Introduction

Malaysia has the potential to be a significant player in the large-scale decarbonization of Asia (Woodmac, 2023). Central Luconia, off the coast of Sarawak, is top ranked for subsurface geological CO_2 storage given the multitude of proven world-class reservoirs for CO2 storage. The area has the potential to expand as a major CCS hub through offshore depleted and aquifer storage sites.

Shell has developed deep knowledge of the regional geological formation through a long history (100+ years) of operation of hydrocarbon assets in Sarawak. Leveraging 12 CCS projects globally in operation and development (eg. Quest, Northern Light, Aramis) together with Shell's expansive knowledge and skills in offshore floater (FSRU, FLNG), and recent successful development of liquid CO2 shipping for Northern Lights, a Floating Storage Injection Unit (FSIU) is proposed to unlock the access to remote offshore CO2 storage site through this cost efficient new technology. This paper provides an overview of the key design considerations and challenges associated with a FSIU that receives, stores and conditions liquid CO2 for injection into storage sites.

Overview of FSIU Development Concept

To store CO2 in depleted reservoir or saline aquifer in remote offshore location, liquified CO2 will be transported via marine tanker from emitter's liquefaction facility to a terminal which receives and temporarily store the CO2 cargo. The intermediate storage tanks in the terminal act as a water shed between the batch wise unloading operation from tankers whilst ensuring continuous CO2 injection to the reservoir. The receiving terminal can be located onshore near emitters or port infrastructure, or near the offshore storage site in the form of a FSIU. Onshore receiving terminal plus pipeline-based development is proven and adopted in industry, for example Northen Light is currently starting up Phase 1. FSIU is one of the few options of CCS terminal located offshore near the storage site without the need for a long pipeline.

FSIU can access remote offshore store location with flexibility to re-deploy from store to store leading to long term cost efficiency. In a remote location, the HSSE footprint is reduced.

Figure 1 is a schematic representation of a FSIU in the CCS value chain from capture, transport to storage. The FSIU is moored near the CO2 injection platform. CO2 tankers can berth in tandem or side by side to offload cargo to the FSIU via flexible hoses or marine loading arms.   The FSIU provides cargo handling, temporary CO2 storage, pumping and heating to condition the CO2 to dense phase for injection via the platform. The CO2 is transferred to the injection platform via a short flexible flowline.

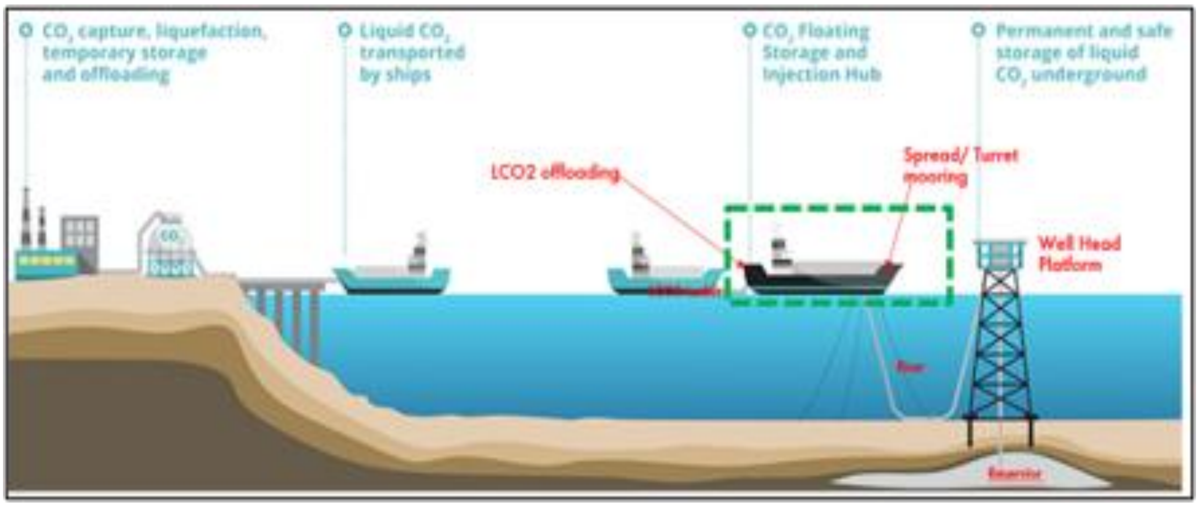

Figure 1: Capture, Transport and Storage of CO2 in a FSIU Development Concept

Key Components and Design Considerations of FSIU

Functionality wise, the FSIU can be considered a liquid CO_2 tanker with add-on requirements for station-keeping, cargo handling, CO_2 conditioning and injection (ie. pumping & heating). To ensure highest berthing availability for safe and frequent cargo offloading to the FSIU, navigation availability and logistic modelling based on local metocean conditions must be performed to select the optimum and integrated mooring and cargo offloading design, as well as storage capacity. The cargo storage system on the FSIU is sized to accommodate the largest supply tanker with add-on buffer capacity to mitigate cargo supply disruptions such as operational delay or weather standby, ensuring uninterrupted injection of CO_2.

The FSIU will be designed to offload low pressure CO_2 carriers (around -50°C and 6–8 barg), which is the emerging standard for the Asia Pacific market enabling larger carrier capacities with economies of scale for long distance transportation. Shell and Brevik Engineering developed a design of up to 74,000 cubic metres liquid CO_2 carrier, mirroring the size of a 174,000 cbm LNG carrier with a 12-meter draft to access key East Asian ports. The vessel is specifically designed for the Asia Pacific market to enable cost competitive transport of CO_2. Low-pressure cargo tank designs are a key enabler for LCO_2 ships with economies of scale for long distance transportation of CO_2. DNV has awarded a detailed Approval in Principle (AiP) covering a comprehensive assessment of specific technical challenges for LCO_2 carriers.

Luconia CCS has developed a tight CO_2 specification based on extensive laboratory experiments performed for Northern Lights and Aramis projects. To ensure safe transport and protect the integrity of the export, shipping and store value chain, it is crucial to harmonize this stringent requirement across the entire value chain. Impurities of particularly strict controls are H_2O, O_2, SOx, NOx and H_2S that can form strong acids resulting in corrosion. Emerging industry standards for developing CO_2 specifications offer opportunities for better management of boil-off gas during cargo loading and offloading operations, preventing cross contamination amongst emitters, shipping and storage hub, or otherwise rejected cargo and venting of CO_2.

The cargo containment system is a major scope and cost component of the FSIU. Storage tank material selection specifies good mechanical properties, safety, corrosion resistance and Class certified materials. Currently available material such as steels with high nickel content are robust for the required low temperature condition but come at a premium cost. The use of alternative, lower cost, high strength low temperature steels is required to make the FSIU as cost competitive as possible. A number of material studies have been undertaken to identify and assess alternative options that give high yield and tensile strength under cryogenic temperatures with lower price.

Conclusions

Shell has demonstrated feasibility and is maturing the design of a Floating Storage Injection Units. The FSIU will be designed to offload low pressure CO_2 carriers (around -50°C and 6–8 barg), which is the emerging standard for the Asia Pacific market enabling larger carrier capacities with economies of scale for long distance transportation. DNV has awarded a detailed Approval in Principle (AiP) covering a comprehensive assessment of specific technical challenges for low pressure LCO_2 carriers. Low pressure shipping and FSIU will enable significant cost reductions compared to conventional onshore terminals and long-distance pipelines to remote offshore CO_2 stores. This enables a cost competitive first development phase for a wider CO_2 transport and storage area development plan off the coast of Sarawak, offshore Malaysia. The FSIU could be replicated or relocated to other stores and combined with CO_2 supply from contaminated gas fields and other domestic emitters.

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