Swappable Container Waterborne Transport Battery

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Reducing the Cost of Large Batteries for Waterborne Transport

D7.3

Production Efficiency Analysis

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1. Glossary of Terms

Term	Definition
CD	Current Direct
KPIs	Key Performance Indicators
ROI	Return on Investment
WT	Waterborne transport

1. Document properties

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2. Revision history

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1.0		Final Version Submitted

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3. Project summary

The transport sector contributes almost 25% of Europe's greenhouse gas (GHG) emissions. Compared to other sectors it is the only one with higher emissions than those of 1990. While minor emission reductions have been achieved, GHG emissions surged by 7% from 2014 until today. The European Commission adopted a low-emission mobility strategy in June 2016 to address this trend, which by 2050 aims to reduce GHG by 60% compared to 1990.

Waterborne transport (WT) emissions represent around 13% of the overall EU GHG from the transport sector. Moreover, they could increase between 50% and 250% by 2050 under a business-as-usual scenario, undermining the objectives of the Paris Agreement. The International Maritime Organization (IMO), in 2018, stipulated a strategy aiming to reduce GHG emissions from the WT sector by at least 50% by 2050.

Large-scale adoption of batteries for WT is mainly limited by the high costs of the battery systems and their integration. New innovative solutions need to be developed to drive down costs.

Together with high costs, the following challenges are identified as hampering the implementation of batteries in WT:

1. WT requires specific safety equipment leading to a higher CAPEX compared to other applications such as an automotive battery of equivalent capacity.

2. Port infrastructure for battery charging often requires upgrades. In several WT sectors, fast chargers are necessary due to the short latency during operational schedules.

3. Specific regulations and training are required to ensure the safety of the battery system installation and operation.

4. There is a small market for maritime battery systems and thus a lack of drivers for cell producers to adapt their manufacturing to create cells optimized for maritime applications.

The Current Direct ecosystem is shown in Figure 1.

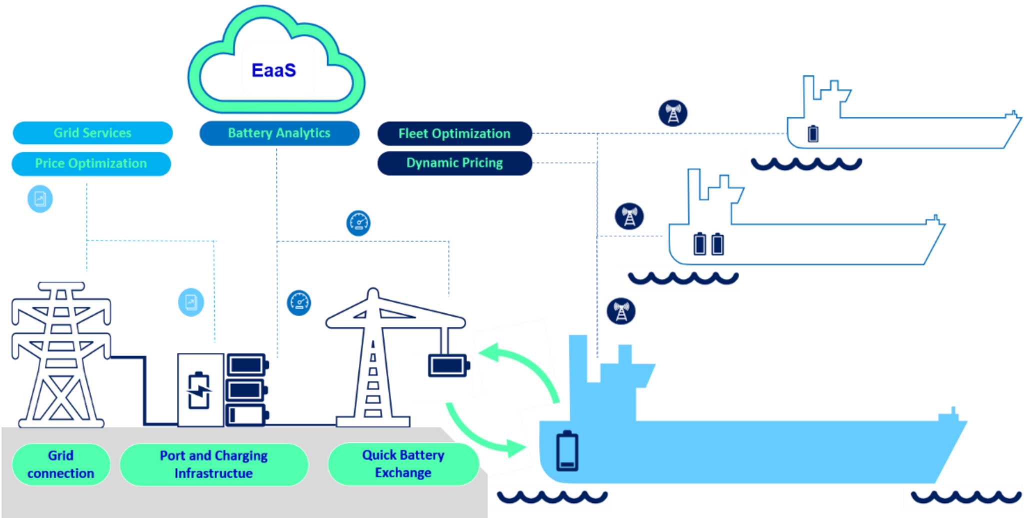

Figure 1: Scheme of the Current Direct Ecosystem.

4. Product Efficiency Analysis and Plan for Battery Cell and System Production

Because our production line is scaled well beyond the capacity required to meet cell-production targets, we conducted an efficiency analysis from a neutral perspective. We simulate a scenario of a production facility with a hypothetical bottleneck in the cell formation.

1. Introduction

The global demand for high-performance battery cells and systems is rapidly increasing, driven by the growth of electric vehicles (EVs), energy storage solutions, and portable electronics. To remain competitive in this dynamic market, manufacturers must continuously optimize their production processes to maximize efficiency, reduce costs, and ensure scalability. This Product Efficiency Analysis provides a comprehensive framework for assessing and improving the efficiency of battery cell and system production, with a particular focus on identifying and resolving bottlenecks in the manufacturing process.

The plan follows a structured methodology, beginning with an in-depth analysis of the current production state, including the identification of bottlenecks and inefficiencies. It then evaluates various optimization strategies, ranging from capital-intensive investments in new machinery to lean manufacturing and automation solutions. A detailed implementation roadmap is provided, outlining short-term, medium-term, and long-term actions to enhance production efficiency. Additionally, the plan includes risk management strategies to mitigate financial, operational, and scalability challenges, as well as key performance indicators (KPIs) to measure success.

By following this plan, a company can systematically improve its production processes, ensuring that it meets current demand while maintaining the flexibility to scale operations in response to future market growth.

2. Current State Analysis

2.1 Bottleneck Identification

The first step in optimizing production efficiency is to identify the primary bottlenecks that limit overall output. A bottleneck is defined as the slowest process in a production line, which restricts the throughput of the entire system. In the context of battery cell production, the formation process has been identified as the most significant bottleneck in Leclanché's case.

2.1.1 Formation Process as the Primary Bottleneck

The formation process is a critical stage in battery cell manufacturing, where the electrochemical properties of the cell are stabilized through controlled charging and discharging cycles. This process ensures that the cell reaches its optimal performance before being integrated into a battery system. However, the formation process is inherently time-consuming due to the need for precise control of voltage, current, and temperature. Additionally, the process often requires manual interventions, such as adjustments to charging parameters or quality checks, which further slow down production.

To confirm the formation process as the bottleneck, a detailed analysis was conducted, including:

- Time studies to measure the cycle time of each production step
- Value stream mapping to visualize material and information flow
- Cycle time analysis to identify the slowest process in the production line

The findings confirmed that the formation process has the lowest throughput rate, limiting the overall production capacity of the facility.

2.1.2 Secondary Bottlenecks

While the formation process is the primary bottleneck, other processes, such as coating, assembly, and testing, must also be monitored to prevent secondary bottlenecks from emerging after the formation process is optimized. For example, if the formation process is accelerated without corresponding improvements in downstream processes, the overall production system may still be constrained by another stage.

2.2 Key Challenges in Current Production

The current production system faces several challenges that must be addressed to improve efficiency:

- Capacity Constraints: The formation process cannot keep up with demand, leading to idle time in downstream processes. This results in inefficiencies, as other production stages must wait for cells to be formed before proceeding. The inability to meet demand can also lead to lost sales opportunities and delayed deliveries to customers.

- High Costs: Investing in new machinery or increasing staff to address the bottleneck comes with significant financial implications. Capital expenditures for new equipment require substantial upfront investment, and additional personnel increase labor costs. Furthermore, the return on investment (ROI) must be carefully evaluated to ensure that the increased production capacity justifies the costs.

- Operational Risks: Hiring additional staff to support increased production introduces operational risks, such as unintended knowledge transfer or data piracy. Employees with access to sensitive production data or proprietary processes may inadvertently disclose information to competitors or external parties. Additionally, a larger workforce requires more extensive training and supervision, which can strain resources.

▪ Scalability Issues: The current production setup may not be easily scalable to meet future demand growth. If the company plans to expand its production capacity significantly, the existing infrastructure may require major modifications or replacements. This highlights the need for a scalable solution that can adapt to changing market conditions.

3. Potential Solutions to Increase Throughput

To address the bottleneck in the formation process, several potential solutions have been identified, each with its own advantages and disadvantages. The most viable options are discussed below.

3.1 Option 1: Increasing Processing Machinery (Capital-Intensive Approach)

One approach to increasing throughput is to invest in additional formation machines or upgrade existing equipment to higher-capacity models. This solution directly addresses the bottleneck by increasing the production rate of the slowest process.

Pros:

▪ Directly increases production capacity, allowing the facility to meet higher demand

▪ Reduces cycle time for the formation process, enabling faster throughput

▪ Improves consistency and quality if new machines are equipped with advanced control systems

Cons:

▪ High upfront investment is required to purchase and install new machinery

▪ Longer payback period due to additional personnel and maintenance costs

▪ Risk of overcapacity if demand does not grow as expected, leading to underutilized assets

3.2 Option 2: Process Optimization (Lean Manufacturing Approach)

Instead of investing in new machinery, the company can focus on optimizing the existing formation process using lean manufacturing principles. This approach aims to eliminate waste, reduce cycle times, and improve overall efficiency without significant capital expenditure.

Pros:

- Lower initial investment compared to purchasing new equipment
- Reduces waste and improves efficiency by streamlining workflows and minimizing non-value-added activities
- Flexible and adaptable to changing production requirements

Cons:

- Requires detailed process analysis to identify inefficiencies and implement improvements
- May not fully eliminate the bottleneck if demand grows significantly, as the underlying capacity constraints remain

3.3 Option 3: Automation & Digitalization

Automation and digitalization offer a modern solution to increasing production efficiency. By integrating automated systems and digital tools, the company can reduce reliance on manual labor, improve consistency, and enable real-time monitoring of the formation process.

Pros:

- Reduces reliance on manual labor, lowering personnel costs and minimizing human error
- Improves consistency and quality through precise control of process parameters
- Enables real-time monitoring and predictive maintenance, reducing downtime and improving equipment reliability

Cons:

- High initial investment in automation technology, including robotics, sensors, and software
- Requires training for existing staff to operate and maintain automated systems

3.4 Option 4: Hybrid Approach (Combination of Solutions)

A hybrid approach combines elements of the above solutions, balancing cost, scalability, and operational efficiency. For example, the company could invest in partial automation of the formation process while also implementing lean manufacturing techniques to optimize workflows.

Pros:

- Balances cost and scalability, allowing for gradual implementation based on demand
- Flexible and adaptable to changing production requirements

Cons:

- Requires careful planning to avoid mismatched capacities between different production stages

4. Recommended Action Plan

To systematically address the bottleneck in the formation process, a structured action plan has been developed, divided into short-term, medium-term, and long-term phases.

4.1 Short-Term (0-6 Months)

The short-term phase focuses on conducting a detailed analysis of the formation process and implementing quick wins to improve efficiency without significant investment.

4.1.1 Conduct a Detailed Bottleneck Analysis

- Perform time studies to measure the cycle time of each step in the formation process

- Use value stream mapping to visualize material and information flow, identifying areas of waste and inefficiency

- Conduct a cycle time analysis to confirm the formation process as the primary bottleneck and assess the impact of secondary bottlenecks

4.1.2 Implement Quick Wins

- Optimize scheduling to minimize idle time in downstream processes, ensuring that cells are formed and moved to the next stage as quickly as possible

- Improve maintenance practices, such as implementing predictive maintenance to reduce unplanned downtime

- Train operators to perform quick adjustments to the formation process, reducing the need for manual interventions

4.2 Medium-Term (6-12 Months)

The medium-term phase involves piloting potential solutions, such as automation or process optimization, and assessing their feasibility before full-scale implementation.

4.2.1 Pilot Automation or Process Improvements

- Test automated formation equipment in a controlled environment to evaluate its impact on throughput and quality

▪ Implement lean manufacturing techniques, such as Single-Minute Exchange of Die (SMED), 5S workplace organization, and Kanban inventory management, to streamline workflows

4.2.2 Assess Financial Feasibility

▪ Calculate the return on investment (ROI) for different solutions, comparing the costs of new machinery, automation, and process optimization

▪ Explore financing options, such as loans, leasing, or government grants, to fund the chosen solution

4.3 Long-Term (12+ Months)

The long-term phase focuses on full-scale implementation of the selected solution, continuous monitoring, and ongoing improvement.

4.3.1 Full-Scale Implementation

▪ Deploy the most cost-effective solution, whether it is automation, additional machinery, or a hybrid approach

▪ Monitor performance metrics, such as throughput rate and cycle time, to ensure that the solution meets expectations

4.3.2 Continuous Improvement

▪ Establish a Kaizen culture to encourage ongoing efficiency improvements

▪ Regularly review production metrics to identify new bottlenecks and opportunities for optimization

5. Risk Management & Mitigation

Implementing changes to the production process introduces various risks that must be managed to ensure success.

5.1 Financial Risks

▪ High Investment Costs: Investing in new machinery or automation requires significant capital, which may strain financial resources.

o Mitigation: Conduct a sensitivity analysis to assess the payback period under different demand scenarios. Explore financing options to spread the cost over time.

5.2 Operational Risks

▪ Data Security and Knowledge Leaks: Hiring additional staff or integrating new systems may increase the risk of unintended knowledge transfer or data piracy.

o Mitigation: Implement strict access controls and employee training to prevent unauthorized access to sensitive information.

5.3 Scalability Risks

▪ Future Demand Growth: The chosen solution must be scalable to accommodate potential increases in demand.

o Mitigation: Ensure that the solution can be scaled up by investing in modular equipment or flexible production systems.

5.4 Technical Risks

▪ Automation Failures: Automated systems may experience technical issues, leading to downtime and reduced efficiency.

o Mitigation: Test automation in pilot phases before full deployment to identify and resolve potential issues.

5. Conclusion & Next Steps

This Product Efficiency Plan provides a comprehensive framework for optimizing battery cell and system production. By systematically addressing the bottleneck in the formation process, the company can improve efficiency, reduce costs, and ensure scalability to meet future demand.

Next Steps:

1. Finalize bottleneck analysis to confirm the formation process as the primary constraint
2. Select the most viable solution based on financial and operational feasibility
3. Begin pilot testing of automation or lean manufacturing techniques
4. Gradually implement the chosen solution while monitoring performance