



T6.2.3 Hybrid ship control system

Session 03: Future Trends in Safe and Efficient Vessel Operation

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FLEXSHIP



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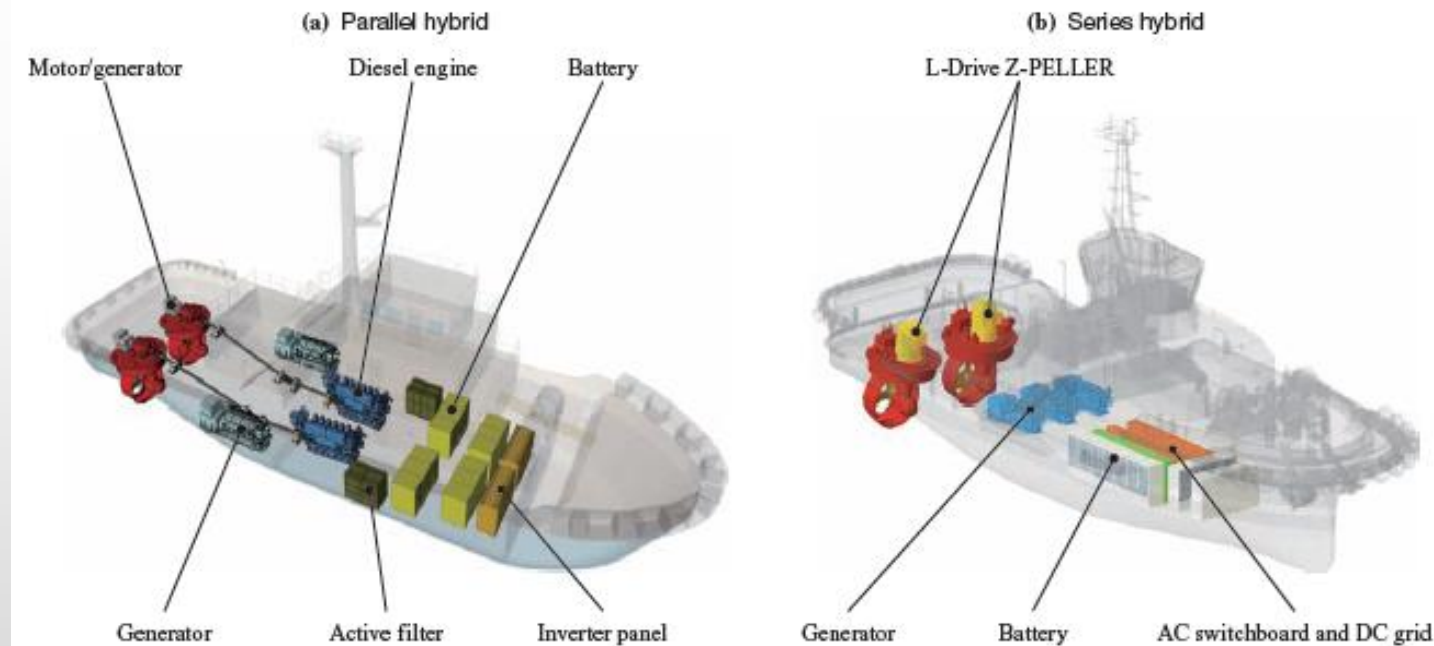
1. Training 1: Regulatory and market developments
2. Training 2: Emerging technologies in battery safety and maintenance
3. Training 3: Li-ion Battery Safety: Risks, Recommendations, and Safety Standards



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1. **Training 1: Regulatory and market developments**
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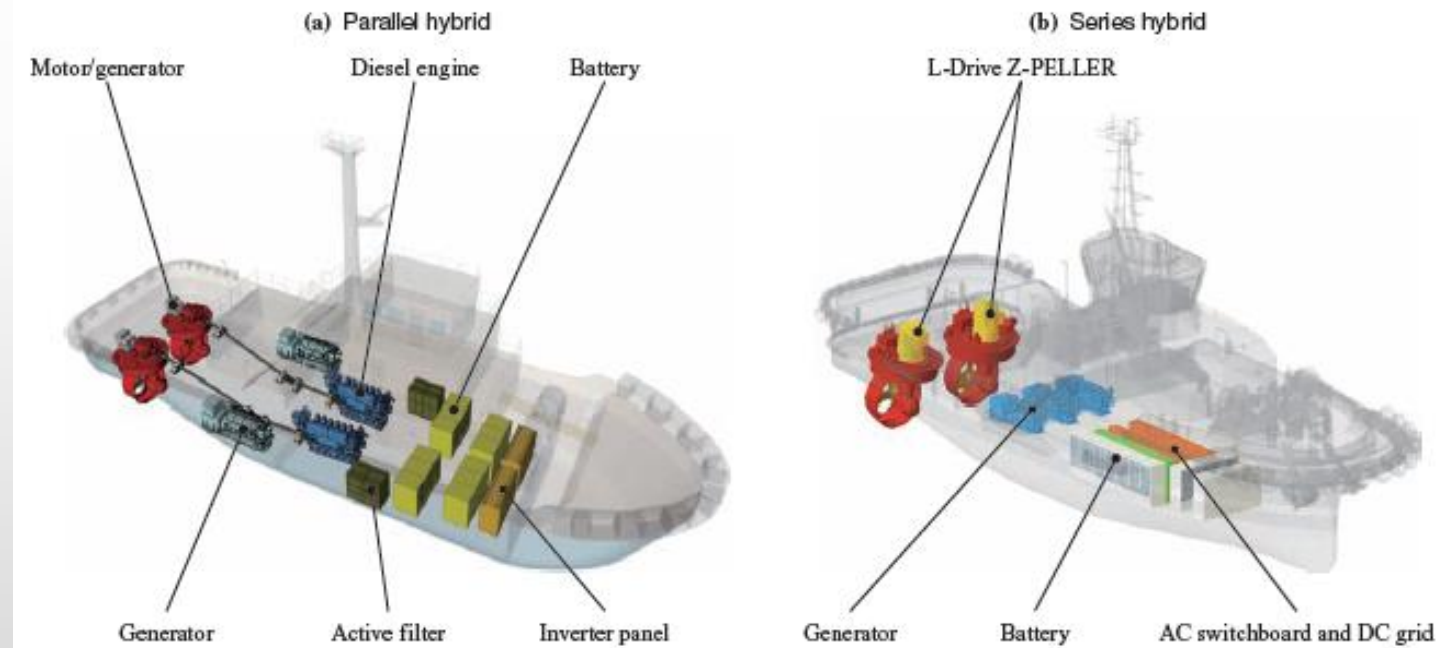
- In recent years, the maritime sector has been subjected to significant regulatory shifts and evolving market expectations.
- These changes have primarily been driven by global climate targets, regional decarbonization policies, and the strategic need for energy diversification.
- In this context, battery-electric and hybrid systems are increasingly being viewed as viable alternatives to traditional propulsion methods.



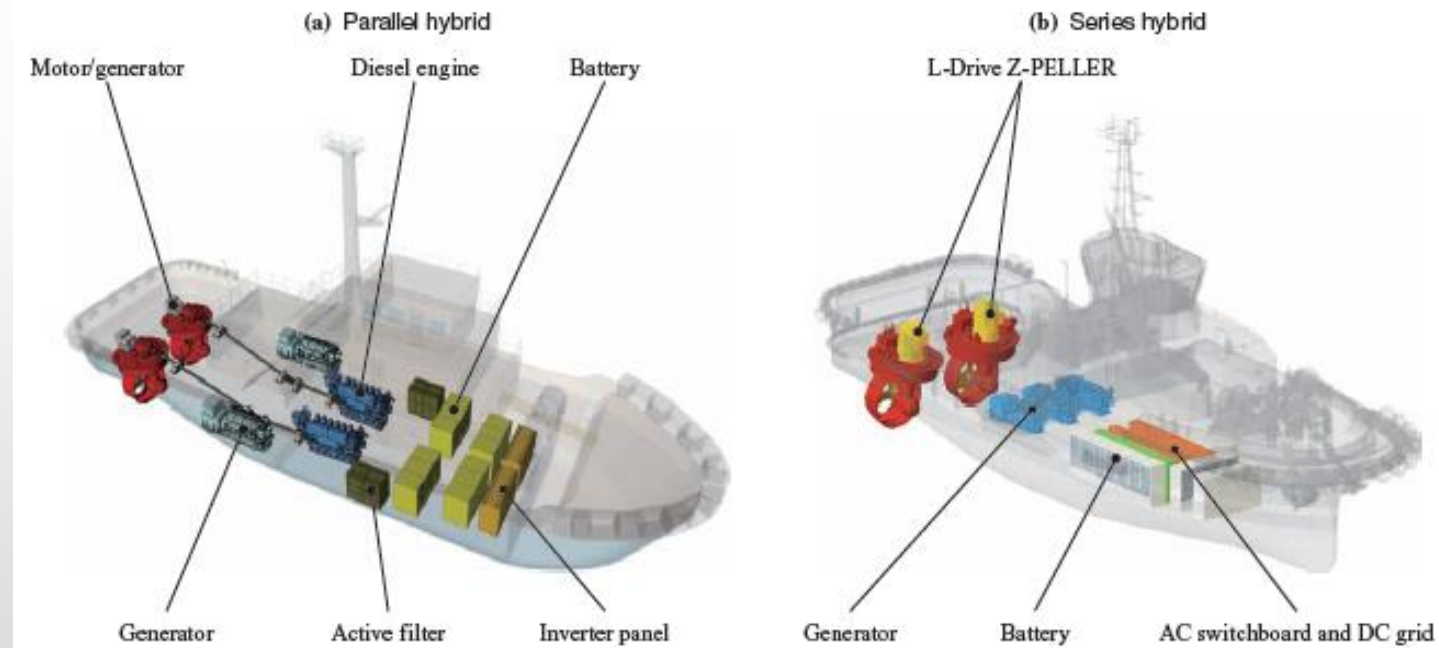
4. Integration

4.1 Overview of system integration

A range of global regulatory frameworks has been introduced or updated to support maritime decarbonization. Notably, the International Maritime Organization (IMO) has mandated reductions in carbon intensity under its **Initial GHG Strategy**, while regional entities such as the **European Union** have enforced directives including **FuelEU Maritime** and the **EU Emissions Trading System (ETS)**. These measures are expected to accelerate the adoption of alternative propulsion and energy storage solutions across fleets operating in compliance-sensitive regions.



New classification notations, such as those issued by **DNV**, **ABS**, and **Bureau Veritas**, are being adopted for vessels powered by lithium-ion battery systems. In parallel, international standards like **IEC 62619**, **ISO 12405**, and **SAE J2464** are being referenced for cell testing, abuse tolerance, and battery integration safety. Regulatory pressure is increasingly being translated into precise design and testing expectations for shipbuilders and operators alike.



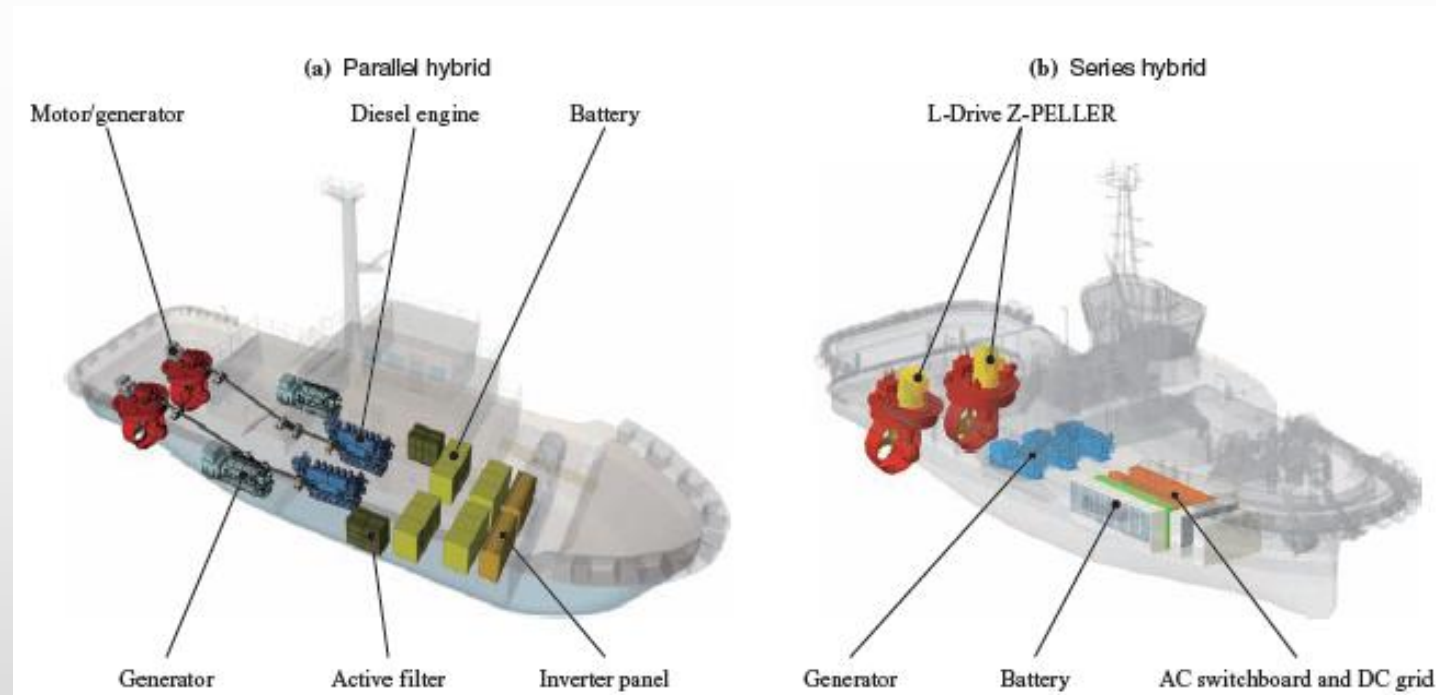
4. Integration

4.1 Overview of system integration

Incentives and financing mechanisms are being implemented at both national and supranational levels. Examples include:

- **Green shipping corridors**
- **Zero-emission berth regulations**
- **Subsidy programs** under the EU Green Deal, Horizon Europe, and CEF Transport

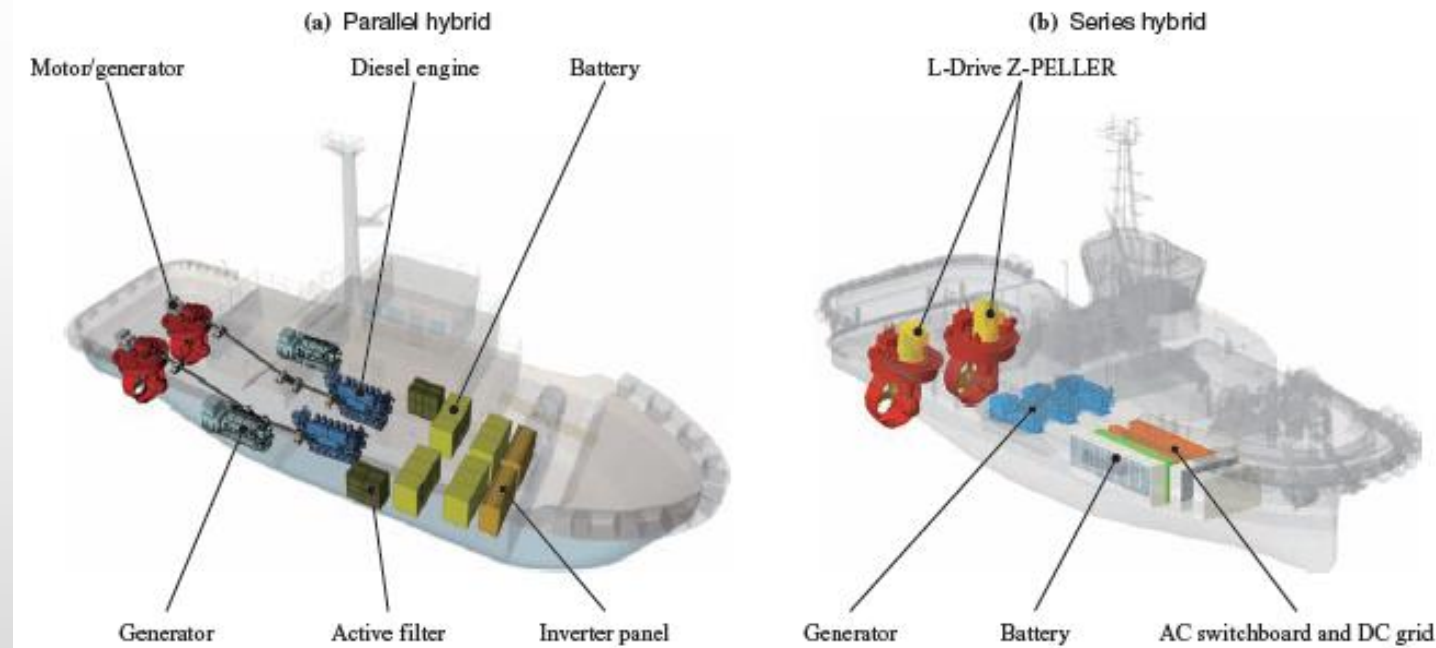
These tools are intended to lower capital expenditure barriers, de-risk investments, and promote early deployment of electrification technologies across short-sea and inland waterway transport sectors.



4. Integration

4.1 Overview of system integration

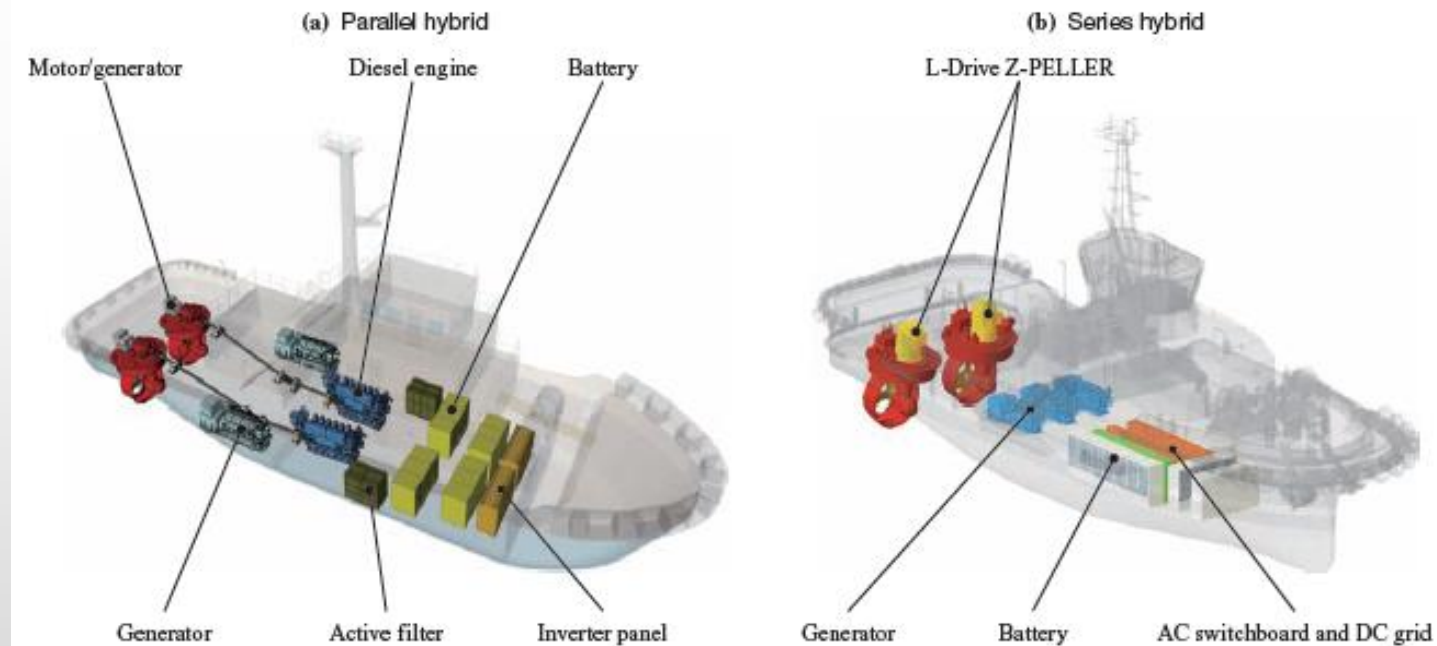
Shipping companies have begun integrating modular ESS (Energy Storage Systems) and hybrid propulsion into vessel retrofits and new builds. Demonstration projects have been accelerated through public-private partnerships. The growing demand for lifecycle carbon reporting has prompted digital platforms to be used for energy monitoring, traceability, and regulatory reporting—thus transforming compliance into an operational performance metric.



4. Integration

4.1 Overview of system integration

The regulatory environment is expected to become more stringent, with dynamic emission thresholds and lifecycle accountability metrics (including Scope 3 emissions) potentially being introduced. Battery passporting, AI-enhanced digital verification, and regulatory sandboxes may be institutionalized to support transparency and innovation. Over the long term, alignment between commercial competitiveness and regulatory compliance is anticipated to be achieved through system-level optimization supported by predictive analytics and smart energy models.





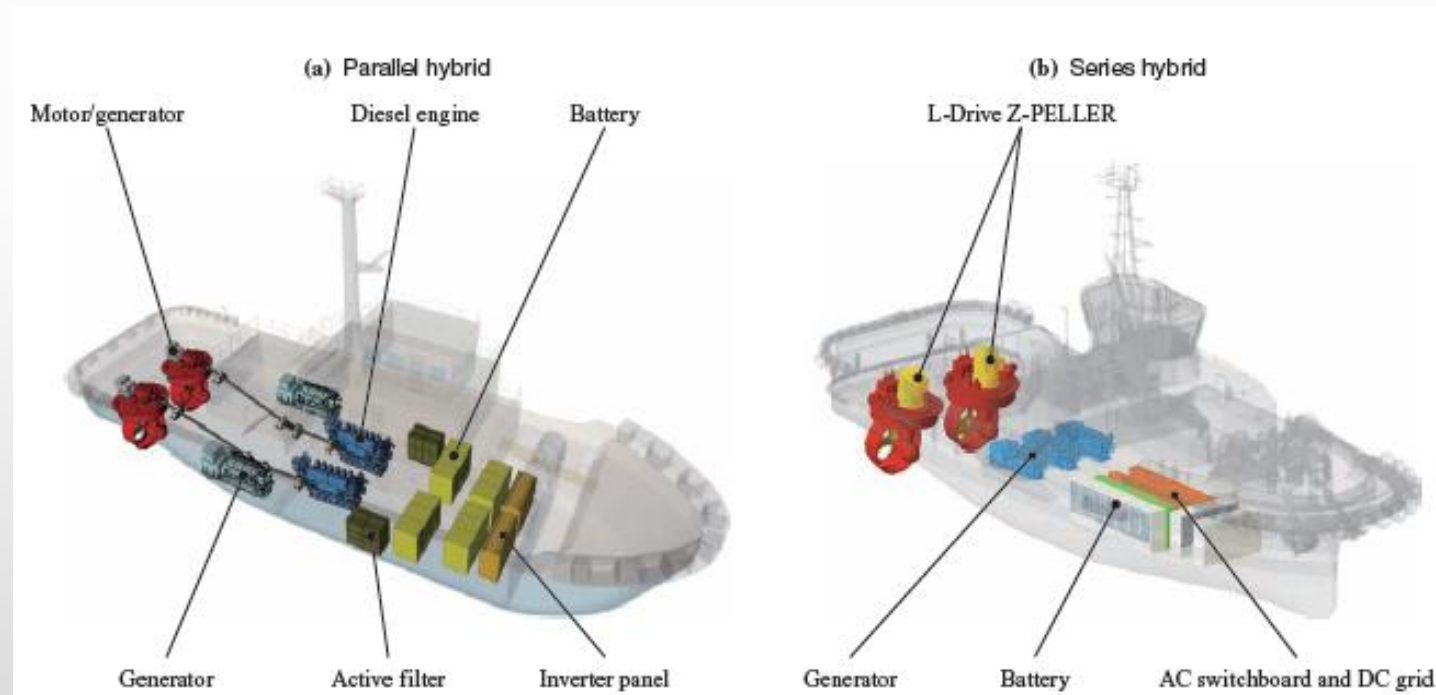
4. Integration

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4.1 Overview of system integration

During various operational phases

- enhance overall operational efficiency
- utilizing the strengths of both systems in different operational scenarios
- vessel's range
- typical operating conditions
- power requirements
- switching between power modes
 - fully electric
 - combined engine
 - battery or engine-only mode



Profound impact on various aspects of vessel operations

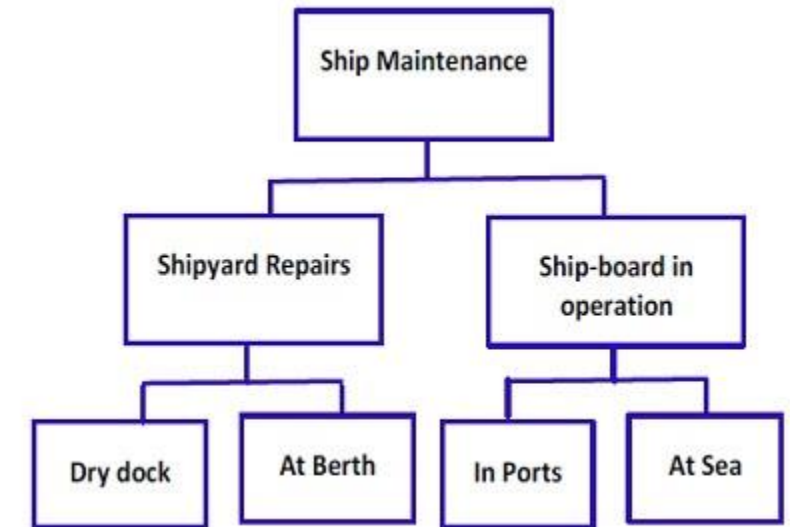
- fuel efficiency
- emissions control
- maintenance needs
- operational flexibility

Leading to significant operational cost savings

Hybrid vessels can operate in electric-only mode during harbor maneuvers

Favorable conditions

- vessel is traveling at a steady speed
- reducing fuel consumption significantly
- significantly reduce their greenhouse gas (GHG) emissions
- impact of hybrid integration extends to maintenance requirements
- less maintenance for internal combustion engines
- lower loads which reduces wear and tear over time





Future Trends in Safe and Efficient Vessel Operation

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- As maritime operations transition toward hybrid and fully electric vessels, ensuring safety and efficiency becomes increasingly critical.
- This module explores the future trends in vessel operation with a focus on maintenance strategies, battery safety, and system integration.
- Effective maintenance protocols are essential for the reliability and longevity of energy storage systems.
- Regular inspections, preventive measures, and diagnostic testing help identify faults early and optimize vessel performance.
- Lithium-ion batteries, while widely used for their energy density, present inherent risks such as thermal runaway, overcharging, and mechanical damage.
- Ensuring safety requires engineering controls like Battery Management Systems (BMS), proper user practices, and emergency preparedness, including fire suppression systems and thermal monitoring.



- Common maintenance issues—including battery degradation, heat buildup and slow power delivery—can be addressed through structured protocols for generators, inverters, converters, and rectifiers.
- Sustainable operation also involves energy-efficient technologies, emissions monitoring, and life cycle management, including second-life battery applications.
- On the safety front, international standards such as IMO, ISM, and SOLAS guide risk assessment, crew training, and emergency response.
- Preparedness for emerging situations (fire, flooding, medical incidents) is crucial, as is the availability of appropriate safety equipment and post-incident support, including mental health care for affected crew.



The integration of hybrid propulsion systems enables vessels to switch dynamically between

- electric,
- engine, and
- combined modes, enhancing fuel efficiency, reducing emissions, and lowering maintenance requirements.

As the industry evolves, technologies like

- solid-state batteries,
- AI-driven diagnostics, and
- IoT-enhanced systems will drive the future of maritime safety and efficiency.

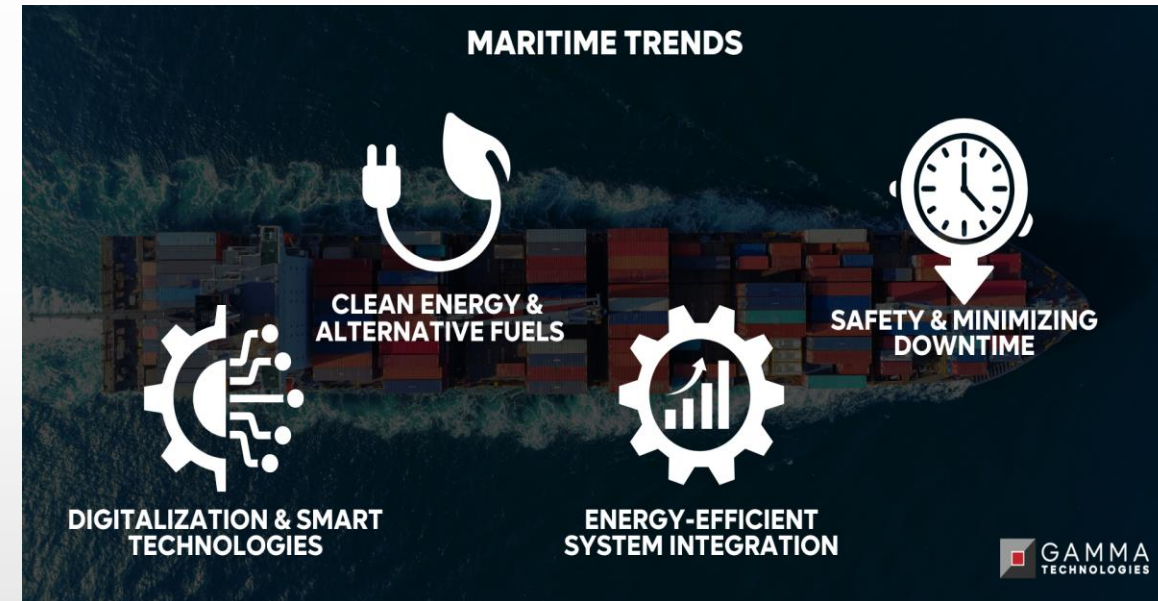




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Why Safety Matters?

Lithium-ion batteries are widely used in:

- Consumer electronics
- Electric vehicles (EVs)
- Renewable energy storage

High energy density makes them powerful but **potentially hazardous**

Key Hazards:

Fire and explosion risks from:

- Overheating
- Mechanical damage
- Manufacturing defects

Importance of Safety:

- Prevent accidents and protect users
- Ensure reliability in mission-critical applications
- Comply with global safety standards





Li-ion Battery Safety: Risks, Recommendations, and Safety Standards

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Common Li-ion Battery Safety Risks

1. Thermal Runaway

- A chain reaction where heat causes further heating
- Can result in fire or explosion
- Often triggered by:
 - Overcharging
 - Internal short circuits
 - Physical damage

2. Mechanical Abuse

- Punctures or deformation can cause internal shorts
- Damaged separators may lead to direct contact between electrodes

3. Electrical Abuse

- Overcharging, deep discharging, and external short circuits
- Leads to heat build-up, chemical instability

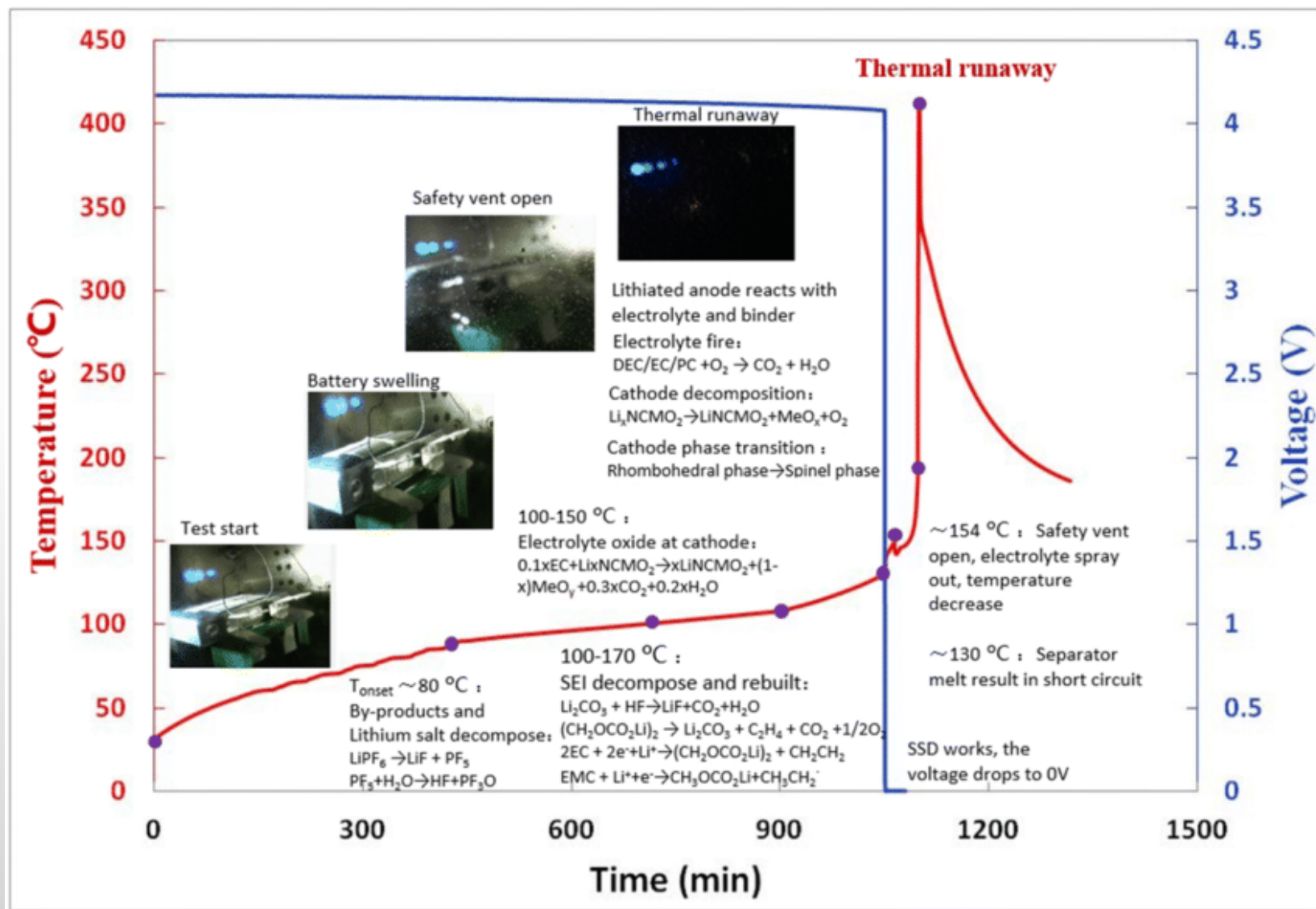
4. Environmental Conditions

- Operating outside recommended temperature or humidity range
- Moisture or extreme heat can degrade cell performance or trigger failure



Li-ion Battery Safety: Risks, Recommendations, and Safety Standards

Managing Hazards and Ensuring Compliance in Li-ion Systems





Li-ion Battery Safety: Risks, Recommendations, and Safety Standards

FLEXSHIP Safety Recommendations

Design & Engineering Controls

- Integrate a **Battery Management System (BMS)** to:
 - Monitor temperature, voltage, current
 - Prevent overcharge/discharge
- Include **thermal barriers, pressure relief vents, and flame-retardant enclosures**

User & Operational Practices

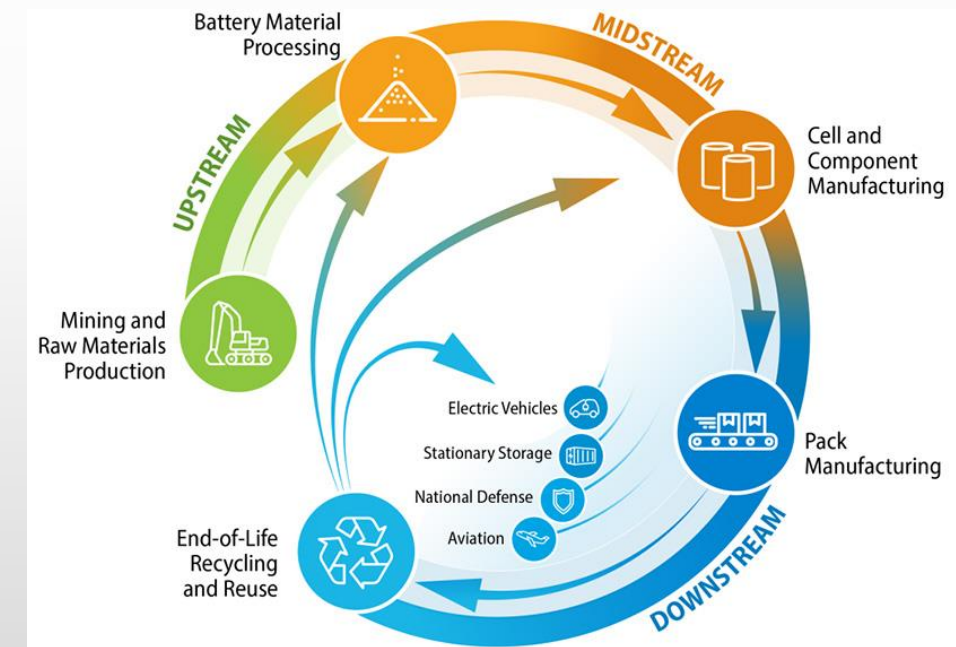
- Use **manufacturer-approved chargers**
- Avoid full charge cycles daily → reduces degradation
- Never crush, puncture, or immerse in water

Storage & Transport

- Store at 40–60% State of Charge (SoC)
- Ideal temperature: 15–25°C
- Avoid metal contact with terminals
- Follow UN38.3 requirements for air/sea transport

Emergency Preparedness

- Use **Class D or clean agent extinguishers** (e.g., Halotron)
- In large installations: Install **thermal imaging, gas detection, and fire suppression systems**



Conclusion

Summary:

- Lithium-ion batteries are safe **when properly managed**
- Risk arises from poor design, misuse, or lack of regulation
- Safety requires **proactive strategies**, including:
 - Engineering controls
 - Best practices
 - Regulatory adherence

Looking Ahead:

- **Solid-State Batteries:** Safer, more stable electrolyte alternatives
- **AI & IoT-based BMS:** Predict failures before they occur
- **Global Harmonization:** Need for unified standards across industries



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Why Battery Safety and Maintenance Matter?

- Increasing energy density → higher risk
- Thermal runaway and fire hazards
- Maintenance ensures longevity and performance
- Critical for electric vehicles (EVs), grid storage, aerospace, etc.

Lithium-ion Battery Safety

 	Only use manufacturer-provided or authorized batteries and charging equipment. All equipment should be certified by a Nationally Recognized Testing Laboratory .		Remove the battery or charging device from power once charging is complete to avoid overheating
 	Keep batteries and charge them at room temperature . Issues can occur below 32° F or above 105° F		Keep batteries and devices from heat sources or anything that can catch fire
 	Do not store batteries in vehicles or direct sunlight		All maintenance on batteries or e-mobility devices should be completed by a qualified professional



Emerging technologies in battery safety and maintenance

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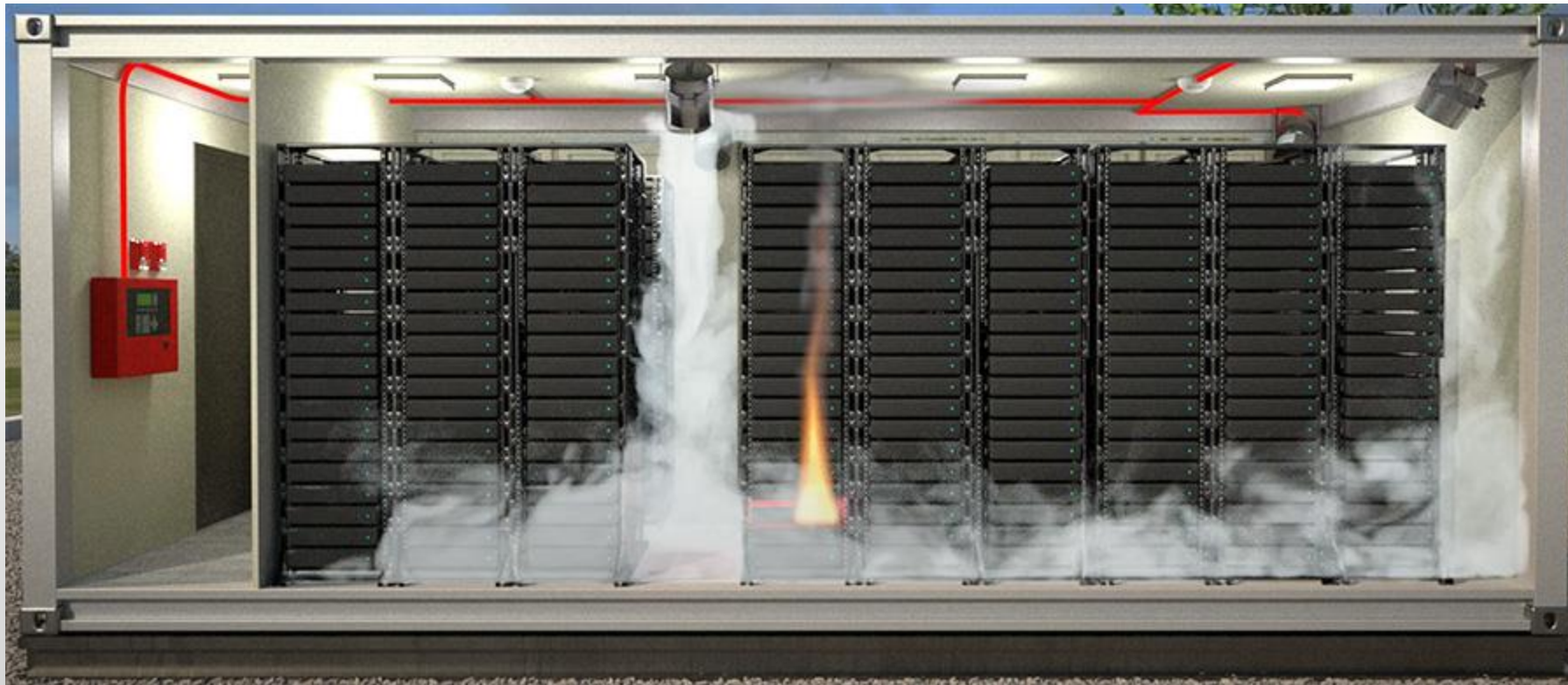
Self-Healing Materials and Smart Electrolytes

- Coatings that repair microcracks
- Electrolytes that suppress dendrite growth
- Thermal shutdown separators
- Flame-retardant additives



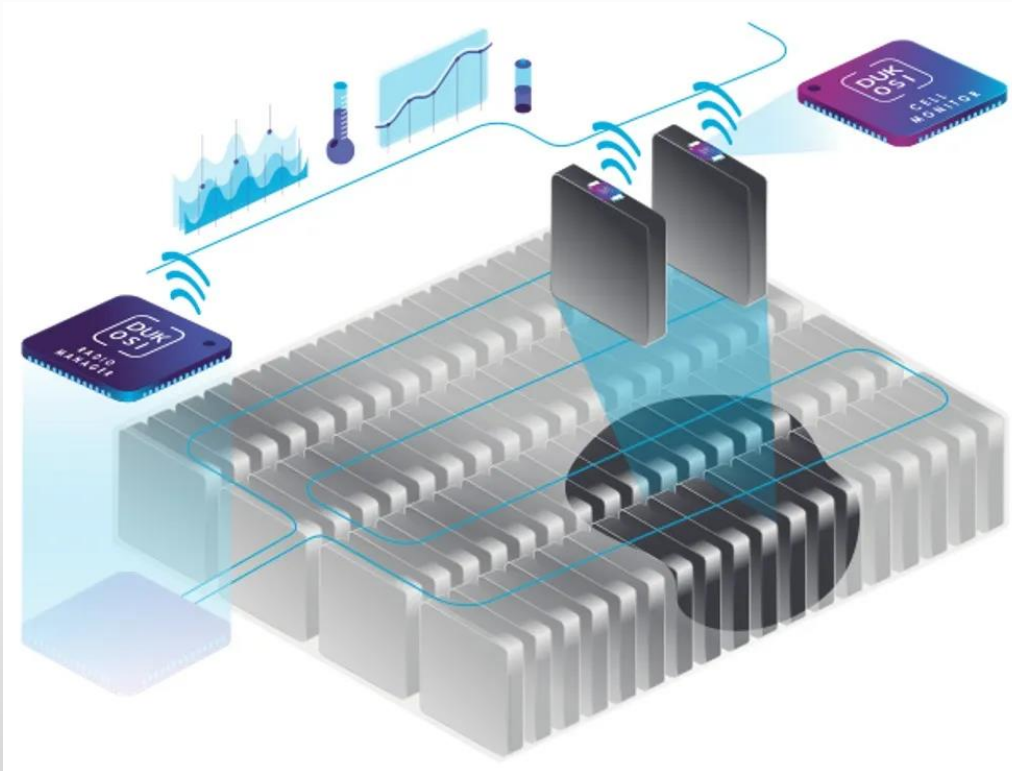
Fire Suppression and Emergency Systems

- Built-in aerosol suppression
- External fire blankets and capsules
- Advanced thermal foams
- Sensor-triggered gas release



Wireless Monitoring and IoT Integration

- Wireless battery sensing systems
- Real-time cloud diagnostics
- Remote failure alerts and control
- Cybersecurity in battery communication



- Autonomous maintenance systems
- AI-coordinated fleets
- Next-gen BMS chips
- Quantum sensors?
- Regulatory updates (UNECE R100, UL 9540A)



Thanks for your attention!