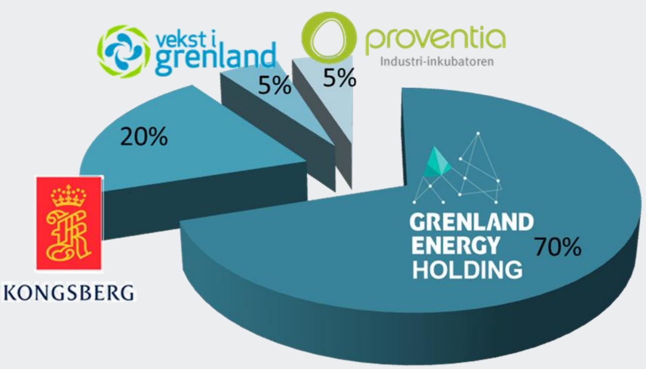
Grenland Energy AS

High power Li-ion battery systems for maritime applications



- **Mission:** We contribute to efficient use of energy
- **Vision:** Sustainable use of energy

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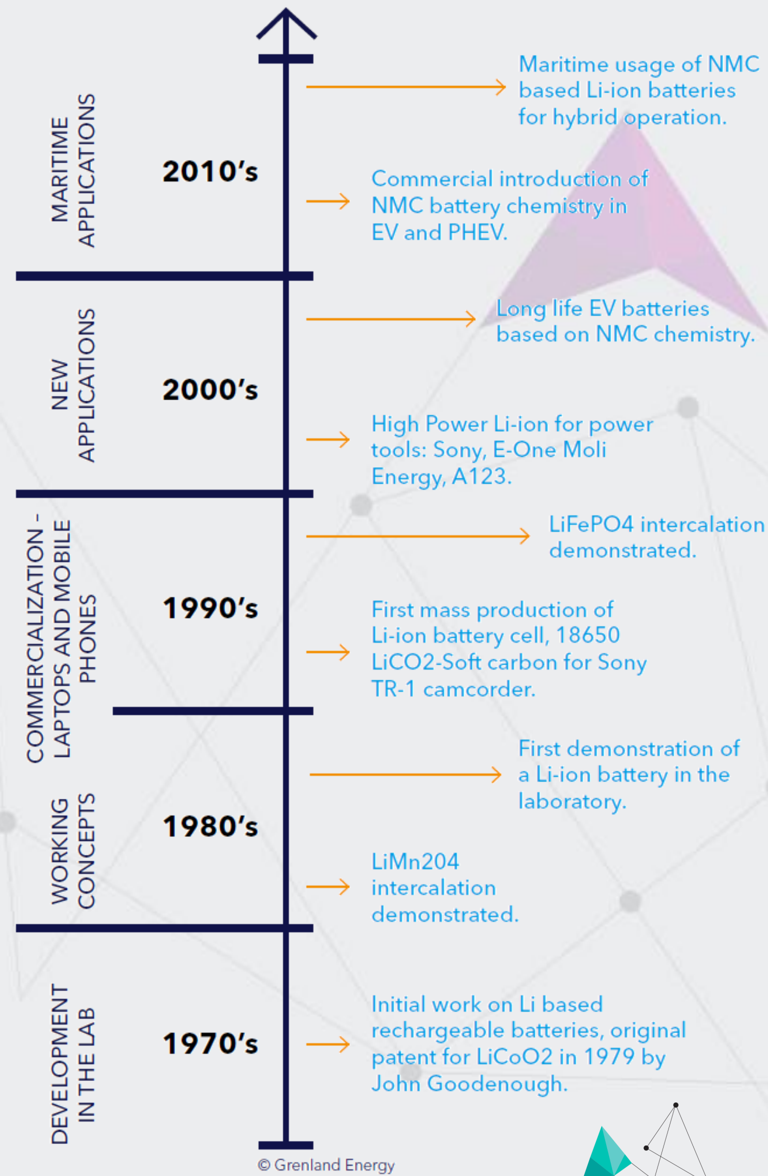
Li-ion history

- Each step in the Li-ion battery history was built on the previous step
- The power tool Li-ion battery effort was the catalyst for the automotive Li-ion battery development
- The automotive Li-ion battery development was necessary for the maritime Li-ion battery system development



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Why batteries in maritime applications?

- Reduced OPEX
  - Reduced fuel consumption
  - Reduced spinning reserve
  - Reduced maintenance costs
- Potentially reduced CAPEX
- Reduced emissions: PM, CO, NOx, CO_2
- Enables utilization of renewable energy
- Improved dynamic response
- Indications of further benefits, safety

RETURKRAFT FRA KRAN - Kranene på skipet skal generere strøm når lasten senkes - tu.no/industri/skip

Rederiet får støtte fra Enova til å bruke returkraften.

TU.NO | VON ØYVIND LIE

Så mye drivstoff kan skip spare på å sette inn batterier

Oppløftende resultater fra hybridlab i Trondheim.

WWW.TU.NO | VON TORE STENSVOLD

Mehr dazu

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Maritime batteries

- Maritime batteries differ from automotive batteries, but automotive development has been a crucial enabler for maritime batteries
- Pack propagation and handling of thermal events is much more important for maritime packs
- Energy and power density potentially less important
- Thermal management is more important
  - Longer life expectancy required
  - Less stringent space requiremets
- Safety and life time are crucial success factors in an early market phase, hence focus on systems engineering

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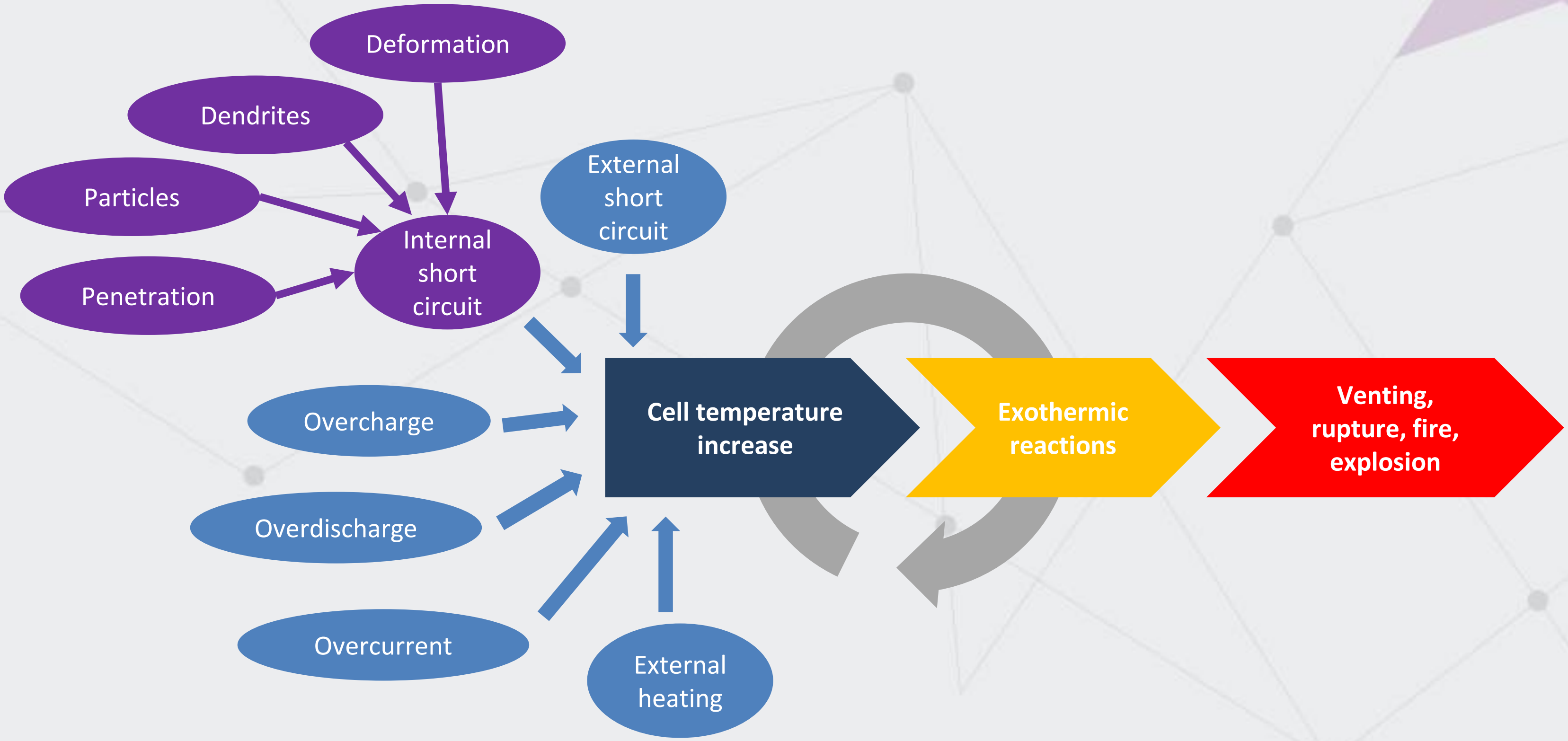
Maritime safety – thermal event



Maritime safety – thermal event II

Cathode side of internal short circuit	Anode side of internal short circuit	Likelihood of thermal runaway event
Bare cathode current collector	Anode active material, any SOC	High
Bare cathode current collector	Bare anode current collector	Low
Active cathode material	Anode active material, any SOC	Low
Cathode active material	Bare anode current collector	Low

Grenland Energy battery systems propagation tests

	4.0V	4.1V	4.2V	4.3V
Maximum temperature	110 °C	85 °C	600 °C	600 °C
Observation	No fire, no explosion, leakage	No fire, no explosion, leakage	Fire without propagation	Fire without propagation

- Nail penetration induced propagation test
- Propagation tests passed
- Detailed test response depends on SOC

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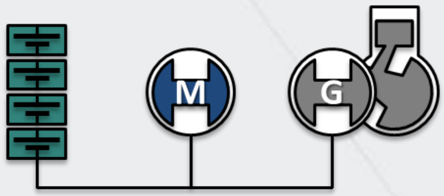
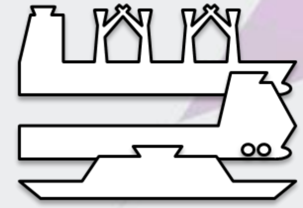
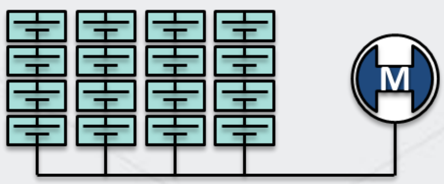
Battery system types and market segments

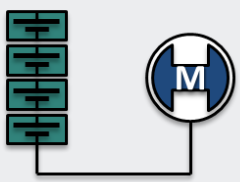


Diesel&LNG electric
hybrid systems with
power optimized battery





Fully electric propulsion
systems with
energy optimized battery



Emergency backup
systems with
power optimized battery

Fully customized
battery systems

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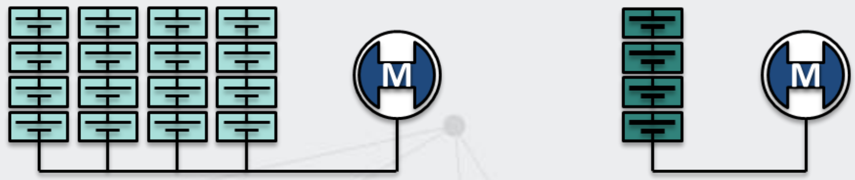
Energy vs. Power optimized systems



	Energy optimized	Power optimized
Discharging	Entire capacity typically discharged within 1 hour	Entire capacity can be discharged within 10 min or less
Charging	Limited fast charging ability, typically 1 hour or more for charging	Fast charging (0...80% SOC) within 15 min or less
Capacity	Relatively high capacity, typically >100 Wh/kg	Comparably low capacity, typically <60 Wh/kg
Low temperature performance	Relatively high impedance, generally good performance at room temperature	Good performance also at very low temperatures due to low impedance
Cycle life	Typically high utilization of SOC window, therefore limited cycle life	Typically low SOC swing for power systems, very high cycle life
Generally	**High capacity – Low power**	**High Power – Low capacity**

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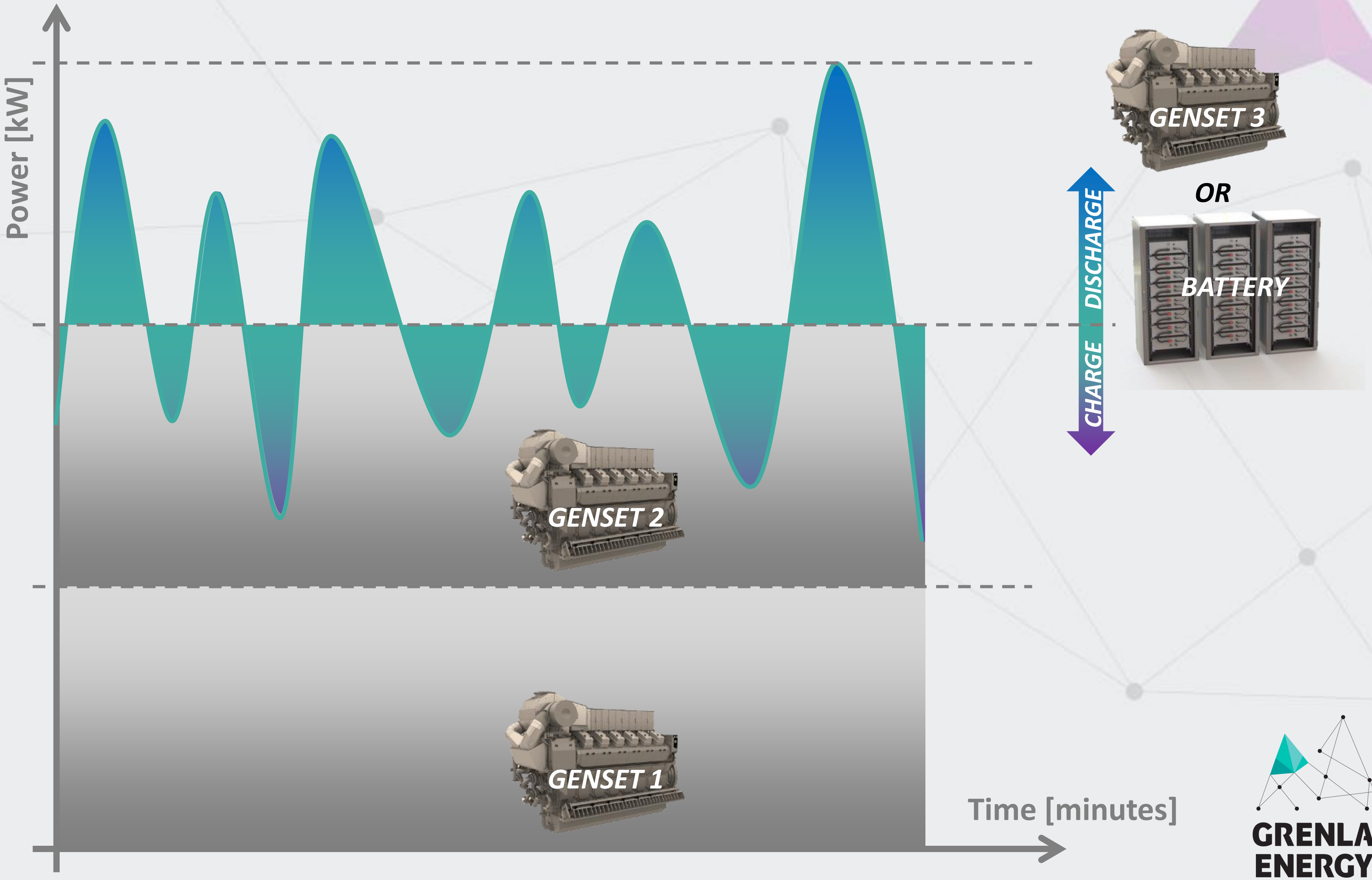
Example – Dynamic Load Profile



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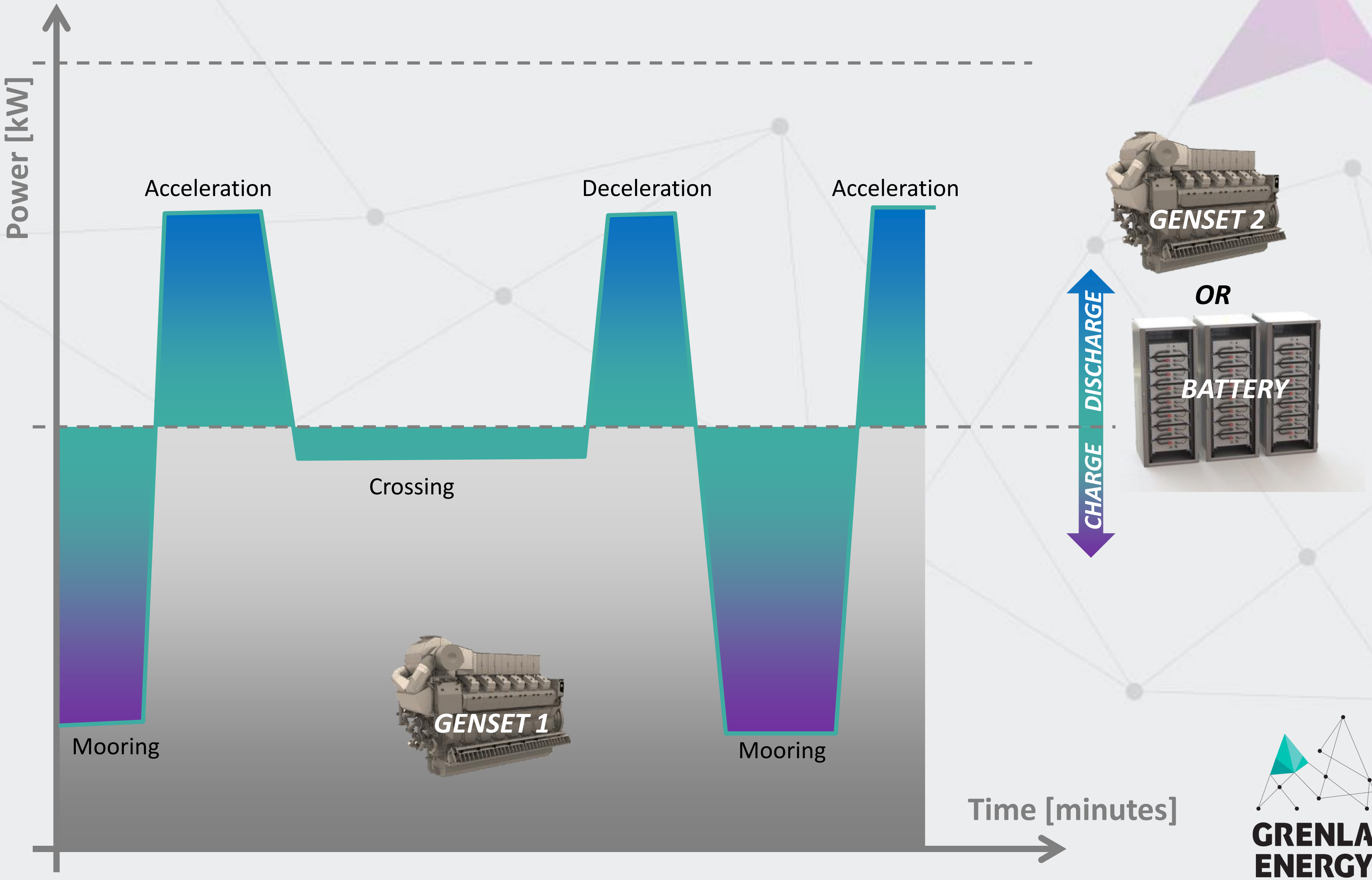
Example – Hybrid Ferry



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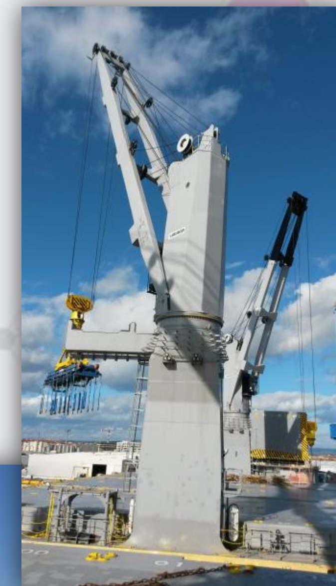
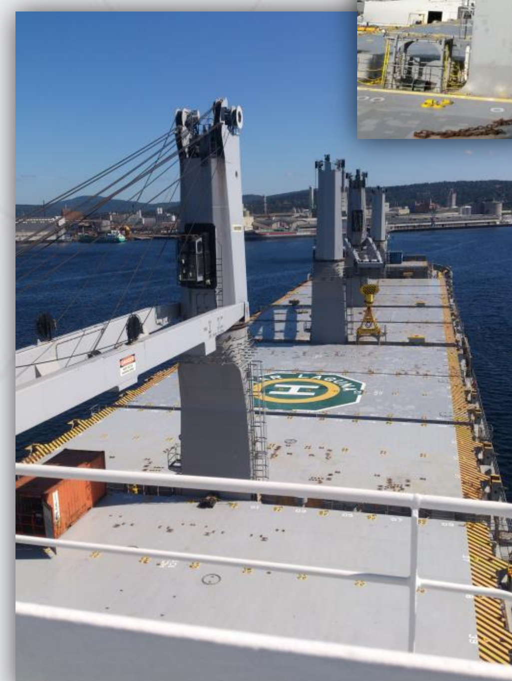
Battery for open hatch general cargo carrier

- World's first battery system for a hybrid crane in a bulk carrier
- Substantial efficiency gains
- Substantial emission reductions every year throughout the lifetime of the battery system:
  - CO2 emissions corresponding to more than 100 cars
  - NOx emissions corresponding to 5000 diesel powered cars
  - Particulate matter emissions corresponding to 7000 diesel cars.
- Power optimized battery system
  - 67 kWh
  - 730 kW peak power





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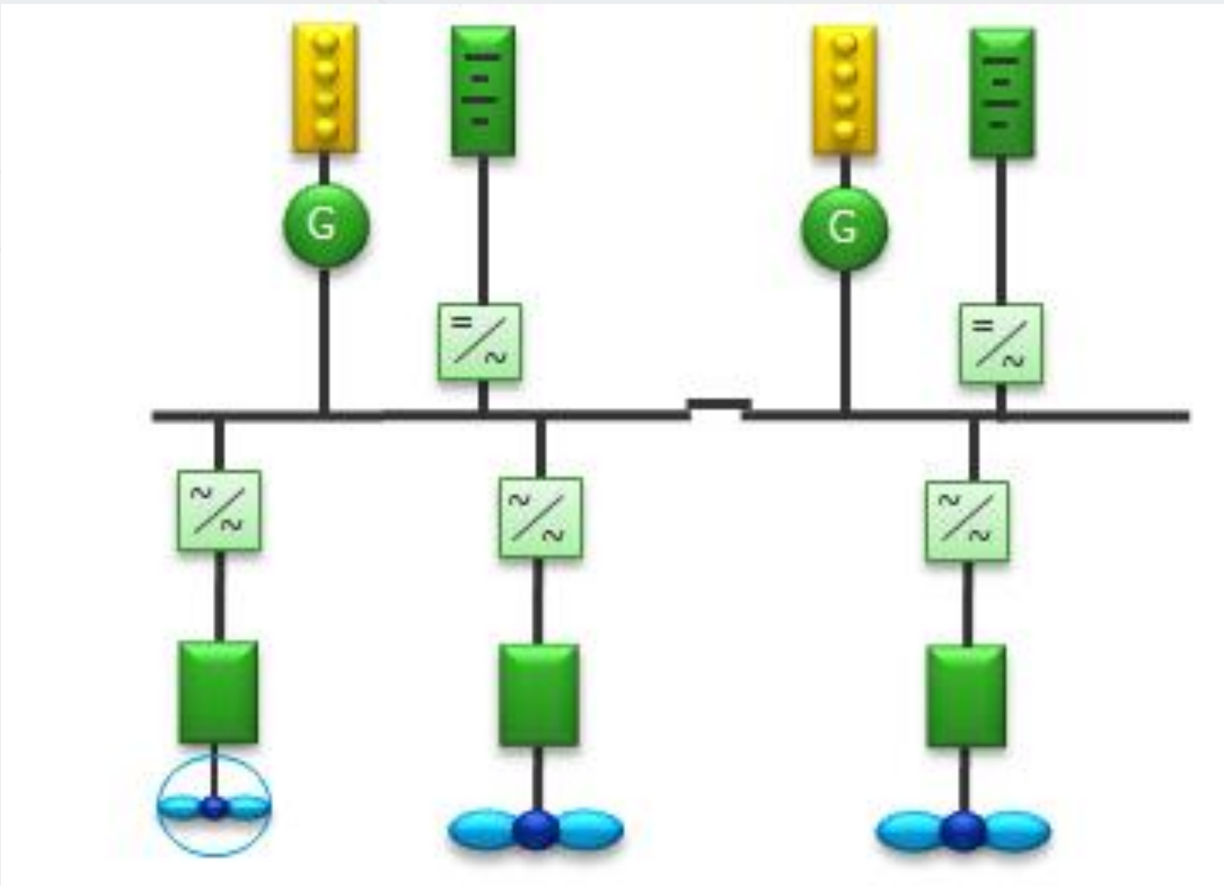
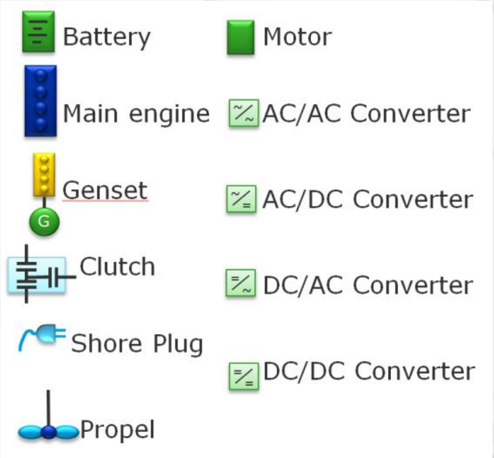
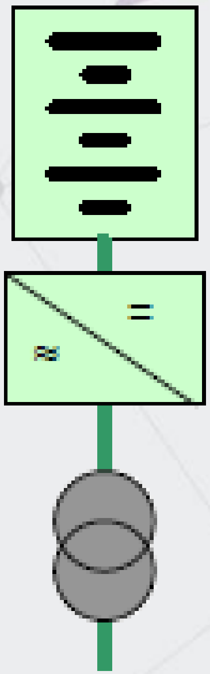
Integration – Battery hybrid propulsion



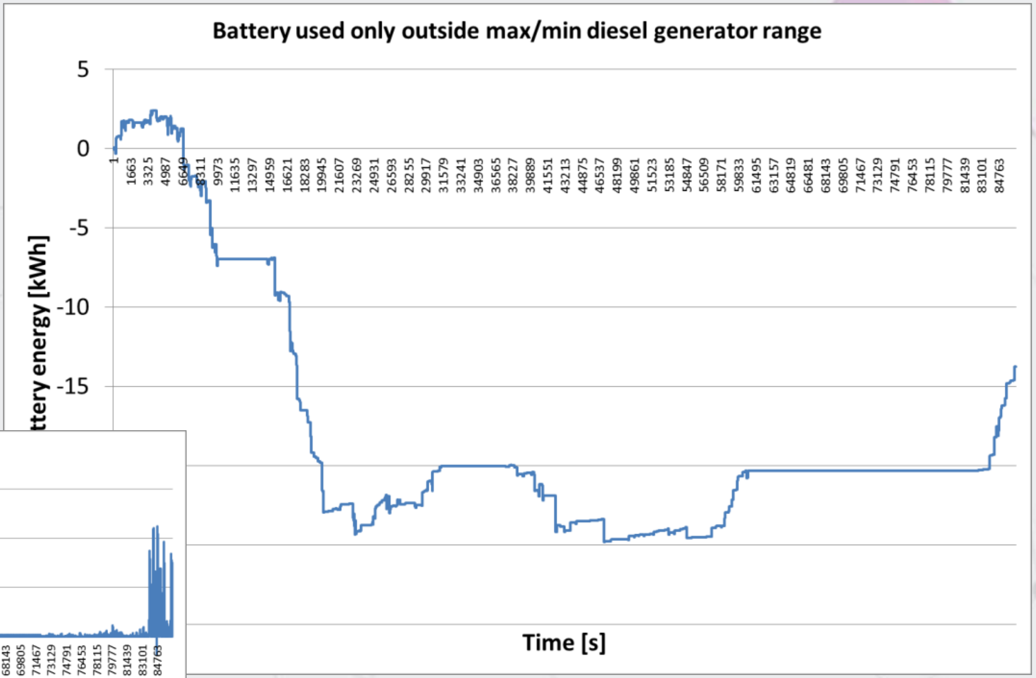


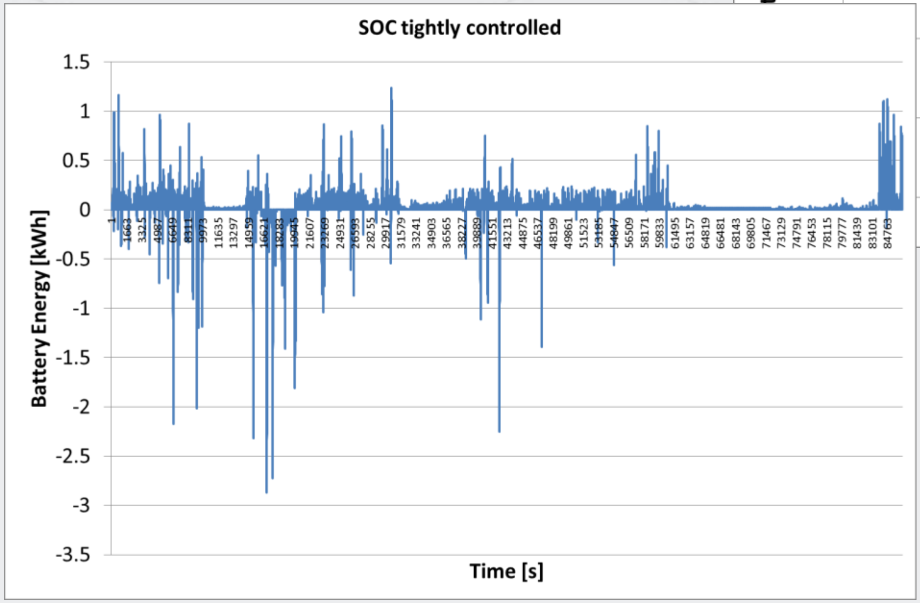
What is needed besides batteries?

- For AC grid, η≈0.9
  - Transformer – Noise reduction
  - Drive – AC/DC conversion
- For DC grid, η≈0.9
  - DC drive – DC/DC conversion
- Round Trip Efficiency
  - Li-ion batteries: η≈0.95 (0.9-0.98)
  - Transformer: η≈ 0.96
  - Drives: η≈ 0.97
  - Total: η≈ 0.85
- Total energy & emissions savings are very dependent on operational strategy and optimization is necessary



Optimum energy management





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Generation 2 Battery System - Example

Voltage:	580…770 V
Discharge power:	560 kW (peak @ 50% SOC)
Charge power:	320 kW (peak @ 50% SOC)
Pack capacity:	54 kWh (max)
Weight:	Approx. 900 kg
Customization:	Modular and scalable

- Integrated active cooling and offgas handling
- Dynamic Master/Slave architecture
- Datalogging and remote diagnostics capable

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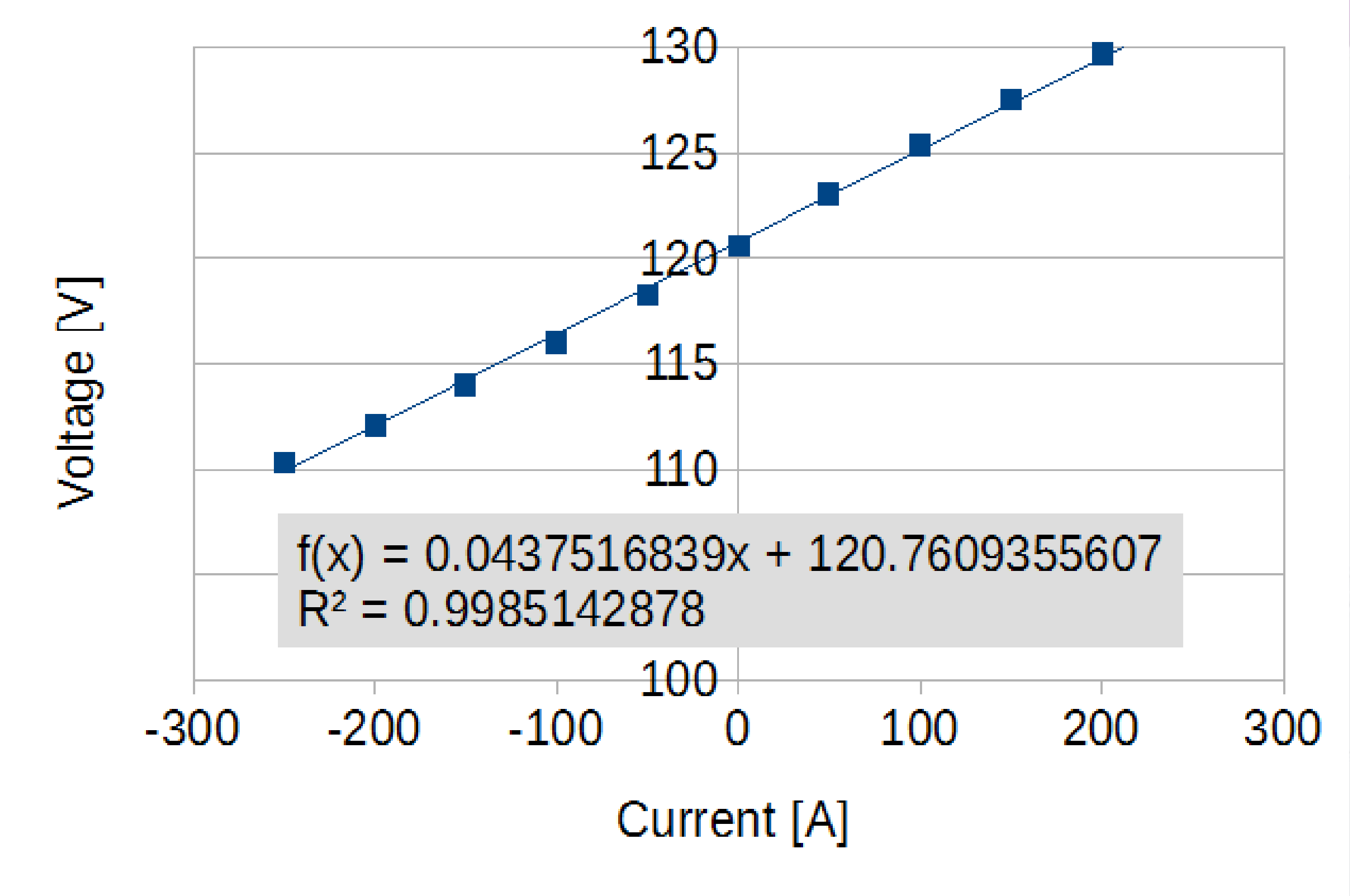
Battery modelling

- Temperature and SOC can be assumed constant over a short period

Model fit, system



Maritime battery systems

- Correct dimensioning to satisfy operational profiles
- Optimized energy-to-power ratio
- Large maritime battery systems require enhanced safety
- Minimizing fuel consumption and emissions require usage strategy optimization
- Simple empirical models are very useful for batteries

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Thank you very much for your attention

If anyone is interested: we have very intersting student projects available

WE MAKE ENERGY DO MORE

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