Actual site image

JMK Research & Analytics

Project Case Study

SOLAR + BESS

April 2023

Plant owner :

BRAHMA KUMARIS

Om Shanti Retreat Center

Location: Bhora Kalan, Gurugram

JMK Research & Analytics is a specialist consulancy 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
AC	Alternating Current
BESS	Battery Energy Storage System
BOS	Balance of System
BTM	Behind the Meter
C&I	Commercial & Industrial
DC	Direct Current
DG	Diesel Generator
DISCOM	Distribution Company
INR	Indian National Rupees
Km	Kilometer
kV	Kilo Volt
kW	Kilowatt
kWp	Kilowatt Peak

ABBREVIATION	DEFINITION
kWh	Kilowatt Hour
MPPT	Maximum Power Point Tracking
MVA	Mega Volt Ampere
MW	Megawatt
MWh	Megawatt Hour
ORC	Om Shanti Retreat Centre
PERC	Passivation emitter rear contact cell
PV	Photovoltaic
RE	Renewable Energy
TOD	Time of Day
Wp	Watt peak
MUs	Million Units
EPC	Engineering Procurement Construction

CONTENTS

OVERVIEW: BRAHMA KUMARIS ORG.

Brahma Kumaris is a worldwide spiritual organization established in 1937. Headquartered in Mount Abu, India, it has centres spread across 110 countries in the world with regional offices in London, Moscow, Nairobi, New York and Sydney.

Om Shanti Retreat centre (ORC), Gurugram is one of the largest learning centres of Brahma Kumaris in the North India. It provides higher education in the Art of Living as well as hold several congregations and events pertaining to Brahma Kumaris organization. The campus was formally inaugurated in 2001 and has an area of 28 acres and houses over 200 residents.

Throughout its history, all the Brahma Kumaris ORCs have focused on optimizing sustainability which include not only utilizing sustainable food practices but also a progressive shift towards renewable energy. Attaining self-sufficiency in energy requirements as well as lack of reliable power supply at several of the centres had been the key motivating factors for this shift. In 2017, Brahma Kumaris commissioned one of the largest concentrated solar thermal plant in India at its headquarters in Mount Abu, Rajasthan.

Table 1: Basic information about "Om Shanti Retreat Centre – Gurugram"

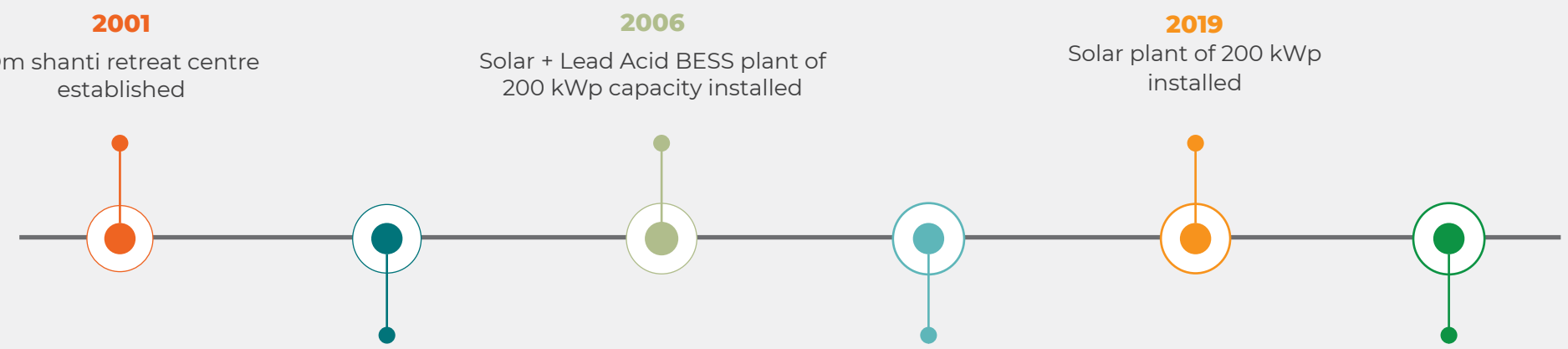
Parameter	Details
Name	Om Shanti Retreat Centre
Location	Bilaspur Kalan, Haryana (around 35kms from Gurugram city)
Parent Organization	Brahma Kumaris
Year of establishment	2001
Area of the campus	28 acres
Number of Residents	200
Capacity	1000 rooms, 5 training halls, 1 Mini auditorium.
Connected Load	440 kW @ 11kV

RENEWABLE INSTALLATIONS

Om Shanti Retreat Centre: Gurugram

Current renewable installation at Om Shanti Retreat Centre (ORC) include a concentrated solar thermal project commissioned in 2003. In subsequent years since, it has commissioned multiple solar, Battery Energy Storage System (BESS) projects.

Figure 1: Timeline of greening initiatives at ORC - Gurugram

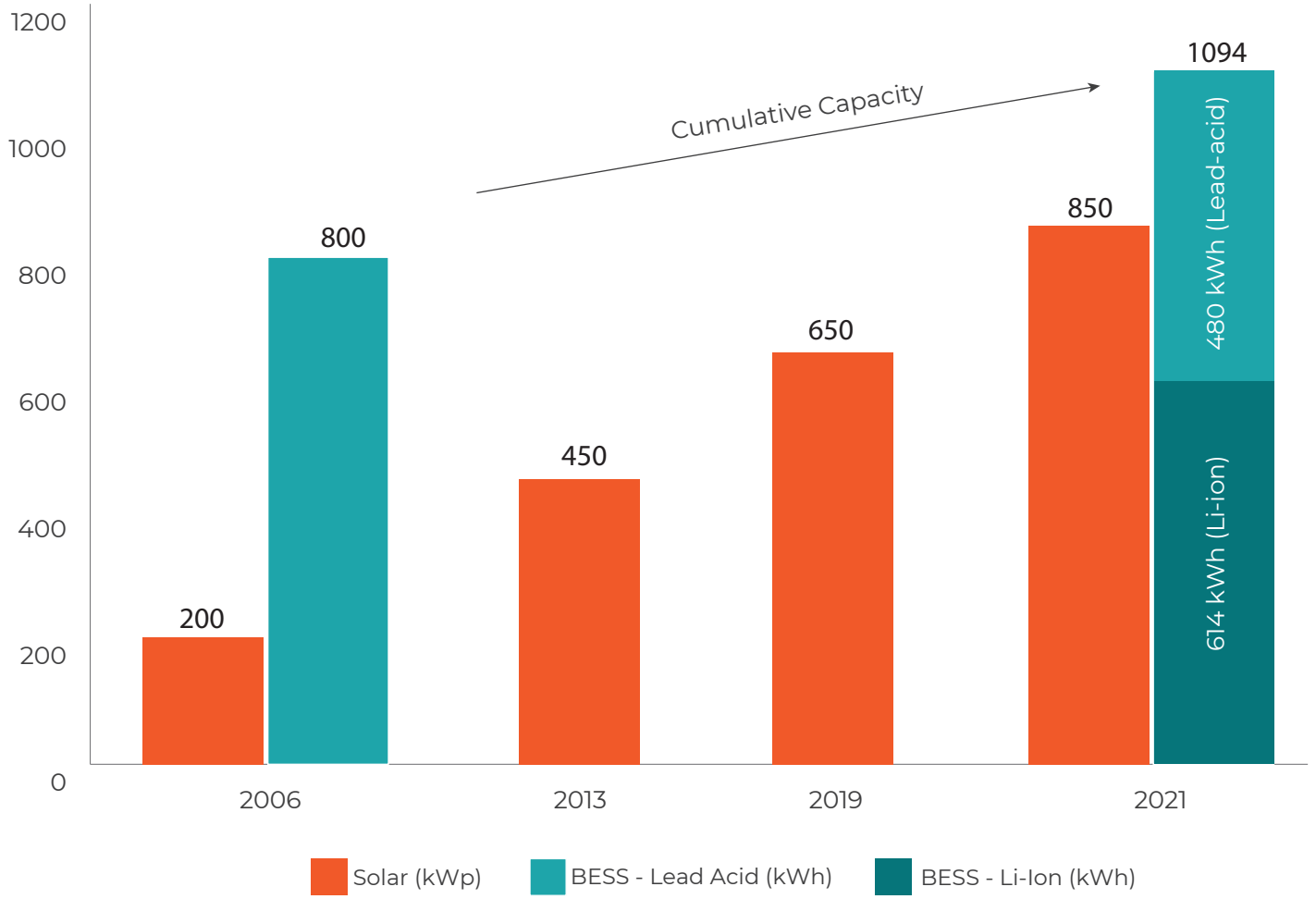


Source: Brahma Kumaris Org.

Figure 2: Solar panels installed on Om Shanti Retreat Centre rooftops (concentrated solar thermal project in the back)

The current cumulative solar PV installed capacity at ORC is 850 kWp. First solar PV project installed at ORC was of capacity 200 kWp commissioned in 2006. It also included 800 kWh Lead Acid battery BESS which achieved its end of life back in 2011. Other solar power projects at ORC were commissioned in 2006 (200 kWp), 2013 (250 kWp), 2019 (200 kWp) and 2021 (200 kWp).

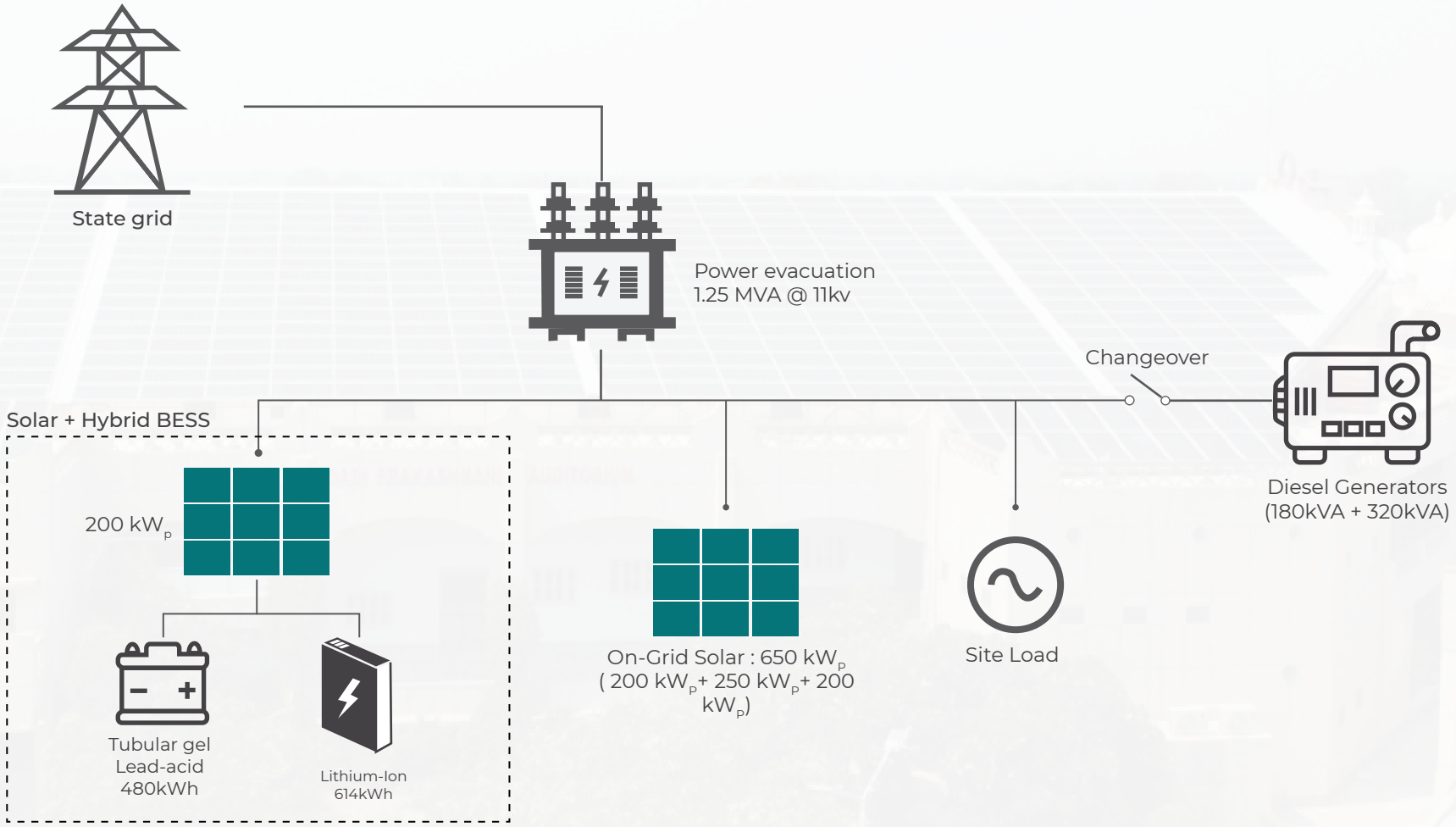
Figure 3: Timeline of solar PV capacity additions at ORC – Gurugram



Project Layout

The latest addition to the renewable energy (RE) portfolio of ORC was the Solar + Hybrid BESS project commissioned in 2021. It implements a hybrid combination of Li-ion and Tubular Gel Lead Acid batteries in tandem with a 200 kWp solar project.

Figure 4: Layout of solar installations in ORC - Gurugram



Actual site image

PROJECT CONFIGURATION

In the next few sections, we study in detail the Solar + Hybrid BESS System commissioned at ORC in 2021. This hybrid deployment utilizes both the tubular gel lead acid batteries and the lithium batteries, providing long duration backup, and ensuring zero blackouts and uninterrupted power supply when the grid fails.

Battery Energy Storage Systems(BESS): Introduction

Energy storage systems (ESS) are swiftly gaining prominence as one of the major components in renewable energy (RE) projects. At the core, ESS basically allow energy to be stored for its utilization later by its beneficiary. ESS addresses the inherent intermittency and unpredictable variability of RE sources such as solar and wind. Battery ESS (BESS), wherein batteries are used for storing energy, is one of the most common and popular way to implement an ESS.

Of late, BESS is often being coupled with solar rooftop by Commercial & Industrial (C&I), as well as residential consumers. "Solar rooftop + BESS" may provide several discernible benefits/advantages. "Solar rooftop + BESS" systems in C&I and residential segment are usually in behind-the-meter (BTM) configuration i.e., interconnected behind the main utility meter of the consumer.

Table 2: Benefits of "Solar rooftop + BESS"

Benefit	Description
Peak load management	• Energy consumers pay fixed charges to DISCOMs for their monthly peak load. Utilizing BESS during peak load periods will reduce the peak load, ultimately helping in reduction of fixed charges.
Energy shifting	• With states having Time-Of-Day (TOD) tariff structure, BESS can be utilized such that consumer uptake energy from BESS during peak tariff hours. • During off-peak hours, BESS can be charged from the solar rooftop and energy consumer meet their consumption from solar/DISCOM. • While the viability of BESS will depend on several other factors such as energy consumption, existing grid tariff etc, **a difference of more than 40-50% in peak and off-peak tariffs** can enhance the feasibility of the overall BESS solution.

Benefit	Description
Diesel abatement	• Majority of C&I facilities in India still use diesel generators (DG) for backup power during outages. • BESS can be used to supply backup power and replace expensive and environmental unfriendly diesel-based power. **BESS is an economically viable solution for the consumers having 2-4hrs of daily DG usage.**
Improved power quality	• BESS can be utilized by consumers to power sensitive critical loads requiring perfect power quality such as robotics, variable speed drives etc. • BESS can manage smooth voltage fluctuations as well as provide immediate backup supply in case of an outage (similar to UPS).
Better RE utilization	• BESS provides a means to store excess solar energy, leading to reduced curtailment, thus enhancing overall utilization of solar generation.

Source: JMK Research

PROJECT CONFIGURATION

Site Name	Om Shanti Retreat Centre (ORC)		Date of Commissioning	June-2021
Location	Bhora Kalan, Haryana		Project owner and off taker	Brahma Kumaris “Om Shanti Retreat Centre”
Total Installed Capacity	Solar	200 kWp	EPC	Vision Mechatronics Pvt. Ltd.
	BESS	1094 kWh		
Project Type	Solar PV + Hybrid BESS System		Total project Cost	INR 3.5 crores
Project Layout	Located on-site within the premises		Construction period	3 months

Solar

Project type	On-site solar rooftop	DC Capacity	200 kWp
Solar AC Capacity	135 kW (Solar inverter) + 69 kW (MPPT Charger)	Module orientation	True-south

Solar Modules

Capacity	Make	No.of Module	Type
390 Wp	RenewSys	512	Mono PERC

Inverter Details

Capacity	Make	Type	No.of Inverters
27 kW	Fronius	String	5

Battery Storage system

Total Battery capacity	1094.4 kWh	Date of Commissioning	June 2021

Lithium Ion

Battery Capacity	Battery technology and type	Battery make	Battery Cost/kWh	Life Expectancy
614.4 kWh	Lithium-ion (Lithium Iron phosphate)	Vision Mechatronics	INR 26,059 (US$ 316)	~10 years (4000 cycles @ 80% depth of discharge)

Lead Acid

Battery Capacity	Battery technology and type	Battery make	Battery Cost/kWh	Life Expectancy
480 kWh	Lead acid (Tubular gel)	HBL	INR 10,417 (US$ 126)	~3-5 years (1500 cycles)

Battery Inverter/Power Conversion System

Inverter make	Inverter model	Total capacity	MPPT DC-DC Chargers, Number	MPPT DC-DC Chargers, Capacity
Victron Energy	Quattro 15kVA	180 kVA (12X15 kVA)	12	~ 69 kW (12 X 5.8 kW)

PROJECT COST

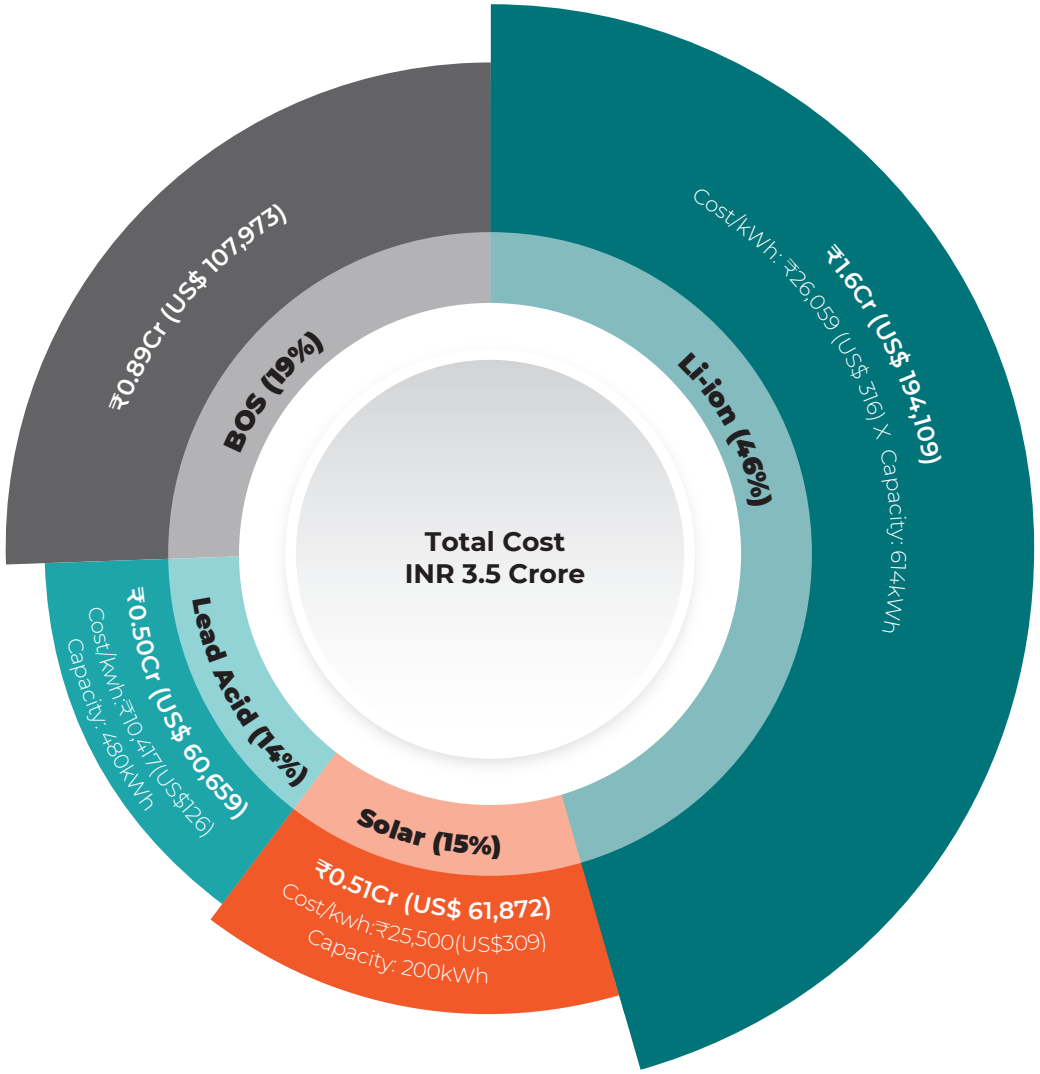
As highlighted in the previous section, "Solar + Hybrid BESS" system consist of solar (200kWp) and Li-ion (614 kWh) and tubular gel lead acid (480 kWh) batteries. The total project cost of the hybrid system is about INR 3.5 crore (~US$ 0.42 million). This value includes equipment cost as well as associated costs for interconnection, installation and commissioning. As the project was set up on existing premises, there was no additional cost in terms of land procurement.

Li-ion batteries contributed almost half (46%) to the entire project cost. Solar and tubular gel lead acid batteries contributed further 15% and 14% respectively. Rest 25% of the cost is attributed to balance of system (BOS) components such as solar and battery inverters, MPPTs, cabling, interconnection etc.

Together, Li-ion and lead acid batteries contribute to a significant share (60%) of the entire project cost. Thus, decline in battery prices, especially of the Li-ion, is critical for the development and growth of energy storage market.

In terms of operation and maintenance cost, Li-ion BESS is largely maintenance free, albeit in cases of system breakdown or failure. Additionally, tubular gel lead acid batteries are also a very significant improvement on vanilla lead acid batteries, which require regular maintenance and periodic refilling of battery electrolytes.

Figure 5: Project total cost (Solar + Hybrid BESS) and its breakup

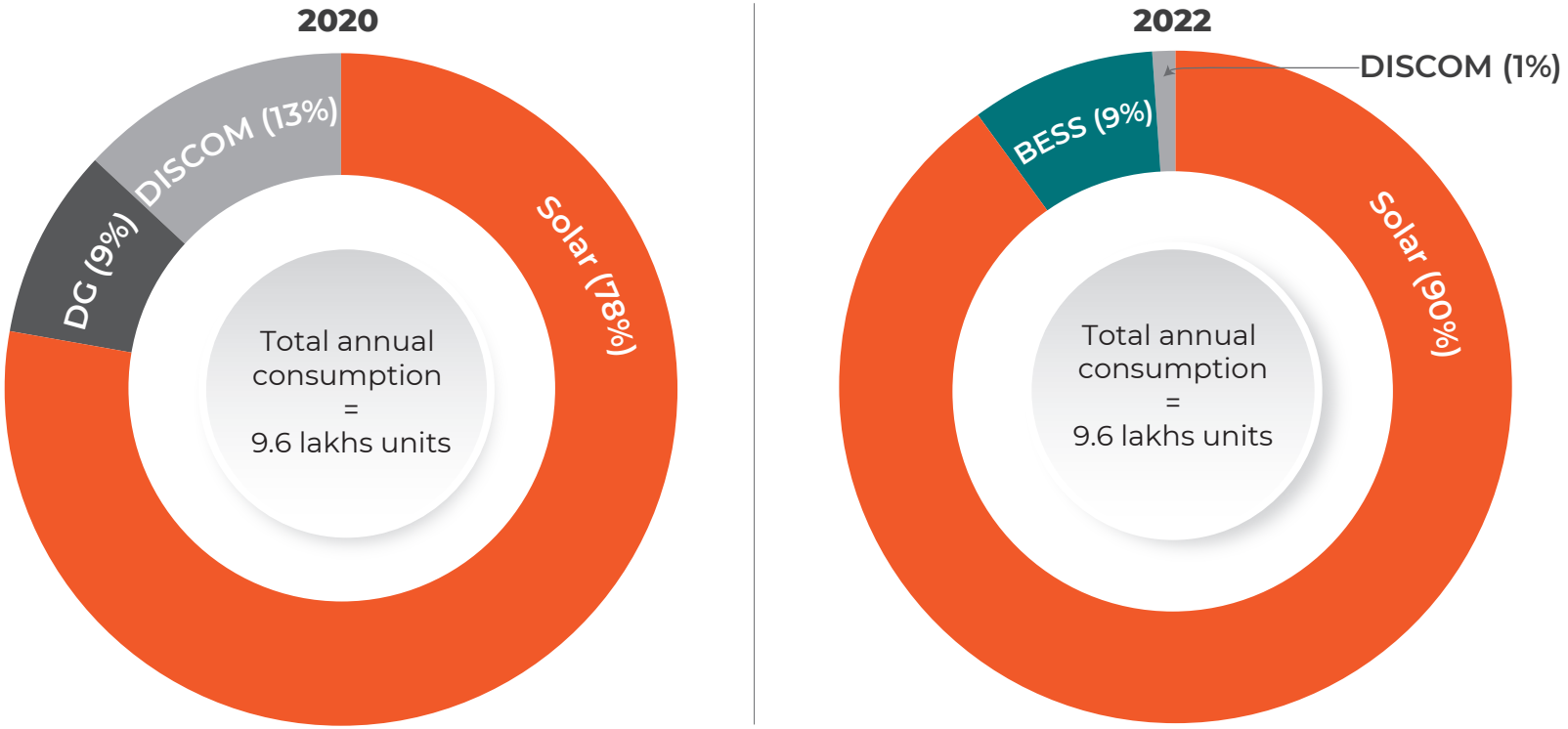


Source: JMK Research, Brahma Kumaris Org.
Note: All values are in INR crores, Includes land and interconnection costs

PROJECT PERFORMANCE

Post commissioning of the “Solar + Hybrid BESS” system, the share of renewables in annual energy consumption of Om Shanti Retreat Centre (ORC) – Gurugram has risen to 99% (as compared to 78% before). BESS (at 9% share) has completely replaced the DG for power backup requirements at ORC.

Figure 6: Annual energy consumption of ORC from various sources, pre and post installation of “Solar + Hybrid BESS” system



Source: Brahma Kumaris Org., JMK Research
Note: BESS generation in 2020 is insignificant

96%

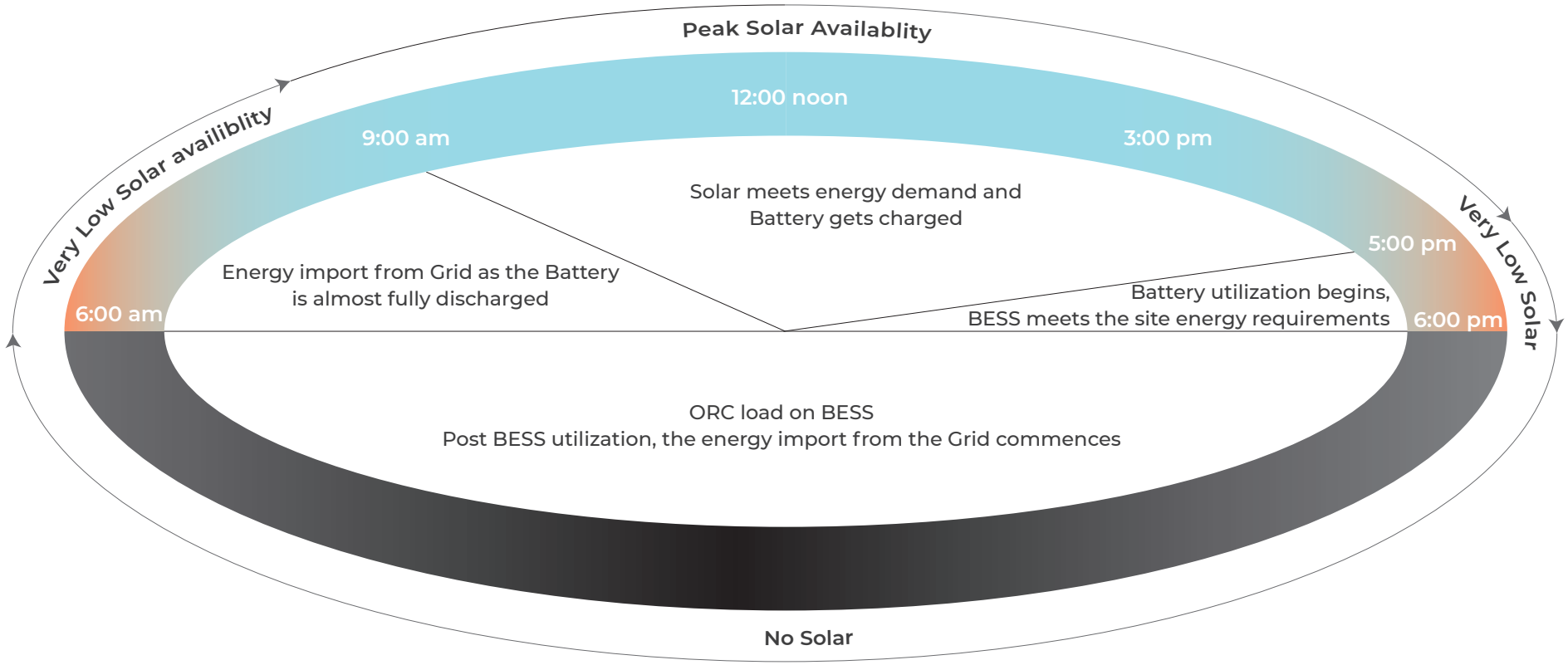
Round Trip Efficiency of BESS at ORC-Gurugram

Solar + Hybrid BESS System Operation

During the day, whenever the solar generation is more than the required load demand, the excess energy is stored in the BESS system. Lithium-ion batteries, with their fast charging rates, ensure that most of this surplus generation get absorbed in the BESS.

Similarly, in scenario of lower solar generation or its unavailability thereof after 5-6 pm in the evening, the BESS gets discharged first. Post utilization of BESS stored energy, the import from grid commences.

Figure 7: Solar + Hybrid BESS system process flowchart



Source: JMK Research

Figure 8: ORC load supply source in different scenarios

Time of Day	Solar	BESS	Grid	ORC Load Supply Source
9:00 AM to 5:00 PM	☀	Fully Charged	Grid Available	Main supply source will be **Solar** *Excess solar after BESS fully charged is sent back to grid through net metering*
	☀	Fully or Partially Charged	Grid Not Available	Main supply source will be **Solar** + **BESS** *Minimal BESS discharge, owing to solar availability*
	☀	Partially Charged	Grid Available	Main supply source will be **Solar** *BESS getting charged*
	☀	Fully Discharged	Grid Not Available	Main supply source will be **DG** *Scenario unlikely to occur*
6:00 PM to 6:00 AM	☾	Fully or Partially Charged	Grid Available	Main supply source will be **BESS** *Fully charged BESS can supply the ORC load for 6-12 hours*
	☾	Fully Discharged	Grid Available	Main supply source will be **GRID** *This scenario occur post complete utilization of BESS*
	☾	Fully Discharged	Grid Not Available	Main supply source will be **DG** *Scenario unlikely to occur*

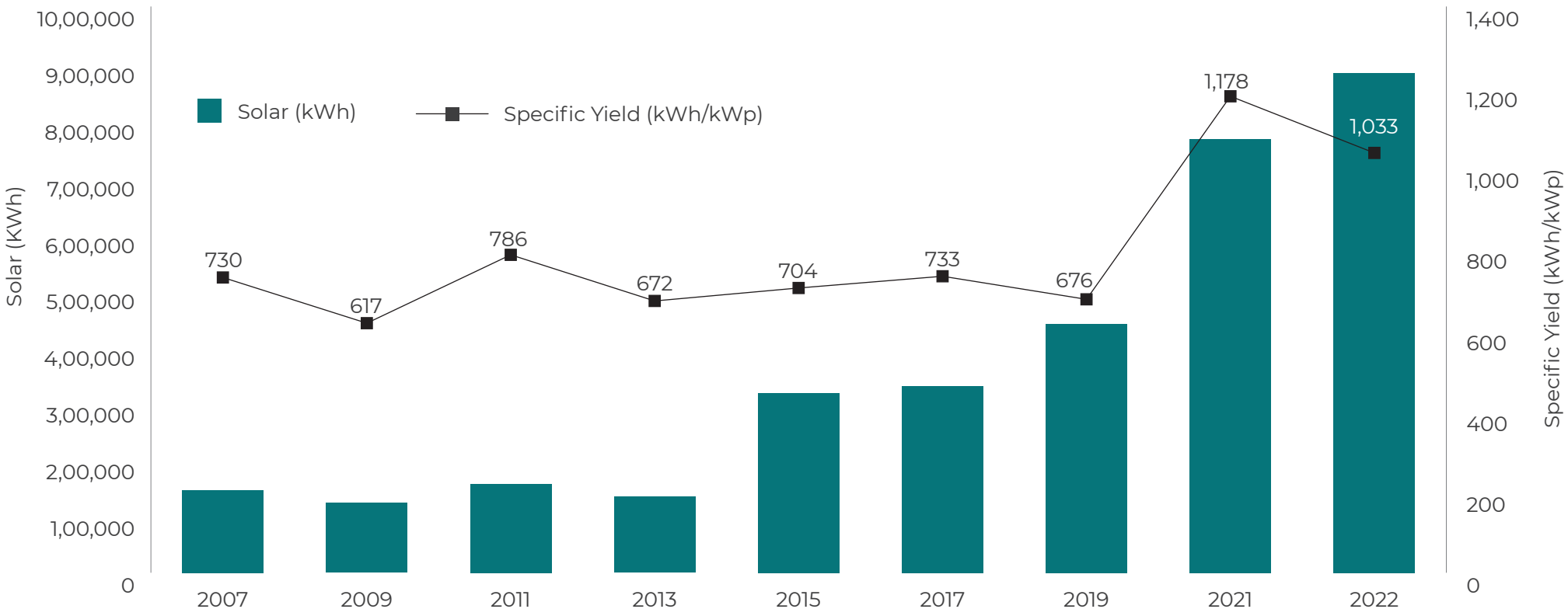
Source: JMK Research

Net Metering Impact on Solar Yield

With augmentation in solar capacity over the years at ORC-Gurugram, the solar generation has also risen immensely. However, the Specific Yield (kWh/kWp), an indicator used frequently to gauge performance of a solar plant, had been quite low (around 600-700 kWh/kWp) from 2007-2019. A major reason for the same was the lack of net metering provision for surplus generation. Commencement of net metering post 2017 and installation of hybrid system in 2021 has significantly increased the specific yield of the project to 1000-1200 kWh/kWp in the recent years.

In recent years, several state DISCOMs have tried to inhibit rooftop solar market by restrictive net metering provisions. In case, Haryana imposes any net metering restrictions in future, the current “Solar + Hybrid BESS" system, through little tweaks and augmentation, can efficiently capture any surplus solar energy in the day.

Figure 8: Annual solar generation trend over the years at ORC-Gurugram



Source: Brahma Kumaris Org., JMK Research

END CONSUMER BENEFITS

ORC is situated on the outskirts of Gurugram, in an area of weak grid infrastructure. ORC usually experienced 4-5 hours power outages everyday. To counter this, ORC utilized expensive and polluting DG power to ensure energy availability and to meet its backup energy requirements.

However, post commissioning of hybrid system,

- ORC-Gurugram is saving an additional **30-40%** in annual electricity costs. A major share of these savings (around 77%) is from additional solar generation leading to reduction in grid consumption.
- BESS replacement of the DG units constitutes the rest of the share in annual electricity savings.

Consumer electricity bills had been reduced to only fixed charges, and the 320kVA and 180kVA diesel generators are completely replaced resulting in increased savings and reduced CO2 emissions.

The entire "Solar + Hybrid BESS" system installed at ORC gives return on investment (ROI) in about 3.5 - 5 years, depending on DG usage, YoY rise in grid tariff, and increase in diesel cost.

ORC-Gurugram, being one of the largest centres of Brahma Kumaris in India, regularly conducts important events and congregations. “Solar + Hybrid BESS” system play a key role by ensuring energy availability during unexpected cases of faults and breakdowns in local grid.

Table 3: Project benefits (”Solar + Hybrid BESS” system)

Benefit	Description
Energy Contingency	• In case of faults or breakdowns in local grid, the BESS of the hybrid system can provide energy backup, ensuring energy availability for 6-12 hours.
Enhancement of power quality	• Supports grid and helps to manage power fluctuations in voltage and frequency, thereby enhancing power quality.
Safety net against future policy changes	• If state net metering policy is altered or removed, the BESS (through its possible augmentation) will act as a safety net in capturing the excess solar generation.
Better energy capture	• Shift to Li-ion batteries has enabled faster charging, thus enhancing the ability to capture excess generation.
DG abatement	• To combat 4-5 hrs daily power outage, ORC previously employed DG’s as a backup source. BESS have completely replaced expensive DG power (around INR 30-35 /unit) for the power backup requirements.

Source: JMK Research

PROJECT OUTLOOK

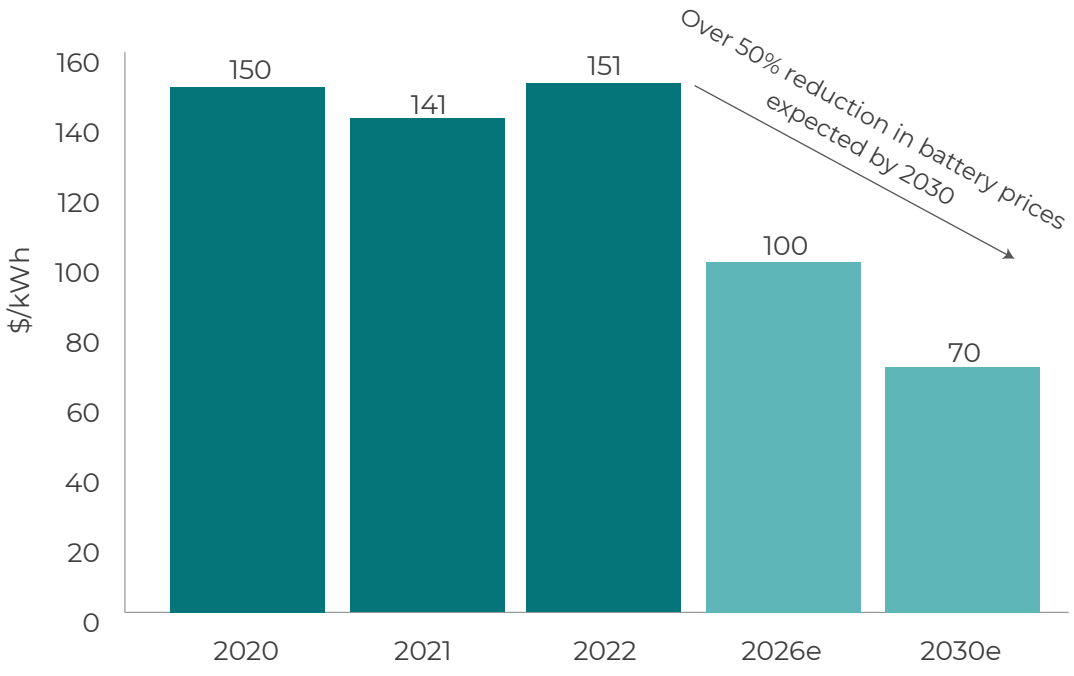
Energy storage market in India is still under development. High battery prices, which constitute a major portion of the BESS project costs, are a major impediment for the growth of the sector. In India, BESS solutions are viable in certain use cases.

One of the use cases of BESS is the replacement of costly DG power in locations where power outages are more than 3-4 hrs because of lack of reliable grid infrastructure.

Another specific use case is for the entities requiring all year around energy availability, with zero tolerance towards grid fault or failure during important events. Both these use cases are applicable to ORC.

Life of Li-ion batteries is around 9-10 years. Hence, the Li-ion batteries installed in ORC will need replacement around year 2030. According to BloombergNEF, the battery prices will almost halve over the present decade. Thus, this replacement, as well as any further augmentation in battery capacity in the future will be achieved at a much lesser expense.

Figure 9: Li-ion battery price trend (2020 - 2030)



Source: BloombergNEF

STAKEHOLDERS : VIEWPOINTS

Project Owner: OM SHANTI RETREAT CENTRE

Over the years, ORC-Gurugram has focused on enhancing the solar capacity along with increasing load requirements. They cite the "Solar + Hybrid BESS" system commissioned in mid-2021 as a major improvement to their energy infrastructure. In addition to electricity cost savings, the 1.094 MWh BESS allow them to ensure uninterrupted power supply in any unforeseen circumstances.

Shift towards Li-ion

ORC-Gurugram had previously employed flooded lead acid batteries for BESS. However, the slow charging rate of lead acid (usually around 0.1C**), usually led to a significant wastage of surplus solar power in the day (Around 50-60% of the surplus power). Post installation of Li-ion based BESS, they are able to capture surplus solar power much more efficiently, owing to much faster charging rate (around 0.8C to 1C) of Li-ion technology.

> ***Installation of hybrid project has instilled confidence and security in our electricity systems, wherein we feel ready to tackle any future scenario pertaining to energy availability***
>
> ***Mr. BK Appa Rao***
> ***Head (Solar Operation & Maintenance)***
> ***Om Shanti Retreat Centre***

Future plans

In future, ORC-Gurugram plan to augment the installed solar capacity, in line with its enhanced load requirements. In case the net metering provision is revoked in the future, then ORC may also plan similar augmentation in BESS capacity.

** C-rating of a battery: The battery C rating is defined as the measure at which a battery is charged or discharged relative to the maximum capacity of the batteries. For e.g. 0.2C 100kWh battery can be charged or discharged at a maximum of 20 kW power.

EPC developer: VISION MECHATRONICS

Vision Mechatronics
www.vmechatronics.com

The hybrid system installed at ORC is still the largest BESS project delivered by Vision Mechatronics. The hybrid system integrates both lead acid and Li-ion batteries as a single unit connected to the same bus bar. This integration of distinct BESS technologies was a challenge as well as a unique learning opportunity. A specialized software was designed and deployed by Vision Mechatronics to facilitate this integration.

We are proud to have completed the 1MWh Hybrid Energy Storage project for Om Shanti Retreat Centre. This project not only enables the centre to utilize renewable energy, reduce emissions and electricity costs significantly, but also provides them with a reliable source of power at all times. We are excited to have achieved this first-of-its-kind milestone in India and believe it demonstrates our commitment to providing innovative solutions to our customers

Dr. Rashi Gupta
Managing Director, Vision Mechatronics

About Vision Mechatronics Pvt. Ltd.

Vision Mechatronics is a leading Indian company that operates in robotics, renewable energy, and lithium-based energy storage solutions. Their mission is to provide transformative and sustainable solutions that enable customers to adopt the latest technologies and reap the rewards of technological advancements.

Leveraging cutting-edge technology Vision Mechatronics creates reliable, cost-effective, and convenient solutions that can help customers reduce emissions, improve efficiency, save money, and ensure electricity at all times. From the most advanced robotics solutions to customized energy storage systems, Vision Mechatronics is determined to help its customers stay ahead of the curve.

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