Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 114 (2017) 7042 – 7046

Energy Procedia

13th International Conference on Greenhouse Gas Control Technologies, GHGT-13, 14-18 November 2016, Lausanne, Switzerland

Perspective of CO_2 for Storage and Enhanced Oil Recovery (EOR) in Norwegian North Sea

Pham V.[a], Halland E. [a] *

[a] *Norwegian Petroleum Directorate, Stavanger, Norway.*

Abstract

The CO_2 Storage Atlas of the Norwegian Continental Shelf has been prepared by the Norwegian Petroleum Directorate. The main objectives have been to identify safe and effective areas for long-term storage of CO_2 and to avoid possible negative interference with ongoing and future petroleum activity. CO_2 can be used to increase oil recovery to increase value of CO_2 sequestration. CO_2-EOR is a proven technology to increase oil recovery, and simultaneously store CO_2 permanently in the subsurface. Today's experiences is from onshore North America and China. The technology is mature for onshore use, with 40 years of injection in the USA. Implementing CO_2-EOR offshore is definitely more challenging and carries operational, commercial and financial risks.

Offshore Norway we have 20 years of experience with storing CO_2 in geological formations and a lot of work has been done to map and evaluate possible storage sites (CO_2 Storage Atlas Norwegian Continental shelf). CO_2 EOR screening studies were done to see if it could be a value to use CO_2 to increase the recovery in some of the oil fields. Studies showing potentially favorable outcomes for using CO_2 EOR, figure 1 shows studied areal in NCS. Both CO_2-EOR with permanent storage in the oilfields as well as CO_2 without storage are studied in three cases. CO_2 for EOR can create a market for CO_2 that improves the economics of CCS and it can be combined with permanent storage of CO_2.

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: author@institute.xxx

Peer-review under responsibility of the organizing committee of GHGT-13.
doi:10.1016/j.egypro.2017.03.1845

Peer-review under responsibility of the organizing committee of GHGT-13.

Keywords: CO_2; storage; EOR; enhanced oil recovery

1. Introduction

The Norwegian part of the North Sea is a mature petroleum province with several oil and gas fields in production, some new, some facing decline and some close to abandon.

The recovery factor from the Norwegian oilfields is on an average of 46%. The main drainage strategy is by water injection, some fields also have primary gas injection or WAG (water alternative gas). A few other EOR methods have been tested, but not implemented on a field scale. With CO_2 flooding, the remaining immobile oil in these reservoirs can be mobilized. Many of the reservoirs in the area are suitable with respect to pressure and temperature (depth).

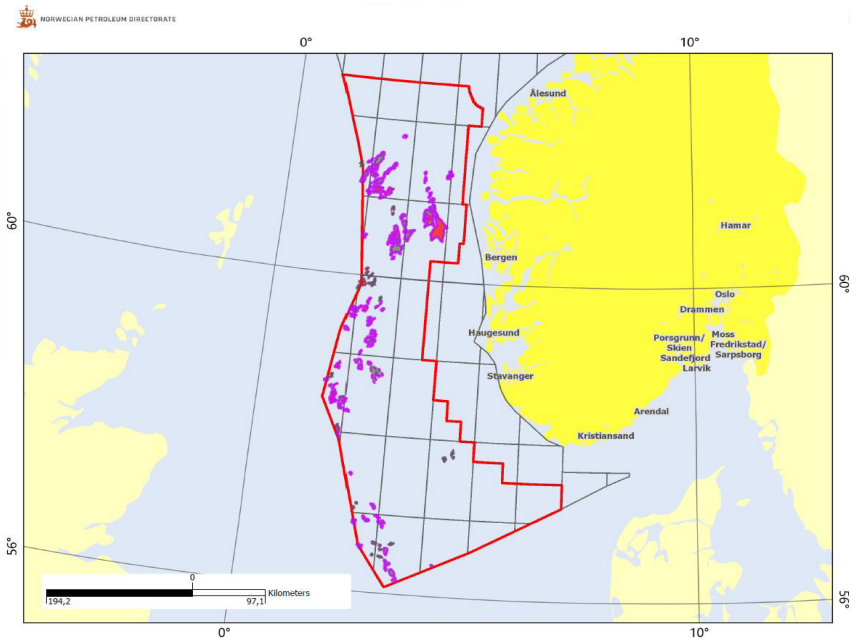

Figure 1. Location of studied areal: the Norwegian North Sea

1) An unrisked screening of technical EOR potential across the oil fields in the Norwegian part of the North Sea was performed and a techno-economic model were used on 23 oilfields, figure 2 and 3. No limits were set on available CO_2 for injection.

2) Three fields have been studied in more detail, with an estimated access of CO_2 at 1-3 million ton annually. These oilfields has different characteristic and CO_2 was injected and circulated up to self-sufficient of CO_2, figure 4. After breakthrough of the CO_2 injection of CO_2 continues into the reservoir, though gradually transport of excess CO_2 to the second field and then further on to the third field. Different ways of transporting the CO_2 was included.

3) A third phase in evaluating the potential for CO_2-EOR in the North Sea has been undertaken a more detailed study on one oilfield with the aim to optimize both the enhanced recovery potential and achieve maximum storage of CO_2.

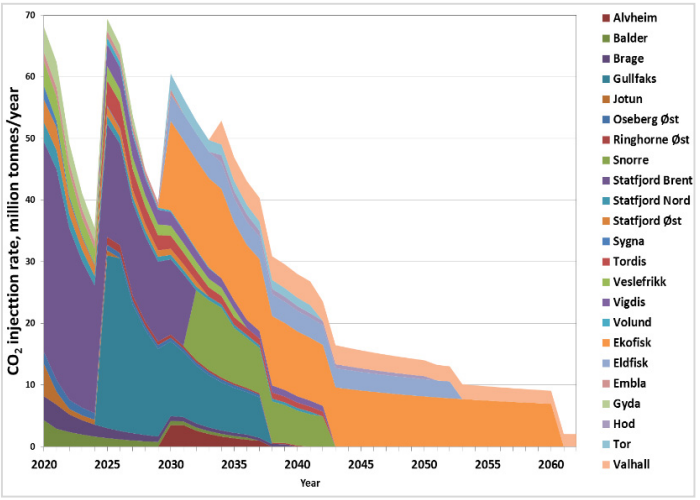

Figure 2. CO2 injection in 23 oil fields in the screening studies.

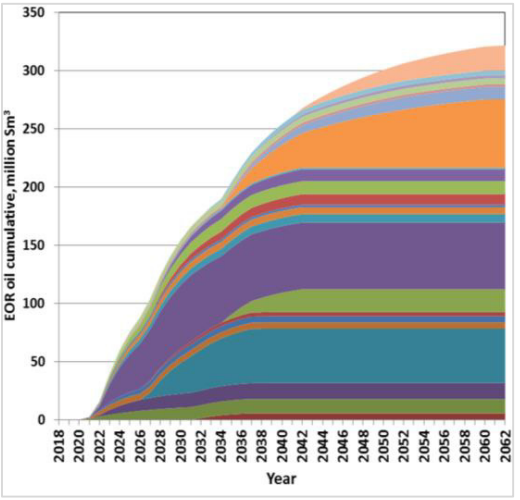

Figure 3. EOR effect (cumulative) from 23 fields.

Using CO_2 for EOR in smaller scale for individual field is studied more comprehensively. The objective of the study is to quantify the potential of CO_2 Enhanced Oil Recovery (EOR) and CO_2 storage in a mature North Sea oil field. The field is produced by partial pressure support from both water injection and gas injection.

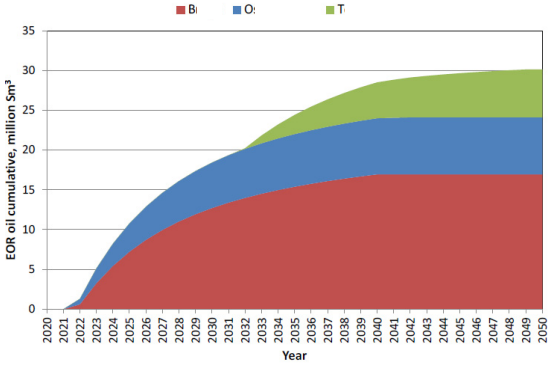

Figure 4. EOR effect from three oil fields have been studied in more detail in the Norwegian North Sea.

2. Reservoir simulation model

The starting point of this study is the Operator's reservoir simulation models in black oil mode including history match to 1.1.2015, and prediction thereafter. The black oil models have been converted to the compositional mode with 8 components where CO_2 is a separate component. The oil field is divided into two parts, with relatively similar size and production history.

The northern part is not in pressure communication with the southern part. For this study, the northern part is chosen as a representative segment of the field. The existing wells are kept unchanged while CO_2 at the rate 1 MSm^3/d or 0.7 Mt/year is assumed injected in one new well. The field has complex geological setting with several formation entered with barriers and segmented by a lot of faults

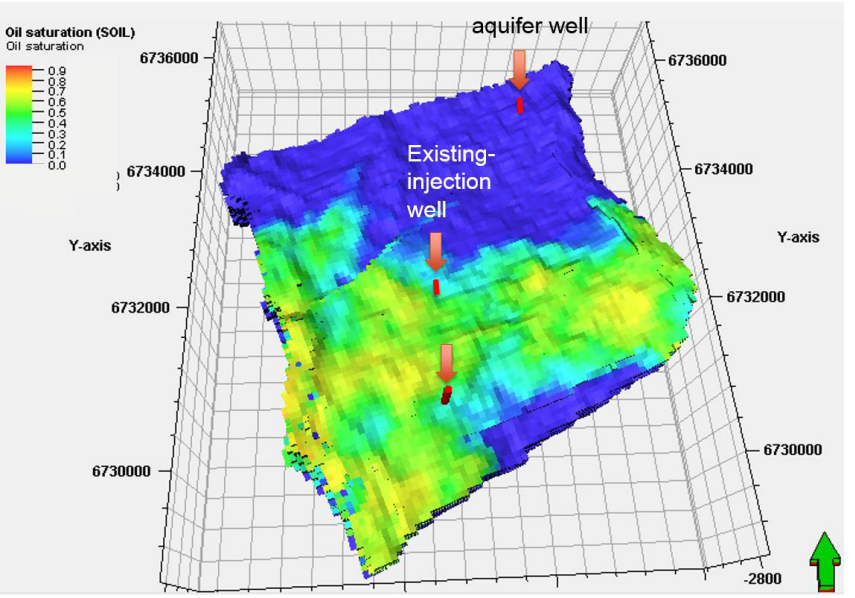

Fig. 2: reservoir model with different location of CO_2 well injection.

3. Results

The study results show that there is significant potential for enhance oil recovery and storage CO2 in oil fields in the North Sea. EOR projects help to extend the oil field life and therefor give better benefit for the field. More than 300 MSm3 oil can be produced by CO2 EOR results shown from screening studies that is big potential in the Norwegian Continental Shelf.

In the more detail study for one oil field in the North Sea shown in figure 5, several runs are then performed to test the sensitivity of the following parameters in the model of the studied oil field:

- Lateral location of the CO_2 injector; in the aquifer or in the oil zone, figure 2.
- Perforation intervals of the CO_2 injector; shallow, deep or all layer.
- CO_2 injection period; 5 or 20 years, both starting from 1.1.2020.

The base case recovery factor at the end of field life 2040 without CO_2 is estimated to be 29 %. The results of simulations for this model show that CO_2 injection in the oil zone gives better oil recovery than that of CO_2 injection in the aquifer.

- Results of sensitivities, the recovery factor is increased with a range of 0.4 % to 8.4 %, with one lowest value 0.4% for injection in aquifer and at the deeper part of the reservoir where the communication with main reservoir is very limited.
- The storage efficiency of CO_2 as an average of all sensitivities is shown very good with a range of 70 %-100 %.
- The test with CO_2 injection in the current gas injector resulted in an recovery factor of + 6.2 %
- If the CO_2 injection period in the oil zone is reduced from 20 to 5 years the following is observed:
  - ✓ Recovery factor goes from +7.5 % to +5.7 % in average for deep injection
  - ✓ Recovery factor goes from +7.7 % to +6.3 % for shallow injection

The storage efficiency goes from about 87 % to 71 % in average

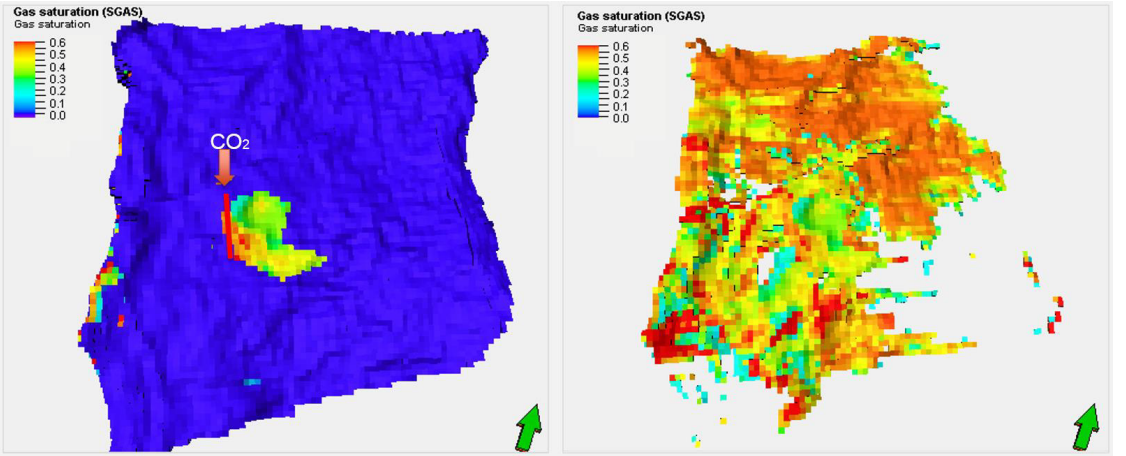

Fig. 3 CO_2/gass saturation is observed from the top of the reservoir (in the left) and the distribution of the gas in all layer of the reservoir (right) after stop injection of the case with 6.2% increase of oil recovery, 12 Mt CO2 injected in one existing-injection well and 87% of the gas is stored in the reservoir.

4. Summary

NPD performed several CO2 EOR studies from regional screening to more detail in individual oil field. The results show that there are big potential increase oil recovery in oil fields in the NCS by CO2 injection.

The results of the more detail study in the oil field shows a potential increase oil recovery average 4 % with CO2 gas injection and it can combine effectively with storage of CO2 gas when effect of storage CO2 gas shown is very high from 70% to 100%. The study shows that CO2 injection in the oil zone gives better recovery factor than that of CO2 injection far in the aquifer. A test with dry gas (CH4) injection is compared with CO2 gas injection indicates better microscopic sweep with CO2 injection than with dry gas injection.

Acknowledgements

Authors greatly acknowledge the colleagues in P-Deponi group NPD helping us to finish this study and the useful discussions that help to improve this paper. We are grateful to thank AGR's contribution to the study.

References

[1] E. K. Halland et al., "CO_2 Atlas Norwegian North Sea," Norwegian Petroleum Directorate, 2011.
[2] T. Eidvin, and Y. Rundberg, "Post-Eocene strata of the southern Viking Graben,northern North Sea; integrated biostratigraphic, strontium isotopic and lithostratigraphic study," Norwegian Journal of Geology, vol. 87, pp. 391-450, 2007.
[3] R. A. Chadwick, P. Zweigel, U. Gregersen et al., "Geological reservoir characterization of a CO_2 storage site: The Utsira Sand, Sleipner, northern North Sea," Energy, vol. 29, pp. 1371-1381, 2004/8//, 2004.