



## Enhancing LV Voltage Stability and DER Hosting Capacity with EcoJoule Energy's LV STATCOM Technology

*This white paper was created utilising multiple real world usage trials of EcoJoule Energy's low voltage EcoVAR STATCOM. Data reproduced with the authority of Ausgrid.*



# Executive Summary

Across Australia, rapid rooftop solar uptake is driving increasingly volatile voltage conditions on low-voltage (LV) networks. Utilities now face the dual challenge of managing growing two-way power flows while preserving power quality for all customers. Traditional network upgrades often involve high capital expenditure, long lead times, and community disruption.

Ausgrid's multi-year field trials, conducted from 2020 onward, demonstrate that LV static synchronous compensators (STATCOMs) provide a cost-effective and technically robust alternative for voltage regulation on LV networks.

With more than 18 first-generation 30 kVAR EcoJoule Energy STATCOMs deployed, Ausgrid has validated that smart, pole-mounted power electronics can significantly stabilise voltages, reduce overvoltage risk, and expand solar PV hosting capacity.

This white paper outlines the challenge, the trial results, the underlying engineering principles, and the emerging business case for future-ready LV grids.



Ausgrid has partnered with EcoJoule Energy to install cutting-edge technology to improve power supply to the community of Nords Wharf on the shore of Lake Macquarie.

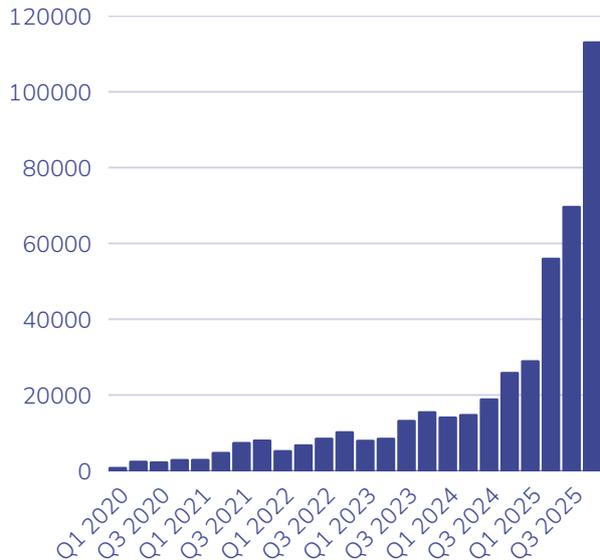


# The Rooftop Solar Revolution

In Australia, rooftop solar uptake continues to lead our national renewables rollout. Rooftop solar PV now accounts for 28.3 GW of installed capacity, eclipsing the country's entire fleet of coal-fired generators (22.5 GW). In the second half of 2025, rooftop solar accounted for 14.2% of electricity generated in Australia, nearly doubling its share since 2020, when it accounted for 7.2%.

- Nearly 140,000 rooftop PV units were installed in the second half of 2025.
- Total installations in 2025 reached 254,664, representing over 2.6 GW of newly installed grid capacity.
- There are now 4.3 million households with rooftop PV, amounting to 28.3 GW worth of installed capacity.
- There were a record breaking 183,245 battery units sold in the second half of 2025 after the introduction of the Federal Government's Cheaper Home Batteries scheme.
- Based on recent performance, rooftop PV is expected to surpass the 2029/30 required total capacity by 1 GW.
- There are currently 6419 approved rooftop PV, inverter and storage products across Australia.

Quarterly battery sales, 2020 to 2025



SOURCE: <https://cleanenergycouncil.org.au/news-resources/rooftop-solar-and-storage-report-july-to-dec-2025>



# The Growing Voltage Challenge on LV Networks

The surge of rooftop solar has created a myriad of operational challenges for DNSPs and their customers:

- LV voltage swing increases with load variability, and is further worsened by load unbalance.
- Daytime solar export raises local voltage, often exceeding statutory limits.
- Evening peak loads contribute to voltage drops on long or lightly meshed distributors.
- Traditional methods (e.g., reconductoring, transformer upgrades) are costly and difficult to stage across large networks.

The result is a growing mismatch between the performance of the existing LV grid and the needs of a solar-centred, electrifying society.



## Consumer Impacts

Unbalanced power supply affects homes and businesses directly:

- Increased voltage fluctuations – Lights flickering, sensitive electronics resetting, and reduced power quality.
- Inhibited rooftop solar export – Solar systems may be curtailed or shut down, preventing customers from making the most of their investment.
- EV chargers failing to operate – As EV adoption grows, many chargers simply won't function under unstable voltage conditions.
- Risk of appliance damage – Unbalanced voltages can shorten the lifespan of household appliances.
- Poor performance of three-phase equipment – Machinery, pumps, and HVAC systems may run inefficiently or fail altogether.



## Utility Impacts

Phase imbalance doesn't just affect consumers—it places significant strain on the network:

- Overheating transformers – Reducing efficiency and accelerating asset degradation.
- Excessive neutral currents – Increasing losses and reducing overall network stability.
- Fuse failures – Leading to more outages and higher maintenance costs.
- Rising customer complaints – As households experience disruption to solar, EV charging, and appliance reliability.

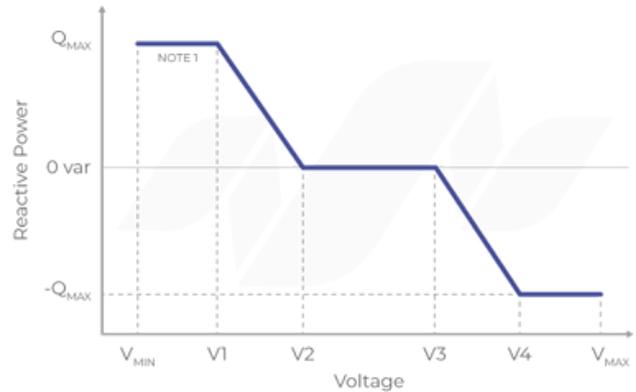


# STATCOMs as a Voltage Regulation Tool

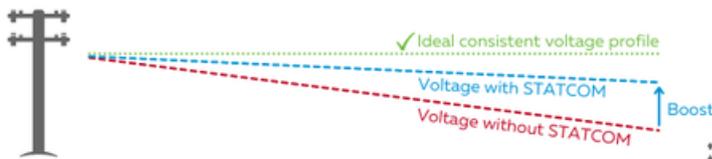
A static synchronous compensator (STATCOM) is a power-electronic device capable of supplying leading or lagging reactive current to regulate voltage at its connection point.

Recent advances in compact power electronics have brought STATCOM technology into the distribution domain. Modern LV STATCOMs in the 5–40 kVAR range can:

- Inject capacitive VARs to correct low voltage
- Absorb VARs to mitigate overvoltage
- Respond rapidly and continuously (24/7)
- Operate independently of solar irradiance
- Provide phase-by-phase voltage support in unbalanced networks



## STATCOM can be used to correct a voltage drop



### STATCOM DEVICE ADDED

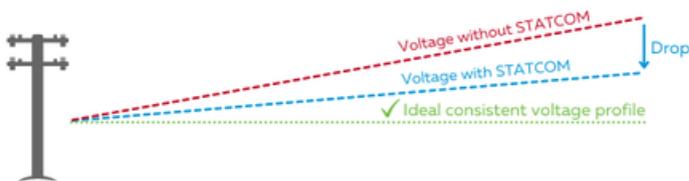
A STATCOM device regulates low network voltages allowing increased capacity and maintaining the voltage to the required standards.



### NO STATCOM

Without a STATCOM device, the voltage may fluctuate below the required standards which may cause customer equipment to malfunction and require additional network investment.

## STATCOM can be used to correct voltage overload



### STATCOM DEVICE ADDED

A STATCOM device regulates high LV network voltages, maintaining the voltage to the required standards and allowing more solar to be exported onto the network.



### NO STATCOM

Without a STATCOM device, the voltage may fluctuate above the required standards. Existing and new solar inverters are not able to export to the network.

# Collaborating to build the future grid

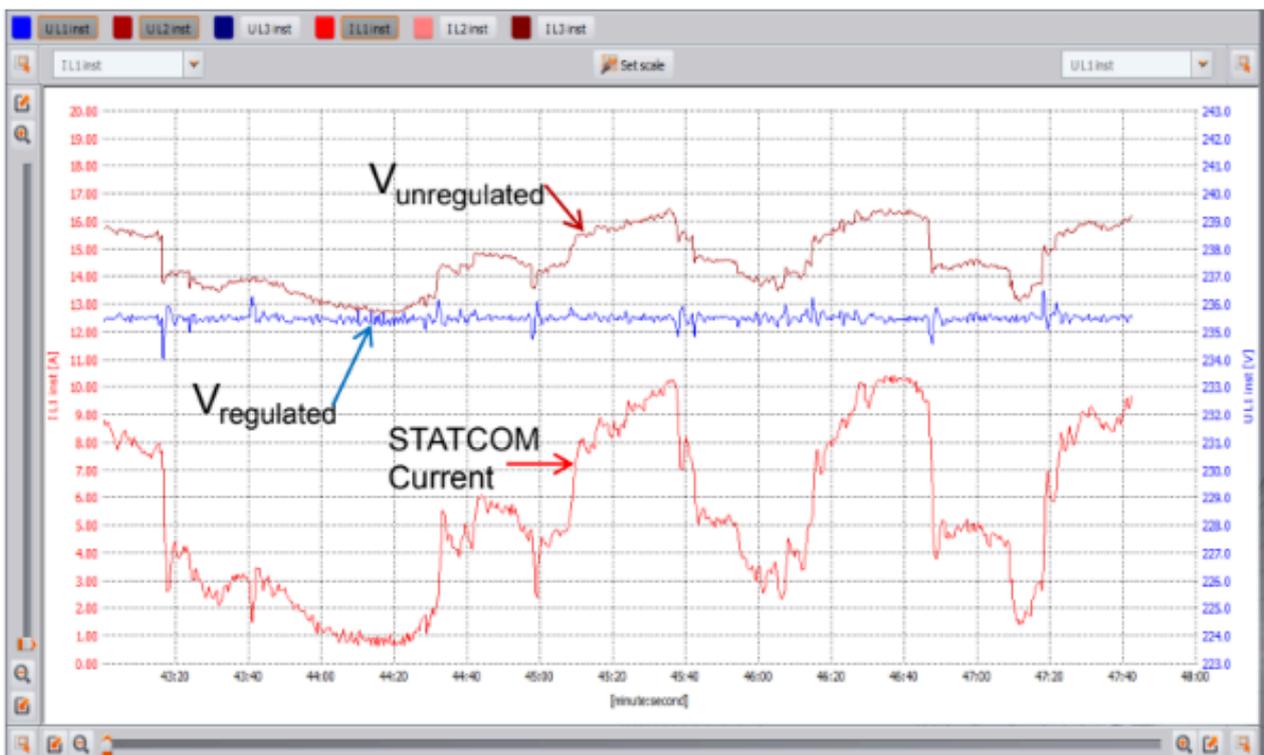
Since 2020, Ausgrid has been working closely with EcoJoule Energy to trial, test and deploy advanced LV STATCOM technology across its distribution network. What began as a lab-validated proof of concept has grown into one of Australia's most comprehensive field programs for low-voltage voltage regulation.



Over several years, Ausgrid has installed EcoJoule's EcoVAR STATCOM units at a range of urban, rural and fringe-of-grid locations, building a detailed understanding of their performance under real-world operating conditions.



The collaboration has enabled Ausgrid to evaluate the technology's ability to stabilise voltages, increase solar hosting capacity and address phase imbalance issues, particularly on long, bare overhead LV feeders. Through this partnership, EcoJoule's devices have demonstrated consistent reliability, strong technical capability and meaningful economic benefits compared with traditional network upgrades. Today, EcoJoule's LV STATCOMs are becoming an increasingly important part of Ausgrid's business-as-usual toolkit for managing the modern, DER-rich distribution grid.



Lab testing in 2020 fully validated the functional performance of an LV STATCOM for voltage regulation.



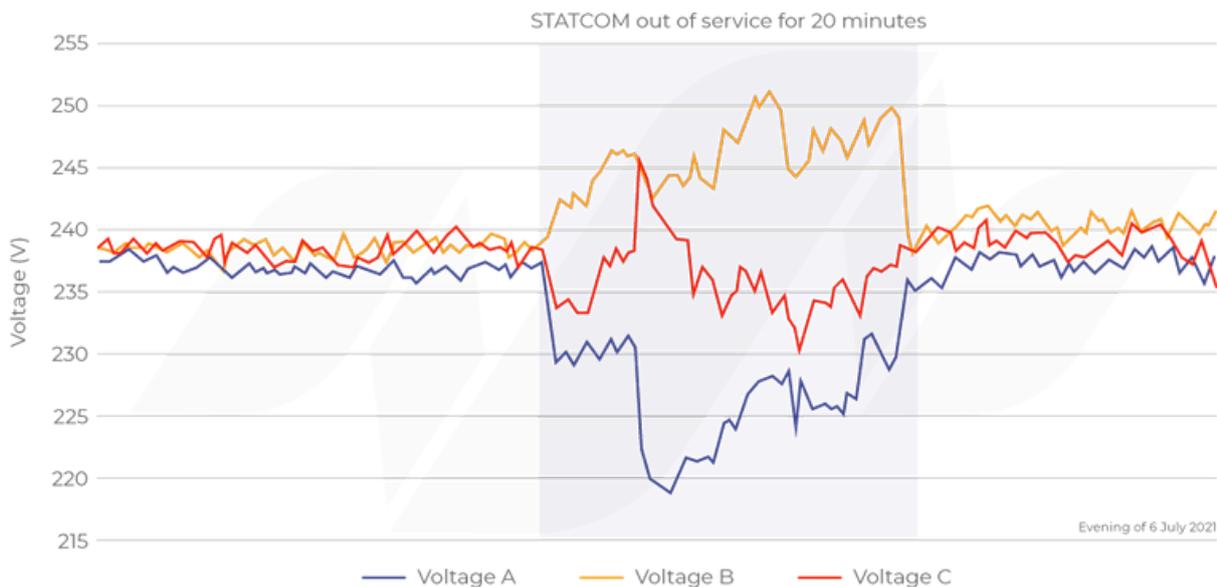
# Case Study 1: Mirrabooka Field Trial

Mirrabooka, a rural residential distributor with 61 customers (36% solar penetration), historically experienced voltage issues due to distributor length and moderate load density.

A 30 kVAR EcoJoule STATCOM was installed approximately 750m from the transformer. The results showed:

- Clear voltage improvement when the STATCOM was active.
- Significant voltage drop (down to ~220 V) during a 20-minute outage period.
- Phase-by-phase stabilisation, especially on the most heavily impacted phase.
- Demonstrated capability to increase hosting capacity for future solar and EV loads.

This real-world data confirmed the STATCOM's ability to maintain voltage within acceptable limits on long radial feeders.

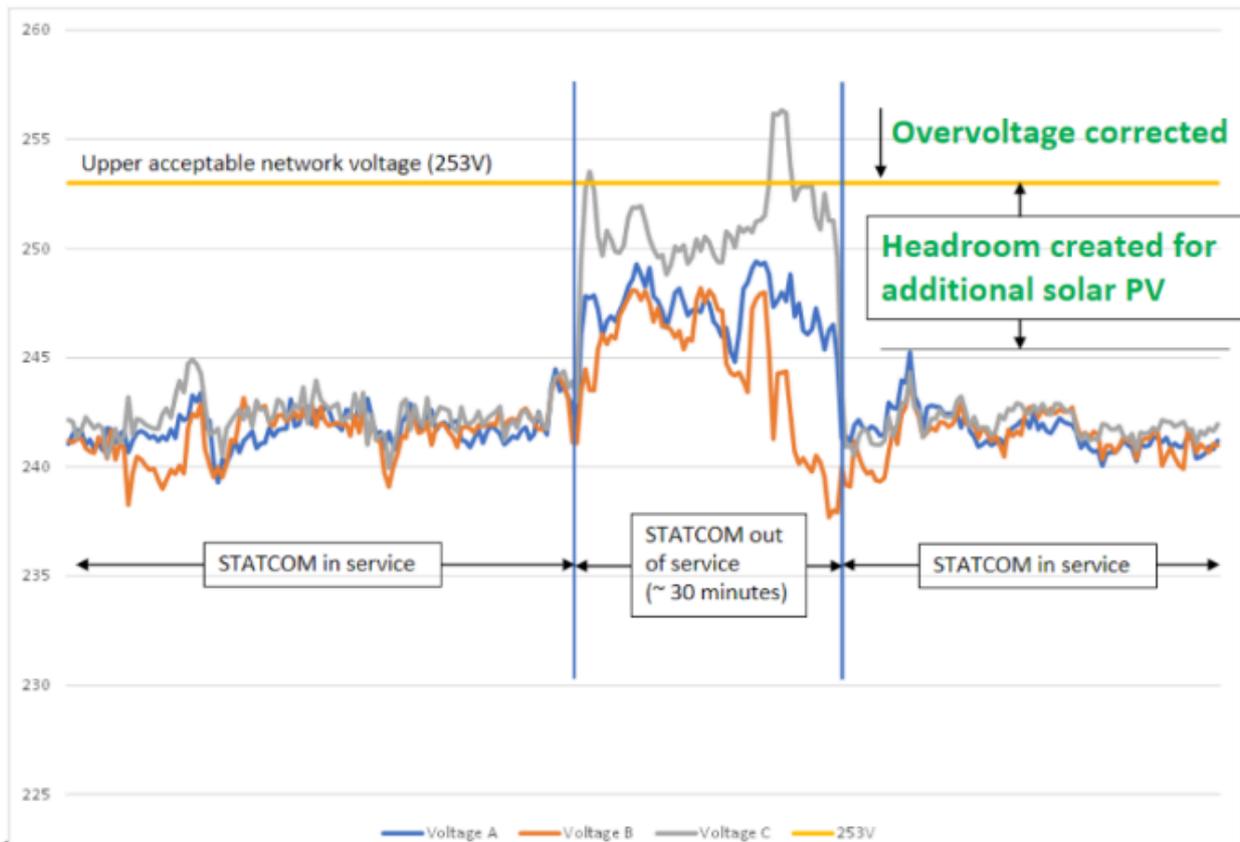


# Case Study 2: Meadowie Deployment

The Meadowie installation (July 2022) highlights a distributor serving large residential blocks with ~30 customers and a >600 m feeder length. Voltage recordings revealed:

- STATCOM effectively corrected overvoltage during periods of high solar export
- Additional voltage headroom was created for future PV connections
- Overvoltage excursions were brought back within the acceptable 253 V limit
- With ~40% solar penetration, the STATCOM created enough margin to support potential 80–100% solar penetration in the future (page 8)

This trial validated that STATCOMs can cost-effectively enable more DER hosting without upstream upgrades.



# The Engineering Principles Behind STATCOMs

Ausgrid's analysis confirms that the voltage correction provided by an LV STATCOM can be estimated with a simple, robust approximation\*:

►  $V_{\text{correction}} \sim I_{\text{STATCOM}} \cdot X_{\text{line}}$  (magnitudes only)

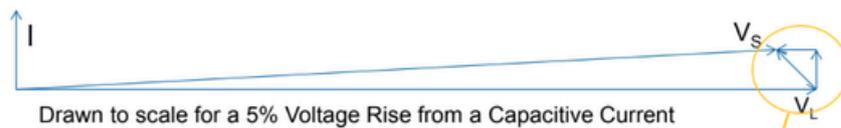
## Key Insights

- On LV networks, line inductive reactance (X) dominates the STATCOM's effectiveness.
- Bare overhead lines have significantly higher X than aerial bundled cabling (ABC), improving STATCOM performance.
- Line spacing, not conductor size, is the main driver of reactance in bare overhead lines.
- The formula remains valid for both leading (capacitive) and lagging (inductive) current injection.

In unbalanced networks, phase-specific correction yields even greater benefit.

## How is it that this approximation holds?

$V_{\text{correction}} \sim I_{\text{STATCOM}} \cdot X_{\text{line}}$  (magnitudes only)

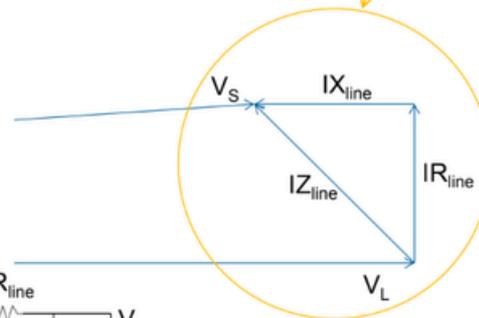


Because the vectors  $V_S$ ,  $V_L$  and  $I X_{\text{line}}$  are almost parallel, the approximation holds true that:

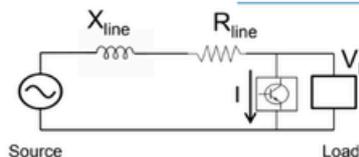
$|V_L| \sim |V_S| + |I X_{\text{line}}|$  (capacitive current)

$|V_{\text{rise}}| \sim |I X_{\text{line}}|$  (capacitive current)

$|V_{\text{drop}}| \sim |I X_{\text{line}}|$  (inductive current)



Note:  $I = I_{\text{STATCOM}}$



\*Note: X for a 66mm<sup>2</sup> Cu OHL is ~j0.303 ohm/km, X for 95mm<sup>2</sup> Al ABC ~j0.0868 ohm/km. This X value of the bare OH line is 350% that of the ABC, hence the STATCOMs superior performance on bare OHL

# The EcoJoule Energy Advantage

EcoJoule Energy's EcoVAR STATCOM is a highly cost-effective and efficient way to deliver CVR benefits across any grid. EcoVAR's advanced reactive power compensation system is specifically designed to enhance grid stability and support CVR strategies. By dynamically regulating voltage and power factor, EcoVAR ensures that voltage levels remain within optimal limits while reducing system losses. Its fast response time and modular design make it well-suited for modern grids with high penetration of renewables. Through precise voltage control, utilities can lower overall energy consumption and reduce peak demand without compromising service quality.

## What EcoVAR Does

- Real-time smart voltage regulation: monitors and adjusts voltage dynamically, ensuring levels remain within optimal ranges even as solar generation, EV charging, and demand fluctuate.
- Scalable deployment: designed to integrate seamlessly across low-voltage networks, from residential streets to commercial precincts.
- Grid-ready intelligence: supports multi-directional energy flows, overcoming limitations of legacy systems designed for one-way electricity delivery.

## Why EcoVAR is Different

- Australian innovation: EcoJoule Energy's solutions are developed and manufactured locally, supporting domestic capability in smart grid technologies.
- Future-focused design: EcoVAR is built to enable the coming wave of distributed storage and electrified transport, not just today's grid challenges.
- Proven benefits: field deployments show reduced voltage stress, increased hosting capacity for solar PV, and measurable consumer savings.

In short, EcoVAR provides not just compliance, but a strategic advantage for networks, regulators, and consumers alike.



# Comparison: PV Inverter Volt/VAR vs Dedicated LV STATCOM

While PV inverters can provide Volt/VAR support, their effectiveness is limited.

PV inverter Volt/VAR limitations:

- Only active when the sun is shining
- Only part of inverter capacity available for VARs
- Three-phase inverters regulate averaged, not individual phase voltages
- Difficult to enforce settings across customer-owned devices
- Reduces customer energy export

STATCOM advantages:

- 24/7 operation
- 100% VAR capability
- Utility-controlled settings
- Remote monitoring of performance
- Targeted placement for maximum network benefit

## Conclusion

Both technologies are complementary, but STATCOMs provide predictable, utility-grade voltage management.



# Economic Viability, Reliability, and Future Directions

## Cost and Business Case

The capital cost of installing a EcoVAR LV STATCOM compares favourably to alternatives such as:

- Reconductoring long LV lines
- Transformer upgrades
- LV regulators
- New feeders

## Reliability

After nearly four years of operation, Ausgrid reports no reliability issues with EcoJoule Energy's EcoVAR STATCOM.

Endeavour Energy, following similar trials, has shifted STATCOM use into business-as-usual deployment.

## Next Steps for Australian Utilities

Ausgrid plans to transition STATCOMs into BAU voltage management, using EcoJoule's 2nd-generation EcoVAR STATCOM, which includes:

- 40 kVAR capability.
- Integrated single-enclosure design.
- Real-time phase-to-phase power transfer to mitigate unbalance.

These enhancements significantly broaden the use cases for LV voltage support.

## Conclusion

EcoJoule Energy's EcoVAR STATCOM solutions have been field-proven across diverse LV networks to stabilise voltage, enhance solar hosting capacity, reduce customer complaints, and delay or eliminate costly network upgrades.

With increasing demand from solar, batteries, and electric vehicles, LV-scale power electronics will become a central tool in Australia's energy transition.

This white paper demonstrates that LV STATCOMs are not merely a trial technology, they are a ready, economical, and reliable solution for modern LV voltage challenges.





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