Simulation of blue hydrogen production by natural gas in the North Sea

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Abstract

Hydrogen is an efficient energy carrier and an important contribution to sustainable energy development. Hydrogen can be produced based on different methods and on different raw materials. Blue hydrogen is hydrogen produced from natural gas via a steam-methane reformer with subsequent carbon capture and storage. The CO_2 from the process can be stored in matured oil and gas fields or in an aquifer.

This paper studies the potential of producing blue hydrogen from methane from the Troll gas field on the Norwegian continental shelf. The production rate of methane from the Troll field is predicted and based on the calculated methane production the steam-methane reformation process is modelled and simulated. The model includes the required steps to convert natural gas into hydrogen and CO_2 and further to catch the CO_2. The volume of captured CO_2 per m^3 of produced hydrogen is calculated. Production of blue hydrogen also includes storage of CO_2, and the required storage capacity is calculated.

The purpose of this paper was to investigate whether blue hydrogen produced by natural gas from the Troll field is an alternative to reducing CO_2 emissions to reach the climate target. The simulation was performed with Aspen HYSYS 12 and the calculation on how much CO_2 must be stored and the storage capacity needed were performed manually. The mass of CO_2 resulting from the conversion of about 2400 tons natural gas/h to blue hydrogen and CO_2 at the Troll field is 5600 tons CO_2/hour or 49 megatons CO_2/year. The produced hydrogen had a purity of 95%. The predicted storage capacity for CO_2 at the Troll field is found to be 136 megatons. A profitability analysis is performed and the results are promising.

1. Introduction

The main cause of climate change is the emissions of greenhouse gases such as carbon dioxide (CO_2), methane (CO_4) and nitrous oxide (N_2O) (European commission, 2023). However, the CO_2 emission is the largest contributor to global warming. The average temperature on earth has increased gradually by at least 1.1°C since 1880 and most of the warming has appeared since 1975 (Nasa.gov, 2023). If the increasing temperature is not limited to 1.5°C but reaches 2°C, serious consequences will arise. For instance, there will be less insect death which lead to less production of rice, corn and other food products. Likewise, there will be less fish in the seas since approximately 70% to 90% of coral reefs will die. Moreover, by 2050 over 300 million people will be affected by the rising seas. Reducing global greenhouse gas emissions will activate the temperature to fall back down and then the climate system probably stabilizes again (NPR, 2021).

For limiting the global temperature rise to 1.5 °C, the Paris Agreement has laid the foundation for the world to cut the greenhouse gas emissions by 45% by 2030 compared to the 2010 level (United Nation Climate Change, 2022) Norway was among 175 countries that have committed to the agreement. Norway is now further increasing the target by submitting to the UN ahead of the UN Climate Change Conference (COP27) in Egypt. The new target is to reduce emissions at least 55 % compared to the 1990 level by 2030 (Government.no, 2022)

The emissions that are focused on in this paper are CO_2 emissions from oil and gas extraction, which have a quantity of about 12.2 million tons CO_2 equivalents. It amounts to approx. 32% of the Norwegian CO_2-emissions (Statistics, Norway, 2023), (Mustafa *et al*., 2016). There are projects that will reduce the greenhouse gases in Norway such as Carbon Capture and Storage (CCS) at Norcem and Klemetsrud and renewable energy like hydropower, wind power, solar energy, and hydrogen.

Hydrogen is a highly efficient energy carrier and is emitting only water vapor when reacting with oxygen. Hydrogen is used in fields like petroleum refining, ammonia production, methanol production, power generation, and transportation. (Energy efficiency&renewable energy, 2023). To meet the Paris Agreement and the COP27 targets, it is required to develop cost-effective low CO_2 emission hydrogen production technologies. Hydrogen can be produced based on different methods and different raw materials, and is named black, grey, green, and blue hydrogen. Black and gray hydrogen is produced using coal and natural gas respectively, and without any CO_2 capture and storage (CCS). Green hydrogen is hydrogen produced from renewable resources. Blue hydrogen is hydrogen produced from natural gas in a gas reformer with CCS (National**grid**, 2023). Steam methane reforming, autothermal reforming, and natural gas decomposition are technologies used to produce blue hydrogen from natural gas. This paper focuses on steam methane reforming with CCS.

Norway is one of the largest exporters of natural gas in the world. Norway was in the third place in 2021 and covered approximately 23% of the gas demand in EU and United Kingdom. Norway exported about 122 billion Sm^3 of natural gas in 2022 and roughly 60% of Norway's natural gas resources have not yet been produced (Norwegian Petroleum, 2022). A large part of the natural gas production in Norway comes from the Troll field, which is the largest field in the North Sea (Equinor, 2023).

To achieve the climate target Norway must shut down some of its old oil and gas fields prematurely unless they can use carbon-free technologies to cut down their emissions (Reuters, 2022). This paper studies the potential of producing blue hydrogen from the Troll field by using the Aspen HYSYS V12 software. The paper covers a detail analysis to determine whether this process is an economically and environmentally friendly way of handling natural gas. In other words, this paper investigates whether the existing gas fields can be used to convert the natural gas to a clean, reliable and affordable hydrogen, instead of shutting them down. Norwegian Petroleum's website indicates that Troll produced 37.36 million Sm^3 o.e. natural gas in 2021 and this paper assumes that natural gas from the Troll field contains 92.74 vol.% Methane (CH_4), 1.83 vol.% CO_2, 0.0045 vol.% Nitrogen (N_2) 4.07 vol.% Ethane(C_2H_6) and 0.91 vol.% Propane (C_3H_8) (Aromada and Kvamme, 2019), (Norwegian Petroleum Troll, 2021).

2. Methodology

Gas reforming using steam is the most common and cheapest method of producing hydrogen and therefore over 95% of the world's production of hydrogen is based on the steam methane reforming process (SMR). There are process plants that have a production capacity of anywhere from 1 to 100 tons of hydrogen per hour. (Rapier, 2020), (Gupta, 2008)

2.1 Modelling of the steam methane reforming process

Gas reforming is a chemical process where natural gas is reacted with steam using a catalyst at quite high temperature to produce carbon monoxide (CO) and hydrogen (H_2) (Gupta, 2008).

The process starts with the natural gas being pre-treated, where organic sulphur compounds (thiols) are converted to hydrogen sulfide (H_2S), using a catalyst such as porous aluminium filled with cobalt (Co), nickel (Ni), molybdenum (Mo) and wolfram (W). The H_2S is removed from the stream by using a catalyst consisting of zinc oxide (ZnO). This step is used for preventing sulphur from polluting downstream catalysts (Gupta, 2008).

The sulphur-free natural gas is processed further in pre-reforming process which is the process that takes place before the reformer. In this process, the larger hydrocarbons are broken down into CH_4, CO_x and H_2 in an adiabatic reactor at a temperature around 300-525°C. The catalyst mass in the reactor consists of aluminium containing nickel. The advantage of pre-reforming is that the plant can run a natural gas feed stream with varying contents of larger hydrocarbons, and the steam-carbon ratio is reduced so that the effect of the plant is increased. The chemical reaction equation for hydrocarbons is (Gupta, 2008):

$$\mathrm{C_nH_m + nH_2O \rightleftharpoons nCO + \left(\frac{m+2n}{2}\right)H_2} \qquad \text{(Rn1)}$$

The natural gas, which now consists of mostly CH_4, CO_x and H_2 is mixed with steam having a pressure of approx. 20 – 26 bar. This mixture is heated before being fed to a catalytic reforming reactor which contains tubes filled with nickel catalyst. In the reformer, methane reacts with water and is converted to CO and H_2 according to the major steam reforming reaction (Rn2) and is then converted to CO_2 and H_2 according to the steam reforming reaction (Rn3) (Gupta, 2008).

$$\mathrm{CH_4 + H_2O \rightleftharpoons CO + 3}H_2 \quad \Delta H^0_{298} = +206kJ/mol \qquad \text{(Rn2)}$$

$$\mathrm{CH_4 + 2H_2O \rightleftharpoons CO_2 + 4H_2} \quad \Delta H^0_{298} = +165kJ/mol \qquad \text{(Rn3)}$$

The reactions are endothermic, which means that the reactions absorb energy from the surroundings, and the enthalpy change from the reaction requires approx. 206 kJ/mol for Rn2, and 165 kJ/mol for Rn3. These energies are supplied by burning some of the natural gas, but electricity (EL) should also be considered. The temperature required is between 700°C and 950°C. Low pressures are preferred for the reactions, but because most industries require H_2 at a pressure of at least 20 bar the reformer is run at a pressure around 20 to 26 bar. High pressures allow a more compact reactor design, increased reactor output, and reduced material costs. According to the stoichiometry in the reactions Rn2 and Rn3, the ratio between methane and steam is 1:1 and 1:2 on a molar basis. In practice, excess steam is used to prevent carbon build-up, hence the ratio1:2 for methane and steam is chosen in the HYSYS simulations (Gupta, 2008).

The steam reforming reactions Rn4 and Rn5 for C_2H_6 and C_3H_8 were not included in the stochiometric reactions in HYSYS V12.

$$C_2H_6 + 2H_2O \rightarrow 2CO + 5H_2 \tag{Rn4}$$

$$C_3H_8 + 3H_2O \rightarrow 3CO + 7H_2 \tag{Rn5}$$

The stream from the reforming stage consists of H_2, CO, CO_2, water vapor and a small proportion of CH_4 that has not been reformed. This stream is processed further in the water-gas shift reactors. Here, CO reacts with steam over a catalytic bed and produces H_2 and CO_2 as seen in reaction (Rn6). The lower temperature with respect to the reformer is needed for this reaction, since it is thermodynamically preferred at low temperatures. This is an exothermic reaction and emits 41.2 kJ/mol (Gupta, 2008).

$$CO + H_2O \rightleftharpoons H_2 + CO_2 \quad \Delta H^0_{298} = -41.2\ kJ/mol \tag{Rn6}$$

The excess water is separated from the gas stream by using a separator with low temperature. Here, the water vapor is condensed and leaves the separator in the gas stream. The H_2 and the CO_2 flows are separated by capturing the CO_2 with monoethanol-amine (MEA) in an absorption tower. The CO_2 will be stored in the reservoir or an aquifer, and H_2 is further sent to a purification process. The remaining CO_2 and CO are removed in a final step called methanisation, where these components are converted into CH_4 as shown in Rn7 and Rn8 (Gupta, 2008).

$$CO + 3\,H_2 \rightleftharpoons CH_4 + H_2O \tag{Rn7}$$

$$CO_2 + 4\,H_2 \rightleftharpoons CH_4 + 2H_2O \tag{Rn8}$$

The stream can be processed further in an activated carbon adsorber to separate CH_4 from the H_2 product. The CH_4 stream is then recycled to the reformer. If the final stream has only H_2 as the product, the recirculation can be skipped. Fig. 1 shows the hydrogen reforming process using the Aspen HYSYS V12. The model includes the required steps to convert natural gas into hydrogen and CO_2. Then the CO_2 is captured with amine-based solution and converting a small proportion of CO back to CH_4. In the simulation, the main processes occur in the reformer, two water-gas shift reactors, a separator, a CO_2 absorber and a methanator. However, there are some processes that are not included in the simulations such as the pre-treatment process, the pre-reforming process, and the activated carbon adsorption process.

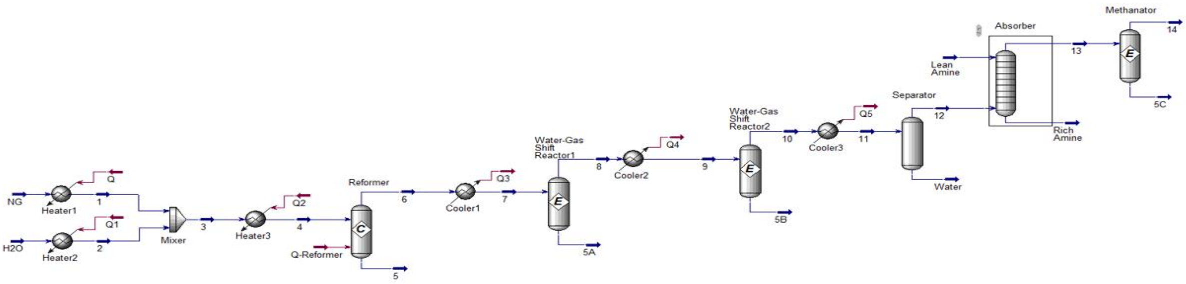

Figure 1: Steam reforming process Aspen HYSYS V12 simulation

2.2. CO_2 storage capacity

A technology for reducing CO_2 emissions is called geological carbon sequestration (GCS) (Lackner, 2003), (Schrag, 2007). Deep saline aquifers have large storage capacity and is therefore well suitable for GCS (Bachu, 2003). However, to ensure a safe utilization of CGS to a particular aquifer, an accurate calculation of the storage capacity of the aquifer is required. Different models can be used to calculate the storage capacity of CO_2 in an aquifer. In this study a model developed by Szulczewski and Juanes (Szulczewski and Juanes, 2009) is used to calculate the mass of trapped CO_2. The model is simple and robust and includes some assumptions to be made. The reservoir is assumed to be horizontal, homogeneous, and isotropic. Other assumptions are that the injected CO_2 follows the direction of the groundwater and that the viscosities and densities of the fluids are constant. It is also assumed that there is a sharp interface between the CO_2 plume and the brine. The storage capacity, C, is calculated from:

$$C = \left[\frac{2M\Gamma^2(1-S_{cw})}{\Gamma^2 + (2-\Gamma)(1-M+M\Gamma)}\right]\rho_{CO_2}\varphi HWL_{tot} \tag{1}$$

where M is the mobility ratio, Γ is the trapping coefficient, S_{cw} is the connate water saturation, ρ_{CO_2} is the density of CO_2, φ is the porosity, H is the thickness of the sandstone, W is the length of the injection array, and L_{tot} is the total length of the simulated reservoir. The storage efficiency, which is the term in brackets in Equation (1), relates the total pore volume to the volume of trapped CO_2. The mobility ratio is expressed as:

$$M = \frac{1/\mu_w}{k^*_{rg}/\mu_{CO2}} \tag{2}$$

where μ_w and μ_{CO2} are the viscosity of brine and CO_2, and k^*_{rCO2} is the endpoint relative permeability of supercritical CO_2. The trapping coefficient, Γ, is defined as:

$$\Gamma = \frac{S_{rCO2}}{1-S_{cw}} \tag{3}$$

where S_{rCO2} is the residual saturation of CO_2 and S_{cw} is the connate brine saturation. The CO_2 storage model developed by (Szulczewski and Juanes, 2009) also includes an equation for the CO_2 footprint. The equation calculates how far the CO_2 plume migrates away from the injection array when it is completely trapped. The distance is expressed as:

$$L_{max} = \left[\frac{(2-\Gamma)(1-M(1-\Gamma))}{(2-\Gamma)\big(1-M(1-\Gamma)\big)+\Gamma^2}\right] L_{tot} \quad (4)$$

The CO_2 footprint is illustrated in Fig. 2. The injection footprint has a length, L_{inj}, and is defined as the distance the CO_2 plume is moving during the injection period and is expressed by:

$$L_{inj} = L_{tot} - L_{max} \quad (5)$$

The injection footprint is marked with darker blue in Fig. 2. The light blue area in the figure presents the trapped CO_2 footprint and has an extent L_{max}. The blue arrays show the groundwater flow direction.

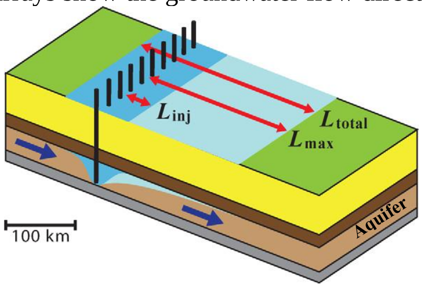

Figure 2: Injection and trapped CO_2 footprints

3. Results and discussion

3.1. Steam methane reforming process simulation

The Peng Robinson equation of state was selected for the simulations due to the types of gas components, chemical reactions and equipment used. A conversion reactor was selected as the reformer and an equilibrium reactor was selected as the Water-Gas Shift reactors and the Methanator. The methane to steam ratio, the pressure (P), and the temperature (T) were adjusted following the methodology in order to achieve the optimum results.

The calculation of energies used for both heating and cooling in the system is done in term of electricity. The heating and cooling duties required to operate at optimal conditions were computed by the HYSYS V12 simulator by adjusting the temperatures in and out of the reactors, the coolers, and the heater. Based on this, the electricity cost was calculated in Excel, by assuming that the electricity price was 0.5 NOK per kWh. The obtained results are shown in Tab. 1.

Table 1: Heat duties of reformer, heaters and coolers from HYSYS simulations. Electricity costs using 0.5 NOK/kWh

El for Heating		**El for cooling**	
Energy Stream	Duty [kW]	Energy Stream	Duty [kW]
Q	405900	Q3	3170000
Q1	511300	Q4	1119000
Q2	1329000	Q5	1700000
Q-Reformer	7297000		
Total:	9543200	Total:	5989000
Cost:	$4.18*10^{10}$ [NOK/year]	Cost:	$2.62*10^{10}$ [NOK/year]

The gas components in and out of the reformer, the water-gas shift reactors, the separator, the absorber and the methanator were likewise computed by the HYSYS simulator, where 85% efficiency was chosen for the reformer. Tab. 2 shows the obtained results where the produced CH_4 was converted into 69.54% H_2 after going through the reformer and the two water-gas shift reactors. The concentration of H_2 increased to 95.33% after passing the purification and methanation process.

Table 2: HYSYS simulation output data for the reformer, Water-Gas Shift reactors, separator, absorber and methanator

Component	**Feed**		**Reformer** $\eta = 0.85$	**Water-Gas Shift reactors**		**Separator**	**Absorber**	**Methanator**	
	Ng		Outlet gas 6	Outlet gas 8	Outlet gas 10	Outlet gas 12	Outlet gas 13	Outlet gas 14	
	Molar percent (%)	Molar flow rate [kmol/h]	Molar percent (%)	Molar percent (%)	Molar percent (%)	Molar percent (%)	Molar percent (%)	Molar percent (%)	Molar flow rate [kmol/h]
CH_4	0.9274	148940	0.0309	0.0309	0.0309	0.0335	0.0331	0.0394	19739
CO_2	0.0183	2938	0.0915	0.1490	0.1747	0.1894	0.0001	0.0001	39
CO	-	-	0.0875	0.0300	0.0043	0.0047	0.0058	-	-
H_2	-	-	0.6122	0.6697	0.6954	0.7542	0.9596	0.9533	477946
H_2O	-	-	0.2659	0.1084	0.0827	0.0052	-	0.0058	2932
N_2	0.0045	722	0.0010	0.0010	0.0010	0.0011	0.0013	0.0014	679
C_2H_6	0.0407	6536	0.0090	0.0090	0.0090	0.0098	-	-	16
C_3H_8	0.0091	1461	0.0020	0.0020	0.0020	0.0022	-	-	0.0002

3.2. Net profit calculations.

Since this paper assumes that the natural gas from the Troll field contains 92.74 vol% CH_4 and that Troll produced 37.36 million Sm^3 o.e. natural gas in 2022, then the mass flow rate of CH_4 is calculated to be approximately 2400 tons/h or 148940 kmol/h. After the gas stream is passing through the steam reforming process the concentration of the H_2 in the final product is 95.33 % which corresponds to about 960 tons/h or 8444000 tons/year.

Different price ranges in the market provide different incomes from selling the blue hydrogen. Tab. 3 shows the estimated income based on various hydrogen prices where the highest income from selling hydrogen is $1.235 \cdot 10^{12}$ NOK/year when the sale price is 195 NOK/kg. According to (glpautogas.info, 2023) the average price of hydrogen in Norway in August 2023 is 195 NOK/kg. This is the price for the customers at the hydrogen refueling stations. The price is including 25% VAT, which means that the real income is 146.25 NOK/kg.

Table 3: Income from selling H_2

Amount H_2		Without VAT 25%	
$8.444 \cdot 10^9$ [kg/year]	Sale Price [NOK/kg]	Real price [NOK/kg]	Income [NOK/year]
Alternative 1	159	119.25	$1.007 \cdot 10^{12}$
Alternative 2	195	146.25	$1.235 \cdot 10^{12}$

The other income comes from using CCS in the process. Hence, there is a price that emitters must pay per tonne of CO_2 emission. This price is the summation of the carbon tax and the emission trading system set by the government. Hence, carbon emissions have a cost, and reducing CO_2 in the process will reduce this cost (avoided cost). This reduction in costs can count as an income to the project (Norwegian Petroleum, emissions, 2022). In Norway, the companies pay approximately 1100 NOK/ton for their CO_2 emissions (Norwegian Petroleum, emissions, 2022). The process simulation results show that the blue hydrogen process at the Troll field can help to reduce the greenhouse gases by almost 49 megaton CO_2 per year (5600 tons CO_2/h) which corresponds to $5.39 \cdot 10^{10}$ NOK/year. The net profits which is the sum of income from selling H_2 and the profit from reducing CO_2 emission are shown in Fig. 3, where the income level is between $1.06 \cdot 10^{12}$ to $1.29 \cdot 10^{12}$ NOK/year.

3.2. Calculation for utilities cost with various electricity price in Norway.

There is uncertainty related to electricity price in Norway since the price is higher in the winter and lower in the summer and changing all day. Therefore, the electricity cost was calculated with a considerable range of electricity prices (0.5 NOK /kWh, 1NOK /kWh and 1.50 NOK/kWh) to cover the large variations. The obtained results are shown in Fig. 4.

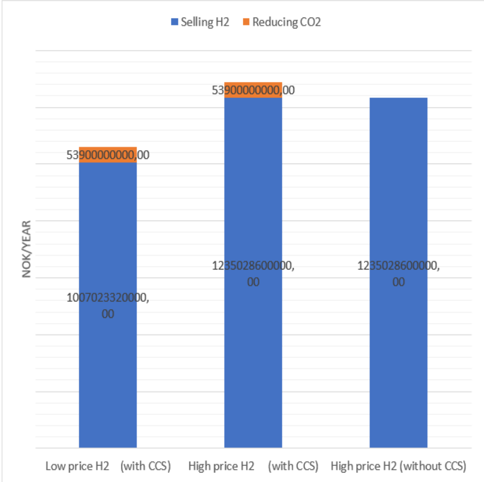

Figure 3: Net income from the H_2 production.

Figure 4: Utilities cost for various electricity prices in Norway

3.3. Production costs and operating costs for hydrogen production and CCS.

There are costs related to production and operation for hydrogen production and CCS. Other costs are maintenance and transportation costs that will affect the net profit of the project. In order to be able to calculate the financial impacts of converting natural gas to H_2, it is necessary to take all negative and positive cash flows into account.

However, there are some uncertainties about these values, and therefore only the estimation of the production cost will be present in this section. As seen in Tab. 5 the production cost varies from $1.10 \cdot 10^{11}$ to $2.29 \cdot 10^{11}$ NOK/year when the H_2 production is $8.445 \cdot 10^9$ kg/year. The exchange rate from US$ to NOK is used as 10.64 NOK/US$. Alt. 1 in Tab. 5 is based on data from a Norwegian report (Klimastiftelsen, 2021) and the estimated production cost includes CCS. Alt.2, Alt.3 and Alt. 4 are presented by (Oni *et al.*, 2022). All the alternatives are based on production of hydrogen from steam methane reforming.

Table 5: Estimates of H_2 production costs. The (Bjartnes *et al*., 2021), (Oni *et al*., 2022).

Amount H_2 $8.445\cdot10^9$ [kg H_2/year]	H_2 production price rate [NOK/kgH_2]	Production costs [NOK/year]
Alt.1(CCS)	17.02	$1.44\cdot10^{11}$
Alt.2(0% CCS)	12.98	$1.10\cdot10^{11}$
Alt.3(52% CCS)	17.66	$1.49\cdot10^{11}$
Alt.4(85% CCS)	27,13	$2.29\cdot10^{11}$

3.4. Profitability analysis

Gas reforming requires energy, which results in lower profitability, but when using CCS, savings from climate taxes can be greater than the expenses. There are some uncertainties regarding these values including some concerns related to simplifying the gas composition of natural gas, which have an impact on the economic perspective. Also, the amount of H_2 produced and the amount of captured CO_2 will be important factors when it comes to assessing the profitability.

There are many factors that can affect the profitability, including the transportation and the price of hydrogen. There are other costs that are not included in this study, such as maintenance cost, deprecitation of investment cost, equipment cost and installation cost for the blue hydrogen process. However, based on the assumptions and calculations that have been made, the profit is large. This means there are good opportunities to produce blue hydrogen from natural gas from the Troll field. For the best-case scenario, the earning after paying the utility and the production costs is $1.11\cdot10^{12}$ NOK/year and for the worst-case scenario the earning is $5.74\cdot10^{11}$ NOK/year.

3.5 CO_2 storage capacity at the Troll field

The storage capacity at the Troll field is calculated based on the Szulczewski and Juanes model (Szulczewski and Juanes, 2009) and is compared to the CO_2 production from the blue hydrogen process.

The density and viscosity of supercritical CO_2 and brine are calculated based on the temperature and pressure at the Troll field which is given as 60 °C and 100 bar, respectively. The thickness of the sandstone (H), the porosity (φ), the total extent of the CO_2 plume (L_{total}) and the length of the injection formation (W) have been chosen based on older available data from the Troll field. The input parameters for the storage calculations are given in Tab. 6. The calculated storage parameters are presented in Tab. 7.

Table 6: Input parameters for calculating CO_2 storage capacity.

Parameter	
ρ_{CO2}	290 kg/m^3
μ_{CO2}	$2.374\cdot10^{-5}$ Pa·s
μ_W	0.00046 Pa·s
S_{rCO2}	0.3
S_{cw}	0.3
φ	0.27
W	40 000 m
H	30 m
L_{tot}	100 000 m
k^*_{rCO2}	0.55

Table 7: Results from the storage capacity calculations.

Parameter	
M	0.0938
Γ	0.4286
E	1.44%
C	$1.36\cdot10^{11}$kg CO_2
L_{max}	89 000 m
L_{inj}	11 000 m

It was not possible to find data for the dimensions of the aquifer under the Troll field, and the storage capacity is therefore calculated based on assumed H, W and L_{tot}. The aquifer under the Troll gas field is most proparly much larger, and the calculated storage capasity is highly underpredicted.

The mass of CO_2 resulting from the conversion of 2400 tons natural gas/h to blue hydrogen and CO_2 at the Troll field is 5600 tons CO_2/h or 49 megatons CO_2/year. The calculated storage capacity for CO_2 at the Troll field is found to be 136 megatons. This gives a perspective on the required storage space and the potential for CO_2 storage at the Troll field.

4. Conclusion

The purpose of this paper is to investigate whether blue hydrogen produced by natural gas from the Troll field is an alternative to reducing CO_2 emissions and thereby contribute to reach the climate target. The prosess of converting naturalgas to blue hydrogen is modelled, and simulations were performed using Aspen Hysys 12. The model includes the required steps to convert natural gas into hydrogen and CO_2 and further to catch the CO_2. Conversion of about 2400 tons natural gas/h gave 960 tons/h of blue hydrogen with a purity 95%, and 5600 tons /h of CO_2 (49 megatons CO_2/year).

The predicted storage capacity for CO_2 at the assumed Troll field is found to be 136 megatons. However, the aquifer under the Troll gas field are most probable much larger and have a much higher storage capasity than predicted here.

There are good opportunities for blue hydrogen production from natural gas fields in the North Sea. The profit is calculated and the results are promising.

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