# Risk Analysis of Gundih Carbon Capture Utilization and Storage: Implications and Challenges of Risk Governance of Technological Advancement for Climate Change Mitigation

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**Abstract.** Carbon Capture Utilization and Storage (CCUS) was unfamiliar in Indonesia before 2012. Since then, twofold efforts have been made to advance CCUS technology among oil and gas industries in the country; as part of climate change mitigation in the contribution for carbon emissions reduction commitment, as well as bringing economic benefits to the nation. However, there are still uncertainties that need to be disentangled and risks that need to be reduced or prevented to convince all stakeholders' support. The paper provides risk analysis for the stages of CCUS in Gundih Field, Indonesia using risk matrix that show towards positive implications in overcoming challenges of technological advancement in the realm of climate change mitigation, global warming and carbon emissions, and economic advantages as the first CCUS project implementation in the Southeast Asia Region.

**Keywords:** Carbon capture storage and utilization, Gundih Field, Indonesia, climate change mitigation, risk analysis

## 1 Introduction

In October 2010, Institut Teknologi Bandung and Kyoto University filed a SATREPS (Science and Technology Research Partnership for Sustainable Development) research proposal to JICA (Japan International Cooperation Agency) and JST (Japan Science and Technology Agency). It was revealed in April 2011 as Indonesia's only successful research proposal. Between May 2011 and April 2012, the project was introduced to the government and the Pertamina as the operator of Gundih block, and a contract was signed between ITB and JICA. A pre-feasibility study for a prototype Carbon Capture Storage (CCS) project in Gundih began in September 2012. Later on, after serial of preliminary studies Geology and Geophysics, discussions with oil and gas industries, experts from scientific agency, and advocacy with the relevant ministries such as Ministry of Energy and Mineral Resources, Ministry of Environment and Forestry, and Coordinating Ministry for Maritime Affairs; it was decided then that the concept of CCS is changed to Carbon Capture Storage and Utilization (CCUS). The concept of utilising $CO_2$ while storing it on the subsurface is new.

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The Carbon Capture, Utilization, and Storage (CCUS) Gundih Pilot Project is a prospective forthcoming $CO_2$ Enhanced Gas Recovery (EGR) pilot project located at the Gundih Gas Field in Central Java Province, Indonesia. Since the end of 2013, the field has been in operation. The $CO_2$ concentration of the feed gas is around 23%. The CO2 will be separated from the valuable methane after passing the amine system in the Central Processing Plant (CPP). The EGR Project intends to use highly corrosion-resistant pipelines to transport separated $CO_2$ at a rate of 800 tonnes/day, consisting of approximately 97.5 percent $CO_2$ and impurities (including approximately 2.5 percent $H_2S$), to be injected into the Kujung Formation within the Kedungtuban Structure at a depth of 2,778.5 – 4,100 m; 4 km to the east from the CPP with the injection period of ten years (Mulyasari et al, 2021). The notion of $CO_2$ use and storage was widely unknown in Indonesia at the start of the pilot project, including among politicians, community leaders, non-governmental organizations, educators, and the general public. Early in the public engagement research, it was discovered that there was little public understanding and much less grasp of the relevance of the term "$CO_2$ use and storage" [1]. Thus, the CCUS was then an unfamiliar technology that posseses great uncertainties. Uncertainty is an unavoidable component of existence and is linked with risk [2]. As CCUS is a complex technology, therefore it is crucial to comprehend the interaction and interplay among these concepts in order to be able to understand the challenges presented by CCUS to human coping systems. Uncertainty is where the direction of change is relatively well known, but the magnitude and probability of events and consequences, and the receptors at risk, cannot be estimated with any precision [2]. On the contrary, risk is where the magnitude of events and consequences are relatively well known, and probability distributions can reasonably be assigned to each [2]. Thus, in order to disentangled the uncertainties, risks must be analysed and evaluated as a basis for decision-making to way forward. A risk analysis for CCUS is then considered to be essential on how the risk analysis results may affect decision-making prosess of all related stakeholders in advancing CCUS as climate change mitigation effort in reducing carbon emmisions, lowering the risk of global warming and at the same time the utilisation of those captured $CO_2$ may trigger the gas production at subsurface; thus bringing the economic advantages to the country. Therefore, the objective of risk analysis of CCUS Gundih is to evaluate potential threats that may posed by CCUS technology advancement in the project area and identify strategies in mitigating and preventing those threats turning into crisis. The results of the risk analyisis is expected to identify possible strategies towards positive implications in overcoming challenges of CCUS for convincing and acquiring support from key stakeholders.

## 2 CCUS Gundih risk analysis

Gundih CCUS Project is claimed as the 1st CCS/CCUS Project in Southeast Asia Region [3]. Based on the knowledge gained through the review of pre-feasibility studies conducted by CCUS Gundih project team; risk analysis especially for surface and subsurface facilities is performed. The scope of the risk assessment included but not limited to $CO_2$ pre-treatment and interfaces with CPP, $CO_2$ transport, $CO_2$ injection, and $CO_2$ storage.

$CO_2$ emitted from the Gundih CPP is targeted as $CO_2$ source for injection into targeted well. The typical feed gas of the CPP Gundih contains around 23% $CO_2$ and 6000 ppm $H_2S$. Therefore, in order to produce sales gas, the acid gas compounds ($CO_2$ and $H_2S$) are removed in the Acid Gas Removal Unit (AGRU) and Bio Sulfur Recovery Unit (Bio SRU). It is estimated that the CPP

Gundih produces 800 tonnes/day of CO2 (15.2 MMSCFD) that is currently emitted and ready to be injected back to the subsurface.

## 2.1 Risk criteria

Risks are in general characterized by their Probability/likelihood (or frequency) of occurrence and Associated consequences (or impacts) if they occur. Applying a common scale for probability for each risk source type and a common scale for consequence to each risk source type allows a common, internally consistent risk value to be assigned. The risk value is usually based on a simple multiplicative product of probability and consequence but can also be given a simple qualitative indicator, which is the common practice for an early-stage risk identification exercise.

The risk analysis for the Gundih CCUS was organised in the form of several virtual discussion and a workshop with relevant experts from the project and related stakeholders. After those approaches, the risk matrix shown in Fig. 1 should be considered, in which the identified hazards have been ranked according to the project's risk criteria.

**Pilot Scale - Gundih CCS Project**

Probability

Consequence

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Event ( E ) | | Very unlikely to occur during operations | Likely to occur during operations | May occur several times during operations |
| | | | | | | Frequency | | once every 10 years | yearly | Daily - Monthly |
| Health and Safety | Schedule | Production | Reputation | Environment | Cost (USD) | | Probability | Low | Medium | High |
| HS | S | P | R | E | C | Consequence | | 1 | 2 | 3 |
| Bruises and minor damages that do not require hospital treatment | Short delay may occur | 1 day production stop | Local stakeholder concern | Minor environmental damages. Restored within days | +10% of total project cost | Minor | 1 | Low | Low | Medium |
| several incidents requiring hospital treatment | Long delay may occur | 1 week production stop | Broader stakeholder concern | Serious environmental damages. Restored within months | +50% of total project cost | Significant | 2 | Low | Medium | High |
| 1 or more killed | Project will likely be required to stop | 1 month production stop | Government will require project to cease | Major environmental damages. Takes 1-2 years to restore. | +100% of total project cost | Major | 3 | Medium | High | High |

**Fig. 1.** Example of risk matrix with probability and consequence categories

## 2.2 Hazard identification

For each analysis objects and for each operation mode hazards were systematically identified by addressing a series of predefined issues, related to a DNV GL's SWIFT (The Structured What-If Technique) checklist. For every discussed hazard, the following was recorded in a risk assessment spreadsheet: What is the cause of the hazard? What will be the event following the cause? What are the consequences of the event? Which barriers/preventive measures are planned/will be implemented? What is the consequence and probability/likelihood (qualitatively) of the effect? Comments, recommendations and required follow up actions. The results of each hazard identification are consequently filled in the spreadsheet to be further discussed as a decision-making tool for the project in implementing the project strategically.

## 3 Methodology

The SWIFT was designed as an efficient alternative to HAZOP (Hazard and Operability Study) for delivering highly effective risks identification when it can be proved that the rigor of a HAZOP is not warranted. The SWIFT is a thorough, systematic, multidisciplinary team oriented analytical technique. SWIFT can also be used in conjunction with or as a supplement to a HAZOP (DNV GL, 2014). The SWIFT differs from a HAZOP. A HAZOP examines the plant line by line, vessel by vessel, etc. SWIFT, on the other hand, is a systems-oriented technique which examines complete systems or subsystems. To ensure comprehensive identification of hazards, SWIFT relies on a structured brainstorming effort by a team of experienced process experts with supplemental questions from a checklist [4].

SWIFT like HAZOP requires the input of a team of process experts to evaluate the consequences of hazards which might result from various potential failures or errors they have identified. When answering all the questions raised about realistic deviations from the normal intended operation of a process unit, the team assesses the likelihood of an incident, the potential consequences and the adequacy of safeguards to prevent or mitigate it should it occur. The "What-if ?" questions, which can be posed by any team member (including the team leader and scribe), are structured according to various categories. When the team is no longer able to identify additional questions in a category, a category specific checklist is consulted to help prompt additional ideas and ensure completeness [4].

The technique is efficient because it generally avoids lengthy discussion of areas where the hazards are well understood or where prior analysis has shown no hazards are known to exist. Its effectiveness in identifying hazards comes from asking questions in a variety of important areas, according to a structured plan, to help ensure complete coverage of all the various types of failures or errors which are likely to result in a hazard within the system being examined. The SWIFT analysis is further strengthened through the use of the checklists [4].

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## 4 Results and discussion

The study that was conducted in Gundih is evaluated after all of study components are finalized, especially to determine the risk that could occur in the future, once the implementation is started. Table 1 shows the detail description of only one aspect of the future Gundih CCUS project, i.e., subsurface. By showing this table to all stakeholders, the related risk could be easily understood and the worst situation during the implementation could be mitigated. Later, the risk of other aspects must be specified as has been shown in the example in Table 1.

**Table 1.** Example of Risk Analysis of Future Gundih CCUS Project, i.e., subsurface issue

| | Uncertainty (L/M/H) and Current Study Status | Related risks and affected items (Inpact of the risk on CCS) | # | Considerable Approach | Expected Results | Implementation Restrictions / Conditions / Necessary Data/Etc. | Imprimentation Timing | Required Period | Priority | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Reservoir1 : Heterogeneity / Fracture, High permeability zone (H) | ·Early breakthrough of injected $CO_2$/$H_2S$ (H)<br>·Stop gas production / stop $CO_2$ injection (H)<br>·Injection well optimization (Perforation interval, Tubing specs, Well head pressure, etc.) : Avoid fracture dense area and depth (M) | 1-1 | Study on seismic guided fracture characterization for the reservoir simulation | Could capture fracture distribution and identify potential highly permeable zone<br>⇒ Reflect in reservoir model and dynamic simulation | 3D seismic Inversion data | Anytime (before POD?) | 2 months | L | Review / Detail discussion |
| | | | 1-2 | Sensitivity study K-phi cross-plot (based on the single porosity model study) | Understanding of the risk on CCS and effects on fracture (high permeability zone) | Need assumption on K-Phi | Before POD | 1 month | H | |
| | | | 1-3 | Construct dual porosity model and dynamic simulation | Prediction & estimation based on dual porosity (fractured) model | Need assumption on input parameters (fracture porosity, shape factor etc.).<br>Need core analysis | In FEED period or after core sampling/analysis (after drlg) | 6-12 months* | M | TBD |
| | | | 1-4 | Study on discreate fracture network model | Fractured model for dymanic simula | Need assumption on input parameters (fracture porosity, shape factor etc.).<br>Need core analysis<br>Software | In FEED period or after core sampling/analysis (after drlg) | 6 month | L | Pertamina's point out<br>Can be covered with 1-1 & 1-3 |
| | | | 1-5 | Hearing on Pertamina's operation experience | Comments & oppinion from field operation side | | Before POD | Anytime | H | |

## 5 Conclusion

The paper shows an example how risk analysis is performed in order to map several issues that could occur during the implementation of Gundih CCUS Project. The risk analysis is currently still conducting and it is involved not only by research team members from ITB, but also from other stakeholders, i.e., from Pertamina, Japan consortium (Japan NUS Co. Ltd., JGC Corporation and J-Power), and government of Indonesia (Directorate General of Oil and Gas, SKK Migas, Directorate of Climate Change Mitigation, etc.). The analysis will be finalized by the end of May 2022, i.e., before the study of FEED (Front End Engineering Design) is started in June 2022. Therefore, by implementing a risk analysis for the Gundih Carbon Capture Utilization and Storage; it illustrates not only the implications and challenges, but it reflects the risk governance as well for the internal (project developer) and external stakeholder (government, oil and gas business industries, communities) of CCUS technology for Climate Change Mitigation to reduce the carbon emissions.

## References

[1] Mulyasari F, Harahap AK, Rio AO, Sule R, Kadir WG. Potentials of the public engagement strategy for public acceptance and social license to operate: Case study of Carbon Capture, Utilisation, and Storage Gundih Pilot Project in Indonesia. International Journal of Greenhouse Gas Control. 2021;108.

[2] Kasperson RE. The social amplification of risk and low-level radiation. Bulletin of the Atomic Scientists. 2012;68(3):59-66.

[3] Sule MR, Kadir WG, Matsuoka T, Prabowo H, Sidemen GS. Gundih CCS Pilot Project: Current status of the first carbon capture and storage project in South and Southeast Asia Regions. In: 14th Greenhouse Gas Control Technologies Conference; 2018; Melbourne. SSRN; 2019. Doi: http://dx.doi.org/10.2139/ssrn.3366415.

[4] NV GL. Gundih CCS Pilot Project: DNV GL Pre-feasibility review. Report Nr. 2014-1490 Rev. Document Nr. 1FCRLSX-8; 2014.