TRINA SOLAR LEVELIZED COST OF ENERGY STUDY – TRINA TRACKER

Independent Assessment

FINAL

B&V PROJECT NO. 413604

PREPARED FOR

Trina Solar Co., Ltd.

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BLACK & VEATCH
MANAGEMENT CONSULTING

Table of Contents

Legal Notice **1-1**

1.0 Executive Summary **1-2**

1.1 Scope of Work 1-2

1.2 Approach and Methodology 1-2

1.3 Assumptions 1-2

2.0 SuperTrack Technology **2-4**

3.0 Production Estimate **3-5**

3.1 Solar Resource and Weather Conditions 3-5

3.1.1 Typical Weather Conditions 3-5

3.1.2 Solar Resource 3-6

3.2 Modeling Inputs 3-6

3.2.1 System Overview 3-7

3.2.2 Model Inputs – Loss and Gain Factors 3-7

3.3 Performance Modeling Results 3-9

3.3.1 Loss and Gain Contributions 3-9

3.3.2 Estimated Annual Energy Production and Performance Metrics 3-11

4.0 Production Estimate Comparison **4-13**

5.0 Project Costs **5-15**

5.1.1 Cost Estimate Basis 5-15

5.1.2 Assumptions / Clarifications: 5-16

6.0 Operations & Maintenance Costs **6-17**

6.1 Cost Estimate Line Items 6-17

6.2 Assumptions 6-17

6.3 Exclusions 6-17

6.4 Region Specific Assumptions 6-18

6.5 Annual O&M Costs 6-18

7.0 LCOE Calculations **7-20**

Appendix 1: Sample LCOE Spreadsheet **7-1**

Appendix 2: PVsyst Report **7-1**

LIST OF TABLES

Table 3-1 Project Name and Location 3-5

Table 3-2 Historic Average Monthly Weather Conditions at the Project Location 3-5

Table 3-3 Key Parameters for the Solar Resource Dataset 3-6

Table 3-4 Major Equipment and Principal System Design Parameters 3-7

Table 3-5 Summary of Model Input Loss and Gain Parameters 3-7

Table 3-6 Monthly Albedo Gain and Soiling Loss Parameters 3-9

Table 3-7 Parasitic and Auxiliary Losses ... 3-9
Table 3-8 PVsyst outputs and results from post-processing including East-West slopes ... 3-10
Table 3-9 Estimates of Expected (P50) Annual Energy Production ... 3-11
Table 3-10 Summary of Key Expected Performance Metrics ... 3-12
Table 4-1 Estimated Percent Gain for TrinaTracker SuperTrack Diffuse Sky and Row-on-Row Shading Recovery Technology ... 4-13
Table 6-1 Estimated Annual O&M Costs ($/kWdc) ... 6-18
Table 7-1 LCOE Model Inputs ... 7-20
Table 7-2 LCOE Calculations ... 7-21
Table 7-3 Initial Construction Cost Breakdown ... 7-22

LIST OF FIGURES

No table of figures entries found.

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1.0 Executive Summary

Black & Veatch Management Consulting LLC (Black & Veatch) was retained by Trina Solar Co., Ltd. (Trina Solar) to perform an estimated levelized cost of energy (LCOE) analysis based on hypothetical project assumptions and single axis tracker (SAT) specifications provided by Trina Solar (Report). This analysis was performed to show the potential impact that different SAT technologies will have on solar project LCOE and to provide Trina Solar with two comparable LCOE values for the following SAT technology types:

- Traditional SAT
- SAT with Trina SuperTrack technology designed to capture diffuse light during cloudy conditions and reduce row-on-row shading on project sites with undulating terrain.

In preparing this Report Black & Veatch has assumed that information and assumptions provided by Trina Solar were current and correct.

1.1 SCOPE OF WORK

To conduct this independent assessment, Black & Veatch provided the following services:

- Review of the Trina SuperTrack technology.
- High-level review of Trina's production estimate modeling capabilities.
- Hypothetical project design.
- Production estimates using PVsyst.
- Project construction cost estimations.
- Project cost estimations including O&M, lease, asset management and financing costs.

This Report will present the assumptions made to develop the above services and the varying LCOE costs. Black & Veatch is uniquely qualified to conduct this study due to its extensive background and experience in solar independent engineering, production estimating, and project cost estimating.

1.2 APPROACH AND METHODOLOGY

The Black & Veatch team, comprised of professionals in solar project design, production estimating, and independent engineering and supporting engineers, reviewed documentation provided by Trina Solar to assess project costs and production estimates of the four hypothetical projects and calculate the resulting LCOE. Black & Veatch submitted data requests to Trina Solar for additional or updated documentation as necessary.

1.3 ASSUMPTIONS

During the assessment of the hypothetical projects, Black & Veatch used and relied upon certain information provided by representatives of Trina Solar.

Trina Solar provided the third-party .PAN files for the module type used in the hypothetical projects. Black & Veatch also notes that the following high level assumptions were provided by Trina Solar and agreed upon.

- Project Site:
  - Spain, Campina – Latitude: 37°23'54.39" N, Longitude: 4°42'32.85" W

- Annual GHI: 1,868 kWh/yr/m^2, determined by project site locations and data source (Clean Power Research) used by Black & Veatch
- Project Size : 100MWdc
- Project Life: 30 years
- Inverter: Sungrow SG3600UD-MV
- Ground Coverage Ratio (GCR): 43.35% (determined by Black & Veatch)
- Inverter and Interconnection DC/AC Ratio: 1.11 and 1.20, respectively (determined by Black & Veatch)
- Lot Shape: Square
- Terrain: 5% East slope, 5% West slope
- Tracker Configuration: One-in-portrait (1P)
- Module: Bifacial, half-cut cell, Trina Vertex_NEG19RC.20 with 3rd party provided PAN file

In preparing this Report Black & Veatch has assumed that information and assumptions provided by Trina Solar were current and correct. Black & Veatch also notes that the primary variable in the LCOE analysis includes the tracker type and resulting changes impacted by the change in tracker type. All other inputs including but not limited to site conditions, capacity, lifespan, and the PV module type are constant throughout the site. Given those assumptions, this Report should only be used to compare the estimated LCOE values between the tracker types and not other solar projects or module types.

Black & Veatch is of the opinion the information provided is true and correct and reasonable for the purposes of this Report. Black & Veatch has not been asked to make an independent analysis, to verify the information provided to us, or to render an independent judgment of the validity of the information provided by others. Because of this, Black & Veatch cannot, and does not, guarantee the accuracy thereof to the extent that such information, data, or opinions were based on information provided by others. In preparing this Report and the opinions presented herein, Black & Veatch has made certain assumptions with respect to conditions that may exist, or events that may occur in the future. Black & Veatch is of the opinion that the use of this information and assumptions is reasonable for purposes of this Report. However, some events may occur or circumstances change in ways that cannot be foreseen or controlled by Black & Veatch and that may render these assumptions incorrect. To the extent that the actual future conditions differ from those assumed herein, or provided to Black & Veatch by others, the actual results will differ from those that have been forecast in this Report. This Report summarizes Black & Veatch's analysis of the LCOE values and assumptions made. Throughout this Report, Black & Veatch has stated assumptions and reported information provided by others, all of which were relied upon in the development of the conclusions of this Report.

2.0 SuperTrack Technology

Trina Solar's SuperTrack algorithms are designed to capture diffuse light during cloudy conditions and reduce row-on-row shading on project sites with undulating terrain. Trina Solar provided a description of the SuperTrack algorithms, which is summarized here. Our description is based on our current understanding of SuperTrack after discussion of the algorithms with Trina's technical team and review of the document, The Calculation Specification of SEB.pdf which was provided by Trina.

The SuperTrack technology applies separate algorithms to correct for shading caused by sloped terrain and capture diffuse light under cloudy conditions. These are termed the SBA and STA algorithms, respectively.

The SBA algorithm utilizes terrain variability and is obtained from digital elevation models or UAV surveys. then the optimal tilt angles are precomputed as a function of solar position and array geometry. The computations account for electrical losses that occur when modules are partially shaded.

The STA algorithm first determines whether the sky is cloudy enough for an adjustment in tracker angle to provide a benefit. This is determined using measurements from on-site pyranometers. The measured data is used to compute the "sunny index,"

$$sunny\ index = 1 - \left(\frac{DHI}{GHI}\right)$$

where DHI is the diffuse horizontal irradiance and GHI is the global horizontal irradiance. If the sunny index is less than 0.3, it is assumed that tracker tilt adjustment will be beneficial.

The total irradiance on the modules is calculated for angles covering the full range of the maximum tracker tilt in increments of 1°. The angle yielding the highest irradiance is then selected and this irradiance is substituted in the irradiance time series in place of the value found at the standard backtracking angle.

Black & Veatch is of the opinion that Trina Solar's SuperTrack methodology is logical and consistent with other advanced tracking algorithms used within the industry. Use of on-site measurements to detect favorable conditions for diffuse light recapture is advantageous and the terrain variability should be well specified.

3.0 Production Estimate

The project location is summarized in Table 3-1.

Table 3-1 Project Name and Location

Project Name	Latitude	Longitude	Address
Trina SuperTrack Tracker Performance	37.398°	-4.709°	Campina, Spain

The performance model discussed in this Report was based on information provided to Black & Veatch, including:

- Information provided by Client
- A representative solar resource dataset
- Manufacturers' equipment performance models and datasheets

Black & Veatch used PVsyst version 7.2.21 and industry-accepted pre- and post-processing algorithms to model the performance of the Project and estimate its expected annual energy production [MWh/year].

3.1 SOLAR RESOURCE AND WEATHER CONDITIONS

Black & Veatch reviewed the project location to assess the typical weather conditions and expected solar resource. Black & Veatch assessed potentially applicable publicly available solar resource datasets. Then, based on the quality, proximity, and quantity of the available data, Black & Veatch selected the resource dataset which was determined to best represent the expected solar resource at the project location. Publicly available weather databases were accessed to estimate the expected number of precipitation events and amount of precipitation; and in turn, estimate the expected amount of soiling loss on the photovoltaic modules from dust, dirt, and snow.

3.1.1 Typical Weather Conditions

Table 3-2 lists the historic average monthly weather conditions reported for the weather station that was selected to be most representative of the expected weather conditions at the project location.

Table 3-2 Historic Average Monthly Weather Conditions at the Project Location

Month	Average Low Temperature [°C]	Average Temperature [°C]	Average High Temperature [°C]	Average Rainfall [cm]	Average Snowfall [cm]
Jan	4.0	9.7	15.4	7.8	0.0
Feb	5.1	11.1	17.1	5.5	0.0
Mar	6.1	13.1	20.1	4.2	0.0
Apr	8.0	14.8	21.5	6.1	0.0
May	10.9	18.0	25.1	4.6	0.0
Jun	14.3	22.2	30.1	1.5	0.0
Jul	17.4	26.0	34.6	0.2	0.0
Aug	18.2	26.3	34.3	0.6	0.0
Sep	16.1	23.5	30.9	2.0	0.0

Month	Average Low Temperature [°C]	Average Temperature [°C]	Average High Temperature [°C]	Average Rainfall [cm]	Average Snowfall [cm]
Oct	12.1	18.5	24.9	5.8	0.0
Nov	7.9	13.7	19.6	7.3	0.0
Dec	5.7	11.0	16.4	9.2	0.0

3.1.2 Solar Resource

Solar resource data produced by CPR was used as input to this performance estimate. CPR is one of the main providers of satellite based solar resource used in utility scale performance estimation. Like the other providers, CPR applies a semi-empirical solar radiation model to satellite imagery and aerosol data. The accompanying weather data (e.g., temperature and wind speed), is taken from a reanalysis model. Key parameters from this data set for the Trina SuperTrack Tracker Performance are listed in Table 3-3.

Table 3-3 Key Parameters for the Solar Resource Dataset

Solar Resource Dataset	Typical Annual GHI [kWh/yr/m^2]	Interannual Variability [1]
CPR SolarAnywhere v3.5	1,868	2.5%

Hourly solar resource and weather data from a "Typical Year" from this dataset were then used as inputs to the solar PV performance model to estimate the expected energy production from the Project.

The variability of the solar resource from year to year is referred to as the interannual variability, and it is needed to estimate the uncertainty in the expected energy production estimate.

3.2 MODELING INPUTS

Black & Veatch used PVsyst version 7.2.21 to estimate the energy that is expected to be produced by the Project. PVsyst is an industry-accepted performance modeling software application for solar PV installations; it was developed at the University of Geneva in Switzerland and is currently maintained by PVsyst SA. The PVsyst application contains a library of the performance characteristics of PV modules and inverters that encompasses most of the types of equipment that are commonly deployed in modern solar PV projects.

A high-level overview of the typical modeling process is the following:

- A performance model for the Project is constructed using: module and inverter performance characteristics, system design, array and site layout configurations, shading models, and various other losses and assumptions.
- Solar resource and weather data are then input to the model, the model is run, and the output is stored as intermediate results.
- The intermediate results are then post-processed using industry-accepted algorithms to account for post-inverter losses, auxiliary consumption, losses due to terrain contours, and other losses to produce the final results.

[1] Expressed as a percentage ratio relative to the mean.

The following sections discuss the various inputs, parameters, performance characteristics and other assumptions that were used to model Project performance and obtain the energy production estimate(s) in this Report.

3.2.1 System Overview

Table 3-4 summarizes the major equipment and principal system design parameters that were used to construct a performance model of the Project. This information was based on drawings, schematics, reports, datasheets, and other information provided to Black & Veatch. When certain information was not provided or was unavailable, Black & Veatch applied representative assumptions for solar PV installations similar to the one discussed in this report.

Bifacial PV modeling incorporates irradiance intercepting both the front and back of the PV modules. Unlike the front side irradiance, which is usually assumed to vary little with array location, backside irradiance varies substantially with module height, row pitch and near field objects which can shade the backside such as wiring, torque tubes and racking. It is also heavily influenced by the albedo of the underlying ground surface.

Table 3-4 Major Equipment and Principal System Design Parameters

System Design Parameter	Value
System DC Capacity [kWp]	100,008
System AC Capacity [kWac]	90,000
System AC Capacity at POI [kWac]	83,300
Module Vendor, Model, Rating	Trina Solar, TSM-590NEG19RC.20, 590[Wp]
Inverter Vendor, Model, Rating	Sungrow, SG3600UD-MV, 3600[kWac]
Module Mounting System Type	Single-Axis Tracking, with backtracking
Tracking Limit [Degrees]	+/- 60°
Modules per String	29
Number of Modules	169,505
Inverter Loading Ratio at Inverter Output	1.11
Inverter Loading Ratio at POI	1.20
String DC Voltage [Vdc]	1,500
Row Pitch [m]	5.50
Collector Width [m]	2.38
GCR (%)	43.35%
Module Racking Configuration	1 Module in Portrait

3.2.2 Model Inputs – Loss and Gain Factors

Table 3-5 summarizes the Project's loss and gain inputs used in the performance model.

Table 3-5 Summary of Model Input Loss and Gain Parameters

Model Inputs – Loss and Gain Parameters	Value	Source of Information
Transposition Model	Perez	Black & Veatch Assumption

Model Inputs – Loss and Gain Parameters	Value	Source of Information
Monthly Soiling Losses and Albedo Gains [2]	See Table 3-6	Black & Veatch Calculation
Incident Angle Modifier	bo = 0.03	Black & Veatch Assumption
External Shading Loss	Meteonorm Horizon Profile	Black & Veatch Assumption
Light Induced Degradation (LID)	-0.60%	Black & Veatch Assumption
Module Quality Factor	+0.30%	Black & Veatch Calculation
Module Mismatch Loss	-0.50%	Black & Veatch Assumption
String Mismatch Loss	-0.50%	Black & Veatch Assumption
DC Wire Loss at STC	-1.50%	Black & Veatch Assumption
Bifacial PV Parameters:		
Average Albedo Factor	See Table 2-6	Provided by Client
Structure Shading Factor	10.00%	Black & Veatch Assumption
Mismatch Loss Factor	5.00%	Black & Veatch Assumption
Module Transparency Factor	1.00%	Black & Veatch Assumption
Module Bifaciality Factor	80.00%	Included in PAN file
Module Height Above Ground	2.00m	Provided by Client
Medium Voltage Transformer:		Black & Veatch Assumption
No Load Losses	-0.10%	
Copper Losses at Full Load	-0.90%	
Total Losses at Full Load	-1.00%	
High Voltage Transformer:		Black & Veatch Assumption
No Load Losses	-0.08%	
Copper Losses at Full Load	-0.72%	
Total Losses at Full Load	-0.80%	
AC Wire Loss	-0.50%	Black & Veatch Assumption
Clipping Loss at the Point of Metering [3]	0.00%	Black & Veatch Calculation
Auxiliary Load [MWh/yr]	153.43	Black & Veatch Calculation
Gen-Tie Loss	0.00%	Black & Veatch Assumption
Power Factor Requirement	+/- 0.95	Black & Veatch Assumption
Availability Loss	-1.50%	Black & Veatch Assumption

[2] Based on historically typical weather data and Black & Veatch proprietary soiling model.
[3] Calculated in post-processing after running PVsyst model.

The soiling loss values shown in Table 3-6 are based on historically typical weather data and Black & Veatch's proprietary soiling model. This model accounts for tracker tilt range, local environmental conditions, and the amount and frequency of precipitation.

Table 3-6 Monthly Albedo Gain and Soiling Loss Parameters

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Albedo Gain	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Soiling Loss [4] [%]	0.4%	0.3%	0.6%	0.6%	0.8%	2.0%	5.1%	9.0%	4.5%	0.7%	0.4%	0.5%

3.2.2.1 Parasitic and Auxiliary Losses

Black & Veatch estimated the auxiliary and parasitic losses due to the energy consumption of equipment operating during nighttime hours, daytime hours, and continuous time periods. These loads, summarized in Table 3-7, reduce the expected net energy production of the facility.

Table 3-7 Parasitic and Auxiliary Losses

Loss Type	Time in Effect	Value [MWh/yr]	Source of Information
Medium Voltage Transformer(s), No-Load Losses	Night	-387.63	Black & Veatch Calculation
High Voltage Transformer(s), No-Load Losses	Night	-287.02	Black & Veatch Calculation
Inverter Standby Losses	Night	-28.43	Black & Veatch Calculation
Tracker Consumption	Day	-35.00	Black & Veatch Assumption
SCADA System Consumption	Continuous	-90.00	Black & Veatch Assumption
Other Auxiliary Loads, net	Continuous	0.00	Black & Veatch Assumption

3.3 PERFORMANCE MODELING RESULTS

3.3.1 Loss and Gain Contributions

Energy production estimates are reported at the point of metering. Between the solar irradiance that is incident on the solar PV modules ("collector") – the Plane of Array (POA) irradiance – and the point of metering, there are various loss and gain contributions. For modeling purposes, these are aggregated and accounted for at three principle points along the energy transfer chain:

- Losses/Gains to the Solar Energy Incident on the Collector Plane (POA)
- Losses/Gains to the Energy Available at Inverter Output Terminals
- Losses/Gains to the Energy Available at the Point of Metering

Table 3-8 summarizes the individual contribution factors that were modeled at each of the respective points of loss/gain.

[4] Soiling losses account for zero module washes per calendar year.

Table 3-8 PVsyst outputs and results from post-processing including East-West slopes

Point of Loss/Gain	Contribution Factor	Value
Solar Energy Incident on the Collector Plane (POA)	Global Horizontal Radiation [kWh/yr/m²]	1,868
	Transposition Model	Perez
	Transposition Factor	37.74%
	Global Inclined Radiation [kWh/yr/m²]	2,573
	Internal Shading Loss	-1.64%
	External Shading Loss	-0.36%
	Incident Angle Modifier Loss	-0.92%
	Soiling Loss	-2.74%
	Global Incident Radiation on Ground [kWh/yr/m2]	846
	Ground Reflection Loss for Rear Side	-80.00%
	View Factor for Rear Side	-66.58%
	Sky Diffuse Gain on Rear Side	+15.35%
	Beam Effective Gain on Rear Side	0.00%
	Shading Loss on Rear Side	-10.00%
	Total Irradiance on the Rear Side [kWh/yr/m2]	**135.0**
	Mismatch for Back Irradiance	-0.28%
	Effective Global Inclined Radiation [kWh/yr/m²]	**2,308**
Energy Available at the Inverter Output Terminals	Loss due to Irradiance Level	+0.31%
	Loss due to Temperature	-4.66%
	Shading Losses due to Electrical Effect	0.00%
	Module Quality Factor	+0.30%
	Loss due to Light Induced Degradation	-0.60%
	Module Mismatch Loss	-0.50%
	String Mismatch Loss	-0.50%
	DC Wire Loss	-1.20%
	Inverter Efficiency Loss	-1.67%
	Inverter Clipping Loss	-0.20%
	Specific Annual Yield at Inverter Output Terminals [kWh/yr/kWp]	**2,139**

Point of Loss/Gain	Contribution Factor	Value
Energy Available at the Point of Metering	Medium Voltage Transformer Loss	-1.04%
	AC Wire Loss	-0.50%
	High Voltage Transformer Loss	-0.85%
	Auxiliary Load [MWh/yr]	153.43
	Gen-Tie Loss	0.00%
	Power Factor Loss	-0.86%
	Availability Loss	-1.51%
	Clipping Loss at the Point of Metering	0.00%
	Annual Energy at Point of Metering [kWh/yr/kWp]	**2,038**

3.3.2 Estimated Annual Energy Production and Performance Metrics

To minimize potential confusion, expected performance metrics and estimates of expected annual energy production are generally reported exclusive of long-term module performance degradation. This convention then allows these results to be used consistently in a variety of applications, which may or may not include/exclude the effects of long-term degradation, and/or may account for it differently.

Table 3-9 reports the estimates of expected (P50) annual energy production, both exclusive of long-term degradation, and, for convenience, including the expected degradation over the first year.

Table 3-9 Estimates of Expected (P50) Annual Energy Production

Estimates of Expected Annual Energy Production	With Flat Scene	With East-West Slopes	With Terrain Recovery (SBA)	With Diffuse Recovery (STA)	With Full SuperTrack Recovery
Annual, exclusive of long-term degradation [MWh/yr]	210,178	203,836	209,603	204,382	210,148
First year, including degradation [MWh]	209,852	203,523	209,278	204,067	209,823

Table 3-10 reports key expected performance metrics, exclusive of long-term degradation.

Table 3-10 Summary of Key Expected Performance Metrics

Performance Metric	With Flat Scene	With East-West Slopes	With Terrain Recovery (SBA)	With Diffuse Recovery (STA)	With Full SuperTrack Recovery
Annual Specific Yield [kWh/yr/kWp]	2,102	2,038	2,096	2,044	2,101
DC Capacity Factor	24.0%	23.3%	23.9%	23.3%	24.0%
AC Capacity Factor	28.8%	27.9%	28.7%	28.0%	28.8%
Performance Ratio	81.7%	79.2%	81.5%	79.4%	81.7%
Plane of Array Insolation [kWh/yr/m2]	2,573	2,573	2,573	2,573	2,573
Long-term Average Annual Module Energy Degradation Rate [%/yr]	-0.40%	-0.40%	-0.40%	-0.40%	-0.4%

4.0 Production Estimate Comparison

An evaluation of the effectiveness of Trina's SuperTrack algorithm was made by comparing the gains resulting from the modification of the tracker angle when the terrain is sloped (which causes row-on-row shading) and when the sky conditions are cloudy (which increases the diffuse irradiance component), as computed by Trina's and Black & Veatch's methods. This comparison assumes that the PV system and meteorological conditions are identical in Trina and Black & Veatch's simulations.

Black & Veatch's methods for computing row-on-row shading and diffuse gain recovery are similar to those employed by Trina. The main differences are that Black & Veatch performs all calculations through the output of the inverter using PVsyst and applies proprietary methods to complete the calculations through the point of interconnect and that the recovery rates are computed in terms of the energy out of the inverter rather than irradiance received on the array. Here we summarize Black & Veatch's methods in brief:

PVsyst's treatment of single-axis trackers on slopes is limited. As a result, Black & Veatch computes the effects of the slopes in each direction (north, south, east, and west) using separate PVsyst runs. The resulting changes in output energy are then combined and the total loss is computed relative to a flat site. As stated in Section 2, we assumed that Trina's algorithms are accurate enough to recover 90% of the total loss.

Black & Veatch's method of computing diffuse irradiance optimization gain consists of two steps. First, energy output is computed for fixed module tilts covering the range of the appropriate tracker (±60° in this case). The angle with the maximum output is identified for each time step. If the weather is considered cloudy, this output is substituted for the output computed for the angle specified by standard backtracking algorithms. In our standard method, "cloudy" weather is inferred when the direct normal irradiance is small. However, Trina's "sunny index" approach found more hours to be cloudy and the contributions of these hours increased our estimate. Since application of Trina's criterion increased the algorithm's gain in our simulations, we assume it will also provide benefits in practice. Therefore, we have adjusted our estimate to reflect this reality. Again, a factor of 90% is applied to the adjustments to account for errors in determining meteorological conditions and uncertainties in tracker positioning in the field.

Our estimates of the gains provided by the Trina SuperTrack algorithms for the specified test PV system are shown in Table 4-1 along with the estimates provided by Trina. We have verified that Trina has used the same modeling parameters, such as solar resource data (TMY from Clean Power Research), surface albedo (0.20), and bifacial gain (80%), so the results are expected to be comparable.

Table 4-1 Estimated Percent Gain for TrinaTracker SuperTrack Diffuse Sky and Row-on-Row Shading Recovery Technology

TrinaTracker SuperTrack Diffuse Sky and Row-on-Row Shading Recovery Component	Black & Veatch Estimated Gain (%)	TrinaTracker Estimated Gain (%)
Row-on-Row Shading Recovery Only (SBA)	2.80%	2.82%
Diffuse Sky Recovery Only (STA)	0.26%	0.46%
Both Row-on-Row and Diffuse Sky Recovery Implemented	**3.06%**	**3.28%**

The result of our comparison is that Black & Veatch's estimates of the gains resulting from application of the SuperTrack algorithms are similar to those provided by Trina. Black & Veatch's estimate of the row-to-row shading recovery matches Trina's very closely while our estimate of the diffuse irradiance recovery is slightly lower than that computed by Trina. Based on these results, Trina's modeling results are judged to be reasonable.

5.0 Project Costs

The hypothetical solar project is a 100 MWdc in capacity located in Puente Genil, Córdoba, Spain. Total project costs and a breakdown of the initial construction costs are shown in Section 7.0.

5.1.1 Cost Estimate Basis

Black & Veatch provided estimated total project costs assuming that the EPC contractor furnishes all equipment including modules, inverters and racking.

This section lists specific assumptions and/or design basis criteria used for developing the probable cost.

- Trackers: Two different trackers were considered, a traditional SAT and an SAT equipped with Trina SuperTrack technology. Pricing was assumed to be $0.08/Wdc for the traditional SAT case and $0.083/Wdc for the SAT equipped with Trina SuperTrack technology. These costs were provided by Trina and represent the actual approximate pricing for the SAT.
- Modules: Bifacial, half-cut cell, Trina Vertex_NEG19RC.20Modules. Pricing was assumed to be $0.35/Wdc for both cases.
- Inverters: A generic central inverter was assumed. Sufficient inverter capacity is included to achieve a unity power factor. Pricing was assumed to be 0.04/Wdc for both cases.
- Racks & Posts: Racks are single-axis trackers (SATs). Design wind speed is assumed to be IBC category I, or a maximum of 105 mph. Given the area of assumed for the project location, the soils are assumed to be of typical quality. Posts are assumed to be typical length (approximately 8' embedment) and no pre-drilling of bedrock is included. A pitch of approximately 26.2' (8 m) is assumed.
- Civil: It is assumed the site consists of acceptable soil that will drain well. Slopes are assumed to be 5% in both the East and West direction, so it is anticipated that grading will generally only be required to meet north-south racking tolerances. This grading is assumed to be minimal. Minimal clearing is expected as the project area is likely to consist of only small brush and trees. Typical road construction methods are expected to be sufficient for these conditions; roads are assumed to use a compacted sub-base, with a geotextile and 6" of aggregate. Interior roads are assumed to be 16' wide. The site layout is assumed to be regularly shaped and generally contiguous, maximizing the efficiency of the layout and minimizing cost.
- Balance of System: BoS costs are based on typical industry methods and material: AC cable (aluminum, direct-buried in trench), DC collector cable (aluminum, direct-buried or installed in CAB), PV wire harnesses (copper, with MC-4 connectors) and combiner boxes.
- Collector Substation: No costs for the collector substation are included.
- Gen-Tie Line: No costs for the gen-tie line are included.
- Construction Management/Construction Indirect Costs (CM/CI): Black & Veatch has based this valuation on industry norms.
- Engineering: This is believed to be a well-understood area. Minimal design challenges are expected.
- Project Indirect Costs (Insurance, Taxes, Bonds, Warranties, Etc.): Black & Veatch has based this valuation on industry norms. No sales taxes on permanent plant equipment are included.

- Contingency/Escalation: Black & Veatch has based this valuation on industry norms. No labor or material escalation has been included.
- Contractor Margin (G&A and EBT): Black & Veatch has based this valuation on industry norms.

5.1.2 Assumptions / Clarifications:

- The costs presented herein represent Black & Veatch's opinion of the price the Owner can expect to receive in a competitive bid process, when market conditions are similar to current conditions. These probable costs are indicative in nature, based on market-derived values and engineering judgement and are not an offer for sale.
- No quantities were developed during the development of these probable costs.

6.0 Operations & Maintenance Costs

Black & Veatch's opinions on solar PV O&M costs are informed by market comparisons from other large portfolios reviewed by Black & Veatch and observed market pricing trends, as well as internal cost modeling. Black & Veatch performs internal cost modeling utilizing input from the PV O&M Cost Model Web Application ("NREL Cost Model"), a cost modelling tool for PV industry operations and finance practitioners designing and budgeting PV O&M plans, benchmarked costs, and documentation from SunPower. The NREL Cost Model was developed as collaboration between the SunSpec Alliance, the National Renewable Energy Laboratories ("NREL") and the Sandia National Laboratory as part of NREL's Solar Access to Public Capital program.

The estimated costs provided include all preventative, corrective, and major maintenance. Black & Veatch's estimates include vegetation scope specified to the region. The estimates are aimed at maintaining high plant availability over the assumed 30 year project useful life.

Black & Veatch acknowledges that unlike thermal plants which have been in operation for many years, there is not a great deal of historical data for solar projects globally operating 5 to 20 plus years, and furthermore gaining access to the operating history of those few plants could be challenging or perhaps not even possible. As such, there is a lack of long-term historical O&M costs available.

6.1 COST ESTIMATE LINE ITEMS

The O&M cost estimate includes the following cost line items:

- Baseline Maintenance: Inclusive of preventative maintenance, corrective maintenance, and major maintenance labor (excluding cost of major spares).
- Vegetation Maintenance: Based on market prices and contracts reviewed by Black & Veatch, specific to the region.
- Major Maintenance: Inclusive of inverter, module and tracker spare parts expenses. Assumes a moderate market forecasted decrease in major equipment costs over the life of the project.

6.2 ASSUMPTIONS

- Selection by the EPC contractor of top tier major equipment
- Two year service warranty from EPC contractor
- Standard major equipment warranties:
  - Trackers: structural component warranty of 10 years, electrical components of 5 years
  - Modules: product warranty of 12 years, performance warranty of 30 years
  - Inverters: product warranty of 5 years

6.3 EXCLUSIONS

- Property tax
- High voltage operations and maintenance
- On site security
- Snow removal

Black & Veatch again notes that due to the exclusions, the LCOE analysis should be used to compare LCOE values on an absolute basis and between the modules included in this Report and should not be used to compare with other projects outside of this study.

6.4 REGION SPECIFIC ASSUMPTIONS

- Low frequency vegetation management
- No annual washes

6.5 ANNUAL O&M COSTS

Table 6-1 presents the estimated annual O&M costs as allocated across the three cost line items. Baseline maintenance and vegetation management are assumed to be fixed for the first 10 years to reflect anticipated near term cost savings that offset inflation. Thereafter, vegetation management is assumed to escalate at two percent annually and baseline maintenance varies year to year reflecting the interval nature of certain maintenance activities upon which Black & Veatch's cost model is based. Major maintenance costs are estimated annually based on assumed failure curves for project equipment and parts. The curves take various shapes for different components, but the build-up is dominated by inverter refurbishment curves. The values in the table below simulate actual expected costs in each operating year, as opposed to a levelized assumption.

Table 6-1 Estimated Annual O&M Costs ($/kWdc)

Year	Baseline Maintenance	Vegetation Management	Major Maintenance	Total ($/kWdc)
1	4.50	0.50	0.37	**5.37**
2	4.50	0.50	0.38	**5.38**
3	4.50	0.50	0.39	**5.39**
4	4.50	0.50	0.42	**5.42**
5	4.50	0.50	0.53	**5.53**
6	4.50	0.50	0.76	**5.76**
7	4.50	0.50	0.87	**5.87**
8	4.50	0.50	1.04	**6.04**
9	4.50	0.50	1.25	**6.25**
10	4.50	0.50	1.65	**6.65**
11	4.66	0.51	1.81	**6.97**
12	4.77	0.52	2.10	**7.40**
13	5.01	0.53	2.35	**7.89**
14	5.10	0.54	2.50	**8.14**
15	5.23	0.55	2.57	**8.35**
16	5.51	0.56	2.37	**8.45**
17	5.46	0.57	2.11	**8.14**
18	5.62	0.59	1.81	**8.02**
19	6.17	0.60	1.56	**8.33**

Year	Baseline Maintenance	Vegetation Management	Major Maintenance	Total ($/kWdc)
20	6.31	0.61	1.55	**8.46**
21	6.18	0.62	1.38	**8.18**
22	6.16	0.63	1.43	**8.22**
23	6.20	0.65	1.52	**8.37**
24	6.42	0.66	1.63	**8.71**
25	6.59	0.67	1.80	**9.06**
26	6.49	0.69	1.83	**9.01**
27	6.12	0.70	1.88	**8.70**
28	6.14	0.71	1.89	**8.74**
29	6.47	0.73	1.84	**9.04**
30	6.52	0.74	1.88	**9.15**

7.0 LCOE Calculations

Levelized Cost of Energy (LCOE) is a calculation measurement used to compare methods of energy production. It is defined as the average total cost of building and operating the generation facility per the total electricity generated over the facility's useful life and is measured in dollars per MWh ($/MWh). This exercise was performed to compare the estimated LCOE for two types of SAT technology. The two types compared area a standard SAT and a SAT with Trina Solar's SuperTrack technology. Additionally, this analysis intends to show the difference in LCOE when utilizing the Trina Solar SuperTrack technology and not the LCOE for an actual project. The LCOE is calculated by taking the net present value (NPV) of the project costs divided by the NPV of the project's generation over the life of the facility, which is shown below:

$$LCOE = \frac{NPV(Construction + Lease + O\&M + Insurance + Asset\ Management)}{\sum NPV[Lifetime\ MWh\ Output * (1 - Degrdation)^t]}$$

The NPV of the total costs includes initial construction, O&M, financing, insurance and asset management costs all divided by one plus the discount rate over the 30 year life of the project.

- Construction: Equals the total Initial Construction Costs
- Financing: Estimated 9 percent discount rate.
- Lease: Equals total project acres multiplied by an assumed $600/acre escalated by 2 percent each year.
- O&M: Equals total DC capacity multiplied by the Annual O&M Costs shown in Table 6-1.
- Insurance: Equals total DC capacity multiplied by an assumed $1.00/kW/year
- Asset Management: Equals total DC capacity multiplied by an assumed $1.50/kW/year.
- Lifetime MWh Output: Equals the NPV of year zero generation less the annual degradation over the 30 year life. Degradation is assumed to equal 0.40 percent.

A sample of the LCOE calculation spreadsheet through the first 10 years of project operation can be found in Appendix 1: Sample LCOE Spreadsheet.

Table 7-1 shows the specific LCOE model inputs that vary by tracker type. Many inputs are held constant throughout each tracker project type however the project costs, acres, lease costs, capacity, and electricity output vary slightly. The assumptions vary slightly due to differences in the number of modules needed to meet a consistent assumed capacity, project site size, and generation output.

Table 7-1 LCOE Model Inputs

	Spain, Campina	
	Traditional SAT	SuperTrack
Initial Construction Cost ($)	$92,278,970	
SuperTrack Cost ($/W)	-	0.003
Acres	375	

	Spain, Campina	
	Traditional SAT	**SuperTrack**
Lease Costs ($/Acre)	$600	
Annual Lease Costs (Year 1)	$225,000	
Annual Lease Escalation (%)	2.0%	
O&M Costs ($/kW/yr)	Variable	
Insurance Costs ($/kW/yr)	1.00	
Asset Management Costs ($/kW/yr)	1.50	
Capacity (kWdc)	100,008	
Capacity (kWac)	90,000	
Annual Electricity Output (MWh)	203,836	210,148
Degradation (%)	0.40	
Project Lifespan (years)	30	
Discount Rate (%)	8.51%	

Black & Veatch utilized the assumptions described in the previous sections to create a spreadsheet model to calculate the LCOE for each tracker given comparable project assumptions and varying project generation. The LCOE values seen below vary slightly which is primarily due to the varying energy generation. Black & Veatch notes that the Trina SuperTrack SAT project results in the lowest calculated LCOE of the two scenarios and is $1.29 less than the traditional SAT project. The calculated LCOE values are shown in Table 7-2.

Table 7-2 LCOE Calculations

Project Site	Tracker Type	LCOE ($/MWh)
Puente Genil, Córdoba, Spain	Traditional SAT	$46.03
	SuperTrack	$44.78

A sample of the LCOE calculation spreadsheet through the first 10 years of project operation can be found in Appendix 1: Sample LCOE Spreadsheet.

The LCOE values seen above vary slightly which is primarily due to the total energy generation of the hypothetical project. The differences in the total project construction costs vary only slightly as a result of the varying rack & post costs due to the additional cost of the SuperTrack technology. A complete breakdown of total initial construction costs for each hypothetical project are shown in Table 7-3.

Table 7-3 Initial Construction Cost Breakdown

	Puente Genil, Córdoba, Spain	
	Traditional SAT	SuperTrack SAT
Module Cost	$35,000,000	
Inverter Cost	$4,000,000	
Rack & Post Cost	$8,000,000	$8,300,024
Module Install	$1,145,680	
Rack & Post Install	$1,689,159	
Civil Cost	$5,063,054	
BOS Material	$4,585,823	
BOS Install	$1,906,468	
Engineering	$1,545,614	
Const. Management	$2,791,458	
Const Equipment & Indirects	$5,700,080	
Startup	$227,206	
Project Indirects	$748,616	
Taxes	$517,877	
Contingency	$3,911,841	
Escalation	-	
G&A and EBT	$12,571,094	
Total	**$89,403,970**	**$89,703,994**

Definitions of the specific cost line items and what they include are shown below:

- **Tracker Cost**: Total SAT cost with and without SuperTrack quoted by Trina.
- **Module Cost**: Total module cost based on a $0.35/Wdc assumption.
- **Inverter Cost**: Total inverter cost based on a $0.04/Wdc assumption.
- **Tracker Install**: Includes labor and equipment to install the trackers, including staging of material in work areas.
- **Module Install**: Includes labor and equipment to install modules, including staging of material in work areas.
- **Civil Cost**: Includes labor and material cost for complete site clearing, grading, roads, and stormwater management.
- **BoS Material**: Includes electrical and miscellaneous materials required for a complete system such as cable, cable management, combiner boxes, and grounding.
- **BoS Install**: Includes labor and equipment to install BoS Materials.
- **Engineering**: Includes design and procurement services.
- **Project Management**: Includes project management, administration, and project controls.

- **Construction Management**: Includes site management, supervision, quality, and safety.
- **Construction Indirects**: Includes site facilities and services such as temporary offices, laydown, parking, electricity, material receiving, handling, and storage, internet, drinking water, and restrooms.
- **Startup**: Includes startup and commissioning personnel and testing equipment.
- **Project Indirects**: Includes insurance and warranty costs.
- **Taxes**: Total tax costs associated with project construction.
- **Contingency**: Total EPC contingency costs.
- **Escalation**: Total escalation associated with project construction.
- **General & Administrative and EBT Costs**: Includes total general and administrative project costs and EPC's profit.

Appendix 1: Sample LCOE Spreadsheet

*Years 10-30 not shown

Assumptions	**SuperTrack**
Initial Investment Cost ($)	89,403,970.00
Acres	375.0
Lease Costs ($/Acre)	600.0
Annual Lease Costs (Year 1)	225,000
Annual Lease Escalation	2%
O&M Costs ($/kW/yr)	Variable
Insurance Costs ($/kW/yr)	1.0
Asset Management Costs ($/kW/	1.5
Cpacity (kWdc)	100,008
Capacity (kWac)	90,000
Annual Electricity Output (MWH)	210,148
Degradation	0.40%
Project Lifespan (years)	30
Discount Rate (%)	9.00%
Entry Date	12/31/2022

Total Costs	Construction	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation
Date	12/31/2022	12/31/2023	12/31/2024	12/31/2025	12/31/2026	12/31/2027	12/31/2028	12/31/2029	12/31/2030	12/31/2031	12/31/2032
Year Frac (From Start Date)		1	2	3	4	5	6	7	8	9	10
O&M Costs ($/kW/yr)		5.37	5.38	5.39	5.42	5.53	5.76	5.87	6.04	6.25	6.65
Project Costs	89,403,970	-	-	-	-	-	-	-	-	-	-
SuperTrack Costs	300,024										
Lease Costs	-	225,000	229,500	234,090	238,772	243,547	248,418	253,387	258,454	263,623	268,896
O&M Costs	-	536,743	537,655	539,417	542,534	553,234	575,703	587,472	603,803	625,155	664,650
Insurance Costs	-	100,008	100,008	100,008	100,008	100,008	100,008	100,008	100,008	100,008	100,008
Asset Management Costs	-	150,012	150,012	150,012	150,012	150,012	150,012	150,012	150,012	150,012	150,012
Total Costs	89,703,994	1,011,763	1,017,175	1,023,527	1,031,326	1,046,802	1,074,141	1,090,879	1,112,278	1,138,798	1,183,566
NPV of Total Costs	**$93,419,663**										

Total Energy Output		1	2	3	4	5	6	7	8	9	10
Yearly Output (MWh)		210,148	209,307	208,470	207,636	206,806	205,979	205,155	204,334	203,517	202,703
NPV of Total Output	2,086,206										

LCOE	**44.78**

Appendix 2: PVsyst Report