# **Solar Energy Analysis Case**

# Recommendations to the Decision maker:

1. The annual household electricity bill ($2633 for the year 2017) is reduced by 3.3% for every solar panel that produces electricity. That is, by installing around 30 solar panels, the annual electricity bill could drop to $0.
2. Cutting down electricity consumption during on-peak hours and increasing consumption during off-peak hours could also cut down annual electricity bill about 23%

So, the decision maker is better off by shifting consumption from on-peak hours to off-peak hours. However, this is not a permanent solution as the demand shift can be possible only to some extent. Thus the long term solution to cut down electricity bill would be to install solar panels for electricity generation.

# Executive Summary:

1. Relationship between number of solar panels and percent savings: Results of the analysis show that as the number of solar panels increases, the percentage savings in electricity bill also increases.
   1. As shown in figure 1, the relationship is almost linear when the number of solar panels are in the order of tens.



Figure : Relationship between number of solar panels and percentage savings in annual electricity bill

* 1. As the number of panels are in the order of 100s, the relationship becomes convex.

Since the decision maker is interested in percentage savings in household electricity bill, the number of solar panels will not be in the order of hundreds. So the linear relationship holds for the scope of this problem.

1. Relationship between number of solar panels and standard deviation of percent savings: As the number of solar panels increases, the standard deviation of the percentage savings increases as well.
   1. This can be explained by the intuition that, if the number of panels increase, the hourly production capacity increases as well. The hourly production depends on the cloud cover and sunshine.
   2. If the sky is clear, then all the panels would generate to its maximum capacity whereas if the sky is overcast, then all the panels would generate nothing. As the range of hourly production increases, the standard deviation of production distribution increases, thus the standard deviation of percent savings as well.
2. Ideal number of solar panels to be installed: When the number of solar panels are 30, the average percent savings is 104% with a standard deviation of 1%. The standard deviation is very small and almost negligible in this case.
   1. So, after excluding basic charges and other one-time charges from the electricity bill, 30 solar panels need to be installed to achieve $0 annual electricity bill.
3. Effect of shifting consumption from on-peak hours to off-peak hours: Shifting the consumption from periods when the rates are too high to when rates are low significantly increases the savings as well.
   1. By shifting consumption from on-peak hours to off-peak hours in both summer and winter, the annual electricity charges were calculated.

Table :Effect of shifting consumption from on-peak to off-peak hours

|  |  |
| --- | --- |
|  | Percentage savings in Electricity bill |
| Without Solar Panels | 23% per annum |
| With Solar Panels | For Actual Demand: 3.3% per panel  For Shifted Demand: 4.3% per panel |

# Technical Analysis:

* Demand and production model are built based on the data from the year 2017, and cost model and other recommendations are made for the year 2018.

## Demand Model:

### *Input Parameters: Past deseasonalized demand data, Demand Clusters*

### *Output Parameters: Distribution of hourly demand*

* Demands of all 4 years of data is plotted to check for patterns or shifts over the years. There are no significant demand shifts.
* Demand factors for all months in the year 2017 was calculated and is used to deseasonalize the demand. The deseasonalized demand data is clustered into 6 groups using hierarchical clustering.
  + First level cluster: (a) public holidays and weekends (b) weekdays
  + Second level cluster: (a) Low, (b) Moderate, (c) High demand

Table : Demand Clusters and their characteristics

|  |  |  |  |
| --- | --- | --- | --- |
| Cluster | Day Type | Hour of the day | Demand |
| 1 | Holidays | 1:00 AM to 7:00 AM | Low |
| 2 | Holidays | 8:00 AM to 1:00 PM | Moderate |
| 3 | Holidays | 2:00 PM to 12:00 AM | High |
| 4 | Weekday | 1:00 AM to 7:00 AM | Low |
| 5 | Weekday | 8:00 AM to 2:00 PM | Moderate |
| 6 | Weekday | 3:00 PM to 12:00 AM | High |

### Modeling Assumptions:

* Demand distribution of each cluster is assumed to follow normal distribution, because a household is less likely to have high consumption and very low consumption values, with most values occurring around the mean.
* However, normal distribution is unbounded and it can have negative values as well, which is not possible in real life. So a truncated normal distribution with min of 0 kW is used.
* The outliers in the demand data were excluded, and only values from 5th and 95th percentile were used while calculating the mean and standard deviation of the past demand data.

Table : Demand Clusters and their distributions

|  |  |  |
| --- | --- | --- |
| Cluster | Mean (kW) | Standard Deviation (kW) |
| 1 | 1.40 | 0.64 |
| 2 | 1.61 | 0.75 |
| 3 | 2.93 | 1.20 |
| 4 | 1.31 | 0.63 |
| 5 | 1.50 | 0.66 |
| 6 | 2.82 | 1.21 |

## Production Model:

### *Input Parameters: Number of solar panels, unit capacity of solar panels, fraction of sunshine - hourly, sunrise hour, sunset hour, monthly clusters*

### *Output Parameters: Distribution of hourly production*

* The only stochastic input of this model is fraction of sunshine/cloud cover which is given by a discrete probability distribution. The year is divided in to 12 clusters and there are 12 different discrete probability distributions given in the data.
* Sunrise/sunset hour also differ over each month/cluster
* Number of solar panels is the decision variable that decision maker can control to tune the output of the model

## Cost Model

### *Input Parameters: 5 different cost clusters, electricity rate structure for each cluster, electricity purchase rate structure, Distribution of hourly production, Distribution of hourly demand, unit capacity of solar panels*

### *Decision Variable: Number of solar panels*

### *Output Parameters: Distribution of percentage savings in electricity bill*

* Percentage savings in annual electricity bill is calculated using the cost model.
* Using @Risk, 1000 runs are simulated to calculate the distribution of percentage savings in electricity bill.

## Sensitivity Analysis:

* For different values of the decision variable, the distribution of percentage savings is calculated.
* The average percentage savings increase as the number of panels increase. However, this relationship is linear when number of panels is of the order of 10 and convex when the number of panels is of the order of 100.
* The standard deviation of percentage savings increases as the number of panels increase. However, When the number of panels are in the order of 10, the standard deviation is almost negligible, whereas when the number of panels are in the order of 100, the standard deviation is much more pronounced.
* The demand of clusters 1&3 and 4&6 were interchanged to shift the consumption from high rate period to low rate period. Then the demand from a high charge period is shifted to a low charge period, it considerably increases percentage savings (about 23%).