery Capacity	63 Ah
Operating Temperatures	-10°C to 50°C (14°F to 122°F)
Depth of Discharge	95%
Warranty	10 years while retaining 60% efficiency

Canadian Solar 300W Mono Solar Panel	
Operating Temperature	-40°C to 85°C (-40°F to 185°F)
Nominal Module Operating Temperature	42 ± 3°C
Nominal Maximum Power	300 Watts
Module Efficiency	18.33%
Product Warranty	10 Years
Linear Power Output Warranty	25 Years

With these specs and the total energy that our client uses, we were able to solve for the total number of panels along with the final cost. In total, our client would need 19 300W monocrystalline solar panels by Canadian Solar, and 4 LG Chem RESU10M lithium batteries to store all the excess energy not used. With those numbers now calculated, our team was able to incorporate the 3D models of both the panel and battery into the model of the house. The below image is the final model of our client's solar home.



The total cost for our client's solar home came out to be about $36,352, but they will have an annual saving of $1,606.40. This will take about 22.6 years to pay off just using the money saved. The client's average annual bill is now only $227.58!

Schedule Report

Our project was broken up into four main points. To stay on track with our deadline, certain things had to be done by certain days.

Milestone 1 – December 2, 2020

- Decide on:
    - Solar panel
    - Lot #
    - House model
- Calculate Ed and Eo

Milestone 2 – December 8, 2020

- Decide on battery
- Design both solar panel and battery
- Recalculate Eo with losses & number of batteries
- House model is 90% complete

Milestone 3 – December 13, 2020

- Calculate expenses and NPV
- Complete model is 90% done
- Suggest alternatives

Milestone 4 – December 17, 2020

- Present report to client

MATLAB Model

Our group had originally begun by calculating all the work based on the data given for the month of September. The team later learned that the “winter season” account began in October rather than September. This caused the group to rework the calculations based on October’s numbers. This was a very easy change and worked out in our favor. Below are all the new calculations for our client’s solar home.

Hour by Hour for Design Month (October)

Conversions:

```
rad = pi/180;
deg = 180/pi;
W_m2 = 3.1525;
ft2 = 10.764;
in2toft2 = 1/144;
```

Variables:

```
ET = 15.4;
delta = -10.5 * rad;
A = 378*W_m2;
B = 0.160;
C = 0.073;
sunrise = 7;
```

Other Constants:

```
noon = 12;
gamma = 45*rad;
sigma = 30*rad;
L = 32*rad;
```

Hour by Hour:

```
Ed = 0;
for i = sunrise:noon
    hr = noon - i;
    min = hr*60;
    H = (0.25*(min+ET)) * rad;
    beta = asin(cos(L)*cos(delta)*cos(H) + sin(L)*sin(delta));
    theta = acos(cos(beta)*cos(gamma)*sin(sigma) + sin(beta)*cos(sigma));
    Pdn = A/exp(B/sin(beta));
    Pd = Pdn*cos(theta);
    Pdr = (Pdn*C*2)/(1+cos(sigma));
    Pt = Pd+Pdr;
    Ed = Ed+Pt;
end
```

Ed for full day:

```
Ed = Ed*2-Pt;
Ed = Ed/1000
```

```
Ed = 6.5543
```

Calculation for One Day of Every Month

Table data.

```
ET = [-11.2; -13.9; -7.5; 1.1; 3.3; -1.4; -6.2; -2.4; 7.5; 15.4; 13.8; 1.6];
delta = [-20; -10.8; 0; 11.6; 20; 23.45; 20.6; 12.3; 0; -10.5; -19.8; -23.45] * rad;
A = [390; 385; 376; 360; 350; 345; 344; 351; 365; 378; 387; 391];
B = [0.142; 0.144; 0.156; 0.180; 0.196; 0.205; 0.207; 0.201; 0.177; 0.160; 0.149; 0.142];
C = [0.058; 0.060; 0.071; 0.097; 0.121; 0.134; 0.136; 0.122; 0.092; 0.073; 0.063; 0.057];
sunrise = [8; 7; 7; 6; 6; 5; 6; 6; 7; 7; 8; 8];
ADL = [22.6; 21.1; 17.7; 23.5; 36.1; 53.6; 66.3; 71.6; 62.9; 36.3; 29.8; 21.1];
```

Hour by Hour for Each Month:

```
Ed = zeros(12,1);
for i = 1:12
    for j = sunrise(i):noon
        hr = noon - j;
        min = hr*60;
        H = (0.25*(min+ET(i))) * rad;
        beta = asin(cos(L)*cos(delta(i))*cos(H) + sin(L)*sin(delta(i)));
        theta = acos(cos(beta)*cos(gamma)*sin(sigma) + sin(beta)*cos(sigma));
        Pdn = A(i)*W_m2/exp(B(i)/sin(beta));
        Pd = Pdn*cos(theta);
        Pdr = (Pdn*C(i)*2)/(1+cos(sigma));
        Pt = Pd+Pdr;
        Ed(i) = Ed(i)+Pt;
    end
    Ed(i) = Ed(i)*2-Pt;
    Ed(i) = Ed(i)/1000;
end
```

Eo calculation

```
Eo = zeros(12,1);
for i = 1:12
    Eo(i) = nu * (S/ft2) * Ed(i);
end
```

Calculation for Number of Solar Panels for Design Month (October)

Eo = ADL for the month of September,

```
Eo = 36.3; %kWh
nu = 0.1833;
```

Surface Area of required solar panels to accomodate for design month,

```
S = Eo / (nu * Ed) * ft2
```

```
S = 325.2297
```

Solar panel dimensions,

```
l = 65;
b = 39.1;
Area = l * b * in2toft2;
```

Number of solar panels required,

```
nPanel = ceil(S / Area)
```

```
nPanel = 19
```

October had a drastic drop in energy use. With the change in numbers, our client will only need 19 solar panels now and use saved power rather than 27 solar panels and waste all the extra power.

Battery Storage for Design Month (October)

System Voltage,

```
sysV=12;
```

Battery Specifications,

```
V = 155.4;
Ah = 63;
r = 0.05;
l = 0.02;
```

Ec of the Battery,

```
Ec = V * Ah / 1000; %kWh
```

El Accounting for all Losses for Design Month,

```
El = ADL(10) * 0.6 * (1 + (r + l) / 100);
```

Therefore, Ecs (energy of the battery system),

```
Ecs = El / r;
```

Total Ah required for battery system,

```
AhS = Ecs * 1000 / V;
```

Calculation for number of batteries,

```
nbs = sysV / V;
nbp = AhS / Ah;
nBattery = ceil(nbs * nbp)
```

```
nBattery = 4
```

We also were able to get rid of 2 batteries and now only buy 4. With fewer solar panels, our client will not have as much energy to save.

Recalculation of Eo Including System Losses

Nominal operating temperature of solar array.

```
nominalTemp = 42 + 273;
ADT = (([65; 75; 79; 85; 94; 106; 107; 104; 99; 84; 75; 66]  - 32) * 5/9) + 273;
TempLoss = 100 - (100*(nominalTemp./ADT));
for i = 1:12
    if TempLoss(i) < 0
        TempLoss(i) = 0;
    end
end
```

Loss Coefficient, k.

```
k = (TempLoss + r + 1) / 100;
```

Eo including losses, Eo_L.

```
Eo_L = ADL(10) + k(10)*ADL(10);
```

Number of Panels to accomodate for loss.

```
S_L = Eo_L / (nu * Ed(10)) * ft2;
nPanels_L = ceil(S_L/Area)
```

```
nPanels_L = 19
```

Financial Logistics for Solar Home

Material and installation costs.

```
cPanels = nPanels_L * 190
```

```
cPanels = 3610
```

```
cBattery = nBattery * 7000
```

```
cBattery = 28000
```

```
cInstallation = 300 * nPanels_L * 2.68 % Wattage per solar panel * number of panels * installation cost per watt
```

```
cInstallation = 1.5276e+04
```

```
cController = 770
```

```
cController = 770
```

```
cInverter = 975
```

```
cInverter = 975
```

```
cElectricalPanel = 342.77
```

```
cElectricalPanel = 342.7700
```

```
cBuildingPermitFees = 150
```

```
cBuildingPermitFees = 150
```

```
federalIncentive = 0.26; % 26% discount on all expenses
```

Daily energy cost per kWh.

```
r = 0.13; % Dollar per kilowatt hour
```

Initial investment.

```
initInvestment = (cPanels + cBattery + cInstallation + cController + cInverter + cElectricalPanel + cBuildingPermitFees) * (1 - federalIncentive)
```

```
initInvestment = 3.6352e+04
```

Average annual cost of electricity.

```
year = [31; 28; 31; 30; 31; 30; 31; 31; 30; 31; 30; 31];
AML = ADL .* year;
annualCost = sum(AML) * r
```

```
annualCost = 1.8340e+03
```

Average annual savings.

```
AMEo_L = Eo_L .* year;
annualSavings = 0;
for i = 1:12
    if AML(i) <= AMEo_L(i)
        annualSavings = annualSavings + AML(i);
    else
        annualSavings = annualSavings + AMEo_L(i);
    end
end
annualSavings = annualSavings * r
```

```
annualSavings = 1.6064e+03
```

Payback period.

```
paybackPeriod = initInvestment / annualSavings
```

```
paybackPeriod = 22.6292
```

Average annual utility bill using solar power in the winter months.

```
avgAnnualBill = annualCost - annualSavings
```

```
avgAnnualBill = 227.5765
```

NPV Calculations

Initial declarations.

```
N = 10; % 10 year period
d = 0.03; % 3% discount
```

Calculation.

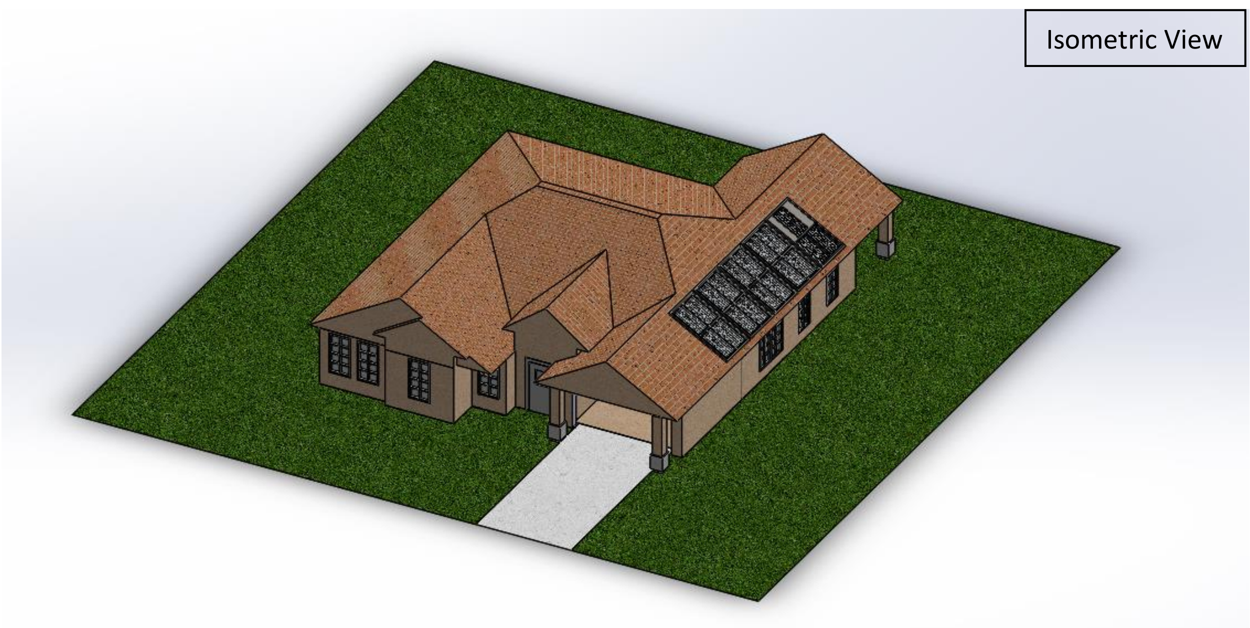
```
NPV = -initInvestment;
count = 0;
for i = 0:N
    if mod(i-1,10) == 0
        NPV = NPV - cBattery;
        count = count +1;
    end
    NPV = NPV + annualSavings / (1+d)^i;
end
NPV
```

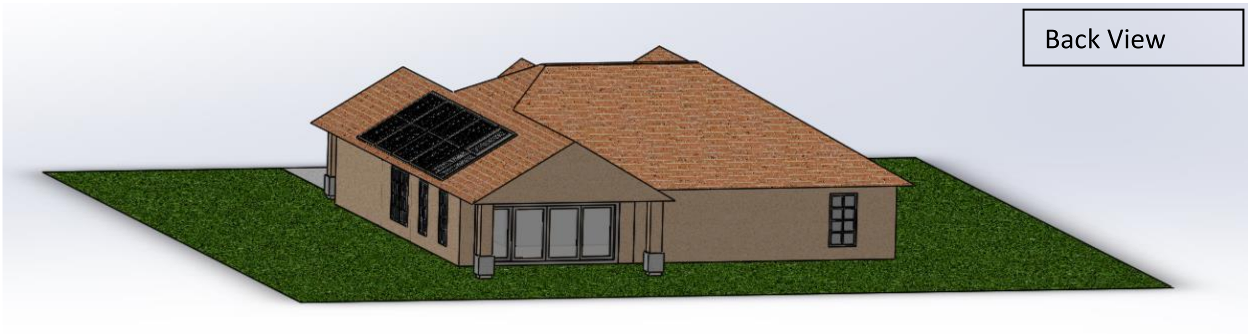
```
NPV = -4.9042e+04
```

With not as many supplies needed, our group was able to save our client a lot of money and cut the payback period down by a whole lot. Unfortunately, the NPV is negative meaning the client is losing value every 10 years.

Drawings and Graphs

After all the parts needed for this house to go green were found, our group was able to create a final 3D model of our client's home that will best represent what their house will look like. Below shows an isometric, front, and back view of the client's solar home.





Justification of Decisions

The main economic tradeoff that our client's solar system is going through is a negative NPV. Our team wanted to use the best products we could get our hands on with no budget in mind. We figured that if our client does not have a budget and is well off for the rest of their time, assuming so, we would rather create the best system we possibly could and not worry about cost.