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Sustainable energy system for ships: Ammonia as energy storage

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1. INTRODUCTION

At a global level, there are several goals to be met in order to mitigate climate change, namely, related to energy efficiency, renewable energy and greenhouse gases (GHG) emissions. In 2018 the International Maritime Organization adopted a global strategy to reduce GHG emissions from international shipping by at least 50% by 2050 (compared to 2008) (MEPC, 2018). In this way, hybrid propulsion systems offer the possibility of incorporating a range of fuels, energy management systems, and batteries to provide peak power for the main engines to reduce GHG emissions and improve efficiency. The option of using ammonia as a fuel become attractive from the point of view of handling, bunkering and onboard safer storage, avoiding safety hazards. In addition, with onboard intermediate processes such as electrolysis by purifying sea water, or renewable energy production, it's possible to consider the onsite production of fuels that would otherwise have to come from shore supply.

Objectives

- The main purpose of this work is to develop the concept for a zero-emissions ship, based on the conversion of a hydrographic ship model. It's proposed a sustainable energy system (SES) based on the adoption of alternative low/zero-carbon fuels and renewable energy systems.
- To develop an energy model, taking into account a typical load demand profile for a 1-month operation of the hydrographic ship. The technologies includes ammonia as fuel, with onboard fuel synthesis, and energy conversion in retrofitted Internal Combustion Engines (IEC).

2. MODEL SHIP

Hydrographic ship (figure 1) with technical specifications (table 1) defined for design purposes.

Its missions are scientific and focused on society support, pollution prevention and protection of marine ecosystems, enhancing the good potential for adopting environmentally and climate friendly sustainable options.

Figure 1.Model: hydrographic ship

Table 1. Technical specifications

Displacement (ton)	2 300
Length (m)	68
Breadth (m)	13
Draught (m)	5,5
Max/Cruise speed (kts)	11/10
Propulsion (Electrical Motors)	2 x 800 kW
Generators (Diesel Engines)	4 x 600 kW

2.1. Ship Structure

- Space (600 m³) to provide the necessary flexibility in the implementation of retrofit solutions: equipment to obtain renewable energy, energy conversion units and storage of alternative fuels.
- Funnels would be removed and all the obstructions of the upper deck would be released to install the photovoltaic (PV) panels (fig.2).

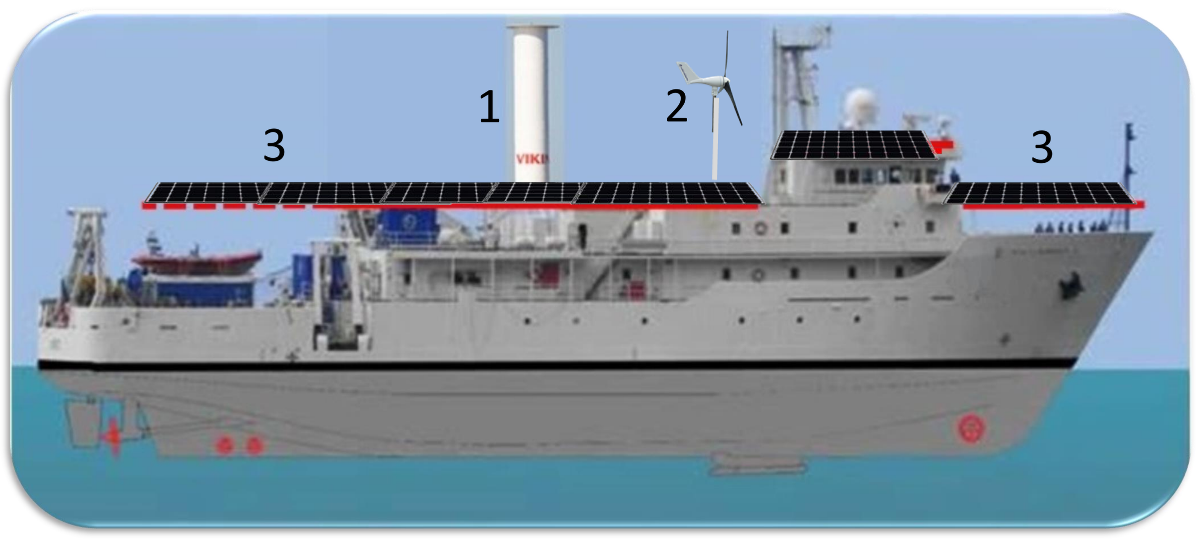

Figure 2. Ship external modifications (1 – Flettner rotor; 2 – Wind generators; 3 – PV panels).

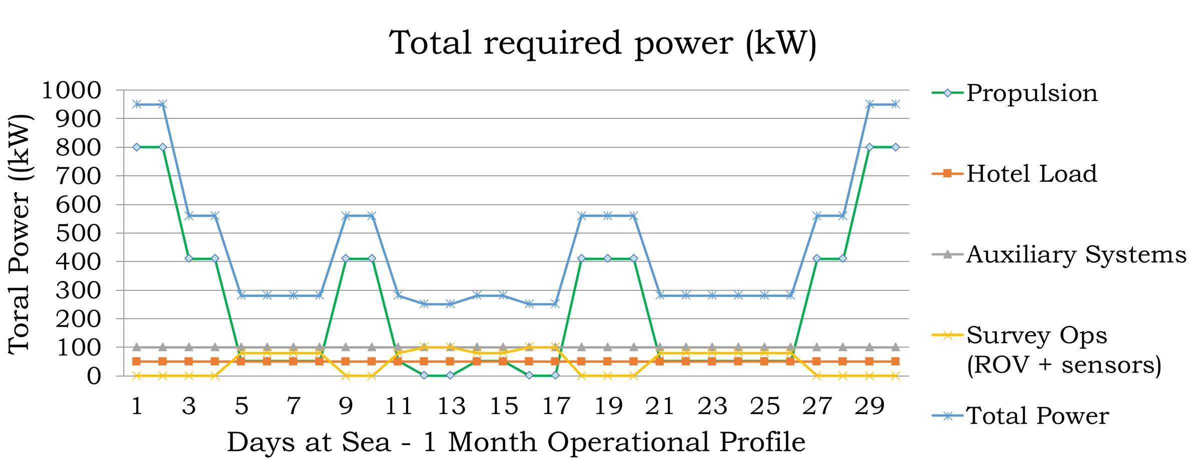

Figure 3. 1-month Operational Profile

2.2 Operational profile

The ship has different operational profiles with the respective energy consumption, according to the task: transit, maintenance of multiparametric buoys, ROV (Remotely Operated Vehicle) operation or hydrographic surveys.

According to the task, 4 typical days of ship operation were defined with specific energy demand.

To establish a profile close to the ship reality, a period of one month was established (fig. 3).

3. SES - AMMONIA

- Less complicated and safer energy storage, compared to hydrogen: Hydrogen storage needs -253 ℃, ammonia needs -33 ℃ and can be stored below deck without risk;
- 50% better energy density with ammonia compared to hydrogen;
- Ammonia can be used as a fuel in the IEC;
- Sharing large-scale production infrastructure from industries making efforts to produce green ammonia using electrolysis at reasonable costs;
- Sharing large-scale distribution infrastructure by chemical tankers that already can carry ammonia (Kobayashi et al., 2018).

4. RENEWABLES

Solar radiation (table 2) and wind speed (fig. 4) data (IPMA, 2014) were obtained for three study areas of operation in Portuguese coast. These areas has different potential for renewable resources.

The proper sizing (Castro, 2011) resulted in 174 PV panels of the model *LG 365W Solar Panel Fixed Frame* (E-Marine, 2019a) in 300 m² and 2 wind turbines of the model *Airdolphin 24V* (E-Marine, 2019b) on the ship deck.

Table 2. Availability of solar resources

Solar Radiation	
Area 1	1550 kWh/m2
Area 2	1600 kWh/m2
Area 3	1650 kWh/m2

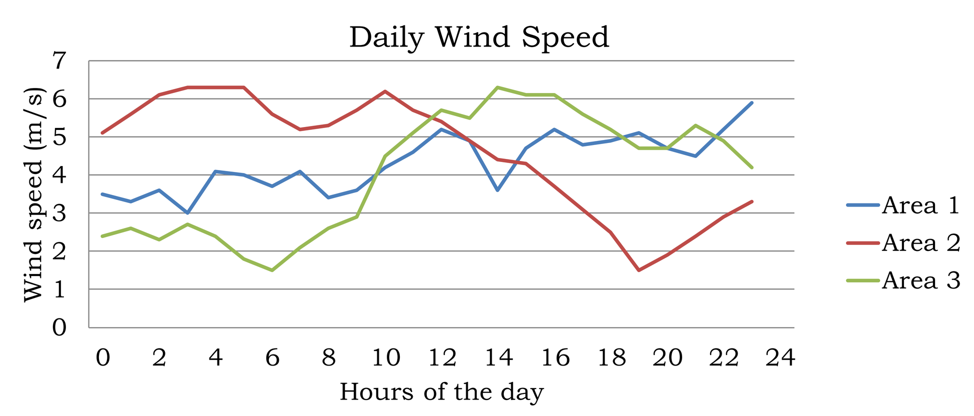

Figure 4. Availability of wind resources

5. BALANCE

- Initial conditions of 90 tons bunkered from land: Ammonia stored as a liquid at -33 ℃ at atmospheric pressure;
- Use of 4 ICE of 600 kW each for ammonia consumption.
- Due to the excess of energy from the renewables and from the combustion of the ammonia, from the third day of the mission it's possible to start ammonia production on board.
- 12 000 kWh of energy to produce ammonia through the electrolysis process and an air separation unit (Bartels, 2008).
- Renewable energies used for the processes of obtaining the H_2 of the water and the N_2 of the air so they combine in NH_3 (ammonia).

Fig. 5 shows the energy balance resulting from the initially stored ammonia, the production of energy from renewable sources and from the ammonia, and from the consumption of all onboard electrical applications during one month.

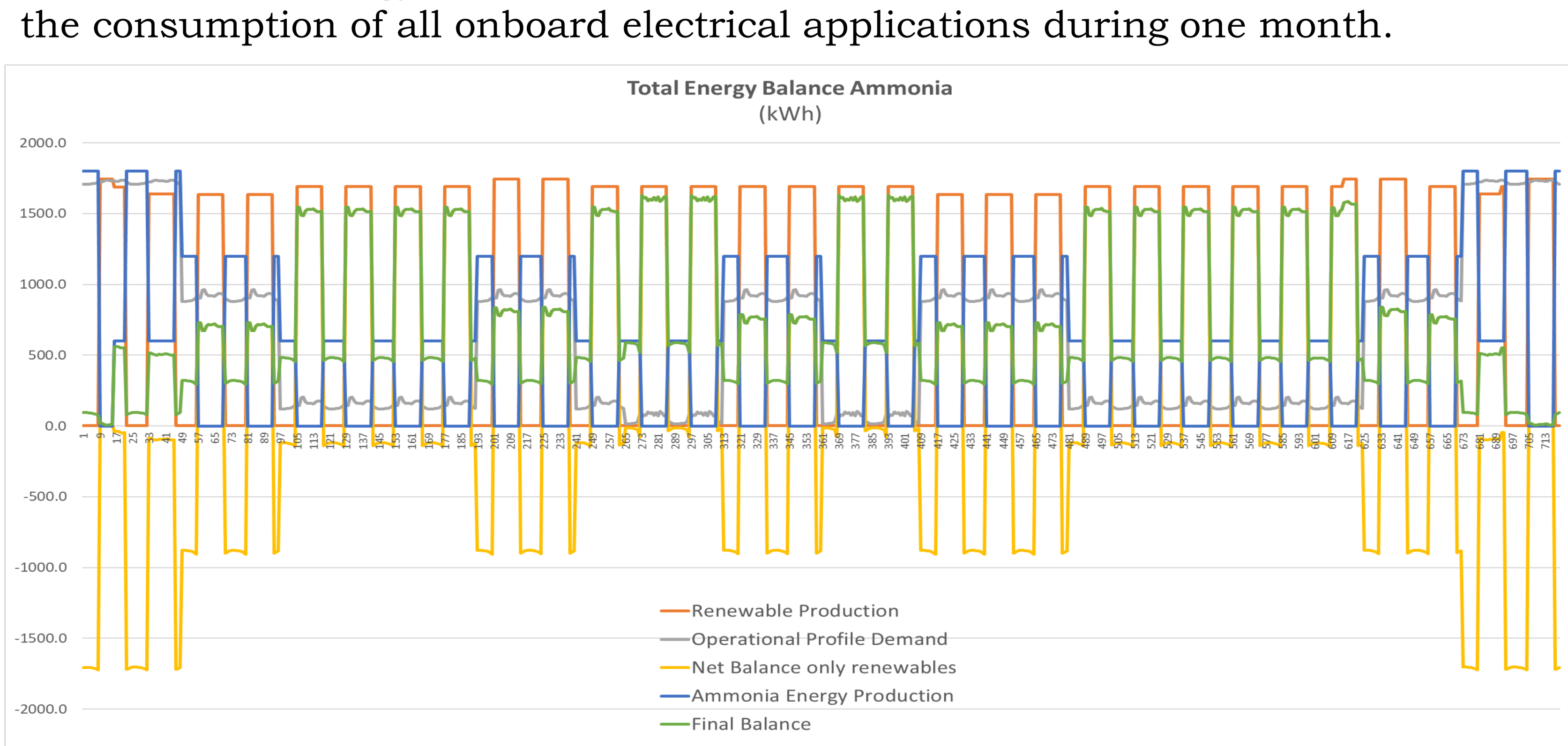

Figure 5. Energy balance for Ammonia SES

6. FINAL CONSIDERATIONS

The storage of ammonia in ships has revealed great potential for storing energy over long distances or for a long time.

The production of ammonia onboard for own consumption becomes a SES: carried out through renewable energies from the wind and the sun. In Portugal, these resources are abundant and should be explored.

With all the international commitments to reduce carbon dioxide emissions, this type of system implemented in ships would be an effective measure. Considering the very high consumption of fossil fuels on ships, the differences in emissions would be significant.

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