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Techno-economic benchmarking of a decarbonized energy hub for offshore power supply

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Abstract

Oil and gas production, transport and processing activities consume vast amounts of energy and are responsible for significant GHG emissions, that resulted in 5.1 billion tonnes of CO_2-eq in 2022 [1]. The integration of renewable energy in the offshore sector has received increasing attention. However, energy storage requirement and variable loads represent a challenge. Since the offshore sector already relies heavily on gas turbines for power, and offshore logistics might make alternatives like electrification challenging [1], integrating carbon capture and storage (CCS) can be a key strategy for cutting CO_2 emissions. The potential proximity of offshore CO_2 storage locations and the storage expertise available in the petroleum industry are attractive aspects. Thus, integrating CO_2 capture for the offshore sector decarbonization represents an interesting alternative to be developed in parallel with renewables. Instead of implementing capture from the various distributed emission points, a strategy could be to enable energy hubs, that are large-scale facilities capable of delivering low-carbon heat and power to clusters of offshore oil and gas production facilities. This study explores the techno-economic feasibility of decarbonized offshore hubs to supply power to a cluster of platforms in the Norwegian Continental Shelf (NCS), with a focus on capturing CO_2 from the relatively diluted exhaust gases of gas turbines.

The proposed system combines a natural gas combined cycle (NGCC) with an absorption-based CO_2 capture process and exhaust gas recirculation (EGR), as shown in Figure 1. NGCC serves as the main power source, while the CCS unit uses chemical absorption to capture CO_2 from turbine emissions. EGR determines a decrease of the exhaust gases flowrate, making the CO_2 capture equipment more compact, playing a crucial role within the challenging offshore environment. It also increases the CO_2 concentration in the exhaust gases, making capture less energy-demanding and, thus, more efficient [2].

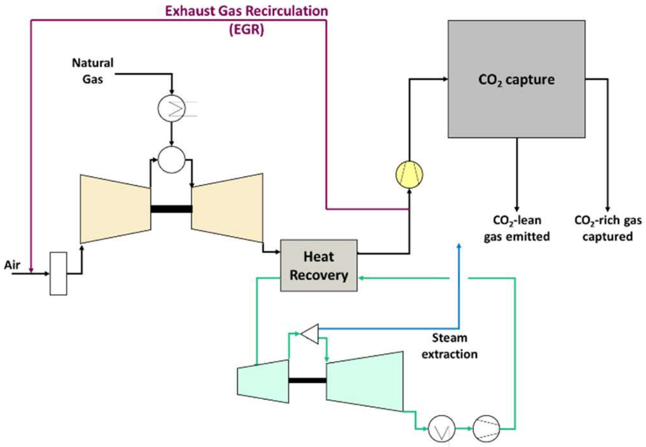

Figure 1 Scheme of the offshore energy hub.

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To simulate the energy hub, we use Oogeso (Offshore Oil and Gas Energy System Operational Optimisation), an open-source Python-based tool designed for offshore platform energy modeling [3]. Simulations with the Oogeso tool are based on a linear, mixed-integer rolling horizon optimization that finds optimal dispatch of resources. To include CCS into Oogeso , we first developed a model of the NGCC and CO_2 capture system using the commercial process modeling software ASPEN HYSYS and the iCCS tool, SINTEF Energy Research's proprietary tool for techno-economic and environmental evaluations of CCS value chains [4], [5]. The simulations were performed at different turbine loads and EGR levels. The outputs were used to create performance maps and build linear and piecewise-linear correlations for key system components. These correlations were then integrated into Oogeso to enable full CCS functionality.

For the case study, we assess a system powered by three LMS100 gas turbines, produced by GE Vernova [6], delivering around 400 MW to a group of offshore platforms. We analyze how CCS affects cost efficiency, CO_2 emissions, and overall system performance while factoring in real-world offshore constraints.

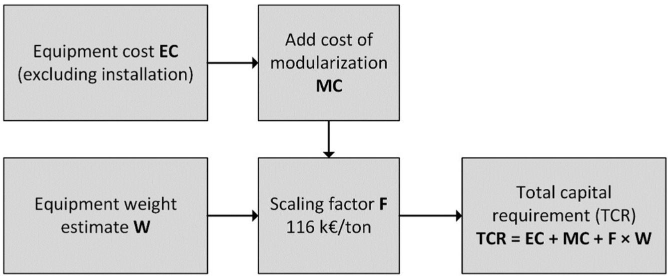

Figure 2 Simplified scheme of the cost estimation methodology for the energy hub equipment.

While the technical analysis is based on process simulations using Oogeso, the economic assessment follows a specialized offshore cost methodology [7], for which a schematic representation is exhibited in Figure 2. This approach considers capital expenses (CAPEX), operational costs (OPEX), and the unique challenges of deploying CCS offshore, including installation and maintenance complexities. The most important factor for offshore equipment is the weight, included in the correlation for the Total Capital Requirement (TCR) calculations.

By combining process modeling and optimization techniques, this study provides a thorough techno-economic assessment of CCS integration into offshore energy hubs. The cost methodology, specifically developed for the peculiar offshore application, allows identifying the key factors driving the cost, hence guiding further efforts to improve the economic outlook while ensuring substantial cuts in emissions. The outputs will be benchmarked against alternatives for decarbonizing offshore operations, such as electrification and integration of renewable energy. The analysis will consider several factors affecting the relative performances of the different approaches to decarbonization, e.g., location, distance to shore, electricity price and carbon footprint, etc. The findings offer valuable insights into the potential for reducing CO_2 emissions in offshore oil and gas operations and outline optimal pathways to meet emissions reduction targets given the specificity of the offshore cases. Ultimately it will contribute to the broader conversation on sustainable energy transitions in the sector.

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