Technical CO_2 Sequestration Assessment for Zelda-Gita Talang Akar Formation, Asri Basin, Offshore Southeast Sumatra, Indonesia

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[Abstract] - The global reliance on fossil fuels, including coal, oil, and gas, remains significant for sustaining economic growth, given the limitations of renewable energy technologies in providing a fully dependable alternative. According to the International Energy Agency (IEA, 2021), there has been a significant increase in Indonesia's energy sector emissions over the past twenty years. Specifically, these emissions have more than doubled from approximately 255 MT CO_2 in 2000 to around 520 MT CO_2 in 2019. The emission sources within Indonesia have a notable concentration on the island of Java, characterized by its high population density and industrialization. It is imperative to establish an initiative aimed at mitigating carbon emissions. The objective of this project is to investigate the potential for carbon dioxide (CO_2) storage in the Widuri Field, located in the Asri Basin, Offshore Southeast Sumatra. The storage resource estimate utilized in Widuri adopts a production-based approach developed by the Carbon Sequestration Leadership Forum (CSLF), which is particularly well-suited for mature fields. The laboratory measurements data, including porosity, permeability, and capillary pressure, were employed in order to get insights into the reservoir properties and lithofacies classifications. The identification of lithofacies types was accomplished by the study of core samples acquired from the Widuri wells. A subsequent study was conducted to identify lithofacies inside un-cored intervals utilizing the log data. Based on the petrophysical interpretations and reservoir quality analysis of each zone, it can be inferred that the Zelda Interval exhibits favorable characteristics for CO_2 injection, as indicated by the storage evaluation.

[Keywords] *Storage Assessment, Storage Capacity, Talang Akar Formation, Widuri Field*

[INTRODUCTION]

Background

The global energy landscape continues to rely heavily on fossil fuels such as coal, oil, and gas, owing to their pivotal role in sustaining economic growth. Despite advancements in renewable energy technologies, their capacity to provide a fully reliable alternative remains limited. According to the International Energy Agency (IEA, 2021). Indonesia's energy sector has witnessed a substantial increase in carbon emissions over the past two decades. Specifically, emissions have more than doubled from approximately 255 million tonnes of CO2 in 2000 to around 520 million tonnes in 2019. This surge in emissions is particularly pronounced in Indonesia's Java Island, renowned for its high population density and industrial activity.

In response to this pressing environmental concern, it is imperative to develop initiatives aimed at mitigating carbon emissions. One promising approach is carbon dioxide (CO_2) storage, which involves capturing CO_2 emissions from industrial processes and storing them underground. The Widuri Field, situated in the Asri Basin, Offshore Southeast Sumatra, emerges as a potential site for CO_2 storage due to its geological characteristics and proximity to emission sources. The primary objective of this research project is to explore the feasibility of CO_2 storage in the Widuri Field. This entails conducting a comprehensive assessment of the field's reservoir properties and lithofacies classifications to determine its suitability for CO_2 injection. The storage resource estimation methodology employed in this study follows a production-based approach developed by the Carbon Sequestration Leadership Forum (CSLF), which is tailored for mature fields like Widuri.

Laboratory measurements, including porosity, permeability, and capillary pressure, serve as crucial inputs for understanding reservoir properties and lithofacies classifications. Core samples extracted from the Widuri wells facilitate the identification of lithofacies types, while log data enable the characterization of lithofacies within un-cored intervals. Petrophysical interpretations and reservoir quality analyses conducted on each zone reveal that the Zelda Interval exhibits favorable characteristics for CO_2 injection. This conclusion is supported by the storage evaluation, indicating the potential for successful CO_2 storage in the Widuri Field.
In summary, this research endeavors to contribute to the development of sustainable energy solutions by assessing the viability of CO_2 storage in the Widuri Field. By leveraging geological and reservoir data, the study aims to inform decision-making processes regarding CO_2 mitigation strategies in Indonesia's energy sector.

Geological/Stratigraphical Settings

The Asri Basin is a component of a sequence of Tertiary half-graben formations that have emerged along the Asian continental margin. These formations have been situated in a retro-arc environment since the early Neogene era. The region under consideration spans an estimated 3500 square kilometers and encompasses sediment deposits with a vertical extent of up to 16,000 feet. These sediments range in age from the Paleocene epoch to the Pleistocene epoch. The eastern boundary of the area is defined by a fault that trends in a north-south direction and exhibits a downthrown displacement towards the west. Additionally, the southern margin is characterized by a regional wrench system that trends in a northwest-southeast direction (Ralanarko et al., 2022). The primary reservoir formations within the Asri Basin consist of Oligocene to early Miocene fluvial, alluvial, marginal marine, and deltaic sandstones that belong to the Talang Akar Formation (TAF). The Tectonostratigraphic Architecture Framework (TAF) of the Asri Basin comprises two distinct members, namely the Zelda Member representing the Lower TAF, and the Gita Member representing the Upper TAF. The composite logs commonly display the vertically arranged sandstone reservoirs found in these fields. The regional seals in this context are established by shales located at the uppermost part of the TAF, as well as directly above it. These shales are accompanied by thick mudstones from the subsequent Gumai Formation, which further contribute to the sealing properties.

After a period of 51 years characterized by extensive petroleum extraction, resulting in a cumulative production of 1.6 billion barrels of oil equivalent (BBOE), with 80% originating from the Gita-Upper Zelda reservoir and the remaining 20% from the BRF reservoir, it is evident that the OSES block is nearing the conclusion of its economically viable phase. The future storage capacity is expected to expand over time due to the depletion of other fields. The aforementioned oil and gas reservoirs that have been exhausted present themselves as highly suitable options for the storage of carbon dioxide (CO_2). Nevertheless, the quantification of the capability of this geological formation remains undetermined. According to prior research conducted at Pertamina, it is projected that the Talang Akar reservoir will be exhausted by the year 2030. Conversely, the utilization of depleted oil resources for gas storage is viable due to their shown impermeability over extended geological time spans.

The Widuri formation function includes several components for preliminary screening. These components are categorized as follows: the Air Benakat Formation serves as the monitoring zone, the Gumai Shale and Marine Shale Baturaja act as the confining zone, the Talang Akar Formation (specifically the Gita and Zelda Members) and Banuwati Formation function as the containment zone, and the Basement (composed of granite/granodiorite and high-grade metamorphic rock) serves as the configuration zone, as depicted in the figure provided.

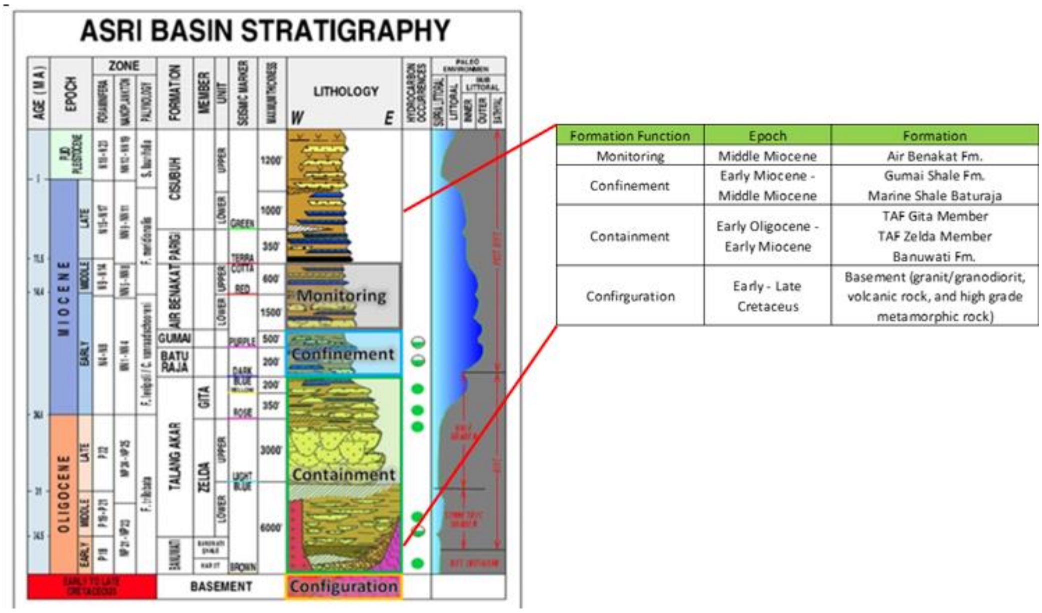


Figure 1. Asri Basin stratigraphy with formation function (modified by Ralanarko et al., 2022)

[METHODS AND MATERIALS]

Methods

The assessment of CO_2 sequestration from a technical perspective involves conducting two types of analyses: surface analysis and subsurface analysis. In order to facilitate CO_2 injection, it is imperative that the surface effectively reaches the sources of CO_2 in the vicinity of the target field. This will enable the determination of an appropriate CO_2 delivery scenario, taking into account factors such as distance and available volume. The subsurface study commences with the examination of well reports, which encompass reservoir characteristics and attributes. The data obtained from this analysis has the potential to ascertain the density of CO_2, calculate aquifer storage, identify lithofacies, and evaluate petrophysical parameters. The density of CO_2 is determined through an estimation calculation for the purpose of CO_2 storage. In the study conducted by A. Raza et al (2016), three participants were identified who provided their definitions of CO_2 storage assessment with a preference for threshold determination. During the discussion session, the calculation of CO_2 storage will involve forecasting the storage capacity following the screening and assessment of formations deemed suitable for carbon capture and sequestration. (**Figure 2**).

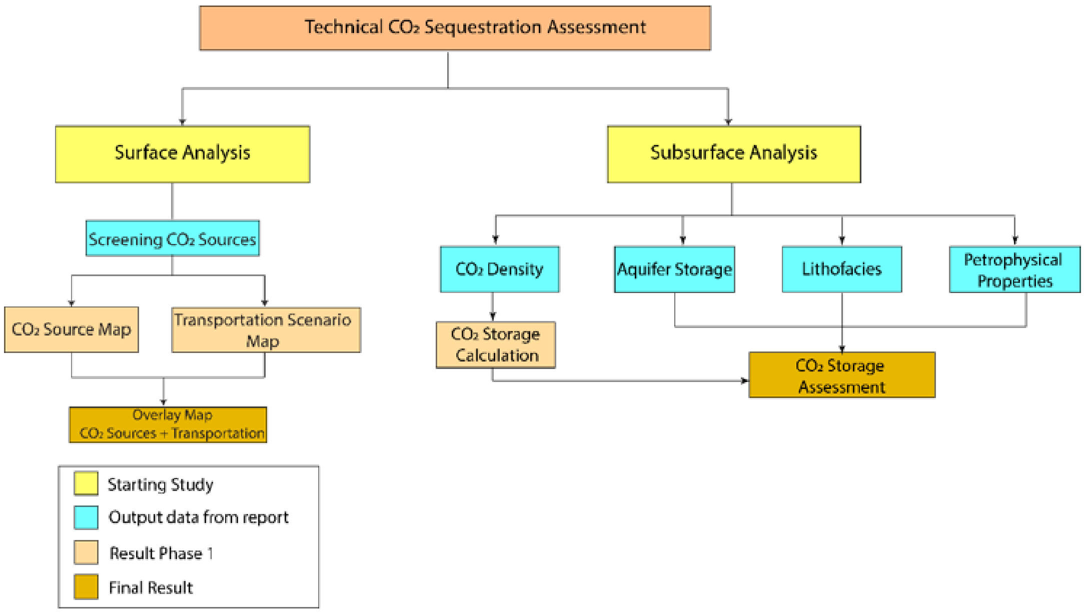


Figure 2 Study Methodology

[RESULT (AND ANALYSIS)]

Surface Analysis

The Asri Basin is situated in close proximity to many sources of carbon dioxide (CO_2), as depicted in **Figure 3**. These sources include steam power plants, petrochemical industries, CO_2 removal facilities, and gas processing industries. Within a 100-kilometer radius, the emission of carbon dioxide (CO_2) is primarily attributed to the gas processing sector located at Pabelokan. Within a 200 km radius, there are several steam power plants and a petrochemical industry that contribute to the emission of carbon dioxide (CO_2). Specifically, the Tarahan steam power plant emits approximately 0.77 million metric tons per year (MT/Year) of CO_2, while the Cilegon steam power plants emit around 24.81 MT/Year. Additionally, the Labuan steam power plant emits approximately 2.43 MT/Year of CO_2, and the Lontar steam power plants emit around 3.64 MT/Year. Finally, the petrochemical industry located in Cilegon contributes approximately 0.13 MT/Year of CO_2 emissions. The maximum distance of the most distant carbon dioxide (CO_2) sources is approximately 300 kilometers. Within this range, there are several notable CO_2-emitting facilities. Specifically, there are gas power plants located in Jakabaring, which emit approximately 0.08 million metric tons (MT) of CO_2 per year. Additionally, there is a CO_2 removal facility situated in

Subang, which emits approximately 0.03 MT of CO_2 annually. Lastly, there is a steam power plant in Indramayu that emits approximately 3.81 MT of CO_2 per year.

The carbon dioxide (CO_2) is captured and afterwards transferred through the utilization of the precombustion technique. The proposed system aims to integrate hydrogen, carbon monoxide, carbon dioxide, and minor quantities of other gases in order to generate syngas. Subsequently, the syngas undergoes a chemical reaction wherein carbon monoxide (CO) and water (H_2O) are transformed into hydrogen (H_2) and carbon dioxide (CO_2), yielding a gaseous composition characterized by a substantial presence of hydrogen and carbon dioxide. The concentration of carbon dioxide (CO_2) typically varies within the range of 15% to 50%, rendering it suitable for the processes of capture, separation, and transportation. With a carbon dioxide concentration ranging from 5% to 15%, this method exhibits greater cost-effectiveness compared to post-combustion approaches. Following the completion of the capture procedure, the subsequent step to be taken into consideration is the distribution of CO_2 to the designated field.

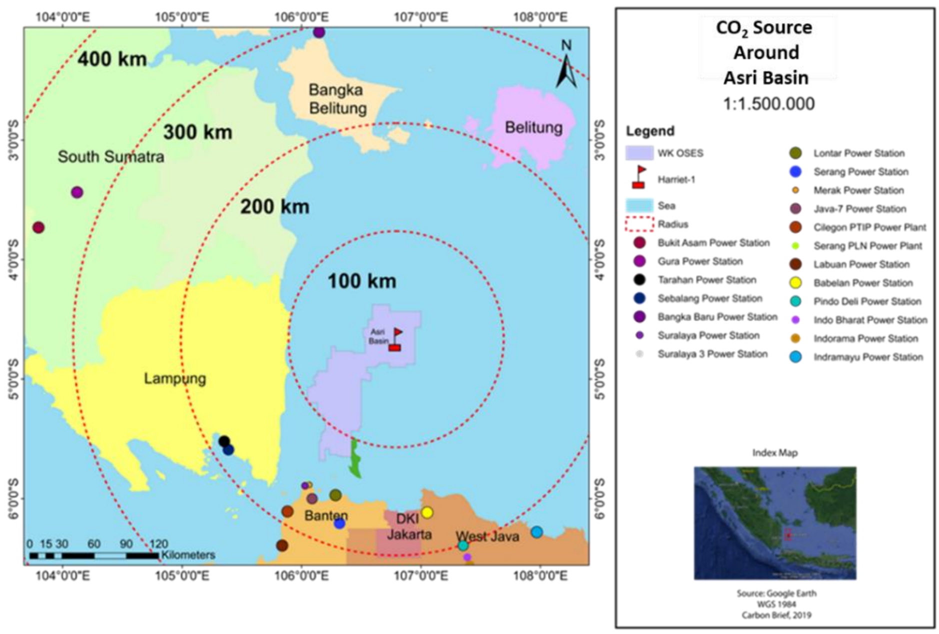
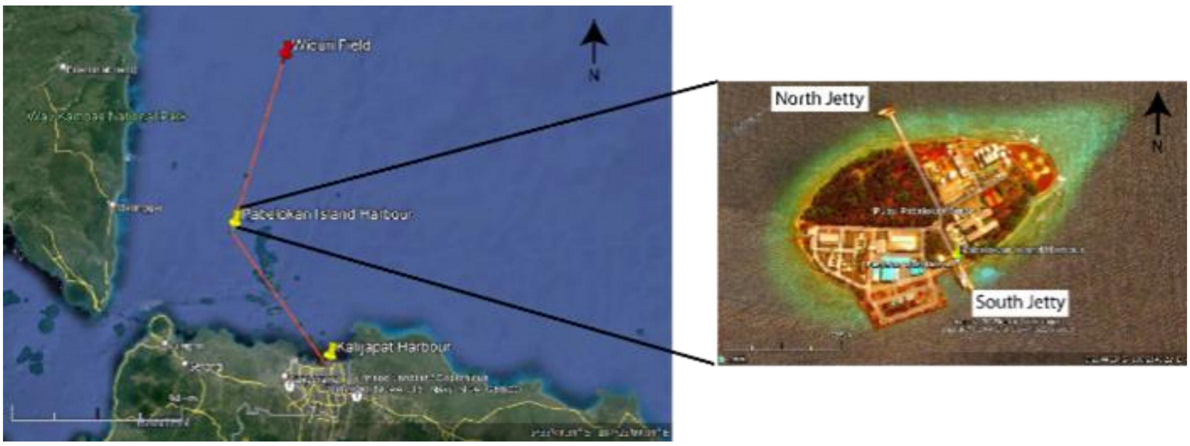


Figure. 3: CO_2 sources around Asri basin

The distribution of CO_2 throughout the field might occur through one of three methods, which are determined by the chosen route of transportation. The composition of the system includes pipes, vessels, and vehicles. On the other hand, the Asri Basin is situated in an offshore location. This section will mostly center on the topics of pipelines and vessels.

Transport appropriateness is determined by multiple criteria. Typically, the pipeline functions under conditions of elevated pressure, ensuring that carbon dioxide (CO_2) remains in a predominantly dense phase throughout its transportation. Subsequently, the operational expenses and utility performance exhibit ideal characteristics. In the interim, shipping serves as a viable option for numerous global regions, encompassing shipments of varying volumes ranging from 10,000 to 40,000 m^3. Nevertheless, the expenses associated with the pipeline exceed its consumption. The concept has the potential for application in the shipping industry, primarily because of the availability of vessel routes.

The proximity between the locations is rather short, ranging from 100 to 400 kilometers, and there are a total of ten carbon dioxide (CO_2) emission sources. This observation suggests that the Asri region exhibits a preference for utilizing ships as its primary form of transportation. This evaluation is predicated upon the geographical proximity and operational accessibility, namely the legal transportation route available to Asri, which involves shipping from Kalijapat Harbour to Pabelokan Harbour, followed by sailing to Asri for the purpose of CO_2 injection processing. In Pabelokan, there are two distinct categories of jetties. The first is the north jetty, which serves the purpose of fulfilling operational area necessities. Conversely, the second is the south jetty, designated specifically for facilitating crew changes (see **Figure 4, top**). The efficiency and effectiveness of shipping operations are influenced by legislative regulations and available resources. However, the distribution process necessitates more financial support in order to facilitate a smooth transition. Based on the data presented in the table, there exist a number of emitters that are presently in operation, intended for future implementation, or in the developmental phase. The projected route of the possible pipeline can be observed in **Figure 4, bottom**.



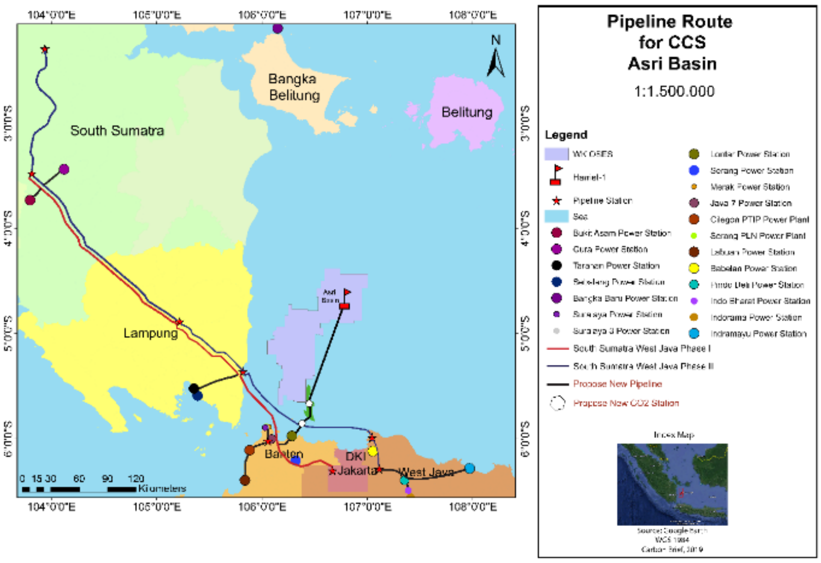


Figure. 4: CO_2 sources transportation: shipping rute (top) and pipeline trend

Subsurface Analysis

CO_2 Density

The storage of carbon dioxide (CO_2) is commonly anticipated to occur at depths over 800 meters, where the prevailing pressures and temperatures facilitate the presence of CO_2 in either a liquid or supercritical phase. The supercritical state, characterized by a temperature of 31.1°C and a pressure of 72.9 atm, has features that are not commonly observed. In the given circumstances, the density of carbon dioxide (CO_2) will vary between 50% and 80% of the density of water. The storage of CO_2 in geological formations in a dense state offers the opportunity to effectively use subsurface storage capacity within the pores of sedimentary rocks. Hence, it is necessary to determine the storage capacity by determining the density of carbon dioxide in its supercritical condition, in order to obtain the most accurate approximation.

Table 1. CO_2 density based on BHT and BHP in Widuri well

Property	Value	Unit
Medium :	**carbon dioxide**	
state of aggregation :	**overcritical fluid**	
Pressure :	106.8725	[bar]
Temperature :	85.555555555556	[Celsius]
Density :	238.28615111111	[kg / m^3]

CO_2 Storage Resource Estimating

The presence of hydrocarbon reserves serves as evidence of their capacity to retain substantial volumes of buoyant fluids. Typical petroleum systems are characterized by the presence of a permeable reservoir rock interval, which is covered by an impermeable unit known as a caprock or seal. Furthermore, the presence of a geometric element, which may be attributed to either the initial depositional system or subsequent tectonic modifications of the rock, is imperative and is commonly referred to as a trap. Therefore, it may be inferred that oil and gas fields possess favorable characteristics for the implementation of CO_2 geologic storage, given that the geological circumstances responsible for confining oil and gas resources are typically conducive to the enduring containment of CO_2.

Production-based estimations of CO_2 storage resources are typically favored over volumetric-based estimates due to the inclusion of comprehensive information obtained from the formation. The CSLF technique offers a set of formulas that may be applied to analyze depleted oil reservoirs, depleted gas reservoirs, as well as reservoirs that have been depleted of both oil and gas. The aforementioned formulas presuppose that the volume formerly occupied by the hydrocarbons generated is predominantly accessible for the purpose of CO_2 storage. Furthermore, it symbolizes the magnitude of computation, specifically the theoretical storage capacity or the uppermost limit for estimating capacity. Furthermore, the outcome of the computation is presented in Table 2.

$$\boxed{MCO_2 = \rho_{CO_2 r} \times UR \times Seff}$$

Where:

ρCO2 r : CO2 density at reservoir conditions (best estimate)

URp : Proven ultimate recoverable oil or gas. URp represents Rf × OGIP and Rf × OOIP respectively of the CSLF equations

Seff : Storage efficiency factor

Table 2. Storage Capacity Estimation

Parameter	Unit	Value	Remarks
ρCO_2 r	kg/m3	238,2861511	
URp (oil)	MSTB	382.598	Proven
URp (diss gas)	BSCF	105,9	Proven
Seff		0,55	Based on EOR experience
Storage Capacity	MCO_2	50.156.172	

Description of aquifer storage resource calculations

The determination of the extent of the productive area of the structures was based on the analysis of spilling points derived from 3D cross-sections and elevation contour lines. The thickness of the aquifer was determined using well data if available, or alternatively, by extrapolating the thickness from the 3D model. The calculation of volumes involves the multiplication of the aerial extent by the thickness of the aquifer, which is determined either by an average thickness derived from well data or by extrapolation of thickness. The efficiency factor was selected to have values of 1 and 0.55, which were determined based on prior experience with Enhanced Oil Recovery (EOR) techniques. The density of CO_2 at the given temperature and pressure conditions is recorded as 238.3 kg/m^3, as depicted in **Figure 5**. The porosities and permeabilities of the aquifer were determined by analyzing well data obtained from the reservoir summary.

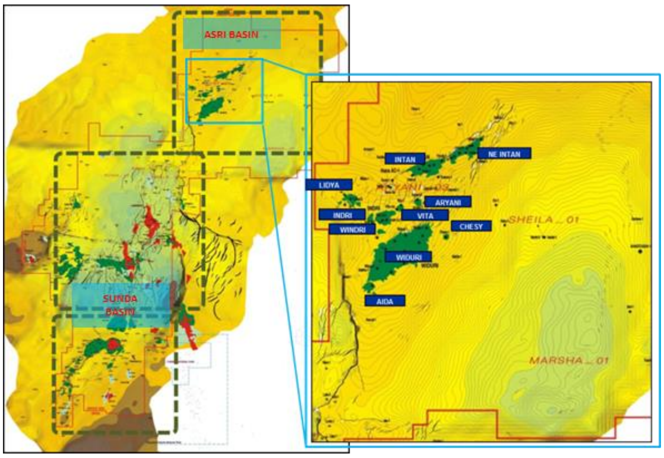


Figure 5 Widuri Field productive area

Lithofacies

The lithological properties were defined through the study of core samples in this publication. A comprehensive classification of lithofacies types was conducted, taking into account several factors such as lithology, sedimentary structure, porosity, permeability, and heterogeneity. As a result, a total of eight distinct lithofacies types were identified. The photograph depicting the textural properties of these lithofacies is shown in **Figure 6**. Based on the categorization of lithofacies according to their sediment composition, porosity characteristics, and the corresponding measurements of porosity and permeability obtained from core samples, a subsequent assessment was conducted to establish a hierarchical arrangement of these lithofacies in terms of their reservoir quality, with the highest quality being assigned the topmost rank:

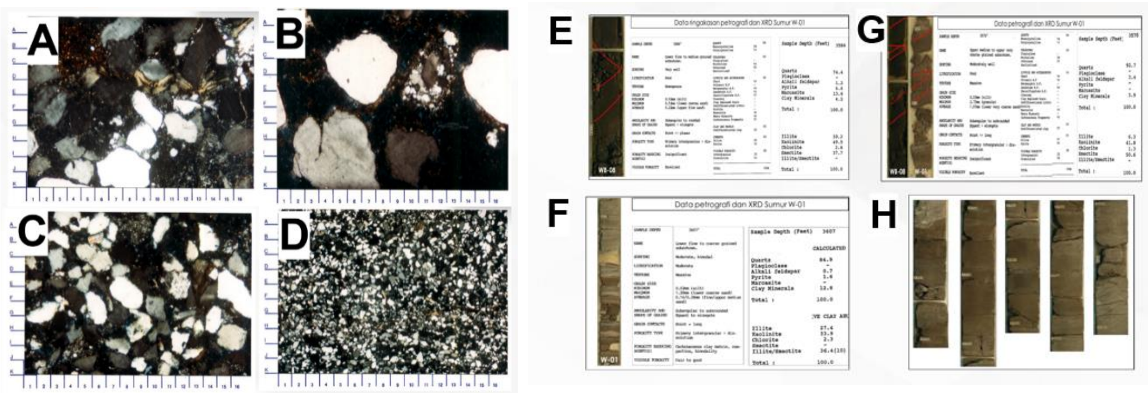


Figure 6. Photomicrographs of textural characteristics

Furthermore, the depiction of lithofacies is presented in **Table 3** provided below. The Talang Akar Formation has two distinct members, namely the Gita and Zelda members found inside the Widuri A-01 site.

Table 3. Lithofacies descriptions

ID No	TAF	Lithofacies	Depth (ft)	Well	Porosity	Permeability
A	Gita	Very coarse grain sandstone trough cross bedding (St)	3460	Widuri A-01	26,90%	200 mD
B		Coarse-medium grain sandstone planar cross bedding (Sp)	3540	Widuri A-01	27,90%	1753 mD
C		Very fine-fine grain sandstone flaser (Sf)	3575	Widuri A-01	27,90%	1753 mD
D	Zelda	Cross bedding medium grained quartzose sandstone with carbonaceous laminae (SCl)	3655,3	Widuri A-01	38,90%	10.000 mD
E		Very coarse grained, cross bedded, Quartzose Sandstone (QSc)	3634,2	Widuri A-01	35%	36.800 mD
F		Wavy bedded medium grained quartz sandstone (Sw)	3674,25	Widuri A-01	24,20%	3320 mD
G		Wavy bedded medium grained quartz sandstone with mudstone layers (SMw)	3674,25	Widuri A-01	34,20%	850-23.000 mD
H		Very coarse grain sandstone trough cross bedding (St)	3686	Widuri A-01	20-26%	2-1100 mD
I		Very fine-fine grain sandstone flaser (Sf)	3607	Widuri A-01	13-28%	6000 - 25000 mD
J		Coarse-medium grain sandstone planar cross bedding (Sp)	3670	Widuri A-01	27-39%	60-2900 mD

Petrophysical Properties

The utilization of wireline logs data for petrophysical analysis is a prevalent method employed to assess various zones inside depleted oil and gas reservoirs with regards to carbon dioxide (CO_2) storage. In order to conduct this investigation, core samples were obtained from various intervals of Widuri A-1 for the measurement of petrophysical parameters, including porosity, permeability, and capillary pressure. Subsequently, core plugs extracted at depths ranging from 3460 ft to 3670 ft were subjected to air permeability and helium porosity tests. These core plugs exhibited a diverse range of porosity values, spanning from 13% to 38.9%, as well as permeability values ranging from 2 mD to 36,800 mD.

The capillary pressure of 8 core plugs was assessed using humidified air, with incremental pressure increments up to 800 psi, until the irreducible water saturation point was attained. The determination of the degree of saturation was thereafter conducted by the gravimetric method following the establishment of capillary equilibrium. The Leverett J-function was employed in order to assess and describe the presence of capillary heterogeneity, and then derive a consolidated reservoir curve. It was assumed that the relative permeability remained constant throughout this analysis. The present study examines a reservoir cross-section, whereby many core samples are extracted at varying depths. In the laboratory, each cores will produce distinct capillary pressure curves, each encompassing the entirety of its unique characteristics. These curves can subsequently be transformed into a reservoir capillary pressure curve. The J-function is utilized to standardize all curves towards a common curve, operating under the premise that the porous medium can be represented as a collection of non- interconnected capillaries. The J function is employed to calculate the average capillary pressure curve of the reservoir, resulting in an average capillary pressure curve as depicted in **Figure 7**.

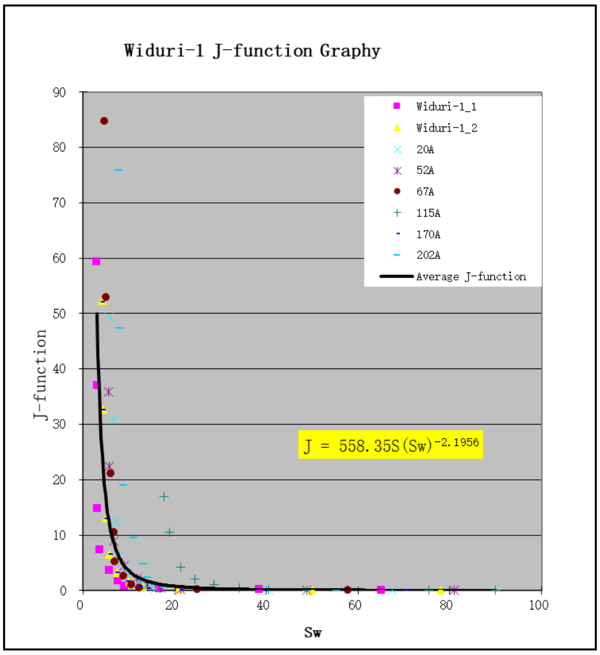


Figure 7. Widuri-1 J-function

Widuri Field exhibits four distinct rock types, each of which demonstrates the variability of pore throat size. The rock types of best grade, namely RT1, RT2, RT4, and RT3, are depicted in Figure 8 and Figure 9. According to the data, rock type 1 has the greatest permeability, whereas rock types 2, 3, and 4 demonstrate progressively lower levels of permeability. The porosity of rock types 1 through 4 has an average range of 16% to 41%.

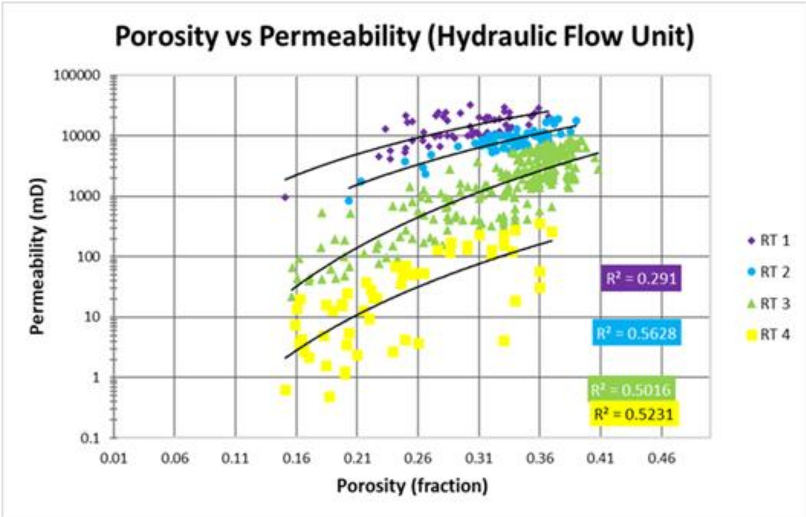
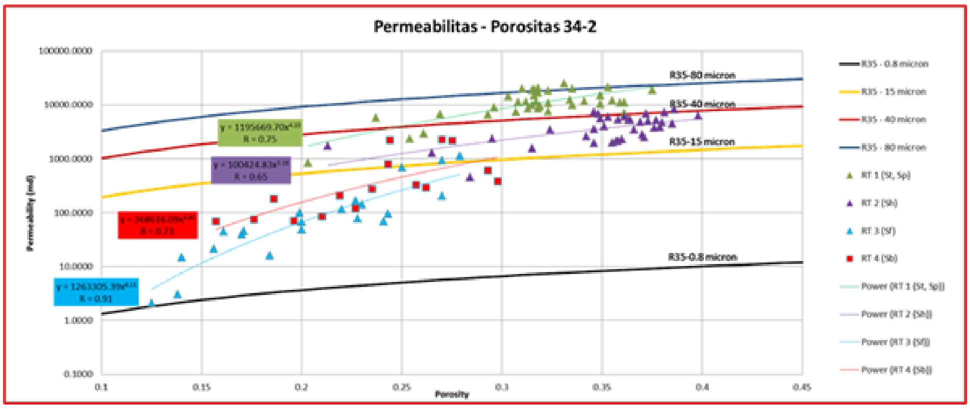


Figure 8. Rock typing Widuri Field



RT 1 – pore throat 40 – 80 µm
RT 2 – pore throat 15 – 40 µm
RT 3 – pore throat 0.8 – 15 µm
RT 4 – pore throat 0.8 – 40 µm

Figure 9. Rock Typing TAF Interval (Windland Approach)

[DISCUSSION]

The evaluation of the CCS project will be conducted by considering both the general surface facility and subsurface criteria, with the aim of assuring the viability of CO_2 injection. The initial analysis is derived from carbon dioxide (CO_2) sources. Determining the extent to which CO_2 sources have the ability to contribute to CO_2 injection beneath the saline surface of the Asri Basin would be of considerable utility. Based on the analysis of data and maps, it is evident that the distribution of CO_2 sources spans a geographical range of 100 to 400 kilometers, primarily encompassing the islands of Sumatra and Java in Indonesia. The region of Sumatra encompasses six distinct sources of carbon dioxide (CO_2), each located within a radius ranging from 170 to 330 kilometers from the area of interest. These sources collectively contribute to a total annual CO_2 emission of 5.42 million metric tons. Java Island is characterized by the presence of 14 carbon dioxide (CO_2) emission sources, each located within a radius ranging from 150 to 210 kilometers from the designated region of focus. These sources collectively contribute to a total annual CO_2 emission of 76.41 million metric tons. In order to facilitate the movement of CO_2 from the Asri basin to various target locations, it is imperative to identify a suitable means of transportation, given the presence of several CO_2 sources strategically located within the basin. There are two potential means of transportation for carbon capture and storage (CCS) based on the distance and geographical placement of the carbon dioxide (CO_2) source: pipelines and ships. The transportation of CO_2 through pipelines will utilize pre-existing infrastructure, such as the South Sumatra West Java pipeline. In order to establish a direct connection with a carbon dioxide (CO_2) source, it is necessary to utilize four connecting pipes that extend from a designated source, such as a power plant or chemical industry, to the main pipe. The main pipe serves as the conduit for delivering CO_2 to Pabelokan Island, ultimately terminating at the Harriet well, which serves as the designated place for CO_2 injection.

In the event that carbon dioxide (CO_2) is transported via maritime vessels, the collection of CO_2 will take place at designated stations situated along the closest coastal areas adjacent to Asri. In the Sumatra region, carbon dioxide (CO_2) will be gathered via a pipeline located at the Tarahan station, whereas in the Java region, CO_2 will be collected using an already established pipeline situated at the Cilegon station. Therefore, the vessel designated for this purpose has the capability to promptly capture carbon dioxide at designated station points and transport it to Pabelokan. Consequently, carbon dioxide (CO_2) will be transported via the pre-existing pipeline infrastructure to the Harriet facility. Furthermore, in order to address the economic aspect, there are numerous potential possibilities for the transportation of CO_2 to the designated region of Harriet.

The subsurface investigation reveals that the reservoir located at a depth more than 3536 ft (referred to as the Zelda Interval) exhibits favorable injectivity. This reservoir demonstrates promising characteristics such as strong permeability, porosity, and thickness, along with a low degree of water/gas saturation. These attributes make it well-suited for reaching a maximum storage capacity. The examination of diverse data sets acquired from three distinct wells and two separate intervals reveals that the Widuri A-05 located in the Zelda Interval has zones of good quality with a favorable thickness, hence enabling a high injection rate. Based on the findings of Raza et al., 2016 it is recommended that the thickness of the injection zone should exceed 164 feet in order to ensure the efficacy of CO_2 injection. In general, the Zelda Interval exhibits superior reservoir quality in comparison to the Gita Interval in Widuri A-05. This is primarily attributed to the Zelda Interval's favorable characteristics, including a substantial thickness of 192.5 ft, high-quality facies, and desirable porosity and permeability. Additionally, the Zelda Interval demonstrates a minimal presence of residual gas/water saturation. Conversely, the Gita Interval is characterized by a notably thin reservoir, resulting in a significantly lower quality. **Table 4** presents the attributes of several zones that have been identified as integral components in the process of selecting suitable targets for the implementation of safe storage practices.

The present study aims to extend its investigation by employing computational and experimental analysis to assess the injectivity of each zone. This evaluation will take into account additional restrictions, including the fraction of water, remaining gas and condensate, as well as the chemical processes involving CO2, brine, and rock.

Table 2. Widuri storage assessment (modified by Raza et al, 2016)

A. Raza et al (2016)				Widuri A-01				Widuri A-05				Widuri B-08			
Parameters	Positive Indicator	Negative Indicator	Indication of Aspect	Gita Interval		Zelda Interval		Gita Interval		Zelda Interval		Gita Interval		Zelda Interval	
Depth, ft	>2625	2625 > depth > 6562	Storage capacity	3460 - 3575	OK	3655 - 3802	OK	4121 - 4252	OK	4275 - 4584	OK	4304 - 4534	OK	4558-4679	OK
CO2 density	High	Low	Storage capacity	Field pressure and temperature conditions											
Porosity, %	>20%	<10%	Storage capacity	27,60%	OK	30%	OK	26%	OK	26%	OK	31%	OK	34%	OK
Thickness, ft	>164	<66	Injectivity	80,6	NO	151,7	NO	61,1	NO	192,5	OK	107	NO	120	NO
Permeability (near wellbore), mD	>100	10-100	Injectivity	1680	OK	2844	OK	682	OK	1444	OK	356	OK	1039	OK
Pore throat size distribution	Less heterogenous	Highly heterogenous	Injectivity	Heterogenous (based on rock typing)											
Average residual gas / water saturation, %	Low	High	Injectivity	4/26,35	OK	4/45,65	OK	4/33,5	OK	4/54,7	OK	4/32,45	OK	4/74,8	OK
Condensate (oil phase) saturation	Low	High	Injectivity	73,65%	NO	54,35%	NO	66,50%	NO	45,30%	OK	67,55%	NO	25,20%	OK
Lithofacies type	Good quality	Low quality	Injectivity	St, Sp, Sf. Good to excellent reservoir quality (high porosity and permeability)	OK	Sw, SMw, Scl, QSc. Good to excellent reservoir quality (high porosity and permeability)	OK	St, Sp, Sf. Good to excellent reservoir quality (high intergranular porosity and permeability)	OK	Sw, SMw, Scl, QSc. Good to excellent reservoir quality (high intergranular porosity and permeability)	OK	St, Sp, Sf, Sb. Good to excellent reservoir quality (high porosity and permeability)	OK	Sw, SMw, Scl, QSc. Good to excellent reservoir quality (high porosity and permeability)	OK

[CONCLUSIONS]

Based on preliminary observations, there exist possible sources of carbon dioxide (CO_2) in the vicinity of the Asri basin, spanning a distance of around 100 to 300 kilometers. These sources collectively contribute to a cumulative emission of approximately 76.41 million metric tons of CO_2. If carbon dioxide (CO_2) is to be transferred by maritime vessels, the process of collecting CO_2 will occur at specified stations located along the nearest coastline areas next to Asri. In the Sumatra region, carbon dioxide (CO_2) will be extracted through a pipeline positioned at the Tarahan station, while in the Java region, CO_2 will be acquired utilizing an existing pipeline located at the Cilegon station. Hence, the chosen vessel have the capacity to efficiently capture carbon dioxide at specified locations and afterwards carry it to Pabelokan. As a result, carbon dioxide (CO_2) will be conveyed through the existing pipeline infrastructure to the Harriet facility. Moreover, to consider the economic dimension, there exist several alternative options for the transportation of carbon dioxide to the specified area of Harriet.

Furthermore, the subsurface analysis of Widuri A-05 in the Zelda Interval reveals the presence of zones characterized by advantageous thickness and good quality, hence facilitating a high injection rate. In order to assure the effectiveness of CO_2 injection, it is advisable to have a thickness of the injection zone that surpasses 164 feet.

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