

The E-ferry Ellen: A fully electric regional ferry

Halfdan Abrahamsen

Information Manager, Ærø EnergyLab

Municipality of Ærø, Denmark

Email: hab@aeroekommune.dk



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 636027"

European Mobility Atlas 2021

June, 2021 ¹

1. The E-ferry is powered by local wind turbines

The E-ferry sails in southern Denmark, from the island of Ærø (Aeroe)



Wind produces 125-140 % of Ærø's electricity usage, electric ferry uses surplus



2. The ferry

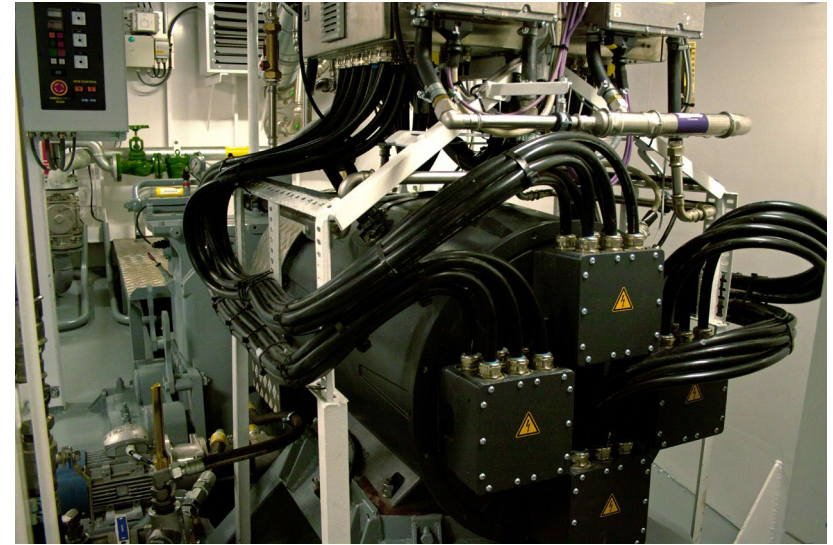
- Municipal operator (Ærøfærgerne / Aeroe Ferries)
 - Task: Demonstrate a replacement for diesel ferries
-
- Passengers: 147/196
 - Vehicles: 31 cars
 - Crew: 3/4 (no engineer)
 - Cruise speed: 12,6 knots



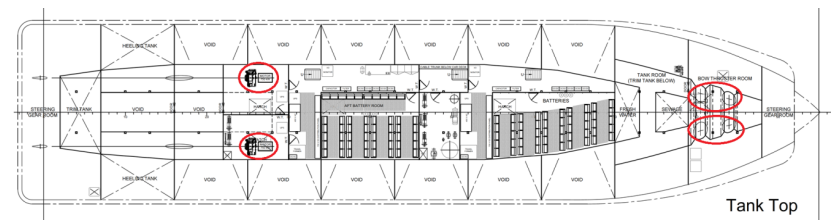
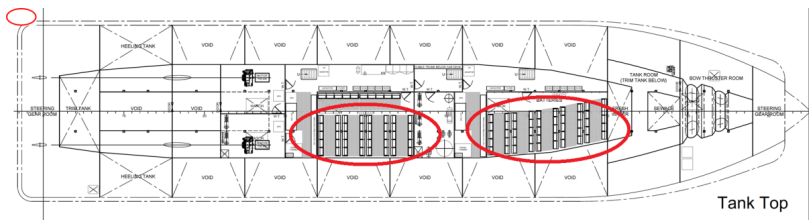
3. Batteries and engines



Batteries:
2 x 420 Lithium Graphite/NMC
Total capacity: 4 MW

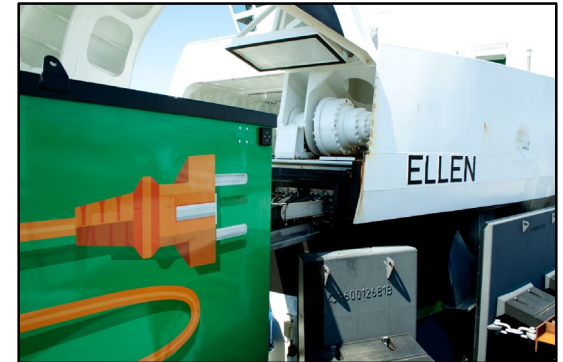


Engines:
Main engines: 2 x 750 kW (1000 HP)
Bow thrusters: 2 x 250 kW



4. Achieving high frequency service

- Ramp-based charger
- 4 x 1 MW transformers
- 4 MW peak charging (1C)
- Energy efficiency (transformer to propeller): 85 %



State-of-charge during the day:



5. Battery life time

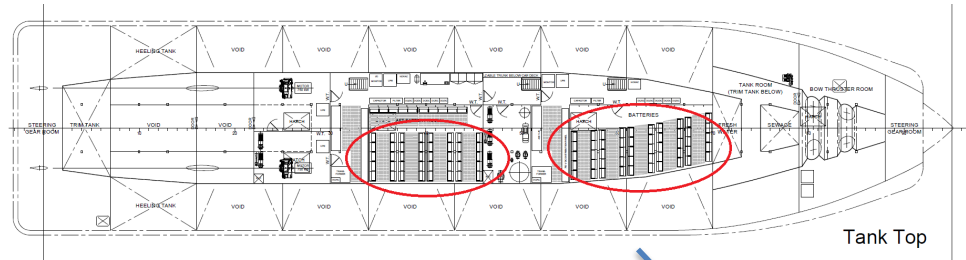
Table 26: Calculation of life time battery capacity flow E-ferry prototype battery pack

Average Depth of Discharge (DoD)	39	%
Number of cycles down to SOH 80%	24.500	cycles
Average energy flow per cycle	1.600	kWh
Life time flow in sailing operation	39.200.000	kWh
Number of years in sailing schedule	11,74	Years

6. Achieving high frequency service

Special features:

- Specially developed for E-ferry
- DNV-GL type approved
- Scalable design
- Redundancy



10 x



= 20 battery strings

= 840 batteries

7. Battery modules

Pros:

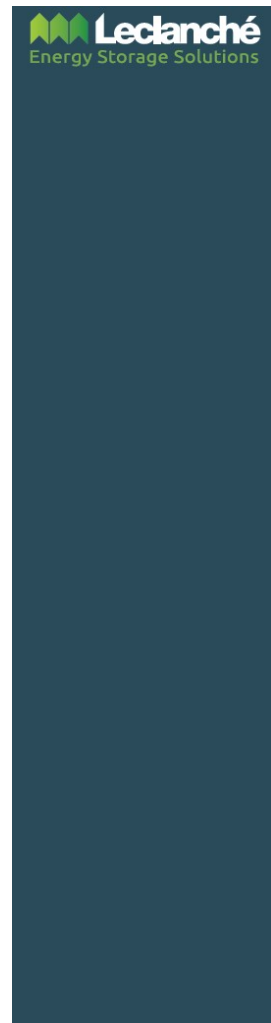
- High energy density
- Fast charge/discharge
- Battery management
- Marine certification
- Commercial viability

Cons:

- Nickel, cobalt and manganese
- Unknown recycling potential

Second life:

- End-of-life: 80 % SoC capacity
- Potential for balancing local grid
- Depends on SoH



HIGH ENERGY BATTERIES
FOR MOBILITY

Energy M2 Modules (G-NMC)



8. Evaluation: Emissions

Annual reductions compared to the diesel replaced by the E-ferry:

CO₂: 2520 tonnes
NO_x: 14.3 tonnes
SO₂: 1.3 tonnes
CO : 1.8 tonnes

The E-ferry also saves the environment from 0.5 tonnes of particulate matter (PM) each year

Bunker fuel:

"[After 2020] .. low-sulphur marine fuels will still account for ~250k deaths and ~6.4M childhood asthma cases annually" *Nature (2018)*