Analytical Decision Modeling II

Case Study:

Solar Energy Analysis

Team Case Analysis

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Executive summary

The Arizona Public Service Electric Company case statement required to develop and analyze a simulation model of solar power generation and electricity costs utilizing analytical methods focusing on predictive and prescriptive modelling. Further, the results and recommendations based on the model were targeted to predict the annual cost reduction percentage by using the outcomes on energy utilization with solar panels and without solar panels.

The strategy applied here to model the solution was subdivided into three major parts which included a demand model, production model and a cumulative price model.Moreover, the data shared in the case was partitioned accordingly under the demand and production model. The outcomes to feature the demand value(kWh) and the production value(kWh) were dependent on multiple variables. The demand model included variations per month/date/hour, daytype, holiday and the production model included variations per cloud coverage/sunrise-sunset timings and panel capacity throughout the years. The final outcome in cumulative cost model uses the values generated by the demand and production model respectively and are dependent on the daily and usage cost slab given by the company.. Hence, final outcome comprises of the number of solar panels to be installed and the costs related to the energy production given the climatic conditions as per demand by installing solar panels and without installing the panels.

Furthermore, sensitivity analysis was performed to analyze the variations in the cost based on the factors affecting the pricing in the former models. Five factors including the decay rate of the panels, change in demand percentage, change in cloud coverage, change in sunlight hours and number of years since the panels installed were considered to establish recommendations over analyzing the variability of the costs calculated in the model affected by these factors. As per this analysis it was found that the maximum number of solar panels that can be installed is 17(achieved from 150% of max peak demand) and the number varies with demand percentage and directly proportional to it. The generation cost with Panel is $11818.73 and cost without Panel is $14,135. The annual cost reduction percentage by installing the panels varies as per the given sensitivity factors mentioned above. Due to data unavailability and the constraints given in the case, the results are based on considerable assumptions.

Finally, it is recommended to install the solar panels since the annual cost reduction percentage increases with the number of panels installed. In this case the maximum number of panel installed is 17 which results in 16.56% annual cost reduction. However, the sensitivity factors may affect this value but the Arizona Public Service Electric Company still be saving a substantial amount on the costs.

Model and parameters

Production Model:

The model parameters that are given in the problem are as follows:

Variable	Interpretation
Daylight hours (daily)	Data on the times of sunrise and sunset by day
Max Production Capacity of Panel	Hourly production capacity of a solar panel under full sun (taken as 0.2 kWh) with decay factor of 1% or 0.01 assumed year-on-year
Cloud cover (hourly)	Calculated from the daily cloud cover data using Arithmetic progression to convert to hourly level. Varies with Mean & Standard Deviation of 0.03% (Source - reference 1)
% of times Sunlight present (hourly)	Represents the % of times the Sunlight was present during the specific hour. Assumed to have no variation year-on-year
Number of Solar Panels	Represents the hypothetical number of Solar Panel installed and is the decision variable
Decay Factor	annual reduction% in panel's capacity
No. of yrs since panels installed	No. of complete years since panel was installed
No. of panels	No. of panels installed(Decision Variable)

We are going to start modeling the prediction of the random kWh production problem by hour over an year through the below formula:

$$Random\ kWh\ production/hr = No.\ of\ panels * (1 - Cloud\ cover\ (hourly)) * \%\ of\ times\ Sunlight\ present\ (hourly)$$

$$*\ Max\ Production\ Capacity\ *\ Number\ of\ Solar\ Panels$$

**(1-Decay Factor)^No of yrs since panels installed*

Demand Model:

The model parameters that are given in the problem are as follows:

Variable	Interpretation
$Historical\ kWh\ demand\ (daily, weekly, monthly)$	Historical kWh demand on hourly, daily and monthly basis. Calculated the descriptive summary measures for all three. All historic data is deseasonalized
$Number\ of\ clusters$	The number of clusters for monthly basis were taken as 12, daily basis as 7, hourly basis as 24
$Demand\ factor\ (monthly)$	Calculated the demand factor for each month as $12 * Di / \sum_{k=1}^{k=12} Di$
$Random\ kWh\ demand/hour$	Since there was Min, Max & Mean values available we leveraged the Triangular distribution for hourly, daily basis by assuming the Mean value as the most likely value in the Triangular Distribution as the data is skewed towards both the ends. Assumed that the demand will follow the same variation hourly, daily, monthly, holiday/non holiday as it followed the previous year.

Holiday Factor	Ratio of mean for holiday days and non holiday days

We are going to start modeling the prediction of the random kWh demand by hour over an year through the below formula:

$$\begin{aligned} \textit{Random kWh demand per hour} = {} & \textit{Historical kWh demand}\text{ (daily cluster)[RiskTriangle]} * \\ & \textit{Historical kWh demand}\text{ (hourly cluster)[RiskTriangle]} * \\ & \textit{Demand factor (monthly) for specific month to reseasonalize} * \\ & \textit{if (Holiday (Holiday factor(ratio of daily demand for holidays \& non} - \textit{holiday days)/} \\ & \sum_{k=0}^{k=23} \text{kWh demand (hourly cluster)[RiskTriangle]} \end{aligned}$$

<u>Predictive Model for Electricity Costs:</u>

We are going to start modeling the prediction of the random electricity costs over one year a given number of solar panels, and random electricity costs with no solar panels using the below formulas :

Electricity Costs (general) / hour *= (Base Charge + Customer Account Charge + Metering Charge + Meter Reading charge + Billing Charge) / 24* - *Equation 1*

<u>Case 1 - Electricity costs per kWh without panel</u>

Electricity Costs per kWh = *Random kWh demand per hour* * All kWh metric slabs (considering on-peak, off-peak, summer, winter, etc.) - *Equation 2*

<u>Case 2 - Electricity costs per kWh with panel</u>

Electricity Costs per kWh = (*Random kWh demand / hr* – *Random kWh production/ hr*) * All kWh metric slabs (considering on-peak, off-peak, summer, winter, etc.) - *Equation 3*

Total Electricity Costs per kWh (with panel) = *Equation 1 + Equation 2*

Total Electricity Costs per kWh (without panel) = *Equation 1 + Equation 3*

Assumptions

- The sunset- sunrise times were shared for the year 2017 in the data file. In this forecasting model, the same data has been assumed for year 2018.
- The data sheet given had 1 week of cloud coverage data. As identified from research that the cloud coverage may vary in the mean and standard deviation by ±0.03% (Ref. 1). The remaining cloud coverage data was pulled out from NASA's free export report (Ref. 2).
- Number of clusters for daily data = 12
- Number of clusters for hourly data = 24
- Number of clusters for monthly data = 12
- The demand values are available in min, mean and max. Hence, RiskTriangle has been used to calculate demand on hourly and daily basis.
- Default decay rate per year of single solar panel = 1% (Ref. 3). The decay rate only takes effect when entire year finished.
- Each mean of parameters equal to the most likely performance of corresponding feature.
- The time of sunrise and sunset will remain the same as previous years.
- Because the student version of @Risk is limited to no more than 100 @Risk random variables, the model we built have not been simulated.

Results

Optimized solution:

Maximum Number of Solar Panels = 17

Number of Solar Panels = Decision variable

Generation Cost with Panel(17) = $11818.73

Cost without Panel = $14,135

Annual Cost Reduction%= 16.56%

{considering Demand Factor = 1%, Years since panel installed=0, Demand%= 0, Cloud Coverage%= 0 and Sunlight %= 0}

1. A slightly concave graph was observed between the number of 'Years Since the Panel Installed' vs 'Annual Cost Reduction %' (Ref. Fig.1 and Fig.2). Hence, it can be said that as the number of years increase or when the demand increases the cost reduction percentage decreases.
2. A linear relationship is observed between the 'Number of panels' and the 'Annual Cost Reduction%'(Ref. Fig.3).
3. A significant effect was observed on the 'Annual Cost Reduction%' by changing the input factors like Demand% shows a concave relationship, with Cloud Cover% shows a convex relationship and with sunlight and decay% it shows a nonlinear relationship. (Ref. Fig 2, Fig. 4, Fig. 5, Fig.6)

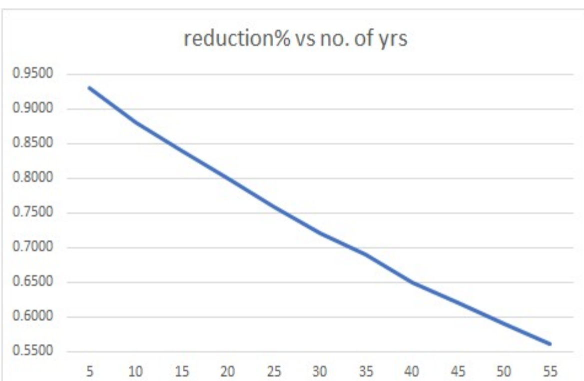

Fig.1

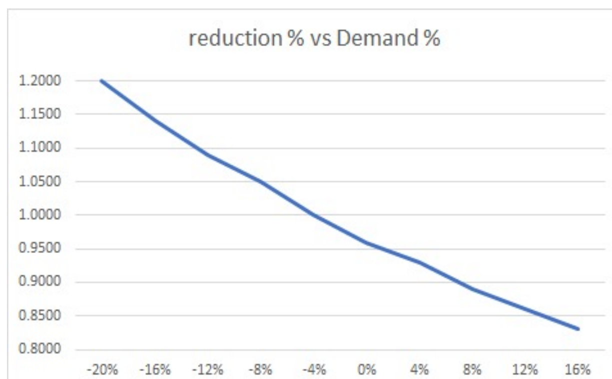

Fig.2

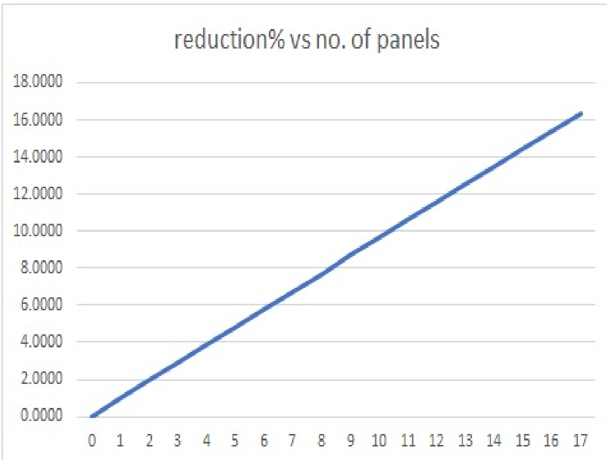

Fig. 3

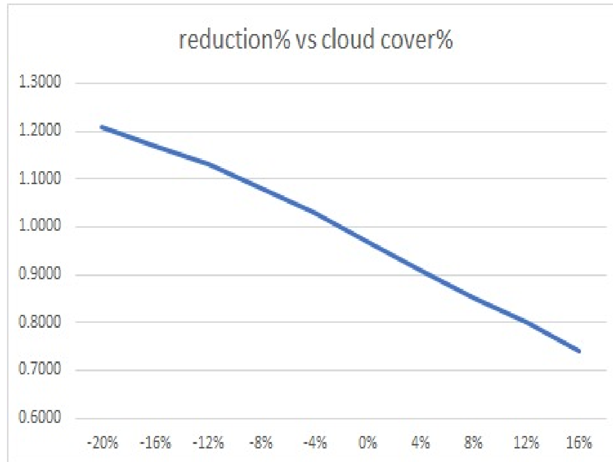

Fig.4

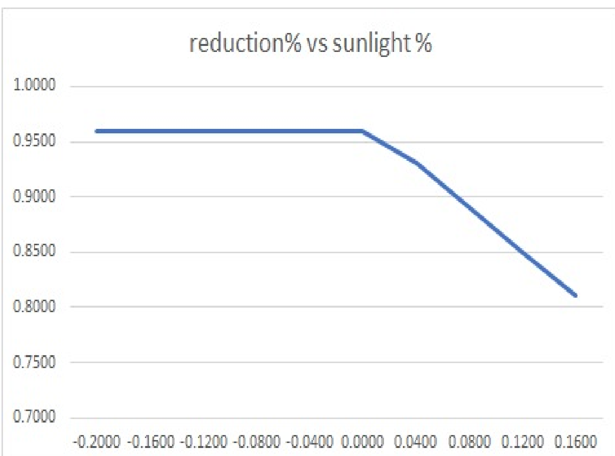

Fig. 5

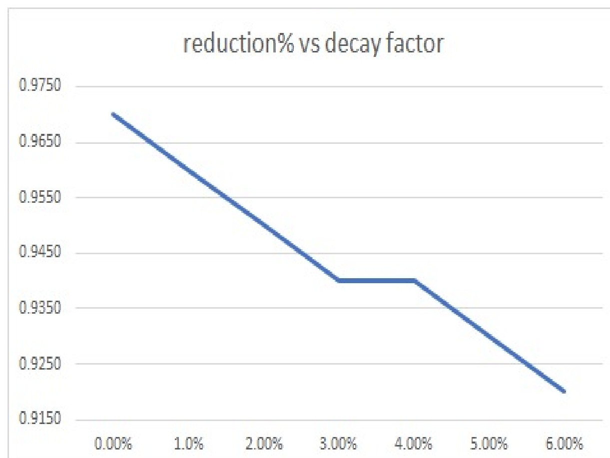

Fig.6

Recommendations

Based on the analysis above it is recommended to install the solar panels since the annual cost reduction is optimally achieved by both minimum value of 1 and maximum value of 17 of number of solar panels that can be installed with a decay factor of 1% considered under an assumption. It is observed that even after the sensitivity factors affecting the costs associated with the generation cost with and without panel, the annual cost reduction gives a significant value. Hence, the consumers can go ahead with the plan of installing the panels.

References

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References 3: What Is the Lifespan of a Solar Panel?

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