"Economics of CCS in the UKCS: CO_2-EOR with the Permanent Storage"

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1. Background

- The UK Government is not ready to support CCS with public money unless the cost of CCS technology is drastically reduced [1].
- The tertiary oil production with the anthropogenic CO_2 could reduce the CO_2 capture costs, as it is anticipated that oil producers would be willing to pay for CO_2 [2, 3].

2. Can the UKCS Repeat the Success of the CO_2-EOR in the Permian Basin of West Texas?

Description	U.S. onshore	UK offshore
Cost	Cheaper than offshore	All costs are much higher than onshore[4].
Source of CO_2	80% from natural CO_2 reservoirs [4,5]	Needs to be captured from the anthropogenic sources
CO_2-EOR Fiscal incentives	Economic and political measures arose in the 1970-1990s[6]: lower tax rate for EOR vs conventional production, and other tax credits [7].	No specific CO_2-EOR incentives, but other capital and investment allowances are present.
CO_2 Emission Reduction incentives	Tax credits for wind and solar energy installations, introduced in 1992 and 2005 respectively getting cancelled by 2019 and in 2021 respectively. Cap-and-trade system analogue to EU ETS operates in several states, there are no other incentives on the federal level [8].	Several legal and fiscal incentives exist to incentivise industry/public to reduce CO_2 emissions including Climate Change Levy and Climate Change Agreements, EU Emissions Trading System, Carbon Price Floor, Electricity Market Reform and Contracts for Difference [9].

3. Literature Review

- **van 't Veld et al. (2013):** theoretical CO_2-EOR model determining the optimal rates of CO_2 injection for an oil field in the U.S., model maximises project's NPV; analyses the impact of oil prices and CO_2 sequestration subsidies; endogenous project's lifetime [10];
- **Kemp & Kasim (2013):** analyses the economics of a cluster field development in the UKCS; considers the CO_2-EOR and permanent CO_2 sequestration phase; exogenous project's lifetime [11].

4. CO_2-EOR Model [8]

- **Maximise** NPV subject to:

  In & out flow balance:

  $$q_i^c(t) + q_i^w(t) = q_p^o(t) + q_p^c(t) + q_p^w(t) \quad \text{- (Eq. 1)}$$

  Constant overall injection rate:

  $$q_i \equiv q_i^c(t) + q_i^w(t) = const \quad \text{- (Eq. 2)}$$

- Oil production is described by a declining curve:

  $$q_p^o(t) = \delta(c(t))R(t) \quad \text{- (Eq. 3)}$$

  $$\delta(c(t)) = 0.06 + 0.2c - 0.16c^2 \quad \text{- (Eq. 4)}$$

- CO_2 fraction in the injection stream proportionally displaces oil produced:

  $$q_s^c(t) = c(t)\, q_p^o(t) \quad \text{- (Eq. 5)}$$

5. Model's Extension with Storage and Taxes

1) **Permanent CO_2 Storage phase is introduced:**

   The CO_2 storage capacity : $\sum q2_s^c(t) \leq CO2Store$ - (Eq. 6)

   $oper(t)$ and $seq(t)$ are binary variables.

2) **Taxes are introduced, T@40%, CT@17%:**

   $$NPV = -I + \sum_{t=0}^{K} \frac{(1-T)Profit^{CO_2\ EOR}(t)}{(1+r)^t} + \sum_{t=K}^{T} \frac{(1-CT)Profit^{Seq}(t)}{(1+r)^t}$$

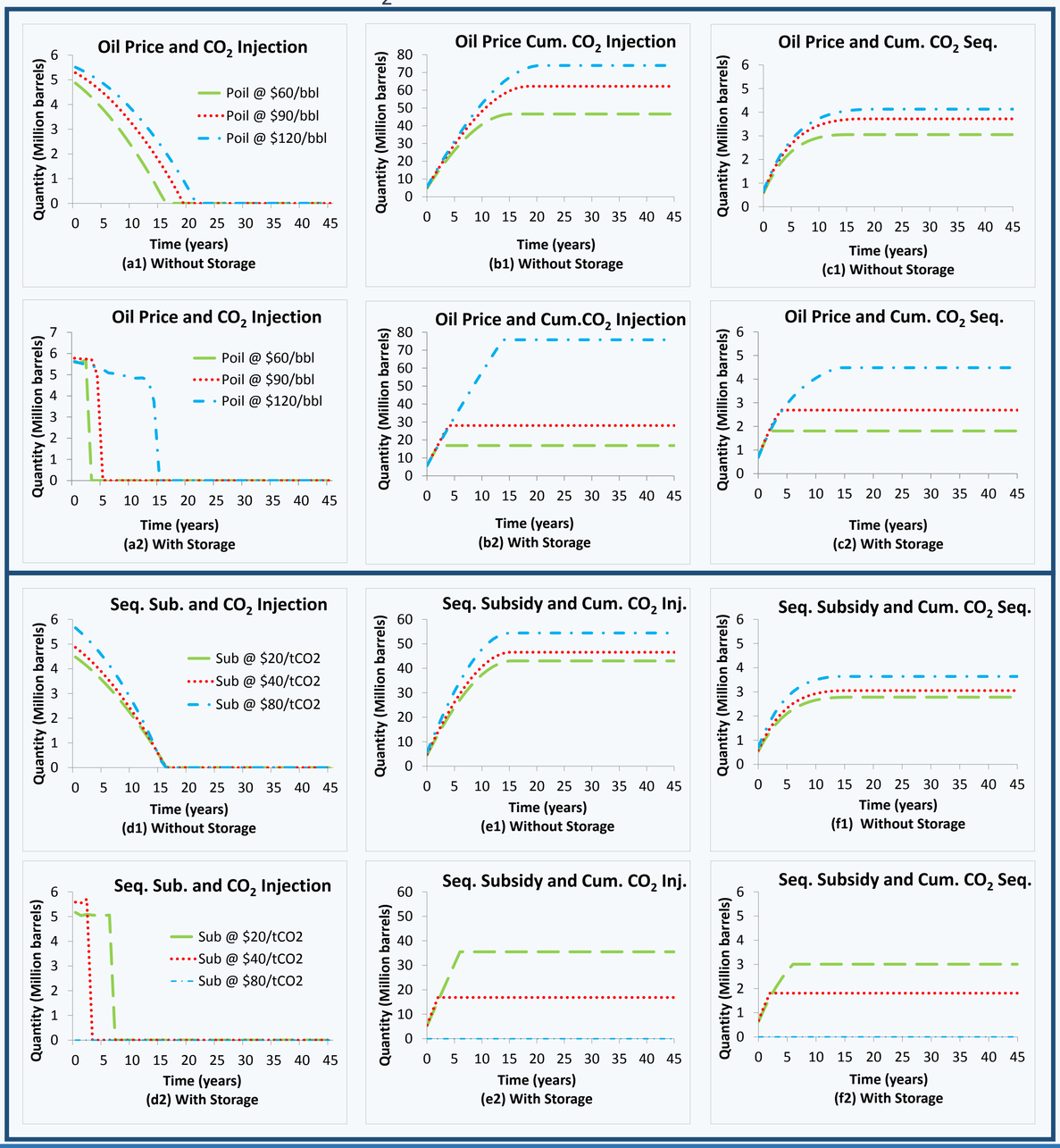
   K – Optimised switching point between the phases

6. Input Data

Symbol	Value	Description
I	10	Overall rate of injection and production (1 million barrels)
R_0	10	Initial stock of oil in reservoir (1 million bbl)
p_{CO_2}	4	Price of CO_2, \$/bbl
C_r	1	Cost of separating and recycling CO_2, \$/bbl
c_{oth}	1	Fixed costs (\$1 million)
r	0.05	Discount rate

7. Results

- A rise in the oil price substantially prolongs the duration of the CO_2-EOR phase of the project in both cases: with and without storage;
- The CO_2-EOR is very sensitive to changes in storage fee/subsidy: an increase in sequestration fee reduces the CO_2-EOR duration and starts the permanent storage.
- The cost of CO_2 does not significantly affect the switching point between the CO_2-EOR and permanent storage.
- The lower the overall rate of the marginal oil and gas tax the longer the duration of the CO_2-EOR.



9. References

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