MARKET NEEDS AND REGULATIONS

ACADEMIC WORKSHOP

10 JUNE 2022

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Market needs and regulations

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WP1– Market needs and regulations focuses on:

- The real market projections and economic aspects linked to battery systems in ships
- On the analysis of the regulations for the reduction of emissions and on the effect it has on the market of energy storage systems on board of vessels
- This will result in a roadmap for battery production and cost targets, taking into account circular economy in Europe

The main objectives are to:

- Understand what are the real market projections on the emission reduction and what are the economic aspects linked to the battery systems for ships, which is one of the main elements to be used to reduce the emissions in general
- To investigate what are the current rules and regulations and what are the modifications of the rules in the following 15 years which will be applied and how those will affect the shipowners' choices.
  This will be carried out by the analysis of the European and International regulations (e.g. IMO, MARPOL, etc), currently in force and coming in, to establish the challenges and requirements with a horizon of 5, 10 and 15 years

D1.1 Emission target within 5, 10 and 15 years

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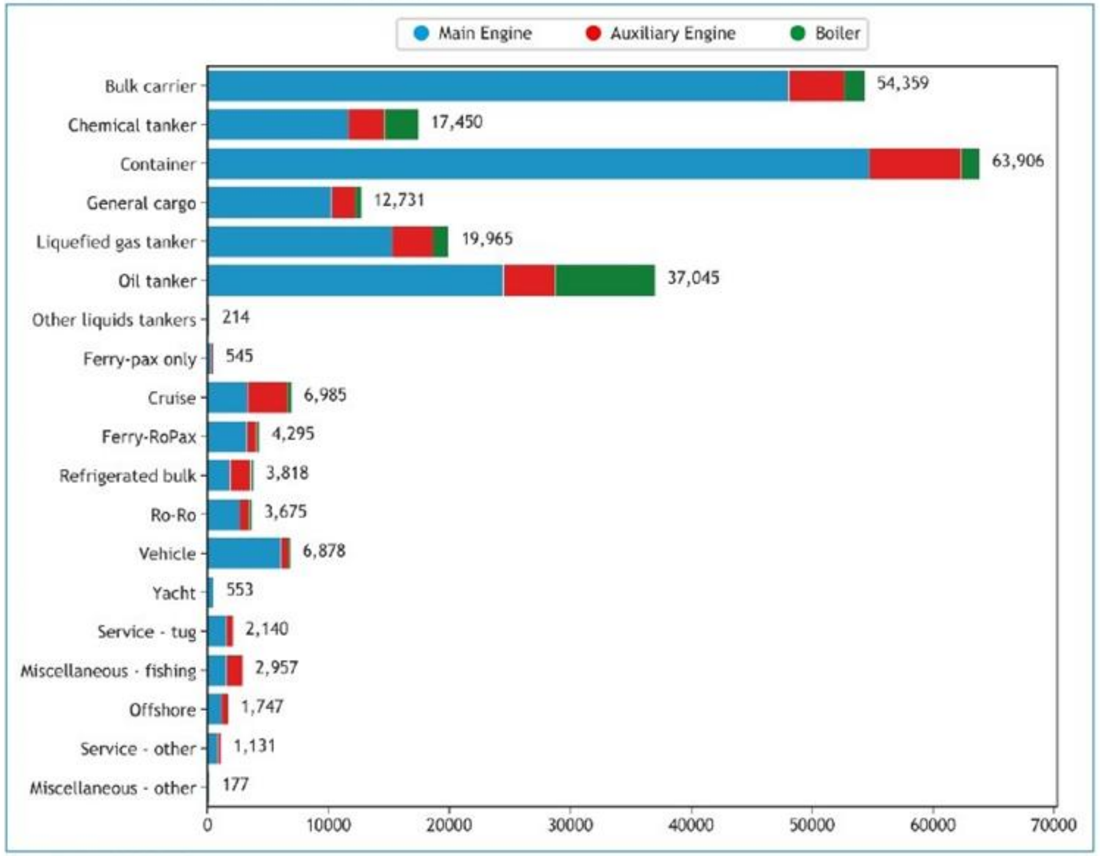
Overview of actual emissions from the maritime sector defining the contribution of different types of ships

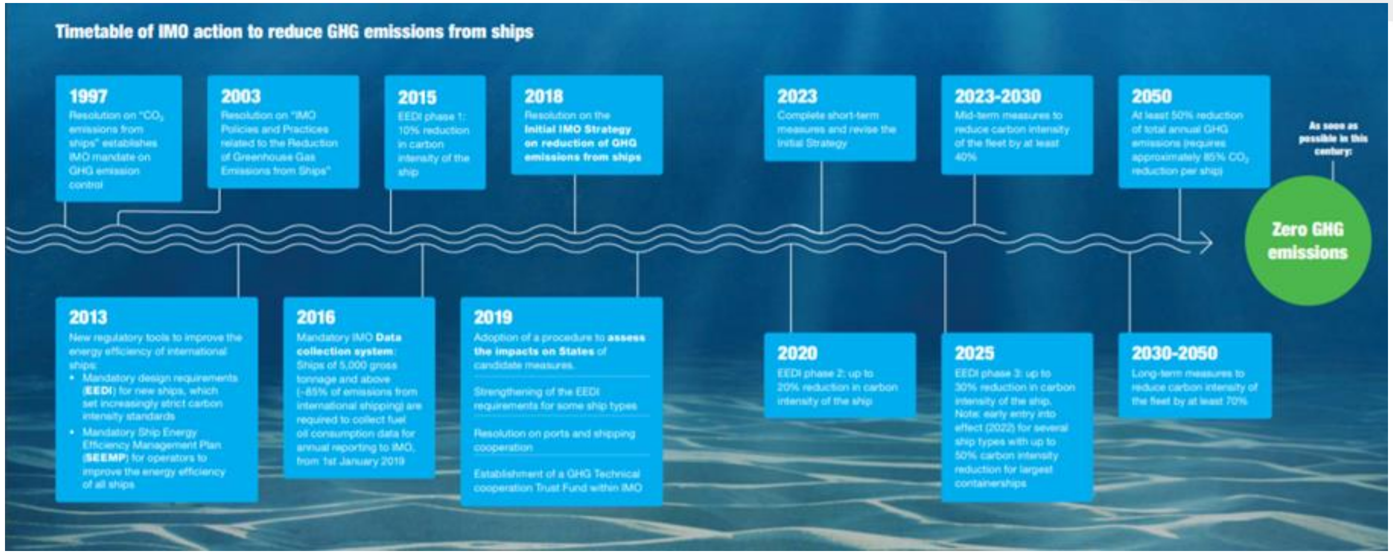
Figure 5 – International, voyage-based allocation, HFO-equivalent fuel consumption (thousand tonnes), 2018, split by main engine, auxiliary engine and boiler. Highlighted values are in thousand tonnes.

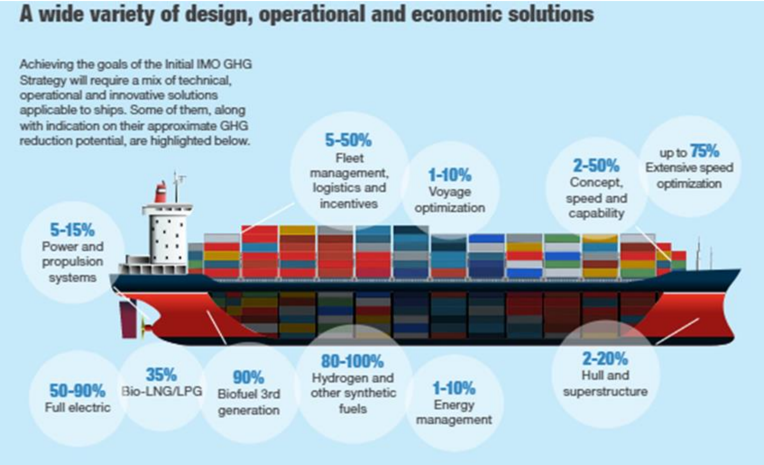


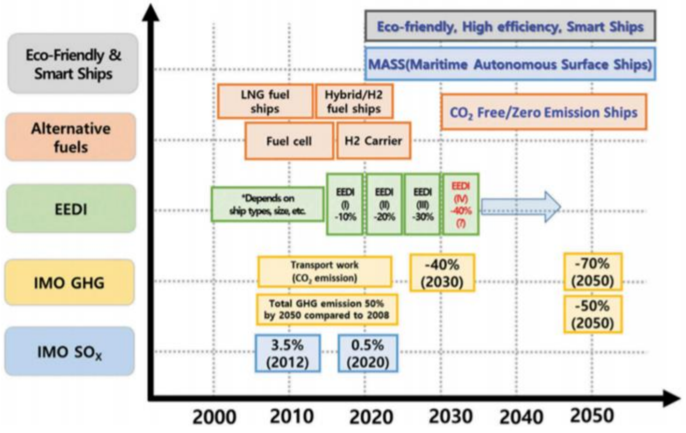
Source: UMAS.

D1.1 Emission target within 5, 10 and 15 years

- **Analysis of IMO actions to reduce GHGs**
- **Overview of solutions applicable to ships**







D1.1 Emission target within 5, 10 and 15 years

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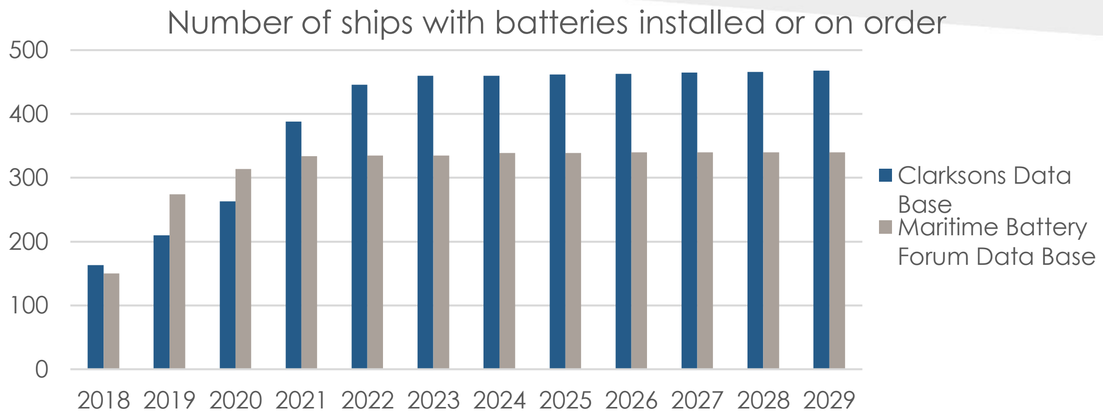
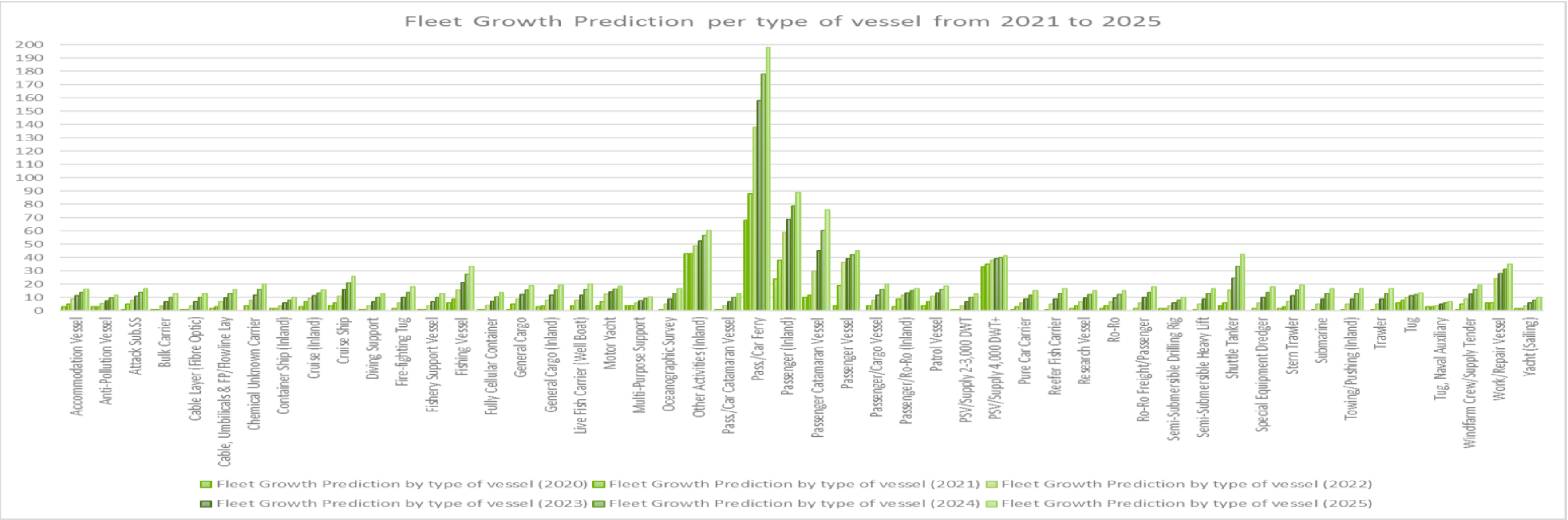
Analysis of ships equipped with batteries from different data sets and prediction of growth potential

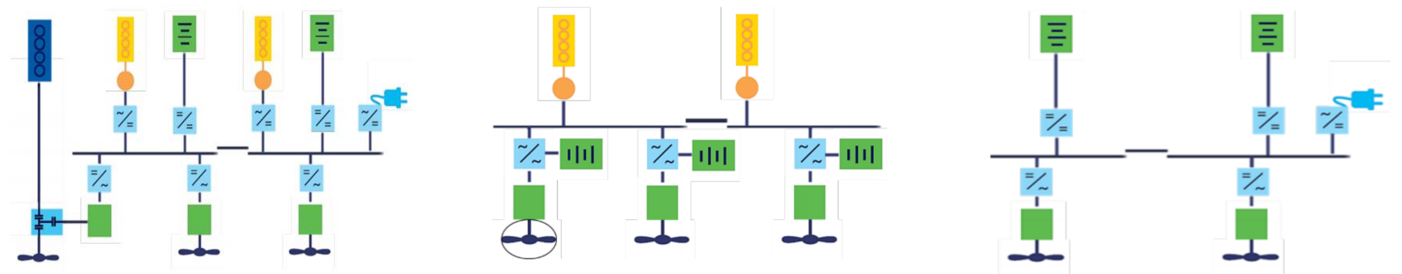




D1.1 Emission target within 5, 10 and 15 years

- **Overview of some applications currently in operation**
- **Presentation of the main electrical diagrams on board with battery systems**

Project name	Type of vessel	Operation capacity	Storage capacity	Cell chemistry
FellowSHIP	Offshore Sypply Vessel	Hybrid propulsion	450 kWh	NMC
MF Ampere	Car Ferry	All-electric powered	1000 kWh	NMC
Sustaniable Traffic Machines II	Ro-Pax Vessel	Hybrid propulsion	1600 kWh	NMC
Sustaniable Traffic Machines II	Ro-Pax Vessel	Hybrid propulsion	2600 kWh	NMC
Zero Emission Ferries	Ro-pax Vessels	All-electric powered	4160 kWh	-
Motorway of the Sea link Rodstcok-Gedser	Ro-Pax Vessels	Hybrid propulsion	1600 kWh	NMC
E-ferry	Ferry	All-electric powered	4300 kWh	NMC
Yara Birkeland	Container ship Vessel	All-electric powered	9000 kWh	-
Port-Liner	Inland waterway barge	Full electrict propulsion	6720 kWh	-

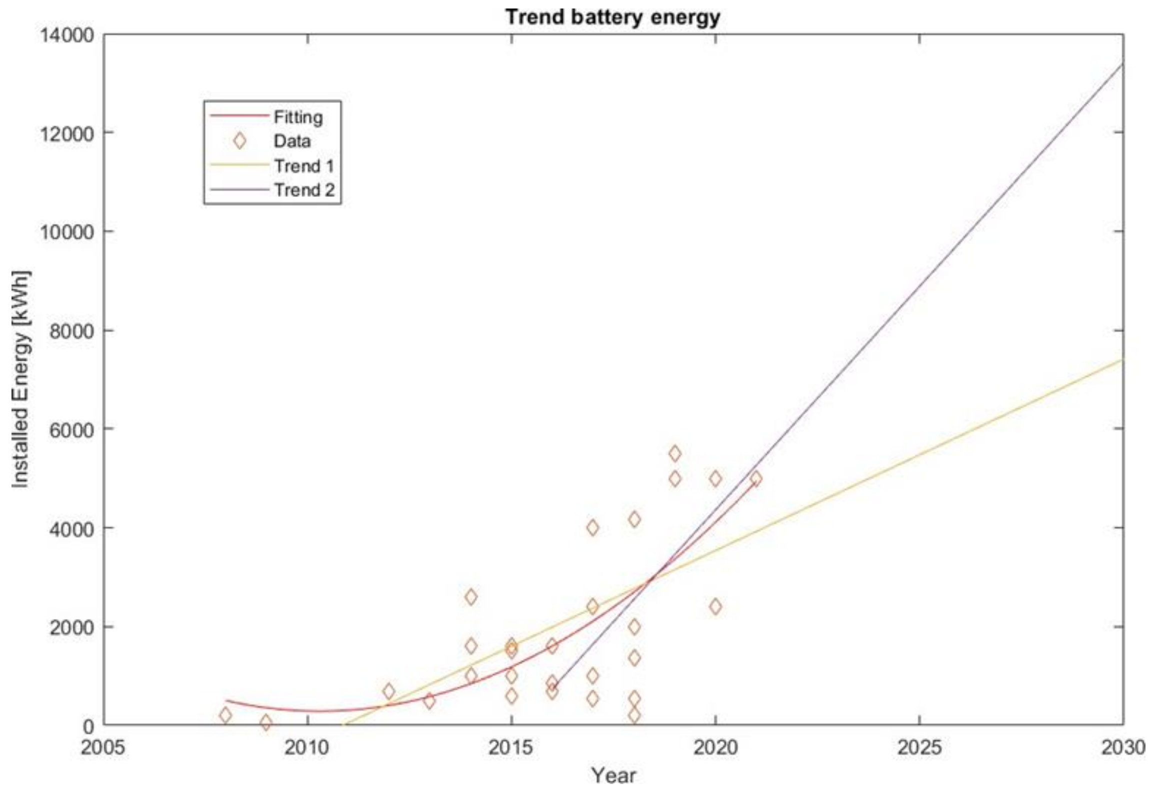


D1.2 Market evolution and potential within 5, 10, 15 years for different marine applications

Trend analysis based on data from ships currently in circulation.

Battery capacity installed onboard is growing mainly due to this reasons:

- **The decreasing prices of ESS**
- **Better ESS performance, smaller footprint and reduced weight**
- **Large ships are interested in using batteries for hybrid applications**
- **Small ships, thanks to the new density of batteries, can be converted into full battery electric ships**



D1.2 Market evolution and potential within 5, 10, 15 years for different marine applications

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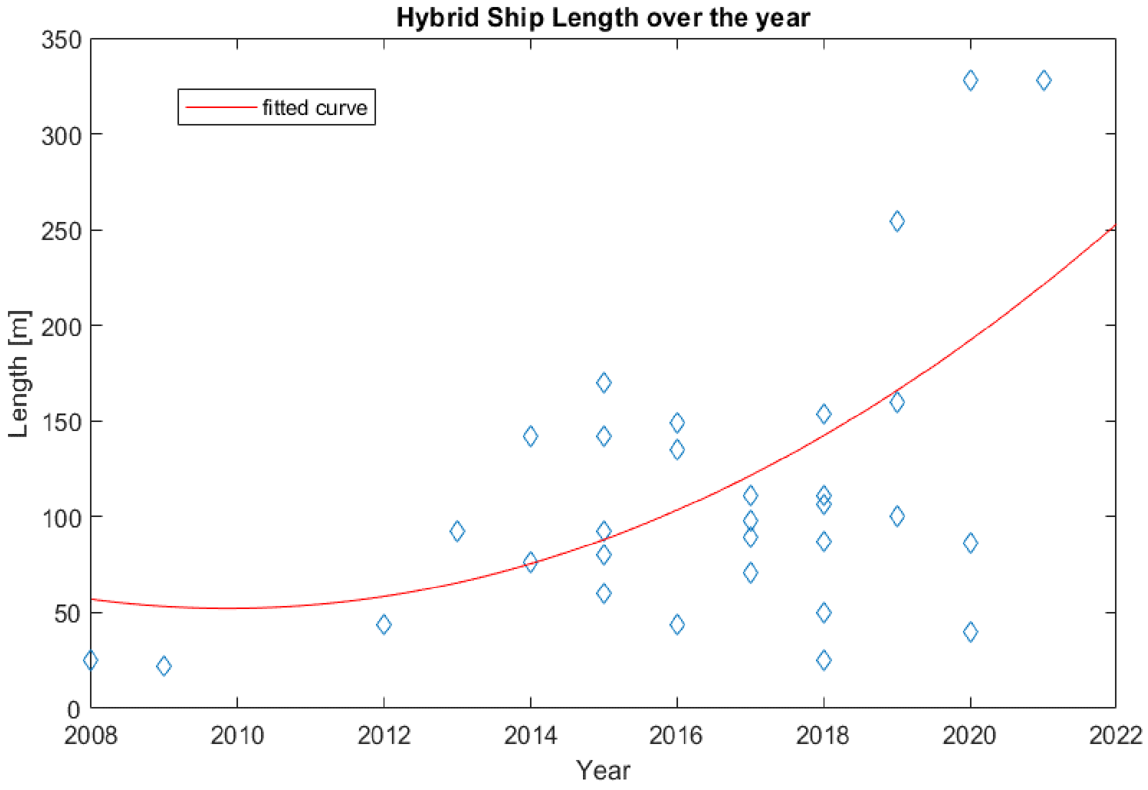
Larger vessels adopting ESS for hybrid propulsion system mainly for these reasons:

- **Larger ships are more subject to retrofit work to extend their useful life**
- **Batteries improve overall performance, efficiency, maneuverability, back up function to prevent black-out…**



D1.2 Market evolution and potential within 5, 10, 15 years for different marine applications

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After an analysis of the different ship and applications, a great variability emerged in the capacity of the batteries adopted on board the ship, demonstrating the importance of a modular and expandable system.

For the analysis the market was divided according to the size of the batteries and analyzed in 3 different scenarios (AVG, MIN, MAX):

- 100-1000 kWh: mainly hybrid applications for small vessels
- 1000-3000 kWh: hybrid applications for large ships and full battery propulsion for small ships
- 3000 kwh: hybrid applications for large ships and battery propulsion for small ships with greater autonomy

The analysis are based on the orderbook for new ships and on the experience of Damen and Fincantieri in identifying the dimensions of the energy storage associated with each type of ship.

For larger ships, a retrofit provision was also introduced with the installation of ESS.

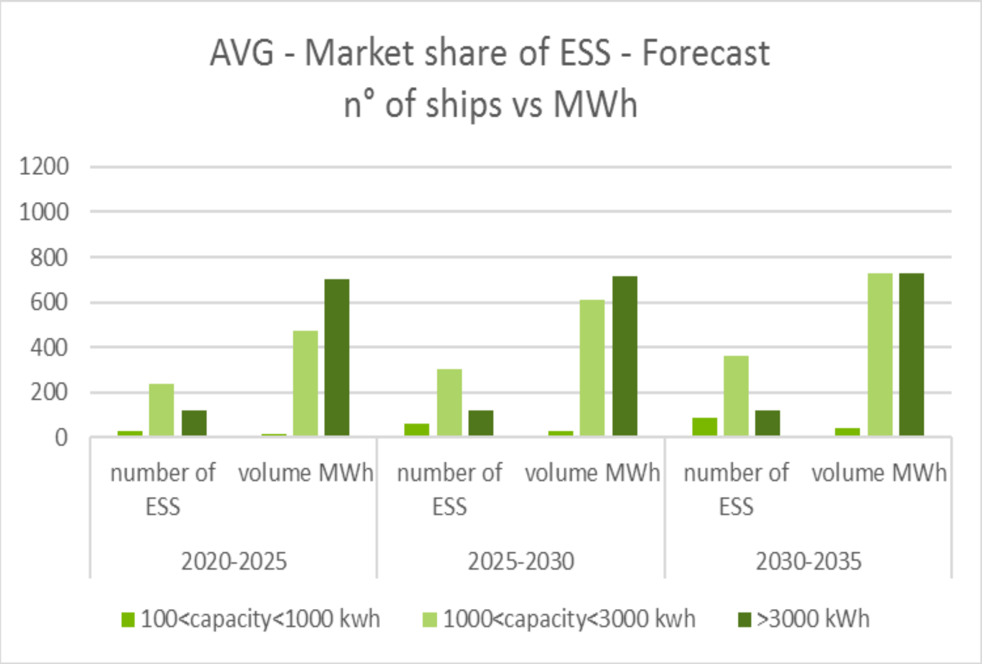
D1.2 Market evolution and potential within 5, 10, 15 years for different marine applications

The figure on the side shows a confirmation on the increase in the size of the batteries used.

We can also see how the main market share in the first period could be dominated by large ESS installations (> 3000 kWh), moreover it is also less inclined to growth this is due to the type of vessels that have lower numbers and usually each intervention is scheduled for years in advance.

Over the years it looks like mid-sized applications will see strong growth.

It also appears that the lower price and better performance of the batteries will make it more attractive to install medium-sized energy storage units than smaller ones.



D1.2 Market evolution and potential within 5, 10, 15 years for different marine applications

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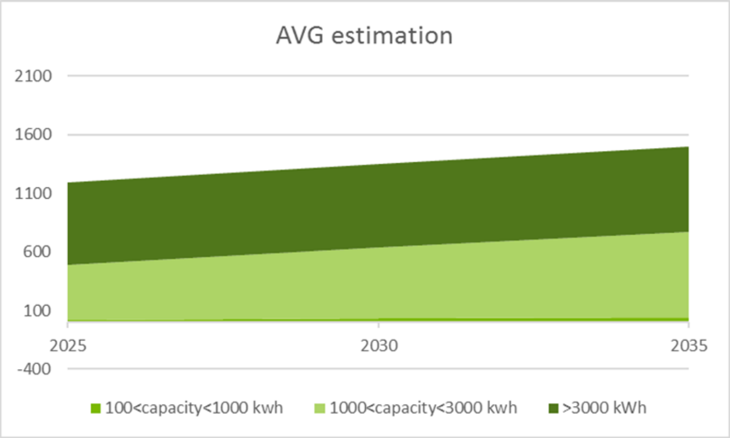
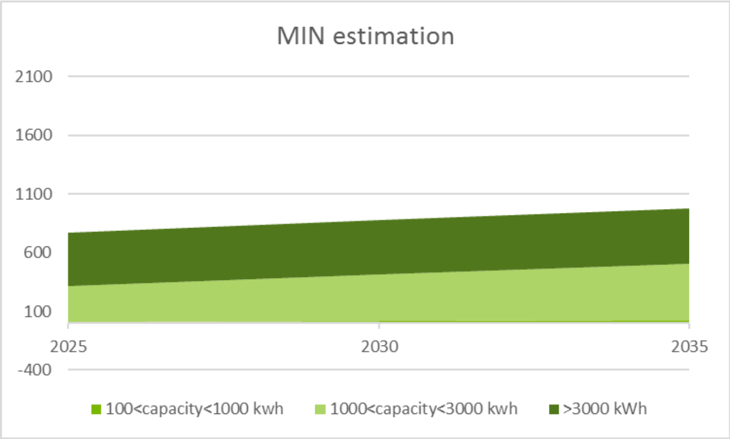
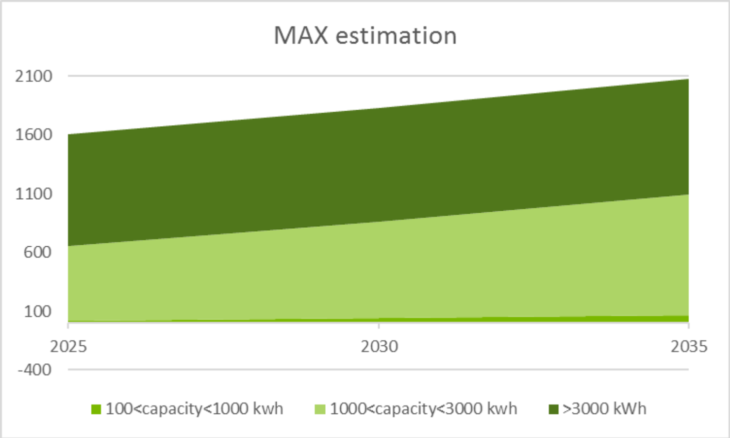
Market forecast

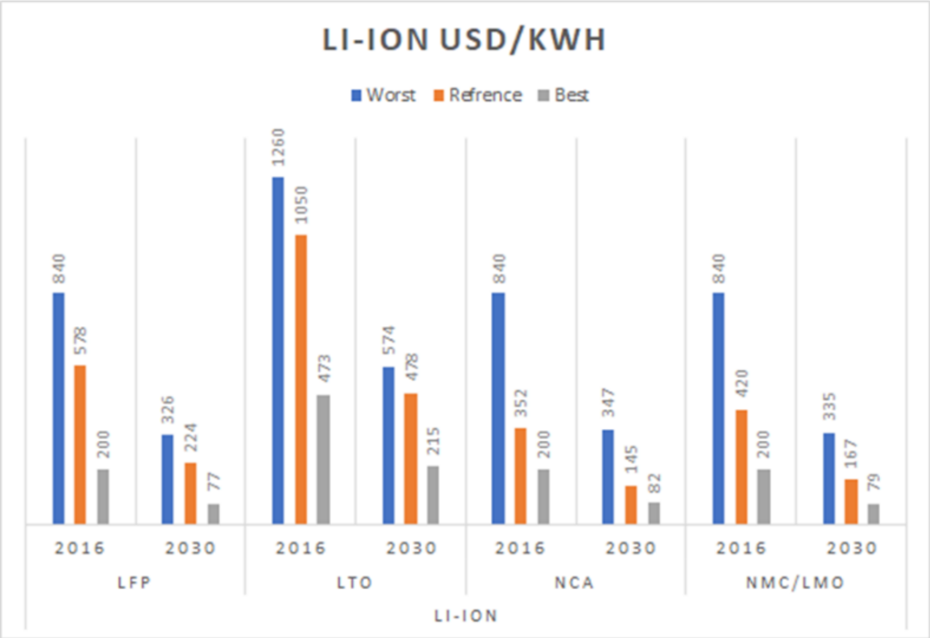




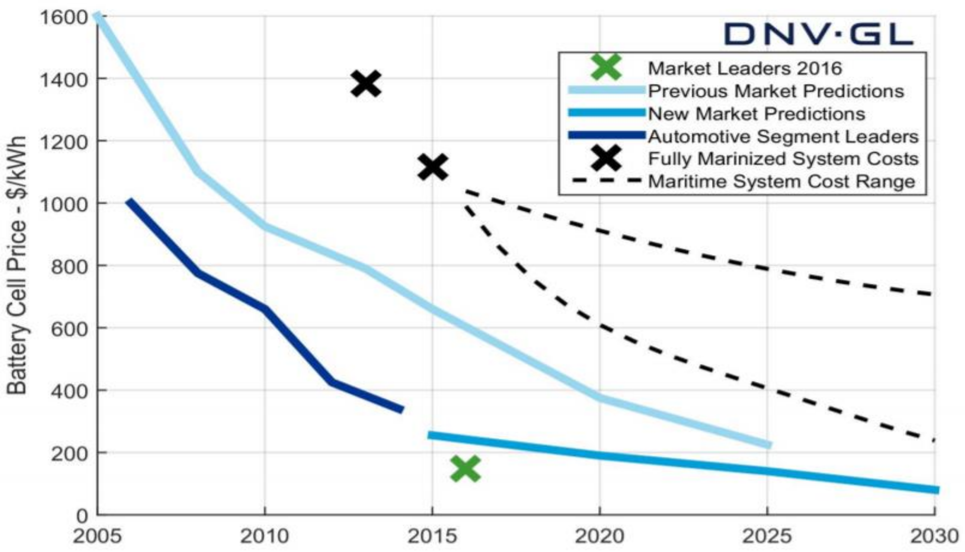


D1.2 Market evolution and potential within 5, 10, 15 years for different marine applications

Trend price of the main chemistries of lithium batteries



Li-ion battery price outlook for electric cars vs waterborne transport



D1.2 Market evolution and potential within 5, 10, 15 years for different marine applications

Analysis price base on data collected from Damen and Fincantieri applications

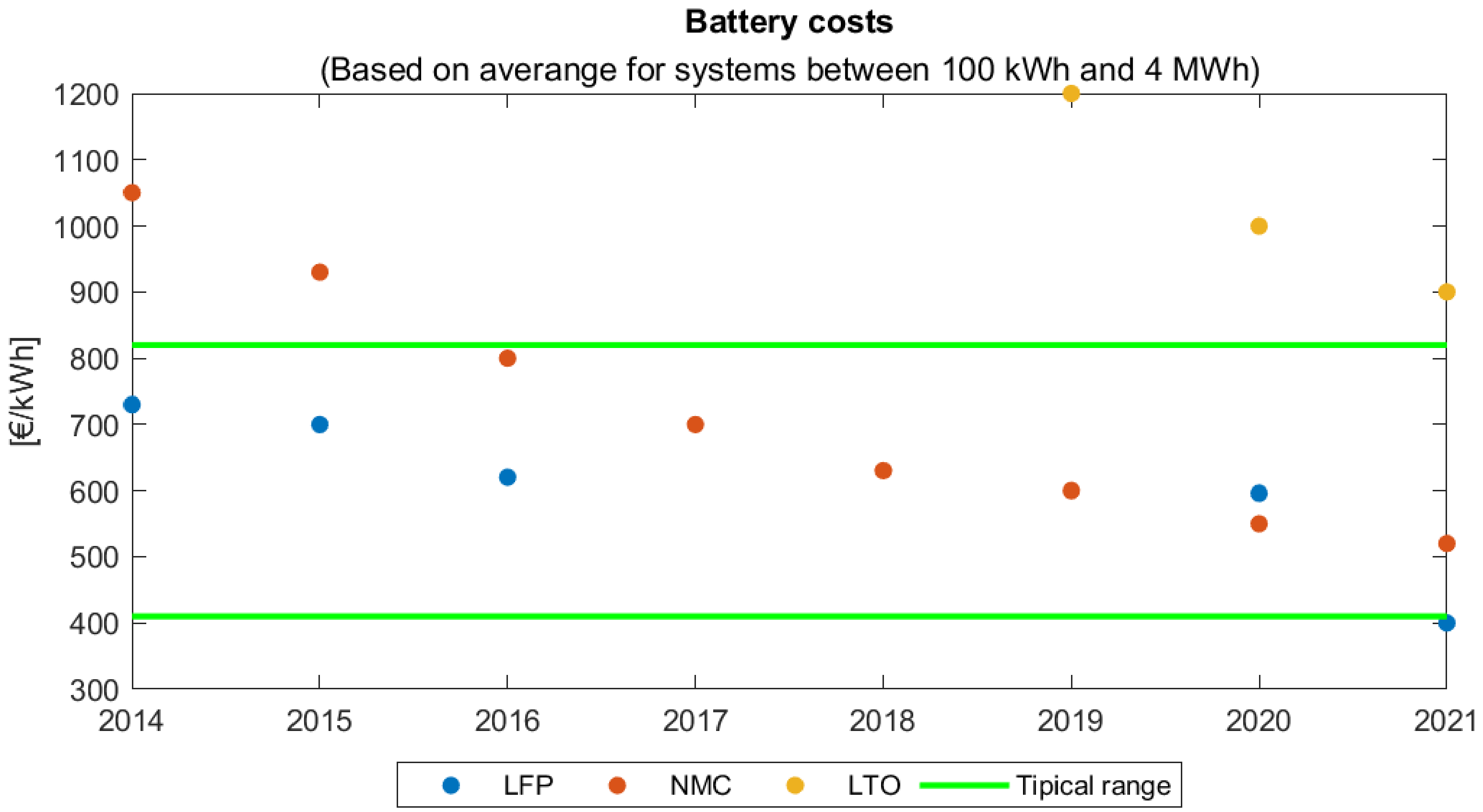


Figure 16 - Battery cost (Based on average for system between 100 kWh and 4 MWh)[1].

D1.2 Market evolution and potential within 5, 10, 15 years for different marine applications

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Table 4 -- Battery electric or hybrid electric ship with energy battery (cruise ship, ferry, ...)

Typical battery size: 500 kWh – several tens of MWh		*ESU: Energy storage unit	
		Current	Target 2035
Typical market size (GWh/year)		~0.2	~4
KPI (ESU* level)	Conditions	State of art	Target 2030
Cell/ESU weight ratio (%)	Full ESU (including rack, gas exhaust system, BTMS, BMS)	60	70
Cell/ESU volume ratio (%)	Full ESU (including rack, gas exhaust system, BTMS, BMS)	30	60
Operating lifetime expectation	10 years of operation	~50,000-80,000h	(<ship lifetime)
Cost (€/kWh)	Full ESU (including rack, gas exhaust system, BTMS, BMS)	600-700	250-300
KPI (cell level)	Conditions	State of art	Target 2030
Gravimetric energy density (Wh/kg)	1C charge and 3C discharge, 25°C	~180	350
Volumetric energy density (Wh/L)	1C charge and 3C discharge, 25°C	400-500	800-1,000
Cycle life [80% SOH] (nb of cycles)	70% DOD, 25°C, 1C charge and discharge	5,000-8,000	>10,000
Hazard level	EUCAR cell-level safety performance	<=5	<=2
Cost (€/kWh)		150	75

D1.2 Market evolution and potential within 5, 10, 15 years for different marine applications

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Table 5 -- Battery electric or hybrid electric ship with power battery (offshore vessel, drilling vessel, hybrid fuel cell, ...)

Typical battery size: 100 kWh – several hundreds of kWh		*ESU: Energy storage unit	
	Source	Current	Target 2035
Typical market size (GWh/year)		~0	~2,5
KPI (ESU* level)	Conditions	State of art	Target 2030
Cell/ESU weight ratio (%)	Full ESU (including rack, gas exhaust system, BTMS, BMS)	60	70
Cell/ESU volume ratio (%)	Full ESU (including rack, gas exhaust system, BTMS, BMS)	30	60
Operating lifetime expectation	10 years of operation	~50,000-80,000h	<ship lifetime
Cost (€/kWh)	Full ESU (including rack, gas exhaust system, BTMS, BMS)	1,300	600-700
KPI (cell level)	Conditions	State of art	Target2030
Gravimetric energy density (Wh/kg)	1C charge and 3C discharge, 25°C	~100	200
Volumetric energy Density (Wh/L)	1C charge and 3C discharge, 25°C	200	400-500
Cycle life [80% SOH] (nb of cycles)	25% DOD, 25°C, 4C charge and discharge	25,000-50,000	>80,000
Hazard level	EUCAR cell-level safety performance	<=5	<=2
Cost (€/kWh)		300	150

D1.3 Road map for battery productions

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Table 1 – Battery cost target, 3000 cycles

Battery cost target (system costs) [€/kWh]					
3000 cycles		Electricity price [€/kWh]			
		0.01	0.05	0.10	0.15
Fuel price [€/ton]	300	276	156	6	-144
	400	332	212	62	-88
	500	388	268	118	-32
	600	443	323	173	23
	700	499	379	229	79
	800	555	435	285	135
	900	610	490	340	190
	1000	666	546	396	246

Table 2 – Battery cost target, 6000 cycles

Battery cost target (system costs) [€/kWh]					
6000 cycles		Electricity price [€/kWh]			
		0.01	0.05	0.1	0.15
Fuel price [€/ton]	300	552	312	12	-288
	400	664	424	124	-176
	500	775	535	235	-65
	600	886	646	346	46
	700	998	758	458	158
	800	1109	869	569	269
	900	1220	980	680	380
	1000	1332	1092	792	492

Table 3 – Battery cost target, 10000 cycles

Battery cost target (system costs) [€/kWh]					
10000 cycles		Electricity price [€/kWh]			
		0.01	0.05	0.1	0.15
Fuel price [€/ton]	300	921	521	21	-479
	400	1106	706	206	-294
	500	1292	892	392	-108
	600	1477	1077	577	77
	700	1663	1263	763	263
	800	1848	1448	948	448
	900	2034	1634	1134	634
	1000	2220	1820	1320	820

D1.3 Road map for battery productions

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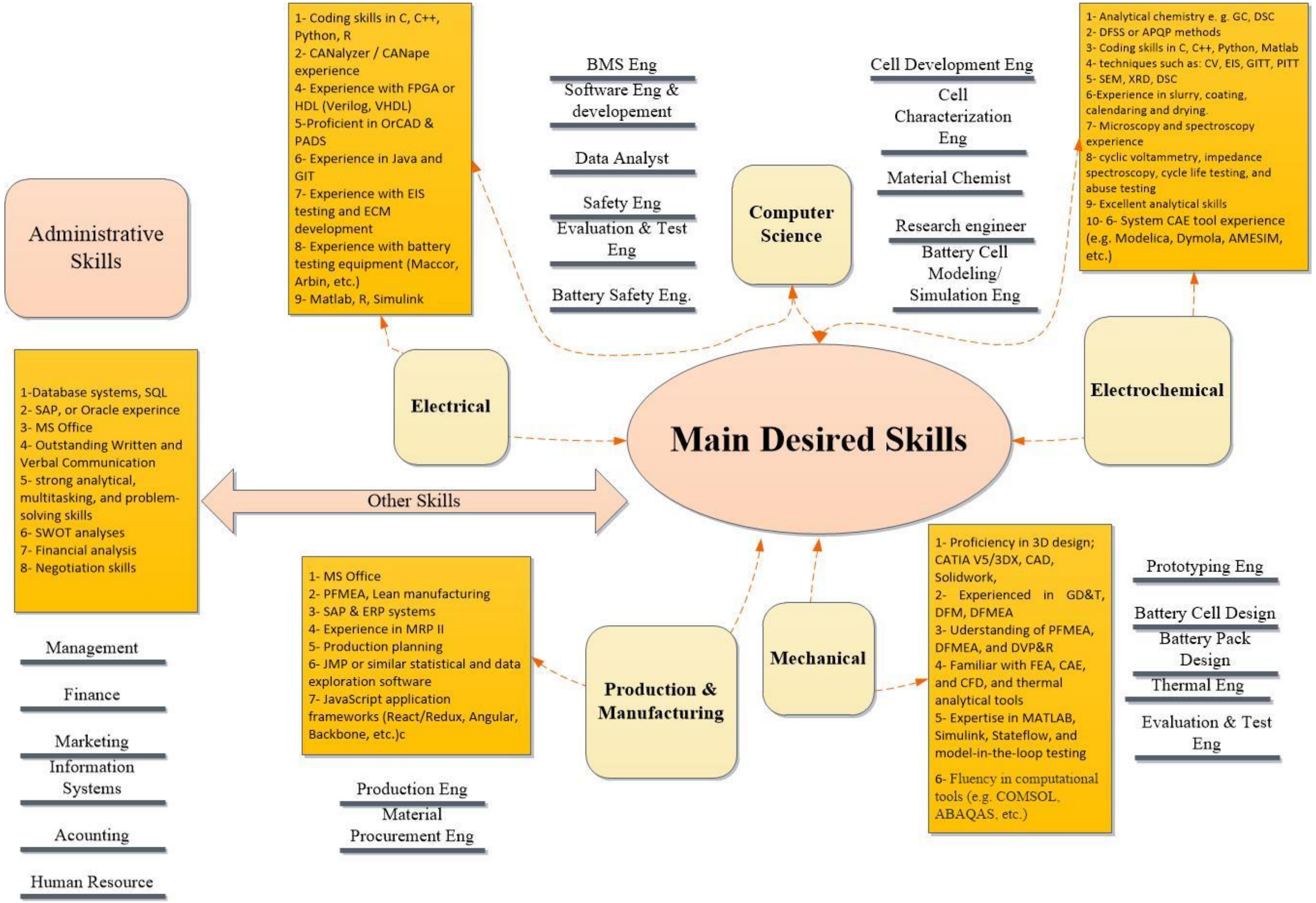

D1.3 Road map for battery productions

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NAME	CHALLENGES/BOTTLENECKS
Specific energy	Bottleneck
Charging	Bottleneck
Temperature	Challenge/Bottleneck
Ageing	Bottleneck
Humidity	Challenge/Bottleneck
Thermal runaway & propagation	Challenge
Electrolyte off-gas	Challenge
Battery Management System (failure)	Challenge
Battery cell and chemistry	Bottleneck
Overcharge	Challenge
Overdischarge	Challenge
Overcurrent	Challenge
Excessive cold	Challenge/Bottleneck
External short circuit	Challenge
Mechanical damage	Challenge
External fire	Challenge/Bottleneck
Internal defect	Bottlenecks

D1.4 Impact on battery production in EU and its circular economy

Overview of:

- **Supply chain**
- **Battery manufacturing process**

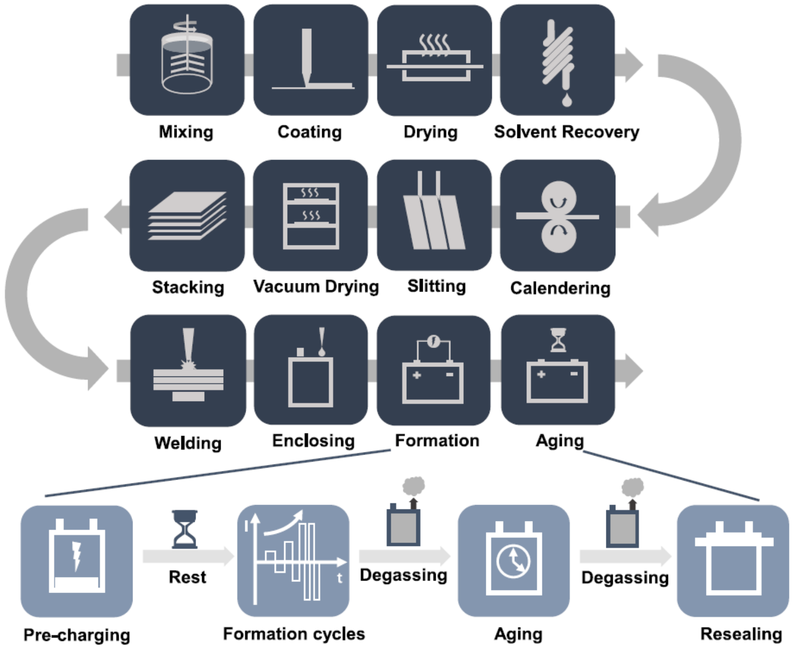


Figure 1: Current state of the art of battery manufacturing process [2]

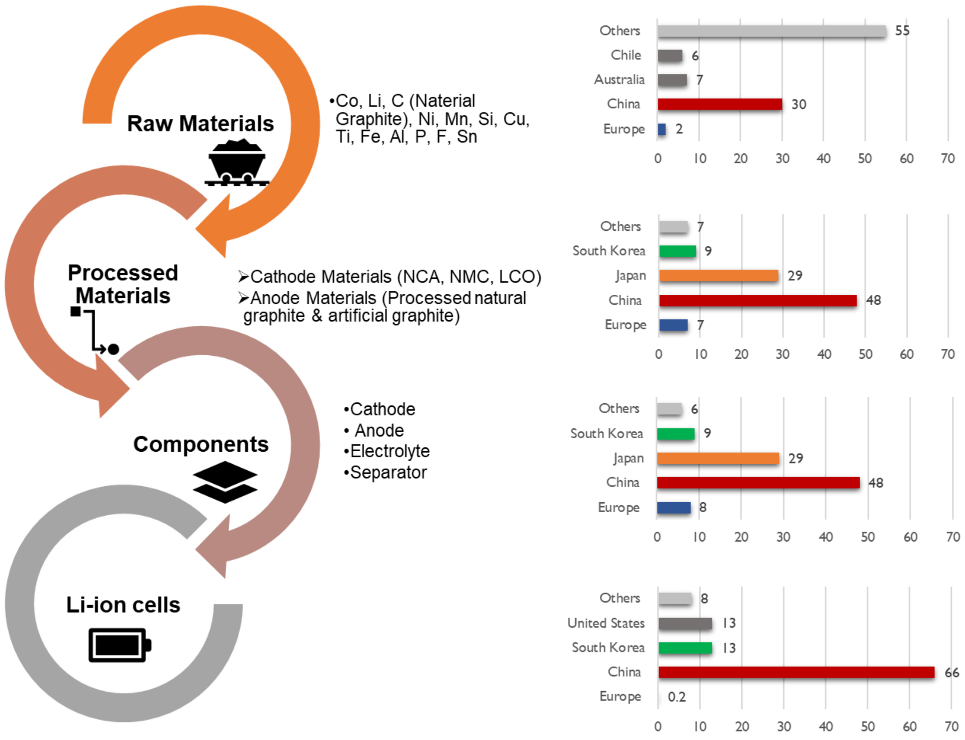
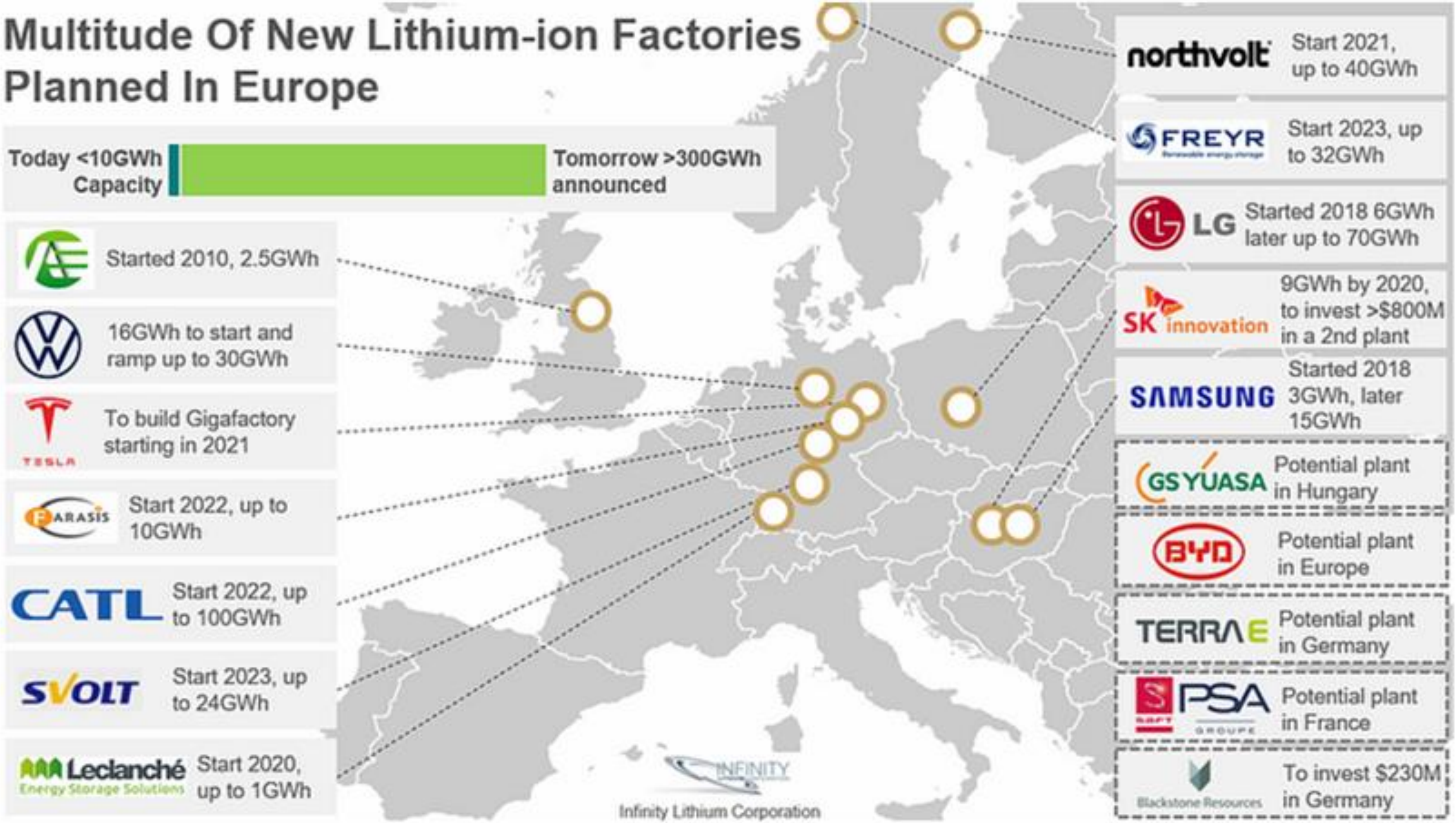


Figure 1: Key players in the Li-Ion supply chain and market shares in percent

D1.4 Impact on battery production in EU and its circular economy



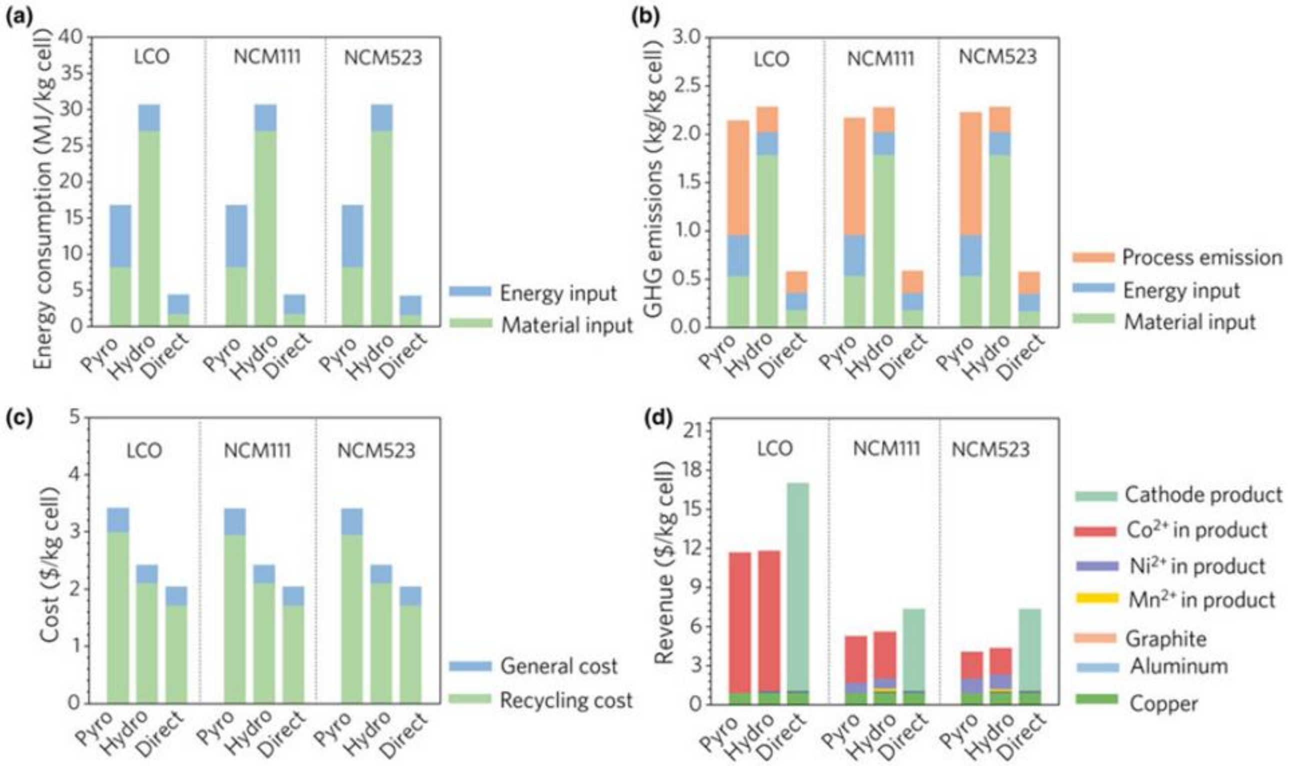
D1.4 Impact on battery production in EU and its circular economy

Circular Economy ↑ Linear Economy	Smarter Product Use and Manufacture	R0 Refuse	Make products redundant by choosing circular products that possess some or all of the qualities of the 9R's
		R1 Rethink	Make product use more intensive (e.g. by sharing product)
		R2 Reduce	Increase efficiency in product manufacturing or use by consuming fewer natural resources and materials
	Extend Lifespan of product and its parts	R3 Reuse	Reuse by another consumer a discarded product which is still in good condition and fulfils its original function
		R4 Repair	Repair and maintenance of defective products so it can be used with its original function. Generally has not been tested and may not include a warranty
		R5 Refurbish	Restore a product and bring it up-to-date or restore functionality. Includes testing for defects prior to resell and usually includes a warranty
		R6 Remanufacture	Rebuilding of a product to original specifications by exchanging worn parts with repaired, used or new parts. The product or machine should perform as a new one and includes a warranty
		R7 Repurpose	Use discarded products or its parts in a new product with a different function
	Useful application of materials	R8 Recyclable Resource Recovery	Process materials to obtain the same (high grade) or lower grade quality
		R9 Recover	(1) Recover or 'cannibalise' from damaged products for the reuse of parts in order to facilitate remanufacturing or refurbishing activities. (2) Incineration of material for energy recovery

From linear to circular economy analysis

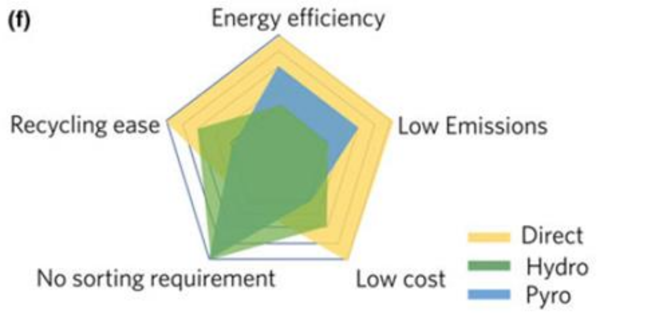
D1.4 Impact on battery production in EU and its circular economy

Recycling profit from cells and process description



(e) Profit of different recycling methods ($/kg cell)

	Pyro	Hydro	Direct
LCO	8.2	9.3	14.9
NCM111	1.8	3.1	5.3
NCM523	0.7	1.9	5.3



D1.4 Impact on battery production in EU and its circular economy

LCA for a small ferry – Ellen a European project:

The project brought the following results of the European project:

- **4300 KWh**
- **Energy efficiency: 85% transformer-propeller**
- **Energy consumption, round trip 22 miles (approximately 40 kilometers): 1600 kWh**
- **Pay-back time: 4-8 years**
- **CO_2 emissions saved compared to a modern diesel: 2,520 tons / year**
- **Passenger satisfaction: very high**

All the data are available in the European Report of the project

D1.4 Impact on battery production in EU and its circular economy

- **LCA for a small ferry with two scenario base on energy mix EU and on Renewable energy**

Global Warming Potential (GWP)
Cumulative energy demand (CED)
Aerosol formation potential (AFP)
Acidification potential (AP)
Eutrophication potential (EP)
Net present value (NPV)
Operating Expense (OPEX)

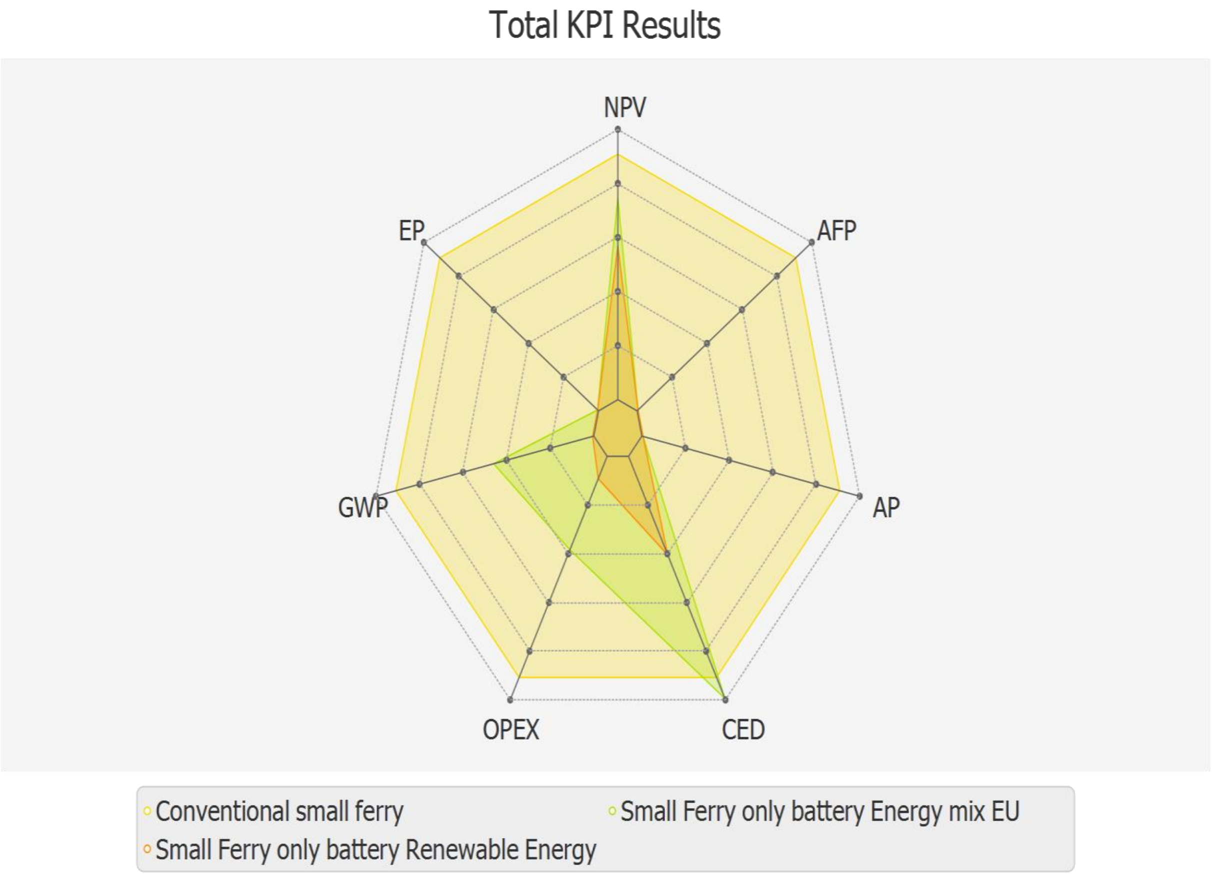


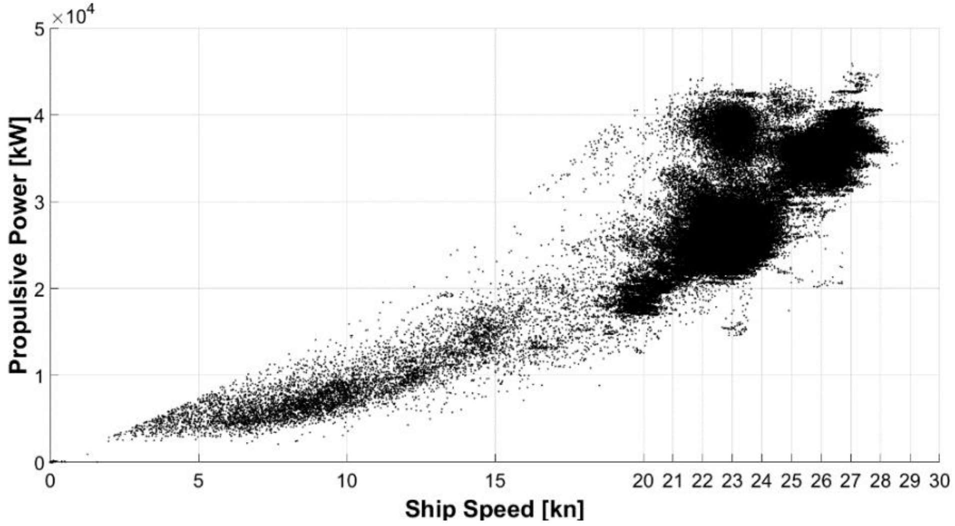
Figure 1 Small/medium size ferry radar chart

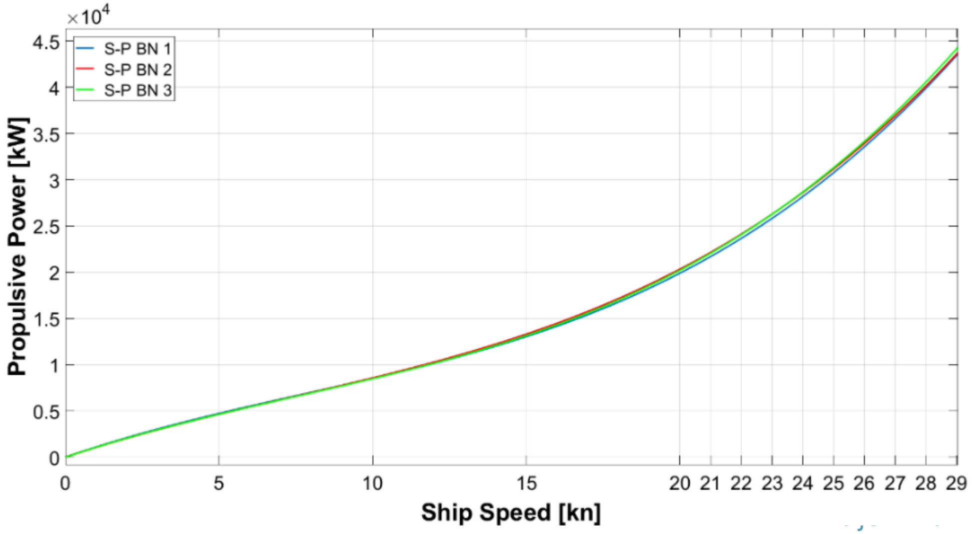
D1.4 Impact on battery production in EU and its circular economy

LCA for a RORO – Data collected from Fincantieri projects:

Will be analyzed a vessel with batteries on board:

- **5000 KWh**
- **Hybrid applications – peak shaving, zero emission in ports**
- **Cold ironing**
- **LOA of 250 m**
- **Gross Tonnage of 50.000**





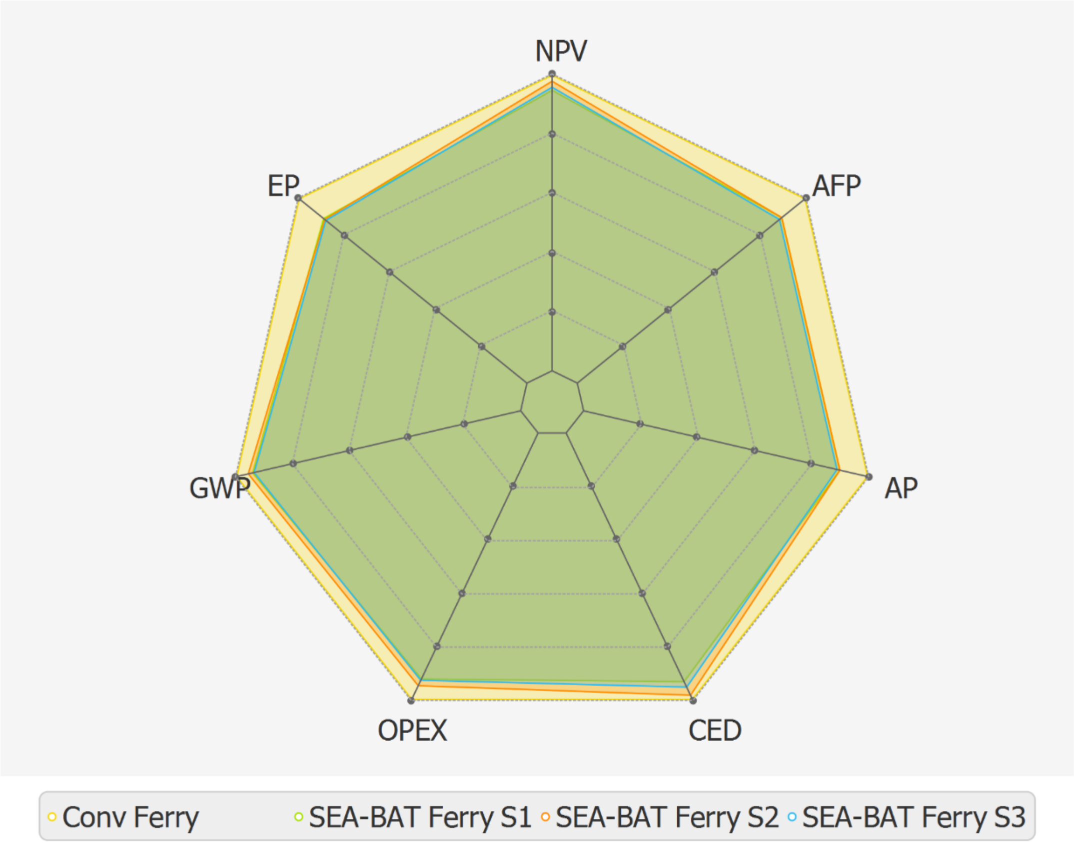
D1.4 Impact on battery production in EU and its circular economy

LCA for a RORO

Three different scenarios were taken into account for calculation

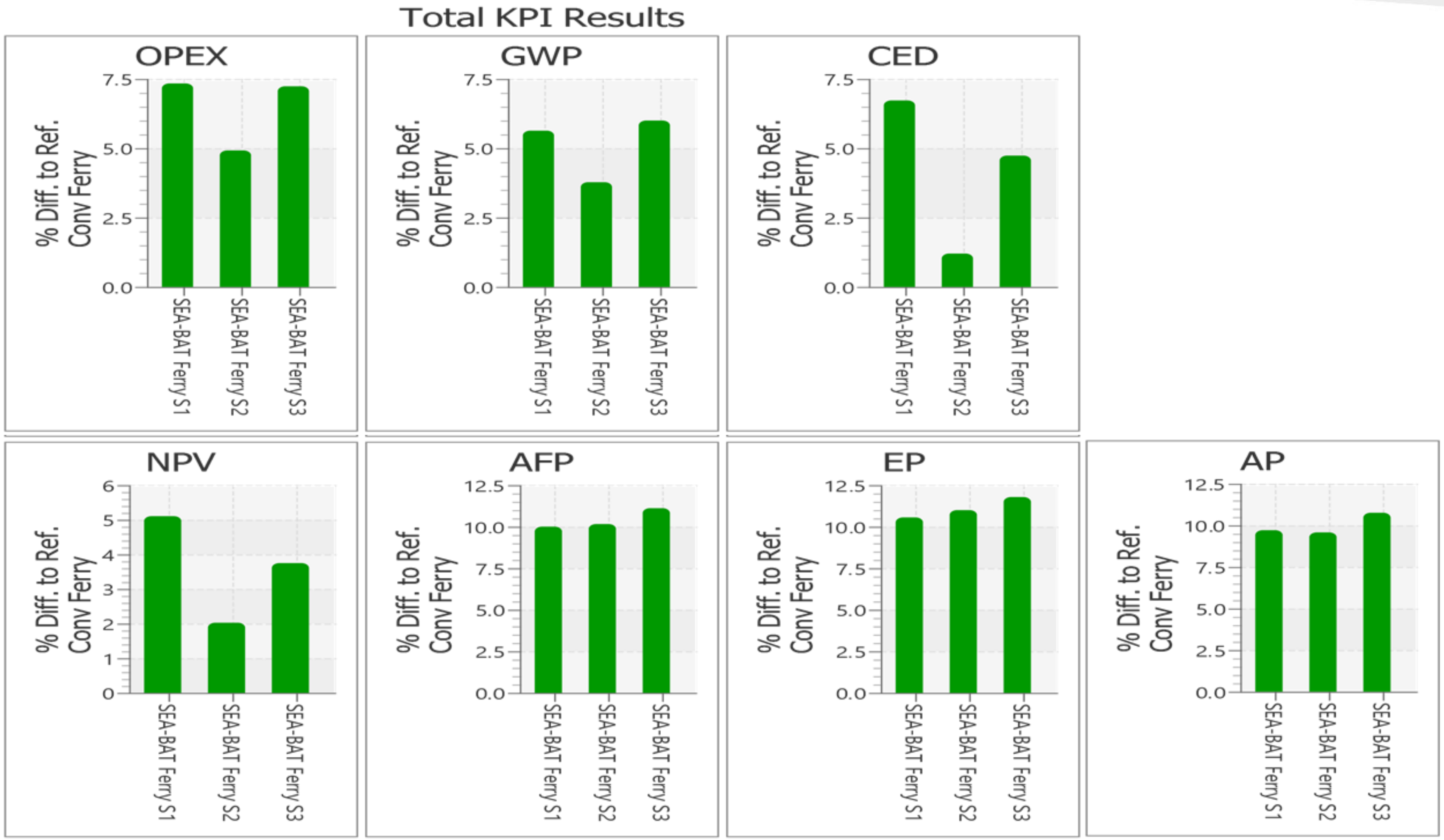
Global Warming Potential (GWP)
Cumulative energy demand (CED)
Aerosol formation potential (AFP)
Acidification potential (AP)
Eutrophication potential (EP)
Net present value (NPV)
Operating Expense (OPEX)

Total KPI Results



D1.4 Impact on battery production in EU and its circular economy

LCA for a RORO



QUESTIONS?

THANK YOU FOR YOUR ATTENTION

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