Clean energy for EU islands

Hybrid and hydrogen ferries in Giglio and Giannutri and in Swedish small islands

BluEnergy Revolution

Clean energy for EU islands
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#CleanEnergyIslands

MOTORWAYS OF THE SEA

Motorways of the Sea is a concept in the transport policy of the European Union, stressing the importance of sea transport. The main aim of these Motorways of the Sea is to improve port communications with peripheral regions of the European continent and thus strengthen the networks between the EU candidate countries and those countries already part of the European Union.

PRESENTATION AGENDA

- **ELECTRIC AND HYDROGEN FERRIES? OPPORTUNITIES AND CHALLENGES**
- **THE GIGLIO GIANNUTRI CASE STUDY**
- **THE SWEDISH SMALL ISLANDS CASE STUDY**

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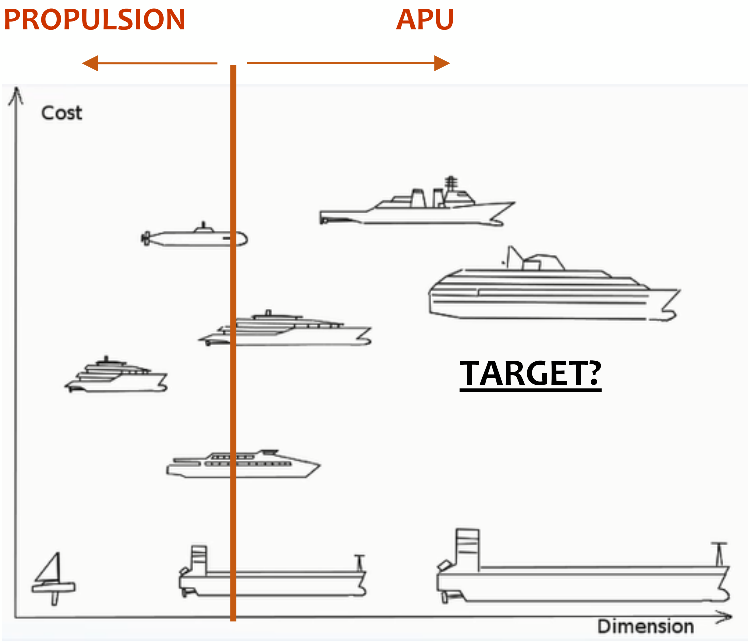
ALTERNATIVE PROPULSION FERRIES

Differently than other transport sectors (in which Hydrogen or electric applications could be studied in an easier way), the maritime sector presents intrinsic challenges for the definition of suitable case studies

- **Engine power capacity is very variable** (from few kW up to MW scale)
- **Different applications** (goods, passengers, amusement boats…) **and different needs**
- **Different regulatory framework in each country per each technology**



Key parameters

- Type of vessels
- Power capacity of the engines
- Residence timing in ports
- Speed and navigation time
- Scheduling of the journey
- Regulatory aspects in the area

Key aspects to be considered once looking at alternative propulsion system

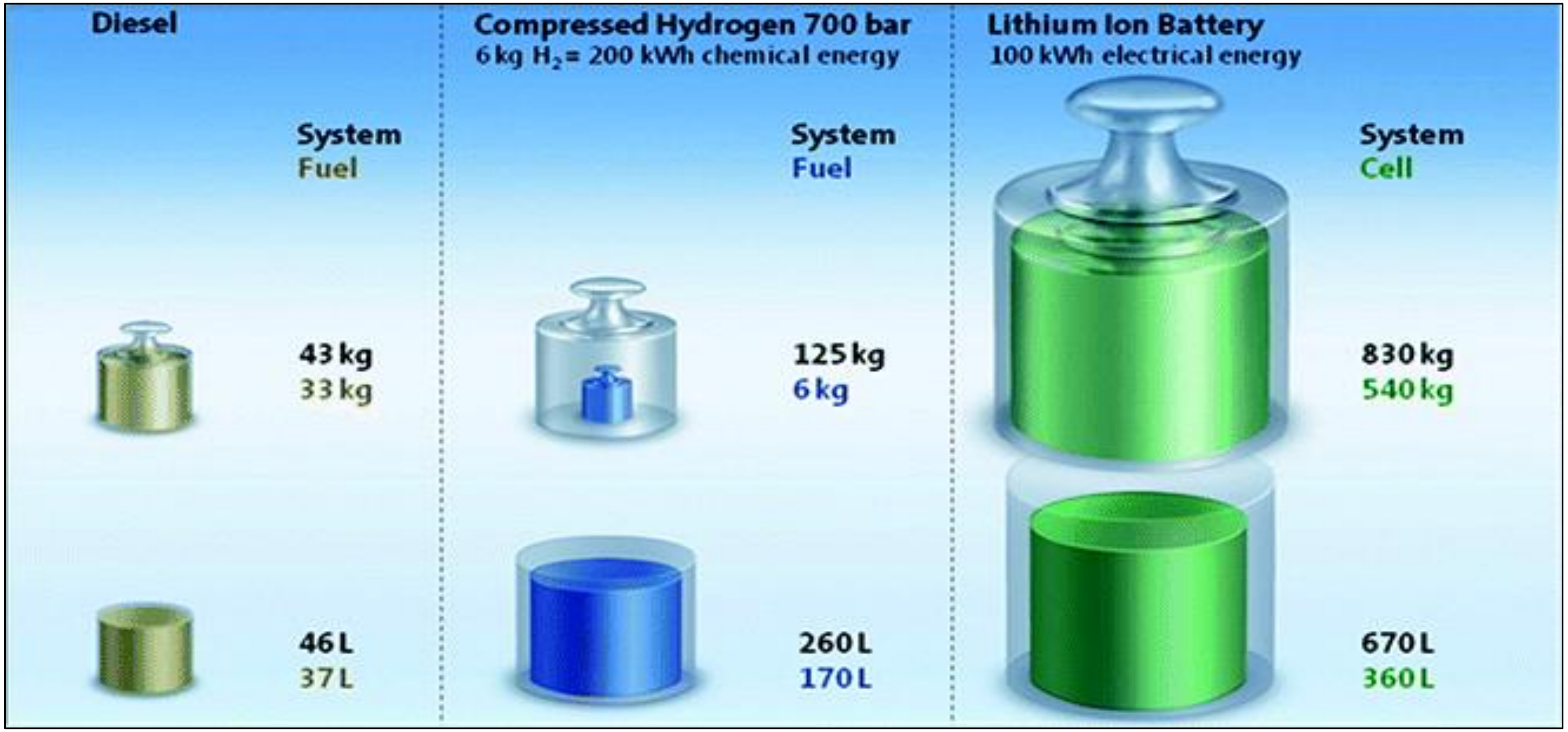
- Start up and response time of the technology
- Emissions saving
- Noise aspects (could be required in some island area)
- Payload and avaliable space on board
- Costs
- Refuelling/recharging procedures and timing

ELECTRIC FERRIES

THE PROBLEM IS THE CHARGING PERIOD AND THE WEIGHT/VOLUME OF STORAGE

(fast chargers foresees high grid capacity of re-charging on the island – large batteries mean reduced payload)

ALTERNATIVE PROPULSION FERRIES



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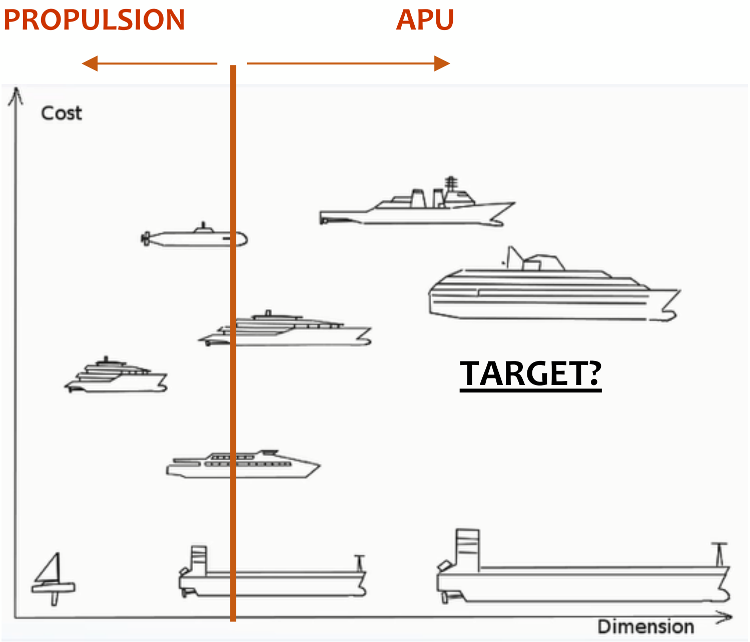

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HYDROGEN AND LOW CARBON FUELS

<u>THE PROBLEM IS THE STORAGE OF HYDROGEN ON BOARD AND ITS SUPPLY/REFUELLING</u>
<u>(liquid fuels offer higher energy density and therefore easier integration on board – we should limit the amount of H_2 on board + regulatory issues)</u>

H2-FUELLED VESSELS

Hydrogen application in maritime segment is spreading in several projects, covering a wide range of applications.

Hydrogen demand is foreseen to increase significantly in incoming future due to launching and operation of H2 deploying units.

As example, table below shows some H2-fueled applications already operational. Several more are under construction or in design phase.

Most suitable applications due to technical/economical aspects are:

- Internal water (**ADVANTAGES:** low power need)
- Small working boats (**ADVANTAGES:** predictable demand)
- Pleasure boats (**OPPORTUNITY:** on board genset)

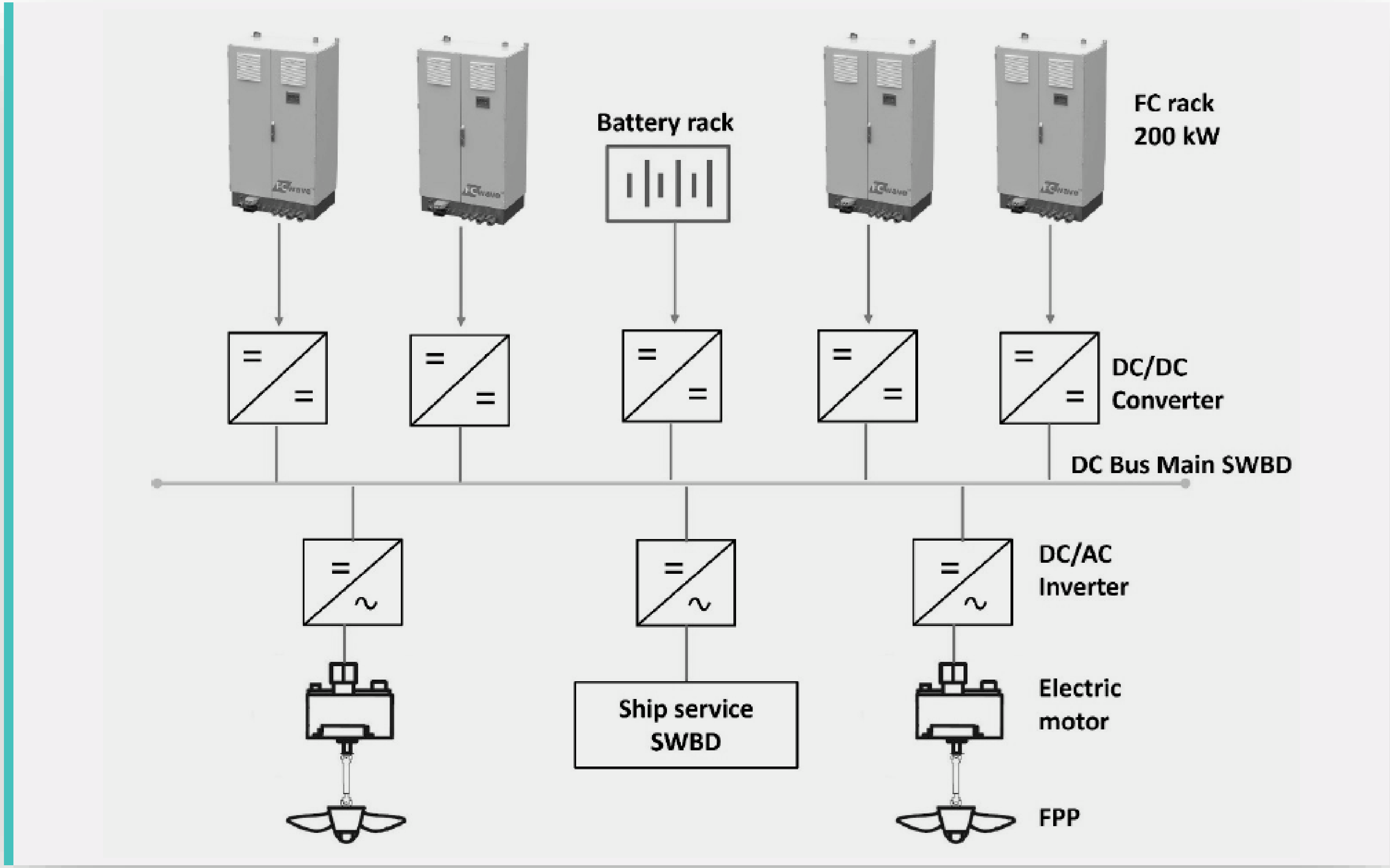
H2 Reference Storage size	
Small Yacht / Tender / Prototype [kg]	10
Mega Yacht / Commercial Vessel [kg]	250

US EXAMPLE – Regulation is a topic particularly for passengers' ferries

Examples of Operational H2 Vessels

NAME	VESSEL TYPE	H2 CAPACITY [kg]	H2 STORAGE	STATUS
BIIM	Port unit	10	MH	Launched
HYNOVA 40	Tender	22	Compressed	In operation
ZEUS	Research vessel	50	MH	In operation
ELECTRA	River Tug Boat	750	Compressed	In operation

Hydrogen FC-E ferry



An example of retrofitting
https://www.mdpi.com/2077-1312/11/9/1735

WHY NOT USING H2 IN EXISTING ENGINES?

Hydrogen Combustion in a “H2 Ready engine” is driven by a fuel/air ratio (α – Stochiometric one is 34:1) that would require in the engine combustion chamber a 29%-71% volume ratio required by H2/air (a mixture which has a lower energy density if compared to liquid fuels).

In order to reduce NOx it is possible to work with lean mixtures ($\alpha < \alpha_{stochiometric}$) also to reduce Combustion temperature and NOx, but this would mean to reduce the power produced by the engine.

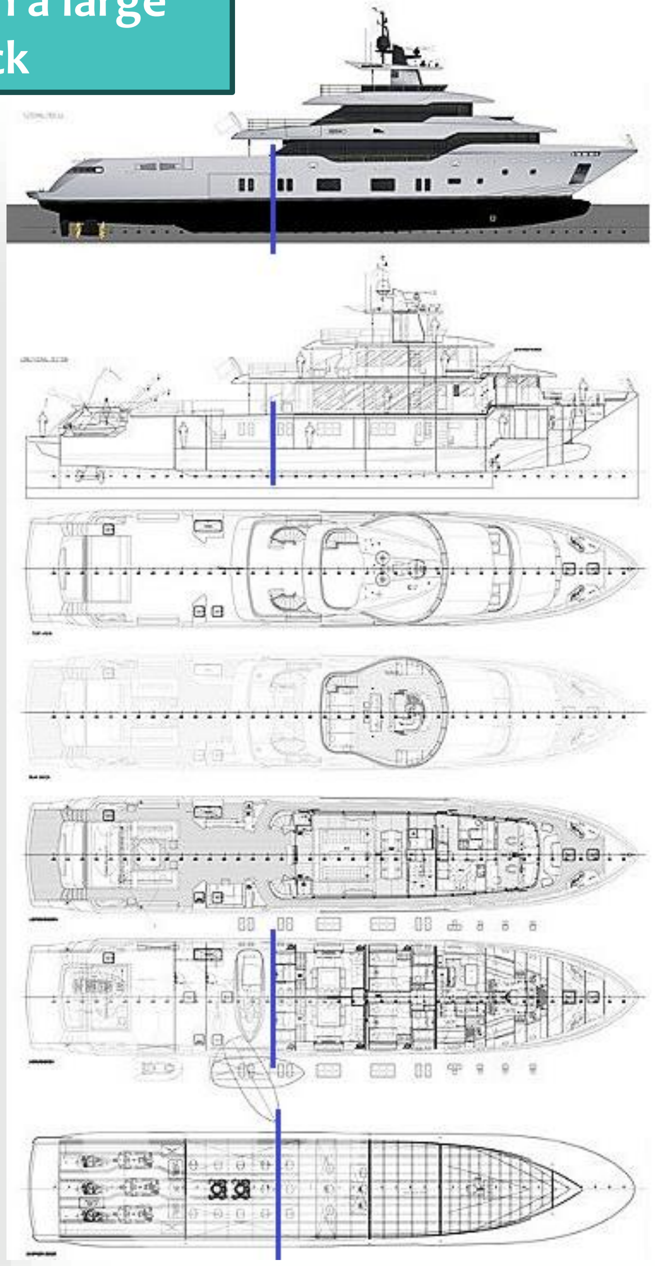
At the end of the day, keeping the same volume of the engine and the same amount of NOx, the work produced by a H2 Engine is 50% of a diesel/NG one

REFIT – Vessels aspects

Example from a Yacht retrofit but with a large open deck

ASPECTS TO BE CONSIDERED

- Preservation of existing structure (e.g. electric white diagram, fuel tanks/areas, machines/engines area…) in order to Minimize intervention on existing plants and equipment, with installation of a turn-key new power equipment enclosed in new structural block.
- At this purpose containerized solutions for FC SuSy and H2 Storage could be an option, but posing challenges for effective integration and optimization of footprint occupation as well as of balancing
- Brand new hull structures designed & prefabricated to host the complete EP System and relevant accessories.
- Introduction of a new hull body section balances added weight and does not significantly impact on vessel draft and manouvering performances
- Presence of «passengers' occupied» area can pose limitation in terms of safety for integration on board
- Wise positioning of Batteies/FC Modules and storage that could offer both challenges and opportunities (e.g. using metal hydride storage could offer opportunities via a ful customization of storing system layout can lower unit Centre of Gravity and improve vessel stability.)



ELECTRIC AND H2-FUELED VESSELS

CONCLUSIONS

- Going for an electric ferry is feasible mostly **if the journey is short** (thus limiting the battery capacity on board), **the timing in port is significant and/or if the «port charging area» has no major grid issues**

- Once looking at potential use of hydrogen on board of vessels the **main issue is the amount of hydrogen to be stored on board**: this aspect poses challenges both from a regulatory point of view and a practical point of view (energy density of H_2 << than liquid fuels usually used on board) also looking at refuelling aspects

- **Short distance and recurrent-scheduled ferries could have good opportunities to be «hydrogenized»** as they can limit the amount of H_2 to be stored on board

- **Retrofitting of a (fossil based) vessel is not an easy issue** also considering that: 1) the full vessel should be Re-balanced, 2) only part of the existing technical systems can be valorised/still used, 3) the volumes/footprint of FCH/BATTERY technologies are usually higher (particularly looking at storage aspects); 4) the H_2 storage could be required to be installed on the deck/open air (e.g. containerized solution already installed on board of FC-powered barges already operating in EU rivers) for safety reasons thus reducing the payload for ferries – **NEW FERRIES SHOULD BE THEREFORE CONSIDERED THUS GOING FOR HIGHER INVESTMENTS**

- **For Hydrogen Refuelling is another key topic:** swapping of H2-bundles/storages/Bottles could be something that can facilitate the refuelling

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FERRY SERVICE H2 DEMAND DEFINITION

The Porto Santo Stefano-Giglio ferry route connects the Italian peninsula with Giglio Island by covering a distance of 10 nautical miles.

Due to the short distance, the ferry journey looks potentially interesting for a hybridization or «hydrogenization» of the local fleet.

The local fleet (with vessels equipped with engine with less than 1 MW of power capacity) could have some chances to be converted to H2, but such fleet decarbonization should be accompanied by a proper H2 Infrastructure development too in both island and mainland.

FERRY Fleet Fuel demand

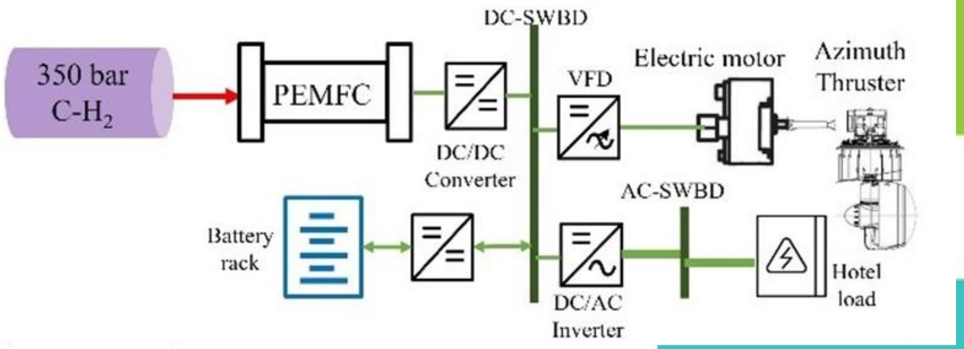
	kg/trip	ton/y	MWhEP/trip	Miles/trip	Time/trip	kn	MW
Dianium	400	119	4.8	20	2.1 hrs	10	2x0,716
H2Ferry - ***REF***	60-100	16-27	1.8-3	20	2.1 hrs	10	0.55
Dianium hyp. retrofit	56-60	16,7	2	20	2.1 hrs	10	0,800

POTENTIAL FUEL CELL CAPACITY INSTALLED
5x200 kW
HYDROGEN STORAGE CAPACITY: 100 kg/day
SWAPPING APPROACH

DAILY NEED OF HYDROGEN FOR DIANIUM

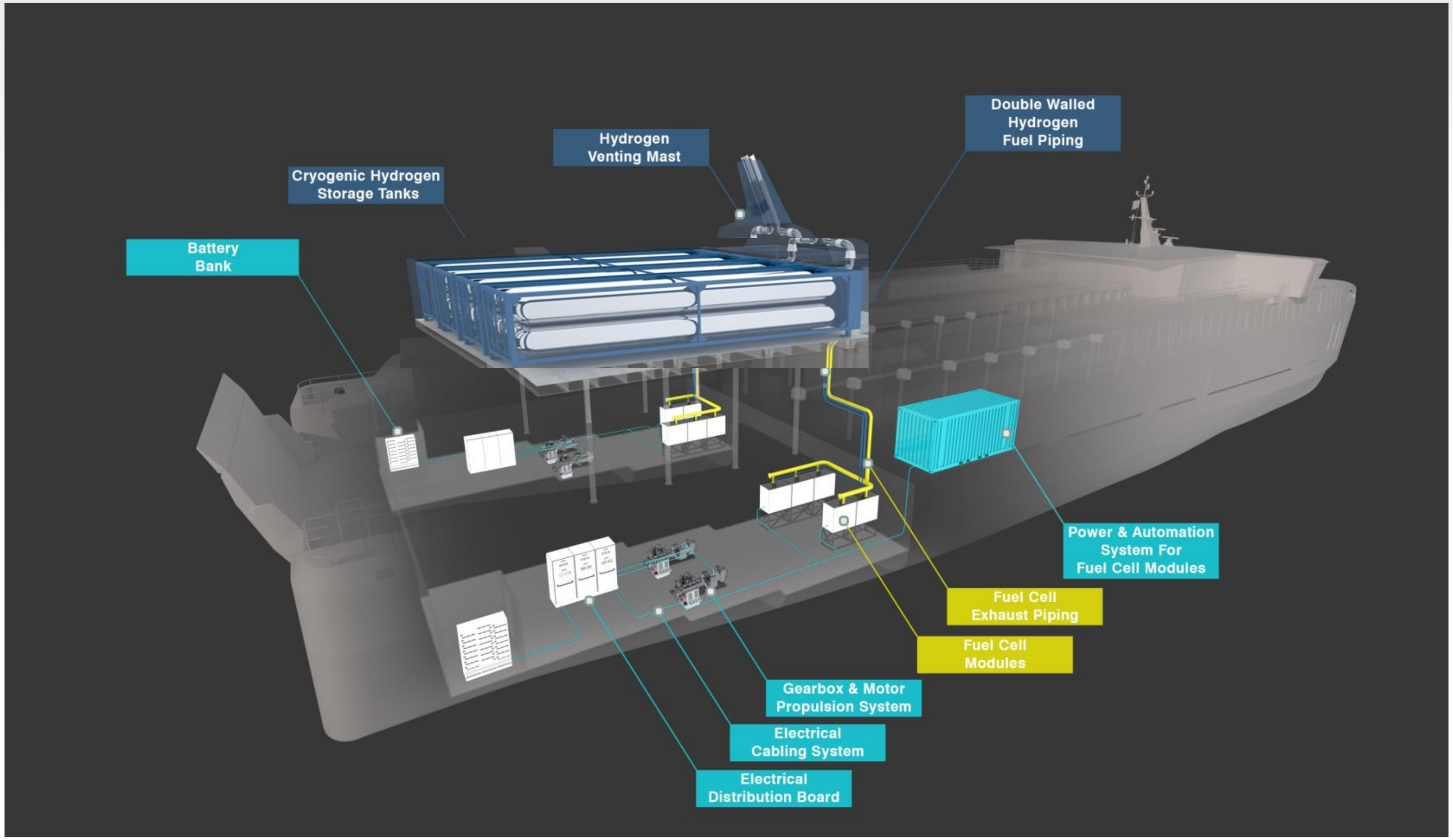
Winter Period (Oct-Apr):
Up to 100 kg/day

Summer Peri:od (Apr-Sep):
Up to 200 kg/day



LAYOUT OF THE FERRY

European Commission



POTENTIAL PERFORMANCES

H2 FERRY 1MW single route performance		
distance	12.0	mil
duration	60	min
Speed	12.0	kn
kWh	690.00	kWh
H2 consumption	38.0	kg

CAPITAL EXPENDITURE ESTIMATION		
Ferry itself	k€	15000 ÷ 18000
Naval certification and regulation aspects (Approval in Principle and RA)	k€	400
Fuel Cell systems	k€	2600
2xH2 Storage (100 kg – swapping approach)	k€	280
Buffer Battery	k€	150
Power Converters (DC-DC/DC-AC) and DC Link	k€	300
Electric Motors and mechanical auxiliaries	k€	400
Redundant diesel engines and diesel fuel tank	k€	450
H2 System BoP (Safety devices, instrumentation and controls)	k€	350
Other costs	k€	1000
Total CAPEX	**k€**	**20930 ÷ 23930**

	Hydrogen deamnd and ferry servicecoverage Porto Santo Stefano to Isola del Giglio												
	Jan	Feb	Mar	Apr	May	June	July	August	Sep	Oct	Nov	Dec	TOTAL
RoundTrip month	26	24	25	90	93	166	171	175	105	26	26	26	953
RoundTrip/day	1	1	1	3	3	7	7	7	3	1	1	1	na
H2 Trip/month	26	24	25	90	93	90	93	93	87	26	26	26	699
H2 /day [kg]]	80	80	80	240	240	240	240	240	240	80	80	80	na
H2/month [kg]	2080	1920	2000	7200	7440	7200	7440	7440	7200	2080	2080	2080	56160
H2 Ferry %	100.0%	100.0%	100.0%	100.0%	100.0%	54.2%	54.4%	53.1%	82.9%	100.0%	100.0%	100.0%	73.3%

HYBRIDIZATION/HYDROGEN FERRIES IN GIGLIO/GIANNUTRI

CONCLUSIONS

- **Ferries currently connecting the island with mainland are low power, short distance and recurrent-scheduled ferries thus showing opportunities to be «hydrogenized»** as they can limit the amount of H_2 to be stored on board. An amount of around 60÷100 kg of H_2 should be stored on board

- **Retrofitting of a (fossil based) vessel is not an easy issue** particularly looking at MAREGIGLIO fleet, which looks quite old and with limited spaces on board and on the open-deck. Due to H_2 volume needs and regulatory aspects, hydrogen retrofitting could require to limit the payload or reduce the available space on open deck (e.g. for Cars)

- **Refuelling:** swapping of H_2-bundles/storages/Bottles could be something that can facilitate the refuelling both in Giglio and in Porto S.Stefano

- **Hydrogen Production:** the amount of hydrogen required **to fuel one of the MAREGIGLIO fleet vessel could not be so significant and could be produced at local level (IN PORTO SANTO STEFANO ON MAINLAND)** via a dedicated green hydrogen plant, to be operated in concert with a local «hydrogen dealer» (e.g. LINDE, SAPIO etc.) that could also support the temporary storage (transportable trailers) for the local refuelling/swapping of the vessel

- A **first demonstration project** on a vessel like DANIUM could be encouraged to prove the feasibility of the idea

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SWEDISH SMALL ISLANDS ANALYSED

VEN – LANDSKRONA → 4 km
(9 daily trips – 14 daily trips in high season)
POPULATION: 500

VISINGSO – GRANNA → 6 km
(16 daily trips – 24 daily trips in high season)
POPULATION: 685

VINON – HAMPETORP → 5 km
(5 daily trips – 10 daily trips in high season)
POPULATION: 100-600

HOLMON – Norrfjärden → 5 km
(5 daily trips)
POPULATION: 65-400

VESSELS ARE MANAGED BY SWEDISH GOVERNMENTAL COMPANY ROAD MANAGERS OR BY PUBLIC BODIES

OPERATING FERRIES


Uraniborg Ven


Capella Holmon


Braheborg Visingso


Sedna Vinon

Island	Ship Name	LOA	tonnage	Power	PAX	Cars
		m	t	MW	#	#
Ven	**Uraniborg**	49.95	1349	1,397	394	14
Visingso	**Braheborg**	58	1500	4 x 0.48	397	34
Vinon	**Sedna**	44	151	2x 0.662	123	14
Holmon	**Capella**	33	201	0.697	150	3

WINTER SEASON (300 days)

Island	Passngrs	Ship capcity	Ship trip		Average	Efficiency
	#/winter	#	RTrip/day	Trip/winter	Pssngrs/Trip	%
Ven	212 000	394	9	5 400	39	10.0%
Visingso	133 333	397	16	9 600	14	3.5%
Vinon	66 667	123	5	3 000	22	18.1%
Holmon	26 667	150	5	3 000	9	5.9%

SUMMER SEASON (60 days)

Island	Passngrs	Ship capcity	Ship trip		Average	Efficiency
	#/summer	#	RTrip/day	Trip/summer	Pssngrs/Trip	%
Ven	106 000	394	14	1 680	63	16.0%
Visingso	66 667	397	24	2 880	23	5.8%
Vinon	33 333	123	10	1 200	28	22.6%
Holmon	13 333	150	5	600	22	14.8%

OPERATING FERRIES

	Ven	Visingso	Vinon	Holmon
Number of inhabitants	500	685	100-600	65 - 400
Local Renewable Energy Annual Production	NA	NA	NA	NA
Distance from mainland in NM	4.5	5.5	5.5	5.5
Typical duration of the journey to the Mainland in minutes	30	30	25	40
Number of journeysoperated per years	7.560	12.000	5.190	1.820
Number of vehicles transiting on M/S per year	32 000	78 000	38 000	
Number of people transiting on M/S per year	318 000	200 000	100 000	40 000
Number of M/S operative	1	3	2	2
Age of the M/S	2012	2014		2015
Number of M/S journeys per year	7 560	12 000	5 190	1 820
AVG Power Capacity of the M/S [MW]	1.0	1.0	0.98	0.52
AVG passengers Load factor M/S journey	10.68%	4.20%	15.66%	14.65%
AVG Fuel consumption per journey [kg]	105	92	90	76
AVG CO2 emission per journey [kg]	330.75	289.8	283.5	239.4

HOW TO DECARBONIZE SUCH FERRIES?

- **The Journeys and the type of ferries thereby operated are perfect from a «TECHNOLOGICAL POINT OF VIEW»** for hybrid or hydrogen ferries: however to effectively decarbonize the maritime transport **an optimization of the journeys to maximise the occupancy of the ferries could be applied as first measure**

- Considering the reduced number of inhabitants and the short duration of the trips**, integration of «low emission taxi boats» in the service fleet could be considered (to avoid to operate large scale vessels empty)**

- Considering the «small scale» of the islands, the reduced number of kms of road**, the possibility to make such islands «Fossil cars free» could be considered, promoting EV car sharing on the island →** Islanders can have their own cars on mainland (properly stored) **avoiding then the need of the use of larger scale vessels**

- Once applied all these aspects (**whose investments are «lower» than realizing a full scale zero emission ferry**), then the **decarbonization of the fleet can take place** (if still needed!) and could be not so complicated according to the journeys and the type of vessels → **ELECTRIC VESSELS SEEM TO BE MOST REASONABLE APPROACH**, but Renewables must be pushed (On mainland and on island) for proper «clean recharging»

- **Whatever is the final solution, the continuity of the service, even via low emission ferries, must be guaranteed to islanders**

~~MOTOR~~WAYS OF THE SEA

To make today on small islands, what we’re imaging in the future in mainland

Thank you!

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