Framdrivning och laddning, ur ett forskningsperspektiv (Propulsion and charging, from research perspective)

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Trends in energy systems – it happens now

Sustainable alternative:

Renewable energy generation and electrified transportation

Enabling technologies

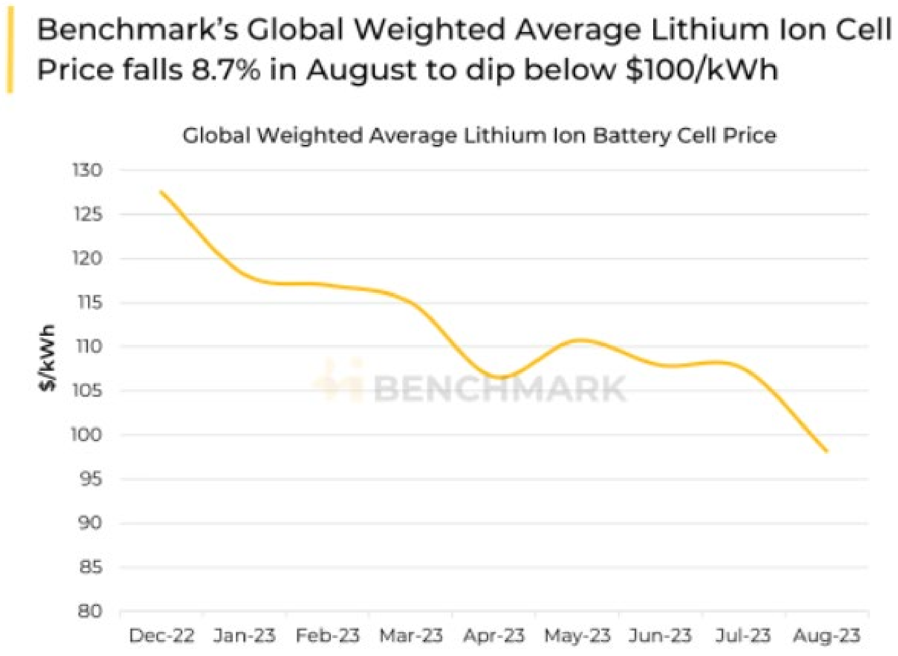
- Wind power (mature)
- Solar cells (mature)
- Battery cells (on-going to be mature)

Parallel technologies under revolution

- Electrical/electrical energy conversion (power electronics)
- Mechanical/electrical energy conversion (generators/motors)
- Smart grid (distributed, diversity)
- Energy trading (flexible, economy)

** Mature: with reasonable payback time*

Battery technology: where we are?

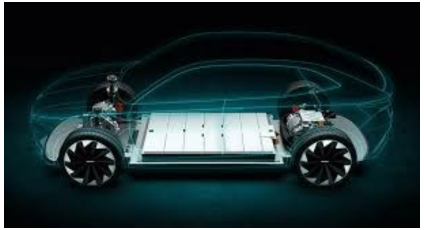


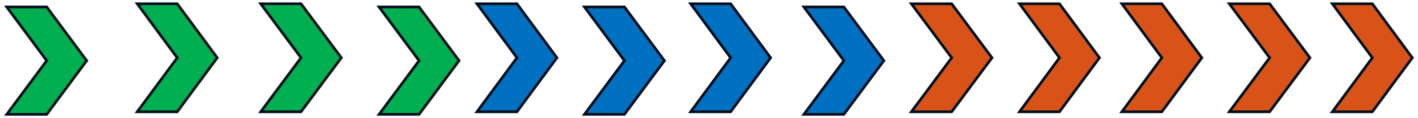
** Report: Global cell prices fall below $100/kWh for first time in two years, from Benchmark Source. 2023-09-06*

- Balance point of battery pack price for electric vehicles:
  - $100/kWh (cell price $80/kWh).
- In China with over-capacity in cell production, the cell price drops to about $70 in 2023.

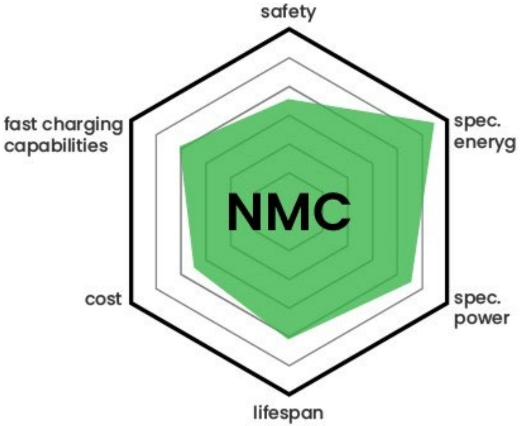
Electric cars are becoming economically competitive to combustion engine cars.

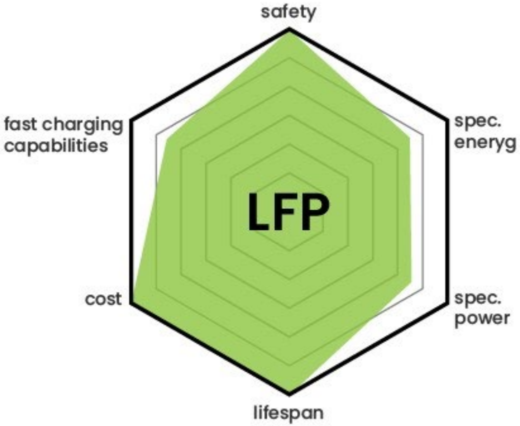
Developments in automotive will speed up marine electrification





Lithium batteries: sustainability and safety?





	LFP	NMC	NCA
Material composition	Lithium	Lithium	Lithium
	Iron	Nickel	Nickel
	Phosphate	Manganese	Cobalt
		Cobalt	
Average cost *US$ per kWh*	$90/kWh	$130/kWh	$130/kWh
Energy density *pack level*	160 Wh/kg	200 Wh/kg	200 Wh/kg
Discharge recommendation	100%	80-90%	80-90%
Discharge cycles *until 80% capacity*	2,500	1,000	1,000

LFP: lithium iron phosphate.

NMC: lithium nickel manganese cobalt oxides.

- LFP batteries have a higher thermal runaway at 270°C, whereas NMC batteries have a lower thermal runaway at 210°C, making the former safer.
- LFP batteries use iron phosphate as the cathode material, which is more abundant and accessible than cobalt.

Developments in automotive will speed up marine electrification

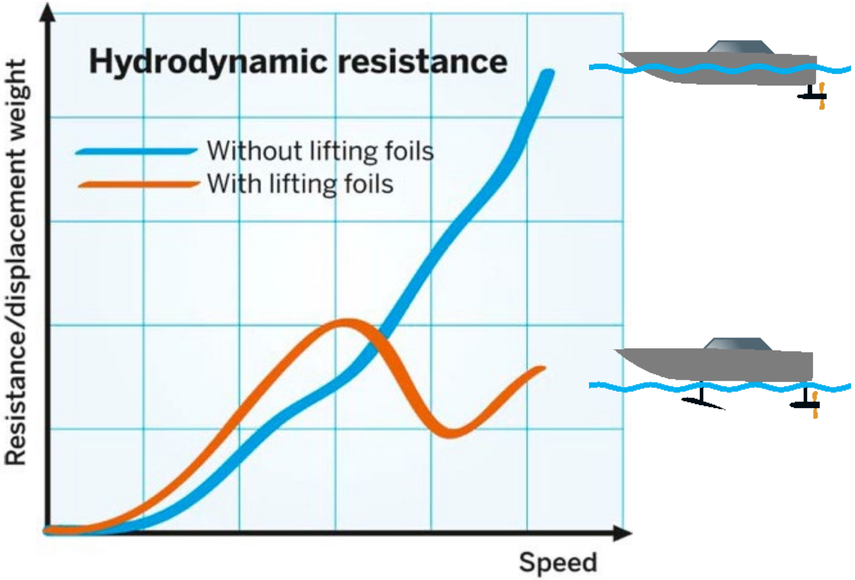
Phases of electrification:

1. City buses
2. Passenger cars
3. Light trucks
4. Medium/heavy trucks
5. City ferries
6. Leisure boats
7. Long-distance ferries
8. Large ships

What we need to work on?

- New vessel designs for energy efficiency.
- Electric propulsion technology (motor drive, integration, etc.)
- Charging technologies for safety.
- On-shore energy storage for power buffering and energy shift.
- Charging infrastructure and grid capacity extension.
- Batteries (safety, lifetime).

Hydrofoiling technology – battery driven for longer distance



- A typical planing hull has a 4-to-1 lift-to-drag ratio;
- Hydrofoil can have up to a 25-to-1 lift advantage.

Candela （Sweden）

Artemis （UK）

TYDE (BMW)

Mantaray

Sea Bubble

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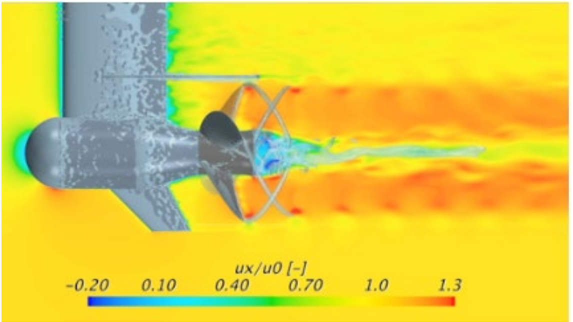
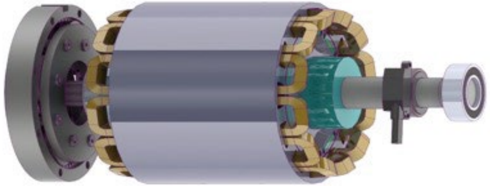
Electric motors enable new designs of propulsion

Example: POD design: reduce noise and save space





- Flexibility: small and powerful electric motors
- Dynamics: fast control for stability and manoeuvre

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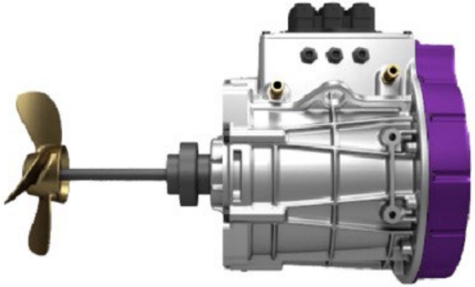
Typical electric propulsion



POD design for low power

Separate motor

Inboard drive

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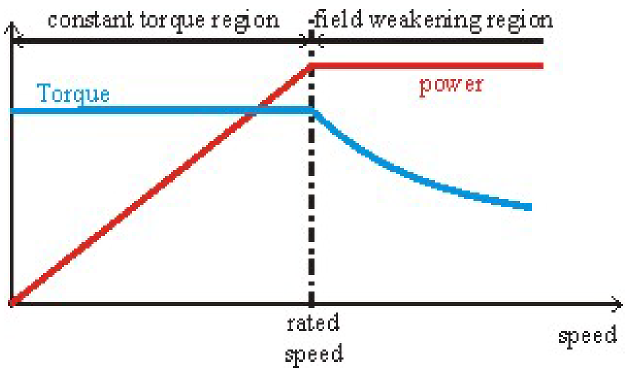
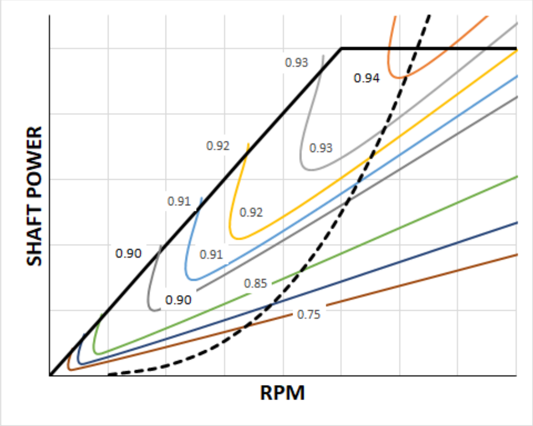
Differences between boat propulsion and vehicle drive

- Vehicle speed at 200 km/h -> wheel speed at 2000 rpm -> motor speed at 16000 rpm (with gear ratio at 8:1). Use high-speed motor to reduce weight/size.
- Boat speed at 40 km/h -> propeller speed at 3000 rpm -> motor speed at 3000 rpm (direct drive) or 15000 rpm (gear ratio at 5:1). Use low-speed motor to eliminate gearbox.

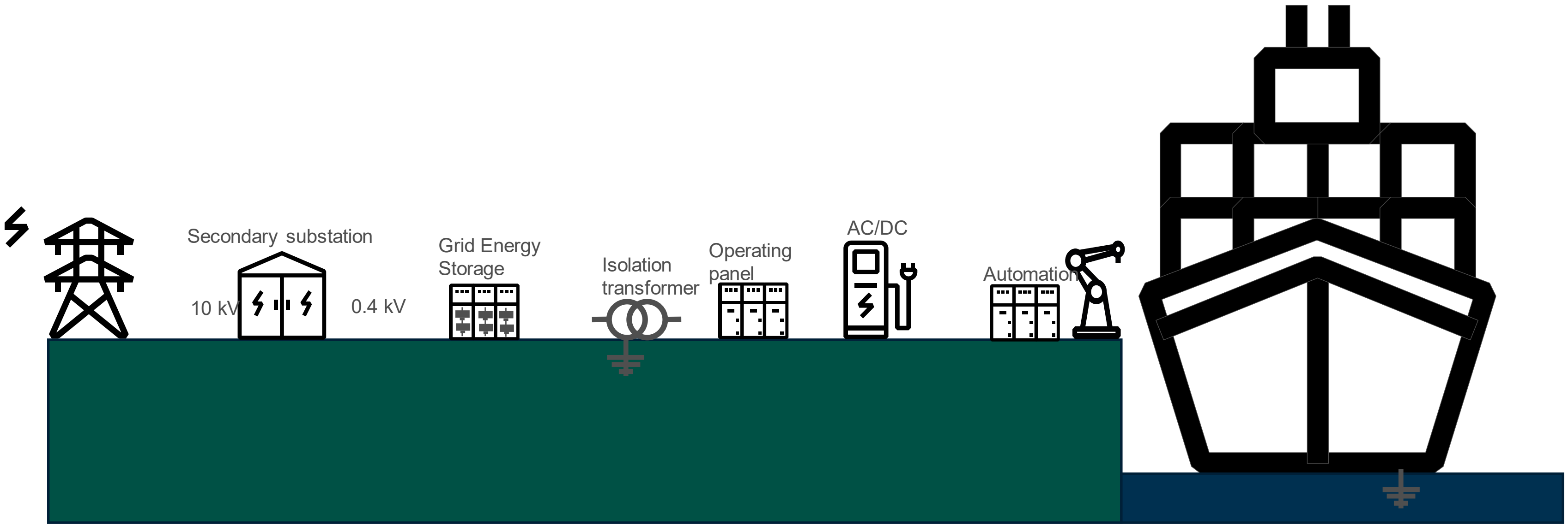


Vehicle motor



Boat motor

Marine charging



Charging solution 1: Vertical charging for small ferries

Name of the ferry: Ar vag Tredan
Newbuild/Retrofit: Newbuild
Energy storage: supercapacitors (6 tons)
Charging: fast charging every round trip
Vessel size: 22.10 m X 7.20 m
Load: 150 people and 10 bicycles
Schedule: 28 daily round trips (20 kWh per round trip)
Area of Operation: Lorient, France

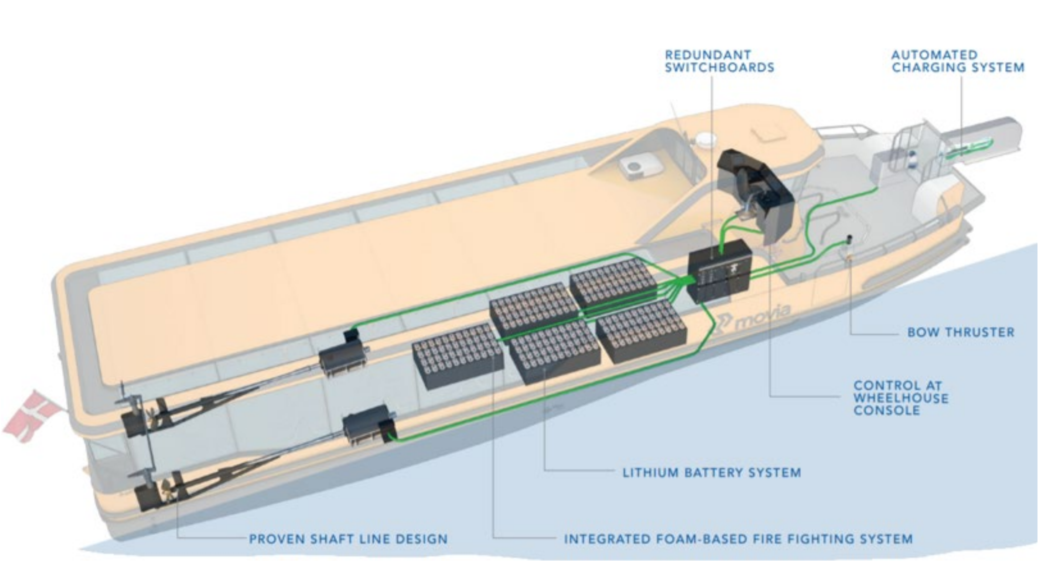
Charging solution 1: Vertical charging for large ferries

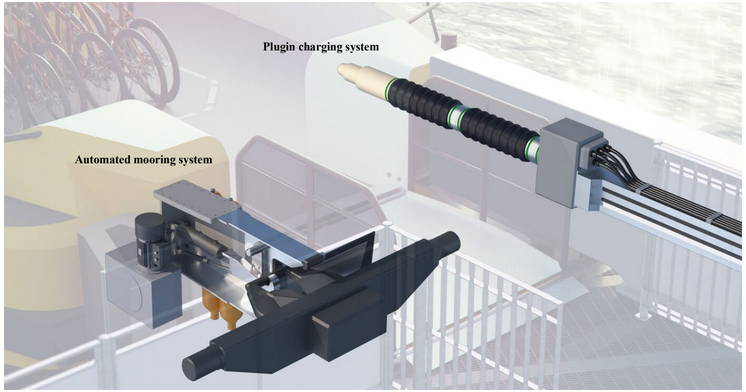
Name of the ferry: Future of the Fjords
Owner: Fjord line
Operator: Fjord line
Vessel size: 45 m x 15 m
Area of operation: Flåm, Norway
Newbuild/Retrofit: Newbuild
Battery: 1.8 MWh
Load: 400 passengers

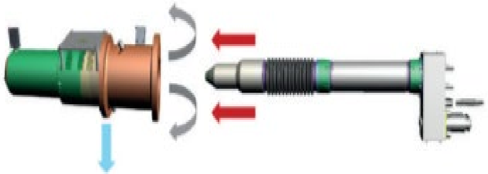
Charging solution 1: Vertical charging for large ferries

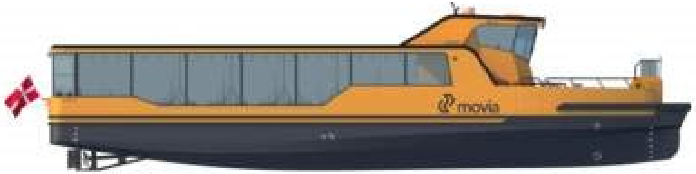
Name of the ferry: M F Ampere
Owner: Norled
Area of operation: Sognefjord, Norway
Newbuild/Retrofit: Newbuild
Battery: 1000 kWh onboard, 410 kWh on shore
Vessel size: 76.4 X 20.8 X 3.7 m
Capacity: 120 vehicles and 360 passengers
Schedule: 17 round trips per day, 20 min per direction, 10 min charging.

Charging solution 2: Horizontal charging for small ferries



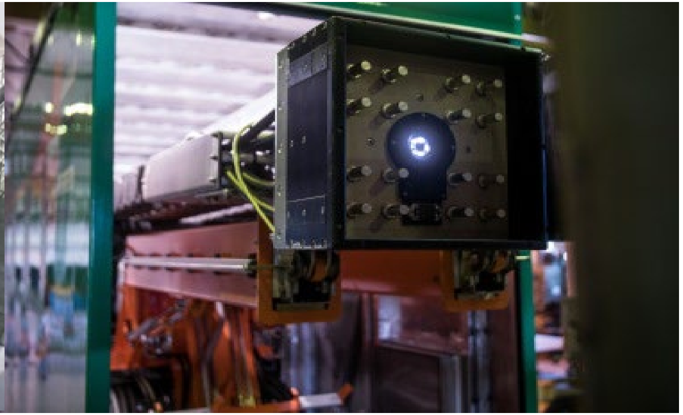






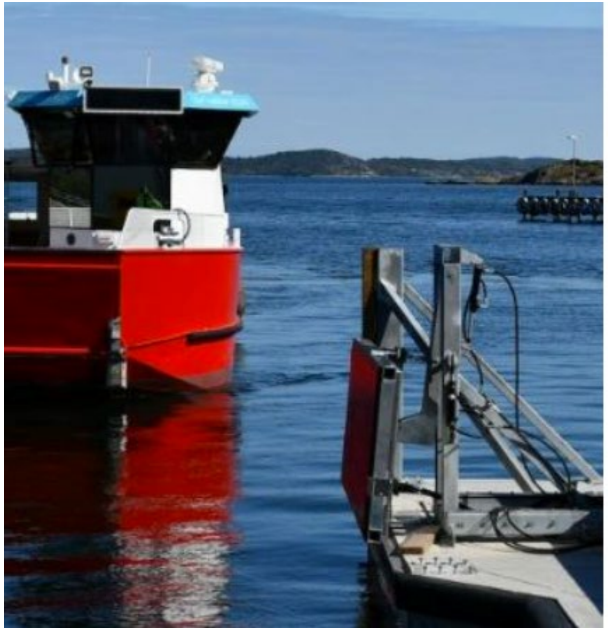
Name of the ferry: Movia
Newbuild/Retrofit: Newbuild
Size: 23.3m x 5.6m, capacity: 80 passengers
Area of operation: Copenhagen, Denmark
Battery: 120 kWh
Charging: 7 min fast charging at both end locations

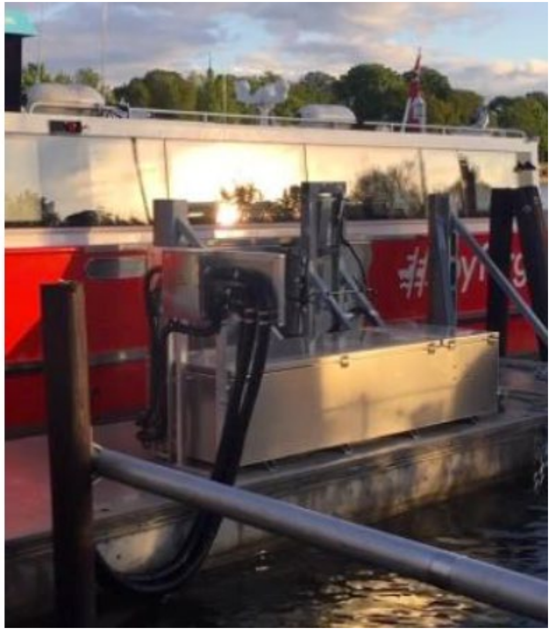
Charging solution 2: Horizontal charging for large ferries



Name of the ferry: Ellen
Area of operation: Denmark
Newbuild/ Retrofit: Newbuild
Vessel size: 60 m X 13 m
Capacity: 31 cars, 5 trucks and 198 passengers
Battery: 4.3 MWh
Charging: 4.0 MW, 15-20 minutes per round trip
Schedule: 5-7 round trips per day; 21.4 km (2 hours) per round trip

Charging solution 3: Wireless charging for small ferries





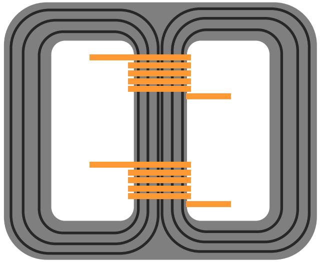
Name of the ferry: Byferga
Owner: Fredikstad and Hvaler
Provider of drive system: Danfoss
Region of operation: Norway
Vessel size: 14.95 m long
Capacity: 50 passengers
Newbuild/Retrofit: Newbuild
Charging: wireless fast charging, 100 kW, 2 min charging per stop

Charging solution 3: Wireless charging for large ferries

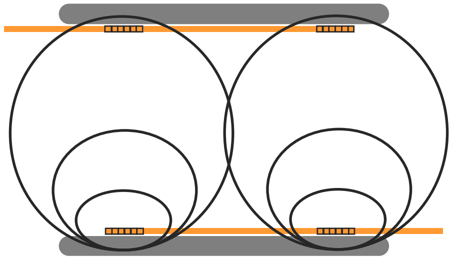
Name of the ferry: MF Flogefonn (hybrid)
Operator: Norled
Area of operation: Norway
Newbuild/ Retrofit: Retrofit
Vessel size: 85 m long
Capacity: 300 passengers and 76 cars
Wireless charging: 1MW, (maybe not in operation)

Charging solution 4: leisure boat charging

INDUCTIVE POWER TRANSFER (IPT) - TRANSFORMER VS IPT COILS



$$Input\ voltage, U_1 = 100\ V$$



$Coppling\ factor, k = 0.99$

$Coppling\ factor, k = 0.2$

$Output\ voltage, U_2 = 99\ V$

$Output\ voltage, U_2 = 20\ V$

Low reactive power

High reactive power

WIRELESS VEHICLE CHARGING

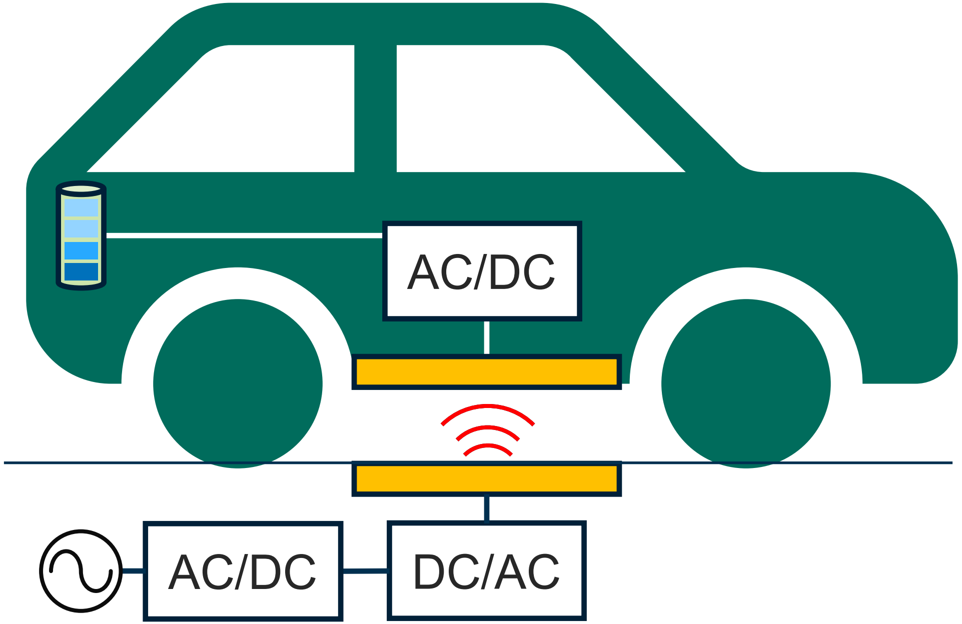
Stages:

I. AC 50Hz / DC

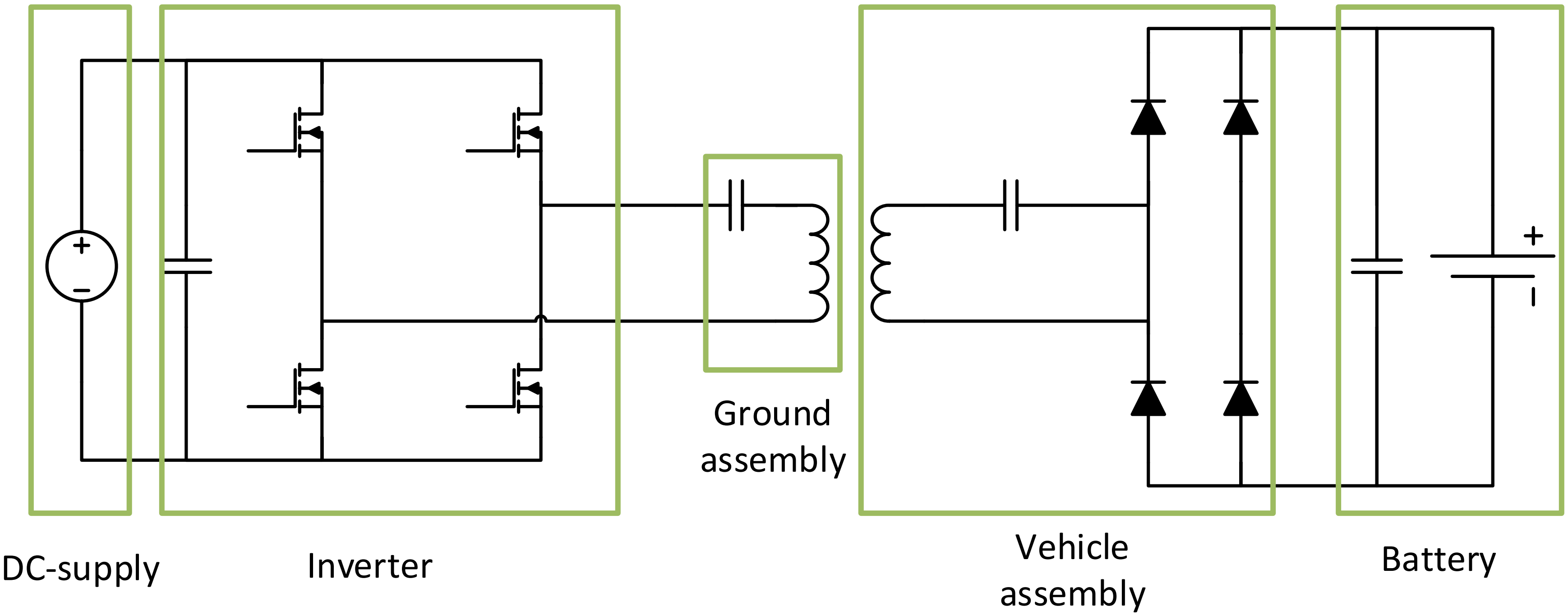
II. DC / AC 85kHz

III. Coils / Pads
- Primary
- Secondary

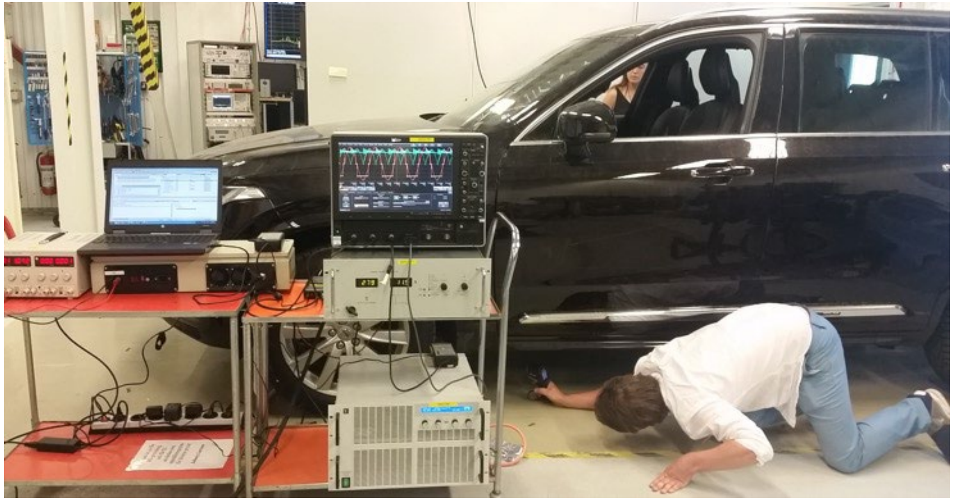
IV. AC 85kHz / DC



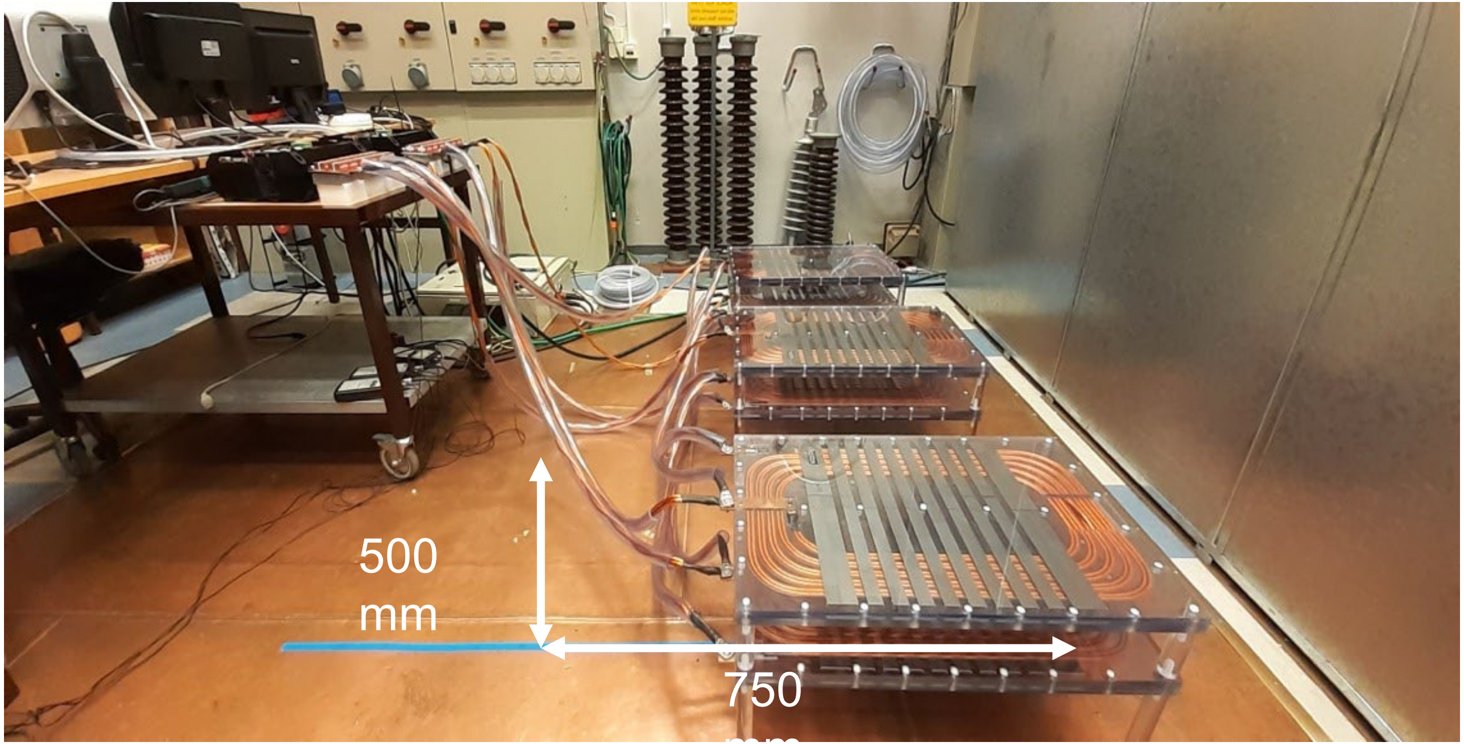
SYSTEM OVERVIEW



STRAY FIELDS – HOME CHARGER FOR XC90

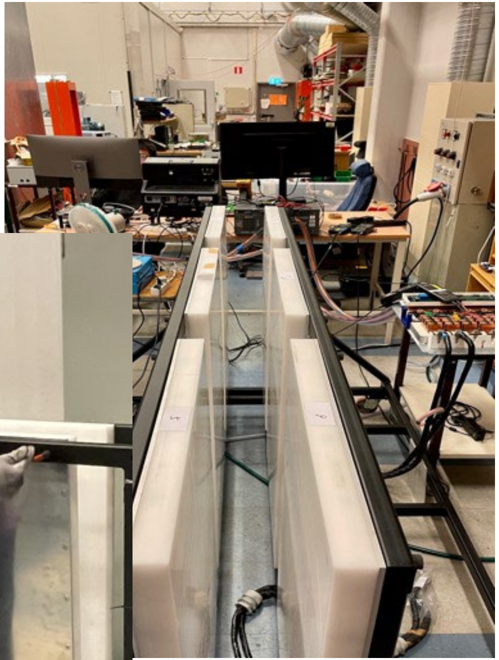


THREE PHASE IPT 250 KW

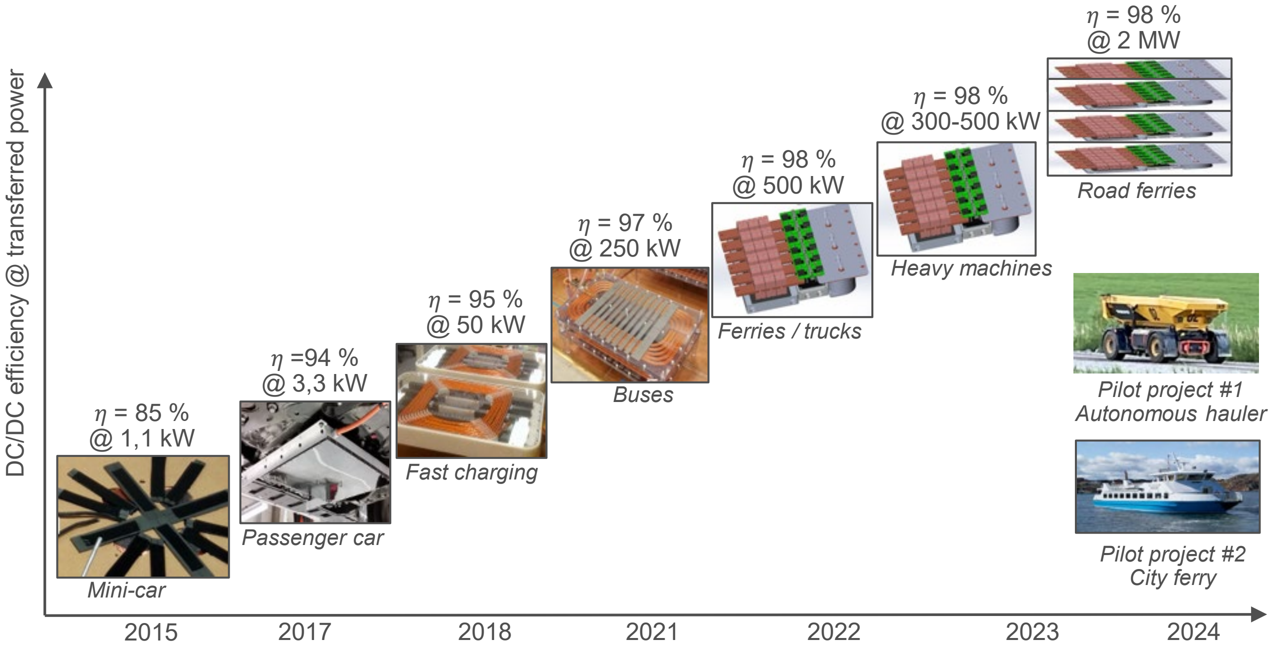


Lab prototype:

- Output power: 500 kW (3 pads)
- Air distance: 130 mm
- Max efficiency: 98 % (DC-DC)
- Power density: 285 kW/m^2
- Stray field: < 27 uT (after 500 mm)
- Modulized design: to reduce costs.



ROADMAP FOR IPT @ CHALMERS



WIRELESS CHARGING SUITABLE FOR LARGER BOATS AND FERRIERS

Summary

To utilize the opportunities of cheaper batteries for sustainable marine environment

To utilize new technologies (electric motors, control, foiling, ..) for efficient propulsion

To develop new infrastructure (charging, energy shift, ...)

To have a more quiet, clean, sustainable and pleasant marine environment

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