ACADEMIC WORKSHOP

10 JUNE 2022

SEABAT - WP 2
SPECIFICATIONS & REQUIREMENTS

SOLUTIONS FOR LARGE BATTERIES FOR WATERBORNE TRANSPORT

CONTENT

- WP overview
- Results
- Outlook / focus

WP 2 – SPECIFICATIONS & REQUIREMENTS

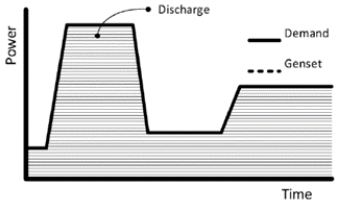
D2.1 – APPLICATION MATRIX

- Marine battery applications
- Basic battery requirements
- Primary and secondary cycles
- Types of applications
- Application matrix

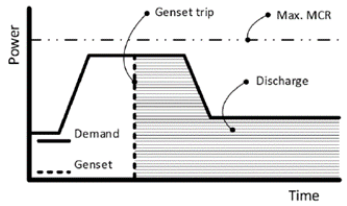
Fully battery powered – Plug-in hybrid – Hybrid

7 marine battery applications:

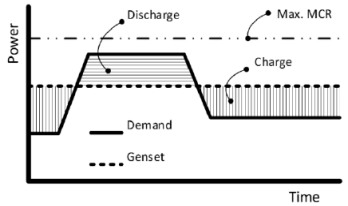
Full electric



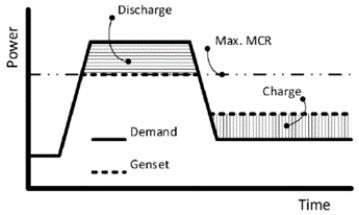
Spinning reserve



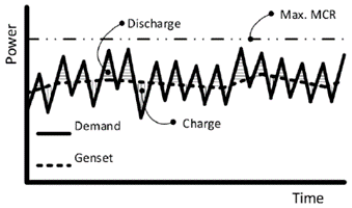
Load leveling



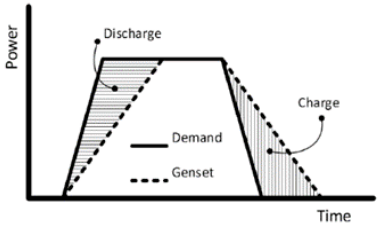
Boost function



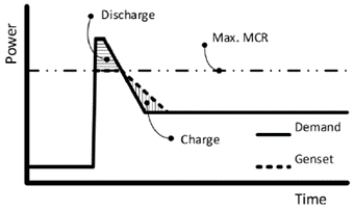
Load smoothing



Ramp support



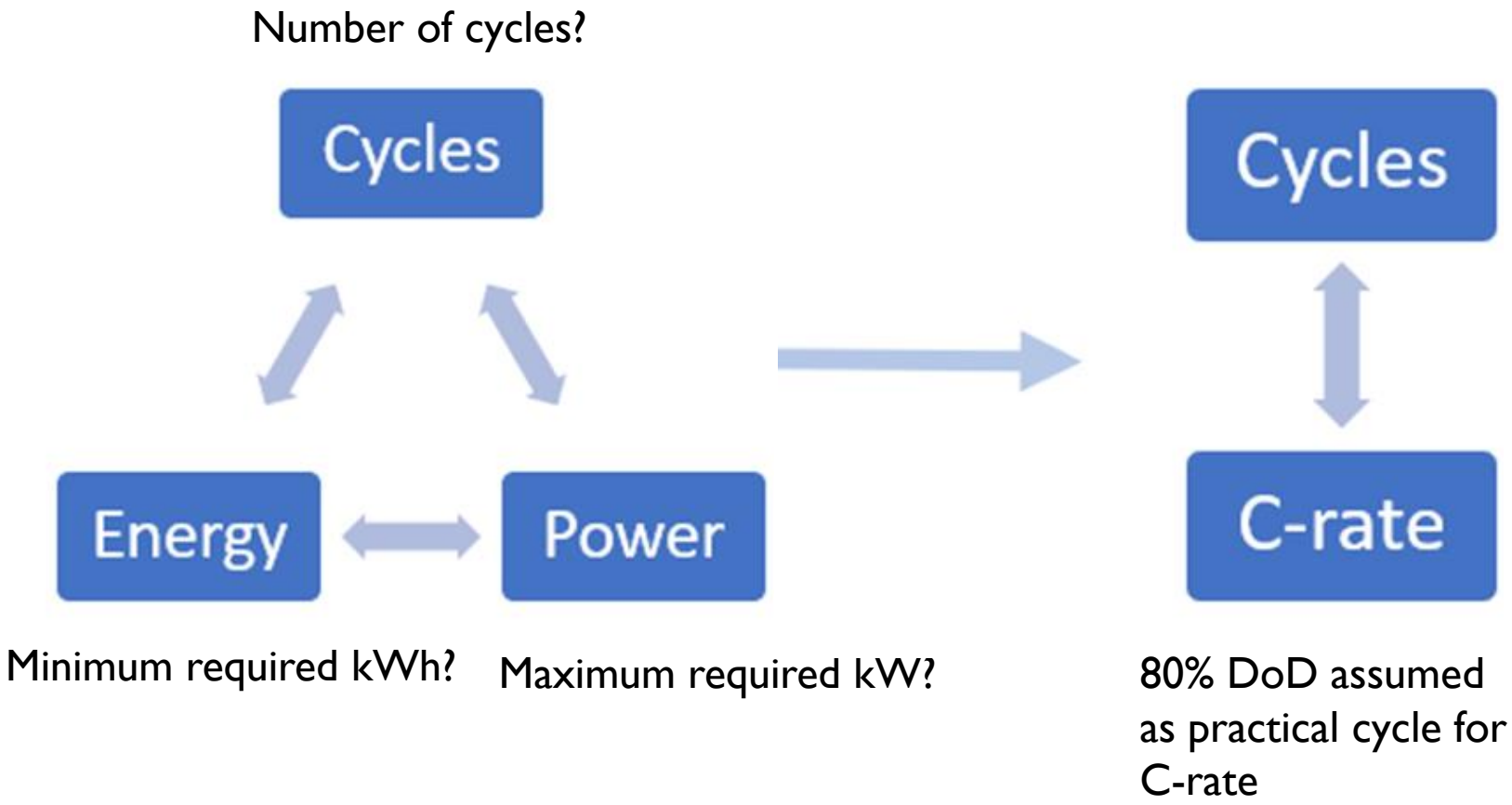
Peak shaving



WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.1 – APPLICATION MATRIX

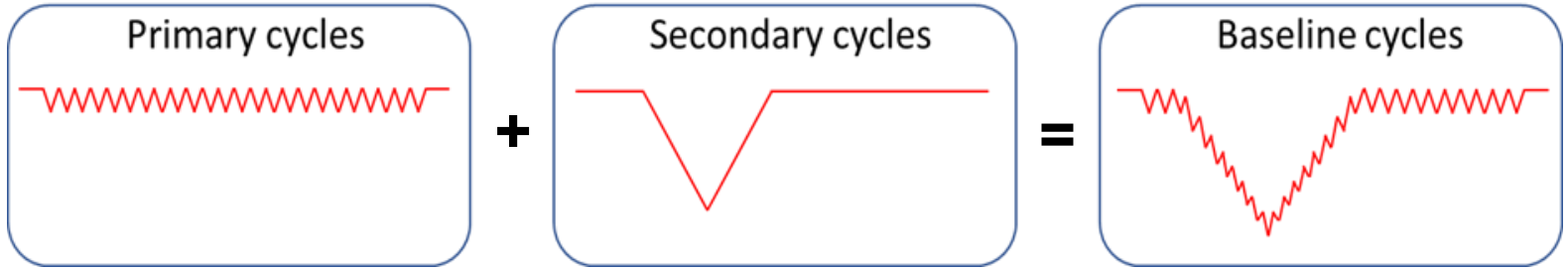
- Marine battery applications
- Basic battery requirements
- Primary and secondary cycles
- Types of applications
- Application matrix

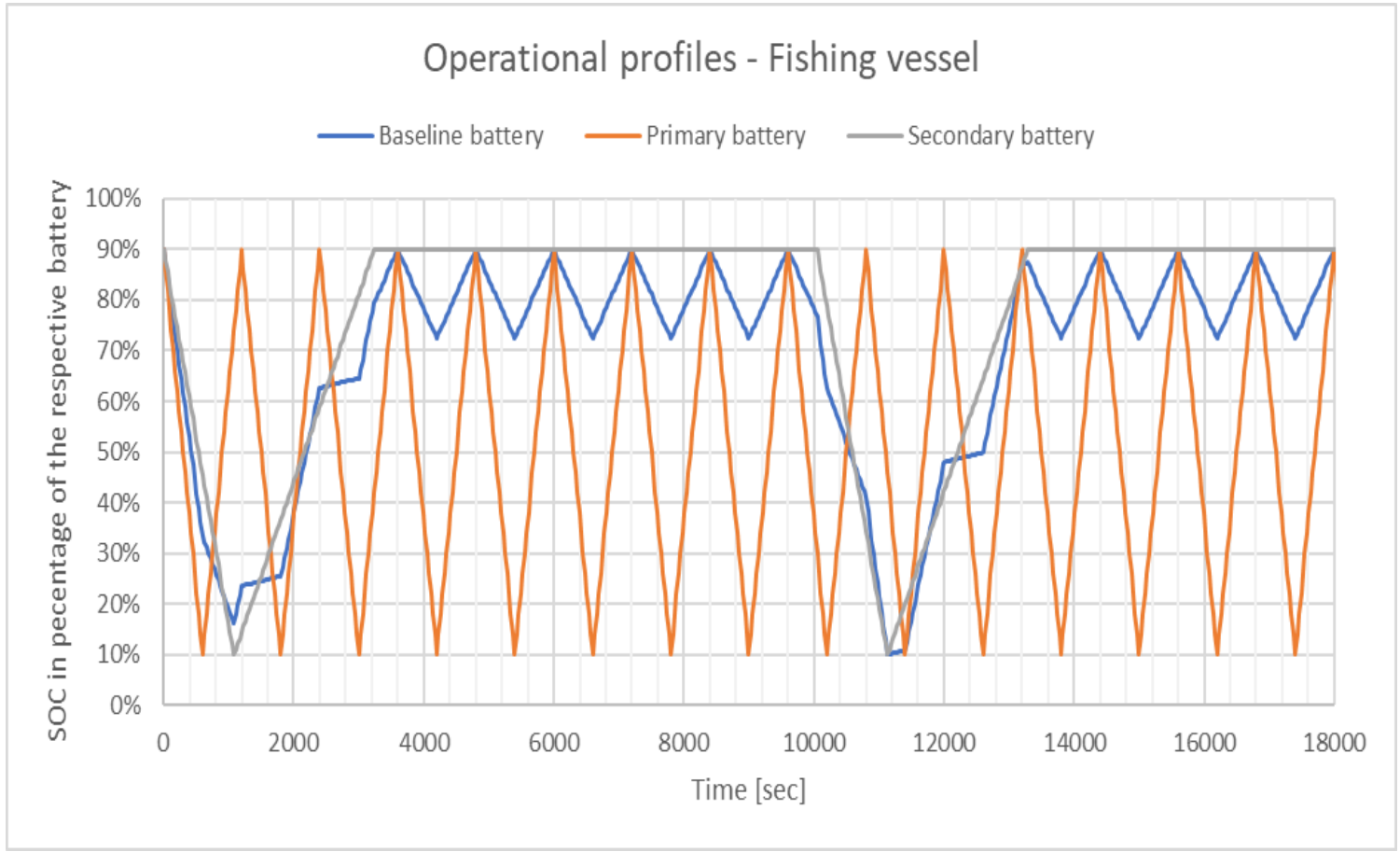


WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.1 – APPLICATION MATRIX

- Marine battery applications
- Basic battery requirements
- Primary and secondary cycles
- Types of applications
- Application matrix



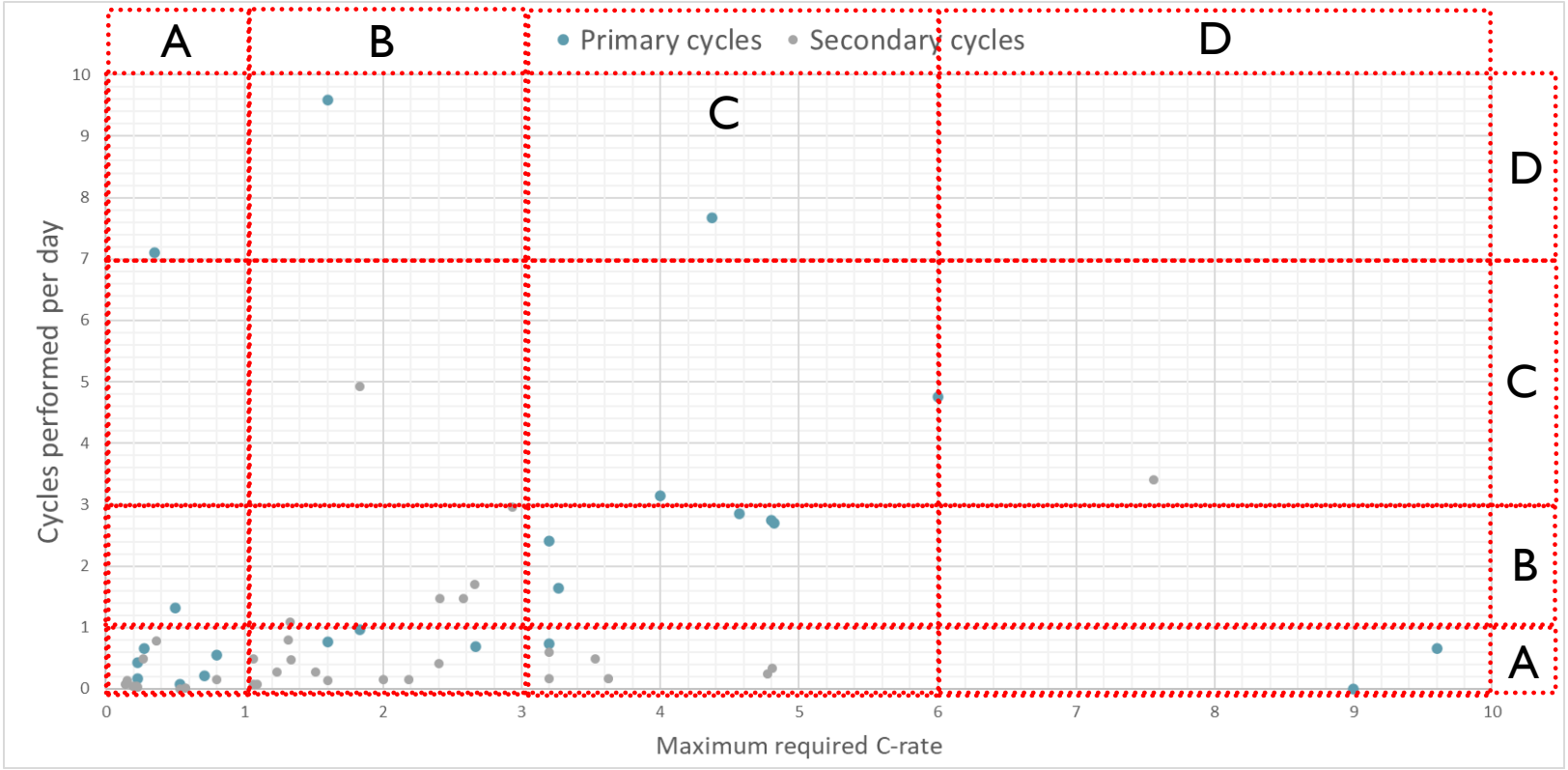


WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.1 – APPLICATION MATRIX

- Marine battery applications
- Basic battery requirements
- Primary and secondary cycles
- Types of applications
- Application matrix

The operational requirements for **34 vessels** have been gathered as input for determining the types of applications



Type	C-rates	Cycles per day
A	< 1C	< 1 cycle
B	1C - 3C	1 – 3 cycles
C	3C - 6C	3 – 7 cycles
D	> 6C	> 7 cycles

WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.1 – APPLICATION MATRIX

- Marine battery applications
- Basic battery requirements
- Primary and secondary cycles
- Types of applications
- Application matrix

Vessel	Application	Primary C-rates	Primary cycles	Secondary C-rates	Secondary cycles
Fishing	Full electric	A	A	A	A
Fast Crew Supplier	Full electric	A	A	A	A
Inland container vessel	Full electric	A	A	A	A
Small tug	Full electric	A	A	A	A
Yacht	Full electric	A	A	A	A
Fast Crew Supplier	Full electric	A	B	A	A
Fast Ferry	Full electric	A	D	A	A
Cable lay vessel	Load leveling, Spinning reserve	B	A	A	A
Hybrid tug	Full electric	B	A	B	A
Patrol vessel	Full electric	B	A	B	A
Fishing	Full electric	A	A	A	A
Ferry	Full electric	B	D	B	A
Shoalbuster	Boost function	C	A	B	A
Harbour tug	Boost function	C	B	A	A
Harbour tug	Full electric	C	B	B	A
Harbour tug	Full electric	C	B	B	A
Fast Crew Supplier	Full electric	C	B	B	C
Fishing	Spinning reserve	C	B	C	A
Cruise	Full electric	C	C	B	B
Urban ferry	Full electric	C	C	C	A
Ro-Ro ferry	Full electric	C	D	B	A
Waterbus	Full electric	C	D	B	A
Waterbus	Load leveling	C	D	B	A
Fishing	Peak shaving, Boost function	C	D	B	B
Ro-Ro ferry	Load leveling, Boost function, Ramp support	C	D	B	B
Ro-Ro ferry	Full electric	C	D	B	B
Ro-Ro ferry	Full electric	C	D	B	B
Fast Crew Supplier	Spinning reserve, Peak shaving	D	A	B	A
TSHD	Peak shaving	D	A	C	A
Harbour tug	Boost function	D	B	B	A
Fish carrier	Peak shaving, Spinning reserve	D	D	C	A
Urban ferry	Full electric	D	D	C	A
Ro-Ro ferry	Full electric	D	D	C	B
Ro-Ro ferry	Full electric	D	D	D	C

WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.2 – KPI REPORT

- Battery properties
- Performance rating system
- Battery types
- Cell chemistrySystem design

- Costs
- Energy density
- Power density
- C-rates
- Cycle life
- Thermal management
- Safety
- Mechanical integration
- Electrical integration
- BMS

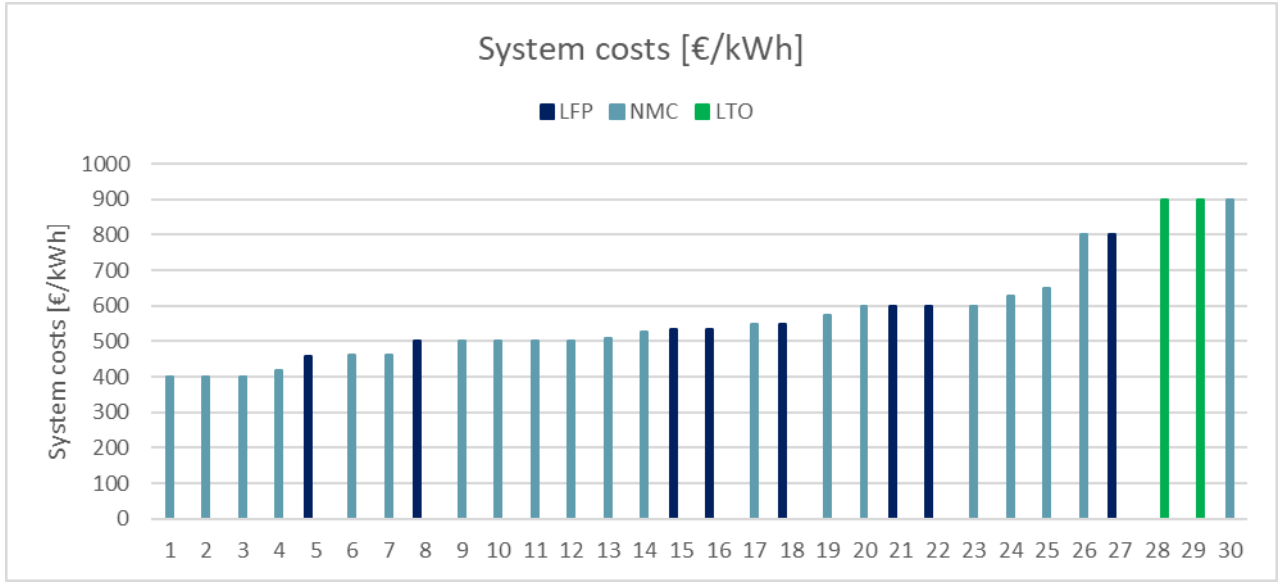
Analysis of **30 battery systems** from 15 manufactures

WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.2 – KPI REPORT

- Battery properties
- Performance rating system
- Battery types
- System design

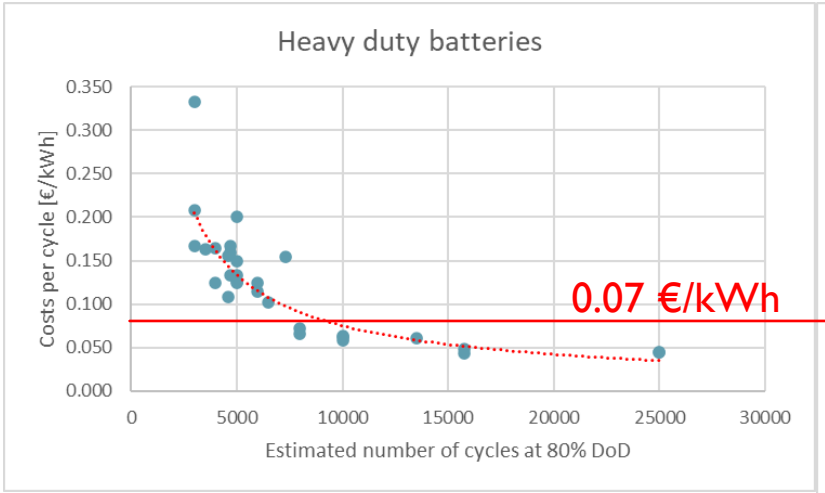
System costs [€/kWh]		
Score	Range	
1	> €900	(Worst score)
2	€631 – €900	
3	€501 - €630	
4	€400 - €500	
5	< €400	(Best score)

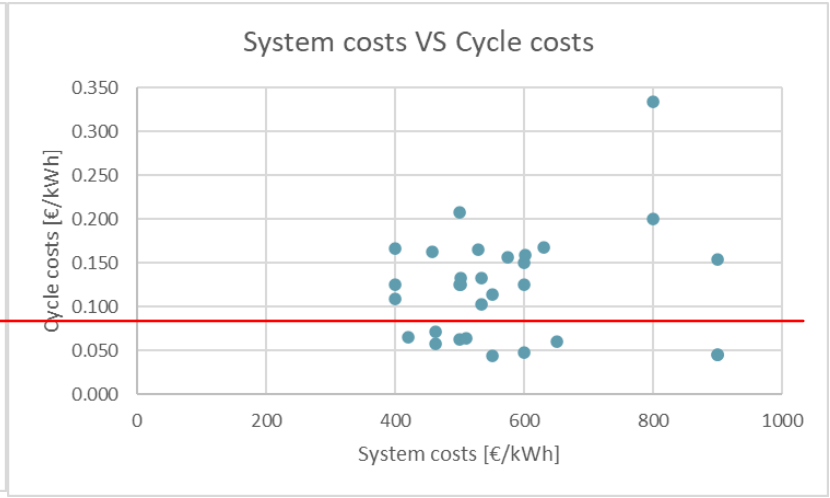


WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.2 – KPI REPORT

- Battery properties
- Performance rating system
- Battery types
- System design





High Energy
- ≤ 1C
- Low: 100 Wh/kg
- High: 185 Wh/kg
- > 0.07 €/kWh

Medium Energy
- 1C – 3C
- Low: -20*[C]+130 Wh/kg
- High: -20*[C]+171 Wh/kg
- > 0.07 €/kWh

High Power
- > 3C
- Low: 50 Wh/kg
- High: 90 Wh/kg
- > 0.07 €/kWh

High Energy / Heavy Duty
- ≤ 1C
- Low: 100 Wh/kg
- High: 185 Wh/kg
- < 0.07 €/kWh

Medium Energy / Heavy duty
- 1C – 3C
- Low: -20*[C]+130 Wh/kg
- High: -20*[C]+171 Wh/kg
- < 0.07 €/kWh

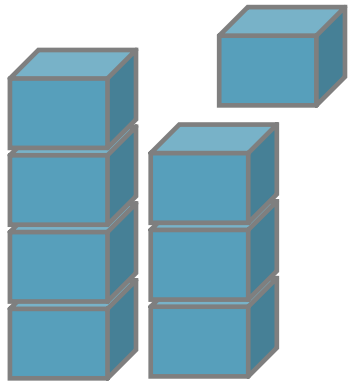
High Power / Heavy duty
- > 3C
- Low: 50 Wh/kg
- High: 90 Wh/kg
- < 0.07 €/kWh

WP 2 – SPECIFICATIONS & REQUIREMENTS

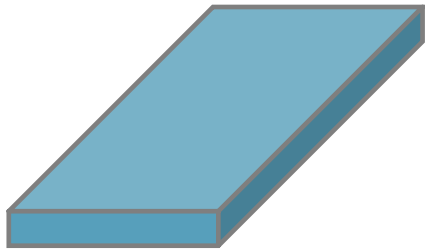
D2.2 – KPI REPORT

- Battery properties
- Performance rating system
- Battery types
- System design

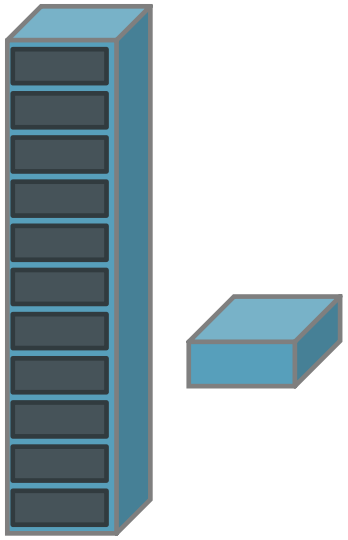
Battery system design



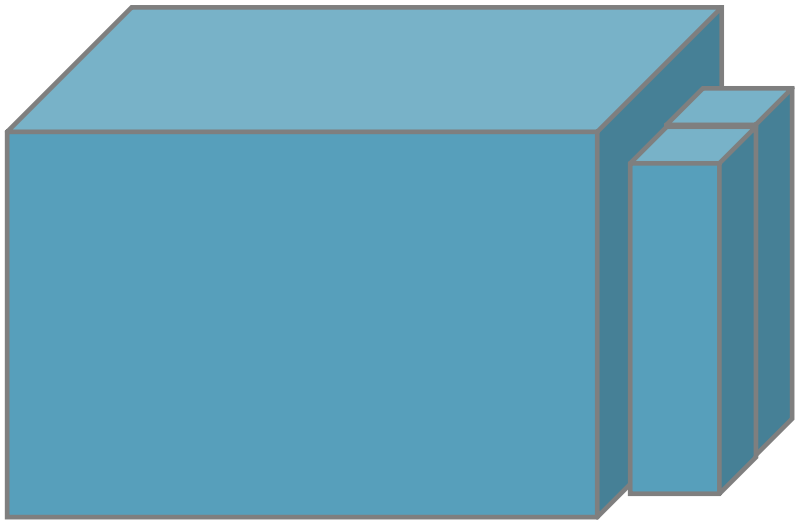
Modules



Trays



Racks



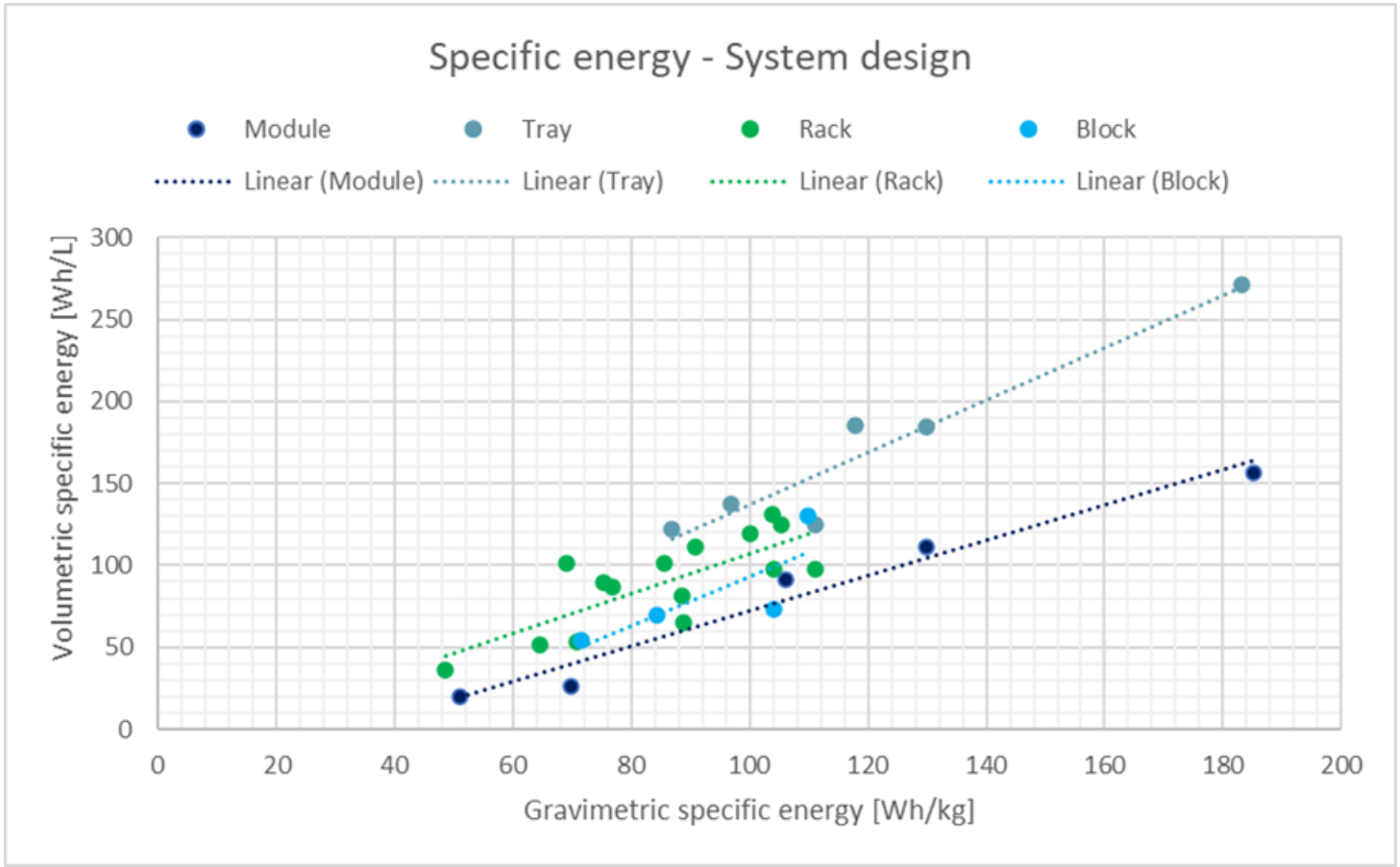
Blocks

WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.2 – KPI REPORT

- Battery properties
- Performance rating system
- Battery types
- System design

Energy density

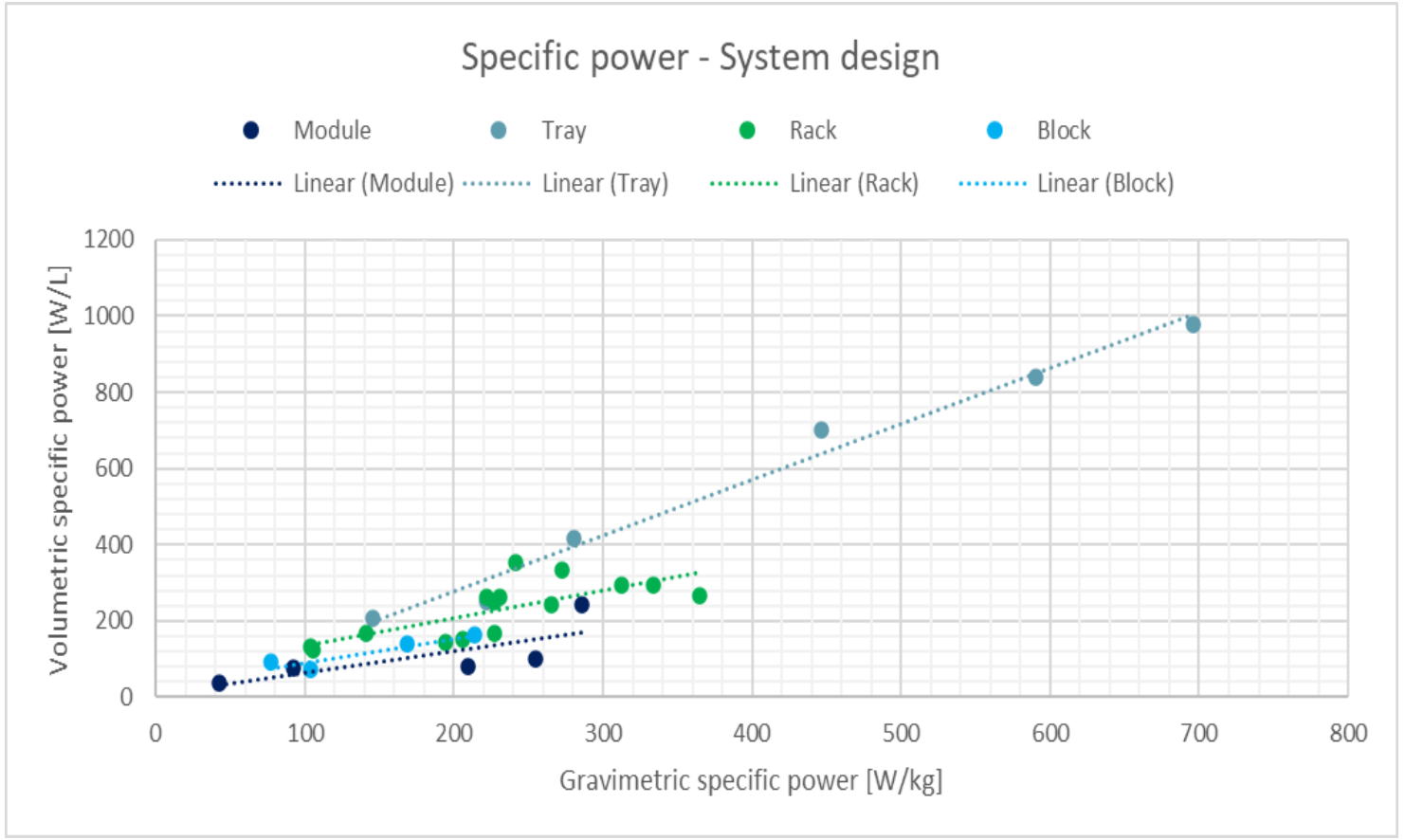


WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.2 – KPI REPORT

- Battery properties
- Performance rating system
- Battery types
- System design

Power density

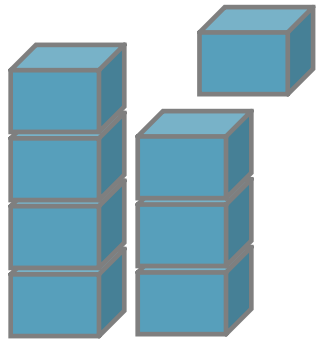


WP 2 – SPECIFICATIONS & REQUIREMENTS

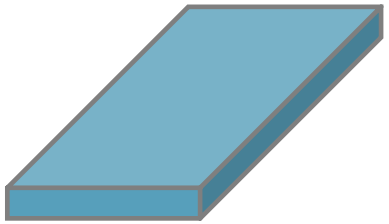
D2.2 – KPI REPORT

- Battery properties
- Performance rating system
- Battery types
- System design

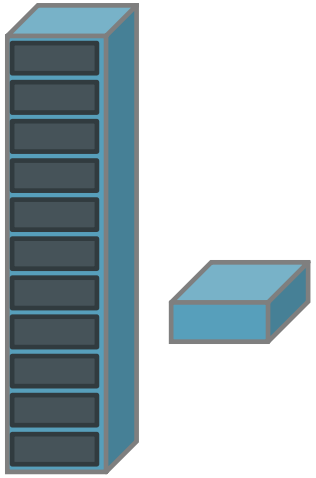
Battery system design



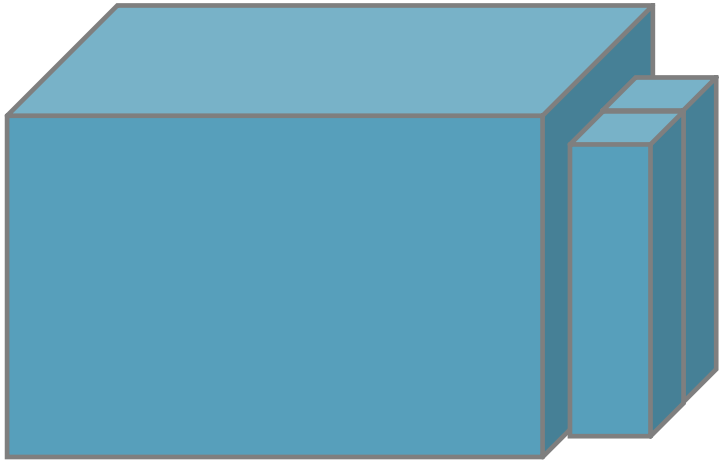
Modules **= light weight**



Trays **= low volume**



Racks



Blocks

WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.3 – REQUIREMENTS DOCUMENT

- Marine regulations
- Automotive and stationary standards
- Battery safety requirements in other sectors

Current regulations, rules, guidelines, codes and standards applicable to marine battery installations were reviewed.

Class rules by:

- American Bureau of Shipping
- Bureau Veritas
- DNV
- Lloyd's Register
- RINA

WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.3 – REQUIREMENTS DOCUMENT

- Marine regulations
- Automotive and stationary standards
- Battery safety requirements in other sectors

- Marine regulations have their origin on lead-acid batteries
- The development of lithium-ion batteries for large energy applications is still relatively new in marine and offshore industries
- Additional basic rules for lithium-ion batteries:
  - fragmented and on conservative principles
  - some reference to IEC battery standards for testing

- …**risk assessment is** required for <u>each</u> ship design

- no specific international standards for marine battery systems yet

WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.3 – REQUIREMENTS DOCUMENT

- Marine regulations
- Automotive and stationary standards
- Battery safety requirements in other sectors

Focus on the regulatory framework

- Safe design, construction, testing, certification, installation, integration, and life-cycle operation on board
- Identification of regulatory gaps / barriers
- Support to the development of battery installations in the relevant WPs and Tasks
- Project results will be used to draft final recommendations and update / harmonise the regulatory baseline (life-cycle)

WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.3 – REQUIREMENTS DOCUMENT

- Marine regulations
- Automotive and stationary standards
- Battery safety requirements in other sectors

Regulatory requirement breakdown

- Design and construction
- System design (safety)
- Location / Installation / Battery spaces
- Battery charging
- Battery Management Systems (BMS)
- Availability of power / energy management
- Electrical protection
- Fire and explosion safety
- Thermal management and ventilation
- Control, monitoring, alarm and safety systems
- Risk assessment
- Testing, surveys, and inspections
- Certification process
- Operation and maintenance

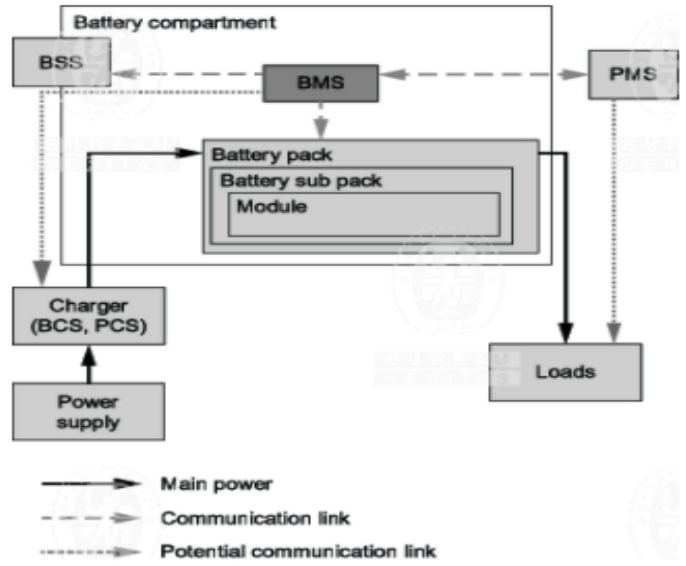
WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.3 – REQUIREMENTS DOCUMENT

- Marine regulations
- Automotive and stationary standards
- Battery safety requirements in other sectors

Integration on board

- Electrical network / installations
- Power availability to ship essential systems:
  - Machinery, Auxiliary Systems, Directional Control Systems, use as UPS for Shipborne Navigational Systems and Equipment…
  - Full electric vessels: redundancy, availability, reliability
- Energy management system - monitoring / control of capacity
- Safeguard principles:
  - individual control system for each battery,
  - individual separation of the cells,
  - protection of the battery space,
  - protection from external fire
- Remote control, alarm and safety systems
- Thermal insulation
- Operational requirements and conditions



WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.3 – REQUIREMENTS DOCUMENT

- Marine regulations
- Automotive and stationary standards
- Battery safety requirements in other sectors

Novel design features / principles

Aspects not prescriptively covered are addressed case-by-case, as part of a Risk Assessment.

Technology Qualification Process is required for non-conventional solutions / technologies:

- Methodology and approval process – Equivalence criteria, experiments, calculations, other supporting information
- Detailed procedures for Failure Mode and Effects Analysis (FMEA)
- Requirements and Compliance Criteria for operational safety
- Possible operational limitations
- Evaluation of design uncertainties vs. safety margins
- Internal failure
- Material certification / Qualification of innovative battery cells
- Construction, Quality Control, Quality Assessment
- Health monitoring – Damage detection quantification and repair

WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.3 – REQUIREMENTS DOCUMENT

- Marine regulations
- Automotive and stationary standards
- Battery safety requirements in other sectors

Regulatory gaps

After the review of current rules and regs. on static / dynamic design, material certification and testing → many aspects are well regulated, but some require a case-by-case approval.

Example:

- Dynamic phenomena
- Assessment of failure modes
- Behaviour in extreme temperature (polar / tropical)
- Evaluation of battery ageing
- Dynamically induced stresses and accelerations (marinization)
- Consequences of fire or flooding
- Fire detection and suppression systems (thermal runaway)

European Commission (DG MOVE) and EMSA are working with EU-Member States to bridge some of the safety gaps

WP 2 – SPECIFICATIONS & REQUIREMENTS

D2.3 – REQUIREMENTS DOCUMENT

- Marine regulations
- Automotive and stationary standards
- Battery safety requirements in other sectors

Existing (non-maritime) standards are reviewed as references for safety, reliability, installation and operation guidelines:

- ISO: International Organization for Standardization;
- IEC: International Electrotechnical Commission;
- SAE: Society of Automotive Engineers;
- UL: Underwriters Laboratories;
- ECE: Economic Commission for Europe.

Field →		Automotive						Stationary
Test		ISO 6469	IEC 62660	SAE J2464	SAE J2929	UL2580	ECE R100.02	UL 1973
Mechanical	Vibration	•	•	-	•	•	•	-
	Mechanical shock	•	•	•	•	•	•	-
	Rollover	-	-	•	•	•	-	-
	Penetration	-	-	•	-	-	-	-
	Drop test	-	-	•	•	•	-	•
	Crush/Crash	•	•	•	•	•	•	-
	Immersion	•	-	•	•	•	-	•
Electrical	Short circuit	•	•	•	•	•	•	•
	Overcharge protection	•	•	•	•	•	•	•
	Over-discharge protection	•	•	•	•	•	•	•
Environmental	Thermal shock and cycling	•	•	•	•	•	•	•
	Fire	•	-	•	•	•	•	•
	Thermal Stability	-	•	•	-	•	•	•
	Low temperature test	-	-	-	-	•	-	-
	Overheat	-	-	•	•	-	-	-
Chemical	Emission	-	-	•	•	•	-	-
	Flammability	-	-	•	•	•	-	-

WP 2 – SPECIFICATIONS & REQUIREMENTS

- Next steps
- Questions?

- Reports have been delivered (End of August 2021) and approved
- Use cases and other specifications and requirements shared with WP3
- WP2 is finished