Solar Design for Inox Wind, Madhya Pradesh, India

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I. Executive Summary

The primary objective of the analysis in this project is to analyze the installation of solar photovoltaics on the rooftop of a wind and blade manufacturing plant belonging to Inox Wind located in Madhya Pradesh, India. Inox Winds primary goal is to reduce the cost of electricity through installation of solar photovoltaics because of a heavy expenditure of energy in the manufacturing plant. The total area of the rooftop is 19656 m$\hat{2}$.

The solar resource available at the project's location is a good resource to take advantage of. The local weather is separated into four seasons (Winter, Summer, Monsoon, and Autumn) because of the weather associated with each season. The most energy will be produced in April and May with the annual energy production of 1,557,424 kWh after losses. This solar design avoids shading other than what is impossible to avoid due to the shade cast by other modules. The solar system will be a fixed, grid-tied system with the availability of net-metering.

The large scale photo-voltaic array was specifically designed for the sloped rooftop using 3D modeling. It was decided that there will be a raised structural frame with a rack system to aid in the support of the weight of the array and securing of the panels. A walking surface will exist on the entirety of the raised structure for maintenance purposes. Below the Tata Power TP310LBZ solar panels where there will be an opening, as well as a 0.2m opening in front of the solar panels in consideration of heat dissipation and rain runoff during the monsoon season. To optimize power output and minimize costs, 60 Delta Solivia inverters with 20.2kW maximum AC power each were used with 4,386 Tata Power TP310LBZ panels with 309W DC maximum power yielding a DC to AC ratio of 1.12 and 17 modules in each string with 258 strings in parallel.

The loading estimates at Inox wind vary from seasons and demand. The highest power consumption, 301,700 kW, was recorded in the month of March(peak summer).

The single biggest driver to assessing whether a project is viable is its financial and economic analysis. The financial assessment of the rooftop solar project was carried out with the help of SAM (System Adviser Model), a performance and financial modeling software designed to facilitate with decision making of energy projects. Financial assessment of the project yielded a payback period of 5.3 years. The Net Present Value (NPV) of the project is valued at Rs. 4,09,79,261.41 ($637,909.00) and the Levelized Cost of Energy (nominal) is Rs. 3.50/kWh ($ 0.0545/kWh). That is, the electricity generated from the rooftop project would need to be sold at Rs. 3.50/kWh to the grid in order for the project to pay for itself within 5.3 years since beginning commencement. This is an impressive result given that the Madhya Pradesh Electricity Regulatory Commission (MPERC) has set a levelized tariff of Rs. 5.45/kWh ($ 0.085/kWh) for 25 years, which is well below above the nominal LCOE of Rs. 3.50/kWh ($ 0.0545/kWh). Given that Madhya Pradesh is blessed with a great solar resource, coupled with increasing support for rooftop solar systems in the form of subsidies and incentives from the Government of India, the proposed rooftop photo-voltaic system atop Inoxs wind turbine manufacturing plant in Khund will be not only be a great addition in terms of an increased energy independence but also as an exceptionally viable financial investment.

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II. Introduction and Background

The market in India, as expected, is different than it is in the United States. This is true when it comes to the solar energy industry as well. In 2010, India launched its National Solar Mission which set a target of deploying 20,000 MW of grid connected power by 2020.[1] The main considerations of this analysis and design process will be the solar irradiance, financial and economic parameters that make a solar array viable for implementation into an industrial process. Technology and design will be looked at as a complimentary aspect to the overall design.

Inox Wind is a leading wind energy company in India that manufactures and supplies wind blades, nacelles and tubular towers. INOX Wind has three manufacturing plants located in Gujrat, Himachal Pradesh and Madhya Pradesh. Team member Zohair Khan had the opportunity to have an internship at newly integrated plant in Madhya Pradesh in summer 2016. This plant manufactures blades and towers and plans to expand towards manufacturing nacelles and hubs. As an intern, Khan's primary objective was to analyze the total energy consumption in the blade and tower manufacturing process. According to the results, tower manufacturing was the most energy intensive and expensive process due to an industrial plasma cutter. The head of projects, Mr. Ramesh Nadagiri, discussed plans of integrating solar energy to cut on costs of electricity.

III. Site Analysis

Site analysis for a large scale solar farm involves consideration of many different factors including location, shading, and power generated by the system. Madhya Pradesh, India is a prime location for solar photo-voltaic implementation to offset the use of fuel costs.[2] The goal of this analysis is to determine whether the deployment of a rooftop solar array will benefit Inox Wind manufacturing plant. The building of interest has 4.8 acres of available space while the length of the building faces due south. The placement of an array of the rooftop allows for maximum use of land available while also eliminating possible shading effects. However, the issue of the weight of the array needs to be considered in the installation and cost of the system. Grid interconnection will be implemented to allow for net metering and transfer of energy that is being generated during times where blade and tower manufacturing was low. After a full analysis has been completed, a recommendation will be made for INOX Wind for the viability of the implementation of a solar array.

The country of India and the state of Madhya Pradesh are both determined to reduce its carbon footprint and to meet standards shown in the Tariff Order for Solar Energy Based Power Generation in Madhya Pradesh in August 2016.[3] This document includes vital information about the incentives and other financial information for the state of Madhya Pradesh. The government is trying to pave the way for the solar industry, as well as other green energies, to expand and take on a larger portion of the countrys base load. The share of renewable energy in the countrys fuel mix is expected to increase from 2% to 8% by 2035.[4]

Across the state of Madhya Pradesh it is starting to be a common sight to see large scale solar projects. In the realm of energy production, India had the largest functioning solar farm in the Welspun Solar MP project. Other companies have taken advantage of solar energy as well. This specific region has roughly 300 days with good sunlight and with the 4.8 acres of available roof space we predict that Inox Wind could produce close to 1.4 MW of energy.

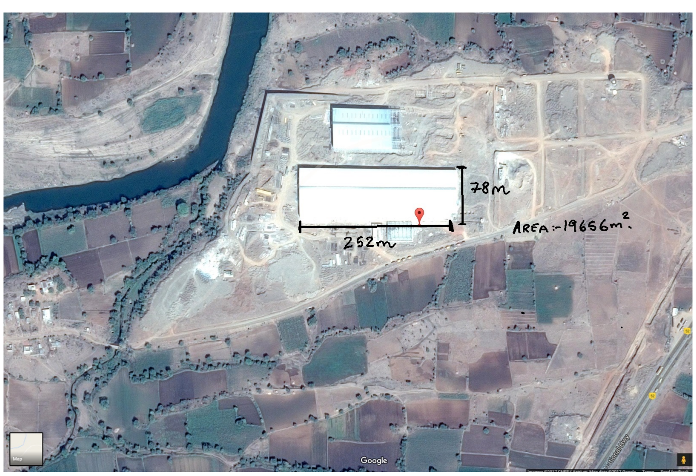

Figure 1 - Aerial View of Inox Wind Warehouse.

IV. Technological Constraints

A. Resource Availability

Solar resource availability, as the name implies, comes from the Sun's radiation. This resource can be divided into beam, ground, and horizontal fractions. In the given locale this resource is available in large amounts during daylight hours. Using NREL's System Advisor Model (SAM) [5], it is possible to model the resource availability. On the location and resource tab the location was set to Indore, India. This city is the closest location to the project site, so it accurately describes the same resource that will be at the tower manufacturing plant to a degree. The following information can be drawn from SAM. The rest of the data in the file will be used in the simulation later in this report.

Global Horizontal	5.48 kWh/m2/d	Average Temperature	26.4 C
Direct Normal (Beam)	4.67 kWh/m2/d	Average Wind Speed	2.2 m/s
Diffuse Horizontal	2.29 kWh/m2/d	Average Snow Depth	N/A

The chart above shows a brief overview of the solar resource of the project's locale. The values represent a good resource to take advantage of.

B. Shading

Shading occurs when a shadow is cast onto the surface of the module. This can be caused by trees, building, air conditioning units, other modules, or any other object that is higher in elevation than the module. Shading is an issue because it reduces the amount of direct sunlight incident upon the surface of the module. The rooftop of the Inox Wind warehouse does not have any shading issues. The only form of shading for this project is self-shading from the modules themselves. This can be seen in the sun chart below.

The shading in the case of this project is from self-shading. This information was taken from the SAM simulation. This effects the amount of modules the rooftop can hold due to a required distance between the modules. Self-shading represents when the Sun is lowest in the sky and the modules are producing negligible amounts of energy. The length of the shadow cast at the solar elevation angle will result in the distance between the modules.

C. Weather and Seasonal Efficiency

The weather in Madhya Pradesh is ideal for a photovoltaic system. It boasts 300 sunny days a year, and has no snowfall. The seasons in India (in order) are:

- Winter - December through March
- Summer/Pre-Monsoon Season - April through June
- Monsoon/Rainy Season - July through September
- Post-Monsoon/Autumn - October through November

The effect the weather has on the solar resource is how the seasons effect the global irradiance. The following chart shows the global irradiance per month. The trends can easily be explained from the information in the list above.

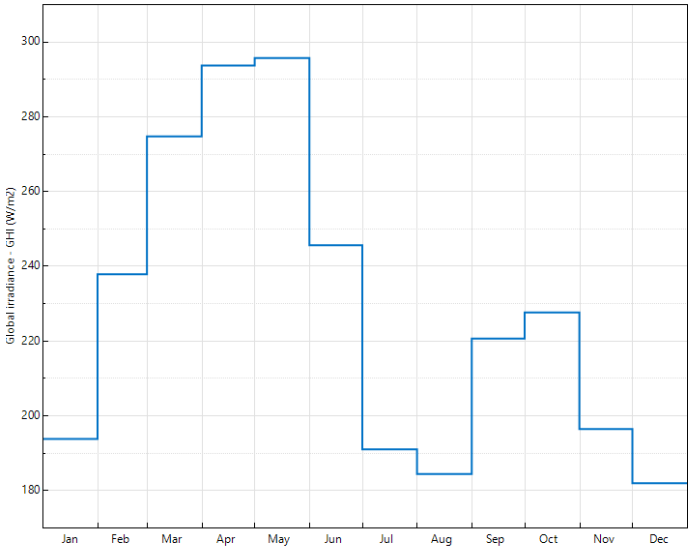

Figure 2 - Global Irradiance of Indore, India.

The global irradiance is directly proportional to the amount of energy the modules produce. As shown above in the summer season, especially in April and May, the system will produce the most energy. In July and August, during Monsoon season, the production of the panels will be much lower. Normally, this is what the design of the system would be based on in order to avoid dumping energy. In the case of this project, maximum capacity for the area provided is the goal;this is because it is suggested for Inox wind to sell it's produced electricity back to the utility company.

D. Fixed v. Tracking

Due to the location and the orientation of the building the azimuth of the modules will be 0, meaning due south. A tracking system is not advised for this project because the added benefit of a larger resource does not outweigh the added costs for installation and maintenance. The 1.36 MW installation will be receiving enough irradiation throughout the day without tracking. Due to the latitude being low, the sun is out for much longer than other places where tracking might be feasible. Moving parts in the system will give it a higher likelihood to break and require more maintenance as well.

E. Net Metering

To maximize the amount of money saved and decrease the payback period of the system, Inox Wind will sell the electricity generated to the utility company. Inox will not be providing any energy directly to the manufacturing plant for the sole reason of taking advantage of the incentives provided by the country. Doing so will provide a positive $/kWh to the company. Since the incentive only lasts the first 10 years, an agreement will be attempted to be reached for those ten years.[6] Following the ten years, Inox wind will begin to provide energy directly to their manufacturing plant to again maximize the cost per energy. Taking advantage of net metering will be more beneficial to Inox Wind than using the energy themselves due to the incentives in place by the government. With this program Inox Wind can sell their electricity at 5.45 rupees/kWh or 0.085 $/kWh.[3] However, with the incentive in the first ten years Inox Wind can sell their electricity at the same price and receive an additional $0.193/kWh [6] incentive from the government which is much better financially than consuming the produced energy themselves. The current rate they have to pay for electricity is$0.096.[3]

V. System Design Criteria

A. Module

A photovoltaic module was chosen based on the location of the company that sells the panels as well as reputable history of photovoltaic array installation. Tata Power is one of the largest solar manufacturers in India and was ranked #1 in the solar rooftop market in India from 2014 to 2016. Shipping costs will be minimized while contributing to the local economy by using the local company. The specific panel chosen was Tata Power Solar System TP310LBZ which has a maximum power of 309.856 W(dc) per panel and is 1.978m by 0.994m and an area of 1.966m2. The nameplate capacity of the array was found to be 1,359.028 kW(dc).[7]

B. Design of Array

The array was designed using Sketchup,[8] a program using 3D modeling to determine how many panels will fit on the specified roof with dimensions of 252m by 78m and an area of 19,656m2. When a large solar array is being designed, it is important to consider heat generated from the panels that can cause overheating due to hot local climate. To allow for this, a ground cover ratio of 45% was incorporated for the rooftop array.[5] When modeled in Sketchup, this gave a total of 4,386 modules in the array with 86 modules along the bottom and 51 rows. There will be 1m between each panel along the bottom, and 2.2m between the front of the panel and the front of the panel behind in each row. The structure that will support the array will be a raised flat rack system above the curved roof. The panels will be supported by crossbars supporting the panels at 19 degrees with no flooring below each panel and 0.2m of space in front of each module for rain runoff, which is especially important during monsoon season. Spaces in between the rows and columns of modules will be floored to allow for workers to access each panel. Figure 3 and 4 bellow show the setup of the solar array.

C. Inverter

The choice of the inverters was based on many different factors such as total capacity, DC to AC ratio, and price. To maximize the power production by the inverter, a decision was made to oversize inverter which signifies having a larger kW capacity for the array than the inverter. This allows the use of inverters with lower AC rating and therefore a significantly lower cost, as well as using a greater number of smaller, less expensive ($2,000 ea.) inverters

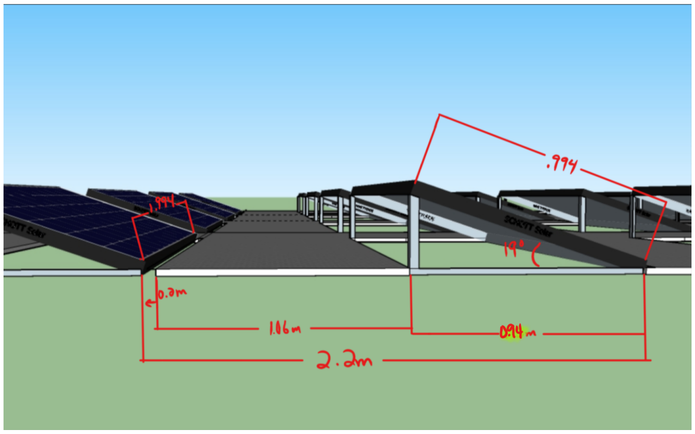

Figure 3 - Side View of Solar Array.

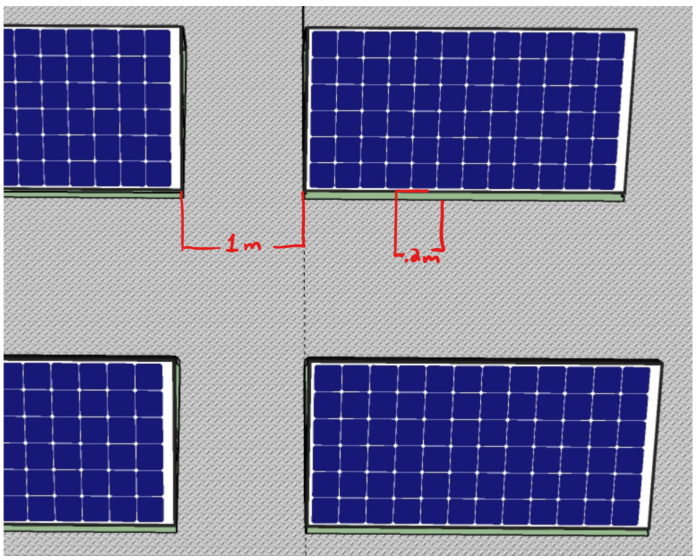

Figure 4 - Top View of Solar Array.

instead of a less number of very expensive ($300,000 ea.) inverters. Another reason to oversize the inverter is to allow the module to run below the standard test conditions (1,000W/m2) most of the time. Also, temperature losses from the module will reduce the high-power times. This means that by oversizing the DC power (DC to AC ratio of 1.12), the system will run at a higher performance for most of the day with little clipping losses, as well as allow for the business to reach its rated AC capacity early in the day and continue to operate at that capacity throughout the day. The inverter chosen is the Delta Electronics 20 TL 720V [9] with a maximum AC power of 20200 W and minimum and maximum MPPT DC voltage of 500 and 800 Vdc respectively. It was determined that there will be 60 inverters used allowing for 17 modules in a string and 258 strings in parallel. All inverters will be housed in a single control room next to the building.

D. Grid Connectivity

The solar array will be a grid tied system with no batteries. Because the cumulative $/kWh sold to the grid from the solar array will be much greater than the $/kWh bought from the utility company, this system will not provide power directly to Inox Wind manufacturing facility. If the array system was to provide direct electricity to manufacturing, then the incentive of $0.193/kWh [6] from the Indian government and the $0.085/kWh [3] from the utility company would not be relevant and the payback period of the system would be much greater. After the 10-year period for the incentive ends, the system can then directly provide power to the manufacturing facility and maximize the fuel avoidance costs.

VI. Socioeconomic Constraints

A. Client Demands

The goal of the client is to minimize the costs of electricity due to power consumption caused by large scale wind tower and blade manufacturing while becoming more independent from electricity rates and outside variables. Typically, the photovoltaic system would be designed such that the maximum energy produced from the system would be equal to or less than the lowest amount of energy consumed by the manufacturing facility so there is no energy being wasted. However, Madhya Pradesh has net metering which allows the solar array to produce the maximum amount of energy it can, without regard to waste, and sell it to the grid. Because of the huge incentives given by the Indian government and the price at which the utility pays for the energy, there will be a positive net income generated from the sale of energy allowing for an even faster payback period, and therefore a feasible venture.

There are other bonus outputs from the design that were not necessarily demanded by the client. Carbon monoxide emissions from energy production is an increasing global concern. Inox Wind has a unique opportunity to blend solar power with wind power, working toward a carbon free power generation process. This can greatly increase the marketing and public response to the company while helping the country meet its mission of increasing renewable energy sources. Implementation of rooftop photovoltaics also lends an advantage for the company as it will not take up land space that can otherwise be used to expand the manufacturing facilities, increasing the efficiency of the land use.

B. Loading Estimates

The total power consumption for the months of February to May is given in the following table.

Month	Cost ($/kWh)	Total Power Consumption (kW)
February	0.110957	256,659
March	0.109395	301,700
April	0.126887	217,955
May	0.129307	217,098

Because of the high amount of power consumption of the facility, a high irradiance value is desired to maximize power production.

Figure 5 was obtained from SAM and shows the monthly electrical consumption and the energy that would be generated by solar array per month at the site. By analyzing the graph, the amount of energy that could be supplied to the plant can be predicted. The companys maximum energy consumption is during the summer (February-June) as transportation of material is easy and humidity is low (affects blade manufacturing).

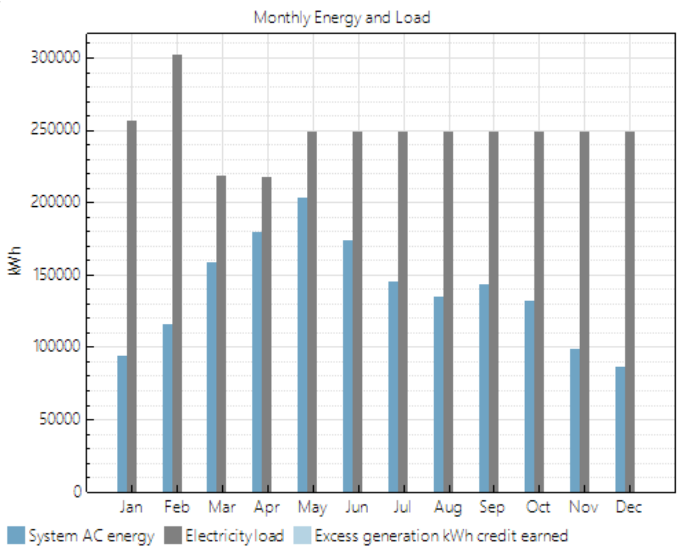

Figure 5 - Energy Consumption and Production by Month.

In this project, the load estimates had to be based off of the values of loads from the months of February, March, April and May. Due to company policies, values for the electrical loads for the entire year were not able to obtain . As a result, the team decided to determine an average value from the values obtained and assumed the calculated average value as the electrical load for the year.

VII. System Performance

A. Performance

The System Advisor Model simulation for the proposed design shows different pieces of data that reflect the systems performance over a monthly and yearly basis. This is represented by many different charts and calculated values. The ones worth highlighting will be mentioned here.

After a year of operation, the predicted annual energy produced will be **1,557,424 kWh** after losses. This number is used in calculating the capacity factor, a ratio of energy produced over the nameplate capacity. This number is a tool used to compare to other systems. The higher the factor, the better. In this case the capacity factor is **13.1%**. Next, the energy yield shows what each module is capable of producing in a year. This is valued at **1,146 kWh/kW**. The performance ratio is a measure of a photovoltaic system's annual electric generation output in AC kWh compared to its nameplate rated capacity in DC kW, taking into account the solar resource at the system's location, and shading and soiling of the array.[1] Here, the performance ratio is rated at **0.68**. The following figures 6 and 7 show energy production in a monthly and yearly sense.

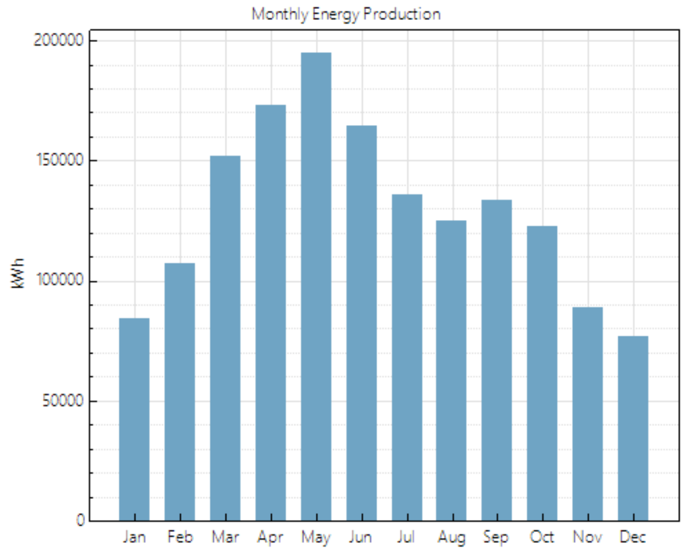

Figure 6 - Monthly Energy Production.

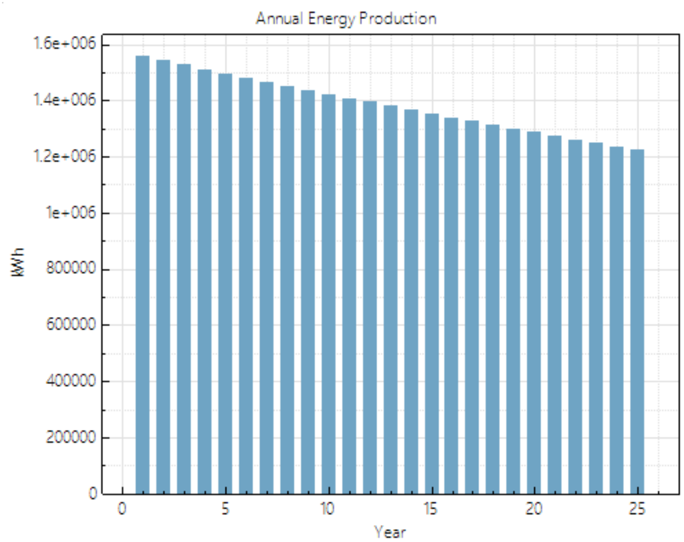

Figure 7 - Yearly Energy Production.

Over 25 years, as seen in the above bar graph, the system is predicted to lose about $0.325 \cdot 10^6$ kWh produced. Over these years due to the mentioned net metering and incentives the project will pay back its cost well before this period is up. This will be discussed in the next section (Economics and Financial Analysis).

B. Losses

As seen in figure 7, there is a 1% degradation loss annually. This is due to many factors that have been minimized but unfortunately can not be erased or forgotten. The figure below is a good visual representation of the losses experienced by the system:

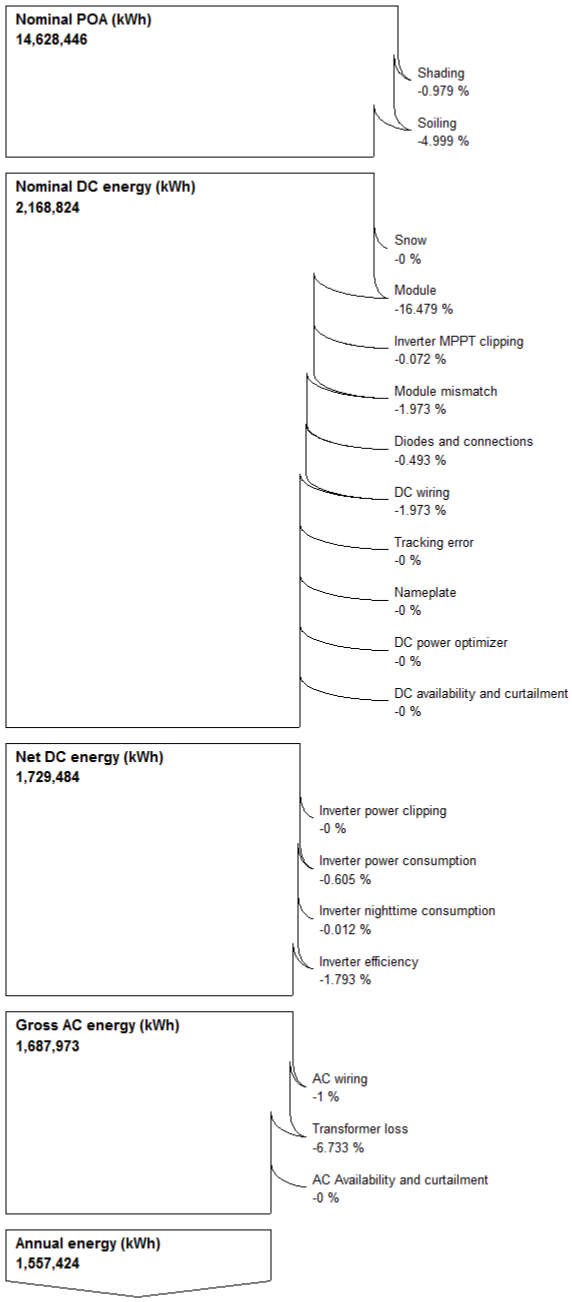

Figure 8 - System Losses.

VIII. Economics and Financial Analysis

A. Background

The economic and financial analysis of the project was carried out using the System Advisor Model (SAM) software, developed by the US National Renewable Energy Laboratory (NREL). [5] SAM is a performance and financial model designed to facilitate with decision making of energy projects. In this section, the following will be examined:

- System Costs
- Financial Parameters used
- State and Central Government taxes
- Electricity Rate Structure

The above parameters will aid in calculating:

- Levelized Cost of Energy (LCOE)
- nominal
- Levelized Cost of Energy (LCOE) real
- Net Present Value (NPV) of project over 20 year lifetime
- Payback Period of project
- Discounted Payback Period

B. System Costs

Calculating Direct Capital Costs

-Panel Costs

As discussed above, the rooftop will have a total of 4,386 panels manufactured by Tata Power Solar Systems (model no. TP310LBZ). The cost per panel is Rs. 29,888.11 ($465.00) and therefore, total module costs Rs. 13,10,89,239.49 ($2,039,490.00).[7]

-Inverter Costs

The project will be using inverters manufactured by Delta Electronics. The inverter model is Delta 20 TL 720V [CEC 2016] and the cost per inverter is Rs. 1,47,833.65 ($2,300.00). A total of 60 inverters will be used altogether, which amounts to a total cost of Rs. 8865810.00 ($138,000.00).[9]

Balance of System [10]

Item	Cost
Supply, Installation, Erection and Commissioning of Modules	Rs. 3,00,00,000.00 ($466,740.83)
Module Mounting Structure and Associated Civil Works	Rs. 90,00,000.00 ($140,022.25)
Installation, Erection and Commissioning of Inverters	Rs. 55,00,000.00 ($ 85,569.15)
Cables and Associated Civil Works	Rs. 35,00,000.00 ($ 544,53.10)
Inverter and Control room, Boundary wall work, approach road with water tank	Rs. 30,00,000.00 ($ 46,674.08)
Total	**Rs. 5,10,00,000.00 ($ 793,459.41)**

-Mounted Rack System

As discussed in Design Considerations, given that the warehouse roof is curved, a leveled platform, that is, mounted rack system, will be required to maximize panels on the roof and minimize shading effects. The cost of constructing this mounted rack system will be included in the direct capital costs. It is estimated this racking system will require 4 months for completion, 20 semi skilled engineering laborers with a minimum monthly wage of Rs. 7893.00 ($ 122.8) per person in Madhya Pradesh. Therefore, total cost of labor amounts to Rs. 6,31,442 ($9,824) [11].

Now the cost of the structural system of the mounted rack system will be considered. The structural frame refers to the load-resisting sub-system of a structure, the load in this case being the weight of the solar panels. This structural system will transfer the load through interconnected structural components. The cost of this structure will be similar to a pre-engineered building construction cost, that is, the structural frame of a building. The cost was estimated to be equal to Rs. 300/sq. ft. ($ 4.67/sq.ft.) [12] Given roof area of 19,656 sq.ft., the total cost of the mounting rack systems structural frame amounts to Rs. 58,96,800.00 ($ 91,742.60).

Therefore, total cost of mounting rack system amounts to Rs. 65,28,242.00 ($ 101,566.6). In summary:

Item	Cost
Cost of Labor	Rs. 6,31,442 ($9,824)
Cost of Mounting Structure Frame	Rs. 58,96,800.00 ($91,742.60)
Total	**65,28,242.00 ($101,566.6)**

Figure 9 - A Sample Structural Frame.

Integrating the above mounting rack system (*the structural frame as seen in Figure-9 above*) over the entire curved roof of the warehouse will enable us to get a flat surfaced roof which can incorporate more modules by preventing shading. Shown below is a 3D generated image of this structure incorporated onto the warehouse:

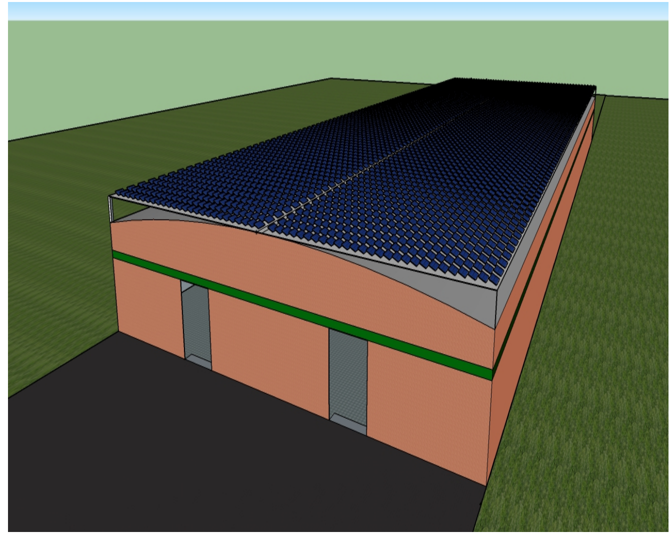

Figure 10 - 3D representation of the system

Indirect Capital Costs

The indirect costs linked to the project will now be considered. The only major indirect cost associated with the project is normative cost of transmission line at Rs. 40,00,000.00 ($ 61,995.69)[3].

Total Installed Cost

Below is the given summary of total installed cost, that is, direct capital costs + indirect capital costs:

Item	Cost
Direct Capital Costs:	
Total Module Cost (TP310LBZ Tata Power Solar Systems)	Rs. 13,10,89,239.49 ($2,039,490.00)
Total Inverter Cost(Delta 20 TL 720V[CEC 2016] Delta Electronics)	Rs. 88,65,810.00 ($138,000.00)
Balance of System (BOS)	Rs. 5,10,00,000.00 ($793,459.41)
Mounted Rack System - Total	Rs. 65,28,242.00 ($101,566.6)
Contingency (0.5% of Direct Capital Costs)	Rs. 9,87,437.51 ($15,362.58)
Indirect Capital Costs:	
Transmission Line	Rs. 40,00,000.00 ($ 61,995.69)
Total	**Rs. 20,14,83,291.5 ($3,149,874.25)**

Yearly Operation and Maintenance Costs (O&M)

It is estimated that the O&M cost per year to maintain the project will be of the amount Rs. 9,50,891.75 ($14794) for the first year. Thereafter, the cost of O&M will rise at an escalation rate of 2.21% (above inflation rate which is valuated at average value of 3.54% for first three months of year 2017)[13] every year.

C. Financial Parameters

i. Project Term Debt

As outlined in Tariff Order for Solar Energy Based Power Generation in Madhya Pradesh[3] authored by the M.P. Electricity Regulatory Commission Bhopal, the following norms were considered for determination of tariff:

- Debt to Equity ratio is of the order 70:30
- Project Lifetime is 25 years
- Interest on debt is 10.2%[14]. Please note that the Tariff Order passed by M.P. Electricity Regulatory Commission Bhopal considers an interest on debt of 12%. However, IREDA (the Indian Governments Renewable Energy lending arm) lends at lower rates (10.2 11.4%).
- Loan term is 15 years
- Inflation rate which valuated at average value of 3.54% for first three months of year 20175
- Real Discount Rate is 7.75%/year and Nominal Discount Rate is 11.56%/year[15]

ii. Tax and Insurance Rates

Given the high electricity load requirement of the client, monthly total electricity generated by rooftop project does not exceed monthly client demand of electricity. Therefore, the client will not make any taxable profit from generation of electricity by the rooftop project. However, as discussed before, the main motivation of the client to pursue the rooftop project will be to offset the high monthly electricity bill.

iii. Depreciation

As per Section 32 of the Income Tax Act, accelerated depreciation rate of 80% is applicable for solar power generating systems for the first year[16] .

iv. Salvage Value[3]
End of analysis period (25 years) salvage value of the project is valuated at 10% of the asset value. This is estimated to amount to Rs. 2,02,45,946.92 ($ 314,987.00).

v. Incentives

- The Indian Government provides a 10-year tax holiday for solar power projects. That is, any profits made from selling generated electricity to grid will not be taxed for the first 10 years of the project. After the 10 years are completed, it is recommended that the client switch from selling 100% of generated electricity to the grid, to consuming generated electricity to meet personal energy demands and thereby take advantage of Net Metering during times of low electric demand, to offset electric bill costs.
- Rooftop solar capital subsidy of 30% sanctioned by MNRE (Ministry of New and Renewable Energy) through Jawaharlal Nehru Mission Scheme will be applicable to the rooftop project[17].
- Generation Based Incentive (GBI) will be applicable for the rooftop project. Grid solar power projects in the capacity range of 100 kW to 2 MW each, connected to HT grid below 33 KV are eligible under the scheme. A project developer is required to be initially pre-registered with the state designated agency and thereafter register online with IREDA[18]. Under the scheme, a GBI of Rs. 12.41/kWh ($ 0.193/kWh) will be provided to Grid solar power projects for a minimum of 4 years and a maximum of 10 years. Thus, as mentioned before, the client will benefit greatly from selling 100% of generated electricity from rooftop project to the grid for the first 10 years. After the 10 years are completed, it is recommended that the client switch from selling 100% of generated electricity to the grid, to consuming generated electricity to meet personal energy demands and thereby take advantage of Net-Metering during times of low electric demand, to offset electric bill costs.

D. Electricity Rate Structure

The M.P. Electricity Regulatory Commission Bhopal determines the levelized tariff of Rs. 5.45/kWh ($0.085/kWh) for 25 years for sale of electricity from Solar Photo-voltaic Power Generation Plants4. Currently, the average rate of electricity in the state of Madhya Pradesh for industrial consumers is Rs. 6.17/kWh ($ 0.096/kWh).

As per suggested strategy, selling 100% of the generated electricity to the grid for the first 10 years will be done at the levelized tariff of Rs. 5.45/kWh ($0.085/kWh). After the ten-year mark, as per suggestion again, the client is advised to consume the rooftop projects generated electricity and participate in grid tied net metering. This way, for every unit of the rooftop projects generated electricity (1 kWh) that is consumed by the client, the client will offset its electricity bill by Rs. 6.17/kWh ($ 0.096/kWh) which is the average rate of electricity in the state of Madhya Pradesh for industrial consumers.

E. Summary of Financial&Economic Analysis

- The net capital cost of the project is projected to be Rs. 20,14,83,291.5 ($3,149,874.25). Therefore, at debt percent of 70%, the loan that can be taken out for this project amounts to Rs. 14,17,21,821.26 ($2,204,912.00), and rest being equity amounting to Rs. 5,97,61,470.244 ($ 929,770.60). Weighted Average Cost of Capital (WACC) is calculated to be 10.61%.
- LCOE (Levelized Cost of Energy) nominal is calculated to be at Rs. 3.50/kWh ($0.0545/kWh). This is the minimum price at which the client will need to

sell the electricity generated by the project to the grid to break even initial costs. LCOE real is calculated to be at Rs. 2.63/kWh ($ 0.041/kWh).

- Given below is a table showing money saved in electricity bill cost by client each year:

- The NPV (Net Present Value) of the project is calculated to be Rs. 4,10,01,919.93 ($637,909). This is the present value of all future cash flows in terms of todays value of money. This highly positive value of NPV is an indicator that the investment in the rooftop project will be very profitable.

- Payback Period is calculated to be 5.3 years, that is, the project will payback its initial costs in 5.3 years due to revenue from generation of electricity that can be sold to the grid, or savings from consuming this generated electricity by the client in order to offset monthly electric bill. Discounted Payback Period is calculated to be 7.3 years.

F. Cash-Flow

The Financial&Economic Analysis section of the report will be concluded by observing the project's cash flow, shown in the table below:

Year	After-tax cash flow ($)	After-tax cash flow (Rupees)
0	(944,962)	(-60737905.03)
1	1,069,309	68730370.63
2	123,801	7957371.176
3	123,305	7925490.528
4	7122,873	7897723.512
5	122,505	7874070.128
6	122,199	7854401.825
7	121,954	7838654.327
8	121,756	7825927.778
9	121,630	7817829.065
10	121,550	7812687.025
11	(150,338)	(-9663050.119)
12	(147,582)	(-9485906.841)
13	(144,836)	(-9309406.318)
14	(142,047)	(-9130141.949)
15	(139,264)	(-8951263.232)
16	156,760	10075827.38
17	159,570	10256441.54
18	162,383	10437248.52
19	165,207	10618762.53
20	168,028	10800083.71
21	170,847	10981276.35
22	173,660	11162083.33
23	176,458	11341926.18
24	179,246	11521126.27
25	496,994	31944537.85

Given here is the graphical representation of the tabulated cash flow:

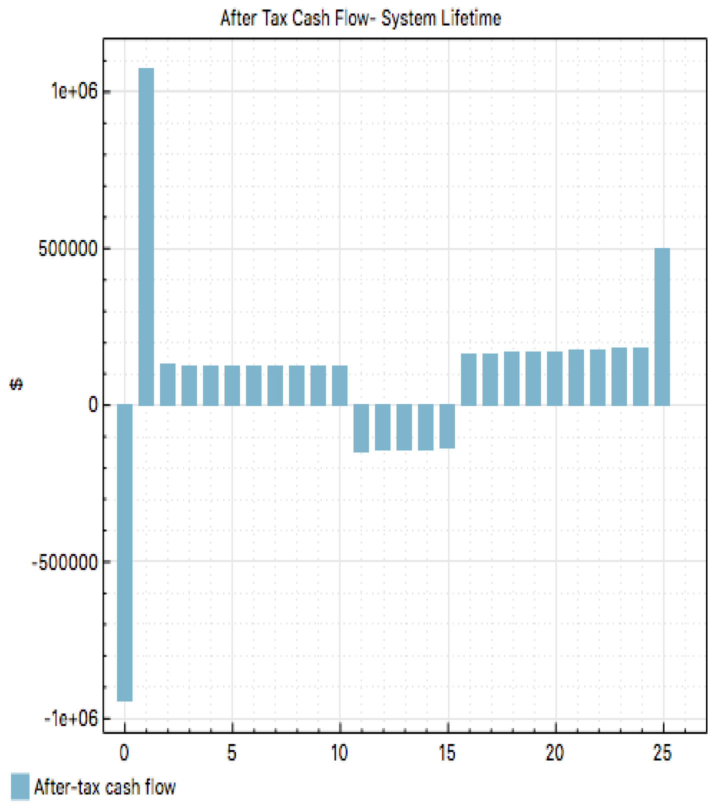

Figure 11 - After Tax Cash Flow For The System

IX. Conclusion

After the final simulation from System Advisor Model and the research that comes along with it, the following financial parameters have been discovered. If Inox Wind sells its energy back to the utility company and capitalizes on the incentives instead of using the energy themselves, the net present value of the project will be $637,909. This metric represents the difference between revenues and costs at the minimum attractive rate of return of the project owner. The overall payback period will be 5.3 years, a much smaller amount of time than if Inox was to use the energy themselves. Finally the levelized cost of energy (LCOE) is 3.50 Rs./kWh or 0.0545$/kWh. This calculation is the net present value of the unit-cost of electricity over the lifetime of a generating asset. It is used as an estimate of the average price that Inox Wind must receive in a market to break even over its lifetime. In this project the lifetime is measured at 25 years. If Inox Wind is awarded the Generation Based Incentive used in the calculations performed by SAM it is economically and financially feasible to go ahead with this project. The power purchase agreement (PPA) for a nascent private company is awarded anywhere from 5 to 10 years. For the purpose of this project the PPA was assumed at 10 years. It is recommended that when the PPA expires, not matter the length, that Inox Wind should switch from selling their electricity to consuming it themselves. This project should be a great addition to Inox Winds already impressive work in the green energy sector.

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Appendix

Year	Annual Energy Generated (kWh)	Cost/kWh (Rs.)	Cost/kWh ($)	Revenue/Savings ($)	Revenue/Savings (Rs.)
0	0.00	0.00	0.00	0.00	0.00
1	1557420	5.45	0.085	132380.7	8508835.683
2	1541850	5.45	0.085	131057.25	8423770.272
3	1526430	5.45	0.085	129746.55	8339524.375
4	1511170	5.45	0.085	128449.45	8256152.623
5	1496060	5.45	0.085	127165.1	8173600.385
6	1481090	5.45	0.085	125892.65	8091813.025
7	1466280	5.45	0.085	124633.8	8010899.812
8	1451620	5.45	0.085	123387.7	7930806.111
9	1437100	5.45	0.085	122153.5	7851477.289
10	1422730	5.45	0.085	120932.05	7772967.98
11	1408510	6.17	0.096	135216.96	8691137.712
12	1394420	6.17	0.096	133864.32	8604196.1
13	1380480	6.17	0.096	132526.08	8518180.055
14	1366670	6.17	0.096	131200.32	8432966.168
15	1353010	6.17	0.096	129888.96	8348677.848
16	1339480	6.17	0.096	128590.08	8265191.687
17	1326080	6.17	0.096	127303.68	8182507.684
18	1312820	6.17	0.096	126030.72	8100687.543
19	1299690	6.17	0.096	124770.24	8019669.561
20	1286690	6.17	0.096	123522.24	7939453.737
21	1273830	6.17	0.096	122287.68	7860101.776
22	1261090	6.17	0.096	121064.64	7781490.268
23	1248480	6.17	0.096	119854.08	7703680.919
24	1235990	6.17	0.096	118655.04	7626612.024
25	1223630	6.17	0.096	117468.48	7550345.286

Above,the tabulated data is prepared on the assumption that the client sells 100% of rooftop generated electricity to the grid at the levelized tariff of Rs. 5.45/kWh ($0.085/kWh) for the first-10 years. This period (years 1-10) represents the clients revenue from selling to the grid. After the ten-year period, as per suggestion made to client, the client will consume all the electricity generated by the rooftop project rather than sell to the grid. This is done due to consideration of end of 10-year tax break holiday end of GBI period. That is, it will be more profitable to consume generated electricity after 10 years of operation given the fact that the electricity load for any given month is higher than the monthly-generated electricity.

The average rate of electricity to industrial consumers (Rs. 6.17/kWh or $ 0.096/kWh) times the annual energy generated will give us the amount by which the annual electricity bill is offset. This period (years 11-25) represents the clients savings from consuming all of generated electricity from rooftop project. For our purpose of payback analysis, money saved on electricity bill is equivalent to revenue generated from selling to grid at the price. And thus, savings on monthly electricity bill will be considered as revenue for purpose of calculating cash flow.