INDUSTRY WHITE PAPER

ROYPOW

Discover How Mobile Energy Storage Enables Low-Carbon, Flexible Power Deployment

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Executive Summary

In a wide range of off-grid applications, diesel generators have long served as the primary source of power supply. However, their inherent limitations in terms of noise, emissions, and operational efficiency are becoming increasingly evident. As requirements for working environments and regulatory standards continue to tighten, conventional diesel-based power solutions are facing growing uncertainties with regard to continuity of supply, regulatory compliance, and long-term operating costs.

With the advancements in battery energy storage and power conversion technologies, mobile energy storage systems are progressively gaining the capability to serve as a primary power source in off-grid environments. Through system-level design, mobile energy storage enables low-noise operation and zero on-site emissions, while offering flexible deployment and cross-project reuse to meet diverse power supply requirements.

This white paper focuses on the typical challenges in off-grid applications, systematically outlining the advantages of mobile energy storage systems in terms of technical architecture, engineering adaptability, and commercial feasibility. It further presents implementation pathways and return-on-investment (ROI) models to support users in evaluating its practical value as a next-generation power solution.

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1. Introduction

In off-grid or grid-limited environments, reliable power supply cannot be taken for granted. Diesel generators have long served as the conventional solution due to their deployment flexibility and broad power coverage. However, as noise regulations, emission standards, and on-site operational requirements continue to tighten, their limitations are becoming increasingly evident.

Beyond environmental concerns, diesel-based power supply also faces growing operational costs and management complexity. Fuel price volatility, on-site refueling logistics, and maintenance burdens contribute to greater uncertainties and cost pressure over long-term operations.

Against this backdrop, users are actively seeking quieter, cleaner alternatives that can still deliver continuous power. Thanks to the maturity of energy storage batteries and power electronics technologies, mobile energy storage systems are emerging as a viable alternative to diesel generation in off-grid applications.

2. Key Industry Challenges

Current off-grid power supply solutions—primarily diesel generators—face the following key challenges in engineering applications:

Emission Characteristics and Compliance Pressure

Diesel generator operation inevitably produces NO_x, particulate matter, and CO_2 emissions. As emission regulations become increasingly stringent, even with after-treatment systems in place to reduce emissions, system complexity and costs rise significantly. In the context of global carbon neutrality commitments, high-emission diesel generators are subject to growing compliance pressure.

Operational Efficiency and Reliability

Under off-design load conditions, diesel generator efficiency drops significantly, and frequent start-stop cycles exacerbate mechanical wear. In scenarios requiring continuous power supply, fuel replenishment and equipment reliability become primary risk factors. Fuel depletion or equipment failure can directly disrupt power supply, and in the absence of redundancy, the consequences can be severe.

Noise Levels and Operational Constraints

Diesel generators typically produce noise levels of 85-100 dB(A) when operating at rated load. Even with soundproofing measures in place, prolonged operation still struggles to meet the requirements of nighttime or environmentally sensitive sites. As a result, their operating hours are restricted in many applications, limiting their ability to support continuous, around-the-clock power supply.

Complexity of Operations and Maintenance

Diesel-based power systems involve fuel storage, transportation, safety management, as well as routine engine maintenance. They require substantial operational effort and a high level of reliance on skilled personnel. In dispersed multi-site or long-term deployments, these intensive operational demands incur additional labor costs and elevate safety risks.

Limitations in System Scalability and Flexibility

Diesel generators are conventionally designed for specific power loads, offering limited modular scalability. As electricity demand fluctuates or operational scenarios evolve, these systems cannot be easily scaled up or down to match real-time requirements, resulting in suboptimal efficiency and constrained deployment flexibility. Overall, traditional diesel power solutions fall short in adaptability and expandability.

Consequently, noise and emission restrictions, high operating costs, reliability risks, complex maintenance, and limited scalability represent the main challenges of diesel power in off-grid scenarios, creating both the need and opportunity for new power supply solutions.

3. Solution Design

In off-grid applications, the core objective of a power system is to provide stable, controllable, and low-interference continuous power. Mobile energy storage systems decouple power delivery from fuel and mechanical operation through energy storage and power management, establishing a system architecture that differs fundamentally from conventional generation and addressing the aforementioned challenges at their core.

3.1 System Architecture and Module Composition

A typical mobile energy storage power system consists of a battery system, a power conversion system (PCS), an energy management system (EMS), and interface modules.

Battery System

Serving as the energy storage module, the battery stores electricity from the grid, solar PV, or generators, and provides continuous power to the load when needed. Its capacity directly determines the duration of uninterrupted power supply.

Power Conversion System (PCS)

The PCS enables bidirectional AC/DC conversion, stabilizes output voltage and frequency, and supports battery charge/discharge management as well as parallel coordination with other power sources such as solar PV, diesel generators, and the grid.

Energy Management System (EMS)

The EMS is responsible for system monitoring, strategic control, and coordinated scheduling of multiple devices.

Standardized Interfaces

These provide connections for external charging and internal power delivery, supporting both standalone operation and multi-unit parallel expansion.

Figure 3-1: Mobile Energy Storage Power System Architecture

3.2 Operating Modes and Expansion Approaches

In typical off-grid scenarios, mobile energy storage systems operate in an independent power supply mode, leveraging power electronics to respond rapidly to load fluctuations while maintaining stable output. Multiple units can be connected in parallel to achieve linear expansion of both power and capacity, easily matching project requirements. Compared with fixed diesel generators, mobile energy storage solution offers greater deployment flexibility and cross-scenario reusability, enabling an efficient operational model of one system serving multiple sites with rapid dispatch.

3.3 System-Level Technical Advantage Analysis

The advantages of mobile energy storage systems are not limited to individual performance parameters but stem from a fundamentally different system architecture compared with diesel generators. Built on power electronics and energy storage technologies, these systems demonstrate superior adaptability in operational characteristics and control capabilities.

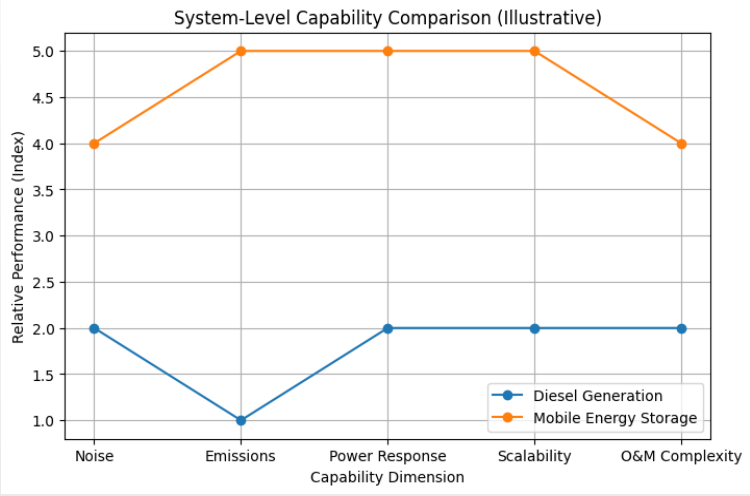


Figure 3-2: System-Level Capability Comparison (Illustrative)

As shown in the figure, mobile energy storage system demonstrates superior overall adaptability across key dimensions such as noise control, emission characteristics, power response, system scalability, and operational complexity. This enables it to better meet the comprehensive requirements for stable and environmentally friendly power supply in off-grid scenarios.

4. ROYPOW Technology and Applications

As a technological innovator in the field of mobile energy storage, ROYPOW focuses on the practical demands of off-grid applications and has developed mobile energy storage solutions with high performance, strong adaptability, and intelligent capabilities. The core design principles and typical application approaches are summarized as follows.

4.1 Product Design Concept

ROYPOW mobile energy storage products exhibit the following key features in terms of system architecture and engineering adaptability:

- Configured for power and energy to support continuous operation
- Capable of dynamic response to engineering load requirements
- Designed for frequent mobility and on-site deployment
- Modular parallel capability for scalable system expansion

4.2 Core Technical Advantages

Continuous Power Output

The products support extended, stable operation within rated power ranges, ensuring uninterrupted power supply for engineering equipment in demanding off-grid environments.

Engineering-Grade Power Conversion

By adopting engineering-grade control strategies and high-performance inverter modules, the system can maintain stable voltage and frequency output even under highly dynamic load conditions, such as inductive loads or start-up surges, ensuring the reliable operation of critical equipment.

Safety and Reliability Design

The system features multi-level electrical protection, real-time status monitoring, and automatic responses to over-temperature, over-load, and over-voltage conditions, enhancing operational stability and safety under high-temperature, humid, or vibration-prone environments.

Modular Parallel Capability

The product supports parallel operation of multiple units, enabling linear expansion of power and energy capacity through flexible combinations. This allows users to adjust configurations according to project stages, avoiding excessive upfront investment or idle equipment.

Intelligent Remote Monitoring

ROYPOW mobile energy storage systems are equipped with built-in GPS and 4G communication modules, enabling the upload of location information, operational status, and fault alarms to the cloud platform. Users can monitor device dynamics in real time via web or mobile app, tracking key metrics such as operating hours and battery levels.

The system also supports OTA updates and remote fault diagnostics, effectively improving maintenance response efficiency. This is particularly valuable in multi-site deployments or rental operations, enhancing asset management efficiency and significantly reducing the risk of equipment misuse or loss.

4.3 Representative Application Scenarios

To illustrate the application of mobile energy storage systems in off-grid scenarios more intuitively, the following examples are based on typical operating conditions.

Scenario 1: Continuous Power Supply for Temporary Construction Sites

At construction sites without a fixed power source, continuous electricity is required for both primary construction equipment and auxiliary facilities. Traditional diesel generators are often restricted during nighttime operations due to noise limitations.

By deploying ROYPOW mobile energy storage systems, the site can be pre-charged in advance, allowing the system to independently supply power throughout operations. This enables low-noise operation and avoids operational interruptions caused by fuel replenishment.

Scenario 2: Periodic Power Supply in Remote Areas

In remote areas with stage-based operations, power demand varies according to project progress. Deploying fixed-generation equipment can be complex and may result in idle capacity.

ROYPOW mobile energy storage systems can be flexibly allocated according to project phases, meeting different power requirements through single-unit or parallel operation. After a project is completed, the systems can be rapidly relocated to the next site, improving overall equipment utilization.

Scenario 3: Hybrid Power Configuration with Diesel Generators

In scenarios with extended runtime requirements, mobile energy storage systems can operate in a hybrid configuration alongside existing diesel generators. The energy storage system handles the primary power supply, while diesel generators are used only for supplementary or emergency power. This approach significantly reduces noise, emissions, and fuel consumption.

5. Implementation Pathways and ROI Analysis

As a new-gen clean power solution, the deployment of mobile energy storage systems typically requires alignment with the user's project lifecycle, load requirements, and management capabilities, and is implemented through a phased approach. Based on practical experience from typical customer projects, ROYPOW proposes staged implementation recommendations and integrates ROI pathways to provide users with a deployment framework that ensures controllable risk and measurable value.

5.1 Recommended Phased Implementation Pathways

The implementation of mobile energy storage systems can be divided into the following three stages. Each stage focuses on distinct objectives, aiming to mitigate overall investment risks while progressively unlocking value potential:

Phase 1: Pilot Deployment and Operational Validation

At the project's initial stage, a limited number of mobile energy storage units are introduced to validate their power supply capability, operational stability, and on-site adaptability in the target scenario.

Through small-scale pilot deployment, the following key aspects should be validated:

- **Meeting required power and operational duration**
- **Complying with noise and environmental regulations**
- **Ensuring controllable operation and maintenance processes**

This stage requires relatively low investment and carries minimal risk, enabling customers to evaluate the technical and commercial feasibility of mobile energy storage as a primary power source without altering the existing power supply infrastructure.

Phase 2: Scaled Deployment and Diesel Replacement

Following successful pilot validation, the deployment scale of the mobile energy storage system can be gradually expanded to assume primary power supply responsibilities, while the existing diesel generators are transitioned to backup or auxiliary roles.

The core benefits of this phase include:

- **Significantly reducing diesel fuel consumption**
- **Improving site-level noise control and environmental performance**
- **Reducing carbon emissions and mitigate regulatory compliance risks**

Phase 3: System Optimization and Multi-Scenario Reuse

As the number of deployed units increases, mobile energy storage systems can be flexibly allocated across different projects and operational scenarios. By enhancing equipment utilization, users can further spread costs over multiple projects and improve overall asset return.

5.2 Illustrative Analysis of ROI

The economic viability of a power supply solution is determined not only by initial procurement costs but also by its long-term operating cost structure and asset utilization efficiency. Extensive studies indicate that hybrid power systems integrating renewable energy and energy storage can significantly reduce lifecycle costs. For example, research by the National Renewable Energy Laboratory (NREL) shows that, in practical applications, the net present cost of hybrid microgrid solutions can be 19%–35% lower than that of diesel-only power solutions. Pilot projects supported by the U.S. Department of Energy have also demonstrated that incorporating battery energy storage reduces diesel fuel consumption and lowers the need for redundant diesel generator capacity, thereby improving overall economic performance.

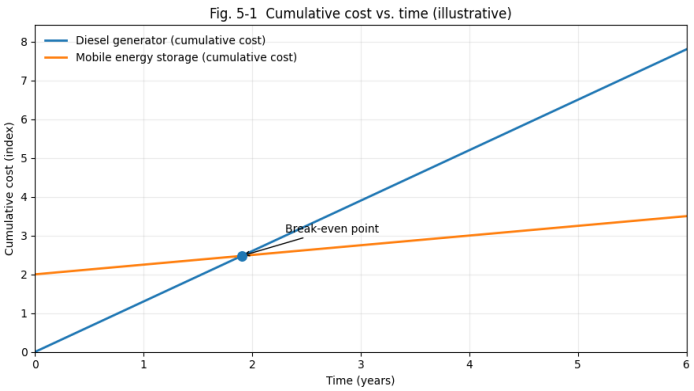
Based on these findings, this white paper adopts an illustrative analytical approach to compare the long-term cost structures of mobile energy storage solutions and traditional diesel generator solutions, providing decision-makers with insight into investment return trends.

Table 5-1: Economic Comparison Between Diesel Generator and Mobile Energy Storage in Off-Grid Applications (Illustrative)

Item	Diesel Generator	Mobile Energy Storage
Initial Investment	Lower	Higher (one-time)
Primary Operating Costs	Diesel fuel, transportation, and maintenance	Electricity replenishment and basic maintenance
Cost Evolution Over Time	Continuous linear increase	Slow and predictable cost growth
Noise and Emissions Impact	High	Very low / zero local emissions
Operational and Maintenance Complexity	High	Lower
Equipment Reusability	Low	High
Long-Term Cost Controllability	Lower	Higher

Note: **The comparison presented in this table is illustrative and intended to highlight differences in cost structure between two different solutions.**

Figure 5-1: Comparison of Cumulative Cost Trends Over Time



ROI Assumptions

The above illustration is based on a typical off-grid, continuous power usage scenario, assuming fixed operating duration, consistent usage frequency, and standard diesel cost levels. Actual investment return periods may vary depending on usage intensity, fuel prices, electricity replenishment costs, and equipment reuse.

5.3 ROI Evaluation Across Different Business Models

The ROI model of mobile energy storage systems varies depending on customer profiles and usage strategies, resulting in multiple value realization pathways. Based on practical experience, ROYPOW has identified the following three typical models through which value can be achieved:

End Users

For end users who directly purchase the equipment, the core value of mobile energy storage systems lies in the long-term substitution of traditional diesel generators. In high-frequency or long-duration operating scenarios, the initial capital investment can typically be recovered within two to three years through fuel savings and reduced maintenance costs. Thereafter, the system enters a stable operational phase characterized by lower maintenance expenses, significantly improving the predictability and controllability of electricity costs.

Leasing Model

In rental scenarios, mobile energy storage system serves not only as a power supply device but also as a reusable energy asset. By deploying the equipment across multiple projects, higher utilization rates translate into greater ROI per unit. The intelligent monitoring platform enables real-time tracking of device status and location, further reducing idle time and loss risks while enhancing overall asset management capabilities.

EPC Model

For EPC contractors, the value of mobile energy storage extends beyond energy efficiency comparisons to the significant mitigation of project-related uncertainties. Its low-noise and zero-emission characteristics help avoid project suspension, penalties, or delays caused by environmental and regulatory compliance issues, thereby supporting on-schedule project delivery and indirectly enhancing contractual performance capabilities and overall market competitiveness.

This comparison illustrates that the commercial value of mobile energy storage extends beyond simple fuel savings. Its true value lies in its role as a mobile, reusable, and remotely monitored energy asset, providing sustained returns, flexible dispatch capabilities, and improved operational efficiency. With a well-planned deployment strategy and asset management approach, the potential ROI can be significantly amplified.

6. Conclusion

Under increasingly stringent environmental and operational requirements in off-grid power scenarios, continued reliance on standalone diesel generator solutions is becoming a high-risk option, characterized by cost uncertainty and growing compliance pressures. While diesel generators were once considered the “standard solution,” their limitations in noise, emissions, fuel costs, and power stability have become increasingly apparent.

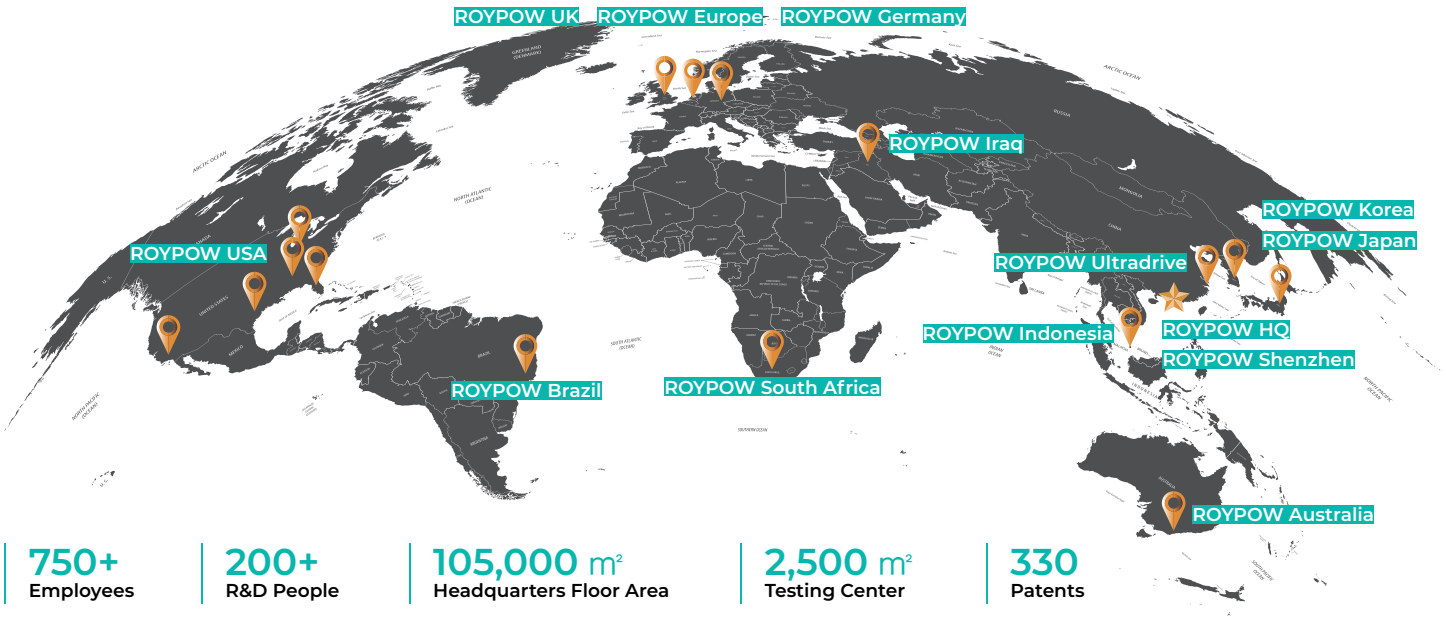
In contrast, mobile energy storage systems are rapidly emerging as a new-gen primary power solution, thanks to their low noise, zero local emissions, flexible deployment, and remote controllability. This represents not only a cleaner and more efficient power supply method but also a reusable, scalable, and asset-based energy strategy.

The value of mobile energy storage solution extends far beyond simple fuel savings. Through system-level deployment strategies and multi-scenario reuse, it delivers long-term, stable returns while effectively mitigating hidden risks and uncertainties associated with noise disturbances, emission non-compliance, and complex management requirements.

Based on industry trends and technological evolution, mobile energy storage solution is expected to gradually replace diesel generators as the core power supply in an increasing number of project scenarios. ROYPOW recommends forward-looking enterprises begin with pilot projects to validate technical and commercial feasibility, then rapidly scale deployment upon proven results, integrating mobile energy storage solutions into their long-term energy strategy.

Driven by ongoing technological innovation and application development, ROYPOW is committed to partnering with customers to build more efficient, sustainable, and strategically valuable power systems, jointly advancing energy infrastructure toward a low-carbon, intelligent, and flexible future.

Disclaimer: The economic analysis presented in this white paper is intended for illustrative purposes only, highlighting trends and logical reasoning. It does not constitute any guarantee of investment return or financial performance. Actual results may vary depending on usage conditions and operational practices.



750+
Employees

200+
R&D People

105,000 m²
Headquarters Floor Area

2,500 m²
Testing Center

330
Patents

Core Business:
R&D, manufacturing and sales of motive power systems and energy storage systems

Industry Experience:
More than 20 years in renewable energy

Corporate Vision:
Energy innovation, better life

Corporate Mission:
To help build a convenient and environmentally friendly lifestyle

R&D Capabilities:
BMS, EMS, and PCS all designed-in-house

Manufacturing Bases:
Factories in China and Indonesia

Global Sales & Services Network:
17 subsidiaries and offices for responsive technical & service support and fast delivery

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