UNDERSTANDING CARBON CAPTURE AND STORAGE (CCS) POTENTIAL IN INDONESIA

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ABSTRACT

National energy policy drawn up by the government through Energy Mix Target 2025 (Presidential Regulation No.5/2006) is still dominated by fossil fuel. Moreover, it is coupled with high dependence on fossil fuel, increasing demand of energy and standard of living and high rate population growth, it can turn Indonesia into one of the biggest emitter in the future. On 2009, the government has pledged a non-binding commitment to reduce country emissions by 26% in 2020.

This aspiring target requires great efforts besides reliying on current strategies such as energy mix improvements, the switch to less-carbon intensive fuels and renewable resources deployment as well as conservation.

Carbon Capture and Storage (CCS) is one of the climate change mitigation tools with the technological capability to reduce CO_2 in substantial amount and deep cut particularly on energy sector. CCS is typically defined as the integrated process of CO_2 separation at industrial plants, transportation to storage sites and injection into subsurface formations.

This paper explains the possibility of CCS potential deployment in Indonesia by reviewing required components and provides comprehensive understanding in each CCS key lements.

Key words: *Carbon Capture and Storage (CCS), mitigation technology, CO_2 abatement*

I. INTRODUCTION

The main composition in Energy Mix Target by 2025 conoixts mainly of natural gas, oil and coal in which has some improvements by reducing oil dependency, increasing the role of renewable energy, and reducing energy elasticity to below one. However, projected CO_2 emissions generated from this policy is still grows since introduction of large scale low carbon technologies were not entered yet into the national energy path.

CO_2 emissions equivalent from energy sector is accounted for 9% (275 $MtCO_2e$) from total country emissions or the second largest emitter after forestry, with average growth of around 6.6% per-year from 1990 to 2005 (CCS WG, 2009). The main contributors to those emissions particularly were industries, power generations and transportations.

Although for Indonesia it is not mandatory to reduce its country emissions but the government has pledged to achieve a non-binding commitment to reduce country emissions by 26% in 2020 and this target would increase to 41% if international financing is available. To respond this commitment the government ratified Environmental Law No.32/2009 which rules about the protection and management of the environment and entered preservation of function within the atmosphere of adaptation and mitigation to climate change.

There is no single solution that will limit CO_2 emissions, given the rising demand for energy and the world's continued reliance on fossil fuels. Current government efforts such as energy mix improvements, the switch to less-carbon intensive fuels and renewable resources deployment are considered still

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insufficient to achieve CO_2 emissions abatement target in 2020. Therefore, correspond to government's target Carbon Capture and Storage (CCS) offers great potential for reducing CO_2 emissions from large point source emitters, such as coal-fired power plants and oil and gas processing plants in Indonesia.

CCS systematically comprised three sequential activities ranging from capturing the CO_2 from the sources, then transporting it to the storage sites and eventually injecting the CO_2 into the geological formation.

II. CO_2 SOURCES IN INDONESIA

There are multiple industrial sources of CO_2 in Indonesia, from power stations, oil and gas processing plants, steel and ammonia plants and cement factories. Scouting work has revealed that most industrial sources are located in Jawa and Sumatra, and to a lesser extent in Kalimantan and Sulawesi. Hence, these islands (high graded areas of interest) will be the focus for further CCS deployment.

Total industry generated CO_2 emissions from power generation flue gas and gas processing are estimated to about 80 million tonnes per annum, of which oil and gas processing is responsible for about 17.5 tonnes per annum. The power generation sector is expected to be the main contributor to future CO_2 emissions in Indonesia

III. CO_2 CAPTURE TECHNOLOGY

Capture involves separating the CO_2 from the other components of a gas stream; the gas stream may be the products of combustion or the fuel gas before combustion. Many separation techniques can be used nowadays such as solvent absorption, solid adsorption, semi-permeable membranes and cryogenic cooling.

The separation techniques mentioned above may be applied in various ways into a capture system either in power plants or industrial plants. The main options are:

- Post-combustion: CO_2 in flue gas from normal combustion then is separated using available separation techniques.
- Pre-combustion: CO_2 generated from gasification is separated prior fuel combustion process begins.
- Modified combustion: usually refer to oxyfuel combustion in which fuel is combusted using high purity O_2 resulting in high CO_2 concentrations in the gas stream.

There are two options in integrating the capture system into existing power plant:

- Retrofit: adding some equipment without any major changes.
- Rebuild: reconstruction of power plant that involving significant changes.

Sufficient space is required to rebuild or retrofit the existing power plant. The consequences of equipping CO_2 capture systems on the power plants are the increase in capital costs and energy requirements. As a result the cost per kWh of electricity generated is also rising and lowering the output of the generator.

IV. CO_2 TRANSPORTATION TECHNOLOGY

Having captured the CO_2, the next step in the CCS chain is to transport it to the storage site. This needs to be done at the lowest cost and with the greatest confidence for safe delivery of the CO_2. Various options are available for transporting CO_2 including road tankers, rail tankers, pipelines and ship tankers in which each will have its particular niche in the market place. The key parameters for assessing transport options are quantity, distance, the nature of the terrain and location (onshore or offshore).

V. CO_2 STORAGE ON GEOLOGICAL FORMATION

CO_2 occurs naturally in sedimentary basins around the world and hydrocarbons are often found in association with CO_2 for example, Natuna D Alpha gas field in Indonesia and Sliepner gas field in the Norwegian North Sea. Hence there is a wealth of geological evidence that CO_2; is naturally stored for millions of years in the subsurface. Thus storing undertaking CCS activities in sedimentary basins can be regarded as mimicking the natural system.

CO_2 storage is generally expected to take place at depths below 800m, where the ambient pressures and temperatures will result in CO_2 being in a liquid or supercritical state. This supercritical state (temperature = 31.1°C and pressure = 72.9 atm) yields rather uncommon properties. It can adopt properties midway between a gas and a liquid. Under these conditions, the density of CO_2 will range from 50 to

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80% of the density of water. This is also close to the density of some crude oils. Being in dense form, CO_2 storage in geological formations provides the potential for efficient utilisation of underground storage space in the pores of sedimentary rocks. Moreover several storage mechanisms also occur in geological formations, consequently enhancing the overall storage capacity.

There are two major storage mechanisms that will operate to keep CO_2 retained underground - physical and geochemical trapping. These two trapping mechanisms consist of specific mechanisms that could either act essentially alone or in combination. The effectiveness of geological storage is determined by the overall combination of physical and geochemical trapping mechanisms. Physical trapping is usually described by the existence of physical barriers to prevent CO_2 migrating upward. The geochemical mechanism is the formation of ionic species as the rock dissolves, accompanied by a rise in pH (IPCC, 2005), resulting in some fraction being converted to stable carbonate minerals.

Currently, depleted oil and gas reservoirs, saline formations (also referred to as deep saline aquifers), and coal seams are considered the most prospective geological formations for CO_2 storage.

A. Depleted Oil and Gas Reservoirs

The potential utilisation of depleted oil and gas fields for CO_2 storage has a number of advantages:

- Reduce the exploration cost to find new sites
- Higher data density due to exploration and production data – including computer models that have been developed to predict the CO_2 movement, displacement behaviour and trapping of hydrocarbons
- Existing infrastructure can be reused.
- These reservoirs are proven traps known to have kept liquids and gasses for million years.

A range of factors affect the containment security of a depleted field. The main issues are associated with the integrity of old wells, the fault and fracture regime and the caprock. The presence of wells penetrating the subsurface in mature sedimentary basins can create potential CO_2 leakage pathways that might compromise the security of a storage site. CO_2 storage in depleted oil and gas reservoirs cannot be assumed that the depleted fields can hold a similar volume of CO_2 compared to hydrocarbons. The CO_2 storage capacity from depleted fields has to be carefully estimated based on the new geomechanical regime created during the production of hydrocarbons and also be limited by the need to avoid exceeding pressures that damage the caprock.

Due the long exploration and production history within Indonesia, there are many depleted oil and gas fields options for potential CCS. Substantial oil and gas exploration activities have taken place in Sumatra, Kalimantan and Jawa. Some oil and gas fields in these regions have reached their mature production stage and many of them are depleted. The future capacity of CO_2 storage will increase in time as more fields are depleted.

B. Saline Aquifer

The second type of CCS storage option considered suitable to sequester CO_2 is saline formations or deep saline aquifers. Saline formations are deep sedimentary rocks filled with brines containing high concentrations of dissolved salts, which makes them unsuitable for potable water or for agricultural use (IPCC, 2005).

Compared with depleted or depleting hydrocarbon fields, saline formations have a number of potential advantages and disadvantages associated with their use for CCS:

- Containment risk low
- Few puncture points (old wells) in the caprock
- No additional costs to assess integrity of old wells
- Data density lower – may require a higher number of appraisal wells compared with depleted field option
- The estimates of potential storage volume are lower – to what extent the aquifer pore volume can be filled with CO_2
- 3D seismic less likely to be available, therefore higher appraisal costs.

At the moment, deep saline aquifer is predicted to be identified in Natuna region. However, there has been no detailed study to identify saline aquifer storage opportunities in Indonesia presently. The capacity and its distribution still remain questioned.

C. Coal Seams (ECBM)

Another potential storage option is unminable coal seams, which can be commercially exploited by Coal Bed Methane (CBM) production. Coal seams often

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contain methane that is adsorbed in the coal matrix and in the cleats. By injecting CO_2 on produced CBM wells the methane will be pushed toward the production wells and replaced by CO_2, this process is commonly called the *enhanced-CBM*. At the same time, the injected CO_2 would replace the methane adsorbed onto the coal surface, hence locking it up permanently. Coal has higher affinity to CO_2 than methane, it appears that it may be able to adsorb about twice as much CO_2 by volume as methane.

ECBM can be applied to certain coal seams (IEA, 2004) with:

- A homogeneous reservoir, laterally continuous and vertically isolated from surrounding strata;
- Minimally faulted and folded;
- At least 1-5 millidarcies (mD) permeability. Most coal seams are much less permeable.

Indonesia has abundant coal seam reserves, particularly low rank coal deposits that are distributed across eleven onshore coal basins with the resources around 453 Tcf. Unfortunately, many Indonesian coal seams are at an early stage of technical development then, its prospects remain uncertain for CO_2 storage.

VI. CO_2 REGULATORY FRAMEWORK

Most of the non-technical challenges of deploying CCS evolve around the regulatory and policy aspects. CCS deployment as a climate change mitigation effort is a recent concept and therefore many of the supporting policies are yet to be developed.

Deployment of CCS also requires enabling policies to minimize risks related to policy and commercial aspects. Partnerships between governments, international organizations and private sector are essential where government sets the policy and provides support while private sector develops, delivers, and deploys the technology (CCS WG, 2009). Effective partnerships on CCS require three key elements: first, an international financing framework that incentivize CCS as a climate mitigation effort; second, clear and workable arrangements around long-term liability of the stored CO_2; and third, public acceptance of CCS driven by shared concerns of cli-

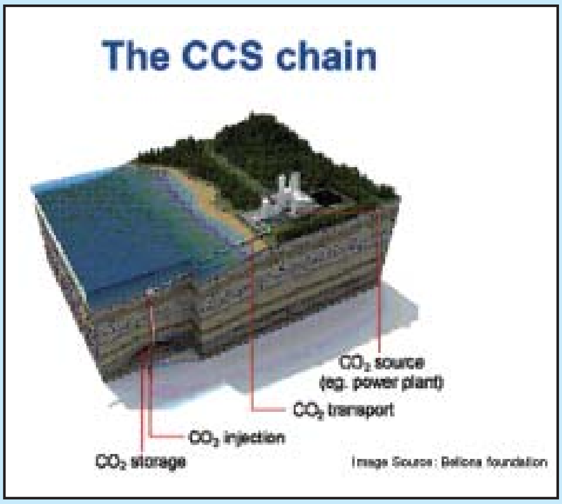

Figure 1
Main activities of CCS (IEA, 2009)

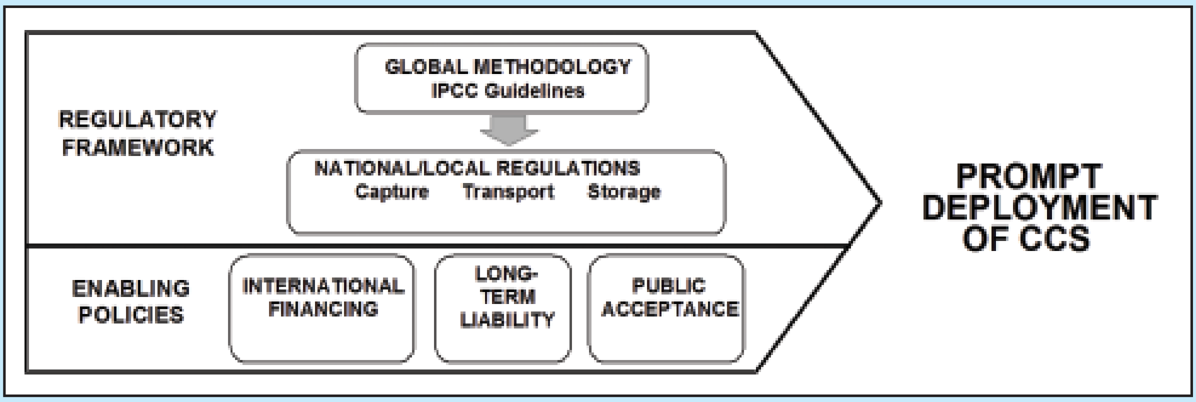

Figure 2
Key elements of CCS regulatory framework and enabling policies (CCS WG, 2009)

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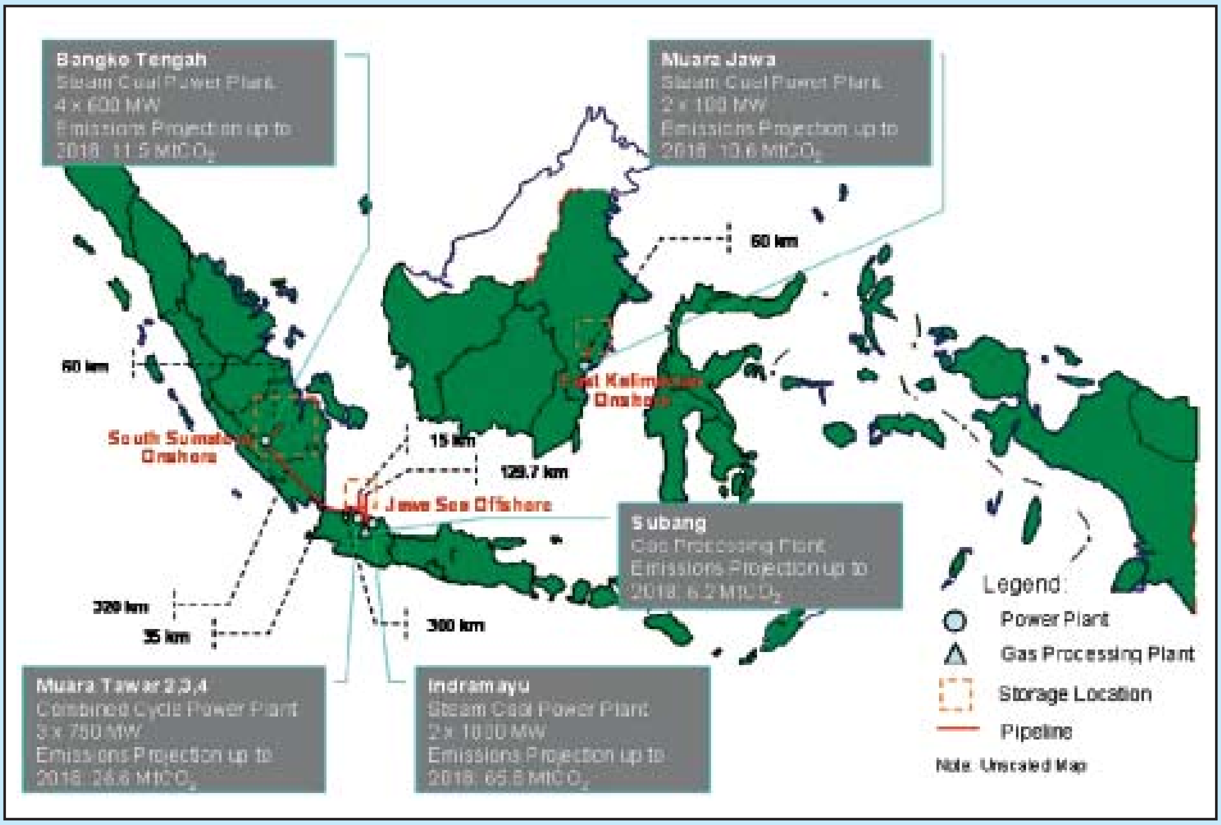

Figure 3
Possible scenario of CCS in Indonesia (CCS WG, 2009)

mate change and the need to substantially mitigate CO_2 released into the atmosphere (Figure 2.).

The most referenced and internationally recognized methodology for greenhouse gas accounting in the energy sectors (including CCS) is the 2006 IPCC Guidelines for National Greenhouse Gas Inventories principles. This can be used as a starting point in drafting regulations and policies of national and local scale, which must be operationalized on the agreed global framework that has been approved to ensure consistency across jurisdictions.

Furthermore, this guideline need to be adapted at national and local scale with more detailed rules and regulations and most importantly CCS must be adaptive to the development and learning curve.

VII. CCS POTENTIAL IN INDONESIA

To achieve government's aspiring target in reducing CO_2 emissions by 26% in 2020, Indonesia can play active role in CCS because it already has CO_2 sources and storage capacity of CO_2. The study conducted recently by the Indonesia CCS Working Group (LEMIGAS et al.) in examining the possibility of CCS deployment in Indonesia has developed several scenarios that illustrates the integration of CCS project in Indonesia (Figure 3.), in which some oil and gas reservoirs in South Sumatra, East Kalimantan and Natuna can be utilized for storage of CO_2. These regions are considered suitable due to geological stability, well characterised, low population density and established infrastructure on the surface (CCS WG, 2009).

CO_2 storage in conjunction with enhanced oil recovery (EOR) or enhanced gas recovery (EGR) is the most attractive option for Indonesia for early deployment of CCS, since it will generate additional revenue from the produced oil and gas. Such revenue can offset the CCS cost. Ready captured CO_2 sources from gas sweetening plant constitute the early opportunity for Indonesia to enhance CCS demon-

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stration project. When the CCS is later designated as CDM activity and carbon price considered attractive enough, it will likely affect the usual gas business nowadays.

Lack of public awareness on Indonesian stakeholders leads to the reluctance to develop legal and regulatory framework. We have to realize climate change is a societal responsibility with the solution to be led by government. Hence, all sectors of the economy must contribute to that solution.

There are several types of CO_2 regulations commonly discussed and in operation are namely cap-and-trade, command and control (mandates) and carbon tax. These policy instruments provide an initial platform in establishing regulatory models. However, currently there is no instrumental policy rules CCS in fully manner.

Some views express that CCS implementation in Indonesia will speed up industrialization and increase electrification ratio (currently 64%) through construction “capture ready” power plants in which can avoid higher retrofit cost in the future.

Deployment and development of CCS in Indonesia is also aligned with current energy policy or corresponds to use extensive coal in its composition. Furthermore, it helps enabling development of highly contaminated gas field as well for instance Natuna D Alpha. The relentless participation of Indonesia in international climate change forum can be used to look for potential funding to demonstrate CCS project in Indonesia.

VII. CONCLUSION

Proactive action from the government to create a encouraging environment to deploy CCS is the most crucial. That such situation can be created when supported by clear procedures and unambiguous permit mechanisms that embed CCS is a *portfolio* of CO_2 *mitigation*

Furthermore, the government can initiate developing a *roadmap* that integrates with long-term national plan. Increase *capacity building* and conduct more in-depth research on CCS should be done to get the comprehensive picture of this technology and improve efficiency and reduce costs as well.

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