



Battery system efficiency in maritime applications

Why Round-Trip Efficiency should drive your marine battery selection



Abstract

This paper is intended for naval architects, procurement managers, and ship operators evaluating battery systems for electric or hybrid vessels. It explains the concept of Round-Trip Efficiency (RTE), how it varies across battery chemistries, and why it should be a central parameter in any battery procurement process. Practical examples and a consolidated comparison table illustrate the significant long-term cost implications of battery selection.



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Why efficiency of a battery system matters

All electrical components generate heat when exposed to a current. This heat represents energy losses. And the higher the losses, the higher the electricity bill. The battery industry uses a standard metric to quantify the efficiency of a battery: Round-Trip Efficiency (RTE).



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Understanding Round-Trip Efficiency

RTE defines how much of the electricity paid for actually reaches the consumer, which in this context is any electrical motor driving propulsion or other equipment onboard a ship.

For example, if 100 kWh is consumed during charging, but 3 kWh is lost during charging and 2 kWh is lost during discharging, only 95 kWh reaches the consumer, giving an RTE of 95%. The losses (here 5 kWh, or 5%) represent electricity

that has been paid for but converted to heat rather than useful work.

The rated RTE of a battery system can range from as low as 90% to as high as 98%, depending on how the battery is used and its specific properties. This difference may not appear significant at first glance, but in the context of a fully electric ferry, it can amount to substantial savings on the electricity bill.

How round-trip efficiency is calculated:

$$\text{RTE} = \frac{\text{Energy delivered on discharge}}{\text{Energy consumed during charging}}$$

To make the role of losses explicit, this can be expanded as:

$$\text{RTE} = \frac{(\text{Energy consumed during charging} - \text{Losses during charging} - \text{Losses during discharging})}{\text{Energy consumed during charging}}$$

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Illustrative example: A fully electric ferry

Operating profile: 10 crossings per day, with a full battery recharge after each crossing (i.e. 10 charge cycles per day). Each crossing consumes 3,000 kWh.

The energy that must be procured from the grid for each recharge differs significantly by battery efficiency.

Battery RTE	Energy required per recharge	Energy saved vs. 90% RTE
90%	3,333 kWh	---
98%	3,061 kWh	272 kWh per cycle

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Round-Trip Efficiency can have a decisive impact on the total cost of ownership and, by extension, the business case for battery selection.

Applying the following assumptions to calculate savings over a battery's lifetime:

- Electricity price: €0.25/kWh (illustrative figure reflecting grid tariffs in a European context)
- Operating days per year: 360
- Battery design lifetime: 10 years

Total savings over 10 years
(272 kWh × 10 cycles/day × 360 days × 10 years × €0.25): €2,448,000

For context, the capital cost (CAPEX) of a maritime battery system with a 10-year lifetime for this application would typically be in the range of €3,000,000–€5,000,000.

This demonstrates that RTE can have a decisive impact on the total cost of ownership and, by extension, the business case for battery selection.

How does RTE vary for different battery chemistries?

Every time a battery is charged or discharged, heat is generated, resulting in energy losses. The magnitude of these losses depends primarily on two factors:

1. Charge and discharge rate: how much current is applied
2. Internal resistance: an intrinsic property of the battery

These factors are closely linked: the higher the current, the more significant the effect of internal resistance on losses.

In the maritime market, three main battery chemistries are available; NMC (Nickel Manganese Cobalt), LFP (Lithium Iron Phosphate), and LTO (Lithium Titanate Oxide).

NMC and LFP have broadly comparable internal resistance characteristics, with NMC typically showing a marginal advantage. LTO, however, stands out with significantly lower internal resistance and correspondingly lower losses.

This inherently lower internal resistance also slows the rate of aging, meaning the increase in internal resistance over the battery's working life is smaller for LTO than for NMC or LFP. As a result, the efficiency advantage of LTO grows with usage intensity.

High-usage, fast charge and discharge profiles (i.e. high current applications) favour LTO most strongly, while moderate usage reduces this advantage. The absolute savings over a battery's lifetime also depend on the total number of charge and discharge cycles.

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In the maritime market, three main battery chemistries are available:

- NMC — Nickel Manganese Cobalt
- LFP — Lithium Iron Phosphate
- LTO — Lithium Titanate Oxide

How to determine the actual RTE for your specific project

All established suppliers of marine-approved battery systems will provide an RTE value. However, not all suppliers provide a project-specific RTE. Many quote laboratory test values derived from usage profiles that do not reflect actual onboard conditions. It is important to request figures that are relevant to your specific application.

When issuing a Request for Quotation (RFQ), always ask for these three things:

- Project-specific RTE (not generic cell-level lab values)
- RTE at Beginning of Life (BOL)
- RTE at End of Life (EOL)

Recommended evaluation method

Base your business case on the average of BOL and EOL RTE values. This reflects the actual efficiency performance across the full lifetime of the battery and enables a fair, like-for-like comparison between competing products.

Illustrative example of batteries evaluated for the same application

A 5% average RTE difference results in 168 kWh savings per cycle in favour of the LTO battery for a ferry consuming 3,000 kWh per crossing.

Over a 10-year operating period at 10 cycles per day, this amounts to €1,512,000 in total savings.

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Over a 10-year operating period at 10 cycles per day, a 5% RTE difference translates into total savings of more than €1.5 million.

	LTO battery	NMC/LFP battery
RTE at beginning of life (BOL)	98%	94%
RTE at end of life (EOL)	96%	90%
Average RTE over lifetime	97%	92%

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Key parameters to define at the early design stage

As the examples above demonstrate, a small number of operational parameters have an outsized influence on actual electricity consumption and long-term costs. These should be established as early as possible in the design and procurement process:

1. Number of crossings per day or per year. Determines total cycle count.
2. Expected minimum battery lifetime, typically minimum 10 years in maritime applications.
3. Charge and discharge rates, expressed as power (kW) and duration (hours), covering both sailing time and charging time.

A complete battery evaluation should request round-trip efficiency (RTE) values at Beginning of Life (BOL) and End of Life (EOL) in every Request for Quotation.

Suppliers who are unable or unwilling to provide project-specific RTE data should be treated with caution during the selection process.



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Summary

Round-Trip Efficiency is one of the most consequential and most frequently overlooked parameters in maritime battery procurement. The choice of battery chemistry, combined with the specific operating profile of the vessel, can result in lifetime cost differences running into the millions of euros. Buyers should request project-specific RTE values at Beginning of Life (BOL) and End of Life (EOL). Procurement decisions should then be based on lifetime average efficiency to ensure a fully informed and economically sound battery selection.

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