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CCUS-EOR Optimization to Achieve Zero Emission Program Targets in Northwest Java Basin

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Abstract: The presence of oil and gas production fields, oil refineries, cement plants, and coal-fired power plants situated close to each other supports the program for zero CO_2 emissions through Carbon Capture, Utilization, and Storage (CCUS) for Enhanced Oil Recovery (EOR). This study aims to investigate the potential of depleted fields in the North West Java Basin as the target for CCUS-EOR in fulfilling the zero CO_2 emission program and boosting oil production. The study uses oil and gas field data to evaluate the CCUS potential both qualitatively and quantitatively. The Geographic Information System was applied through a clustering method with a 50 km and 100 km buffer from CO_2 emission sources. The calculation of CO_2 for EOR purposes with a 50 km buffer radius is 287.504 million tons, which could result in a 575.009 million stock tank barrel (STB) increase in oil production in the case of immiscible injection and 379.506 million tons for an increase of about 1.150 billion STB of oil production in the case of miscible injection. For a 100 km buffer radius, 632.541 million tons of CO_2 is required to increase 1.265 billion STB of oil production in the case of immiscible injection and 834.955 million tons of CO_2 for an increase of 2.530 billion STB of oil production in the case of miscible injection. These results are expected to be implemented as part of the program to reach the goal of producing 1 million barrels of oil per day by 2030 and achieving net zero emissions by 2060.

Keywords: CCUS, EOR, carbon dioxide, oil refinery, power plant, cement industry.

1. Introduction

Carbon capture utilization and storage (CCUS) is the process to capture and purify carbon dioxide (CO_2) from large-point industrial CO_2 sources, such as coal power plants, gas processing plants, and other industrial plants for storage and/or industrial utilization[1,2]. The primary process of CCUS includes capture, transportation, storage and utilization CO_2[2]. In oil and gas industry, enhanced oil recovery (EOR) is a technique of oil production through injection of materials not normally present in petroleum reservoirs[3]. This EOR is often also called tertiary recovery since it is considered as the third stage of oil production. Such a term was attained after secondary recovery (such as water flooding), and primary production, the initial stage resulted from displacement energy naturally existing in a reservoir[4]. The application of CCUS has been carried out widely around the world. CCUS is one of the zero CO_2 emissions programs to reduce greenhouse gas (GHG). An Exemplary CCUS program has been developed by The U.S. Department of Energy (DOE), Office of Fossil Energy (FE), and National Energy Technology Laboratory (NETL) since 1997 and has securely stored more than 10.5 million metric tons (MMT) of CO_2[5].

The CCUS–EOR is capture CO_2 for reducing CO_2 and then storing CO_2 in oil reservoirs to enhance oil production in the tertiary stage[6]. Utilization of CO_2 for enhanced oil recovery (CO_2 EOR) is one technology being considered to provide a positive business for CCS owing to its economic profitability from incremental oil production offsetting the cost of carbon capture storage (CCS). CO_2 EOR has been proven effective for increasing

oil production substantially while a consistent amount of CO_2 injected is stored permanently at the same time[7,8]. Approximately 40% of the injected CO_2 remains trapped in the reservoirs during the CO_2 EOR operations. Additional recovery can amount to 5% - 20% of the original oil in place (OOIP) depending on the characteristics of the hydrocarbon and the reservoir conformance[9]. Application of CO_2 EOR becomes a key drive for CCS in many parts of the world, particularly in the US and Canada[10,11]. The CCUS-EOR program has been carried out in Mexico by implementing a CO_2-EOR pilot project at the Cinco Presidentes oilfield[12]. The project confirm that CCUS technology is secure and can be applied in oil and gas fields safely.

Indonesia has committed to achieving net zero emissions by 2060. To support this program, a pilot project for CO_2-EOR will be carried out at the Sukowati oil and gas field, East Java, in which a detailed study of the field conditions has been carried out[13,14]. The CO_2 emission sources may come from nearby chemical plants and natural gas processing, paper mills, power plants, refineries, cement plants, and iron and steel plants[15]. Additional CO_2 emission source could also originate from gas fields, which act as impurities. To reduce CO_2 emissions into the atmosphere, it is therefore necessary to capture CO_2 to be stored in the earth and or used for other purposes such as fuels, chemicals, building materials from minerals, building materials from waste, and CO_2 use to enhance the yields of biological processes. It is estimated that the market needs for these five categories may reach 10 $MTCO_2$ per year. These needs are almost the same as the need for CO_2 for food and beverage purposes[16,17]. The need for CO_2 is nevertheless small compared to its emissions that reached 34,344,006 $MTCO_2$ worldwide and around 619,840 $MTCO_2$ for Indonesia in 2019[18].

Various efforts should be conducted to prevent and control CO_2 emissions. It is conceptually straightforward, but such an implementation requires a detailed study. These are due to oil and gas industry activities, steel industry, cement, LNG, and the transportation sectors are fundamentally needed, but yet still producing CO_2 emissions. Since 1980 several countries, such as the United States, Britain, France, and Norway, have begun to conduct studies on combating CO_2 emissions. An important stage of controlling CO_2 emissions is through the CCS program. The detailed stages of the CCS program include: (1) CO_2 is captured directly from the sources (industry, refineries, cement, LNG, and others). The CO_2 can be captured by using absorption, adsorption, membrane separation, cryogenic separation process and also directly capture CO_2 from flue gases[19,20]. The capture of CO_2 from flue gases is based on the use of CaO particles as sorbent in circulating fluidized-bed (CFB) reactors[21]. (2) Transport of CO_2 by compressing it into the liquid so that it will be economically transported to the appropriate storage areas. The transportation process can be through pipelines, ships, or a combination of both. (3) CO_2 storage can be injected into depleted/mature oil or gas reservoirs[22]. The proven model has been built for CCUS-EOR from the CO_2 sources to EOR fields within the cluster model within radial distances of 100 km, 200 km, and/or the maximum straight distance of 300 km[23–25]. The cluster model can promote greater efficiencies in the planning and construction of capital-intensive transport and storage infrastructure[26].

Despite reasonable efforts have been performed in those studies, limited amount of research dedicated specifically to evaluate potential deployment sites for CCUS projects and application of CCUS technologies in Indonesia has been found. Such adequate research and development efforts are crucial to understanding the Indonesian specific challenges, opportunities, and potential deployment sites for CCUS projects.

An analysis of depleted fields was therefore carried out to assess the potential CCUS-EOR from CO_2 sources in the North West Java Basin, Java Island, Indonesia within the radius of 50 km and 100 km. The area covers several industrial activities with high emissions, such as Indramayu power plant, Cirebon power plant, Balongan oil refinery, and Indo-cement factory. This study aims to examine the potential of depleted fields in the North West Java basin as the target for CCUS-EOR in achieving the zero CO_2 emission program and increasing oil production in the North West Java Basin. The advantage of implementing CCUS in the oil and gas fields is that subsurface conditions have been identified clearly on well log data and their volumes can be calculated from the oil and gas that have been produced. The increase in oil production at the tertiary stage needs a fluid injection, one of which is by CO_2 injection with high pressure. It is expected that by having CO_2 injection into oil fields through the CCUS-EOR program, a nearly close CO_2 cycle of those factories, refineries, coal-fired power plants and other industrial activities could be realized. Such a need for EOR technology implementation is necessary as most oil fields in Indonesia are already in depleted stage.[23]. This case is particularly appropriate as the North West Java Basin has about 153 oil and gas fields from two working areas and has larges potential for CCUS-EOR[27].

2. Materials and Methods

2.1 Study area

The research location is in the North West Java basin located to the north or back of the Java Volcano Arc, so it is currently known as the back-arc basin. The basin is bordered by the Thousand Platforms in the west, the Sunda Basin in the northwest, and the Vera Basin in the north (**Fig. 1**). While the northeastern part is bordered with the Vera Basin and Karimunjava Arc, the North West Java basin shares a border to the east with the North Central Java Basin, and to the south with the Bogor Basin bounded by the Baribis Fault. The North West Java Basin has an area of 23,340 km^2, and its sediment thickness is between

2,000–4,500 m, with deposits thickening to the south of the basin[28]. The North West Java basin confirmed to be an oil and gas producing basin with about 65 fields situated on the land and 88 fields at sea[29].

The main source rocks in this basin are deltaic carbonaceous shales and coals in the upper Talangakar formation deposited in a late syn-rift–post-rift tectonic setting occurred in the late Oligocene stage[30]. Oil and gas exploration activities in this basin have discovered a large deposit of oil and gas, especially in the anticline structures. The main oil and gas producing layers are sandstone from the Talangakar and Cibulakan Formations and limestone from the Baturaja and Parigi Formations. In this basin, oil has also been produced from volcanic tuff rock and breccia from the Jatibarang formation[31]. Drilling of oil and gas wells are mostly carried out in the structures near the faults areas where the main line of hydrocarbon migration took place[32].

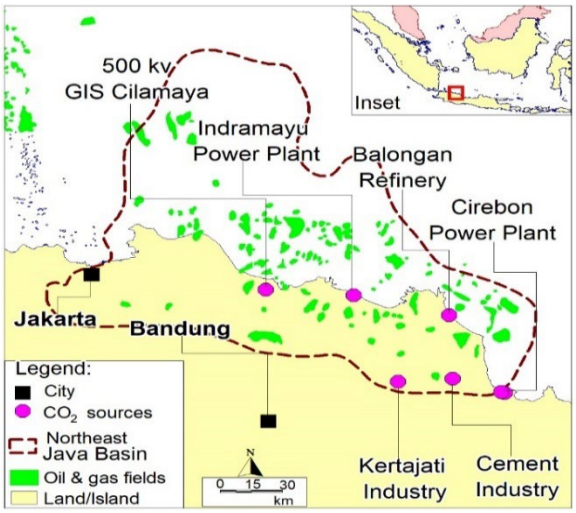

Fig. 1: The potential CCUS-EOR program in depleted oil and gas fields, Northwest Java Basin.

2.2 CO_2 emission sources

2.2.1 Oil refinery

The existing oil refinery in this basin area is Balongan oil refinery, which was built through the export-oriented refinery I (EXOR-1) project that began in 1990[33]. The Balongan oil refinery, which operated in 1994, is the 6th of seven refineries built by Pertamina to process crude oil into fuel, non-fuel, and petrochemical products. The products of the refinery include various gasoline products (premium RON 88, pertamax RON 92, pertamax plus), various automotive diesel oil (diesel oil CN 48, pertamina dex-diesel oil CN51), kerosene, LPG, and propylene. The raw materials of this refinery are crude oils from Duri and Minas fields[34]. In addition to those crude oils, this refinery also receives the crudes Jatibarang, Cinta, Banyu urip, and surrounding oil fields[35]. Oil refineries generally produce waste and pollutants that have adverse impact to the environment, such as carbon monoxide (CO) gas, CO_2 gas, sulfur oxide gas (SO_2), ammonia (NH_3) and water vapor[36]. CO_2 emissions produced at the Balongan refinery originate from various process units such as boilers, heaters, flares, and others[37]. However, through the production process of residue catalytic cracking (RCC) it was able to reduce emissions of 84,900 CO_2 eq per year[38]. The total CO_2-equivalent (CO_2-e) emissions produced at the Balongan refinery in 2013 were around 1,753,255.01 tons and went down in 2017 to 732,139.20 tons[37].

2.2.2 Coal-fired power plant

Two coal-fired power plants, the Indramayu power plant and the Cirebon power plant, have been developed in the North West Java basin. The Indramayu power plant began its construction in 2013 and is commercially operated in August 2018[39]. The plant's rated capacity is 990 MWe with an operating hour of about 1,008 hours. Its CO_2 emissions with bituminous coal fuel is thus estimated at 6,953.1 Ktons[40]. Cirebon coal fired power plant meanwhile, comprises of two units, the Cirebon 1 with a capacity of 660 MW that has been operating since 2012 and the Cirebon 2 with a capacity of 1000 MW, which is planned to operate in 2022. The two units of power plant in Cirebon employ ultra-super-critical (USC) technology, which is considered as a clean coal technology (CCT) technology Such a technology may reduce CO_2 emissions and could achieve coal consumption efficiency by around 36%-42%[41]. Wahid et al calculated that the USC coal fired power plant generated net power of 22 MW with the amount of raw materials 20 ton/h coal feed[42]. The Cirebon coal-fired power plant thus produces CO_2 emissions of less than 1.00 kg of CO_2eq/KWh[43]. The CO_2 emission of Indramayu and Cirebon power plants are correspondingly lower than the average CO_2 emission of power plants in Indonesia, which was at 1.140 kg/kwh in 2019[44].

2.2.3 Oil and Gas Fields

Sources of CO_2 in the subsurface may come from mantle degassing, reactions (metamorphic and diagenetic) carbonates, and coal catagenesis. Geological factors influence the evaporation, concentration and presence of CO_2 below the earth's surface[45]. In the North West Java basin, especially in the Tugu Barat-C field, CO_2 is estimated to be generated from the decarboxylation of coal aged upper Oligocene-early Miocene Talangakar Formation. CO_2 is also derived from the dissolution of carbonate reservoirs of Baturaja by formation water[46]. Results of the analysis indicated that the total feeds entering from oil and gas wells contains CO_2 around 7.32%[47]. Furthermore, some oil and gas field structures in the Northwest Java Basin are sources of CO_2 that should be included in the zero emission programs (**Table 1**).

2.2.4 Cement Industry

The existing cement industry is part of the Indo-cement Tunggal Prakasa company located in Palimanan. This company is a cement industry holding consisting of eight

factories established in 1985, two of which are situated in the North West Java basin, in Palimanan Cirebon district, West Java. Cement industries during its production process is estimated to emit a total of CO_2 emissions of around 5–7% and considerable energy consumption up to 15% of the Indonesia total industry CO_2 emission and energy consumption. Another source of CO_2 emissions from cement plants is cement bag waste[48]. This is still recurring in spite of the considerable effort has been put in place in the carbon management improvement on its supply chains process to improvement[49]. In addition to the CO_2 emission from the use of coal and carbonaceous fuel as its energy source, the cement industry also emits CO_2 from its various process stages of calcination of raw materials, CO_2 from electricity consumption, transportation, and lighting. CO_2 emissions due to the cement and ceramics industry in 2007 were estimated at 12.16 million tons. Indo-cement is currently implementing a clean development mechanism (CDM) project to reduce CO_2 emissions afterward[50].

2.3 Analysis of CO_2 sources and depleted oil & gas fields

This research is the initial stage of the CCUS-EOR study, which focuses on identifying and calculating the oil and gas field capacities in the North West Basin that potentially serve as storage for EOR. The sources of CO_2 studied are coal-fired power plants, cement and oil refineries industries, and oil and gas fields that produce CO_2 by-products as impurities. In the next stage, clustering was carried out to map the closest oil and gas fields to CO_2 sources, namely power plants, Balongan refinery and cement industry. Clustering is carried out based on distances (50 km and 100 km) with the CO_2 sources as the central points. Simulation for clustering utilized geographical information system software. The clustering method is carried out in a narrow geographical location to make infrastructure planning cheaper and easier. The other consideration is that cluster development can be linked to high concentrations of CO_2-producing industries and the closest capacity to store CO_2 in the depleted oil fields[11]. The original oil in place (OOIP) of fields in the Northwest Java Basin is obtained from the Ministry of Energy and Mineral Resources (MEMR) of the Republic of Indonesia and The Special Task Force for Upstream Oil and Gas Business Activities (SKK Migas) through Research Centre for Oil and Gas Technology "LEMIGAS".

This study was carried out to calculate the ability of oil fields that may not only be used for storage CO_2 (CCS), but also suitable for CCUS-EOR implementation. The calculations of the oil field capabilities make use of oil-in-place data in each cluster at a buffer of 50 km and 100 km from the CO_2 sources. Within 50 km buffer, there are about 147 oil fields, and within 100 km buffer, there are 339 oil fields that have the potential for CCUS-CO_2 injection. The method for CO_2-EOR for predicting CO_2 requirement and incremental oil recovery is presented in **Table 2**. There are two cases of CO_2-EOR injection, namely miscible and immiscible. In the case of miscible injection, it can increase the recovery factor of oil by up to 12% with a CO_2 requirement of around 0.33 tons per incremental STB. Meanwhile, in the case of immiscible injection, it can increase the recovery factor of oil by 5% with CO_2 required of around 0.5 tons per incremental stock tank barrel (STB).

Table 1. Oil fields in the North West Java basin that has the potential to be a source of CO_2[51].

No.	Fields	CO_2	Average-CO_2 Prod.	Potency of CO_2	Prod. Cum. of CO_2
		% Mol	MMSCF/D	BSCF	BSCF
1	Subang	22.43	32.7	132.4	174.41
2	Melandong	61.66	5.42	15.03	7.83
3	Karangenggal	94.13	5.35	29.74	6.13
4	Jadibarang	27.39	2.91	10.43	71.4
5	Karang Baru	39.50	2.2	4.66	7.74
6	Randegan	69.54	1.96	7.57	24.01
7	Cilamaya Utara	36.95	1.78	11.11	32.59
8	Cemara	18.84	1.63	17.79	14.08
9	Tambun	7.07	1.4	0.03	0.02
10	Pegaden	13.56	0.45	5.9	10.83
11	Gantar	44.15	0.43	21.28	54.2
12	Pondok Tengah	26.98	0.39	0.45	0.02
13	L-Parigi	0.18	0.1	0.17	3.06
14	Bojongroang	4.22	0.08	0.28	0.53
15	X-Ray	3.02	0.07	0.11	0.33
16	Cilamaya Timur	12.58	0.05	0.57	0.54
17	Sindang	4.56	0.04	1.48	1.6
18	Sindang Turun	4.56	0.02	0.04	0.22
19	Karangbaru Barat	31.28		0.21	0.02
20	Karang Tunggal	27.72		2.59	
21	Jatikeling	13.64		0.45	0.13
22	Pasir Catang	30.41		2.35	0.08
23	Haurgeulis	73.00		0.08	
24	Tunggulmaung	6.60		7.22	

Table 2. The Assumption of CO_2 consumption and recovery factor of oil.

CO_2-EOR Recovery Factor, %OOIP		CO_2 Requirement Ton/STB	
Miscible	Immiscible	Miscible	Immiscible
12%	6%	0.33	0.5

This clustering system is carried out to facilitate subsequent studies in the analysis of transporting CO_2 using pipeline from sources to the depleted oil and gas fields to achieve a zero CO_2 emission scenario. However, this study is only limited to clustering from CO_2 sources to oil and gas fields as preliminary comprehensive information.

3. Results and Discussion

CO_2 sources in the North West Java basin have been linked to develop a clustering model for the application of CCUS-EOR in oil fields. The purpose of this clustering is to achieve cost efficiency by using CO_2 waste from the Indramayu power plant, Cirebon power plant, Balongan oil refinery, and cement industry and injecting it into nearby oil fields. To optimize the CO_2 separation process, it can be carried out in the flue gas, where CO_2 is captured using an adsorbent,[52] and subsequently distributed directly to the oil and gas fields for CCUS. The clustering results of these four CO_2 sources for CCUS are presented in **Fig. 2.**

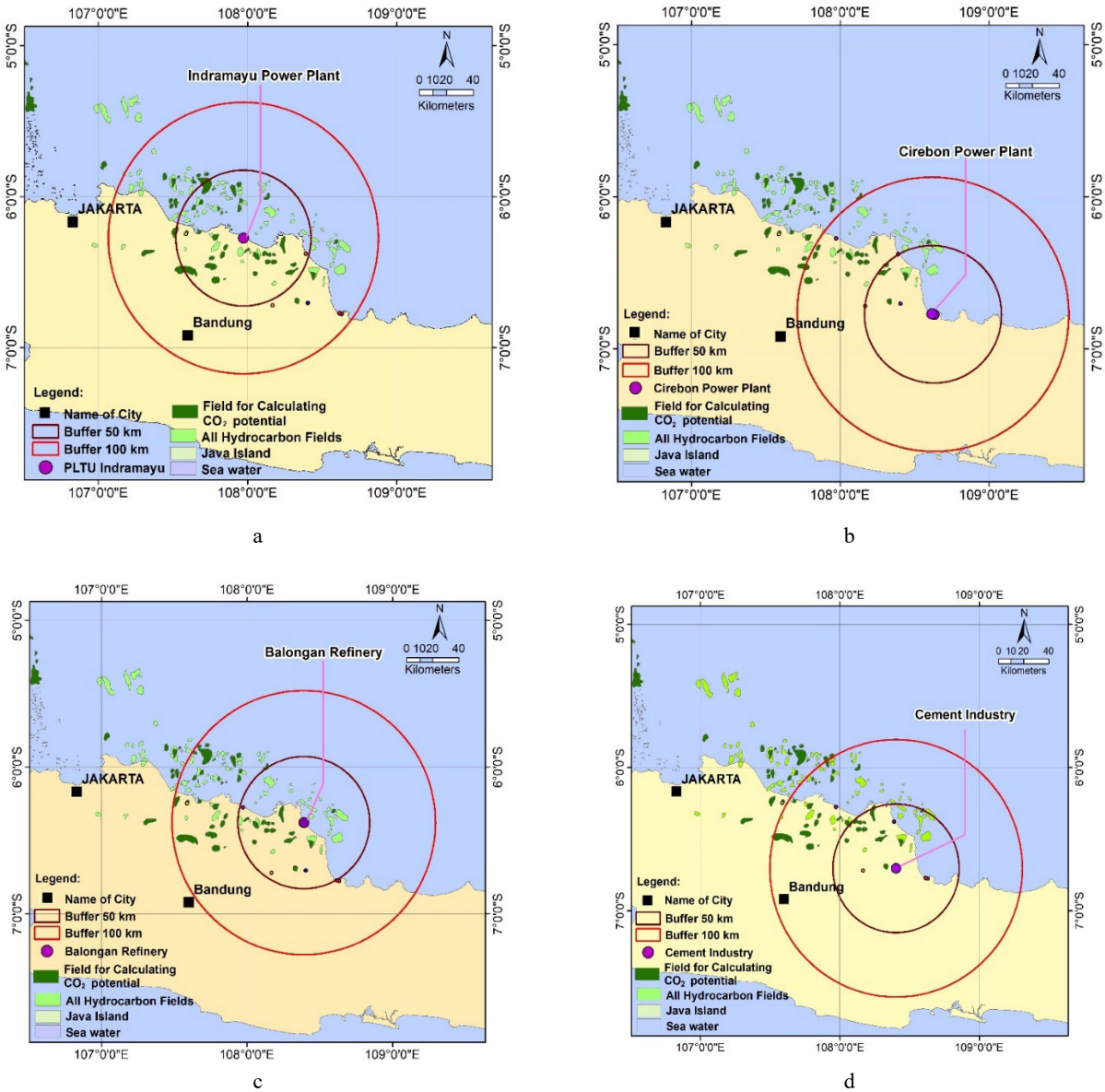

Fig. 2: Clustering sources CO_2 against oil and gas fields. a) Indramayu power plant as CO_2 sources, b) Cirebon power plant as CO_2 sources, c) Balongan Refinery as CO_2 sources, and d) Cement industry as CO_2 sources.

Indramayu power plant is situated in the middle of the Northwest Java basin so that the clustering system at the source of CO_2 emissions is ideal and relatively easy. This is because the power plant is surrounded by depleted oil and gas fields (**Fig. 2a**). The results of the buffer analysis with 50 km radius found 74 oil and gas fields, while in the 100 km buffer, 122 oil and gas fields were obtained. Clustering analysis for Cirebon power plant as CO_2 sources with a buffer of 50 km extension, discovers 9 oil and gas fields. Increasing the cluster buffer zone up to 100

km discovers 44 oil and gas fields. The Cirebon power plant is located on the edge of the eastern Northwest Java basin (**Fig. 2b**). Balongan oil refinery is in the south of Indramayu City and is on the shoreline of the Java Sea facing to the east. Surrounding this refinery are several oil and gas fields, such as the Jatibarang, Sindang, and Waled. The results of the 50 km buffer analysis identified 41 oil and gas fields, while the 100 km buffer found 98 oil and gas fields (**Fig. 2c**). *Cement industry* is located on the edge of the southern Northwest Java Basin. Clustering analysis from this industry with a buffer of 50 km resulted in a total of 23 oil and gas fields, while clustering within 100 km buffer reveals 75 oil and gas fields (**Fig. 2d**). Detailed results on the calculation of oil improvement by injecting CO_2 EOR and CO_2 requirement for each cluster are depicted in **Table 3**. Calculated CO_2 requirement and improvement in oil recovery follow two scenarios, miscible and immiscible cases at 50 km and 100 km radius buffer.

Table 3. The Incremental oil recovery and CO_2 requirement. The figures are estimated CO_2-EOR oil incremental gains in thousand stock tank barrel (MSTB) as the results of injected CO_2 following ton/STB ratios under immiscible and miscible schemes.

CO_2Sources	CCUS Calculation											
	50 km Radius Buffer						100 km Radius Buffer					
	No. of Fields	OOIP	Immiscible Case		Miscible Case		No. of Fields	OOIP	Immiscible Case		Miscible Case	
			EOR (6%)	CO_2 (0.5)	EOR (12%)	CO_2 (O.33)			EOR (6%)	CO_2 (0.5)	EOR (12%)	CO_2 (O.33)
Indramayu Power Plant	74	4,576,198	274,572	137,286	549,144	181,217	122	8,316,181	498,971	249,485	997,942	329,321
Balongan Refinery	41	2,547,684	152,861	76,431	305,722	100,888	98	5,666,460	339,988	169,994	679,975	224,392
Cirebon Power Plant	9	982,266	58,936	29,468	117,872	38,898	44	2,291,658	137,499	68,750	274,999	90,750
Cement Industry	23	1,477,329	88,640	44,320	177,280	58,502	75	4,810,412	288,625	144,312	577,249	190,492

Note: OOIP, EOR in thousand STB; while CO_2 in thousand tons

It has been shown in Table 3 that the Indramayu power plant cluster has the potential to increase oil production by approximately 549.144 million standard barrels and would require around 181.217 million tons of CO_2 at a 50 km buffer. At a 100 km buffer, it could increase oil production by approximately 997.942 million standard barrels, but it would require CO_2 injection of around 329.321 million tons.

The Cirebon power plant cluster could potentially increase oil production by approximately 117.872 million standard barrels and would require around 38.898 million tons of CO_2 at a 50 km buffer. At a 100 km buffer, it offers an increase in oil production by approximately 274.999 million standard barrels with CO_2 injection of around 90.750 million tons.

On the other hand, the Balongan refinery cluster has a prospective increase in oil production of around 305.772 million standard barrels and would require 100.888 million tons of CO_2 at a 50 km buffer. At a 100 km buffer, it could increase oil production by approximately 679.975 million standard barrels, but it would need CO_2 injection of around 224.392 million tons.

Meanwhile, the cement industry cluster in the southern part of this region is expected to increase oil production by 177.280 million standard barrels and would require around 58.502 million tons of CO_2 at a 50 km buffer. At a 100 km buffer, it could increase oil production by approximately 577.249 million standard barrels, but it would require more CO_2 injection of around 190.492 million tons. These efforts are expected to be implemented as part of the program to reach the goal of producing 1 million barrels of oil per day by 2030 and achieving net zero emissions by 2060.

Hence, the CCUS-EOR in general offers efficient storage potential and as a means for increasing oil production. This condition is also considered more profitable in terms of financing than having CCS only. Presence of the CCUS-EOR may, in the future allow for CO_2 buying and selling transactions that have been captured to be utilized in EOR[53]. This is evident as 38 large-scale CCS and CCUS projects in 2016 are in the process of being implemented[54]. CO_2 storage in the depleted field is generally considered as a cost-efficient measure and can serve for EOR activities. However, the amount of oil and gas field capacity is relatively limited, which suggests other options are needed to store CO_2. Therefore, if the depleted field in the Northwest Java basin are no longer able to accommodate CO_2, it can be stored in saline aquifers[55] or in coal seams[56]. Research R&D Center for Oil and Gas Technology "LEMIGAS" - The World Bank shows that the potential for saline aquifers in the Northwest Java basin is around 4,937 million tons CO_2[57]. This potential makes it serve as considerable buffer to the need for CO_2 storage in the North West Java basin. This role will even be more critical with the development of the Kertajati industrial area, the Java 1

CCPP (Combined-cycle power plant) gas power plant (500kV Gas-Insulated high-voltage switchgear/GIS Cilamaya) and other industrial estates in the region.

Estimation of the CO2 storage capacity of depleted oil and gas fields in Northwest Java Basin has underlined the potential economic values in the future. Albeit being abandoned as the reservoirs have reached – or are approaching – their economic limit, as current practices dictate, they may prove themselves as still possessing economic values. However, it should be underlined that estimations carried out following the radial distances shown in Fig. 2 are not synchronized in CO2 quantities and the resulting EOR gains for the overlapping circles around the four CO2 sources. The estimates presented in Table 3 are stand-alone in nature, and attempts to synchronize among the source–sink circumferences lead certainly to lower CO2 storage capacity to the four CO2 sources and the resulting quantities of CO2-EOR oil gains, both immiscible and miscible schemes. Nevertheless, these estimates are not essentially meant to present the exact potentials and capacities involved. Instead, they serve more to provide an example of CCS/CCUS potentials in one of the sedimentary basins in Indonesia. Review and evaluations over CO2 source-sink for other cases related to other sedimentary basins are expected to follow suit.

4. Conclusions

The North West Java basin has multiple sources of CO_2 emissions, including-oil refineries, power plants, various industries, and other carbon emission sources. The proposed clustering model with Geographic Information System for the application of CCUS-EOR in oil fields with a 50 km and 100 km buffer from CO_2 emission sources situated at the North West Java basin has been shown to be effective to achieve a cost-efficient CO_2 sequestering. Those emission sources are from the Indramayu power plant, Cirebon power plant, Balongan oil refinery, and cement industry.

The CO_2 produced from four sources in the region can also enhance the potential of the carbon economy through incremental oil production by CO_2-EOR activities, both in immiscible and miscible schemes. With an assumption of 6% and 12% incremental CO_2-EOR recovery through immiscible and miscible schemes, respectively, within a radius of 50 km, all depleted oil fields can absorb between 287 and 380 million tons of CO_2 to yield between 575 and 1,150 million stock tank barrels (MMSTB). In the area within 100 km radial distance around the CO_2 sources, all depleted oil fields can absorb between 633 – 835 million tons of CO_2 to yield 1,265 – 2,530 MMSTB incremental oil. These figures, however, are stand-alone figures that are not synchronized with overlapping areas of the four CO_2 sources. Nevertheless, this study can estimate CO_2 storage potential and its conceptual oil production gains through CO_2-EOR in the Northwest Java Basin.

It is also important to note that this study is only a preliminary analysis, and further detailed studies, including laboratory analyses, reservoir simulation studies, and pilot-scale CO_2-EOR injection implementation plans, should be carried out before full-scale implementation.

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Nomenclature

CCUS	Carbon Capture Utilization and Storage
EOR	Enhanced Oil Recovery
GHG	Green House Gas
CDM	Clean Development Mechanism
CCPP	Combined-Cycle Power Plant
GIS	Gas-Insulated High-Voltage Switchgear
OOIP	Original Oil in Place

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