CHAPTER 61

Smart Energy Management for Sustainable Operations at a Warehouse – A Case Study

Rahul Aggarwal and Bhagwanti Nanwani***

ABSTRACT

Large warehouses/ delivery centres have thus been setup for consolidation of goods across categories. These warehouses operate 24x7x365 and consume lots of energy primarily for illumination (lighting) and environment management Heating Ventilation and Air Conditioning (VAC) systems. These warehouses have vast roof for installing solar power however with innovation, a major delivery organization is aggressively implementing solutions to reduce their carbon footprint. This paper covers how a retailer, by using innovative automation solutions and using the data generated by various sensors/ equipment, not only reduced their usage of traditional grid energy (primarily coal based) by enhanced usage of solar power, harvest the energy in storage batteries while reducing the overall energy cost. This resulted in reduced cost of energy/ operation expense, improved profitability, reduced carbon footprint, better workplace for their employees thus impacting all aspects of ESG. The success has motivated them to implement similar solutions across their enterprise.

Keywords: Smart energy; Energy transition; IIoT; Sustainability; ESG.

1.0 Executive Summary

Large warehouses/ delivery centres are being setup for consolidation of fast-moving consumer goods across categories. These warehouses operate 24x7x365 and consume lots of energy primarily for illumination (lighting) and environment management via Heating Ventilation and Air Conditioning (HVAC) systems. Large corporates have sustainability as one of their focuses and energy transition is a way for sustainable operations. The delivery centres have a key role in this as they can help reduce their fossil fuel energy consumption as well as being located closer (reduced transportation) to consumers.

**Corresponding author; Research Scholar, Department of Management, SVIMS for Girls, Pune, Maharashtra, India (E-mail: rahul.aggarwal1969@gmail.com)*
***Director, Department of Management, SVIMS for Girls, Pune, Maharashtra, India (E-mail: director@svims-pune.edu.in)*

DOI: 10.17492/JPI/ICISI2025/251261 *ISBN: 978-93-49790-69-8*

The study is intended to share, how a major retailer, by using innovative automation solutions based on smart technologies and the data generated by various sensors/ equipment, was able to reduce their carbon footprint. They have reduced their usage of grid energy (primarily coal based) by enhanced usage of solar power. Excess solar power is used to charge batteries during daytime, and this energy was then discharged during non-solar hours. This resulted in reduced cost of energy/ operation expense, improved profitability, reduced carbon footprint, better workplace for their employees thus impacting all aspects of ESG. The success has motivated them to implement similar solutions across their enterprise.

2.0 Context and Background

The retailer is one of the largest e-commerce store for fashion and lifestyle products in India. It aims to offer its customers a hassle free and enjoyable shopping experience online and offers almost 500 leading Indian and international brands and products with choice of apparel, accessories, cosmetics and footwear. Their value proposition "revolves around giving consumers the power and ease of purchasing fashion and lifestyle products online".

With policies like 100% authentic products, cash on delivery, 24x7 dedicated customer connect team and customer friendly return policy, they are one of the most preferred shopping destination in the country. We are experiencing extreme weather events like cloudburst, forest fire, extreme rainfall, high temperatures, floods, extreme cold etc across all the regions of the world. Most of these are attributed to various actions taken by human activity.

Industry is a key stakeholder for sustainable development. With increasing awareness about environmental protection in the society, enterprises have initiated alignment of their business activities to be environmentally friendly. Infact most companies have made Sustainability a key strategic initiative. The intent is to reduce material risks while creating new business opportunities due to changes in natural environmental. This also helps minimize business losses due to non-compliance of government rules and regulations, though in very nascent stage, while creating/ maintaining positive impact amongst customers and suppliers alike.

Russo et al. in their seminal article posited that economic performance and environmental performance have positive correlation. Further research has established that "it pays to be green" and that this relationship strengthens with industry growth, making sustainability one of the top agenda item for most global Chief Executive Officers (CEO).

DOI: 10.17492/JPI/ICISI2025/251261 *ISBN: 978-93-49790-69-8*

Environmental, social and governance (ESG) factors are a set of criteria used to evaluate how a company operates in terms of its environmental, social, and governance risk and opportunities. These factors can have a material impact on the financial performance and long-term sustainability of the company. It has been observed that adopting ESG practices lead to operational efficiency and cost reduction by transition to renewable energy, resource efficient, energy efficiency, supply chain optimization, attracting and retaining talent, compliance management and many more. ESG practices helps companies build resilience, ensuring they are not only financially viable, but also responsible and adaptable.

As one of the largest retailer in India, the company intends to have sustainable operations. They are looking at various avenues to be net zero by 2030. Few of the solutions retailer was looking for are those that will help carbon emissions, waste management, water usage, and resource conservation from environment perspective. If the solution entails commercial benefits that will be preferred.

3.0 Case Evaluation

Technology has a key role in energy efficiency and some of them are

1. *Energy-efficient appliances*: usage of star rated equipment that reduce the energy consumption without impact their performance/ output
2. *Building automation*: using automation for climate control, lighting, access management
3. *Advanced Materials & Insulation* especially in building so that there is minimal heat loss helping in reducing overall energy requirement
4. *Internet of Things and Sensors*: Usage of sensors to sense and transmit field parameters over the networks for monitors, control & analytics
5. *Data Analytics and machine learning*: Usage of data from sensors/ IoT to identify patterns, build models, improve/ optimize performance; convert data to information to knowledge and them wisdom
6. *Renewable energy technologies*: use solar, wind, hydro, bio-mass, geo-thermal and other non-fossil fuels for energy generation and reduce carbon foot-print and environmental impact
7. *Energy efficient Transportation*: usage of electric/ hydrogen fuel cell based vehicles, public transport to reduce individual carbon footprint
8. *Energy Storage solutions*: With the higher ingress of intermittent renewable energy sources, energy storage solutions will help harness this energy when in excess and discharge it when there is power deficiency. Various storage options like Pumped hydro energy storage, flywheels, electro-chemical (Lithium-ion, Redox flow etc) technologies,

DOI: 10.17492/JPI/ICISI2025/251261 *ISBN: 978-93-49790-69-8*

thermal energy storage, molten salt thermal energy storage, hydrogen storage & fuel cells etc, are currently available in the market with different adoption rates. Besides these some other storage technologies are emerging like the solid state batteries, super capacitors etc.

9. *Energy Management System (EMS)* are used to increase the power resiliency while ensuring energy optimisation, load management, efficient use of various generation resources for cost, availability and reduced carbon emissions.

Energy was identified as higher priority focus area. The company started the initiative by identifying all the electrical loads followed by energy audit, deployed energy efficient equipment/ approaches to reduce overall energy consumption. As a power backup, they had large Diesel Generating sets which when operational were a costly power source while also creating noise and air pollution.

These warehouses have large roofs and install large capacity of solar panels however there are state specific regulations regarding the size of the solar installation. There are also limits, vary from state to state, regarding amount of power, if at all it can be, being fed back to the grid in case of excess generation (power available after internal consumption), the compensation and the rates. Additionally, there is a Time of the Day (ToD) tariff that is differential tariff that the industrial/ commercial entities have to pay for power consumed from the discom. The tariff is higher during non-solar hours.

To further optimize on their energy usage, they tied up with an Independent Power Producer (IPP) with an Energy-as-a-Service (EaaS). In this model, client and the IPP gets into a long-term Power Purchase Agreement (PPA) with term varying from ten years to twenty-five years.

All the Capital Expenditure for various equipment is made by the IPP. Customer consumes power from the power plant based on the usage with minimum committed cutoff at a fixed/ escalation tariff for the entire duration of the project with an option to buy the asset after a minimum lock-in period at a pre-decided value. This helped them reduce their carbon footprint besides reducing their overall energy cost.

4.0 Proposed Solution

Even though the overall goals were clear, it was very important to ensure that –

1. The solution shall be reliable & robust while being user friendly
2. It shall offer resilience in energy supply while maximising usage of renewal energy
3. There shall be overall reduction in the carbon footprint
4. There shall be overall reduction in the energy cost

Some of the aspects which require innovative approach were:

1. Sizing of Solar Photo Voltaic (SPV) plant

DOI: 10.17492/JPI/ICISI2025/251261 *ISBN: 978-93-49790-69-8*

2. Sizing & deployment of battery energy storage system
3. Selection of Industrial ruggedised hardware with high availability and reliability
4. Selection of the smart technologies – Networks, Industrial Internet of Things (IIoT), Data, Cloud, Analytics

Renewable Energy from solar has certain advantages like no raw material cost, minimal maintenance cost, no carbon emissions etc however there are certain limitations like intermittency – sunlight is available for only 10-12 hours and the magnitude varies in case of cloud cover, seasonality – solar irradiation is low in monsoon and in winter months. It was decided that the solar energy shall serve the load and excess generation shall be stored for usage later - as and when required. Energy storage is important as it ensures a steady supply of energy and enables load management.

For large/ utility scale projects it enhances the grid stability and reliability. Storage helps in supporting the seasonal nature of renewable energy. Energy storage are becoming prevalent for microgrid applications where the communities and far-flung areas where it is not practically or commercially not viable to provide transmission lines from the grid, power can be made available to such communities/ areas for their social upliftment.

To harness available renewable energy, Battery Energy Storage System (BESS) with lithium-ion (Li-ion) batteries were proposed. Li-ion BESS uses the principle of electro-chemical energy conversion, storing energy through the movement of lithium ions between cathode and anode during charging and discharging.

BESS comprises mainly of battery & battery management system, Power Conversion System (PCS) which converts alternating current (AC) to direct current (DC) power and vice versa and an energy management system (EMS). There are some other electrical switchgears like the transformers for stepping up/ down of voltage, protection and isolation equipment of various power circuits, AC and DC distribution boards.

- *Battery System:* This is the heart of the BESS System and comprises of Cells of certain ratings connected in series and parallel combination to support and certain bank voltage and power. Lithium-ion technology was selected as it offered high energy density, more cycle life and efficiency. Batteries are installed in containers for safety as well for temperature and humidity control using HVAC/chillers for safe operation and performance.
- *Power Conversion System (PCS):* PCS is responsible for converting alternating current (AC) power to direct current (DC) power while charging the battery and vice versa during discharge.
- *Energy Management System (EMS):* EMS controls and monitors BESS operation. It has primary and secondary levels of control.

DOI: 10.17492/JPI/ICISI2025/251261 *ISBN: 978-93-49790-69-8*

It is designed to meet all the requirements of connectivity, protocols, interfacing with different sub-systems ie PCS, energy meters at various points, electrical switchgear, transformer, BMS, Diesel Generating sets etc. EMS also manages the safety, health, monitoring and control of various sub-systems/ equipment and ensures that all the functional requirements/ use cases from BESS, as planned, are executed as expected.

4.1 Functions of BESS in the project

BESS serves various functions that enhance energy stability and flexibility, including:

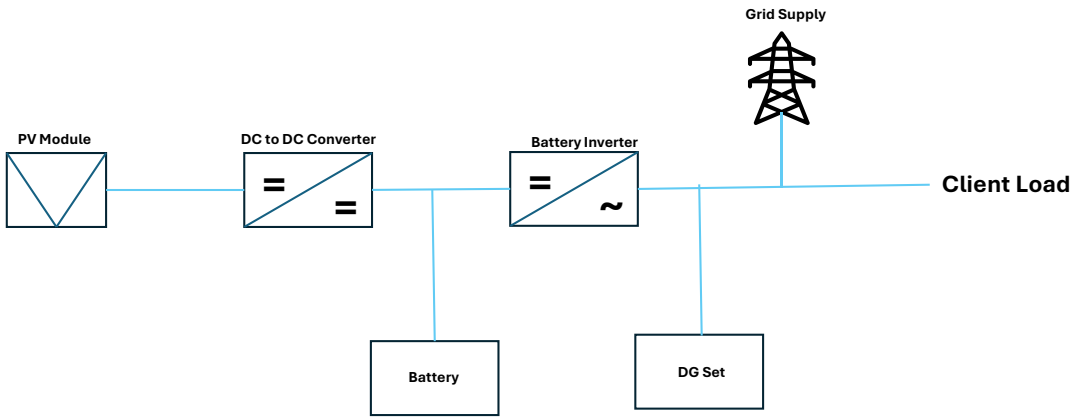
- *Enhance usage of solar power:* All the power generated from Solar Photo-voltaic is to be fully utilized. There shall be no curtailment of solar
- *Energy recapture:* Excess solar power shall be harnessed to charge the battery
- *Energy shifting:* Excess solar energy was used to charge the battery during solar hours however the battery was discharged when demanded. or for DG supply mitigation
- *Support during higher tariff period:* discharge energy stored in Battery during the evening time/ whenever grid power was expensive
- *Renewable Smoothing:* Reduces the variability in renewable energy output to ensure a more stable supply.
- Reduce Diesel Generator (DG) set usage – battery shall be commanded to discharge while DGs are in operation due to absence of grid supply.
- Eliminate power feeding into the grid – as per state regulation, there was no net metering thus the solar power had to be consumed within the generation premises. As per applicable regulations of certain Indian states, consumers are penalised for feeding power into the grid beyond the sanctioned capacity/ no net-metering case.
- *Power Management:* Controls the battery discharge so as to maintain balance of energy considering cost, availability, renewable ingestion and other business cases.

4.2 Sizing of sub systems

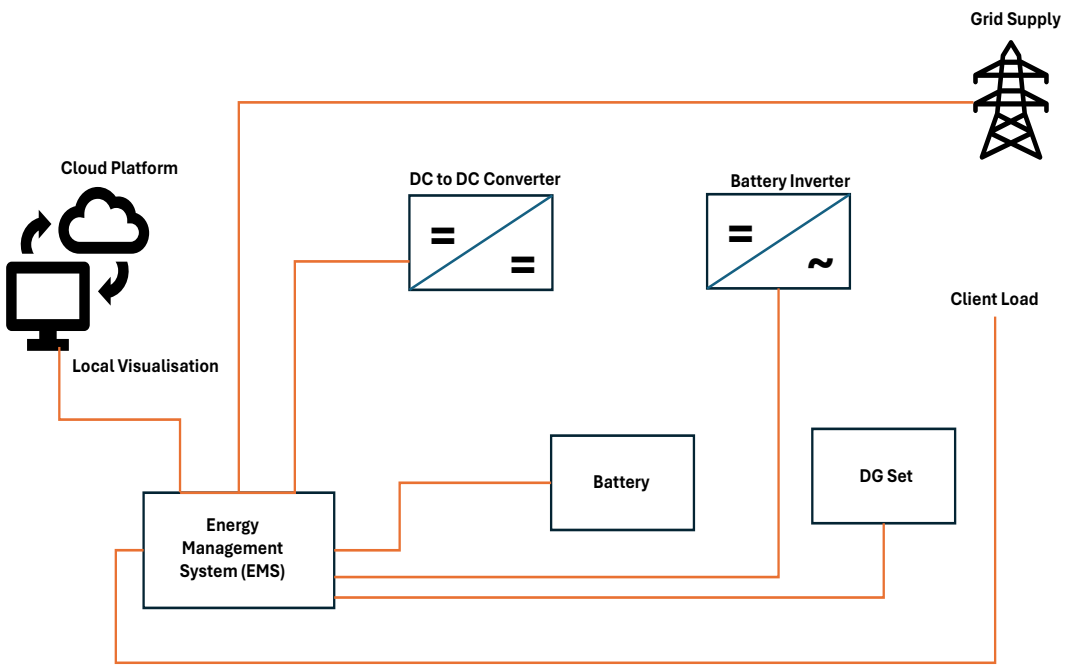
The photo voltaic module rating and quantity were selected based on the available roof space as well as load profile of the retailer. Solar plant of 600KWp/ 250KW AC generation capacity was installed due to shortage of space. 468KWh of Lithium-ion batteries were selected so that they were able to supply almost 230KW of load for approximately two hours. PCS chosen was of adequate capacity so that it is almost fully loaded during solar hours resulting in less losses in the system.

The typical power circuit is as below.

DOI: 10.17492/JPI/ICISI2025/251261 *ISBN: 978-93-49790-69-8*



System architecture was so designed that it provides fast communication with controls while meeting most of the statutory requirements of discom, power quality, data storage, visualisation control. There is local visualisation for the operations personnel to view the status locally. Critical parameters of the BESS system with faults/ alarms is being sent to the cloud platform so that they can be viewed by any person with credentials and authorisation to view the data and the system performance. Based on their roles users could view data and also make their role specific dashboards. The control & monitoring architecture is as below.



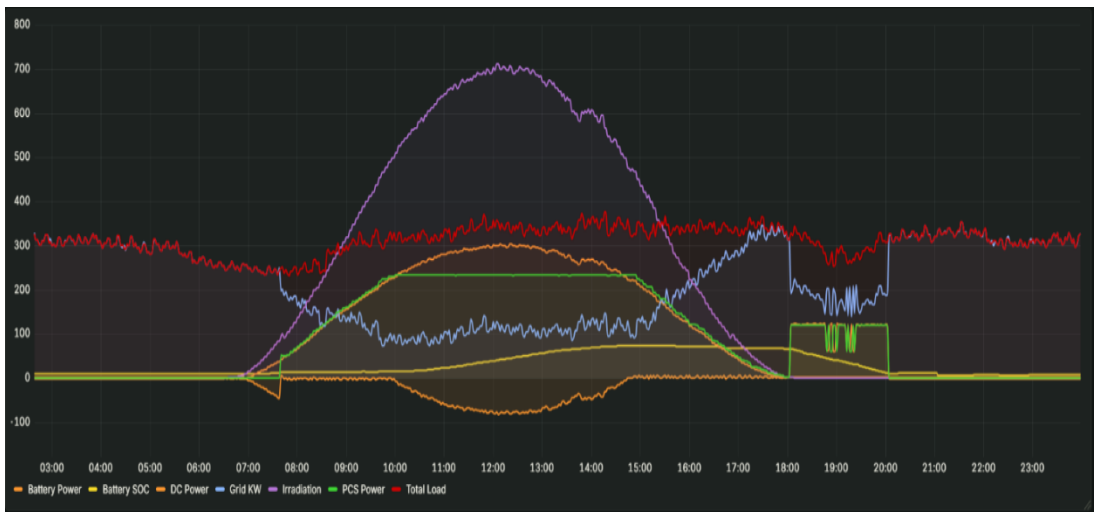
DOI: 10.17492/JPI/ICISI2025/251261 *ISBN: 978-93-49790-69-8*

5.0 Conclusion

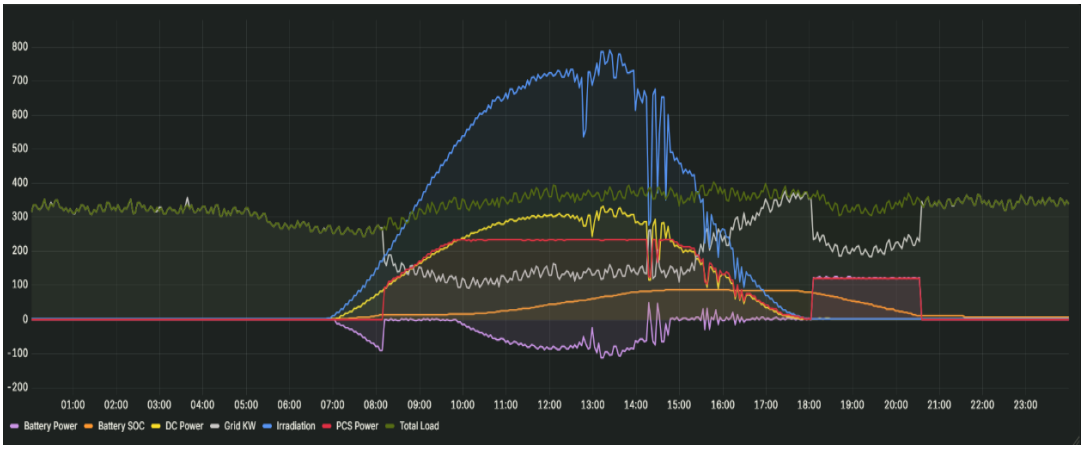
The complete system was designed, engineered, manufactured, application development, testing, supply, installation and commissioning and Site acceptance test was completed successfully. Some of the salient features of the solution accomplished are:

1. Full utilisation of renewable energy (RE)
2. Renewal energy, whenever it is available, is fed directly to the load after conversion to reduce on the losses
3. Excess renewable energy, subject to maximum PCS capacity, is fed to the battery for charging so that it can be used later
4. With dynamic controls, it is ensured that no renewable power is fed back to the grid hence no penalty is applicable on this account from discom.
5. DG set, if they are running in absence of grid supply, are made to run at optimal capacity and balance load is served by renewable power/ battery system.
6. BESS usage is maximised during high tariff periods subject to its charging status
7. Local Human Machine Interface enables the operator to view the status and take informed decisions/ customise the settings.
8. Critical real time data regarding equipment parameters/ metering/ faults & alarms is sent to the cloud for visualisation on a dedicated cloud application for usage and analysis by various stake holders.

Below are some of the curves demonstrating the BESS operation.



DOI: 10.17492/JPI/ICISI2025/251261 *ISBN: 978-93-49790-69-8*



Post installation, these are some of the key benefits accomplished are

1. Renewable energy is approximately 30% of the energy mix
2. Diesel usage has substantially reduced
3. 20% Savings against grid tariff during peak hours.
4. Better utilization of available roof space as it is used for solar modules installation
5. No upfront Capital Expenditure (CAPEX) which they would be paying if RESCO model in off-Grid mode was not proposed

References

1. M. V. Russo and P. A. Fouts, “A resource-based perspective on corporate environmental performance and profitability,” The Academy of Management Journal, vol. 40, pp. 534–559, 06 1997.

DOI: 10.17492/JPI/ICISI2025/251261 *ISBN: 978-93-49790-69-8*