Hydrogen storage in depleted offshore oil and gas fields in Brazil (P-6H)

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1. Introduction

Hydrogen, as an energy carrier, is seen as a key factor in the energy transition to a net-zero economy, and Brazil is beginning to promote its use [1],[2]. Even if this process is in its early stages, it is highlighted that the production of green hydrogen in Brazilian offshore associated with wind generation appears as an increasingly viable possibility [3],[4],[5],[6]. Given this context, hydrogen storage may be one of the main options linked to this potential, using offshore geological reservoirs. The study on the use of Brazilian offshore fields for CO_2 storage has already started, but there is still no mention of using these fields for hydrogen storage [7]. Therefore, in this study, we sought to present the initial approach to this issue, investigating the possibility of hydrogen storage in depleted offshore oil and gas fields in Brazil.

2. Literature Review

2.1 Underground hydrogen storage

There are a variety of feasible hydrogen storage reservoirs, just as there are for carbon dioxide storage [6]. The most evident possibilities include saline aquifers, depleted oil and gas fields, and salt caves [5]. The usage of depleted fields has several advantages, including a better understanding of local geology (because this knowledge is acquired in the oil exploration process) and the existence of a transportation network and local infrastructure [7]. In the case of Brazil, offshore oil and gas deposits appear to be viable choices, especially given the previously studied feasibility of CO_2 geological storage [7]. In addition, storage of hydrogen in salt caves and depleted gas or oil reservoirs allows large-scale and long-term storage, having lower costs than using tanks [8].

2.2 Hydrogen in Brazil

Due to favorable climatic conditions, a competitive industrial sector with variable options, and a predominantly renewable electricity matrix, Brazil has stood out as one of the possible candidates for leadership in the global hydrogen market [9]. In July 2021, the Brazilian government also presented the guidelines of the National Hydrogen Program (PNH2), to demonstrate the country's strategies for the development of the hydrogen economy [10]. PNH2 also sought to map existing laws and regulations to support and promote hydrogen as an energy vector and fuel in the Brazilian energy matrix [10]. Also, the Energy Research Company (EPE) (a public company affiliated with the Ministry of Mines and Energy) recently released technical notes on the country's potential for grey and blue hydrogen, with plans to publish on turquoise hydrogen soon [11]. Currently, one of the priorities of the National Energy Policy Council (CNPE) focuses on research, development, and government support for international partnership and project initiatives aimed at accelerating the formalization of the national hydrogen strategy [10].

2.3 Hydrogen-rock interaction

CH_4, H_2, and CO_2 can all be stored in the same geological formation [11]. As a result, the same geological features may be used for several purposes. Some conflicts of interests may emerge, such as the competition to store CO_2 or H_2 at the same reservoir [11], [12]. However, the odds are very low, since all projects with these natures are still very incipient, and competition issues may be addressed from the beginning [11], [12].

In-depth geological characterisation is important to understand the storage capacity of Brazil's offshore oil and gas fields. Although the storage possibilities are initially the same for different gases and purposes, it is necessary to understand how each gas reacts when in contact with different mineralogies, permeabilities and porosities [11].

3. Methodology

The underground hydrogen storage depends especially on the geological conditions (e.g. the mineralogy of the rocks of the chosen formation and their structural stability) and physicochemical conditions of the fluid-rock interaction. In this work, we seek to ascertain the traditional methodology for calculating stocking as well as to approximate the required calculations to the available data, considering the need for an initial approach to the problem.

The traditional calculation methodology consists of 2 steps drawn from the available literature on the subject [4], [5], [12], [13], [14], [15]: i) geological site selection; ii) hydrogen storage capacity estimate.The reservoir hydrogen storage capacity is determined by replacing the recoverable natural gas volume in the gas field with hydrogen using Eq. (1), assuming that the reservoir natural gas has methane properties [12]:

$$E_H = HHV_H \times \rho_{H,s} \times OGIP \times \frac{\rho_{CH_4,stp}}{\rho_{CH_4,s}} \times UG \quad (1)$$

Where E_H is the total energy stored as hydrogen in the working gas (MWh·m³), HHV_H is the higher heating value of hydrogen (MWh/kg), $\rho_{H,s}$ is the hydrogen density (kg/m³) at the pressure (MPa) and temperature (°C) when the store is full, $OGIP$ is the original gas in place in the store expressed as a volume (m³) at standard temperature and pressure (STP), UG is the recoverable amount of gas also expressed as a volume (m³) at STP. $\rho_{CH_4,stp}$ is the natural gas density (kg/m³) at STP, $\rho_{CH_4,s}$ is the natural gas density at the pressure (MPa) and temperature (°C) when the store is full [10].

Considering the initial impossibility of obtaining some of these data, we will approximate the storage capacity by calculating the CO_2 storage capacity, whose storage capacity calculation also considers the switch from using porous natural gas spaces to injected gas.

4. Results

4.1 Depleted oil and gas fields distribution

Figure 1 shows the 85 studied fields and their location in the Brazilian offshore.

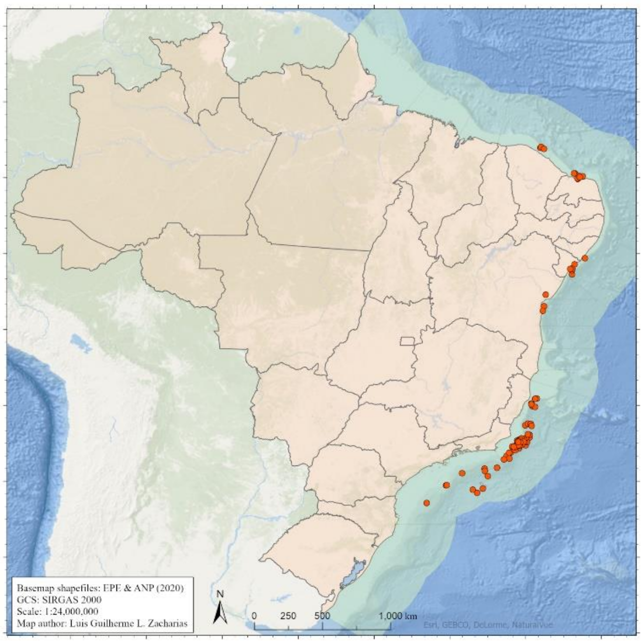

Fig. 1. Brazilian offshore fields. Source: [7].

The Brazilian offshore fields are not equally distributed along the country's coast, being concentrated in the southeast region, especially in the Campos and Santos basins. In this sense, it is to be expected that hydrogen storage will be concentrated in this region. This idea is also favoured by the greater availability of infrastructure and proximity to consumer centres in this location. However, this does not preclude the use of different regions for hydrogen storage, given fields in the northeast offshore region.

4.2 Possible reservoirs

Considering the impossibility of compiling all the necessary data for the calculation of hydrogen storage capacity in the first moment, we will consider that the fields with the highest CO_2 storage capacity fit as the most adequate candidates for hydrogen storage. This fields, possibly the most suitable hydrogen storage sites in the Brazilian offshore, are shown in table 1.

Table 1. Possible most suitable oil and gas fields for hydrogen storage.

Field Name	Basin	Geologic Formation
Buzios	Santos	Barra Velha Formation
Tupi	Santos	Barra Velha Formation
Jubarte	Campos	Carapebus Formation
Roncador	Campos	Carapebus Formation
Marlim Sul	Campos	Carapebus Formation
Marlim	Campos	Carapebus Formation
Albacora	Campos	Carapebus Formation
Marlim Leste	Campos	Carapebus Formation
Albacora Leste	Campos	Carapebus Formation
Peregrino	Campos	Carapebus Formation

5. Discussion

Several reasons lead one to believe that offshore southeastern Brazil has the greatest potential for hydrogen storage: greater infrastructure, proximity to consumption centres, advanced geological knowledge of the oil and gas fields, and studies indicating potential storage of other gases such as CO_2. Within this context, the Santos and Campos basins stand out with their large oil and gas production fields. However, it is important to mention that, even though storage capacity is relevant knowledge, it is possible that fields with smaller capacities serve different purposes. For example, fields with smaller storage capacity may serve as pilot projects or less be located in strategic locations.

It is relevant that future studies consider separating the oil fields from the gas fields, bearing in mind that oil fields are more likely to have complex multiphase fluid flow interactions with hydrogen, resulting in reduced pore space occupancy and greater storage costs, as well as the lack of a cushion gas already in place [12].

6. Conclusions

Brazil begins to analyse the introduction of hydrogen into its energy matrix, and doing this in an integral way requires evaluating possible sites for storage. The depleted fields of oil and gas in the Brazilian offshore appear as an interesting possibility due to their broad technical knowledge, available infrastructure and previous studies indicating the capacity to store CO_2. It is also pertinent to consider hydrogen as a long-term, large-scale energy storage solution, especially when coupled with renewable energy sources or grids with dynamic electricity pricing schemes.

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