



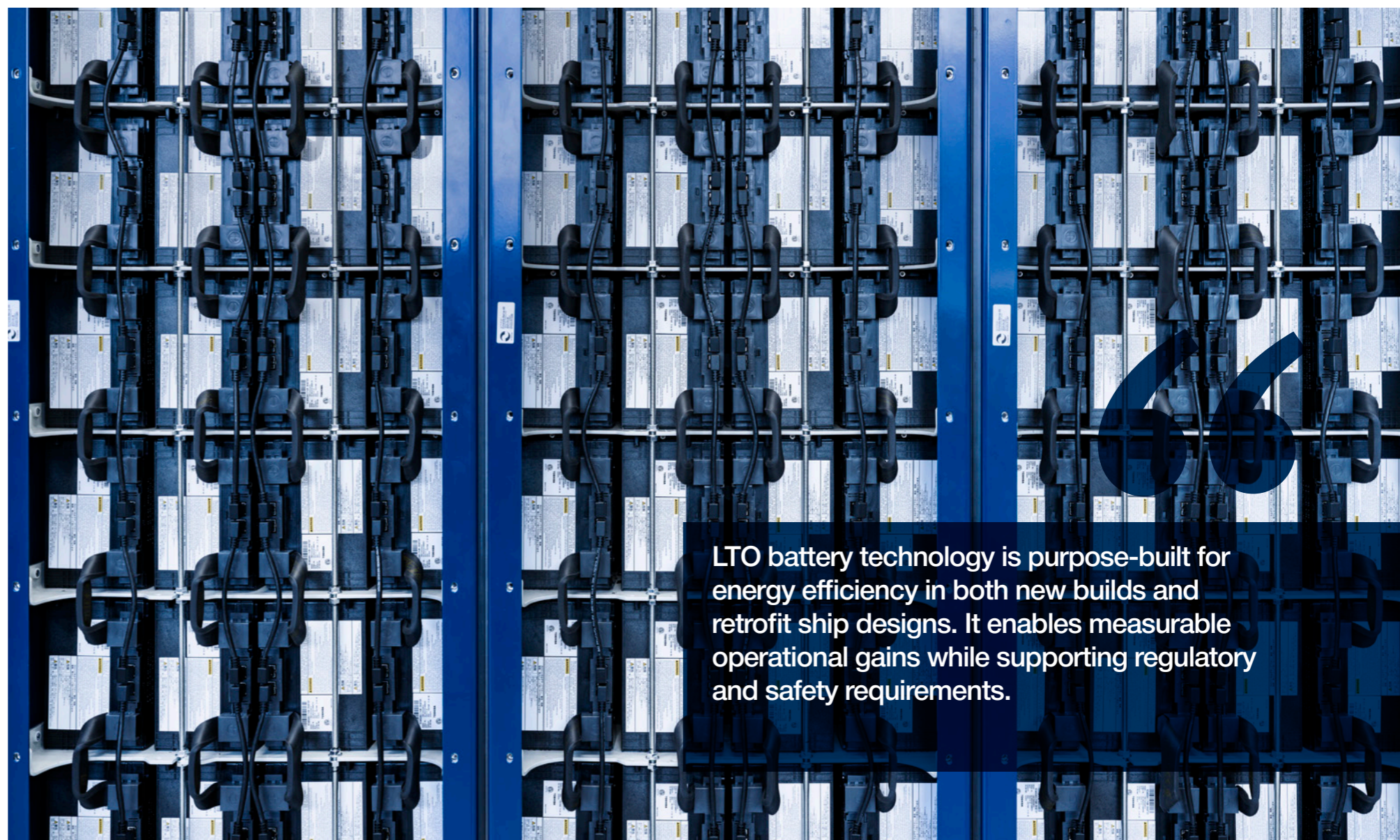
# Stabilizing load, reducing fuel

The role of LTO batteries in  
merchant vessel power systems



# Chapters

- 01 The energy efficiency challenge in marine power systems
- 02 Battery-enabled energy optimization
- 03 Application examples
- 04 Why LTO battery systems for energy optimization?
- 05 Selecting the right battery solution
- 06 Integration in marine power systems



LTO battery technology is purpose-built for energy efficiency in both new builds and retrofit ship designs. It enables measurable operational gains while supporting regulatory and safety requirements.

# Executive Summary

**Batteries reduce fuel consumption by keeping generators at stable, efficient loads without compromising redundancy or safety.**

Conventional marine power systems are dimensioned for peak demand and redundancy, but operate most of the time at low load. This results in inefficient generator operation, with increased fuel consumption, higher emissions, and unnecessary running hours.

Integrating a battery as an active component of the power system shifts generator operation from low-load inefficiency to high-load optimization. By replacing mechanical spinning reserve, absorbing load fluctuations, and supporting transient demand, the battery enables fewer generators to run, at higher and more stable load.

This change directly improves system efficiency and reduces fuel consumption without compromising redundancy or safety.

Lithium titanate oxide (LTO) battery technology is specifically suited to this operating mode. Its high power capability and tolerance for frequent cycling enable continuous daily operation with minimal degradation, supporting system lifetimes of 15–20 years under demanding conditions.

Depending on vessel type and operating profile, battery-enabled energy optimization can reduce auxiliary 4-stroke generator set fuel consumption by approximately 10–15 %, while also reducing running hours and improving operational stability.

This paper explains the efficiency challenges in marine power systems and shows how Echandia's LTO battery systems address them through practical operating strategies and real-world use cases.



## Higher generator efficiency

LTO batteries help shift generators from low-load operation to more efficient load points.

## Lower operating cost

Improved generator operation reduces fuel consumption, emissions, and unnecessary running hours.

## Maintained operational safety

Battery-based reserve and load support improve efficiency while preserving redundancy and blackout protection.

## 01

## The energy efficiency challenge in marine power systems

Marine electrical systems are typically dimensioned to cover peak demand, transient loads, and redundancy requirements. During normal operation, electrical demand is significantly lower than installed capacity, leading to prolonged low-load operation. Generators operating at low load for extended periods have three primary consequences: reduced fuel efficiency, increased emissions and increased engine wear. This has long been a structural energy efficiency challenge in marine power systems.

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Generator capacity is conventionally determined by worst-case scenarios and redundancy requirements. During normal operation, this results in excess capacity and inefficient utilization.

### Low-load operation of four-stroke generators

Four-stroke generators achieve optimal efficiency at mid to high load levels. At low load, fuel consumption per unit of power increases and overall efficiency declines.

Industry data shows that operation below approximately 40% load results in a fuel consumption penalty of 10–12% compared to optimal load conditions. This operating pattern is common across both conventional auxiliary generator setups and diesel-electric vessels, despite differences in propulsion architecture. Generator efficiency drops significantly below 40% load, which creates a direct fuel penalty compared to optimal mid to high load operation.

### Oversizing and installed redundancy

Generator capacity is determined by worst-case scenarios and redundancy requirements. During normal operation, this results in excess capacity and inefficient utilization. For gas and dual fuel engines, low-load operation also increases methane slip due to incomplete combustion.

### Spinning reserve and parallel operation

To maintain blackout protection during critical operating conditions such as maneuvering, harbor operations, and dynamic positioning, vessels often operate multiple generators in parallel as mechanical spinning reserve. While this ensures redundancy, it reduces average generator loading and keeps operation away from optimal efficiency. A similar effect occurs when shaft generators operate in parallel with auxiliary generators. Even though shaft generators are efficient, load sharing across multiple sources leads to suboptimal utilization and continued low-load operation of auxiliary generators.

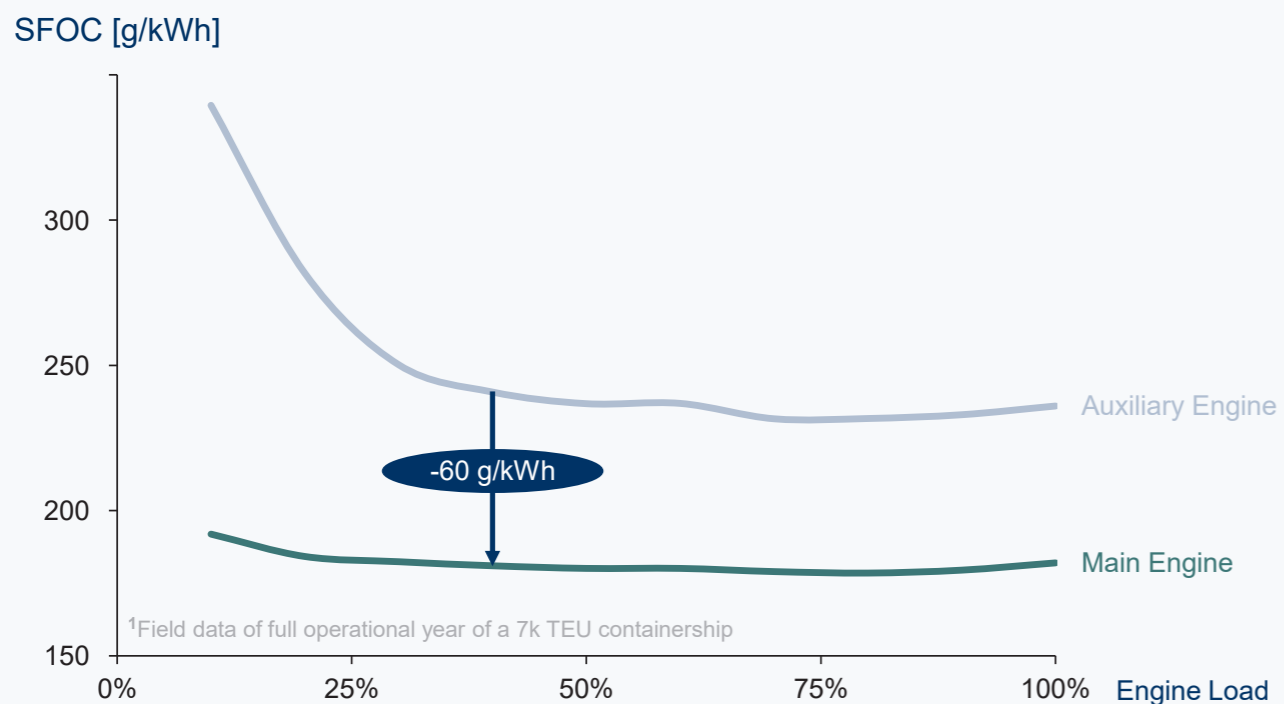
# Fuel consumption of auxiliary engines and main engine

## Fuel savings potential through auxiliary engine load optimization

A containership's auxiliary engines and main engine differ substantially in how efficiently they convert fuel into useful energy. Efficiency is commonly expressed as Specific Fuel Oil Consumption (SFOC), the grams of fuel burned to produce one kilowatt-hour of energy, where a lower value means a more efficient engine. Measured data from one full year of operation on a 7,000 TEU vessel shows that the auxiliary engines consume roughly 330 g/kWh at very low loads and settle around 240 g/kWh once loaded

above about 40 percent. The main engine, by contrast, operates at approximately 185 g/kWh across essentially its entire load range. At a typical operating point, the main engine therefore burns about 60 g/kWh less fuel than the auxiliaries to deliver the same energy. This efficiency gap is the basis for the fuel-saving potential of shifting electrical load away from the auxiliary engines, for example by using a shaft generator or a battery-based hybrid system to supply onboard power from the main engine instead.

Fuel consumption of auxiliary engines and main engine<sup>1</sup>

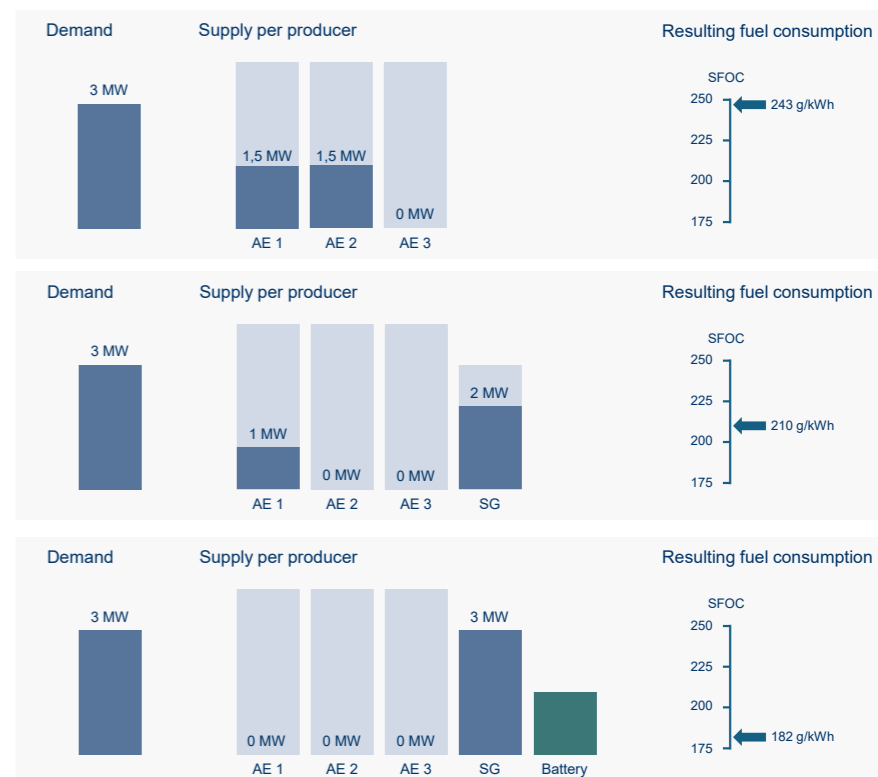


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Batteries keep engines at peak efficiency

The illustrations below compare fuel efficiency across three power-generation configurations on a vessel, each meeting the same 3 MW load demand. In the top scenario, two auxiliary engines (AE) share the load at 1.5 MW each, running well below their rated capacity, which yields a poor specific fuel consumption of 243 g/kWh. The middle scenario adds a shaft generator (SG) that supplies 2 MW while a single AE covers the remaining 1 MW, allowing each producer to run closer to its optimal load point and

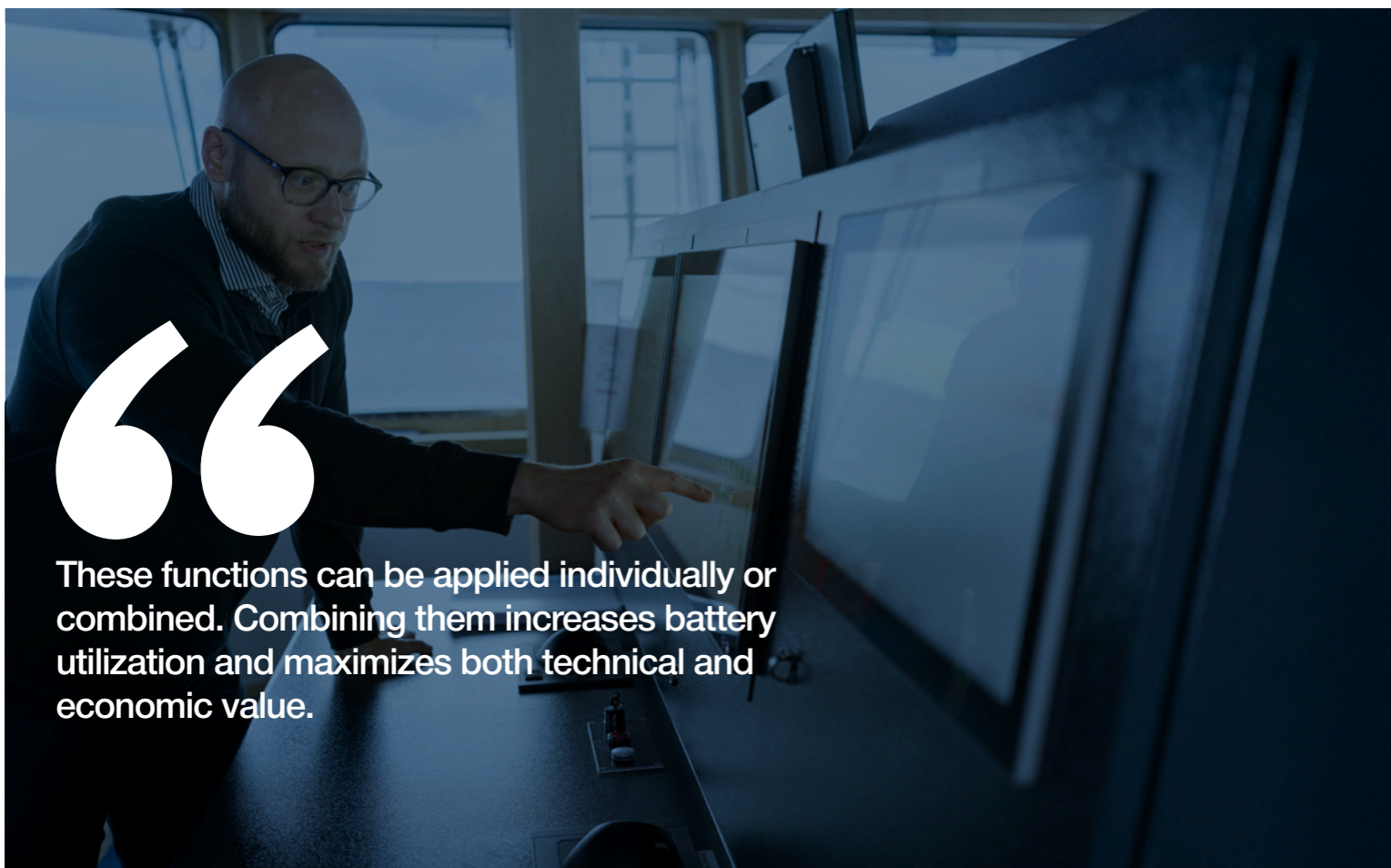
dropping fuel consumption to 210 g/kWh. The bottom scenario adds a battery, which lets the shaft generator carry the full 3 MW load at peak efficiency while the battery absorbs fluctuations and maintains a redundancy reserve, bringing fuel consumption down further to 182 g/kWh. The takeaway: loading fewer producers closer to their sweet spot, with a battery smoothing the variability, materially reduces fuel burn for the same delivered power.



# Battery-enabled energy optimization

## 02

Battery systems enable a set of operational functions that address the structural inefficiencies of conventional marine power systems. When integrated with the vessel's power management system, they allow generators to operate at higher and more stable load levels while maintaining redundancy and safety.



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These functions can be applied individually or combined. Combining them increases battery utilization and maximizes both technical and economic value.

## Applications of battery systems

### Spinning reserve replacement

The battery replaces mechanical spinning reserve by providing immediate power in the event of a generator trip or sudden load increase. This allows generators to be shut down during normal operation instead of running at low load

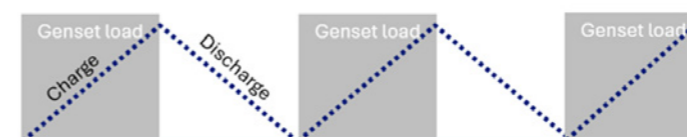
for standby purposes, reducing fuel consumption, emissions, and running hours. In a battery-enabled power system, the battery absorbs fluctuations and provides reserve capacity.



### Generator load optimization

The battery provides full power demand until depleted, with the generator turned off. Afterwards, the generator is turned on and loaded to optimum, providing full power demand and

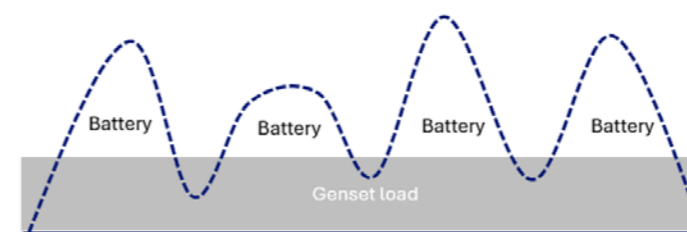
charging the battery back to full. This pattern is repeated continuously, leading to improved fuel efficiency and lower engine running time.



### Peak shaving and load levelling

The battery absorbs short-duration power peaks and smooths load fluctuations from onboard consumers. This stabilizes generator operation,

reduces mechanical stress, and prevents inefficient load-following behavior.

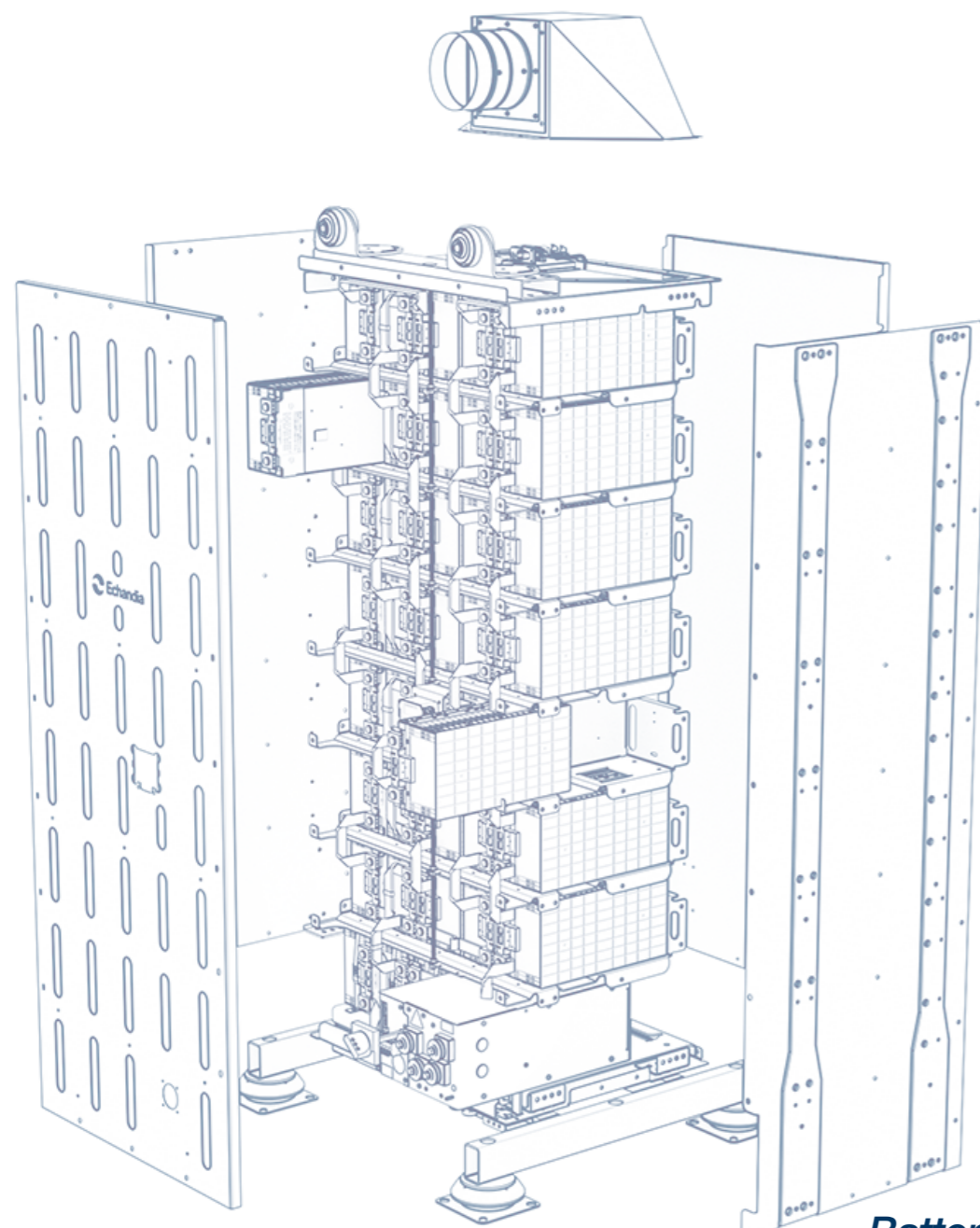


## 03

## Application examples

The application examples on the following pages illustrate how battery-supported energy optimisation translates into measurable economic value across different vessel types and operating profiles. While the technical mechanisms are consistent, the financial impact varies depending on how the vessel operates, including load variability, redundancy requirements, and generator utilisation patterns.

In each case, the battery enables a shift from inefficient low-load operation to controlled, high-efficiency operation, forming the basis for reduced fuel consumption, lower running hours, and improved total cost of ownership.



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*Battery systems form the basis for reduced fuel consumption, lower running hours, and improved total cost of ownership.*

# Car carrier: Increased load of shaft generator

On a car carrier, shaft generators often operate alongside auxiliary generators that provide spinning reserve. This leads to auxiliary generators running at very low load, typically 15 to 20%.

This case illustrates energy optimisation on a car carrier equipped with a shaft generator and multiple auxiliary generators. In a typical operating scenario, the shaft generator supplies part of the vessel's electrical demand while two auxiliary

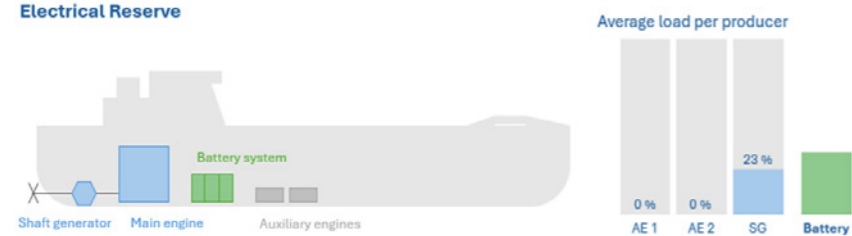
generators are kept online in parallel to provide mechanical spinning reserve.

By introducing a battery system as an electrical spinning reserve, the auxiliary generators can be stopped during normal operation. The shaft generator alone supplies the vessel's electrical demand, allowing it to operate at a higher and more efficient load point while maintaining immediate reserve capacity through the battery.

## Mechanical Spinning Reserve



## Electrical Reserve



## Case results with LTO battery systems

- 45% reduction in auxiliary generator running hours
- 6% fuel savings
- Maintained operational redundancy
- Maintained blackout protection



# Chemical tanker: Load optimization of auxiliary generators

On a large tanker vessel with three 1.4 MW auxiliary generators, average demand is 0.6 MW, resulting in low-load operation around 35 to 40%. An integrated 830 kWh LTO battery enables high frequency charge and discharge cycling at high C-rates. During charging, the generator operates

at 80 to 95% load. During discharge, the battery supplies approximately 0.6 MW, allowing the generator to reduce load or shut down. This cycle repeats continuously, maintaining efficient generator operation.

**Case results with LTO battery systems**

- 8% fuel savings
- ROI below 3 years
- Battery lifetime of 25 years under intensive cycling

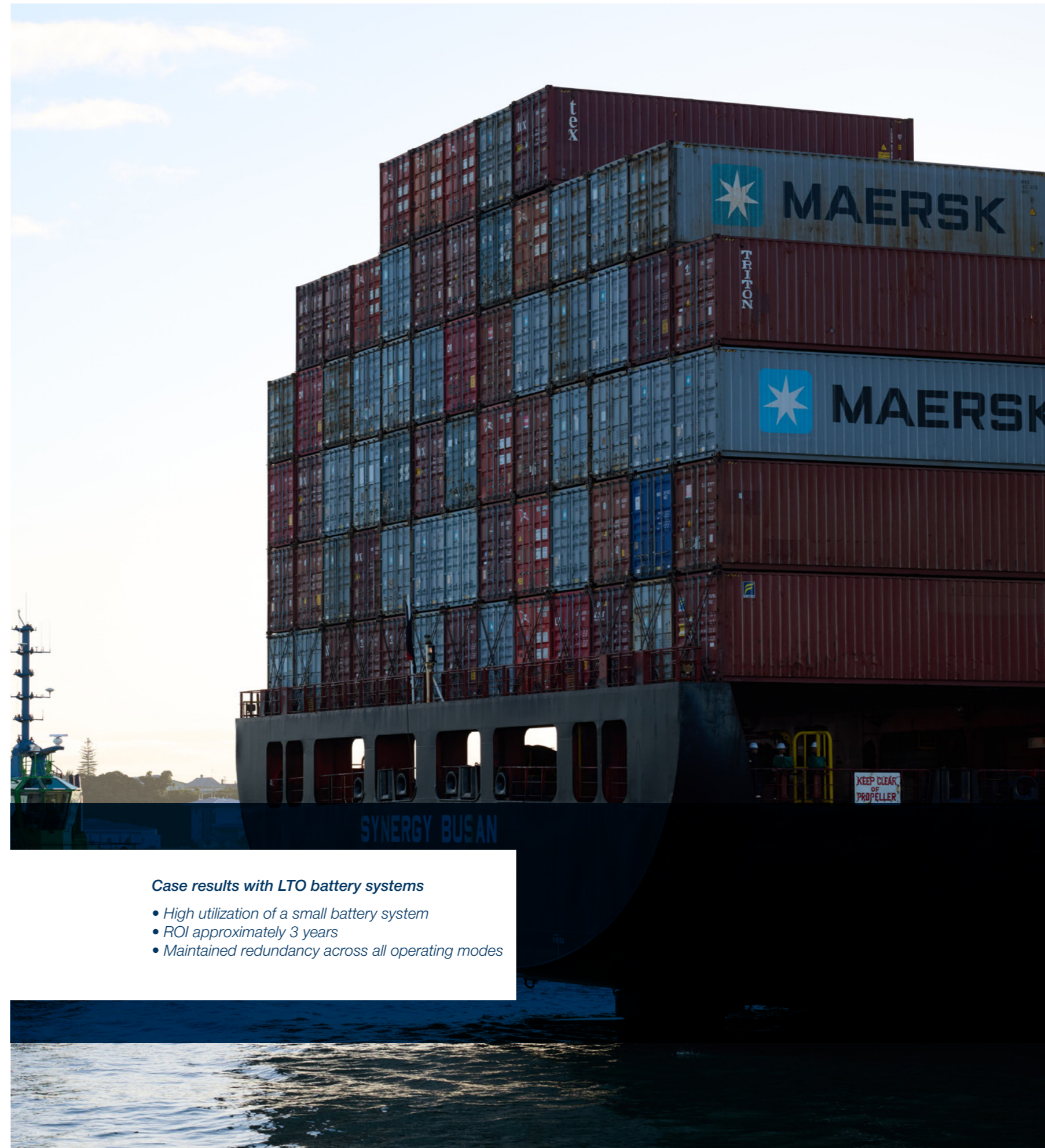
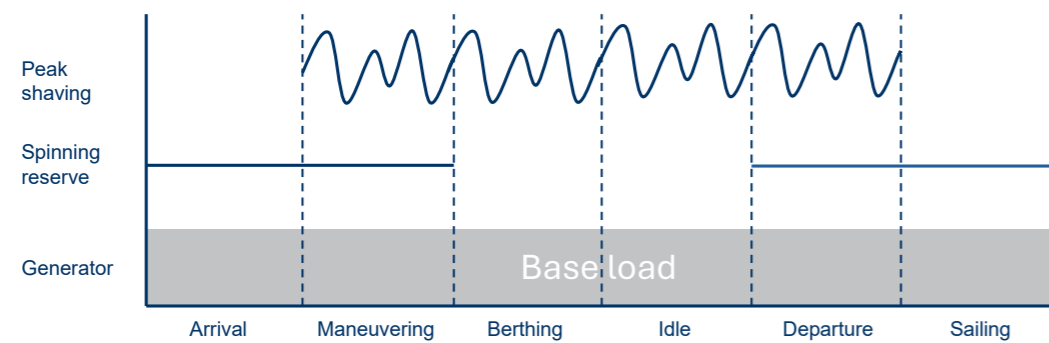
## Load levelling reduces fuel consumption by 8%



# Container ship: Combined peak shaving and spinning reserve

On a container ship, peak shaving and spinning reserve are combined on a single 250 kWh battery system. The battery supports multiple operational phases, including maneuvering, berthing, idle, and sailing, while generators operate at stable base load.

The figure illustrates a typical operational sequence for a shuttle tanker or chemical tanker across arrival, maneuvering, berthing, idle alongside, departure, and sailing. The generator baseload remains stable throughout, while the battery contribution is layered on top through complementary functions.

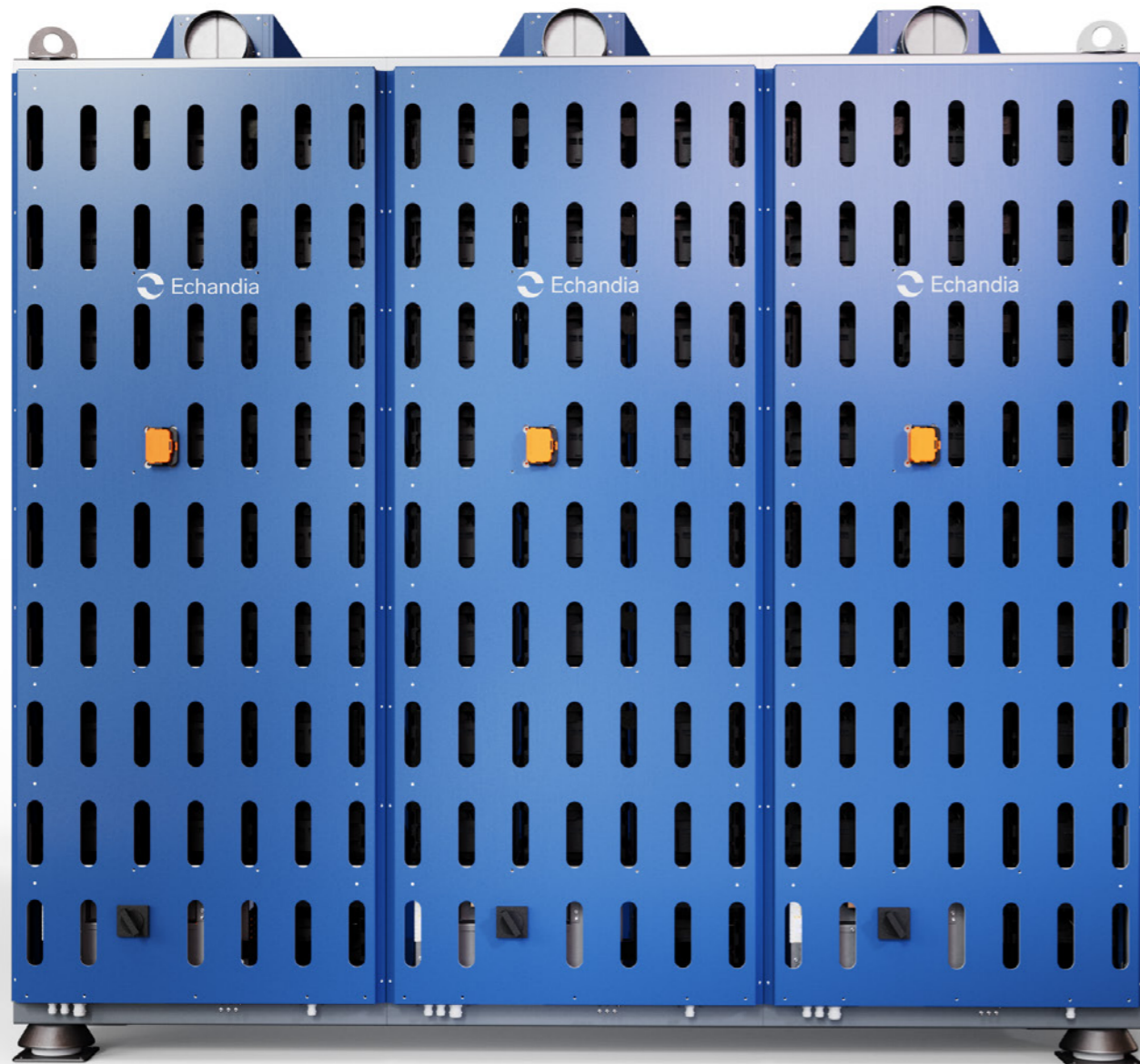


## Case results with LTO battery systems

- High utilization of a small battery system
- ROI approximately 3 years
- Maintained redundancy across all operating modes

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*High charge and discharge capability, exceptional cycle life, and minimal degradation, even under intensive use.*



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## Why LTO battery systems for energy optimization?

Energy optimization applications require batteries that can handle frequent daily cycling, high power exchange, and continuous operation over a vessel's lifetime. In these applications, the battery functions as an active power system component rather than a backup energy source.

Lithium Titanate Oxide (LTO) battery systems are well suited to these conditions due to high charge and discharge power capability, exceptional cycle life, and minimal degradation, even under intensive use. This enables implementation of energy optimization strategies without excessive oversizing and supports long system lifetimes, typically in the range of 15 to 20 years.

## 05

## Selecting the right battery solution

Battery systems can support a wide range of vessel designs and operating profiles. The optimal solution depends on how the vessel operates. For moderate duty profiles, NMC or LFP batteries may be sufficient. For demanding applications with high cycling and power requirements, LTO provides a robust and efficient solution. Each system should be designed based on

the vessel's operational profile, including:

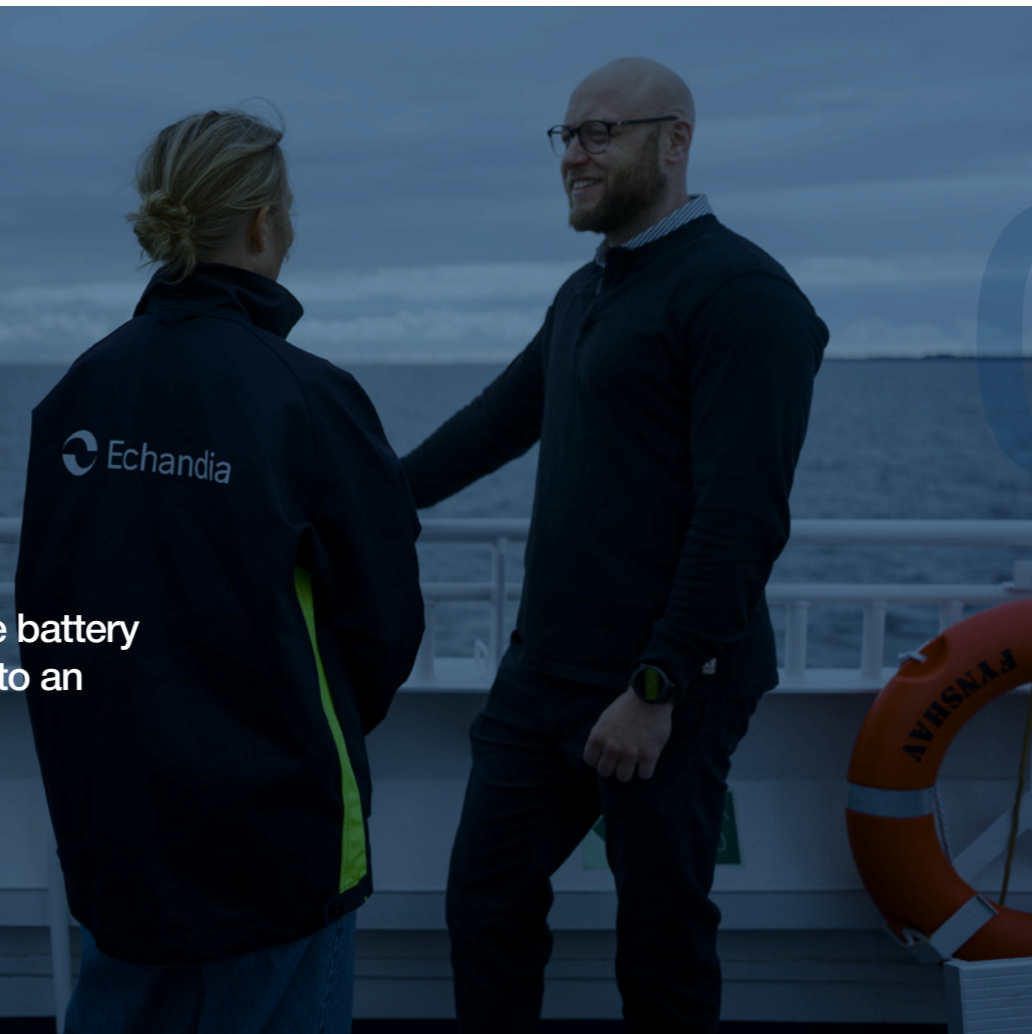
- Load characteristics
- Cycling requirements
- Power vs energy needs

This approach can reduce required battery size, avoid oversizing, and improve life-cycle performance.



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Proper integration transforms the battery from a standalone component into an active power system asset



## 06

## Integration in marine power systems

Battery systems can be integrated in both newbuild and retrofit applications, across a range of vessel types. A complete system includes:

- Battery system
- Battery management system (BMS)
- Power management system (PMS)
- Electrical integration (e.g. DC grid)

Proper integration ensures that the battery operates as a coordinated part of the overall power system, enabling the full value of energy optimization strategies.

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