

Case Study C&I RE Sector

Bifacial + Solar Tracker Project

Project Developer:



August 2023



JMK Research & Analytics is a specialist consultancy firm that provides research and advisory services to Indian and International

clients across Renewables, Electric mobility, and the Battery storage markets.

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GLOSSARY

ABBREVIATION	DEFINITION
1P	Single Portrait
AS	Additional Surcharge
BLDC	Brushless Direct Current
C&I	Commercial and Industrial
CSS	Cross Subsidy Surcharge
DISCOM	Distribution Company
FoB	Free on Board
GW	Giga Watt
HJT	Heterojunction Technology
IEC	India Excellence Centre
INC	Installation and Commissioning
INR	Indian National Rupee
IT	Information Technology
KV	Kilovolt
kWh	Kilowatt Hour
kW _p	Kilo Watt Peak
LCOE	Levelized Cost of Energy

ABBREVIATION	DEFINITION
MTPA	Million Tonne per Annum
MW	Megawatt
MW _p	Megawatt peak
MWh	Mega Watt Hour
MWh	Megawatt-hour
OA	Open Access
PERC	Passivation Emitter Rear Contact
PLF	Plant Load Factor
PV	Photovoltaic
RE	Renewable Energy
R&D	Research & Development
SAT	Single Axis Tracker
ToD	Time of Day
TOPCon	Tunnel Oxide Passivated Contact
USA	United States of America
Wp	Watt-Peak

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ABOUT PROJECT STAKEHOLDERS

Juniper Networks, Inc. (Project Off taker)



Juniper networks, Inc. is one of the largest networking hardware companies in the world. Headquartered in California, it has development offices across the globe in China, India, Canada, Israel etc. As part of its sustainability efforts, Juniper Networks aims to attain carbon neutrality across its operations by 2025. Juniper Networks' Bangalore centre is one its largest and most energy intensive site.

Table 2: Company Overview - Juniper networks

Parameter	Description
Name	Juniper Networks, Inc.
Headquarters	Sunnyvale, California, USA
Sector	Networking, IT Services
Founded	1996
Revenue	US\$ 5.3 billion (2022)
Number of Employees	10,901 (December 2022)
Sustainability Target	Carbon Neutrality by 2025
Green House Gas (GHG) emissions (CO2 equivalent)	~3.7 MTPA (2021)
Total Global Energy Consumption	262,812 MWh (2021)

Source: Juniper Networks, Inc.

Radiance Renewables (Project Developer)



Radiance Renewables is a leading renewables energy (RE) developer in India that mainly operates in Commercial & Industrial (C&I) segment, with both on-site (rooftop) and off-site (open access) solution offerings. The company was founded in 2018 and has commissioned close to 419 MWp of renewable energy projects as of June 2023. In addition, it has more than 1 GW capacity of projects under pipeline across solar, wind, hybrid, energy storage segments.

Table 1: Company Overview - Radiance Renewables

Parameter	Description
Name	Radiance Renewables Pvt. Ltd.
Headquarters	Mumbai, Maharashtra
Type	Privately owned Independent Power Producer (IPP)
Operational Assets (as of June 2023)	419 MWp
Pipeline	More than 1 GW
Number of Consumers	45
Solution Offerings	Solar, Wind, Energy Storage under open access/behind-the-meter configurations
Investor	Eversource Capital (joint venture of Everstone Group and Lightsource bp)
Number of FTE employees	93
Presence	Pan-India

Source: Radiance Renewables

GameChange Solar (Tracker Supplier)



GameChange Solar, headquartered in USA is one of the leading solar tracking companies in the world. Globally, it has supplied trackers for a cumulative capacity of more than 29 GW. GameChange Solar has supplied its “Genius Tracker 3.0” for the Radiance “bifacial+solar tracker” project.

GameChange Solar has mainly operated in utility scale solar segment in India. This project is one of the only few commissioned by the company in the C&I segment. With C&I segment poised for growth in the coming years, the resulting performance of this project will be a key factor in future endeavours of GameChange Solar within the segment.

During project construction, GameChange worked closely with Radiance to provide support in installation of its solar trackers. This coordination, along with specialised preassembled clamp and drive systems supplied by GameChange enabled a swift project commissioning.



INTRODUCTION TO SOLAR TRACKERS

Solar trackers follow direct incidence of the sun to maximize the output of a solar plant. Although global adoption of solar trackers already started in 2010, the technology only started gaining acceptance in India around 2016.

Broadly, a solar tracker system consists of a tracking algorithm, control unit and driving mechanism. A tracking algorithm helps in determining the approximate position of sun. The output of tracking algorithm is fed into the control unit which reorients the solar module array through the driving mechanism.

Figure 0: Tracking system process flow

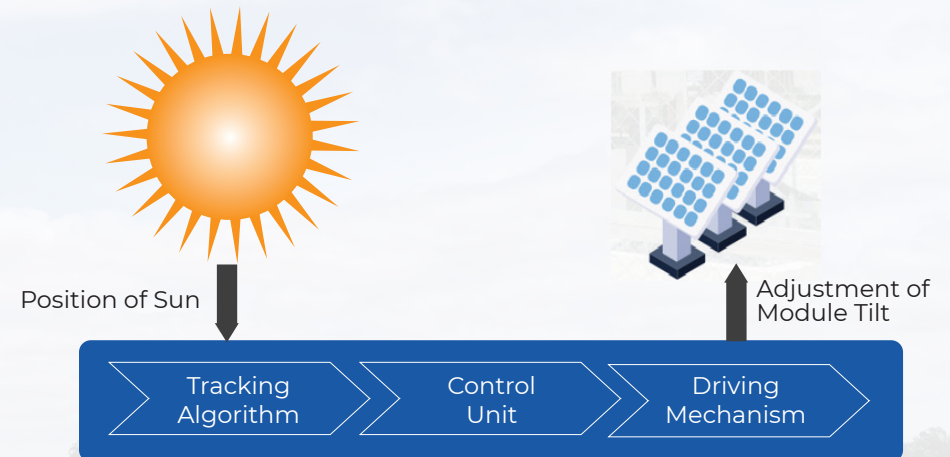
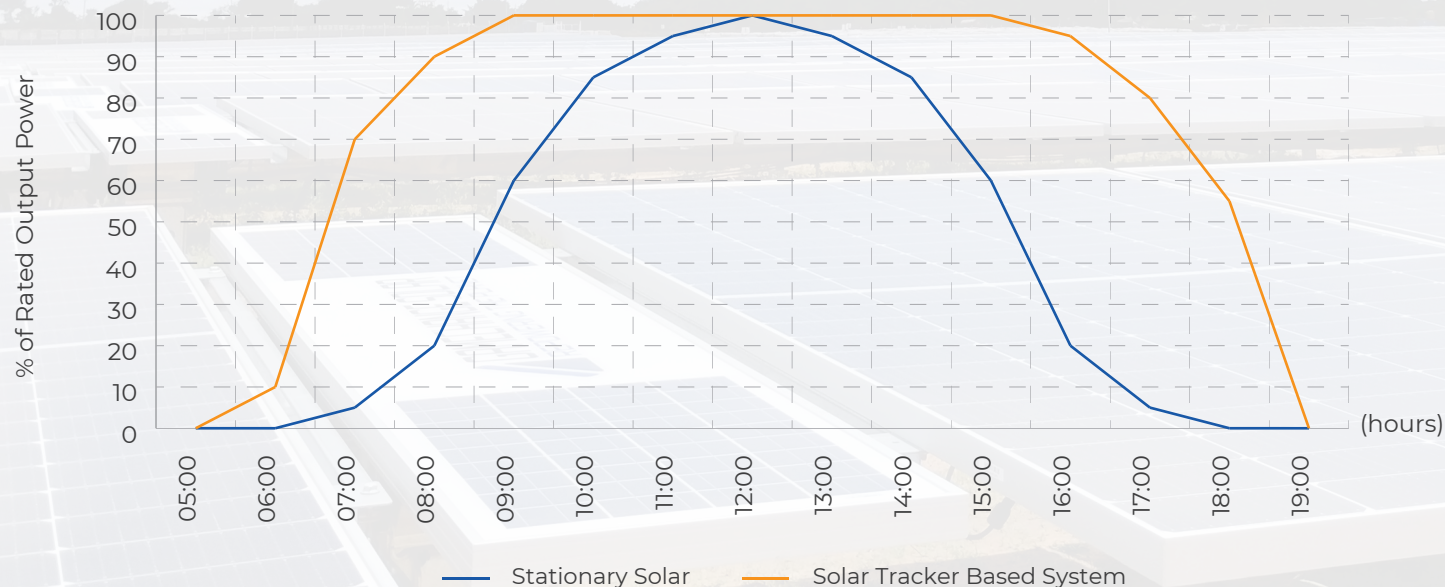


Figure 1: Indicative daily generation profile of a solar tracker project



Types of Solar Trackers

The solar tracking systems are most frequently categorized based on its associated degree of freedom. It includes:

- **Seasonal fixed tilt:** Seasonal fixed tilt is a passive tracking system wherein the module tilt is manually adjusted by maintenance staff multiple times (generally seasonal, two to three times) over the year to align with sun direction of dence.
- **Single-axis:** Single-axis trackers actively track movement of the sun from east to west during a day.
- **Dual-axis trackers:** Dual-axis trackers, in addition, also track the seasonal movement from north to south.

As compared to a normal solar project, addition of single or dual axis trackers may increase overall generation of the plant by

14%-42%, depending on various influencing factors such as tracker design, terrain undulation etc. In addition, the overall generation profile is relatively flatter and smoother, which is increasingly becoming the preference of energy off takers, especially for data centres type of constant loads like Juniper. Generation in early mornings and evenings, which may be peak hours as per respective state time of day (ToD) regulations, is an additional benefit. For example, in Karnataka, ToD peak hours are 6 AM to 10 AM and then 6 PM to 10 PM. Hence, tracker based systems in Karnatka can accure ToD benefits for up to 3 to 4 hours of equivalent peak hour tariffs

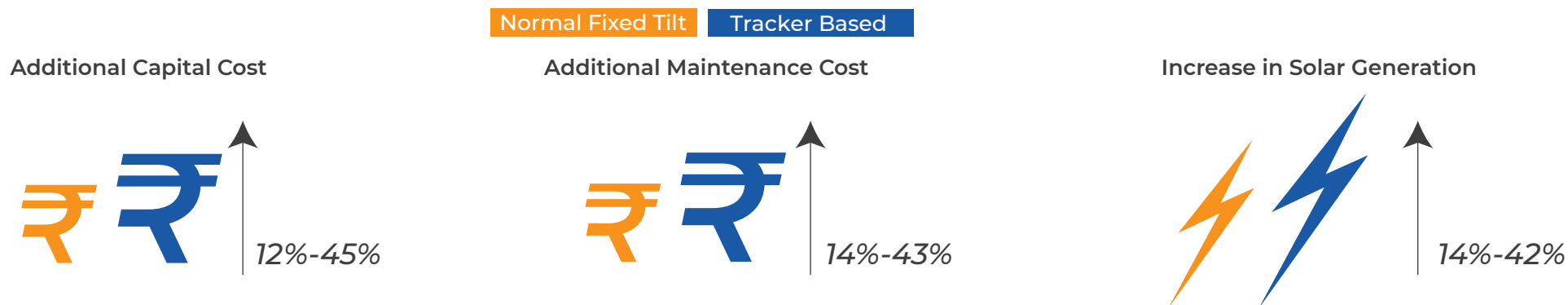
However, trackers increase the project upfront as well as maintenance cost. In addition, solar tracker projects' need a larger area to set up. Inter row spacing is generally increased in solar tracker projects to avoid the risk of shadows on PV modules. Involvement of larger number of moving parts also increases the overall system complexity.

Table 3: Comparison of Solar + Tracking Systems (vis-à-vis a normal fixed tilt solar project)

Parameter	Normal Fixed Tilt	Solar + Tracker	
		Single-axis	Dual-axis
Capital Cost (per MWp), excluding land	INR 4 crore	INR 4.5-5 crore	INR 5.3-5.8 crore
Maintenance Cost* (per MWp)	INR 3.5 lakh	INR 4 lakh	INR 5 lakh
Land Requirement	3 acre/MWp	3.5 acre/MWp	4.5 acre/MWp
Specific Yield* (kWh/kWp/annum)	1400-1600	1600-1800	1800-2000
Capacity Utilization Factor (CUF)	16%-18.3%	18.3%-20.5%	20.5%-22.8%
System Complexity	Low	Moderate	High
Terrain Compatibility	Compatible on most land terrain	Low to moderate undulation tolerance	Least undulation tolerance

*Per annum values

Note: All values excluding goods and services tax (GST)



There are several contributing factors (or favourable conditions) to ensure financial viability of a solar tracker-based system:

- **Consistent Land Profile:** Even and consistent land profile is a must for solar tracker systems as it involves simultaneous movement of a large section of connected modules and solar arrays.
- **Lower Land Cost:** Lower land cost is favourable as solar tracker projects require significant larger amount of land area (around 16%-50% more) as compared to normal fixed tilt solar.
- **High Priced PV modules:** Solar trackers present an attractive proposition to enhance solar generation output in periods of higher module cost. (> module landed cost of US\$ 30 cents/Wp)
- **Availability of high-efficiency modules:** Additional generation due to solar trackers increases if the solar project utilizes higher efficiency modules, enhancing the overall project viability.

Bifacial modules are high-efficiency high-wattage modules which produce solar energy from both front and rear side. Thus, pairing solar trackers with the bifacial modules is a very effective solution to enhance financial project viability. Furthermore, the tracking movement of the solar modules leads to a greater amount of energy being absorbed by the rear side of the solar modules, thereby improving the overall bifacial gain.

Bifacial gain is also dependent on albedo factor of the surface viz. an indication of amount of light it can reflect back. For maximum bifacial gain, surface towards the rear side of the bifacial module should have high albedo. White painted concrete, desert sand, white gravel are some of the surfaces with very high albedo factors.

INTRODUCTION TO PROJECT CASE STUDY

“BIFACIAL + SOLAR TRACKER PROJECT”

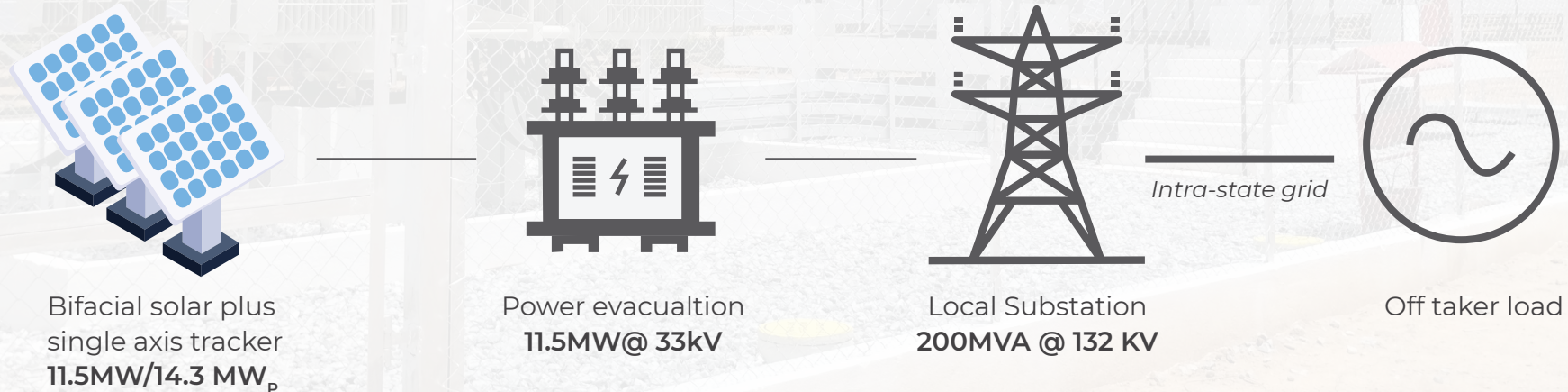
After a period of stagnant growth, Indian solar tracker market has experienced a strong rebound recently. A major contributing factor to this trend has been the rise of module prices in the past couple of years. When solar modules prices increased post mid-2020, implementing tracker solutions to increase generation made more economic sense vis-à-vis installing more number of solar modules to attain the same generation.

According to industry stakeholders, most of the solar projects with tracker systems under construction include bifacial modules. In June 2023, JMK Research team visited a recently commissioned “bifacial + solar tracker” project to understand and observe the dynamics of this emerging technology pairing. This project was implemented by Radiance Renewables and situated near the town of Challakere, Karnataka at a distance of around 200 km from Bengaluru.

The 11.5 MWac/14.379 MWp project was commissioned in April 2023. The project is implemented under group-captive mechanism of open access solar. The power is wheeled to project off taker 200 km away in Bengaluru through 132 kV intra-state transmission lines.

To further understand the visual layout of the project, please click the following [link](#).

Figure 2: Project Layout



Source: Dalmia Cement, JMK Research

Table 4: Project Configuration

PROJECT CONFIGURATION

Site Name		Radiance Solar Park in Nerlagunte, Challakere		
Location		Challakere, Karnataka	Annual Generation	>27000 MWh
Installed Capacity		11.5 MWac/14.38 MWp	Interconnection Capacity	5.75 MW X 2
Project Type		Group-Captive Open Access, ground mounted solar	Interconnection Voltage	33 kV
Project Technology		Bifacial + Solar Tracker	Date of Commissioning	Apr-23
Project Developer		Radiance Renewables	Construction period	4 months
Project off taker		Juniper Networks	Project PPA	25 years
Project layout		Off-site power wheeled to Bengaluru, around 200 kms away	Banking Availability	Monthly Banking is available
Total Project Cost		Approx. INR 65 crore (US\$ 7.9 million)	Yearly Maintenance Cost	INR 58 lakh (US\$ 0.07 million)
Bifacial Solar Plant	AC Capacity	11.5 MW	Albedo factor	~0.2-0.3
	DC Capacity	14.379 MWp	DC Over-loading	25%
	Solar Module Technology	Bifacial mono PERC	Module Orientation	True East (in morning) -> True West (in evening)
	Solar Modules			
	Capacity	Make	No.of Module	Type
	540 Wp	JA Solar	28,628	Bifacial Mono PERC
	Inverter Details			
	Capacity	Make	Type	No of Inverters
	3125 kW	Sineng	Central	4
	Module Cleaning System			
Solar Tracker System	Type		Make	
	Robotic Cleaning		Aegeus Technologies Pvt. Ltd.	
	Tracker Supplier	GameChange Solar	Maximum allowed operational weight (per tracker)	7400 lbs (~3357 Kg)
	Model	Genius Tracker 3.0	No. of modules (per tracker)	56 (2 string configuration) or 84 (3 string configuration)
	Country of Origin	USA	Power requirements (per tracker)	36-50 Vdc, 2 Adc (self-powered through an inbuilt 100Wp module)
	Tracker Type	1P Horizontal Single Axis	Driving Mechanism	Brush Less Direct Current (BLDC) motor driven linear actuator, decentralised
	Module tilt range	-45° to 45° (w.r.t horizontal)	Control System	Open Loop
	No. of trackers/module rows	354		

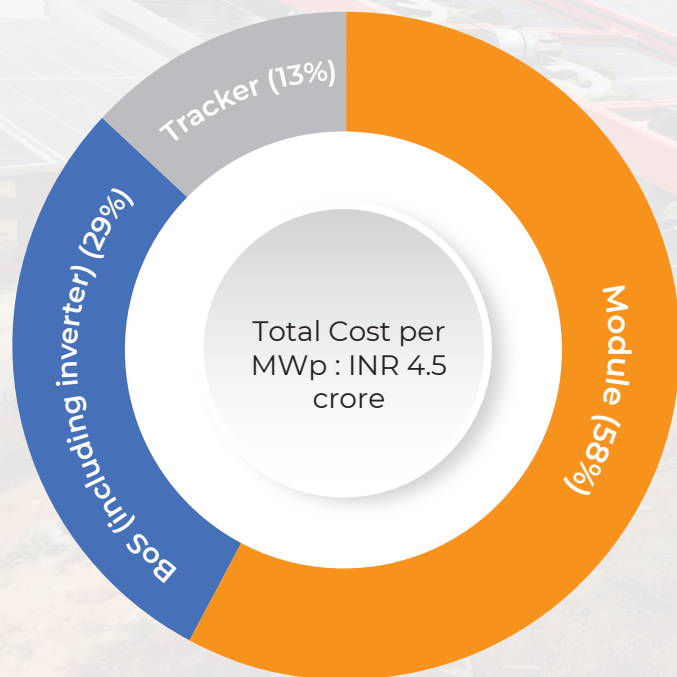
PROJECT COST

As highlighted in the introduction section of this report, project cost of a solar tracker project, being higher than a normal solar project, have a significant impact on its financial viability. Herein, we analyse the overall project cost, with an emphasis on the share of solar trackers.

Capital Expenditure

Total capital expenditure of the “Bifacial+Solar Tracker” project was approximately INR 65 crore (US\$ 7.9 million). This includes equipment, structure and “installing and commissioning (INC)” costs. As the project was commissioned within an already operational solar park, no significant additional land and interconnection costs were incurred.

Figure 3: Project Capital Expenditure (Components and Share)



While the share of solar modules was 58%, the single axis solar tracker system contributed 13% to the entire project cost. For the project, the solar modules were procured at a landed cost of INR 26/Wp (US\$ 33 cents/Wp). This high solar module cost, prevailing at the time of equipment procurement, was a crucial factor that made addition of trackers a viable option.

Operation & Maintenance (O&M)

The project incurs an annual O&M cost of around INR 4 lakh/MWp. Radiance has deployed a robotic cleaning system at the site. The semi-automatic robotic cleaning system is supplied by Aegeus Technologies. Using this robotic cleaning system, dry module cleaning throughout the project is done at a frequency of every 2 days. In addition, the manual water cleaning of the solar modules is done once every quarter.

Source: Radiance Renewables, JMK Research

Note: All values are in INR crore, does not include land and interconnection costs. Excludes GST also.

PROJECT GENERATION AND PERFORMANCE

The bifacial solar + tracker project under consideration, was commissioned in early April 2023. Since then, the project has generated 6594 MWh of electricity until the end of June 2023, with a resultant CUF of around 23%.

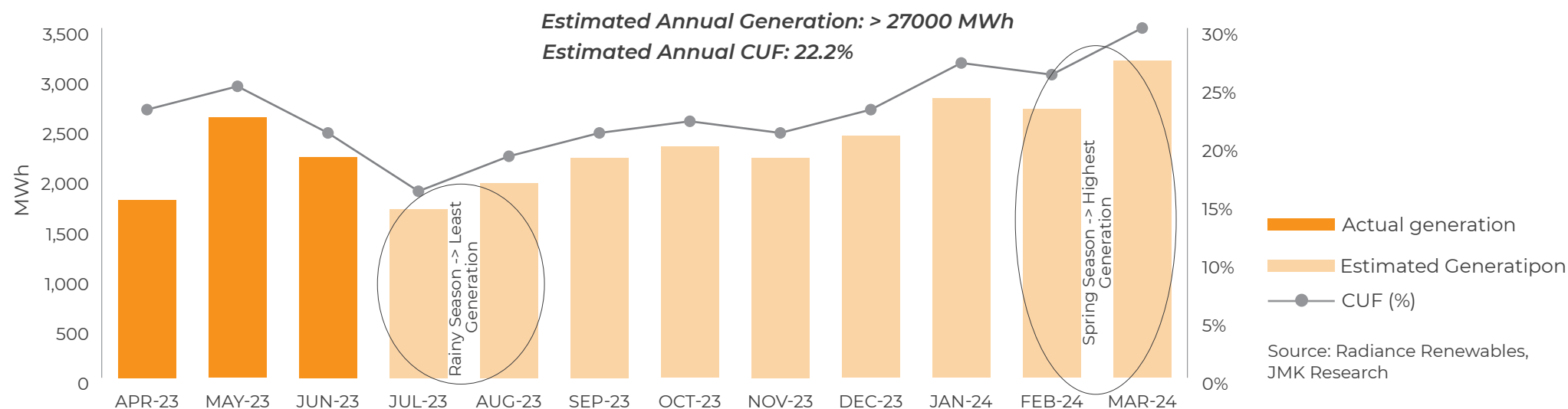
Table 5: Project generation and performance (Apr 2023- June 2023)

Parameter	Value
Generation period	8th April 2023 to 30th June 2023
Solar Generation (MWh), until June 2023	6594
Estimated Annual Generation (MWh)	>27000
Capacity Utilization Factor (CUF)	~23%

Source: JMK Research, Radiance Renewables

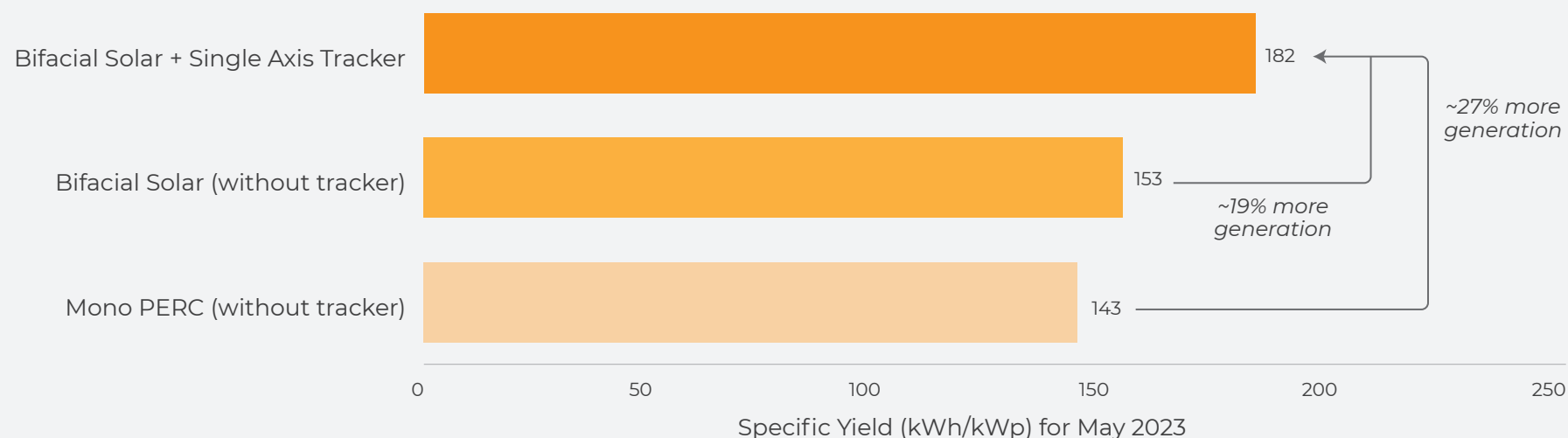
Overall, the project is estimated to generate >27000 MWh annually. The generation is likely to be highest during the period of February and March, due to a combination of clearer skies and lower temperatures in the spring season.

Figure 4: Energy generation trend



Additional generation from tracking the movement of sun is the most significant advantage of solar tracker solutions. Also, while comparing this “bifacial + single axis tracker” project to a nearby located mono PERC project without trackers, there is an additional generation of about 27% during the month of May 2023. To gauge the true benefit of adding solar trackers, we again compare the generation with a bifacial project without trackers located in the vicinity. Impressively, the “bifacial + single axis tracker” project still generated around 19% more electricity.

Figure 5: Comparative Performance Analysis of Radiance “Bifacial + Solar Tracker” Project



Source: Radiance Renewables, JMK Research

Combining bifacial modules with solar trackers enhance energy gain of both these technologies. This project was the first large scale deployment and pairing of bifacial technology with solar trackers by Radiance Renewables. The project presents Radiance with a unique opportunity to study and observe firsthand the various benefits as well as any likely challenges posed by this pairing.

“Due to the use of Bifacial Solar PV modules and Single Axis Tracker (SAT) this plant will deliver significantly higher plant load factor (PLF) thereby reductions in Levelized Cost of Energy (LCOE) and improving the project IRR for the investors. It has been observed that bi-faciality gain is better in combination with SAT as compared to fixed tilt system. This plant has been commissioned in less than three months from the groundbreaking to plant commissioning while adopting highest standards of safety and quality in project execution. Robotic cleaning system is also deployed to further improve the generation and save water and meeting our sustainability goals.”

-Amit Kumar Mittal: Executive Director (Operations), Radiance Renewable

CONSUMER BENEFIT AND SAVINGS

Commercial & Industrial (C&I) consumers in India are increasingly exploring ways to green their electricity consumption. Maximizing use of renewables such as solar enables electricity cost savings and carbon emission reduction. Adding trackers to a solar project is becoming a popular and viable technology to augment the overall generation output. Additionally, the generation profile of a solar tracker-based project is more stable and smoother throughout the day. This is an attractive proposition for constant round-the-clock energy demands of some consumers, such as data centres.

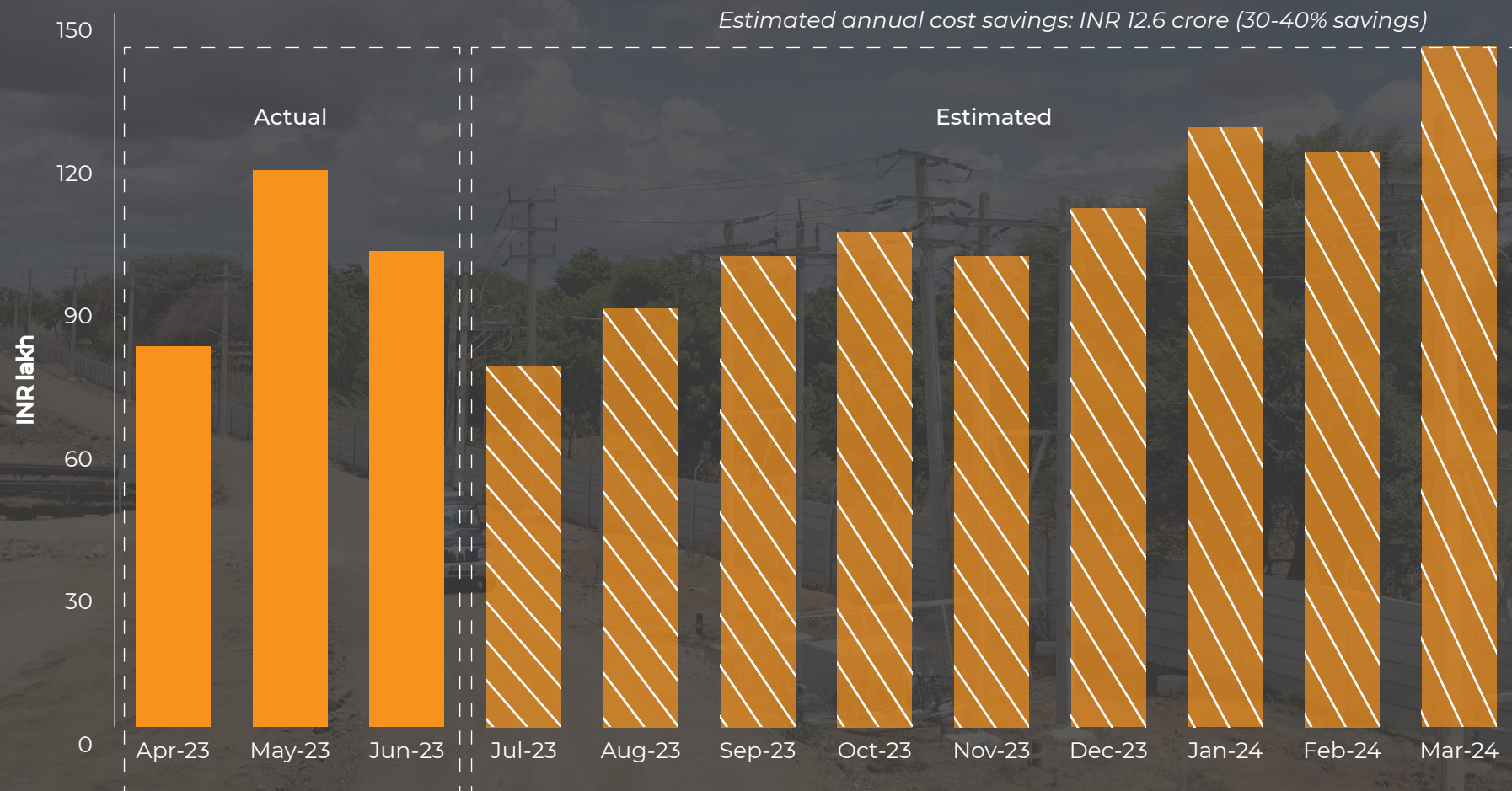
Juniper Networks, a networking and IT services multi-national, is the sole consumer from the Radiance “bifacial + solar tracker” project. Data centres, being the main energy load, are usually housed in urban locales inside commercial buildings having little rooftop area to implement any on-site solar projects. Hence, open access (OA) is the most preferred route to procure renewable energy. The current project is implemented under group-captive open access mechanism to avoid hefty OA charges under third party route, mainly cross subsidy surcharge (CSS) and additional surcharge (AS).

Table 6: Project Consumer Details

Parameter	Description
Name	Juniper Networks India Excellence Centre (IEC)
Location	Bengaluru, Karnataka (around 200 km from project site)
Sector	Networking, IT services
OA procurement type	Group-Captive
Project Size	14.379 MWp
Date of Commissioning	April 2023
Estimated electricity consumption met from Bifacial + Tracker solar project	>27000 MWh/annum
% share of RE in total consumption	70%
% savings in electricity costs	30-40%
CO2 emission abatement	22,417 tonne/annum
PPA tenure	25 years
PPA tariff details	Approx. INR 3.9/kWh

The “bifacial + solar tracker” alone meets around 70% electricity requirements of the Juniper’s site, internally called as India Excellence Centre (IEC) situated in Bengaluru. For Juniper Networks, the project will directly lead to an estimated annual savings in electricity costs of around INR 12.6 crore (US\$ 1.5 million). Moreover, the electricity consumption from the project will also lead to an annual abatement of 22,417 tonne of overall CO2 emissions of Juniper.

Figure 7: Electricity Cost Savings trend



Source: Radiance Renewables, JMK Research

Note: Savings calculation is done wrt to net commercial grid tariff that has been estimated to be INR 10.25/kWh (including fixed charges of INR 1/kWh) basis latest state tariff orders

SECTOR OUTLOOK

Even though the technology for solar trackers has been around globally for a long time now, it is still at a nascent phase in India. In addition to technological complexities, cost economics play a major role in ensuring the financial viability of solar tracker solutions in any given scenario. Hence, it is important to look at the likely future developments in solar tracker adoption in India.

Impact of Module Prices on Solar Tracker Market Growth


The period from mid-2020 to early 2023 was an unprecedented period for solar module prices. In contrast to earlier trend, the solar module prices during this period increased significantly. Consequently, the interest in solar trackers as a solution to boost overall plant generation output also increased simultaneously.

However, more recently, the solar module prices have started to show a declining trend. Between January 2023 and July 2023, the per Wp free on board (FOB) price of mono PERC module in the global market have fallen from US\$23.2 to US\$18 respectively (22.4% decrease) mainly due to fall in poly silicon prices globally. Thus, developers may again follow a cautious approach towards installation of tracker-based solutions.

However, a similar scenario of higher module costs may again occur in the future. Thus, in that period, tracker-based solutions will again be an economically viable option to consider. Regardless, consumers favouring a more stable and better power output quality will continue to find tracker-based solutions appealing.

Innovative Tracker Design Features

Genius Tracker 3.0, supplied for the project by GameChange Solar, boasts several unique design specificities. The most important among them is the lack of any separate auxiliary power system for solar trackers. Each tracker is self-powered by a smaller module installed separately within module row by GameChange. This reduces both the cost and complication of laying and maintaining cables for auxiliary power circuits usually required to power trackers over the project area.



Small 100 Wp module powering tracker driving mechanism

Centralised control of trackers from a single master controller is another highlight of this tracker design. The module rows are not physically connected, and this allows for an optimum and customised module spacing for maximum energy gain. Also, in case of a breakdown, the downtime will be limited to just that row and will not affect a larger project area.

These design features mark a step towards addressing the challenges sometimes associated with tracker systems, such as their high maintenance cost and complexity. Thus, going forward, several manufacturers may likely to incorporate some of these features or their similar variations in their tracker design.

Technological Advancements in Solar Modules

As discussed previously in the report, larger and more efficient modules translate to an enhanced viability of a solar tracker project. Consequently, coupling high efficiency bifacial modules with solar trackers enhance energy gain of both these technologies.

Going forward, PV module technology will continue to improve. From polycrystalline a few years back, the entire PV market has shifted to mono PERC at present. High efficiency newer PV Technologies such as TOPCon, HJT, n-type etc. are already on the horizon. Their widespread adoption and availability in the future can be a potential boost to the growth of solar tracker market.





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