MESD Seminar

1st December 2023

SEA FORREST®

Practical Considerations for Vessel Electrification

Capt. Kevin Wong

Chief Operating Officer

SEA FORREST

VISION

GREEN SOLUTIONS FOR THE BLUE ECONOMY

MISSION

To deliver cost-efficient, innovative and simple solutions,
enabling mass adoption to reduce maritime carbon footprint

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TIMELINE

2011

Incorporation

Specializing in project management of oil rig construction, afloat repairs/maintenance and fabrication services

2019

Electrification

Development of marine electrification, charging and marine energy storage solutions
Provided the hybrid solution for Singapore's first hybrid powered pilot boat.

2021

Acquisition

Acquired by BH Global and rebranding to Sea Forrest Technologies with Sea Forrest Power Solutions and Sea Forrest Engineering, as wholly owned subsidiaries

2023

Delivery

Delivered:

- Full Electric Propulsion
- Full Electric Ready Propulsion
- Green Hybrid Propulsion
- Green Cabin Energy Saving System

SEA FORREST

OUR TEAM

GEORGE LEE
FOUNDER & CEO
BEng Mechanical and Prod Engrg
MSc in Industrial and System Engrg
Project Manager, Keppel FEL
CTO & Proj Dir, CIMC Raffles Shipyard

CAPT KEVIN WONG
CHIEF OPERATING OFFICER (COO)
Master Mariner / MSc Maritime Studies
Port Master, MPA
GM Grp Ops & Sustainable Developments,
Penguin International Ltd

DR TAN WEI KIONG (PhD)
CHIEF TECHNOLOGY OFFICER (CTO)
BSc EEE and PhD Optoelectronics, University of Glasgow
ASTAR, STE, BroadCom Inc.
CTO, TSMART

EDMUND CHAN
CHIEF FINANCE OFFICER (CFO)
MBA at Heriot Watt University
VP Commercial at Gryphon Energy

Supported by in-house talents specializing in:

- Automation Software & Controls
- Electrical Engineering
- Marine Engineering
- Maritime Operations
- Mechanical Engineering
- Mechatronics

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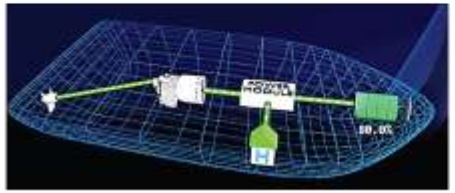
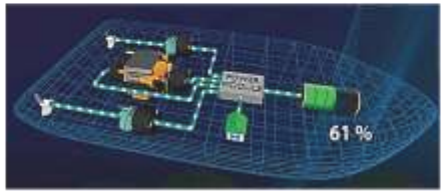
OUR SOLUTIONS

Helping vessel owners to *make step changes* to decarbonize

MARINE ELECTRIC PROPULSION SYSTEM



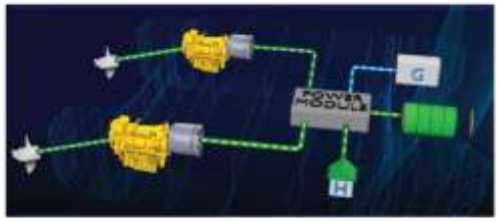
Full Electric Propulsion
Electric motor-driven
Zero-emissions
Suitable for harbour crafts, ferries, etc



Full Electric-Ready Propulsion
Electric motor-driven with generator
Serial hybrid
Improve efficiency & reduce emissions
Suitable for harbour tugs, supply boats, bunker tankers, container feeders, AHTS, PSVs, SOVs, etc

Green Hybrid Propulsion
Electric motor & diesel engine-driven
Parallel Hybrid
Reduce fuel consumption & emissions
Suitable for pilot boats, fast crew boats, CTVs, patrol crafts, etc

HYBRID POWER



GREEN CABIN
Energy Saving System
Peak-shaving and energy storage functions, powers hotel load when generators are off
Available for retrofitting and new builds
Suitable for fast crew boats, ferries, tankers, containerships, etc

- **Device agnostic to equipment brands and future energy sources**
- **In-house developed AI assisted Energy Management System**

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OUR SOLUTIONS

ENERGY STORAGE SYSTEMS

SEAGEN 11 & 22

Marinized Batteries

First marinized battery designed, built and type-approved in Singapore by BV & RINA (pending LR & ABS)

ENERGY CUBE

Marine & Offshore Energy Storage System

Peak-shaving and energy storage functions, for offshore vessels and platforms

Suitable for oil rigs, FPSOs, AHTS, SOVs, containerships, tankers, bulk carriers, etc

Marinized Battery Type Approval

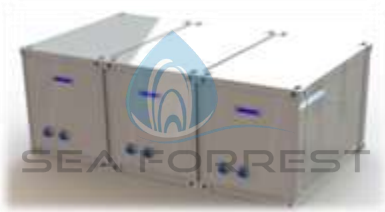
MOU for development of maritime electrification technologies

ENERGY CHARGING SYSTEMS

MARINE SMART ENERGY CHARGING SYSTEM

Shore-to-ship charging
Consists of charging arm, energy pillar, power pillar
Utilises constant tension cables & connections
300kWh, 400A, up to 950V

Suitable for harbour crafts, supply boats, tugs, ferries and pleasure crafts etc



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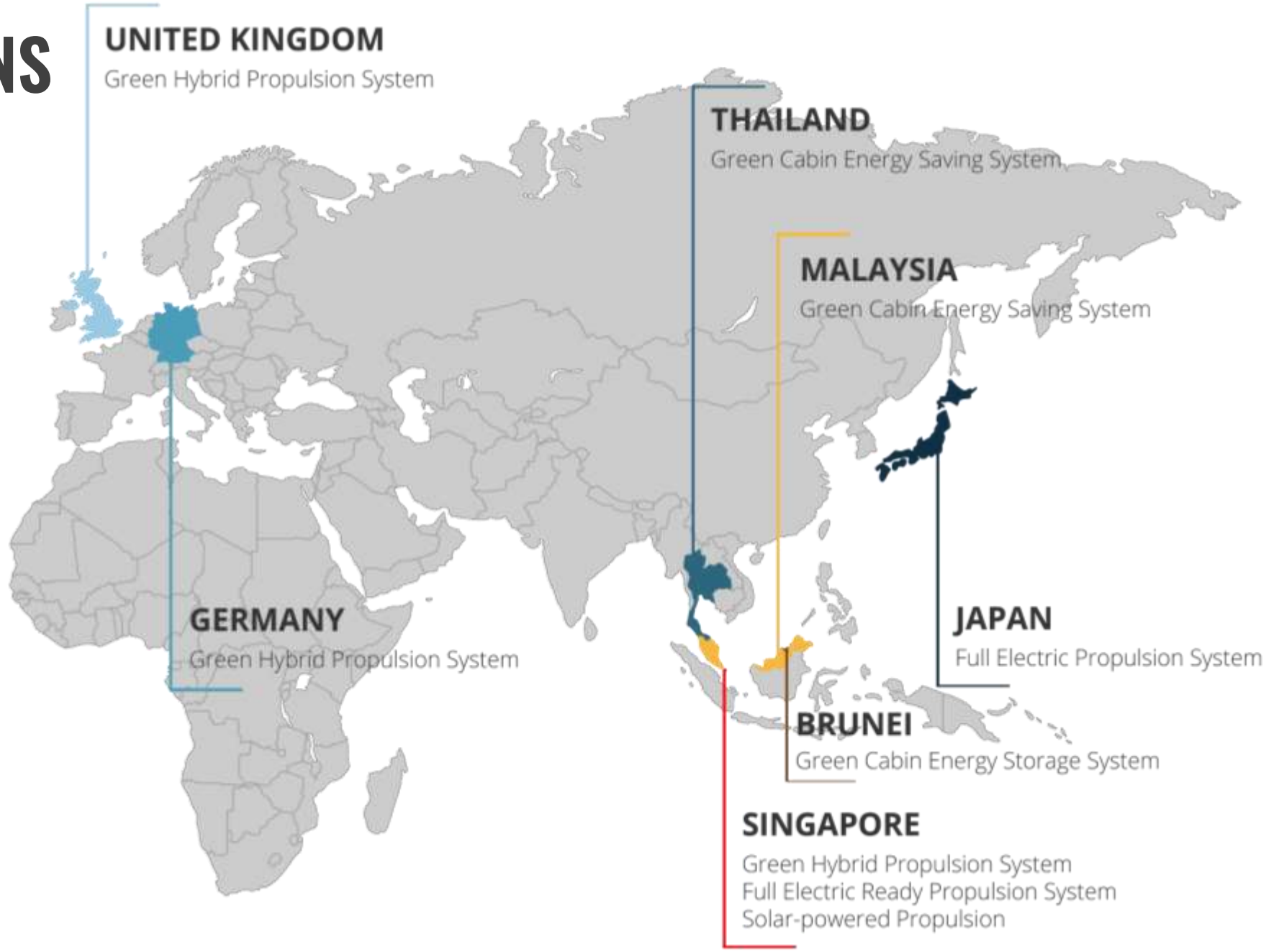
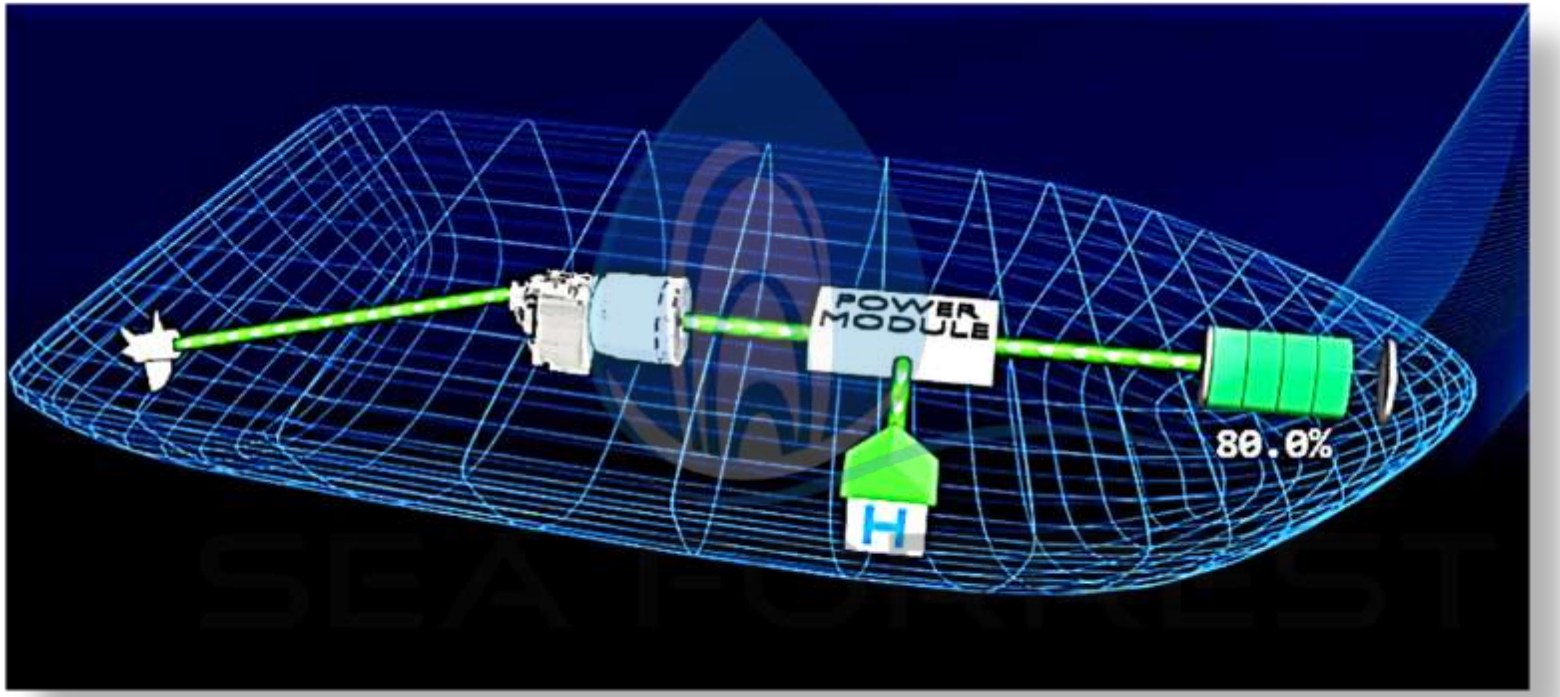
OUR SOLUTIONS



Types of Electric Hybrid Propulsion Systems

FULL ELECTRIC (FE) PROPULSION SYSTEM



Electrical motor driven, zero emission

Power source - onboard lithium-ion battery and plug-in charging from shore

Charging infrastructure (shore & offshore) required.

Application: Harbour tugs, passenger ferries, supply boats, harbour launches, etc.

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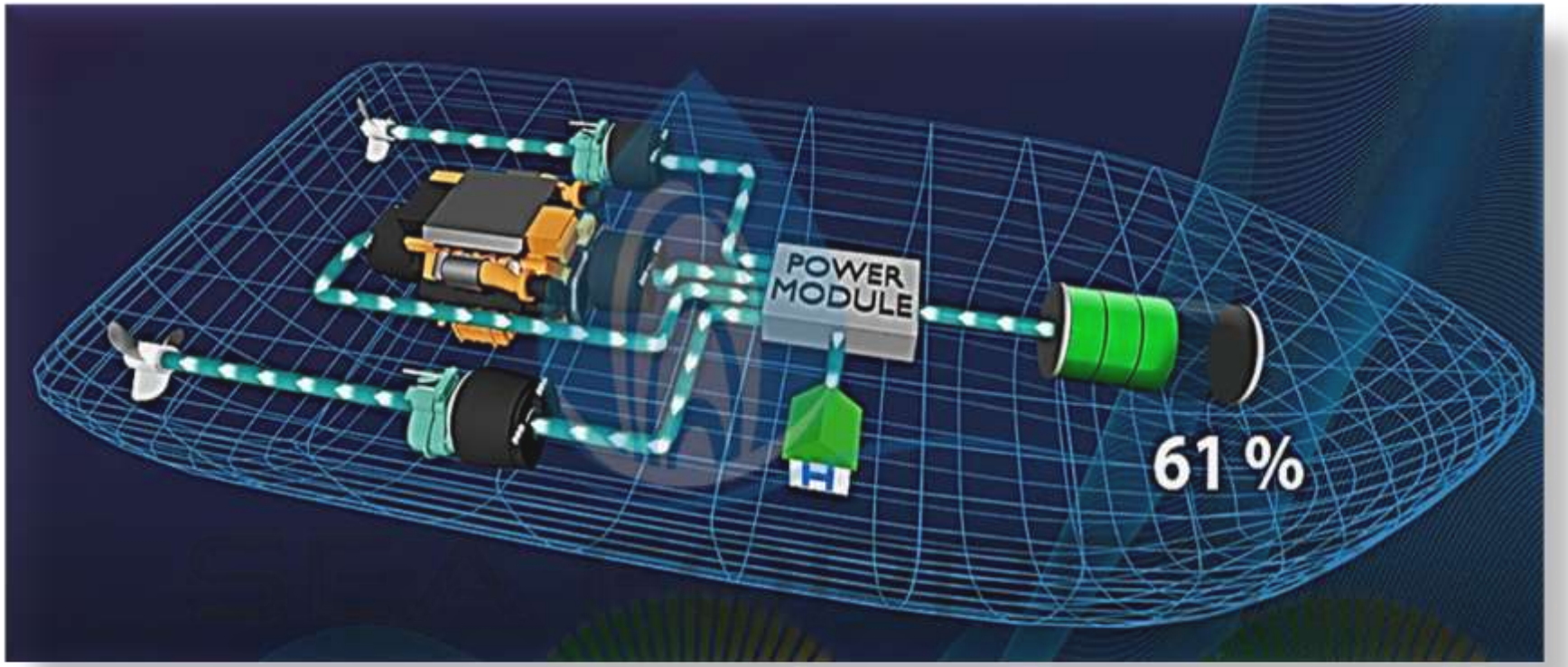
[SERIAL HYBRID] FULL ELECTRIC READY (FER) PROPULSION SYSTEM



Electrical motor driven, **serial hybrid**

Power source – onboard lithium-battery and/ or diesel (Bio) generator

Can be retrofitted with ***plug-in & fuel cells*** *(replacing generator)*

Applications - Bunker tankers, harbour tugs, supply boats, etc.

Suitable for vessels with varying operating profiles.

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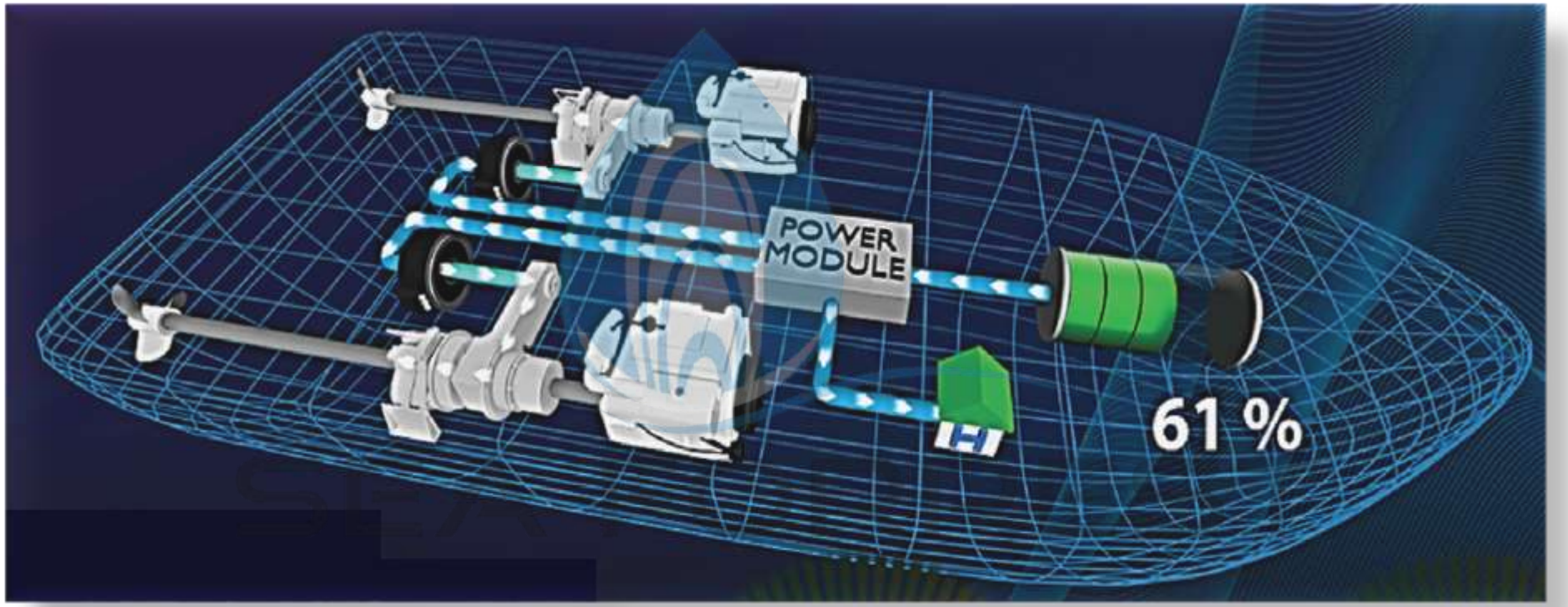
[PARALLEL HYBRID] GREEN HYBRID PROPULSION SYSTEM



Diesel and electric motor driven, **parallel hybrid**

Electric, Hybrid and Diesel Modes

Accepts **alternative net zero fuels** & retrofittable with **plug-in**

Suitable for vessels with high-speed loitering operating profiles.

Applications – Pilot boats, Wind farm CTVs, Fast crew boats, Patrol crafts etc

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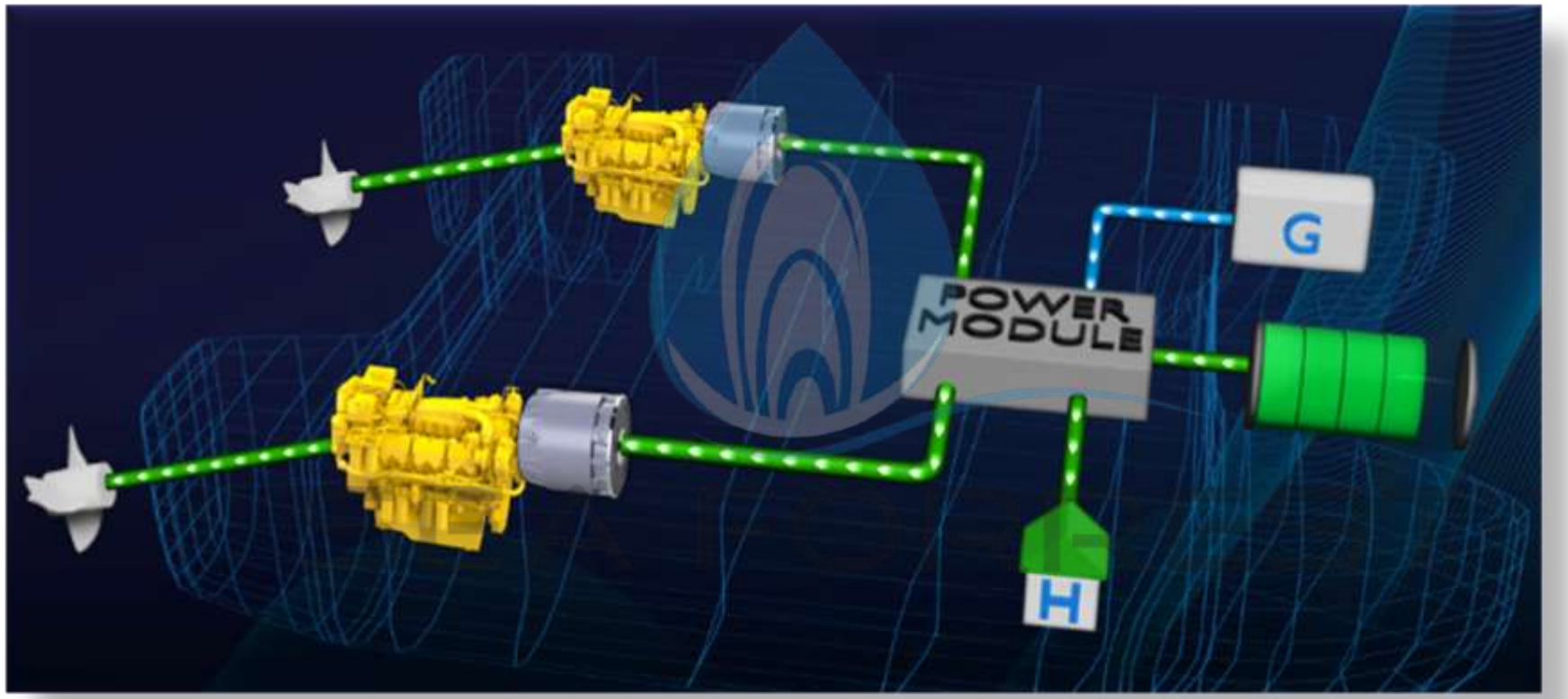
[HYBRID POWER] GREEN CABIN ENERGY SAVING SYSTEM



Taps excess energy from propulsion engines to generate electricity

Peak-shaving and energy storage functions, powers hotel load when engines are off, reduce generator running hours

Applications – Crew boat, ferries, bunker tankers, container feeder, etc

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Main Components for Electric Propulsion

Motors	Motor Drive & DC/AC Inverters	Battery & Battery Management System

Types of LI-ION Batteries

MAJOR TYPES OF LI-ION BATTERY

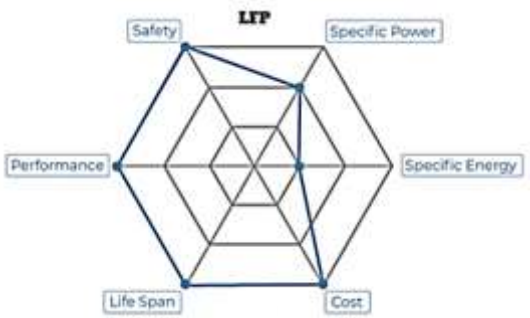
Lithium Iron Phosphate (LFP)

Benefit

Durability,
Long life cycle,
Safety

Drawbacks

Lower energy density,
poor performance in cold,
Low C rate



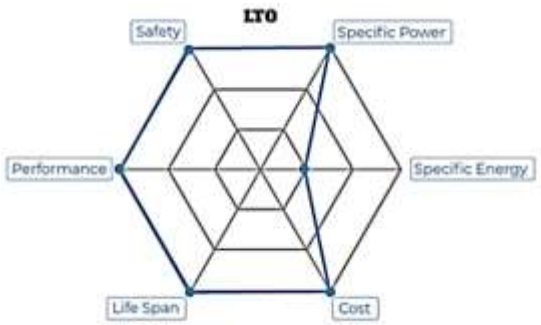
Lithium Titanate (LTO)

Benefit

Long life cycle,
Superbly Safe,
Wide operating temp.

Drawbacks

Expensive,
Low energy density



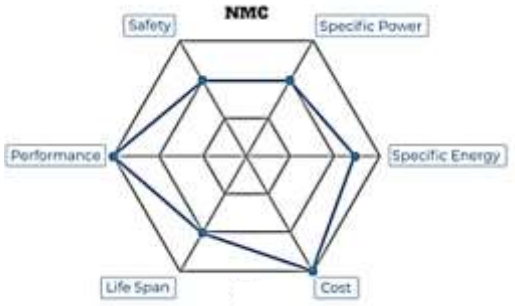
Lithium Nickel Manganese Cobalt (NMC)

Benefit

High energy density,
Long life cycle,
Higher voltage,
High C Rate

Drawbacks

Poor performance in cold,
Not as safe



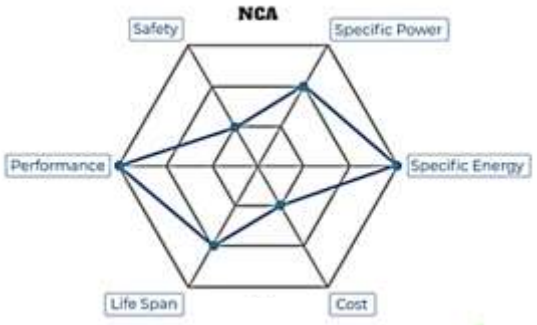
Lithium Nickel Cobalt Aluminum (NCA)

Benefit

High energy density,
Long life cycle,

Drawbacks

Not as safe,
Expensive



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SAFETY PROTOCOLS – EMERGENCY RESPONSE

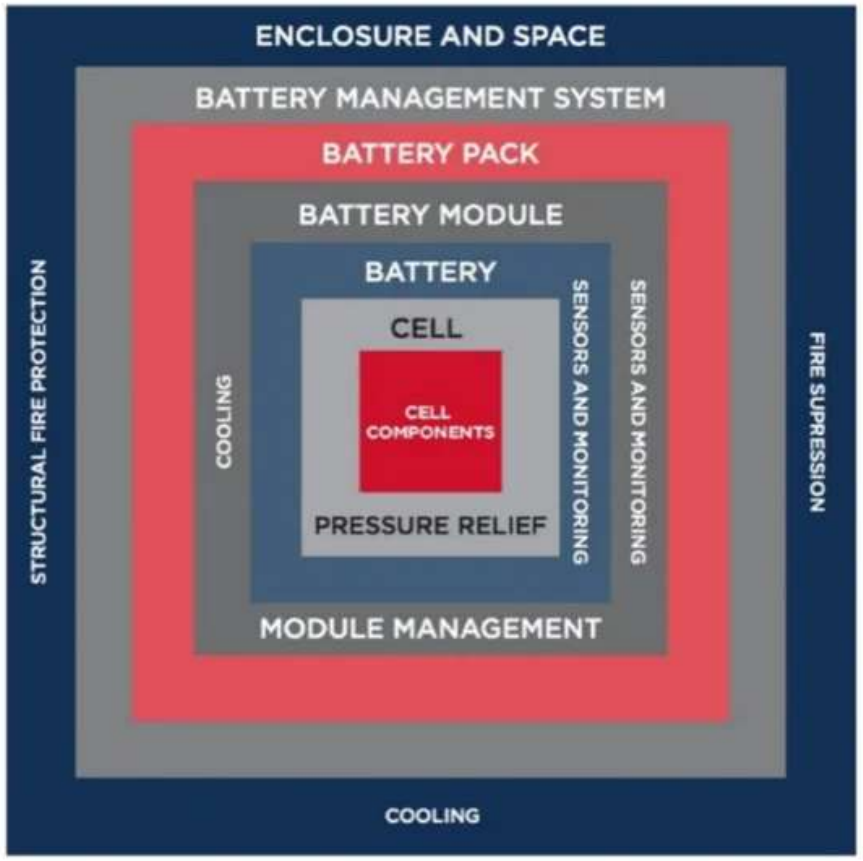
Lithium Iron Phosphate (LFP)

Thermal Runaway leads to

White smoke
(contains % of hydrogen)

Emergency Response

Ventilation through pressure valve



Lithium Nickel Manganese Cobalt (NMC)

Thermal Runaway leads to

Naked flame,
potential secondary fire

Emergency Response

1. Control temperature of adjacent cells to prevent heat propagation
2. Suppress fire

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Battery Chemistry Selection Considerations

- LFP battery chemistry is chosen from an overall suitability
- Most cost competitive from an overall ownership over useful lifetime of vessel
- Best in safety in terms of thermal stability
- Commercial readiness
- Energy density is lower compared to others, but overall considerations balanced out this con.

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MARINIZED BATTERY SEAGEN11

First Marinized Battery Type-approved in Singapore

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MARINE & OFFSHORE ENERGY STORAGE SYSTEM

- Peak shaving for marine & offshore vessels & platforms
- Backup power solutions
- Regenerative power storage
- 20-ft container
- Energy Cube 12, 12+, 18, 18+
- Applicable Oil Rigs, Offshore Platforms, FPSO, Cranes, Winches, AHTS, PSV, SOV Containerships, Tankers, Bulk Carriers, Car Carriers, etc.

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Maintenance

LI-ION BATTERIES MAINTENANCE

Regular checks of battery's SoC through BMS

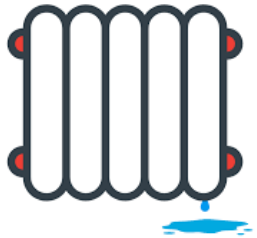
- Erratic movements in SoC -> **notify vendor**
- Voltage increases above SoC -> **stop charging**
- Monitor battery temperature

Check for **burns** on the connection of DC cable

Check for **water ingress** within internal of battery enclosure or room

- Leaks
- Sweating/condensation
- Salt build-up

- Functional checks on cooling system
- Check for cooling system **leaks** – poor piping



Others:

- Vibrations on eMotors – Poor alignment, poor foundation, eMotor's biggest failure point is the bearing
- Discoloration of eMotor junction box and inverter surfaces
- Check for degradation of the electrical performance of eMotor and inverter
- Housekeeping – A battery room is not a storeroom

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Battery Charging

CHARGING INFRASTRUCTURE

- **Charging systems considerations**
  - Onshore Shore-to-Ship
  - AC versus DC charging compatibility
  - Contact charging – connector head
  - Wireless charging
  - Battery swapping
  - Charging control systems
  - Offshore Ship-to-Ship charging

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SUMMARY

1. **Battery Technology**
   a) Types of batteries suitable for maritime use
   b) Energy density and storage capacity considerations
   c) Operations profile and cost efficiency
2. **Safety Protocols**
   a) Fire safety measures
   b) Emergency response plans for electric vessels
   c) Maintenance
3. **Operating Profile, Range and Charging Infrastructure**
   a) Addressing concerns about range limitations
   b) Developing robust charging infrastructure in harbors
4. **Training**
   a) Training for stakeholders, i.e. shipyards and operators
5. **Mindset**
   a) Mindset change - unlearn certain traditional practices
   b) Develop new processes and procedures (installations, operations and maintenance)

Molecules to Electrons

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Green Solutions for the Blue Economy