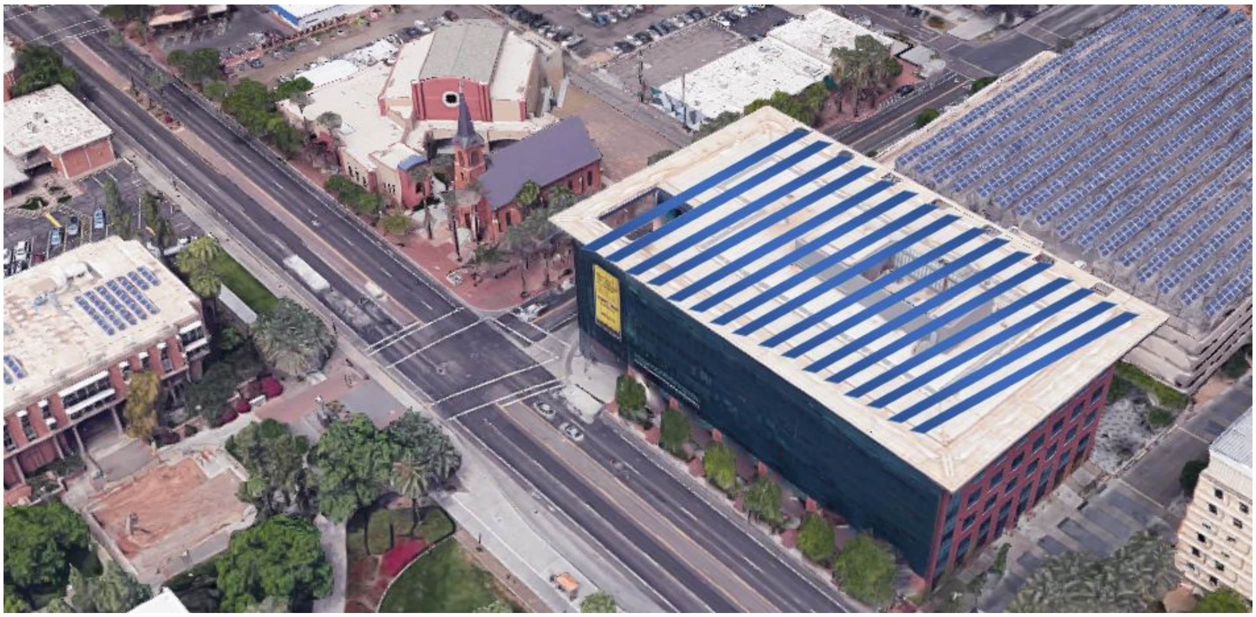
Effect of West Facing Panels on Cost Reduction for Businesses



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Introduction

Typical Demand curves peak around afternoon to evening. As a result energy companies charge On-Peak hours costs which can be 2 to 4 times the off-peak hour rates. In this project we explore if West Facing Fixed PV Panels can improve energy bills by cutting energy costs when it the most expensive. For the analysis, a demand profile is required and hence the 2017 Energy Consumption Data for the fulton center was used as the test case.

Analysis

Manipulating insolation data to find west facing power profile

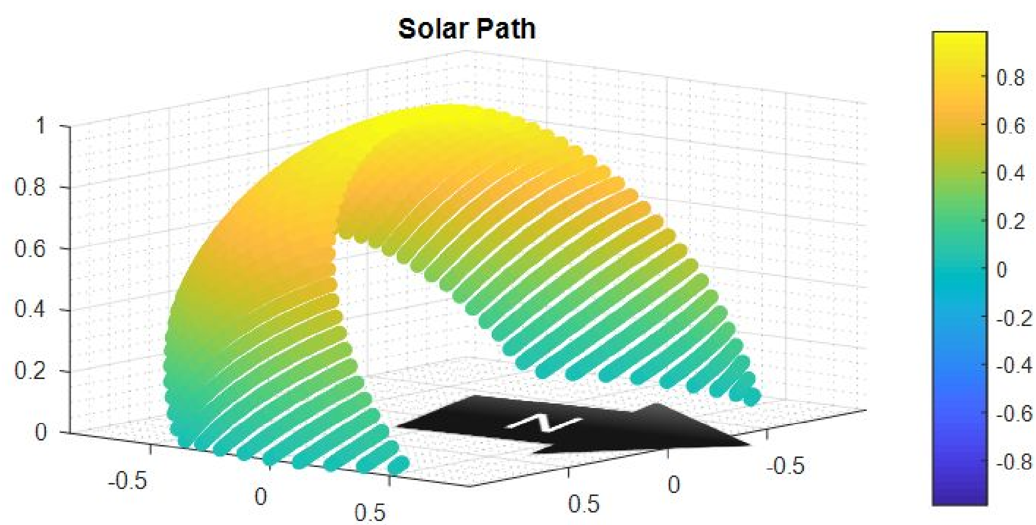
$$\sin(\beta) = \cos(L)\cos(\delta)\cos(H) + sind(L)\sin(\delta)$$

$$\Phi_s = \sin^{-1}\left(\frac{\cos\delta \sin H}{\cos\beta}\right)$$

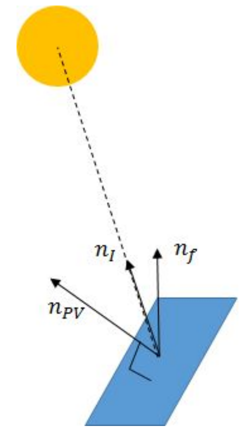
From the azimuthal angle and zenith angle one can compute the normal position in the sky.

$$x = \cos\left(\Phi - \frac{\pi}{2}\right)\sin(\beta)$$
$$y = sin\left(\Phi - \frac{\pi}{2}\right)\sin(\beta)$$
$$y = \sin(\beta)$$

This results in the following solar path



Given this information one can compute ratio between insolation on flat plate and titled panel. Hence the data from a flat upward pointing sensor can be used to compute power generated by a titled west facing panel.



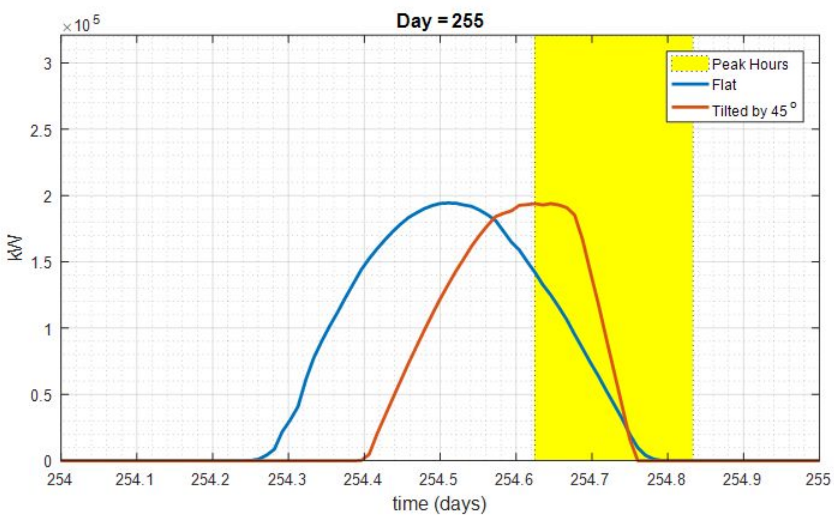
$$n_I = \begin{pmatrix} x \\ y \\ z \end{pmatrix}, \qquad n_f = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix}$$

$$I_{PV} = I_f \frac{n_I \cdot n_{PV}}{n_I \cdot n_f}$$

Since there are a lot more factors like horizon, shading and efficiency, one can express the overall power generated by the panels as such:

$$S(t) = \varepsilon(T)\varepsilon_s N I_f A R\left(\frac{n_I \cdot n_{PV} H(n_I \cdot n_f)}{n_I \cdot n_f}\right) e^{-km(\beta)}$$

Here S(t) represents the total power outputted by Photovoltaics in AC. This depends of efficiency ε which is a function of temperature (T), shading efficiency (ε_f), panel count (N), flat plane irradiance (I_f), area of of single panel (A), insolation vector (n_I), panel normal vector (n_{PV}), flat normal vector (n_f), optical depth (k), air mass ratio (m) and zenith angle (β**)**. R represents the ramp function and H represents the heaviside function. This results in the following result of 45 degrees west facing panels in Tempe.



Energy Balance

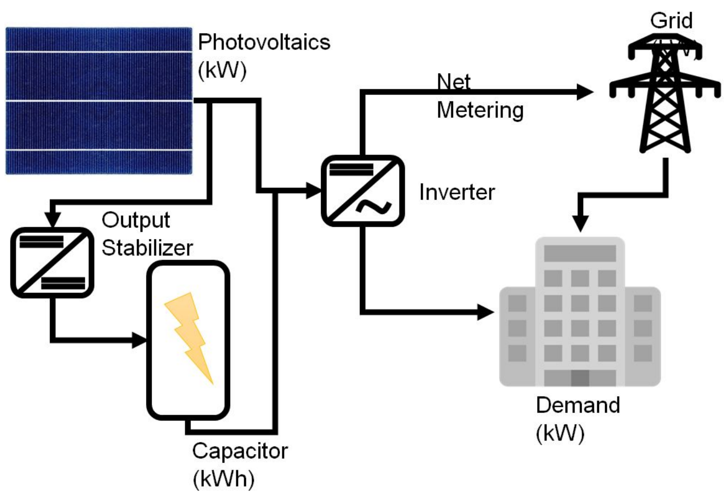
In order to reduce cost we need to reduce the amount of grid power being consumed. We tap into solar as well as battery resources to reduce grid consumption. As such a differential equation is required to describe the flow of energy between grid solar and battery to satisfy demands.

$$S(t) + \frac{dC(t)}{dt} + G(t) = D(t)$$

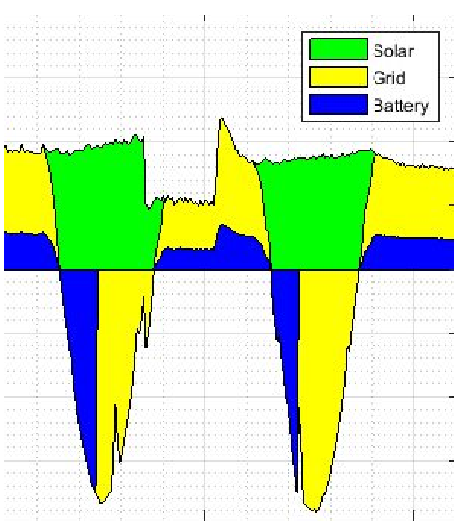
$$\frac{dC(t)}{dt} = \begin{Bmatrix} S(t) - D(t) & if\ (D < S\&C < M)or(D > S\&C > 0) \\ 0 & else \end{Bmatrix}$$

$$C = C + 0.15(-C)H(-C)$$

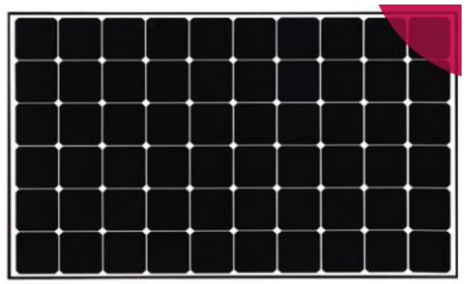
Here C(t) is the charge in the battery and M is maximum charge. The rate of change of charge depends on the difference between solar power input (S(t)) of demand power output (D(t)) if power is between minimum and and maximum (M). The remaining power to meet demand is met by Grid Power (G(t)) which is metered. This flow of energy can be represented by the following energy flow diagram.



It is important to realize managing between solar and grid is hard to optimize for all days of the year without sophisticated algorithm. Hence chose the simplest model i.e. charging with the batteries with solar energy during the day and using it for the rest of the peaks hour times and off peak hour times for as long as it can run when demand is higher than production. Shortfalls are made up by the grid. The following results from 500 kWh of storage over 2 days. For no battery, the function parameter of battery capacity was set to zero. This results in this profile.



Solar Installation



In this project, we chose LG350Q1C-A5 from LG Company for our solar panels. LG is well known for its high quality electronics and the company's solar PV panels are no different.

There are many reasons that we chose LG350Q1C-A5 out of other LG panels. First of all, the series LG NeON R has been designed to significantly enhance its output marking it efficient even in limited space. With this model, the efficiency rate is 20.3%. Secondly, LG offers a 25 years warranty with their performance warranty as well and NeON R is the first product to provide an enhanced performance warranty. After 25 years, the LG350Q1C-5A is guaranteed at least 87.0% of initial performance. Thirdly, they have better performance on sunny days with improved temperature coefficient. The temperature coefficient states how well the solar panel will perform in less-than-ideal conditions and it gives a sense of how the panel's performance will change during hot sunny summer days. The LG350Q1C-5A panel has a temperature coefficient of $-0.30\%/℃$, which means, if the panel's temperature increases 1 ℃, the electricity production efficiency will be reduced by 0.30%. Lastly, LG offer cheaper price compare to other solar panels with the similar efficiency. The LG350Q1C-5A panel costs 430 dollars and it can produces maximum energy of 350 watt each. In our project, based on the area of Fulton Center in Arizona State University, we used total number of 840 panels (28 panels per array x 30 arrays), which cost $395,671 included shipping and tax. However, with Federal Solar Investment Tax Credit (ITC), which has 30%, the panel cost dropped to $276,970.

The initial cost for the solar panel system is also included labor cost and installation material cost. According to Lawrence Berkeley National Laboratory (LBNL), the average cost of the labor is about 10% of the total system cost, which gives about $27,697 for this project. Also, based on the installation material cost research, we assumed that cost of the material was approximate $40,000. Therefore, in our project, the total initial cost was about $344,667 for the solar system with 840 pieces of panels.

Energy Costs

To govern the energy costs, an energy plan is selected for the project to give realistic pricing. For this project, a plan was selected from APS known as E-32 Time Of Use Medium. This plan aligns with the project scale and goes into great detail all all energy costs and the time frames in which these costs take effect in. For this plan, it is important to note that the On-Peak hours are between 3:00 pm - 8:00 pm on Monday through Friday. All Off-Peak hours are the remainder hours of the day throughout the week, with a service at transmission voltage charge of $36.795 per day. These time frames govern the demand charges of the company.

A demand charge is the amount of money charged to a company based on the highest demand of the company within a 15 minute time period. These demand charges apply differently depending on the plan the company chooses. With the E-32 Time Of Use Medium plan, the On-Peak hour demand charges and the Off-Peak demand charges are shown in the table below.

Demand Charges of E-32 Time Of Use Medium APS Company Plan

On/Off Peak	Demand Charge
First 100 On-Peak Hours	$17.546/kW
All Additional On-Peak Hours	$11.647/kW
First 100 Off-Peak Hours	$5.934/kW
All Additional Off-Peak Hours	$3.216/kW

Along with demand charges are also energy charges. These energy charges are separated into two categories. On-Peak hours for summer months and winter months, and Off-Peak hours for summer months and winter months. Throughout the year, the amount of energy needed by the company varies in relation to the environment. Summer months proves to have a higher energy charge than winter months due to the large increase in temperature. Meaning more energy is needed to operate at an optimal level. Below is a table containing the energy charges of the APS plan.

Energy Charges of E-32 Time Of Use Medium APS Company Plan

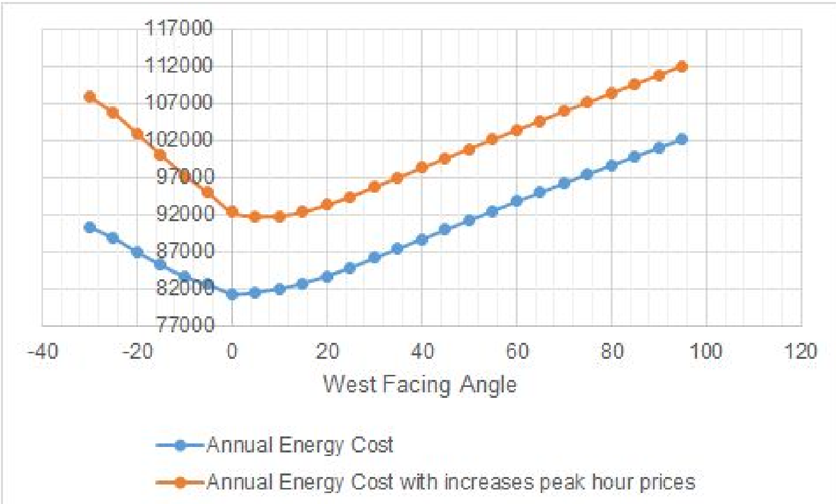
On/Off Peak Hours	Summer Energy Charges	Winter Energy Charges
On-Peak Hours	$0.07170/kWh	$0.05783/kWh
Off-Peak Hours	$0.05952/kWh	$0.04566/kWh

To conclude the E-32 Time Of Use APS plan, the final important numerical value to consider is the net metering charge. Net metering is something that has the potential to benefit the company by taking the company's export energy and netting it against the import energy. This excess energy, after a year of operation, is bought with a specific purchasing price. This numerical value is based off the EPR-6 document provided by Torey Barr, APS's Key Account Manager for Arizona State University, and at a value of **$0.02895/kWh**.

Results

Finding Cost Saved as a function of west facing angle

Below is a graph representing the optimum angle for lowest annual energy cost.

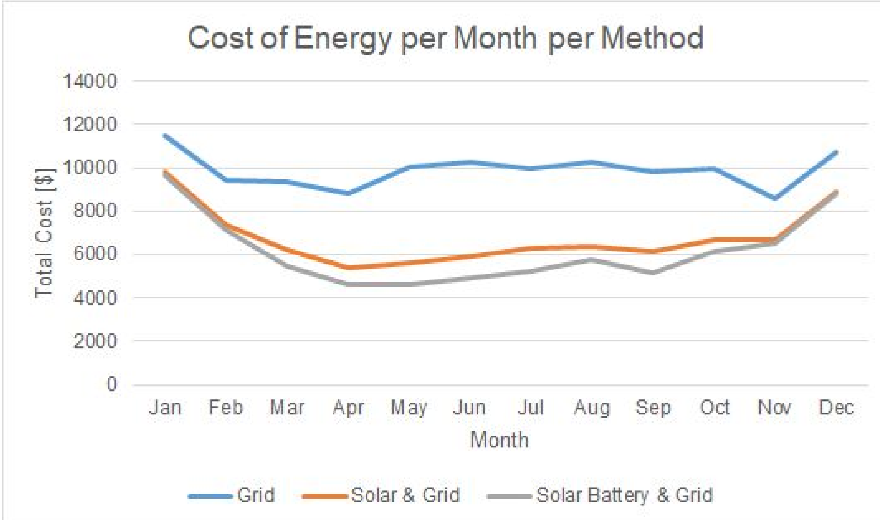


The results show that at the current peak hour prices, the optimum angle is at about 0 degrees west. This means that the optimum set angle that produces the most energy cost savings is when all the panels are flat. The total annual energy cost with flat panels is $81,350.60. Thus debunking the hypothesis that facing solar photovoltaics west will produce better cost savings. The design operation of the panels to face west was to try and make the most use of peak hours when the sun was in the west. The problem that occurred however as the sun set on the west was that as the sun set more, self-shading began to occur. Self-shading means that the shadow of the previous solar panel catches the surface of subsequent one, thus reducing the surface area the sun can hit on each solar panel. Having solar panels lay flat ends this problem.

However, during the initial peak hours, before much or any self-shading has occurred, the panels do prove to be effective at reducing cost. Therefore, an example was run when the prices during peak hours was raised to see how it affects the angle of the panels. As peak hour prices increased there was also an increase in west facing angle.

Comparison of Solar, Battery and Grid Scenarios

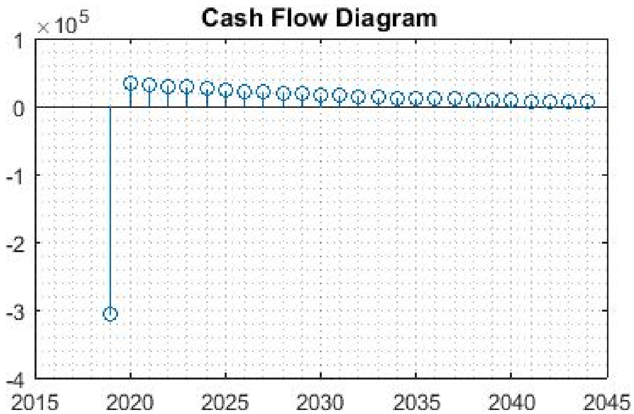
The prior analysis for solar was run in order to be able to compare to how much only using the grid costs. An additional battery energy storage option was included into the analysis to see if battery storage being charged by excess energy produced by the solar panels could incur more energy and cost savings. The following figure and table show the results.

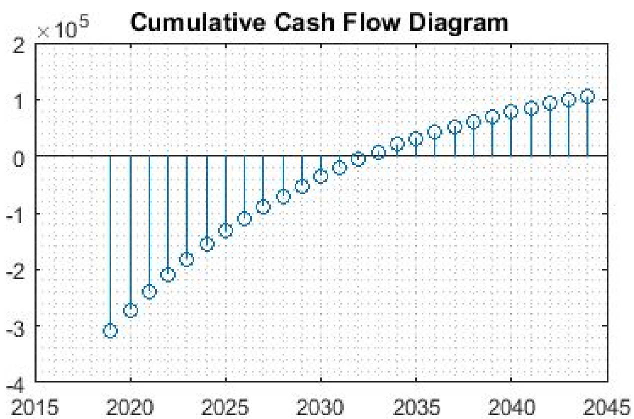


Total Annual Cost [$]		
Grid	Solar and Grid	Solar Battery and Grid
$118,636.26	**$81,350.60**	**$74,077.92**

The results of the analysis show that using integrating solar and the grid decreases the annual cost of energy by about $**37,000**. This was a substantial decrease in the annual cost, and sets up solar for an LCOE and Break-Even analysis in the next section. Integrating batteries that are recharged by excess energy and then used when energy is needed produced an even lower total annual cost of $74,077.92. However this was not a large reduction in annual costs saving compared to just solar and the grid. Furthermore, the initial investment to acquire this amount of batteries was substantial, and the batteries would have to be replaced every few years as their lifespan is not as long as the solar panels. This therefore meant that there would never be a break-even point if batteries were utilized.

Levelized Cost Of Energy & Break even





The above graphs show cash flow over 25 years of operation for only solar panels with the grid. An LCOE analysis for the lifespan of 25 years for the solar panels resulted in the levelized cost of energy equaling 6 cents/kWh. This coupled with the annual cost savings calculated previous, married with 7.2% annual inflation, assumed constant electricity prices, decreasing efficiencies of the solar panels, and flat panels, show that the break-even point for this scenario would be after 13 years.

Conclusion

In conclusion, there are several points to be made after this analysis. The first is that introducing solar panels to the Fulton Center does decrease total annual cost of energy in the building. The hypothesis though that facing them west to make the most of on-peak prices is seen to not show any real benefits to the system. South Facing the panels might give better results. Laying them flat proved to be the optimum angle versus in any angle west. However, as on-peak hours increase, facing the panels west becomes more beneficial to cost savings. The use of batteries to try and reduce annual costs does not lower them enough to offset the initial investment of batteries. Lastly, solar would present even more cost benefits if the net-metering rates were more agreeable to solar energy. Ultimately, if measures were taken to make net-metering rates fairer, there would be much more of an opportunity for solar to offset annual costs of energy for much more than just the Fulton Center.

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Appendix

Panel Information

LG NeON® R LG350Q1C-A5

Mechanical Properties

Cells	6 x 10
Cell Vendor	LG
Cell Type	Monocrystalline / N-type
Cell Dimensions	161.7 x 161.7 mm / 6 inches
Dimensions (L x W x H)	1700 x 1016 x 40 mm
	66.93 x 40.0 x 1.57 inch
Front Load	6000Pa
Rear Load	5400Pa
Weight	18.5 kg
Connector Type	MC4
Junction Box	IP68 with 3 Bypass Diodes
Length of Cables	1000 mm x 2 ea
Glass	High Transmission Tempered Glass
Frame	Anodized Aluminium

Electrical Properties (STC *)

Module	350
Maximum Power (Pmax)	350
MPP Voltage (Vmpp)	36.1
MPP Current (Impp)	9.70
Open Circuit Voltage (Voc)	42.7
Short Circuit Current (Isc)	10.77
Module Efficiency	20.3
Operating Temperature	-40 ~ +90
Maximum System Voltage	1000
Maximum Series Fuse Rating	20
Power Tolerance (%)	0 ~ +3

* STC (Standard Test Condition): Irradiance 1,000 W/m², Ambient Temperature 25 °C, AM 1.5
* The nameplate power output is measured and determined by LG Electronics at its sole and absolute discretion.
* The typical change in module efficiency at 200 W/m² in relation to 1000 W/m² is -2.0%.

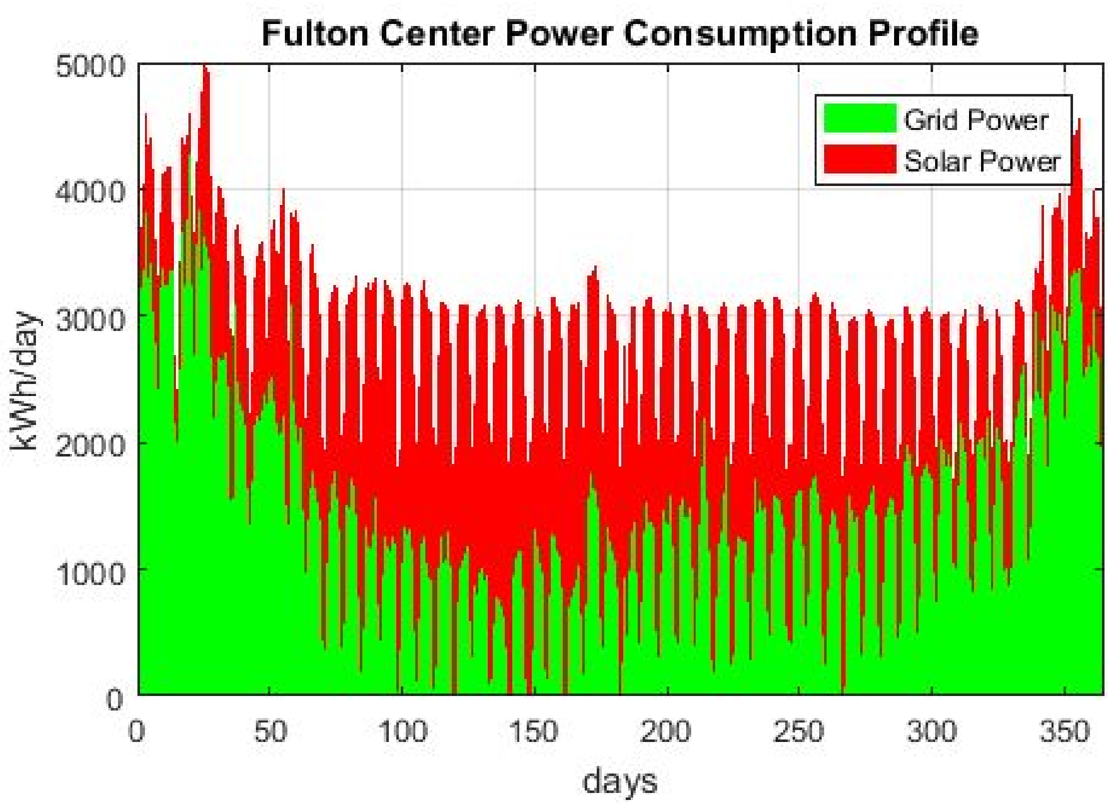
Temperature Characteristics

NOCT	44 ± 3 °C
Pmpp	-0.30 %/°C
Voc	-0.24 %/°C
Isc	0.04 %/°C

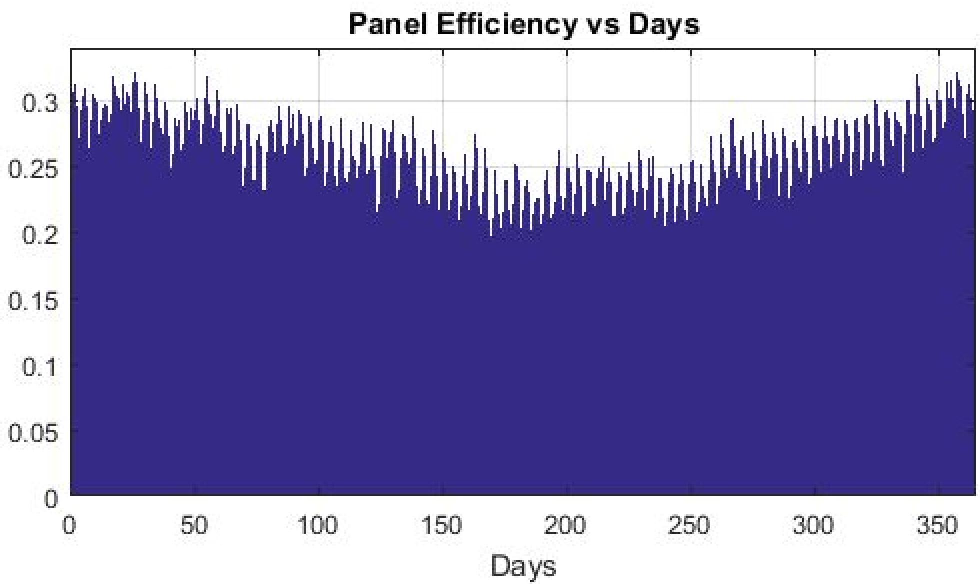
Annual Energy Billing Simulation

Grid	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Energy Cost On-Peak	$1,325.57	$994.27	$1,079.99	$1,011.97	$1,323.38	$1,351.30	$1,281.95	$1,356.87	$1,234.48	$1,284.44	$962.92	$1,113.87	
Energy Cost On-Peak	$4,658.93	$3,525.97	$3,326.23	$2,999.69	$3,906.66	$3,930.06	$3,851.26	$3,991.68	$3,670.64	$3,791.77	$2,817.53	$4,060.25	
Net Metered Energy	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Demand Charge On Peak	$3,023.31	$2,656.89	$2,592.37	$2,651.30	$2,573.03	$2,752.86	$2,581.42	$2,663.07	$2,694.98	$2,640.82	$2,619.27	$3,119.86	
Demand Charge Off Peak	$1,103.39	$988.07	$934.42	$843.15	$825.34	$863.99	$831.93	$845.66	$851.61	$845.15	$842.22	$1,043.90	
Service Charge	$1,392.58	$1,257.82	$1,392.58	$1,347.66	$1,392.58	$1,347.66	$1,392.58	$1,392.58	$1,347.66	$1,392.58	$1,347.66	$1,392.58	
Total	$11,503.78	$9,423.02	$9,325.60	$8,853.78	$10,021.00	$10,245.88	$9,939.14	$10,249.86	$9,799.37	$9,954.76	$8,589.61	$10,730.47	$118,636.26
Solar Grid													
Energy Cost On-Peak	$1,063.33	$653.33	$550.14	$444.50	$511.89	$492.18	$518.95	$626.01	$670.11	$869.08	$779.64	$935.93	
Energy Cost On-Peak	$3,478.45	$2,368.99	$1,867.93	$1,557.09	$1,888.29	$1,891.38	$2,009.92	$2,051.19	$1,877.00	$1,998.09	$1,699.93	$2,830.34	
Net Metered Energy	-$123.26	-$285.34	-$699.85	-$958.56	-$1,055.95	-$848.07	-$741.27	-$642.09	-$632.50	-$471.56	-$241.02	-$117.42	
Demand Charge On Peak	$2,905.64	$2,424.07	$2,241.33	$2,240.16	$2,163.18	$2,293.74	$2,282.78	$2,221.12	$2,210.96	$2,172.59	$2,296.85	$2,857.10	
Demand Charge Off Peak	$1,075.99	$939.03	$880.43	$744.26	$719.69	$761.95	$812.78	$718.79	$710.27	$692.07	$775.52	$996.94	
Service Charge	$1,392.58	$1,257.82	$1,392.58	$1,347.66	$1,392.58	$1,347.66	$1,392.58	$1,392.58	$1,347.66	$1,392.58	$1,347.66	$1,392.58	
Total	$9,792.74	$7,357.90	$6,232.57	$5,375.11	$5,619.68	$5,938.84	$6,275.75	$6,367.60	$6,183.51	$6,652.85	$6,658.57	$8,895.48	$81,350.60
solar battery grid													
Energy Cost On-Peak	$946.25	$494.39	$385.31	$311.42	$358.58	$344.97	$363.86	$446.23	$469.29	$614.34	$618.19	$827.08	
Energy Cost On-Peak	$3,397.42	$2,129.81	$1,382.96	$1,095.38	$1,325.02	$1,326.21	$1,412.79	$1,500.93	$1,348.97	$1,567.75	$1,533.34	$2,743.88	
Net Metered Energy	-$7.77	-$46.50	-$306.07	-$590.65	-$721.74	-$510.04	-$385.89	-$300.56	-$288.23	-$168.51	-$50.11	-$1.33	
Demand Charge On Peak	$2,905.70	$2,401.19	$1,745.90	$1,745.08	$1,691.19	$1,782.59	$1,774.93	$2,009.32	$1,724.71	$2,019.22	$2,296.97	$2,857.10	
Demand Charge Off Peak	$1,043.07	$938.99	$880.43	$709.90	$585.32	$615.77	$650.49	$697.57	$579.80	$686.70	$775.52	$996.94	
Service Charge	$1,392.58	$1,257.82	$1,392.58	$1,347.66	$1,392.58	$1,347.66	$1,392.58	$1,392.58	$1,347.66	$1,392.58	$1,347.66	$1,392.58	
Total	$9,677.25	$7,175.70	$5,481.11	$4,618.79	$4,630.97	$4,907.16	$5,208.76	$5,746.07	$5,182.19	$6,112.08	$6,521.57	$8,816.27	$74,077.92

Annual Everyday Solar Grid Profile



Annual efficiency Profile



Codes

Main.m

```
clear all
t = 0:1/96:(365-1/96);
count = 0;
for alpha = 0+.001
    count = count + 1;
    %S = insolation3(alpha);
    D = Demand();
    [G,S] = Battery(80,.3,alpha);
    %Solar+Battery+Grid
%      Gt  = (D(t)-S(t)+G(t)).*heaviside(D(t)-S(t)+G(t));
%     Et = -(D(t)-S(t)+G(t)).*heaviside(-(D(t)-S(t)+G(t)));
    %Solar+Grid
    Gt = (D(t)-.87*S(t)).*heaviside(D(t)-.87*S(t));
    Et =(-D(t)+.87*S(t)).*heaviside(-D(t)+.87*S(t));
    %Solar+Grid
%     Gt = (D(t)-0*S(t)).*heaviside(D(t)-0*S(t));
%     Et =(-D(t)+0*S(t)).*heaviside(-D(t)+0*S(t));
    %%%
```

```
    weekdays = mod(t+1,7)>2;
    pkhours = mod(t,1)>(15/24) & mod(t,1)<(20/24);
    summerp = t>120 & t<303 ;
    onpeak = weekdays & pkhours;
    energyCost = (onpeak&summerp)*0.07170 +
(onpeak&~summerp)*0.05783...
        + (~onpeak&summerp)*0.05952 + (~onpeak&~summerp)*0.04566;
    md = [31 28 31 30 31 30 31 31 30 31 30 31]; %month days
    m = cumsum(md);
    month = t*0;
    for i = 12:-1:1
        month(t<m(i)) = i;
    end
    EnergyCost = zeros(2,12);
    CDt = Gt.*energyCost;
    for i = 1:12
        EnergyCost(1,i) = sum(CDt( (month==i) & pkhours))/4;
        EnergyCost(2,i) = sum(CDt( (month==i) & ~pkhours))/4;
        EnergyCost(3,i) = sum(-0.02895*Et( month==i) )/4;
    end
    maxP = zeros(2,12);
    for i = 1:12
        maxP(1,i) = max(Gt( (month==i) & pkhours));
        maxP(2,i) = max(Gt( (month==i) & ~pkhours));
    end
    DemandCharge = (maxP-100).*[11.647;3.216]+100*[17.546;5.934];
    basicCharge = (1.160+2.020+4.947+36.795)*md;
    All = [EnergyCost;DemandCharge;basicCharge];
    AnnualCost(count) = sum(All(:));
%     fprintf('Annual Cost = $%.2f\n',AnnualCost(count));
%     area(t,D(t),'Facecolor','g'); hold on;
%     area(t,D(t)-S(t),'Facecolor','y');
%     area(t,-G(t),'Facecolor','b'); hold off;
    frame = getframe(gcf);
     fprintf('Annual Cost = $%.2f\n',AnnualCost(count));
end
% plot((-30:5:95)+.001,AnnualCost)
```

Demand.m

```
function demand = Demand()
data = csvread('fultonCenter3.csv');
t = data(:,1);
```

```
P = data(:,2);
demand = griddedInterpolant(t(P>1e-1),P(P>1e-1));
```

Battery.m

```
function [Etg,S] = Battery(storageCapacity,dischargeRate,alpha)
if nargin == 0
    storageCapacity = 80; %.5MWh
    dischargeRate = .5;
    alpha = 0.001;
end
t = 0:1/240:(365-1/240);
S = insolation(alpha);
global D; D = Demand;
E = rhs2(t);
plot(t,D(t),t,D(t)-S(t),t,D(t)-S(t)+E);
xlim([144 145]+1)
E = E + .15*(-E).*heaviside(-E);
plot(t,D(t),t,D(t)-S(t),t,D(t)-S(t)+E);
xlim([14 25])
Etg = griddedInterpolant(t,E);

    function [dEdt,E] = rhs2(t)
        E = t*0;
        dEdt = t * 0;
        for i = 3:length(t)
           dt = t(i)-t(i-1);
           Dt = D(t(i));St = S(t(i));
           if (Dt <= St) && (E(i-1)<storageCapacity/24)
                dedt = (St-Dt);
           elseif (Dt > St) && (E(i-1)>0)
                dedt = (St-Dt)*dischargeRate;
           else
                dedt = 0;
           end
           dEdt(i) = dedt;
           E(i) = 2/3*(dt*dedt-1/2*E(i-2)+2*E(i-1));
        end
    end
end
```

Insolation.m

```
function westTiltIns = insolation3(alpha)
```

```
if nargin==0
    alpha = 45;
end
num = xlsread('Weather 15 Minute data 2016-2017.xlsx','Sheet2');
% corrdinates: 33.4242° N, 111.9281° W , Meridian: 105
n = num(:,1);
Temp = (num(:,2)-32)*5/9;
Temp = interp1(n(Temp>-15),Temp(Temp>-15),n,'PCHIP');%fix
Im = num(:,3);

B = 360/364*(n-81);
E = 9.87*sind(2*B) - 7.53*cosd(B) - 1.5*sind(B);
ST = n - (4*(105 - 111.9281) + E)/(60*24);
decl = 23.45*sind(360/365*(n - 81));

L = 33.4242;
H = (0.5-mod(n,1))*24*15;
beta = cosd(L).*cosd(decl).*cosd(H) + sind(L).*sind(decl);
phis = asind(cosd(decl).*sind(H)./cosd(asind(beta)));
cond = cosd(H)>=tand(decl)/tand(L);
phis(~cond) = -phis(~cond)+sign(phis(~cond))*180;

x = cosd(phis-90).*cosd(asind(beta));
y = sind(phis-90).*cosd(asind(beta));
z = beta;
IV = [x';y';z'];
NV = [0;0;1];

normal = dot(IV,[0;0;1]+IV*0);
% plot(n,normal);

%%% Temperature and Shading Efficiency
Spacing = 2.5;'??????\ ??????\';
countPerArray = 28; %??????
Width = 1.016;
Span = countPerArray*1.700;
arrays = 30; %??????\??????\??????\??????\??????\??????\
TotalArea = Width*Span*arrays;  %"??????\... ??????\ --[/]--";
TotalFlatAreaNeeded = [Span+Width*2 Spacing*arrays+Width
Span*(Spacing*arrays+Width) TotalArea];
fprintf('Total Flat Area: %1.1fm x %1.1fm = %1.1fm^2, PV Area:
%1.1fm^2\n',TotalFlatAreaNeeded)
eff = 0.203+(Temp-44)*(-0.30/100);
```

```
fprintf('Total Panels: %i\n',countPerArray*arrays)
%plot(eff)

L1 =
1-Spacing*tand(alpha)*tand(asind(beta))./(Width*sind(alpha).*(tand(al
pha)+tand(asind(beta))));
L2 = (Span-Spacing*sind(phis+90))/Span;
seff = (1+(arrays-1)*(1-L1.*L2))/arrays;
seff(seff>1)=1;
seff(seff<0)=0;
seff(phis>0)=1;
%plot(n,seff,n,beta)

%%% Compute ratio between west facing and flat panels
betan = dot(IV,[-sind(alpha);0;cosd(alpha)]+0*IV)'./beta;

betan = betan.*heaviside(beta);
betan(isnan(betan)) = 0;
betan(betan<0) = 0;
beta = beta.*heaviside(beta);
plot(n,beta,n,betan);

%Atmospheric Extinction

k = 0.174 + 0.035*sind(360/365*(n - 100));
A = 1160 + 75*sind(360/365*(n - 275));
m = 1./beta; m(beta==0)=0;
C = 0.095 + 0.04 * sind(360/365*(n - 100));
Ib = A.*exp(-k.*m);
Ibc = Ib.*C*(1+cosd(0))/2;
Ib(beta==0)=0;
Ibc(beta==0)=0;
betan = betan.*exp(-k.*m/10);

plot(ST,beta,ST,beta.*betan)
betann = interp1(ST,betan,n,'PCHIP'); %interpolate from solar time to
=spaced time
It = Im.*betann*10/9.7; %Calibrate.
fprintf('Max Power Generated:
%1.1fkW\t%1.1fkW\n',max(Im.*eff.*TotalArea)/1000,max(It.*eff.*TotalAr
ea.*seff)/1000);
```

```
for i = 255
    area([i-1+15/24 i-1+20/24],[321000
321000],'LineStyle',':','FaceColor','y');hold on;

plot(n,Im.*eff.*TotalArea,n,It.*eff.*TotalArea.*seff,'linewidth',2);
hold off
    xlim([i-1 i]);  ylim([0 321000]);
    xlabel('time (days)'); ylabel('kW'); grid on; grid minor
    legend('Peak Hours','Flat',num2str(alpha,'Tilted by %.0f^o'))
    title(num2str(i,'Day = %03d')); hold off;
    drawnow;
end


%
% plot(n,Im.*eff.*TotalArea,n,It.*eff.*TotalArea.*seff);
% FlatTiltIns = griddedInterpolant(n,Im.*eff.*TotalArea/1000);
westTiltIns = griddedInterpolant(n,It.*eff.*TotalArea.*seff/1000);
trapz(n,It.*eff.*TotalArea.*seff/1000)/(n(end)-n(1))
```