

SMARTER ENERGY USE

# Powering merchant vessels with LTO battery systems



## LTO Technology Benefits for Marine Applications

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.

- Fuel & emission savings through optimized energy use
- Regulatory compliance with evolving environmental standards
- Safe and stable operation under demanding marine conditions

# Executive summary

Marine power systems are structurally designed 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 limited 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 15–20%, 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.

PRATA TIDIGT OM  
Auxiliry Engine  
/main engine  
- våra preferred terms

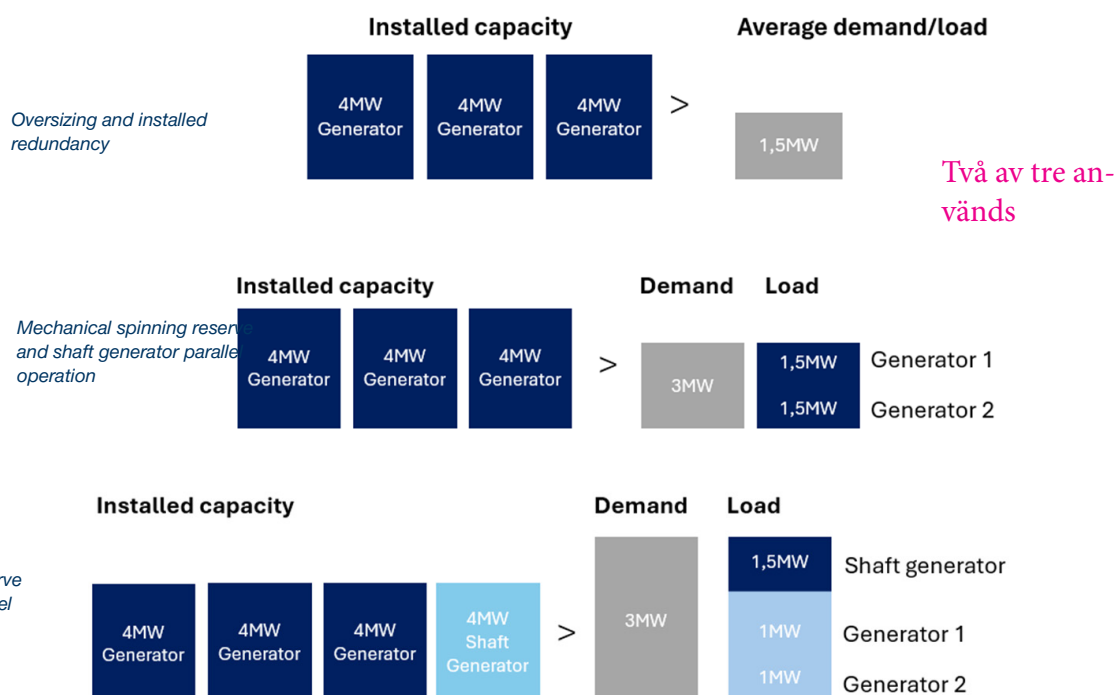
# 1. The energy efficiency challenge in marine power systems

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 has three primary consequences:

- Increased fuel consumption
- Reduced efficiency
- Higher emissions and engine wear

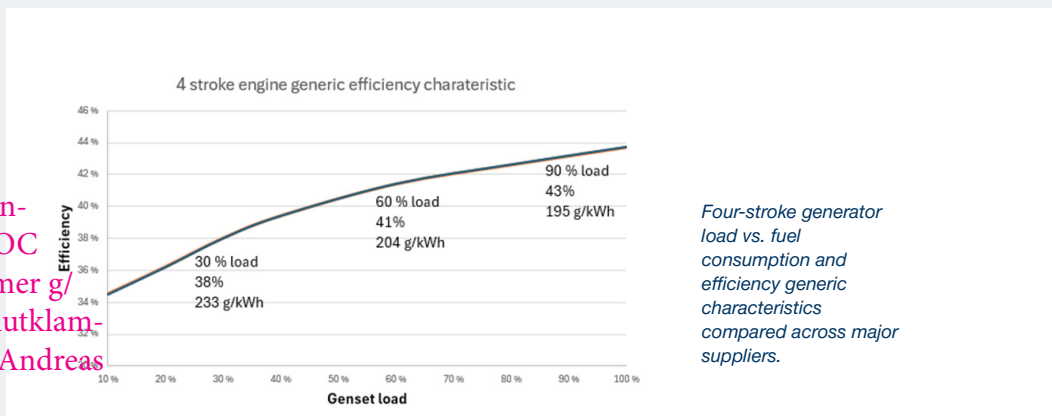
NOT  
BUT



## 1.1 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, creating a direct fuel penalty compared to optimal mid–high load operation:



Efficiency, SFOC  
Klammer g/kWh  
slutklammer - Andreas

## 1.2 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 can also increase methane slip due to incomplete combustion.

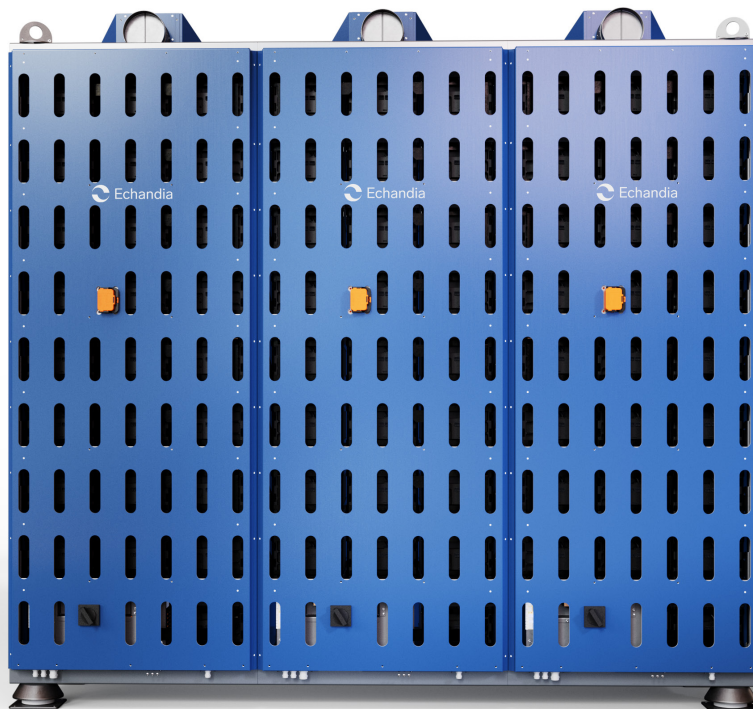
## 1.3 Mechanical spinning reserve and parallel operation

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.

## 2. Battery-enabled energy optimization

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.



## 2.1 Electrical spinning reserve

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.

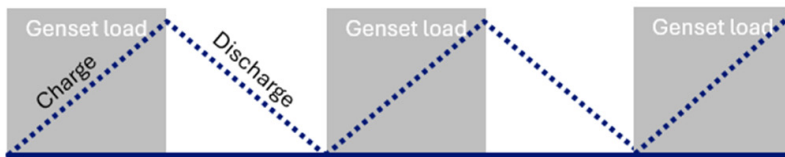
In a battery-enabled power system, the battery absorbs fluctuations and provides reserve capacity.



## 2.2 Generator load optimization

By charging during periods of low demand and discharging during higher demand, the battery shifts generator operation toward optimal load ranges.

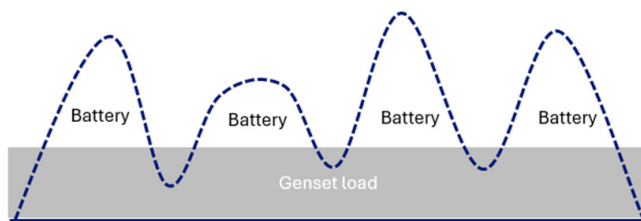
This improves efficiency and reduces the fuel penalty associated with sustained low-load operation.



These could be clarified further, I guess the blue line is power usage, then the battery should have its own box, like the genset load? Or is the line battery usage?

## 2.3 Peak shaving and load levelling

The battery absorbs short-duration power peaks and smooths load fluctuations for onboard consumers. This stabilizes generator operation, reduces mechanical stress, and prevents inefficient load-following behavior.



## 2.4 Combined operation

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

# 3. Application examples

These application examples 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.



### 3.1 Car carrier: Increased utilization of shaft generators

Results with LTO battery systems in this car carrier example case:

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

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%. By introducing a battery as electrical spinning reserve, auxiliary generators can be shut down during normal operation. The shaft generator then supplies the full electrical load at a higher, more efficient operating point.

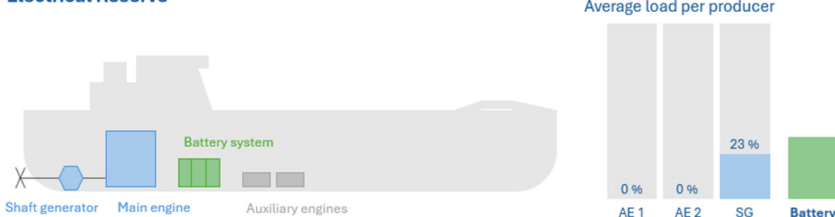
This case illustrates energy optimisation on a car carrier equipped with a shaft generator and multiple auxiliary generators. In a typical operating scenario, the shaft generator supplies part of the vessel's electrical demand while two auxiliary generators are kept online in parallel to provide mechanical spinning reserve.

**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.

**Electrical Reserve**



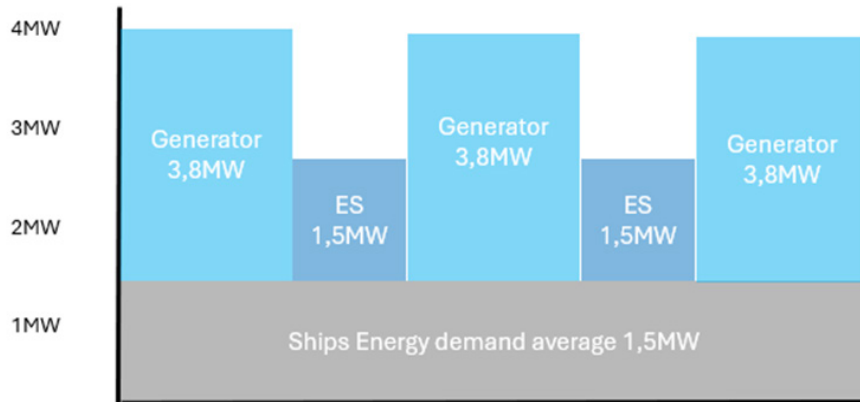
### 3.2 Cargo vessel: Load optimization of auxiliary generators

Results with LTO battery systems in this cargo vessel example case:

- 1 to 2% total vessel fuel savings
- ROI below 3 years
- Battery lifetime of 25 years under intensive cycling (8,000+ cycles per year)

On a large cargo vessel with four 4 MW auxiliary generators, average demand is 1.5 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 1 MW, allowing the generator to reduce load or shut down. This cycle repeats continuously, maintaining efficient generator operation.



When redesigning: change U  
English manoeuvring to US  
English: maneuvering

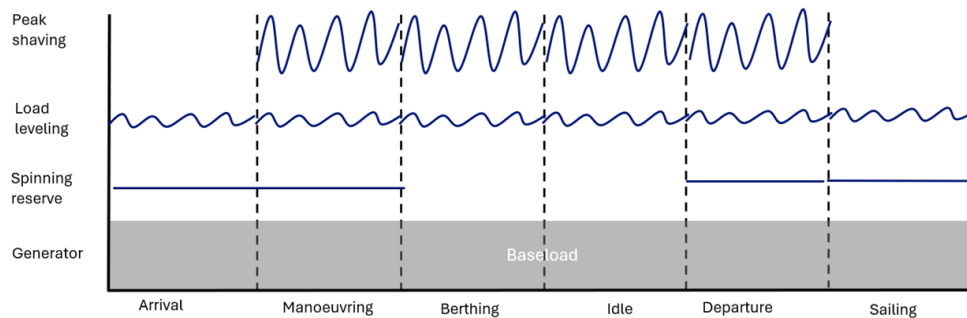
Change this illustration: looks like ES and Generator is on top of the demand. Shouldn't it be ESS or BESS instead of ES + if acronyms are used, we should explain them

### 3.3 Shuttle tanker: Combined peak shaving, load levelling, and spinning reserve

Results with LTO battery systems in this example case:

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

On a shuttle tanker, peak shaving, load levelling, 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.

# 4. Why lithium titanate oxide (LTO)?

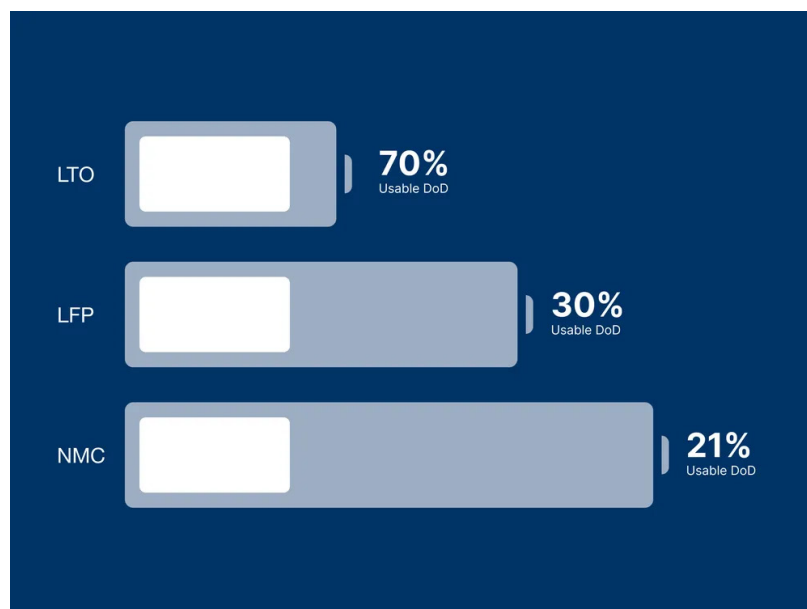
Energy optimization applications require batteries that can handle:

- Frequent daily cycling
- High power exchange
- Continuous operation over vessel lifetime

In these applications, the battery functions as an active power system component rather than a backup energy source. LTO battery technology is well suited to these conditions due to:

- High charge and discharge power capability
- Exceptional cycle life
- Limited degradation 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.



*LTO battery systems retain their capacity over time, removing the need to oversize systems. Unlike other battery chemistries that lose usable capacity and must be oversized from day one, LTO systems deliver 15 to 30 times more lifetime energy with consistent performance throughout their service life.*

# 5. 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 lifecycle performance.

# 6. 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.

# Conclusion

Marine power systems are structurally biased toward inefficient low-load operation due to design requirements for peak demand and redundancy.

Battery integration addresses this by enabling generators to operate at higher, more efficient load points while maintaining safety and redundancy.

LTO battery technology is particularly well suited to these applications, enabling frequent cycling, high power delivery, and long system lifetime.

By aligning system design with actual operating conditions, battery-supported energy optimization delivers measurable reductions in fuel consumption, emissions, and running hours, with attractive return on investment across a range of vessel types.

