Carbon Sequestration in Gundih: Pioneering CCS Capacity Assessment in Indonesia

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Introduction

As the Indonesian government's energy and petroleum company, Pertamina is actively developing its business lines in both existing and new low-carbon businesses. Pertamina has targeted to reduce its carbon dioxide emissions by 29% by 2030. In fact, to support the national target, Pertamina also aims to achieve net zero emissions (NZE) by 2060 or sooner. One of the strategies launched by Pertamina in realizing the energy transition and reducing carbon emissions is through the implementation of carbon capture and storage (CCS) technology.

Currently, Pertamina is conducting a series of studies on the potential for CCS/CCUS implementation in the oil and gas that Pertamina is implementing throughout Indonesia. This study can be divided into three categories: (1) the development of CCS hubs (which capture CO2 from various sources), (2) CCUS to increase the production of oil and gas, and (3) CCS as a facilitator for the production of natural gas and carbon-based chemicals. On the other hand, the initial findings indicate that the studied area can emit 7.3 giga tons of CO2 annually, with inflation reaching 6.97 giga tons per year by 2030. This considerable capacity and injectivity not only has the potential to support Pertamina's own decarbonization business but also has the potential to be commercialized by receiving CO2 from both domestic and foreign sources.

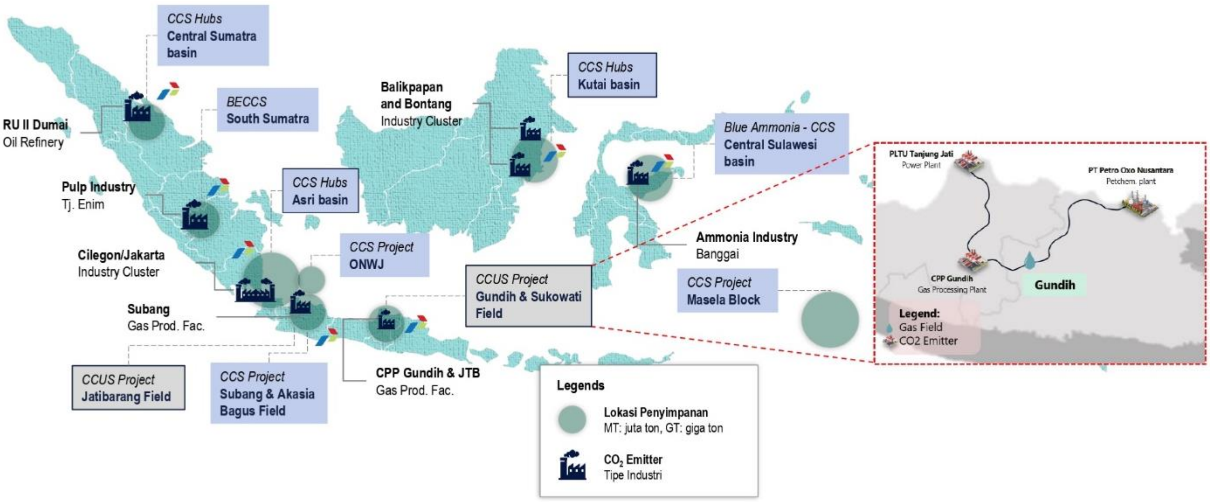

Figure 1. CCS/CCUS Initiative Project in Pertamina

Carbon Capture and Storage (CCS) is a critical technology to mitigate global CO2 emissions and align with international climate goals. (Fontenelle, Peyerl, Ciotta, Moretto, & Zacharias, 2023). Indonesia, with its vast geological resources, stands at the forefront of this technology, offering significant opportunities for large-scale CO2 sequestration. Indonesia's geological formations, including depleted oil and gas fields and deep saline aquifers, provide a substantial capacity for CO2 storage, estimated at over 577 gigatons (GT) nationwide (LEMIGAS, 2023). Specifically, the East Java Basin, with its extensive saline aquifers and mature hydrocarbon fields, is identified as a key region for CO2 storage, with a potential capacity exceeding 100 GT (IEA, 2021; Hakim, Tony, Chandra, Nugraha, & Nandiwardhana, 2025). One of the CO2 storage potentials in East Java is located in Gundih.

Gundih located within the East Java Basin, marks a pioneering effort in Indonesia's strategy to implement large-scale carbon sequestration (Hadj, Rahmanian, & Mwenketishi, 2023). Focused on injecting 800 tonnes per day (TPD) of CO2 into the Kedung Tuban (KTB) structure for a decade, the project uses the Kujung formation aquifer as a secure and efficient storage site.

As a first-of-its-kind project, the Gundih CCS endeavor seeks to overcome key challenges, including technical feasibility, economic viability, and environmental safety. This paper presents an in-depth examination of the Gundih project, exploring its methods, theoretical foundations, and significant implications for the future of CCS in Indonesia. Through this case study, the paper aims to provide valuable insights into the potential of carbon sequestration to contribute to Indonesia's sustainable energy future and global climate objectives.

Method and/or Theory

The Gundih CCS project is grounded in geological principles, emphasizing the importance of understanding subsurface formations and their capacity to store CO2 securely.

Geological Settings

The research area is located in the North East Java Basin, one of western Indonesia's tertiary basins that has been shown to produce hydrocarbons. (Marbun, et al., 2019; Kitamura, et al., 2014; Tsuji, et al., 2014). The East Java Basin is classified as a back-arc basin (Zhou, Peng, Sun, Fu, & Zhu, 2024). Two primary structural tendencies govern the East Java basin's basic configuration: the east-southwest trend, which h is found in the Central Mandala plateau and the southern basin, and the northeast-southwest trend, which is typically only found in the northern shelf. (Tsuji, et al., 2014; Bransden & Matthews, 1992).

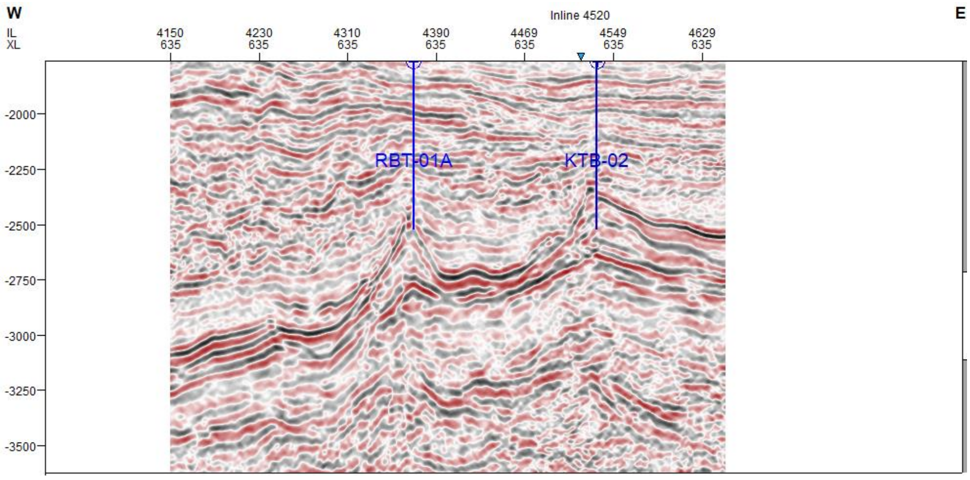

Figure 2. 2D Seismic Profile

The Kujung formation, provides the geological setting for CO_2 sequestration. Its carbonate reservoirs, characterized by high porosity and permeability, are well-suited for CO_2 injection. Additionally, the overlying caprock, composed of impermeable shale, ensures long-term containment of injected CO_2. The kujung formation zone is shown in Figure 2. Detailed stratigraphic and structural analyses were conducted to identify potential fault traps and ensure minimal leakage risks (Miocic, et al., 2019). The kujung formation is overlaid by tuban formation, composed by shale-dominated. This formation is deposited during late early to middle miocene in the neritic to deep marine environment. (C, et al., 2018; Fifariz, Janson, Kerans, & Sapiie, 2020). Since this formation has low permeability so this formation is known as the seal/caprock in gundih field.

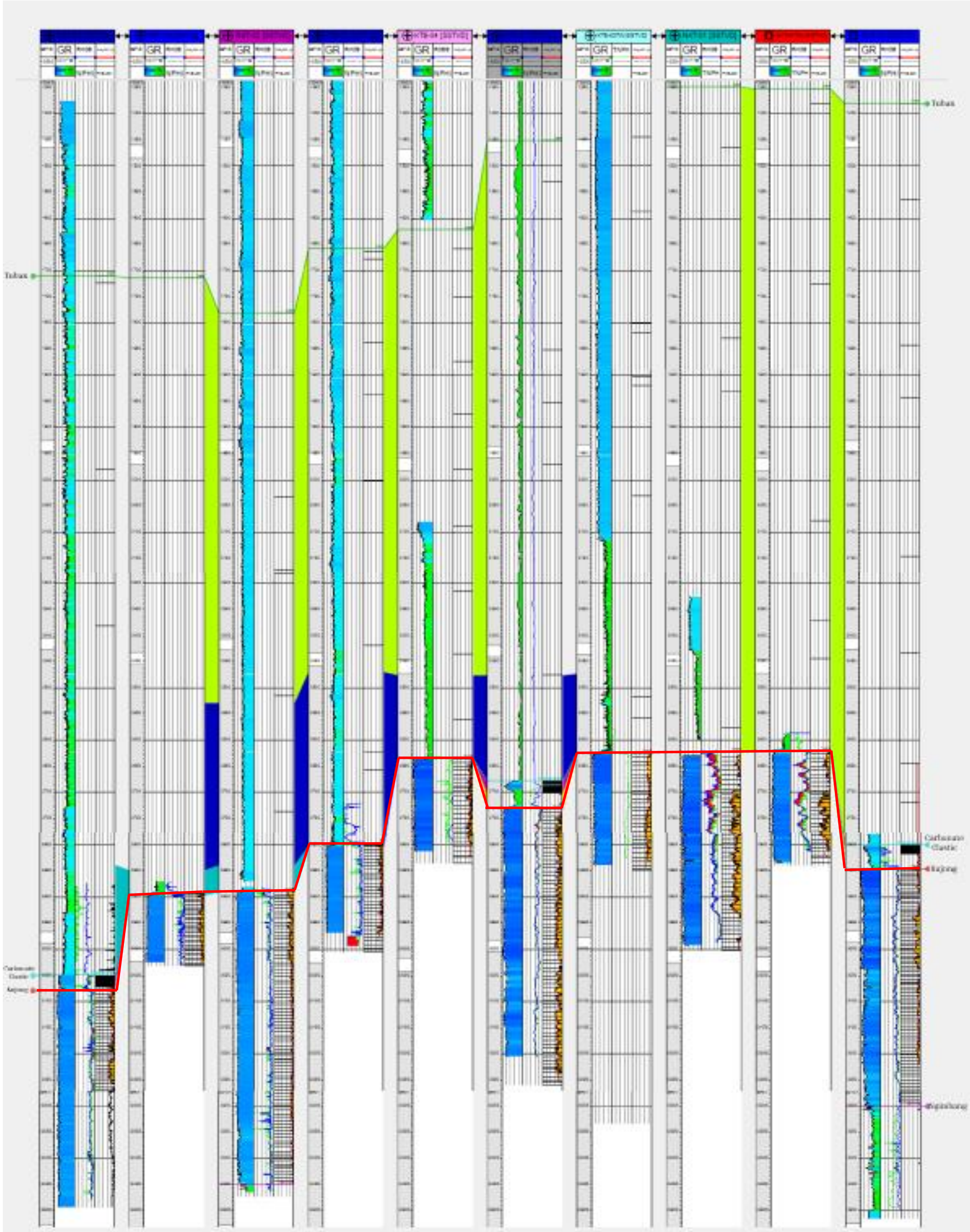

Figure 3. Well Correlation

Geophysical and Petrophysical Studies

Geophysical surveys, including seismic imaging, were employed to map the subsurface structure and delineate the Kedung Tuban reservoir. Petrophysical data from well logs were analysed to determine reservoir properties such as porosity, permeability, and fluid saturation, critical for assessing injectivity and storage capacity (Hajiabadi, Bedrikovetsky, Borazjani, & Mahani, 2021; Misra, Jin, Tathed, & Han, 2021). Velocity modelling, calibrated with check shot data, enhanced the accuracy of depth conversion, ensuring precise structural mapping (Yang & Ma, 2019; Grechka & Wapenaar, 2014; Sexton, 1998). Seismic inversion techniques further delineated reservoir properties, producing acoustic impedance models and pseudo-porosity maps that identified high-porosity zones suitable for CO_2 injection and storage. (CAF, 2022; González R. , Reeves, Eslinger, & Garc, 2007).

Petrophysical analyses provided detailed insights into the reservoir's quality and CO_2 storage potential. Logs from wells such as KTB-1 and NKT-1 TW revealed effective porosity values averaging 20–25%, supported by permeability conducive to fluid migration. Lithological studies showed the Kujung Formation to be predominantly carbonate, with favourable porosity types for CO_2 sequestration. Additionally, the overlying Tuban Formation's calcareous shales were identified as reliable seals, while fault seal analyses confirmed lateral containment, reducing risks of CO_2 leakage.

The integration of geophysical and petrophysical data resulted in a comprehensive static reservoir model, highlighting the KTB structure's suitability for CCS. The model estimated a CO_2 storage capacity in kujung aquifer of 119,22 MMT, supported by simulations predicting stable plume migration and minimal risk of fault reactivation. This study underscores the importance of combined geophysical and petrophysical approaches in ensuring safe and efficient carbon sequestration in the Gundih field.

Conclusions

The Gundih CCS project underscores Indonesia’s commitment to addressing climate change through innovative carbon management solutions. The study highlights the Kedung Tuban structure’s capacity to securely store substantial volumes of CO_2 while enhancing gas production, thus achieving both environmental and economic objectives. Key conclusions include:

1. The Kujung formation offers robust geological conditions for long-term CO2 storage with minimal leakage risks.
2. The Gundih initiative provides a replicable model for future CCS projects, aligning with Indonesia’s energy transition strategy and global climate goals.

By demonstrating the feasibility of large-scale carbon sequestration, the Gundih CCS project sets a precedent for sustainable energy practices in Southeast Asia and beyond.

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