Preliminary Assessment Potential of Underground Energy Storage for Renewable Energy in Cuu Long Basin, Vietnam

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Abstract. Vietnam is in the monsoon climate zone and has more than 3,000 km of coastline that has extensive resources to develop offshore wind energy. Moreover, offshore wind has the advantage of not taking up land. The rapid development of technology in recent years has resulted in a drastic decline in the cost of wind power. However, the biggest drawback of wind power is its fluctuating electricity supply, which depends on daily and seasonal variation of wind conditions. Therefore, energy storage will play an important role in facilitating the development of wind energy. In this study, an overview on how to select a georeservoir for energy storage and a preliminary evaluation of the underground energy storage potential in the Cuu Long basin, which is situated closest to the area of highest wind energy potential and is also the largest petroleum-producing basin in the country, making it a promising target for underground energy storage. In this study some geological and petrophysical information were collected and used for a preliminary evaluation of energy storage capability for a number of geological formations, based on porosity, permeability and depth to the top. As a result, two formations of Dong Nai and Bien Dong show to be possible good candidates, however more studies should be conducted in future.

Keywords: Underground energy storage · Cuu Long Basin · Renewable energy

1 Introduction

To reduce the carbon footprint, renewable energy resources including wind, biomass, solar and geothermal energy are increasingly utilized [1, 2]. However, using solar and wind energy is that it heavily depends on the weather and geography. Therefore, electricity production fluctuations require cheap, reliable and accessible storage of energy on a scale of seasonal usage to stabilize the power system [1–3]. Energy storage systems comprise of mechanical, chemical, biological, magnetic, thermal and thermochemical types [4]. Each technique can be used for different purposes depending on the storage capacity and discharging time (Fig. 1).

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The solar and wind energy storage will compete directly with fossil-based electricity options [5]. In the system, storage can play a significant role in reducing the cost. An example of hydrogen storage in France [6], shows that investing in storage is more economical than building more renewable capacity to meet demand. The energy storage facilities are man-made [3] or georeservoirs [1, 2, 7]. A comparison among storage techniques [4] shows that for long duration and large scale storage, pumped hydro storage (PHS), compressed air energy storage (CAES) and underground hydrogen storage (UHS) are dominants. The large storage demand for renewable energy (ranging from GWh to TWh) can be primarily satisfied by underground geological formation [5]. PHS also have large capacity storage; however, this storage system requires a large surface footprint and high cost [2]. In contrast, the underground storage system has a small surface footprint, is long term and of low cost [8]. This is the cheapest method for storing a large amount of gaseous hydrogen [9]. But, it is entirely dependent on the existence of suitable geological conditions and rock types. Therefore, research on the geological formation for underground storage is vital. For the Cuu Long Basin geological conditions, there are two main suitable reservoirs, which are depleted gas or oil fields and porous rock geologies.

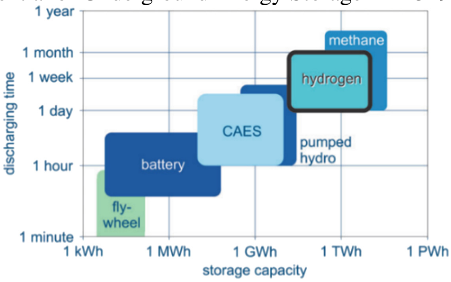

Fig. 1. Energy storage options (After Chen, Cong [4])

2 Wind Energy Status in Vietnam

Vietnam has a great potential for offshore wind energy (Fig. 2). A recent analysis by the Danish Energy Agency (DEA) and the World Bank projected that Vietnam offshore wind, if fully harnessed, could generate up to 160 GW of power, and Vietnam is capable of generating 10 GW of electricity by offshore wind farms by 2030 [25]. Wind power in Vietnam is projected to develop rapidly in the future. Before 2018, there were only a few wind plants with a small amount of capacity. The capacity has increased significantly in 2019, obtaining 0.45 GW of wind at the end of June 2019 (EVN, 2019). The expectation of the investment costs of wind will decrease drastically in the coming 30 years. It is projected that wind powerplants at optimal locations will be more cost-effective than coal plants in 2030 for the first 20 GW [10].

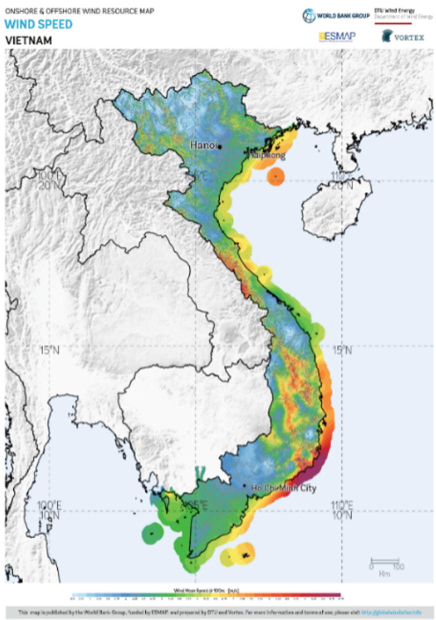

Fig. 2. Map of wind potential energy in Vietnam. Source: Ministry of Industry and trade/GIZ Energy support program.

The challenges of developing wind power sources are the ability to integrate and balance the wind power into the energy system. Power systems must balance in periods from seconds to seasons. In Vietnam, base-load generation has used coal plants. Medium demand range and peak demand range have been stabilized by natural gas-based and hydropower plants, respectively [10]. However, these balance-based are of low flexibility, high cost and high environmental impact. The solution for these issues may be energy storage in the geological reservoirs with large scale, long term, and low cost. Vietnam has great potential storage in the sedimentary basin [11]. Thus, research on the basins for energy storage is vital. In this work, we focus on the Cuu Long basin as it not only has the potential of storing 1,757 Mt of CO2 [11]. It also has great potential of wind energy (Fig. 2). Moreover, it is also the largest petroleum-producing basin in the country. The data in the petroleum exploration and production can be transferred into the research of underground energy storage. The petroleum reservoirs may prove promising for underground energy storage. Oil and platform rigs in defunct fields can be used as offshore structure base of wind turbines [12].

3 Assessment of Underground Storage Potential

3.1 Suitable Geologies for Energy Storage

CAES is currently the commercially mature technology for energy storage in salt caverns. The CAES could be applied to porous rocks in sedimentary basins, where legacy data from hydrocarbon exploration are available, and if geographically close to renewable energy sources [2]. Generally, CAES operation requires an anticline that is comprised of permeable, porous media [7]. Porosity needed for CAES is shown in Table 1 and Table 2. There have been several studies carried out in Israel using fractured rock aquifers [14]. Underground gas storage options include depleted gas/oil reservoirs, aquifers, and salt caverns. The geologic conditions of hydrogen storage have not been researched in detail like CAES as this technique was developed later. The fundamental geologic aspects of hydrogen storage are stated in the work of Liebscher, Wackerl [15]. To select the potential underground hydrogen storage sites, geological criteria such as the volume of the reservoir, lithology and tectonic activity, the depth of occurrence, are taken into account [16].

Table 1. Score-based system for identifying the candidate sites for aquifer CAES (after [13]).

Score	Permeability (md)	Porosity (%)	Type of reservoir
Unusable	<100	<7	Highly discontinuous
Marginal	100–200	7–10	Moderately vulgar limestone & dolomite
OK	200–300	10–13	Reefs, highly vulgar limestone & dolomite
Good	300–500	13–16	Channel sandstones
Excellent	>500	>16	Blanket sands

Table 2. Rank the suitability of potential sites for porous reservoir, modified from [17]

Score	1	2	3	4	5
Score interpretation	Unusable	Marginal	OK	Good	Excellent
Permeability (mD)	<100	100–200	200–300	300–500	>500
Porosity (%)	<7	7–10	10–13	13–16	>16
Total reservoir volume (VR/VS)	<0.5		0.5–0.8 or >3.0	0.8–1.0 or 1.2–3.0	1.0–1.2
Total closure rating (h/H)	<0.5		0.5–0.75	0.75–0.95	0.95–1.0
Depth to top of reservoir (m)	<137 or >760	140–170	170–260 or 670–760	260–430 or 550–670	430–550
Reservoir pressure (MPa)	<1.3 or >6.9	1.3–1.5	1.5–2.3 or 6.1–6.9	2.3–3.9 or 5.0–6.1	3.9–5.0
Type of reservoir	Highly discontinuous	Moderately vugular limestone & dolomite	Reefs, highly vugular limestone & dolomite	Channel sandstones	Blanket sands
Cap rock permeability (mD)			$>10^{-5}$	$<10^{-5}$	
Cap rock threshold pressure (MPa)			2.1–5.5	>5.5	
Cap rock thickness (m)			<6		>6

Table 3: Worldwide hydrogen storage potential sites (after [1])

Field/project name	Storage type	Properties	Note
Diadema, Argentina	Depleted gas reservoir	Pressure = 10 bar Temperature = 50 °C Depth = 600 m	Volume and status of operating are not reported
Underground Sun Storage, Austria	Depleted gas reservoir	Pressure = 78 bar Temperature = 40 °C Depth = 1000 m	Volume is not reported, status is operating
Rough gas storage facility, UK	Depleted natural gas reservoir	Capacity = 48 million m^3 ϕ = 20% K = 75 mD Pressure = 50–100 bar	- Chemical stability - Biological consumption - Leakage - Operational condition
Midland Valley, UK	Oil reservoir	K = 60–80 mD Thickness = 100–1000	- Geological uncertainty - Storage capacity
Rhaetian, Schleswing-Holstein, Germany	Gas reservoir	ϕ = 13–33% K = 2.1 575.2 mD Pressure = 65 bar Depth = 460–490 Thickness = 5–30 m	- Feasibility of hydrogen storage into the proven possible natural gas reservoir - Storage performance (deliverability)

The depleted hydrocarbon reservoirs, which are usually well-understood geological conditions, have good tightness, integrity of caprock and pre-existing surface and subsurface installations, are the most appropriate options for underground gas storage (Table 2 and Table 3). This enables the conversion of the depleted hydrocarbon reservoirs into the storage in a shorter time and at a lower cost. However, the conversion requires a comprehensive study because the possibility of chemical reactions and conversion of hydrogen into, e.g., methane will increase.

3.2 Methodology for Assessment of Storage Potential in Porous Formations

In general, CAES and UHS are in the stage of research and lack industrial experience. There has not been a specific norm of geological criteria. Several studies have illustrated that geological criteria for CAES and UHS [17, 18] have many similarities to natural gas storage. Therefore, we infer the key requirements of the natural gas storage industry to evaluate the potential CAES and UHS sites (Table 2 and Table 3).

4 Preliminary Assessment of Underground Storage Potential in Cuu Long Basin

4.1 Geological Setting

The Cuu Long Basin is an Early Tertiary age pulled apart rift basin. It intersects the most northern extent of the Cuu Long Basin. It is part of the Con Son Swell and the Nam Con Son Basin (Fig. 3). The Cuu Long Basin was formed as an extensional or a pull-apart basin. It was initiated during the Early Tertiary period as a result of the movement and collision of various tectonic plates, especially the collision between the Indian and Asian plates [20]. The relative movements of these tectonic plates created differential movement along pre-existing zones of weakness between Sundaland and Indochina subplates. This resulted in the creation of rift basins such as the Cuu Long rift basin [21]. The tectonic elements and evolution of Cuu Long basin consist of three main elements, which are rifting, compression and thermal sag. There are described very clearly in the research of Schmidt et al. (2019) [21]. We adopted their definition of sequence stratigraphic scheme (Fig. 4).

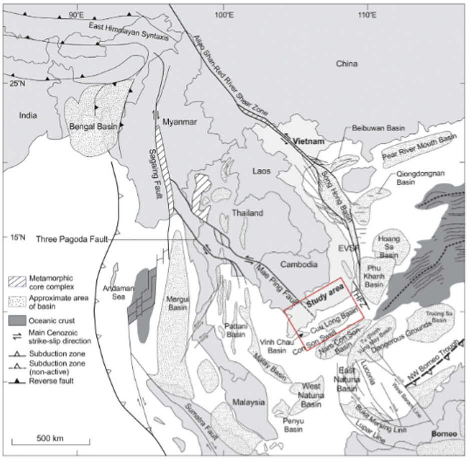

Fig. 3. Location of major structural features and Cenozoic basins for the greater IndoChina area, after Fyhn et al. (2009) [19]. The study area is marked by the red rectangle.

4.2 Potential for Energy Storage in Cuu Long Basin

Storage Potential in Porous Sediments

Based on the stratigraphy of the Cuu Long basin (Fig. 4) and some of the criteria of the storage reservoir (Table 2), the most favorable sedimentary units are Late Miocene to Quaternary (Dong Nai and Bien Dong Formation). The depth of top porous reservoirs should be from 137 to 760 m (Table 2). Thus, below Con Son Formation (Fig. 4) the depth will exceed that range. Moreover, these formations contain sandstone layers that are favorable lithology for reservoir storage [2]. The seismic data [19] show that the sediments of Late Miocene to Recent are characterized by relatively continuous, intermediate-amplitude reflections interrupted by patchy channel features. This suggests continued alluvial to shallow marine deposition in the area in accordance with well data. It is worth noting that these formations are not the objects of the oil and gas industry. Thus, the data are limited. We have not had well information to estimate directly the porosity and permeability of these formations. However, the porosity and permeability of reservoir of these formations should larger than the below reservoir in Con Son formation where the values of porosity varies from 10 to 31% and the permeability from 100 to 3066 mD [22].

Storage Potential in the Depleted Oil and Gas Reservoirs
The main oil and gas reservoirs in Cuu Long basin (Table 4) are fractured basement reservoirs. The porosity and permeability are very good, in comparison with the conditions shown in (Table 2 and Table 3) for the underground storage. However, further research on the conditions of the reservoirs is needed [23].

Table 4. Summarize basic information of the main reservoirs in Cuu Long basin

Reservoir names			Reservoir properties			
			Depth (m)	Temperature (oF)	Permeability (mD)	Porosity (%)
Miocene	White Tiger	North	3100	110	50	16.5
		Central	3050	100	30	15
		South	3000	95	160	18
	Dragon		2800	90	253	19
	Rang Dong		2700	91	185	23.2
	Ruby		1800	84	300	19
	STD		2100	87	1292	26
	TGT		3100	105	293	18.8
Oligocene	White Tiger	Upper Oligocene	3200	120	31	12.04
		Lower Oligocene	3300	125	20	10.25
	Dragon		3200	115	10	15
	STD		3200	105	247	22
	TGT		3200	110	24.8	15

5 Discussion

Georeservoirs can store large amounts of hydrogen or compressed that can help to balance production fluctuation of offshore wind energy. The Cuu Long Basin that is closest to the area of highest wind energy potential in Vietnam and also one the largest petroleum-producing basins in the country was selected for a preliminary screening regarding its potential for underground energy storage. In this study, an overview on the criteria to screen a gereservoir for hydrogen or compressed air storage capacity was conducted, based on which a preliminary investigation was done to show that the depleted oil and gas reservoirs and the porous sedimentary rock in Dong Nai and Bien Dong formations can be the possible target candidates for underground energy storage in the Cuu Long basin in future.

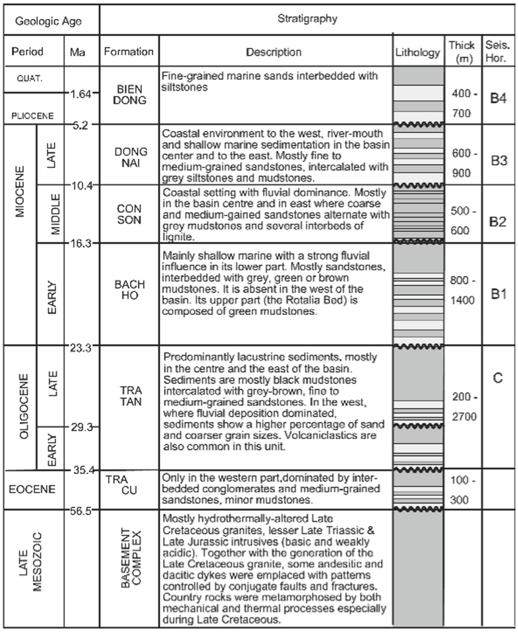

Fig. 4. Stratigraphic units of the Cuu Long basin (After Cuong and Warren [24])

It is also recommended more systematic studies on this issue should be done immediately to keep pace with the rapid development of offshore wind energy development activities in the southern Vietnam these days.

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