

Lessons learned from Installing a 1.1 MW Rooftop Photovoltaic system and strategies for improvement



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1. ABSTRACT

This paper details the technical aspects of a 1.1 MW photovoltaic (PV) solar installation, covering key components such as inverter selection, PV panel specifications, and the municipal approval process. It also explores the construction challenges encountered and the solutions implemented. Lessons learned through collaboration with clients are shared, along with strategies to enhance future installations, including the integration of battery storage and the synchronization of diesel generators to improve overall system efficiency. The discussion further addresses the next steps for system expansion, examining the potential of Power Purchase Agreements (PPAs), the rental option, the feasibility of feeding excess power into the municipal grid, and the role of energy wheeling in maximizing project viability.

Integrating AI into future solar installations, especially in the context of energy arbitrage, microgrids, complex energy mixes, can significantly enhance savings, system efficiency and resilience.

2. INTRODUCTION

South Africa's industrial sector is grappling with escalating electricity costs and frequent grid instability. These challenges are prompting manufacturers to explore on-site renewable energy generation as a viable solution. This focussed case study is on ACTOM, a leading electrical equipment manufacturer, which identified one of its largest power-consuming division, MV Switchgear, as the initial target for deploying photovoltaic (PV) systems. The primary objective of this deployment was to offset up to half of the division's peak load, thereby reducing dependency on energy input costs and demonstrating the feasibility of expanding such solutions to other facilities.

Investing in energy arbitrage and photovoltaic solutions, particularly those integrated with battery storage, offers several compelling advantages. Firstly, it provides significant cost savings by reducing reliance on expensive and above inflation increasing grid electricity and enabling the use of stored energy during peak demand periods. Secondly, it generates revenue through mechanisms such as feed-in tariffs or selling excess power back to the grid. Thirdly, it enhances energy independence, allowing manufacturers to maintain operations even during grid outages by using the PV system in conjunction with other onsite generation sources and battery storage systems planned for the future. Lastly, it supports sustainability goals by reducing the carbon footprint and aligning with environmental, social, and governance (ESG) principles.

The focus on these benefits makes the investment in renewable energy solutions not only economically attractive but also environmentally responsible. By prioritizing sustainability and leveraging advanced energy technologies, manufacturers can achieve long-term operational resilience and contribute to a greener future.

3. SITE OVERVIEW

The Knights site in Germiston comprises multiple manufacturing divisions served by an 11kV ring network. MV Switchgear, producing medium-voltage switchgear, represents the highest single energy consumer on site. Its expansive roof area provided an ideal mounting surface for the PV array, minimizing additional land use and streamlining electrical interconnection.



The site is based at Knights in Boksburg and a Grid tied solar PV 1.1MW system was installed on the roof.

4. SYSTEM DESCRIPTION

PV Array and Inverter Stations

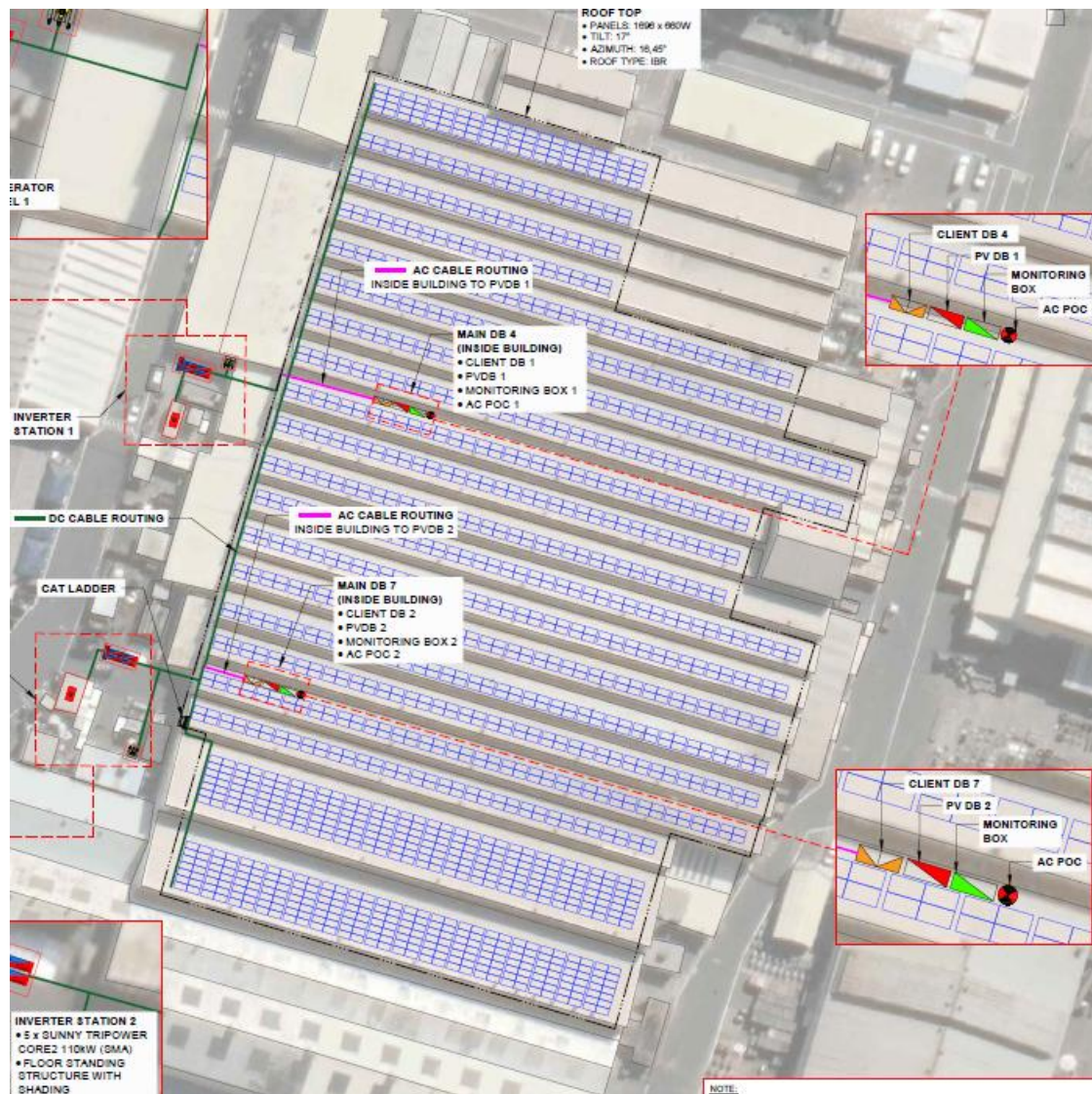
The system is integrated with the grid and will automatically disconnect and isolate itself in the event of a grid outage. It comprises two independent units, each rated at 550 kW (AC), supplying electricity to the two largest distinct low voltage (LV) network “transformer locations” within the factory. The maximum output from the PV system is immediately consumed at each location according to the load profile at each transformer location. If the power generated by the PV inverter stations exceeds the local factory demand at each of the two LV networks, any surplus energy is then consumed at other ACTOM locations via the 11 kV on the same Knights premises.

The system includes two 550 kW inverter installations; connected to the two largest transformers supplying different parts of MV Switchgear’s factory. Each inverter station contains five 110 kW inverters, an inverter collector box (LV switchboard), and a data management system.

Solar panels are installed on the roofs and supply DC power to inverters, which then convert(invert) it to AC for use at the site.

Electrical Integration

Each inverter station connects to the low-voltage distribution board of its associated transformer. Excess generation is routed through the 11 kV ring network to support other transformer locations and divisions. This approach allows for effective maximum use of PV-generated energy within the system.



5. EQUIPMENT SELECTION

Inverter selection: The site uses ten SMA SUNNY TRIPOWER CORE2 110 kW inverters, selected for their durability and efficiency, with a combined maximum DC peak of 1,119,360 watts.



Solar panel selection: The selected panel was the Trina Solar TSM-DE21 **660W**, a monocrystalline solar PV module with a maximum efficiency of 21.6%. This high-power module was used due to limited roof space and the requirement to maximize output power per square meter. Bifacial panels were not used because of the dusty environment and challenges associated with cleaning the underside of these panels. A total of **1,696** Trina Solar panels were installed.

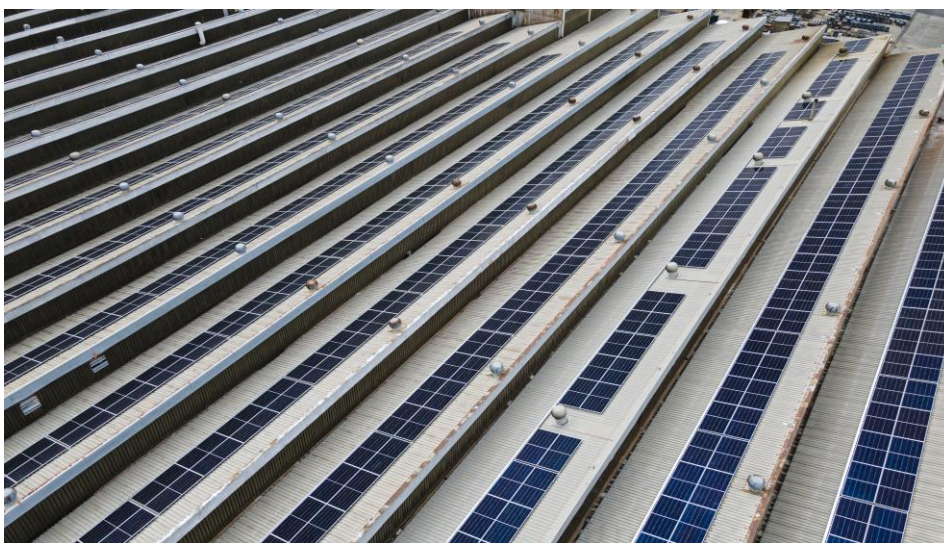


Municipal approval – The Embedded Generation application was submitted to the Ekurhuleni Council and permission granted. Municipal requirements were included in the design. Currently, all energy produced is used on-site and not fed back into the grid.

6. INSTALLATION PHASE CHALLENGES AND SOLUTIONS

Comprehensive planning and structural evaluations were undertaken in early 2023. During implementation, the original specification for 380W PV panels was upgraded to 660W units. This modification introduced new complexities, as the larger panels necessitated central reinforcement of the roof structure. The resulting increase in weight required re-certification by a structural engineer, leading to project delays while roof strengthening was performed without interrupting factory operations. Additionally, heightened safety measures were implemented due to the need to work at heights above operational areas, including over liquid baths used in metal fabrication.

Installation of the PV modules and inverter stations was completed by June 2023. System commissioning concluded in the same month, with the facility reaching full operational status in July 2023.



7. SYSTEM PERFORMANCE & OPERATIONAL LESSONS

Generation Capacity

The 1.1 MW peak capacity aligns with MV Switchgear's peak load and constitutes roughly 25 to 35 percent of the Knights site's combined peak demand during the winter.

Impact on Grid Consumption and Costs

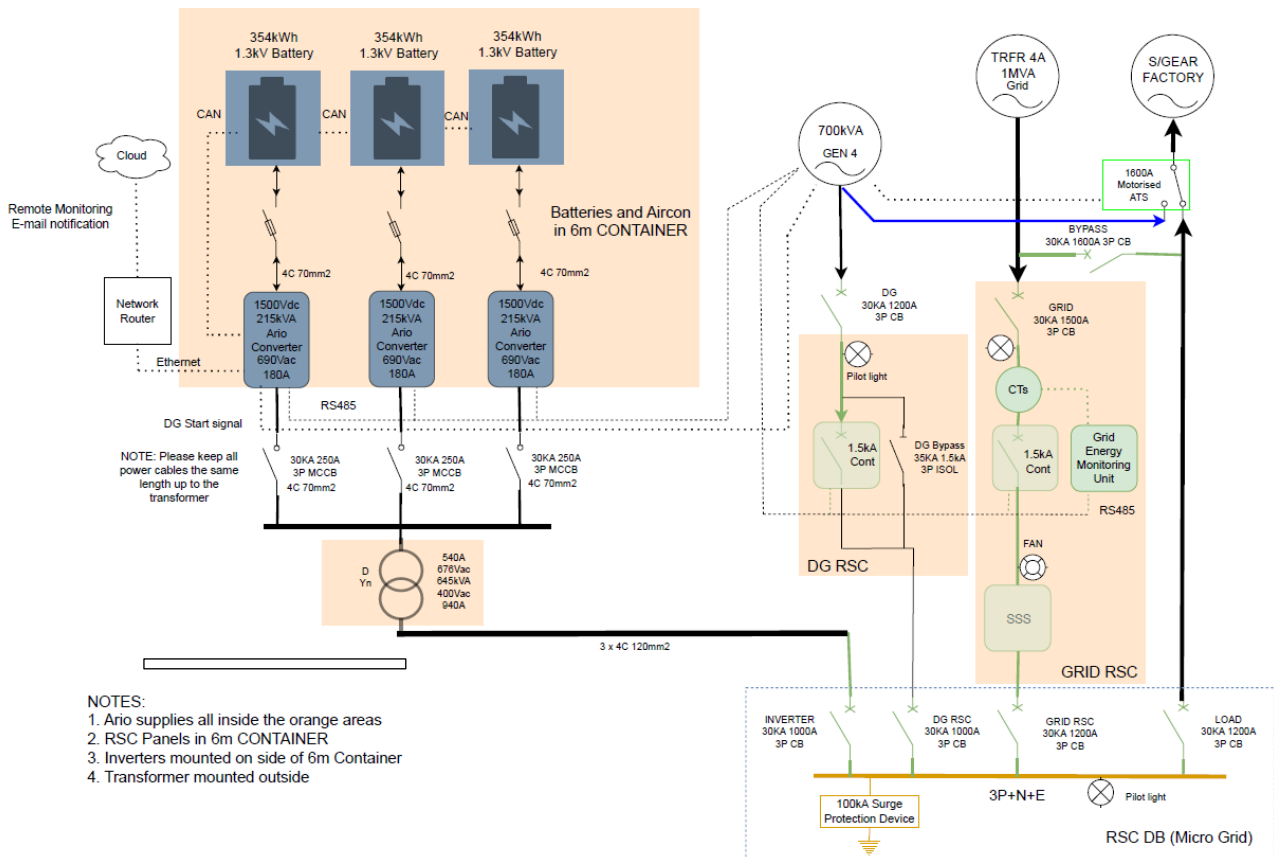
Grid-drawn energy was projected to decrease between 25 to 35 percent. MV Switchgear's electricity expenses would be reduced by as much as 65 percent, depending on weather conditions, operational schedules and time of use. Actual savings will be updated as more system performance data becomes available across different seasons. The decision to use a grid-tied inverter system restricts operation during loadshedding. Future expansion plans, including measures to address this limitation, will be provided in the proposal.

8. FUTURE EXPANSION PROPOSAL

Since its 2023 installation, advances in panel sizes, lower battery costs, and shifts in energy priorities have made energy arbitrage and peak clipping more valuable at the Knights site, especially with load shedding suspended. By adding Battery Energy Storage Systems (BESS) to shift grid use from peak to off-peak periods, Knights can reduce its Levelized Cost of Electricity (LCoE). BESS is expected to deliver an IRR of about 25% through these savings. Plans include two identical Low Voltage installations beside each diesel generator, one per building, each with a 645 kVA inverter and 1.062 MWh battery. The system features Remote Synchronisation Contactors for both the generators and grid, plus an Energy Management and Monitoring System (EMS) for integration.

During load shedding, the BESS reduces reliance on diesel generators, which operate at costs above R7.00/kWh. Grid failures are detected and isolated in less than 5 milliseconds, allowing the battery inverter to supply power with full Uninterrupted Power Supply (UPS) functionality.

The EMS manages the start-up of the diesel generator to recharge the batteries and synchronises it with the grid, ensuring seamless UPS operation during transitions between grid-tied, off-grid, and back to grid-tied modes.



With loadshedding no longer, a current concern but not to be disregarded, the focus is now on energy arbitrage and peak clipping. Energy arbitrage involves buying (or generating/storing) electricity when it's cheap and using or selling it when it's expensive. AI can enable predictive arbitrage by using forecasts of Time-of-Use (TOU) tariffs and demand to schedule battery discharge or generator usage optimally.

Energy arbitrage involves charging the battery with cheap energy during off-peak rates and discharging it during peak times. This strategy, combined with peak clipping, can significantly reduce the Levelized Cost of Electricity (LCoE) and provide a substantial internal rate of return (IRR).

Battery Energy Storage Systems (BESS) can lower the Levelized Cost of Electricity (LCoE) by shifting grid demand from peak to off-peak periods through charging during off-peak and discharging during peak times. Peak clipping involves releasing battery power before reaching the maximum demand threshold. Whenever possible, batteries are charged with solar energy first, followed by off-peak grid charging, as prioritized in system settings.

Energy Arbitrage Only

The business case for **energy arbitrage only** is illustrated in the table below:

The inputs are based on the assumptions that the 2024 tariffs have been increased by 12.7% for 2025.

Electricity Tariffs			
	Summer	Winter	Hrs
Peak	R2.79	R7.48	5hrs
Std	R1.83	R2.63	11hrs
Off Peak	R1.44	R1.58	
Demand Charge		R123.0	

BUSINESS CASE RESULTS PER LOAD SHEDDING STAGE								
Load Shedding Stage	Monthly Diesel LS Net Cost Saving	Monthly Energy Arbitrage Benefit	Monthly Peak Clipping Benefit	Payback as % of battery life	Battery Lifetime (years)	Net monthly cash flow	Battery Payback in years	System IRR over battery life
0	R0	R155 196	R0	50.0%	10.00	R155 196	5.00	17.5%
1	R158 067	R144 284	R0	27.5%	10.00	R302 350	2.75	38.0%
2	R316 133	R133 371	R0	22.6%	8.11	R449 504	1.83	54.8%
3	R450 490	R122 641	R0	22.1%	6.78	R573 131	1.50	68.6%
4	R553 233	R112 153	R0	20.6%	6.06	R665 386	1.25	78.9%
5	R652 024	R101 696	R0	19.7%	5.50	R753 720	1.08	88.8%
6	R663 879	R91 905	R0	19.5%	5.55	R755 784	1.08	89.1%
7	R674 944	R82 120	R0	19.3%	5.60	R757 065	1.08	89.2%
8	R695 493	R72 263	R0	19.4%	5.59	R767 756	1.08	90.5%

Energy arbitrage only yields a 17.5% IRR, increasing to 54.8% during constant stage 2 load shedding because of higher diesel costs. Diesel savings are based on reduced diesel use minus battery charging costs, but frequent load shedding shortens battery life. If stage 2 occurs 15% of the time, the IRR is 24%.

Energy Arbitrage & Peak Clipping

The business case for **energy arbitrage and peak Clipping** is illustrated in the table below:

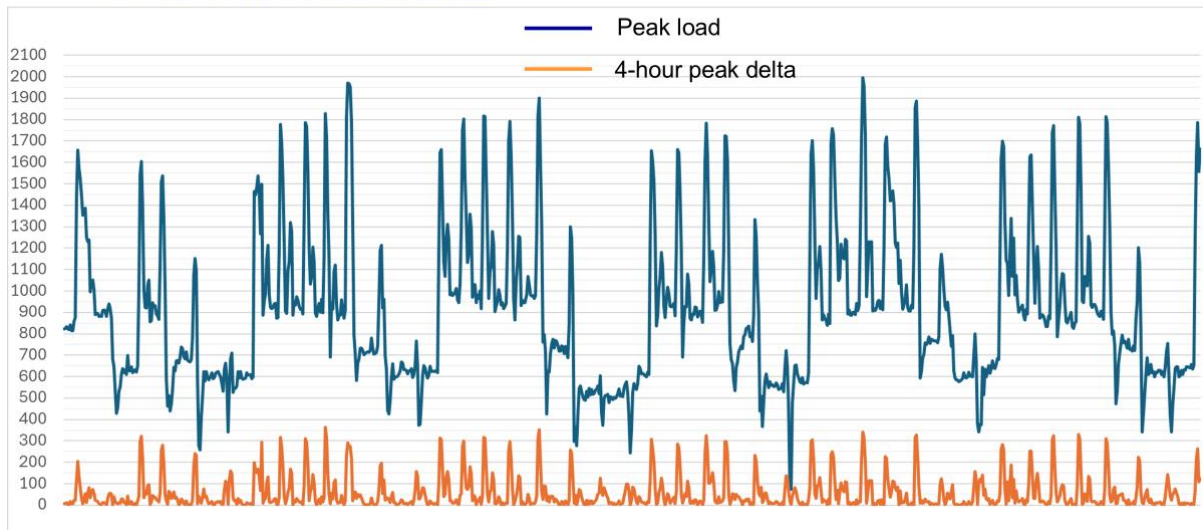
Business Case: Energy Arbitrage plus Peak Clipping

BUSINESS CASE RESULTS PER LOAD SHEDDING STAGE								
Load Shedding Stage	Monthly Diesel LS Net Cost Saving	Monthly Energy Arbitrage Benefit	Monthly Peak Clipping Benefit	Payback as % of battery life	Battery Lifetime (years)	Net monthly cash flow	Battery Payback in years	System IRR over battery life
0	R0	R155 196	R43 040	40.0%	10.00	R198 235	4.00	24.8%
1	R158 067	R144 284	R40 013	24.2%	10.00	R342 363	2.42	43.2%
2	R316 133	R133 371	R36 987	21.6%	8.11	R486 492	1.75	59.4%
3	R450 490	R122 641	R34 011	20.9%	6.78	R607 142	1.42	72.7%
4	R553 233	R112 153	R31 103	19.3%	6.06	R696 489	1.17	82.7%
5	R652 024	R101 696	R28 203	19.7%	5.50	R781 923	1.08	92.1%
6	R663 879	R91 905	R25 487	19.5%	5.55	R781 272	1.08	92.1%
7	R674 944	R82 120	R22 774	19.3%	5.60	R779 838	1.08	91.9%
8	R695 493	R72 263	R20 040	19.4%	5.59	R787 796	1.08	92.9%

- The energy arbitrage benefit combined with peak clipping, with no load shedding, returns an IRR of 24.8% - a 7.5% increase of the IRR to the energy arbitrage case only
- At a permanent load shedding stage 2, the IRR increases to 59.4%
- A more realistic scenario is a 15% occurrence of stage 2, for which the IRR is 30.4%

Peak Clipping Measurements

- The blue line graph shows the peak demand plotted over a 4-month period
- The orange line graph shows the maximum peak loads minus the 4-hour moving average
- From the graph below, a conservative estimate is that 350kVA can easily be clipped without draining the battery capacity to the extent that it impacts on energy arbitrage or availability for load shedding



9. STRATEGIES FOR FUTURE INSTALLATIONS

The strategies for upgrading the Knights site as well as for future installations have evolved including the integration of battery storage and the synchronization of diesel generators to improve overall system efficiency.

Integrating AI into future solar installations, especially in using predictive analytics for load forecasting, complex energy mixes, automated controls for optimizing battery usage would significantly enhance savings, system efficiency and resilience by charging batteries during off peak, clipping the peaks as required and possibly even avoiding usage during peak tariff periods.

The potential of Power Purchase Agreements (PPAs), rental options, the feasibility of feeding excess power into the municipal grid, and the role of energy wheeling in maximizing project viability are all currently being explored. Preliminary studies have been conducted, and a mini microgrid is a possibility at the Knights site.

10. OPPORTUNITIES FOR SYSTEM IMPROVEMENT

Using AI for Optimized Solar and Microgrid Installations, one can do the following:

1. Energy Forecasting & Load Prediction:

AI models (especially machine learning and deep learning) can accurately forecast:

- Solar production using real-time and historical weather data (e.g., cloud cover, irradiance, temperature).
- Energy demand patterns across different timeframes, based on historical usage, time of day, seasonality, and behavioral trends.

These forecasts enable:

- Better battery charging/discharging decisions.
- Accurate load shifting to minimize grid usage during peak tariff times.

2. Dynamic Energy Arbitrage

Energy arbitrage involves buying (or generating/storing) electricity when it's cheap and using/selling it when it's expensive. AI enables:

- Predictive arbitrage: Using forecasts of Time-of-Use (TOU) tariffs and demand to schedule battery discharge or generator usage optimally.

CONCLUSION

The 1.1 MW rooftop PV system at ACTOM's MV Switchgear facility at Knights highlights the potential for large-scale industrial solar in South Africa, with early results showing significant energy savings, cost reduction and attractive capital investment payback periods. Ongoing monitoring will guide operational improvements. Adding generator integration, batteries, energy arbitrage, and peak shaving could further cut costs, boost efficiency, enhance grid stability, support the environment, and improve energy independence.

Benefits of battery over solar only:

Benefit	Solar Only	Solar + Battery
Lower electricity bills	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Avoid peak tariffs	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Backup during outages	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Sell stored energy	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Hedge against price hikes	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Maximize self-consumption	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
ESG / green branding	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

REFERENCES

ACTOM installs 1 MW rooftop solar system at Knights factory, Green Building Africa, September 19, 2023.

Solar generation system at ACTOM's Knights site now operational at MV Switchgear, WhatsWatt ACTOM.

ACTOM switches to solar generation at its Knights site, Crown Energy Management.

ACKNOWLEDGEMENT

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