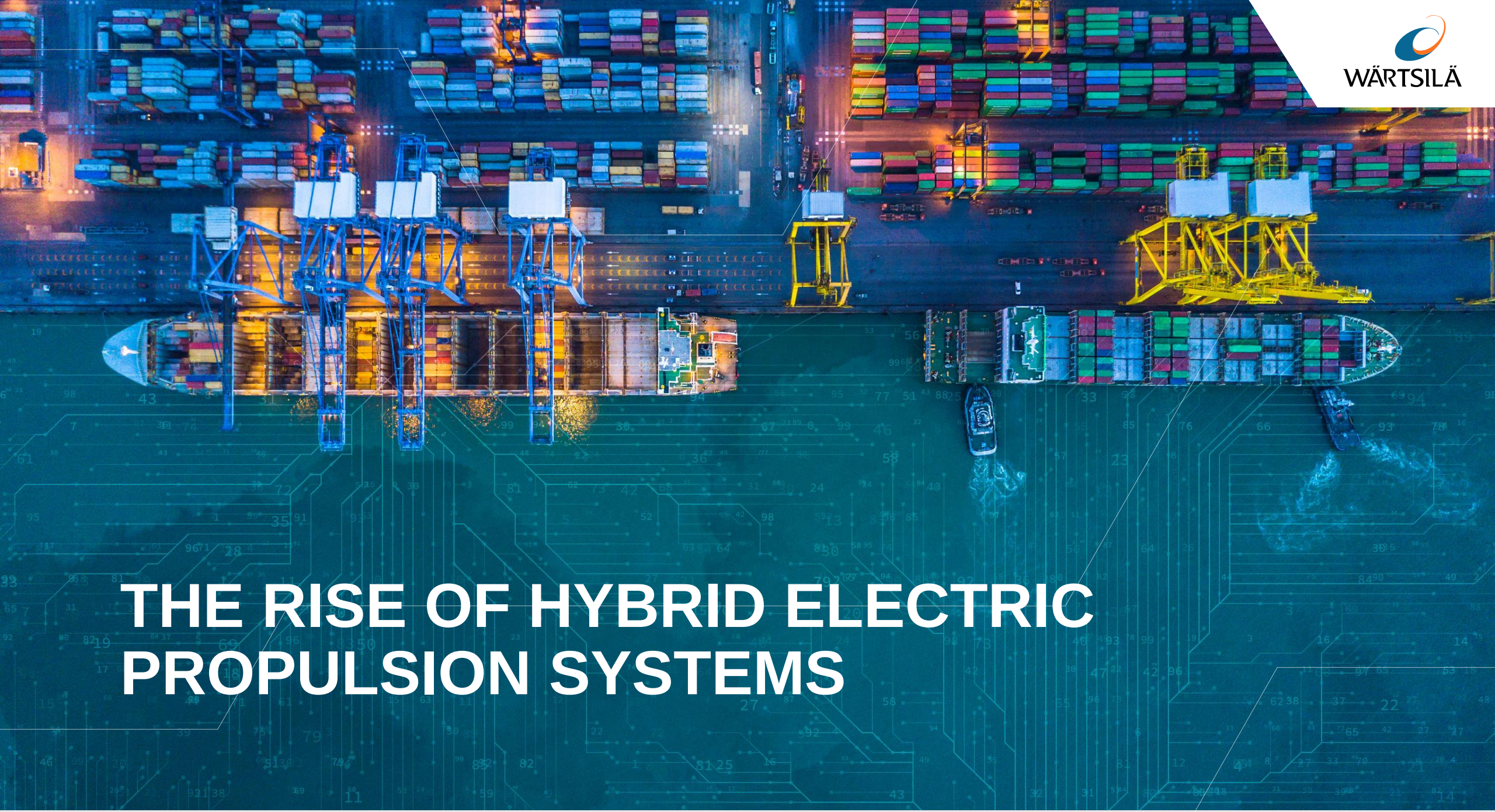


THE RISE OF HYBRID ELECTRIC PROPULSION SYSTEMS

Decarbonzation triangle

ENERGY EFFICIENCY

NEW FUELS

ELECTRIFICATION

THE ONLY THING THAT IS CERTAIN IS THAT ALL WILL BE DIFFERENT IN THE FUTURE

- What are the future power sources on vessels (wind, solar, fuel cells, batteries)?
- What will be the future fuels for a vessel (and how many different ones)?
- What will be the operational profile (speed, port stay times)?
- What other consumers will come in the future (e.g. air lubrication)?

You need to make your propulsion train flexible for future options!

Hybrid propulsion is the most flexible known today!

Smart electrical system design ensures that you have low electrical losses (e.g. reduce conversion steps (add. AC -> DC for DC Grids), get rid of transformers (Wartsila Low Loss DFE))

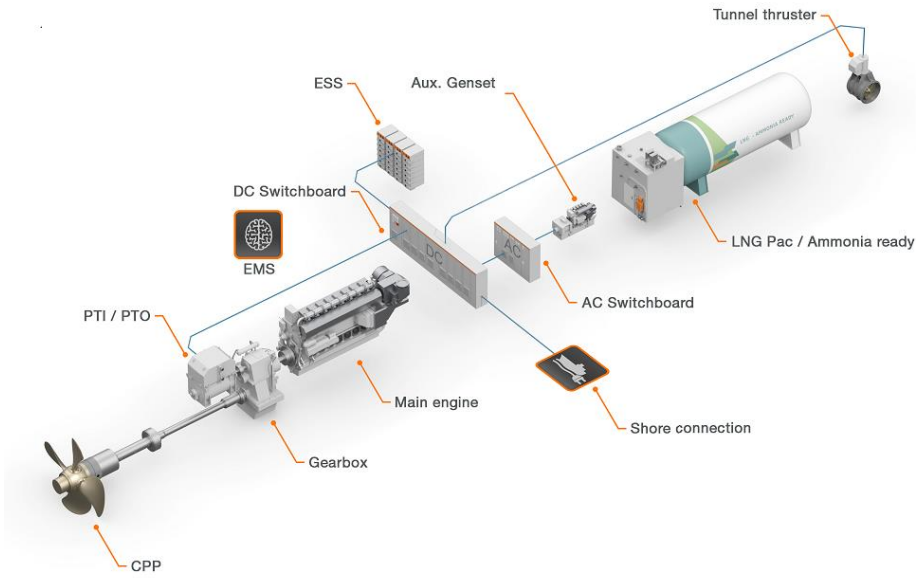
ALL VESSELS WILL BE HYBRID AT SOME POINT – ALREADY TODAY POSITIVE ROI

Case	Fuel consumption reduction
Ropax	-14%
Ferry	-17%
Shuttle tanker	-22%
PSV	-25%
Tug	-16%
Mini-Bulker	-15%
Bunker vessel	-23%
PCTC	-7%

- Reduce installed power
- Optimized vessel operations by hybrid functionality (peak shaving, spinning reserve, load optimization, thruster mode, crane operations, etc)
- Optimize vessel operation with new power sources (additional variable loads)
- Zero-emission operations e.g. close to port
- Get (partly) green energy from the grid via charging

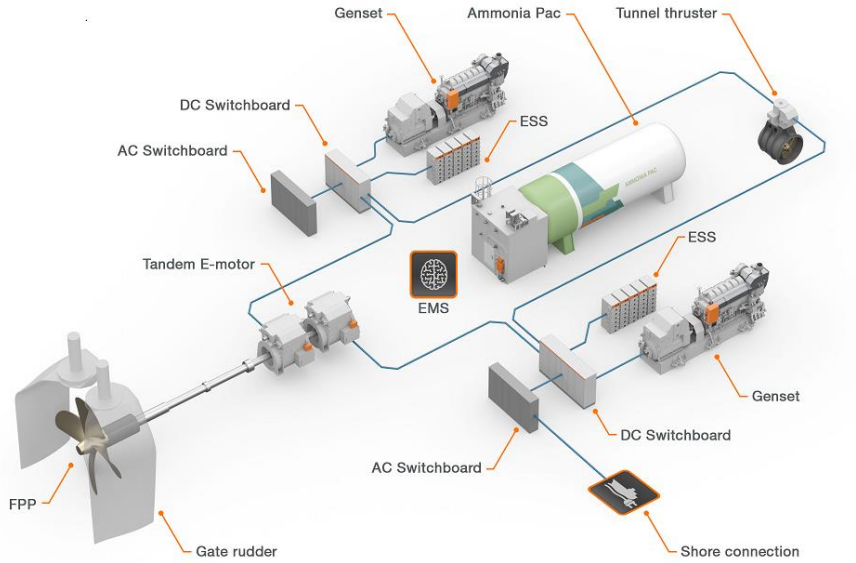
THERE ARE TWO HYBRID OPTIONS TO CHOOSE FROM
EXAMPLE SMALL MERCHANT VESSELS

Hybrid Mechanical



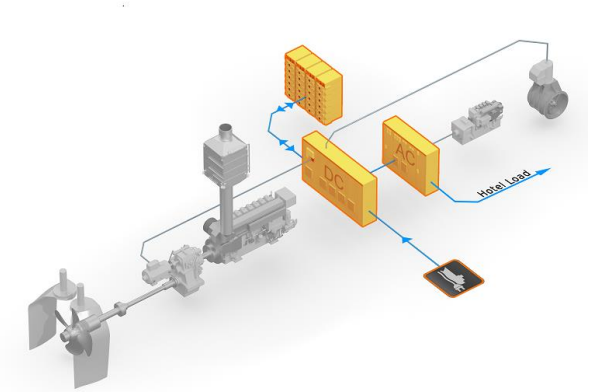
- Hybrid-Mechanical CPP with Energy Storage, Shore Connection and Alternative Fuel
- Integrated propulsion and electrical distribution

Hybrid Electric

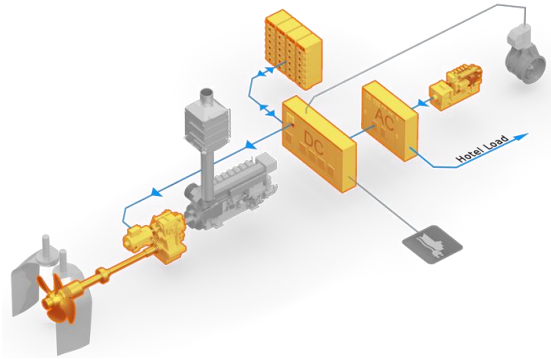


- Hybrid-Electric FPP with Energy Storage, Shore Connection and Alternative Fuel
- Direct driven FPP with large PM motors

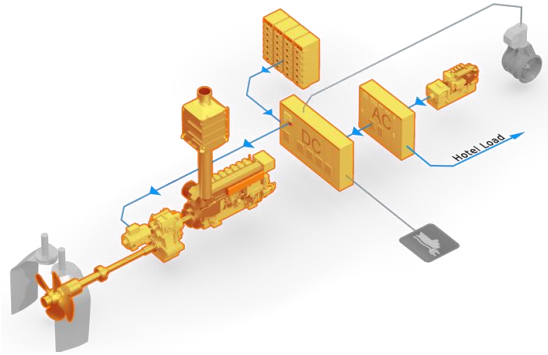
WE TALK ABOUT PROPULSION SYSTEM FUNCTIONALITY, NOT EQUIPMENT



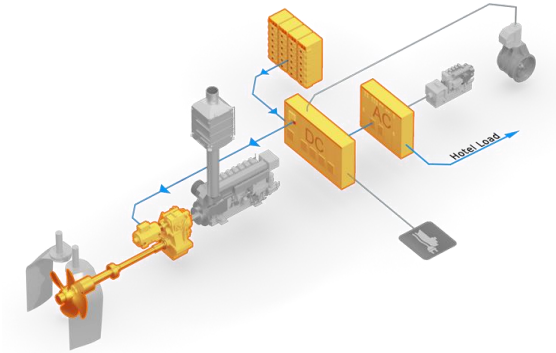
- Harbor – Zero emission electric mode



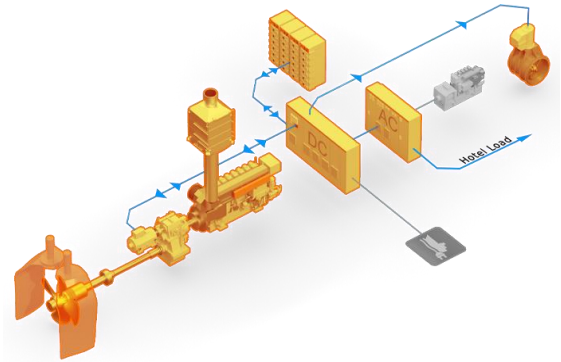
- Harbor - Genset maneuvering mode



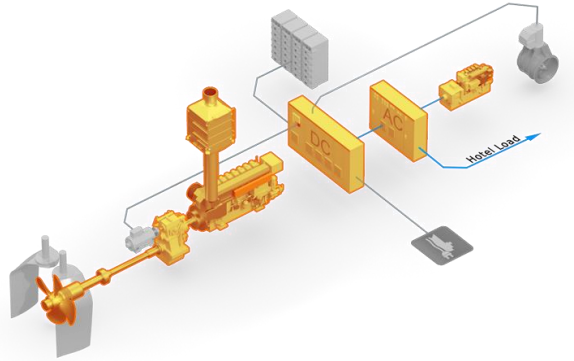
- Propulsion in e-boost mode



- Zero emission sailing mode



- Propulsion – Main Engine as GENSET mode



- Main Engine mechanical mode, Genset in Aux mode

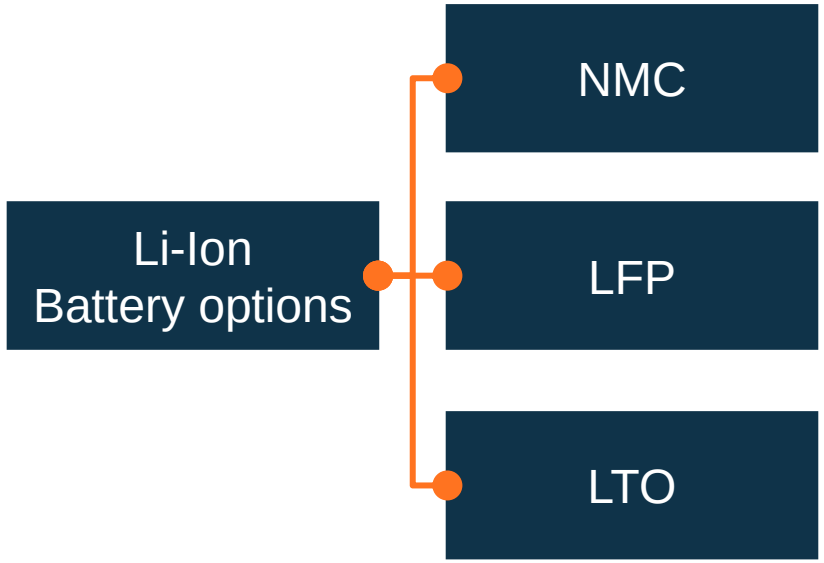
WE LIKE TO PUSH THE BOUNDARIES

- Currently > 30 hybrid PCTCs in yards with Wartsila HY
- Grimaldi with largest ESS, 5MWh
- On top of spinning reserve, peak shaving also zero emission in ports

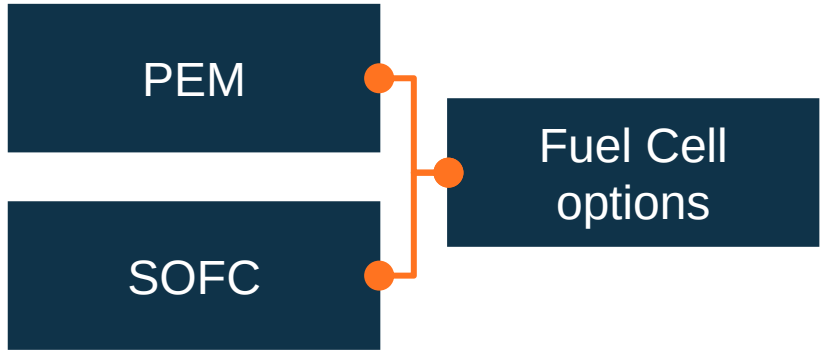
- All Ropax go Hybrid currently, most hybrid mechanical
- BF / Stena 11.5MWh ESS hybrid allows full power at maneouvering only on batteries
- IEC Shore power for charging

- Full electric fast ferry (25kn) with 40MWh battery, 225 cars, 2000 passengers
- 16MW propulsion power via 8 waterjets
- 2h trip in shallow water (<4m) with 90min turnaround
- DC charging on both sides

HYBRIDIZATION TODAY HAPPENS WITH BATTERIES, BUT ALSO FUEL CELLS ARE COMING

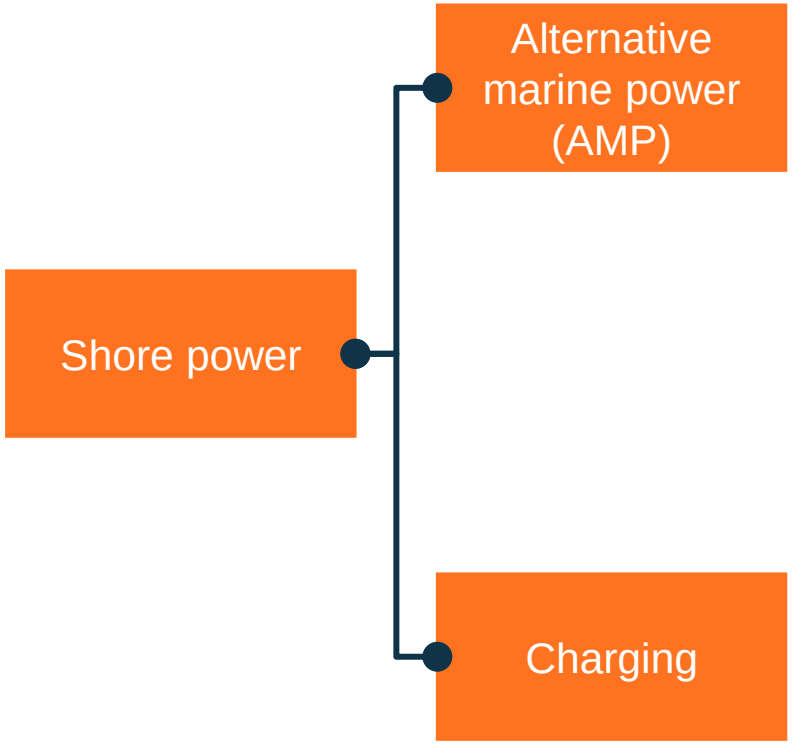


Batteries are good at variable loads…



…while fuel cell are baseload providers.
(and are coming always with a battery)

TWO VERY DIFFERENT CHARGING / SHORE POWER TECHNOLOGIES EXIST TODAY

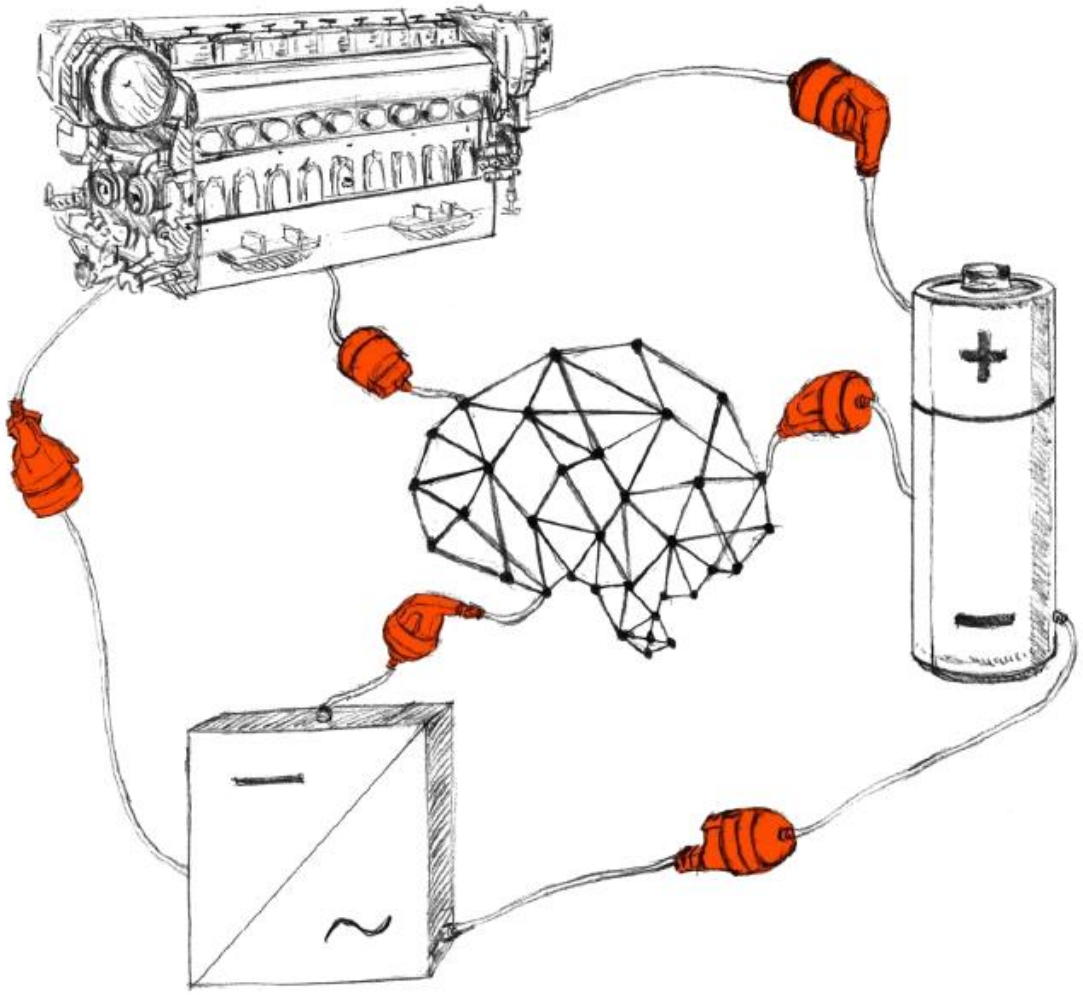


- Vessel takes electricity when in port and shuts down all engines
- Reduces local emissions and fuel consumption in port
- Is already standardized in IEC 80005 that all commercial ships and ports can easily connect
- Highest adoption for High Voltage solutions (6.6kV or 11kV)

- Vessel takes electricity when in port and recharges batteries
- Allows vessel to sail zero-emission for some time
- Typically used in a closed infrastructure, e.g. for a specific ferry going back and forth
- Not standardized yet, custom for each project

An IEC connection can of course be used for charging e.g. a RoPax.

A HYBRID VESSEL IS NOT DONE BY ADDING A BATTERY TO THE PROPULSION TRAIN



- The hybrid control (= energy management) system give the optimization functionality to the vessel and safeguards battery lifetime
- They are not available on the market, only the experienced hybrid integrators have one
- A normal power mgmt. system can only turn the battery on and off a hybrid vessel and will not deliver its functions
- A normal PMS cannot safeguard charging / discharging speed that is so important to keep battery lifetime as engineered

SOME TYPICAL MISUNDERSTANDINGS THAT EXIST IN THE MARKET

- Hybrid systems are only for newbuilds
  - No we have retrofitted apx. 30 ships and made them hybrid with 20%+ fuel savings
- Hybrid vessel always need a central DC distribution grid
  - Not true, although batteries need a DC converter, total DC grids have higher electrical losses, than AC, so you need a smart combination
- PM machines are always better, as more efficient
  - This is typically promoted by providers that only offer PM machines, you need to look at a total system efficiency (AFE converter, gearbox, transformer, etc).
- Batteries stop working after 10 years
  - 10 years is the engineering criteria that ensures that same power or energy as on day 1 is available, battery will work afterwards
- When replacing the batterie, all modules must be replaced
  - Only all modules on a string should be replaced (otherwise new module need to age to old ones), to keep needed power or energy after 10 years a stepwise replacement plan can be made
- Shipyard or shipping company can buy batteries separately and cheaper
  - The integrators engineer and buy a big volume and all electrical equipment incl. batteries and take the technical risk that it works together
- Charging is something you can consider later (relevant for vessel charging on shore)
  - Charging power and time is typically a key condition to size the battery and rest of the electrical system. It always needs to be engineered together.


WÄRTSILÄ