Double funnel approach for screening of potential CO2 storage opportunities in the Norwegian Continental Shelf

Introduction

Carbon capture and storage (CCS) is a key waste management strategy for reducing carbon dioxide (CO2) emissions and mitigating climate change. The Norwegian continental shelf has significant capacity for CCS, as it has several depleted oil and gas fields that can be used for storage of CO2. The field of CCS has seen significant growth in recent years, as the need to reduce carbon CO2 emissions becomes increasingly urgent. However, despite the increasing number of studies on CCS, there remains a lack of consensus on the most effective methods for accelerating and scaling up CCS projects.

In this study, the integration of Machine Learning (ML) whereby the reports from the Norwegian Petroleum Directorate (NPD) are ingested into one platform creates potential cost-effective solution by screening previous knowledge gathered for depleting oil and gas fields and significantly reduces the time of the screening, the evaluation and the ranking of CCS prospects. We investigate the feasibility of such a study on the Norwegian Continental Shelf by analyzing the geology and capacity of existing oil and gas fields. The analysis is conducted on historical data from final well reports for 361 wells (NPD, 2023) which are priorly ingested using Machine Learning (ML) and Artificial Intelligence (AI) by indexing and tagging metadata from the documents, extracting, and classifying images and generating geological interpretable output such as heat maps or knowledge graphs. Our research includes a detailed characterization and interpretation of the subsurface geology, including the identification of potential storage formations, the analysis of reservoir properties such as porosity and permeability and the evaluation of seal characteristics. We also conducted a comprehensive assessment of the capacity for CO2 storage, considering factors such as injection rate and pressure buildup.

Methodology

Depleting oil and gas fields in the Norwegian Continental Shelf with their massive amount of data being collected over decades of development and production are often considered good candidates for CCS opportunities. Unfortunately the vast amount of knowledge come with the challenges associated to the lack of normalization of the data and the diversity of the different format and template utilized making it difficult to utilize the full potential of such data without allocating significant manual work.

In our case study, Machine learning pipelines are used to classify, cluster, and extract insights from such an unstructured data. Priorly trained and G&G domain specific natural language processing (NLP) transformers are executed on the text to perform indexing, metadata tagging and topic modeling, when Deep Convolutional Neural Network (DCNN) extract, classify and segment extracted images. Such an approach has the advantage of significantly lessening manual human intervention allowing G&G experts to focus on the interpretation of the data itself using a front end deployed interface (Baillard et al., 2019).

As seen in Figure 1 the data visualization and interpretation are performed through a suite of six analytical tools: (1) summarizes the important attributes of the well automatically extracted from the document, (2) aids in portraying the well data on a map and visualizes the lateral distribution of search queries, (3) provides an in-depth search within all the corpus for the text and any tagged associated metadata using NLP, (4) correlates wells between each other's to understand and interpret the semantic structure of the basin(5) searches the images extracted from DCNN into its respected geological categories, (6) quantifies the frequency of different lithologies present from the different wells.

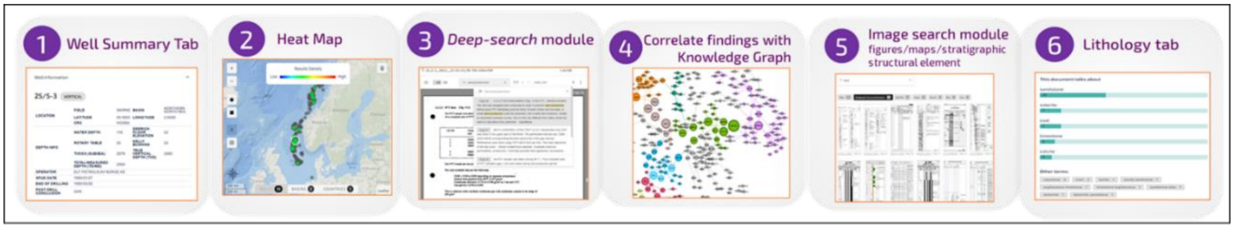

Figure 1 *Analytical tools used for the case study research strategy for CO2 storage screening*

Such a set of tools provides powerful means for understanding and interpreting large and complex sets of data. It can help to identify patterns, trends, and relationships that might not be immediately apparent from raw data due to the segregation of information in separate files for each well. By narrowing down the scope of focus on selected wells, the exclusion of non-relevant well and time frame reduction of the process can be accomplished.

In this paper, we propose a new CCS screening workflow called Double Funnel Approach (DFA), seen on Figure 2 which consists of a “data sweep” and a “data target”. The “data sweep” aims to reduce all findings from all ingested data to key learnings and key wells over the area of interest, allowing to review and rank the most suitable field candidates for potential CCS opportunities. The “data target” follows the “data sweep” and focuses only on the field selected candidates and aims to refine and enhance the existing unstructured data with seismic, logs, interpretation and geomodel data. During this exercise, redundant and irrelevant data are removed through efficient automated version indexing and cross-correlation with the unstructured data. Finally, the data is now ready for screening for CO2 injection capacity and monitoring analysis.

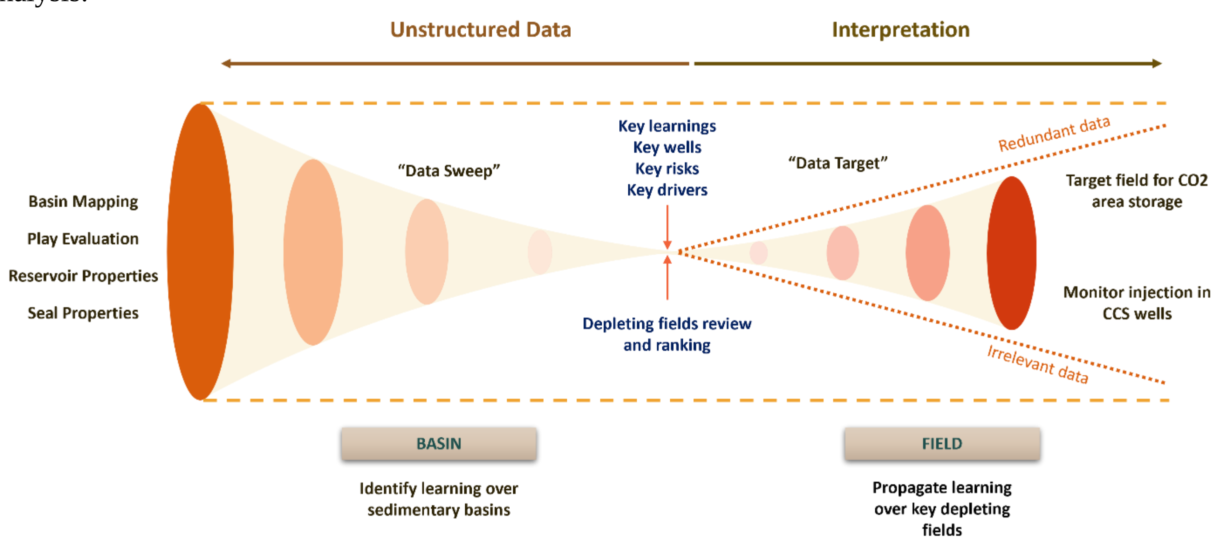

Figure 2 *Proposed Double Funnel Approach for CCS Screening Studies*

CCS “data sweep” use case offshore Norway

The ingestion of data for the case study comprises of 490,000 pages and 440,000 images, covering a total of 361 wells within 5 basins in Norway consolidating 50 years of exploration, development, and production. All these data has been retrieved from the Norwegian Petroleum Directorate (NPD). The “data sweep” of the data was completed in 21 days which evaluated various hypothesis and converge on the key learnings, key wells, key risks, and key drivers.

Figure 3 shows the generated knowledge graph associated to the zone of interest. Knowledge graph is a structured way to represent and organize knowledge in a way that is easily queried and traversed across all the corpus of documents ingested. This makes it useful for a holistic interpretation of the wells present in the area of interest, interpreting and ranking them based on their location and importance in the graph respectively as "alpha" or geological analogue, "scouts", "pack or "lone-spirit" wells. As observed, the structure of the knowledge graph does indicate a non-homogeneous distribution with 7 different clusters being identified. Each cluster is centered around key wells acting as key geological analogues ("alpha" well) for the surrounded wells located within the cluster. "Scouts" wells define the unique critical paths between adjacent clusters, allowing geologists to deeper understand the geology and exploration history of the area of interest (Hernandez et al., 2019).

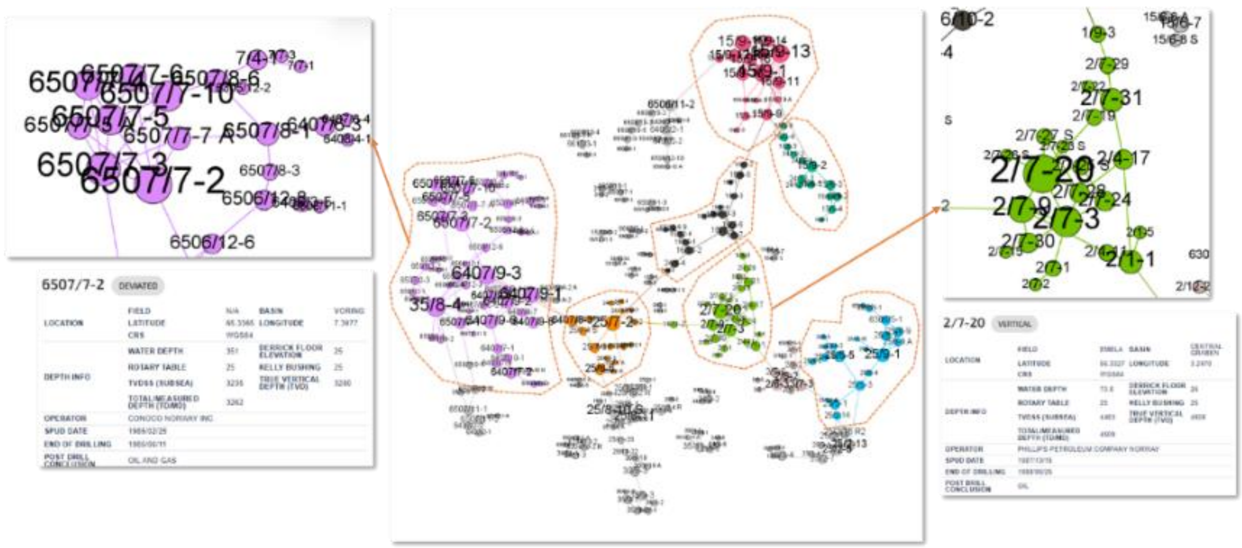

Figure 3 *Knowledge graph with clusters of wells from the Norwegian dataset*

Based on the recognized clusters, wells are further investigated by cross-correlating their respective post drill conclusion, formation penetration and keywords search associated to reservoir properties, seal characteristics or a specific search allowing a deeper dive in the corpus. An example of such full corpus search for 'porosity' detected from the well final well reports, within text, images and tables identifying the relevant values of the porosity and their associated formations. Auto-classified images can enhance the analysis by providing detailed information about the textures, layers, and structural characteristics of the rocks through different scales, from field scale with seismic stacks or isochrone map, to microscopic scale with thin section images. Additionally, image analysis techniques such as pattern recognition can be used to automatically extract features and classify rock formations.

In this example, the "data sweep" suggests suitable areas for CCS in the Norwegian Sea corresponding to Heidrun and Marulk fields. The study highlights the potential of Ile and Garn formation within the Fangst Group under the Heidrun Field. These intervals show good average depths for CO2 storage for supercritical storage, and are characterized by good porosity and permeability, with a significant net sand thickness. Seal integrity has been confirmed and validated. The interval above Ile and Garn are currently producing, and therefore has seismic and velocity data which allows precise CO2 injection monitoring through microseismic. The upper Ile and Garn aquifers have good reservoirs in the southern part of the Froan Basin which may indicate additional potential CCS storage in this area.

Well	Depth	Field	Formations	Average Porosity	Average Permeability	Seal	Lithology
6507/7-6	2144.5 – 2189.5	Heidrun Field	Ile Fm	Good (25%)	Very Good	Claystone	Sandstone
6507/2-2	3670 – 3695	Marulk Field	Garn Fm	Moderate	-	Claystone	Sandstone
6507/7-10	2507 – 2531.5	Heidrun Field	Garn Fm	Fair to Good	-	Shaly Claystone	Sandstone
6507/7-5	2411.2 – 2473.5	Heidrun Field	Ile Fm	Good (24%)	Good (160 mD)	Claystone	Sandstone
6507/8-1	2248 – 2323.5	Heidrun Field	Tomma Fm (Ile Fm)	Moderate	Good	Claystone	Sandstone

Figure 4 *Screening CO2 storage candidates based on lithology, average porosity, average permeability, and seal characteristics.*

Conclusion

The study showcases how a “Double Funnel Approach” through an ML data ingestion pipeline can be an efficient screening tool to analyze, review and rank CCS potential using readily available unstructured data. In this case, 490,000 pages of documents have been analyzed in 21 days to identify potential CCS opportunities below Heidrun producing field, extended across the Froan basin. Additional analysis through the “data target” may now be undertaken around Heidrun field on related wells, seismic and interpretation data.

To conclude, such an analysis suggests the scalability and the cost effectiveness of the methodology for rapidly addressing the requirements of new CCS capabilities to mitigate the impact of the Climate Change.

Acknowledgment

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