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Best Energy Paper Competition 2023
Underground Hydrogen Storage: Effect of Hydrogen on Saline Aquifer and Depleted Hydrocarbon Reserves

Prepared by: Abiodun Abimbola
MSc Drilling and Well Engineering
Presentation Outline

• Project Background
• Aim and Objectives
• Methodology
• Results
• Conclusions and Recommendations
Project Background

• Hydrogen's ability to balance variable renewable energy makes it crucial for global net-zero goals

• Global hydrogen value chain success relies on sufficient storage capacity and functionality

• A key challenge is hydrogen's low volumetric density, requiring extensive storage for rising energy needs
To overcome these hurdles, diverse hydrogen storage technologies must be developed for various industrial, transportation, and electricity uses.

UHS enables terawatt-hour scale storage in formations like salt caverns, saline aquifers, and depleted oil and gas reservoirs.

Selecting UHS sites requires detailed geological surveys considering depth, impermeability, pressure, rock properties, and suitable caprocks.

Global Map Showing Sedimentary Basins Identified as Potential Sites for Geological Hydrogen Storage Worldwide
Aim and Objectives

**Aim**

- To explore the geochemical effects of hydrogen on saline aquifers and depleted hydrocarbon reservoirs

**Objectives**

- Investigate geochemical reactions between aquifer rocks, brine, and hydrogen in saline aquifers
- Examine geochemical reactions between reservoir rocks, residual formation fluids (oil and gas), and hydrogen in depleted reservoirs
- Analyse the petrophysical impact on the rocks
- Explore the rock suitability for Hydrogen storage
Methodology

• Data and Mineralogical composition sourced from Utsira formation within the Sleipner Field in the North Sea

• A geochemical modelling software PHREEQC was utilized for this analysis

• A 1D batch model replicated geochemical interactions of hydrogen, brine, and gas in sandstone

• Simulations used two methods: equilibrium and kinetic approaches
Mineral composition of sandstone used in this model

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Modelled Mineral</th>
<th>Mass Fraction %</th>
<th>Molecular weight, g/mol</th>
<th>Amount mol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>Quartz</td>
<td>76.19</td>
<td>60.083</td>
<td>1.268</td>
</tr>
<tr>
<td>K-feldspar</td>
<td>K-feldspar</td>
<td>6.92</td>
<td>278.33</td>
<td>0.025</td>
</tr>
<tr>
<td>Calcite</td>
<td>Calcite</td>
<td>6.72</td>
<td>100.09</td>
<td>0.067</td>
</tr>
<tr>
<td>Mica</td>
<td>Illite</td>
<td>5.20</td>
<td>1509.5</td>
<td>0.003</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>Albite</td>
<td>3.00</td>
<td>263.02</td>
<td>0.011</td>
</tr>
</tbody>
</table>
Analysis and Results

Static Equilibrium Simulation

• Quartz, Albite, and K-feldspar remain stable, illite and calcite dissolve as a result of the reaction.

• These changes mainly impact minor fractions of the rock's mineral composition, with quartz and K-feldspar constituting over 90% of the sandstone.

Fig. 1: Rock Mineral Saturation indices in relation to pH
Fig 2: Precipitation of CH4 as hydrogen concentration increases in a saline aquifer.

Fig 3: Precipitation of CH4 as hydrogen concentration increases in a depleted hydrocarbon reservoir.
Kinetic Model

- Quartz and illite do not reach saturation within the modelled years.

- K-feldspar, calcite, and albite reach saturation in the fourth, one, and ninth year, respectively.

- High reactivity was observed in all minerals within 10 years, after which the system stabilized.

- Changes proceeded at a prolonged rate afterward.

Fig 4: Saturation index of the primary minerals over 30 years
Fig 5: Geochemical simulation of sandstone mineral dissolution in a brine-hydrogen fluid
Effect on Porosity and Permeability

• The reservoir's porosity increased by 2.8% over the course of 15 years, but there was no further increase in porosity observed during the subsequent 15 years.

• Under the same reservoir conditions, the permeability can increase by up to 13.2% relative to its first value.

Fig 6: Hydrogen's Kinetic Impact on Reservoir Porosity and Permeability Over 30 Years
Conclusions and Recommendations

• Equilibrium models found no major impacts on the reservoir's integrity, observing minor changes in some minerals due to hydrogen interaction

• Hydrogen's geochemical reactions have no long-term impact on abundant minerals like quartz and K-feldspars. Dissolution of primary minerals increases rock porosity and permeability, stabilizing after 15 years in the reservoir

• The dissolution of major minerals is less than 1% over 30 years, indicating their stability when exposed to hydrogen

• The study highlights potential biotic reactions under Utsira formation's conditions, which might cause hydrogen loss and reservoir instability

• Further research can be carried out to study the impact of microbial activities on underground hydrogen storage
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Economic Analysis of Decommissioning Oil Fields: A Case Study of UKCS

Taiwo Samuel Onanubi (ACA)  
Msc Petroleum, Energy Economics and Finance  
University of Aberdeen  
21 November 2023
Oil fields in the UKCS have matured
Matured oil fields will require decommissioning
Uncertainties in key parameters e.g. oil price, Production decline rates decommissioning cost etc.
Environmental sustainability
Economic efficiency
North Sea Transition Authorities (NSTA) decommissioning strategy
Uncertainty in fiscal policy
Possible Criteria for Making Decommissioning Decisions

**Negative Net-profit**
Oil field decommissioning should be considered when operating cost surpasses actual gross revenue generated.

**Minimum Margin on ongoing Expenditures**
Based on the assumption that oil field should generate sufficient income to cover all cost incurred, including an acceptable profit margin.

**Maximization of the Remaining NPV**
This approach involves conducting a comprehensive evaluation of all future costs and revenues, specifically taking into account decommissioning costs.
## Economics of Mothballing

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assume COP</td>
<td>Assumes that the company will cease production when cost surpasses revenue</td>
</tr>
<tr>
<td>Cold Stack Transition</td>
<td>Transition the oil field to cold stack status by incurring plug and abandonment cost (P&amp;A cost)</td>
</tr>
<tr>
<td>Incur only maintenance cost</td>
<td>Incurring only maintenance costs inline with environmental guidelines</td>
</tr>
<tr>
<td>Postpone decommissioning</td>
<td>Strategically postponing decommissioning activities to a later date</td>
</tr>
<tr>
<td>Maximize remaining NPV</td>
<td>Optimize the remaining NPV</td>
</tr>
</tbody>
</table>

Mothballing model: Effect of delay on removal cost  
*Source: Kemp, 1997*
Assessment of optimal decommissioning time

❖ Analyses the influence of taxes
❖ Fluctuations in decommissioning cost

To Propose an analytical approach for abandonment decision

❖ Considers risk and uncertainties
❖ Operator flexibility

Source: Shell - Brent field decommissioning
Methodology

Three (3) Oil Fields were modelled to reflect the behaviours of UK continental shelf assets of recent vintage

**Small field**
- 10MMbl Reserves
- DEVEX @ 19 USD/bbl
- OPEX @ 5% DEVEX
- DECOMX @ 10% of DEVEX

**Medium field**
- 50 MMbl Reserves
- DEVEX @ 12 USD/bbl
- OPEX @ 5% DEVEX
- DECOMX @ 10% of DEVEX

**Large field**
- 100 MMbl Reserves
- DEVEX @ 10 USD/bbl
- OPEX @ 5% DEVEX
- DECOMX @ 10% of DEVEX

The Total Culzean platform is pictured in the North Sea
Source: Commondreams.org
Methodology Continued: DCF Model

**Deterministic Model Analysis**
- Assume a base year
- Calculate the remaining NPV

**Stochastic Model Analysis**
- Assume a base year
- Determine stochastic distributions
  - decommissioning cost (triangular)
  - maintenance cost (uniform)
  - oil price (lognormal)
- Calculate the remaining NPV
- Monte Carlo simulation

**Sensitivity Analysis**
- Determine variations of remaining NPV in input variables
Results: Deterministic Model

There is an incentive to postpone at from 2.5% discount rate

The incentive is more as the discount rate increases

<table>
<thead>
<tr>
<th>Discount factor @ %</th>
<th>t</th>
<th>t+1</th>
<th>t+2</th>
<th>t+3</th>
<th>t+4</th>
<th>t+5</th>
<th>t+6</th>
<th>t+7</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>61.5</td>
<td>61.3</td>
<td>61.2</td>
<td>60.8</td>
<td>59.8</td>
<td>58.7</td>
<td>57.8</td>
<td>56.5</td>
</tr>
<tr>
<td>2.5%</td>
<td>58.9</td>
<td>59.5</td>
<td>50.1</td>
<td>50.0</td>
<td>49.4</td>
<td>48.8</td>
<td>48.2</td>
<td>47.6</td>
</tr>
<tr>
<td>5%</td>
<td>51.2</td>
<td>52.0</td>
<td>52.8</td>
<td>47.3</td>
<td>44.7</td>
<td>44.1</td>
<td>43.6</td>
<td>42.9</td>
</tr>
<tr>
<td>7.5%</td>
<td>46.7</td>
<td>47.6</td>
<td>48.4</td>
<td>45.3</td>
<td>44.4</td>
<td>43.8</td>
<td>43.1</td>
<td>42.3</td>
</tr>
<tr>
<td>10%</td>
<td>38.4</td>
<td>39.2</td>
<td>39.8</td>
<td>40.4</td>
<td>41.0</td>
<td>41.6</td>
<td>42.3</td>
<td>42.9</td>
</tr>
<tr>
<td>12%</td>
<td>37.3</td>
<td>37.6</td>
<td>37.8</td>
<td>38.0</td>
<td>38.2</td>
<td>38.3</td>
<td>38.5</td>
<td>38.7</td>
</tr>
<tr>
<td>15%</td>
<td>29.2</td>
<td>29.9</td>
<td>30.6</td>
<td>31.2</td>
<td>32.4</td>
<td>33.5</td>
<td>34.0</td>
<td>34.6</td>
</tr>
</tbody>
</table>
Results: Stochastic Model

Distribution of the remaining NPV

The large field has a mean NPV of £233 million

Red shade indicate the probability of negative remaining NPV

Blue shade indicate the probability of positive remaining NPV

The field should be decommissioned at year eight

Large field remaining NPV distribution and cumulative distribution
Source: Output from Crystal Ball
Sensitivity analysis is based on variations in input variables

- Decommissioning cost @ 20% of CAPEX
- Discount factor @ 15%
- Maintenance cost @ 5% of OPEX
Impact of Energy Profit Tax

No tax is paid in Year 1 and 2

Supplementary charge is the least

Energy profit levy has the major tax effect
Conclusions

Investors can choose to mothball

Government policy should entail granting reliefs for decommissioning cost

Risk and uncertainty impacts the remaining NPV
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Sensitivity Analysis of Operational Parameters on an Advanced Geothermal Energy Storage System

Agga Agga
MSc Oil and Gas Engineering
Energy Institute Best MSc Student Paper Competition
Special Thanks to

Kirsten Pasturel, Kenny Watt, Gillian White (ZeGen Energy)

William Harrar (Ross Offshore DK)
Presentation Outline

1. Project Background
2. Rationale for Project Work
3. Aim & Objectives
4. Methodology
5. Results and Analysis
6. Conclusions & Recommendations
Project Background

- Ability to Store Energy
  - Thermal Energy → Subsurface Reservoirs
- Numerous Methods and Nomenclature
- Thermal Energy Storage Principle

Fig 1 – A basic conceptual model of an AGES system (Jello et al. 2022)
Rationale for Project Work

- General Mismatch in Energy Generation and Energy Use
- Lack of Transmission Availability and System Balancing Challenges (Bird et al. 2016)

### Table 1 – Statistics for Curtailment of Wind Energy for countries in 2013 (Bird et al. 2016)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>Canada</th>
<th>China</th>
<th>Denmark</th>
<th>Germany (2012)</th>
<th>Ireland</th>
<th>Italy</th>
<th>Japan</th>
<th>Portugal</th>
<th>Spain</th>
<th>Sweden</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind Generation (GWh)</td>
<td>17,500</td>
<td>142,000</td>
<td>11,100</td>
<td>50,600</td>
<td>5,872</td>
<td>14,811</td>
<td>4,000</td>
<td>11,900</td>
<td>54,338</td>
<td>9,900</td>
<td>167,840</td>
</tr>
<tr>
<td>Wind/Electricity Generation</td>
<td>3.1%</td>
<td>2.6%</td>
<td>31.9%</td>
<td>9.8%</td>
<td>22.5%</td>
<td>5.1%</td>
<td>0.4%</td>
<td>23.0%</td>
<td>19.2%</td>
<td>6.5%</td>
<td>4.1%</td>
</tr>
<tr>
<td>Wind Curtailment (GWh)</td>
<td>-</td>
<td>16,230</td>
<td>-</td>
<td>358</td>
<td>196</td>
<td>152</td>
<td>-</td>
<td>-</td>
<td>1,166</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wind Curtailment/Generation</td>
<td>-</td>
<td>11%**</td>
<td>-</td>
<td>0.7%</td>
<td>3%</td>
<td>1%</td>
<td>-</td>
<td>-</td>
<td>2%</td>
<td>-</td>
<td>1.3%**</td>
</tr>
</tbody>
</table>

*Electricity generation statistics were sourced from national/regional resources for each country. Canadian energy generation values and wind generation data were sourced from the IEA Wind 2013 Annual Report [23]. European countries, including Denmark, Ireland, Italy, Portugal, Spain, and Sweden were sourced from total gross electricity generation statistics provided by Eurostat [24]. China electricity generation was sourced from the China Electricity Council [25]. Germany electricity generation was sourced from a 2013 monitoring report from Bundesnetzagentur [7]. Electricity generation information for Japan [26] and the United States [27] was sourced from the U.S. Energy Information Administration.

**Curtailment levels vary across individual balancing areas.
Aim
Propose Optimum Field Development Strategy for Implementation of AGES System

Objectives

• Develop
  • Static Reservoir Model
  • Dynamic Reservoir Model

• Identify Key Operational Parameters
  • Injection/Production Mass Flow Rate
  • Injection Fluid Temperature
  • Maximum Cycle Part Durations
  • Well Patterns

• Sensitivity Analysis
  • Technical Yardsticks
    • Thermal Storage Energy Efficiency
    • Average Power and Electricity Generation
  • Economic Yardsticks
    • Net Present Value (NPV)
    • Levelized Cost of Energy (LCOE)
Methodology

• Drainage Area of Study

• Static & Dynamic Reservoir Modelling

• Sensitivity Analysis

• Technical and Economic Yardsticks
Methodology – Drainage Area of Study

Fig 2 – Wells that Penetrate the Gassum Formation (GEUS 2023)

Fig 3 – Assumed Combined Drainage Area

Fig 4 – Formation Surface Tops for the Assumed Combined Drainage Area
Table 2 – Average reservoir properties of the Gassum Formation penetrated by Borglum-1 and Flyvberg-1 as analysed by GEUS 2023

<table>
<thead>
<tr>
<th>Properties</th>
<th>Borglum-1</th>
<th>Flyvberg-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Porosity (%)</td>
<td>29.3</td>
<td>-</td>
</tr>
<tr>
<td>Avg Reservoir Temperature (degC)</td>
<td>44</td>
<td>42</td>
</tr>
<tr>
<td>Formation Thickness (m)</td>
<td>155</td>
<td>197</td>
</tr>
<tr>
<td>Potential Sands (m)</td>
<td>82</td>
<td>-</td>
</tr>
</tbody>
</table>

Fig 6 – Single Phase ‘Rel-Perm’ Curve

Table 3 – Initialisation Conditions

<table>
<thead>
<tr>
<th>Initialisation Conditions</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Datum Depth - FWL</td>
<td>972 m</td>
</tr>
<tr>
<td>Pressure at Datum Depth</td>
<td>102.6597 bar</td>
</tr>
<tr>
<td>Capillary Pressure at FWL</td>
<td>0 bar</td>
</tr>
<tr>
<td>Geothermal Gradient</td>
<td>27 degC/km</td>
</tr>
</tbody>
</table>
## Methodology – Sensitivity Analysis

### Table 4 – Operating Conditions for Different Simulation Cases

<table>
<thead>
<tr>
<th>Operation Conditions</th>
<th>Base Case Model</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection Mass Flow Rate (kg/s)</td>
<td>10</td>
<td>40</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Injection Fluid Temperature (degC)</td>
<td>90</td>
<td>90</td>
<td>250</td>
<td>90</td>
</tr>
<tr>
<td>Production Mass Flow Rate Limit (kg/s)</td>
<td>10</td>
<td>40</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Charging Period (days)</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Well Pattern</td>
<td>2 Well Line Drive</td>
<td>2 Well Line Drive</td>
<td>2 Well Line Drive</td>
<td>2 Well Line Drive</td>
</tr>
<tr>
<td>Strategy</td>
<td>Borglum-1 Inj, Flyvberg-1 Prod</td>
<td>Borglum-1 Inj, Flyvberg-1 Prod</td>
<td>Borglum-1 Inj, Flyvberg-1 Prod</td>
<td>Seasonal Storage Both Wells</td>
</tr>
</tbody>
</table>

---

### Fig 7 – Schematic of Decision Tree for Sensitivity Analysis

- **Base Case Model**
- **Injection Mass Flow Rate = 40 kg/s**
- **Injection Temperature = 250 °C**
- **Optimum Operating Conditions**
- **Seasonal Storage Cycles**
- **Proposed Field Development Strategy**
- **2 Well Line Drive**
- **5 Spot Pattern**
Methodology – Technical and Economic Yardsticks

Equation Set 1 – Thermal Storage Energy Efficiency (Zheng et al. 2014)

\[ \eta_s = \frac{M_{\text{prod}}}{M_{\text{inj}}} \]

\[ M_{\text{prod}} = \int_{t_1}^{t_2} (q_{\text{prod}} h_{\text{prod}}) \, dt \]

Equation 1

Equation Set 2 – Average Electric Power Generation (Jello et al. 2022)

\[ W_e = 0.45 \, f \, W_h \]

\[ f = 1 - \left( \frac{T_{\text{rej}}}{T_{\text{prod}}} \right) \]

\[ W_h = q_{\text{prod}} \, h_{\text{prod}} \]

Equation 2

Table 5 & 6 – CAPEX and OPEX (Wendt et al. 2019)

<table>
<thead>
<tr>
<th>Description</th>
<th>UNIT</th>
<th>UNIT COST ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of AGES well</td>
<td>LOT</td>
<td>$2,000,000.00</td>
</tr>
<tr>
<td>Cost of Water Injection Facilities</td>
<td>LOT</td>
<td>$3,000,000.00</td>
</tr>
<tr>
<td>Land Cost</td>
<td>LOT</td>
<td>$2,000,000.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation &amp; Maintenance: Energy Source</td>
<td>$7/MWh</td>
</tr>
<tr>
<td>Operation &amp; Maintenance: Facilities</td>
<td>$25/MWh</td>
</tr>
<tr>
<td>Water Injection Cost</td>
<td>$0.001/Ag</td>
</tr>
</tbody>
</table>

Equation Set 3 – Economic Yardsticks (Wendt et al. 2019, Jello et al. 2022)

\[ NPV = \sum_{n=1} \frac{\text{Cash Flow, Year } n}{(1 + r)^n} \]

\[ LCOE = \frac{\text{NPV, Project Costs ($)}}{\text{NPV, Electricity Produced (kWh)}} \]
Results & Analysis – Reservoir Models

Fig. 8 – Calculated and Generated Petrophysical Well Logs

Figure 9 – Reservoir Model of Porosity (PHI_SP)

Table 7 – Critical Comparison of Petrophysical Properties

<table>
<thead>
<tr>
<th>Petrophysical Properties</th>
<th>Static Reservoir Simulation</th>
<th>GEUS &amp; Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porosity (%)</td>
<td>6.91-36.3</td>
<td>25.78</td>
</tr>
<tr>
<td>Permeability (mD)</td>
<td>0.7069-6585</td>
<td>2346</td>
</tr>
<tr>
<td>Volumetric Heat Capacity (MJ/m^3K)</td>
<td>2.113-2.762</td>
<td>2.529</td>
</tr>
<tr>
<td>Thermal Conductivity (W/mK)</td>
<td>3-3.99</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Results and Analysis – Simulation Cases

Fig 10 & 11 – Technical Yardsticks Applied to Simulation Results

Comparison of Thermal Energy Storage Efficiencies

Fig 12 & 13 – Economic Yardsticks Applied to Simulation Results

Comparison of LCOE
Results and Analysis – Field Development Plan

Fig 14 – 5 Spot Well Pattern on Assumed Drainage Area

Fig 15 – Case 1 vs. 5 Spot Pattern Thermal Energy Storage Efficiency

- 5-Spot
  - 4 Injector, 1 Producer
- Injection Mass Flow Rate
  - 40 kg/s for each well
- Injection Fluid Temp.
  - 90 °C
- Charging Period
  - 3 months before production
Conclusions & Recommendations

• AGES is Novel and Unique
  • Combatting issues of Energy Storage and Curtailment of Energy
  • Implementation of AGES in Conjunction with Renewable Energy System → Flexibility

• Optimum Field Development Plan
  • Injection Fluid Temperature = 90 °C
  • Injection Mass Flow Rate = 40 kg/s
  • 5 Spot Well Pattern
  • 3 Months Charging Period

• Technical and Economic Yardsticks
  • Thermal Energy Storage Efficiency – 70%
  • Average Power Generation – 0.15 bn kWh
  • NPV – US$35 Million
  • LCOE – 0.4 $/kWh

• Further Studies
  • Cost Analysis Considering Incremental CAPEX
  • Adding extra petrophysical properties


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Hydrotreated Vegetable Oil as a Replacement for Diesel within TotalEnergies Exploration and Production UK Ltd. (TEPUK)

Amy Emslie

Supervised by Alfonso Martinez-Felipe, Katie Abbott, Andy Bain, and Louise Oatey
• Diesel still widely utilised in TEPUK
  - Backup diesel generators (offshore and onshore)
  - Marine transport
  - Vehicles onshore

• Diesel use responsible for over 120,000 tonnes of CO₂e emissions in TEPUK in 2022
Aims of this Project

1. Compare different types of biofuels and select most suitable for use in TEPUK

2. Carry out lifecycle emissions analysis for the biofuel and diesel

3. Complete two case studies for biofuels within TEPUK including emissions reductions and costs

4. Based on results make conclusions on whether the switch to biofuel would be viable for TEPUK
What is a Biofuel?

Short term balanced cycle taking months

Long term unbalanced cycle taking millions of years
Hydrotreated Vegetable Oil (HVO) (Renewable Diesel)

- Drop-in replacement

- 2nd Generation

- Higher gravimetric energy content than diesel

- Doesn’t attract water

- Longer storage life
Lifecycle Emissions Assessment of Diesel vs HVO

- Raw Material Extraction / Cultivation
- Fuel Refinement
- Transport
- Combustion

TotalEnergies

21st November 2023
1. Raw Material Cultivation: 0 tonnes of CO$_2$e per tonne of HVO
HVO Lifecycle Emissions Assessment

2: HVO Refinement: 0.54 tonnes of CO$_2$e per tonne of HVO
HVO Lifecycle Emissions Assessment

3: HVO Transport to Aberdeen: 0.41 tonnes of CO$_2$e per tonne of HVO
HVO Lifecycle Emissions Assessment

4: HVO Combustion: 0 tonnes of CO$_2$e per tonne of HVO
Lifecycle Emissions Assessment of Diesel vs HVO

78% emissions reduction through use of HVO

Lifecycle CO$_2$e Emissions for Diesel vs HVO

- Raw Materials Extraction / Cultivation: Diesel 0.85, HVO 0
- Fuel Refinement: Diesel 0.23, HVO 0.54
- Transport: Diesel 0.03, HVO 0.41
- Combustion: Diesel 3.27, HVO 0

Stage of Lifecycle

Tonnes of CO$_2$e per Tonne of Fuel

21st November 2023
Cost

- HVO cost 3x diesel cost (£1800 per tonne vs £600 per tonne)
- UK-ETS scheme savings – around £250 per tonne of fuel
- High prices mean full switch not financially viable at the moment
- Option to use on small scale or in blends
Case Study 1

- Planned shutdown period for 35 days on platform
- Power supplied by 2 Rolls Royce diesel generators
- 500 tonnes of diesel forecast for the period

76% reduction in emissions
112% increase in costs
Future HVO Production

HVO Production

- 2020: 7.5mt
- 2025: 30mt

- Europe:
  - 2020: 5mt
  - 2025: 15mt

- Global:
  - 2020: 2.5mt
  - 2025: 15mt

Total Energies
Future Steps

- Investigate Claimed Emissions Saving
- Source HVO
- Investigate Potential Maintenance Cost Savings
- Complete Small Trial
Conclusions

- HVO most suitable biofuel for use within TEPUK as a diesel replacement
- Use of HVO could reduce lifecycle emissions by up to 78% compared to diesel
- Currently HVO costs around 3x cost of diesel
- HVO production expected to quadruple between 2020 and 2025
- Complete switch to HVO not currently financially viable for TEPUK, but HVO could still be utilised on a small scale until costs are reduced
Thank you for listening 😊
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MSc Students
Best Energy Paper Competition 2023
Electrification of Offshore Petroleum Installations with Offshore Wind Integration

Prepared by Suzanna Carson
MSc Oil and Gas Engineering
Presentation Outline

• Project Background
• Aim & Objectives
• Methodology
• Analysis & Results
• Case Study
• Conclusion & Recommendations
Project Background

• The UK Government has committed to climate change improvements with:
  • Net-Zero emissions targets by 2050 and;
  • a 50% reduction in 6 years, by 2030.

• Oil and Gas operators are held in a negative light, the emission of greenhouse gasses being a bi-product of fossil fuel extraction

• Power generation is one of the largest contributors from gas or diesel turbines, emitting straight to the atmosphere from exhausts

• Wind power electrification is proposed by the oil and gas regulator (NSTA) as an enabler to achieving the Government’s targets

• Around 50% of North Sea assets are potentially reaching end of life in the next 10 years.
  • Are operators likely to upgrade them with expensive electrification projects?
Aim & Objectives

- **Aim**
  - Identify when platform electrification could be justified with financial investment to reduce its carbon footprint.

- **Objectives**
  - Determine the state of the art for alternatives to fossil fuel power generators
  - Understand the average power demand of an oil and gas asset, and how it could be fulfilled utilising wind power energy
  - Conclude the scenario for a successful investment decision against carbon reduction and power fulfilment
  - For when this is unlikely, provide alternative methods that can support reducing CO2 emissions
Methodology

• Carry out a critical literature review of how alternative power sources could be used to electrify oil and gas platforms

• Canvas industry opinion for the use of floating wind electrification

• Produce a case study of a North Sea asset to determine feasibility of a new power source

• Provide a statistical analysis of the parameters needed in recommendation of a carbon-reducing electrification project

• Research measures to reduce carbon emissions where an innovative power generation project may not be recommended for sanction
Analysis & Results

• What does the literature say?
  • 13 sources from between 2010 and 2022
  • Wind power is a viable solution for supporting emissions reduction targets
  • Conclusive full lifecycle costs have not been determined
  • The stage of field life for electrification by wind power remains inconclusive
  • Wind power alone may not be sufficient to eliminate reliance on fossil fuelled power sources, stability issues featuring heavily
  • Half highlighted additional support could be made available to supplement the power shortfall, technological advances unlocking hybrid opportunities
  • No clear picture of wind power solutions being the way forward for ageing assets
From the industry survey, what is the opinion?

- There is a high level of desire to improve carbon emissions levels
- The age of oil and gas assets becomes an obstruction to FOWT electrification projects
- Current levels of financial incentivisation are not sufficient in reducing the financial burdens
- Technological advancement is not sufficient in supporting current FOWT electrification projects
- Supply chain demands will likely be problematic for future FOWT electrification projects
Case Study

• Represent the average North Sea oil and gas installation to provide a benchmark for power requirements
  • Fossil fueled power generation with 45% efficiency
  • 8.5MW power demand
  • 13-year remaining field life

• Eliminating carbon emissions from power generation requires the generators to be removed from service

• The goal: determine whether it is possible to power the platform under study using FOWTs without requiring additional support
• What does a simulation prove?
  • Utilising 1x 9.5MW FOWT fulfills 31% of a 1-year power demand
    • Emitting 37.8 ktonnes of CO₂
  • Utilising 2x 9.5MW FOWT fulfills 64% of a 1-year power demand
    • Emitting 20.3 ktonnes of CO₂
  • Utilising 2x 9.5MW FOWT + 9MW BESS, 71% of a 1-year power demand is observed
    • Emitting 17.6 ktonnes of CO₂

• A result without the need for conventional power generation in this scenario was found not to be feasible

Analysis & Results
Analysis & Results

- What does a cost analysis model prove?
  - 2x 9.5MW FOWT reduces carbon emissions from fossil-fuelled power generation by 86%
  - Government set targets are met by 1 year when adopting an average 6-year project lifecycle
  - Final project lifecycle costs exceed £26m
  - A reduction in CAPEX by 32% would result in a cost neutral project
  - A field life extension to 16.3 years would result in a cost neutral project
What could be done to provide a more economically viable solution for short-life assets, offering additional incentive to asset owners?

- Selling power to the grid post field-life could potentially generate a profit of £36.3m
  - The buyer would need to collect the electricity

- Selling as hydrogen for the remaining 18-year turbine life could potentially generate a profit of £141m
  - Hydrogen sale prices are figurative as it stands, with no current market as a tradeable commodity
Analysis & Results

• What are the available alternatives? Incremental gains.
  • Power wastage from heating and cooling processes can be reduced, in turn reducing emissions.
    • Nanofluid technology is said to improve energy efficiency up to 35% when used at a concentration of between 0.3% to 0.5% volume
  
• CO₂ capturing through exhaust releases
  • The addition of an amine plant can reduce emissions by 14%
  • The captured CO₂ can also be utilised for enhanced oil recovery

• CO₂ capturing through flare gas releases
  • Flare gas processing and rerouting could reduce emissions by 23%
Wind power alone successfully results in achieving the government set reduction targets of 50% by 2030, but does not eliminate the emissions.

Floating offshore wind turbine projects may not be economically viable for ageing assets unless upfront costs are reduced by more than a third, incentives are provided for cost reduction, or additional revenue streams are generated beyond CoP.

Investigation into the ability to utilize power produced from wind post field-life is recommended to open up further revenue streams.
Thank you
Your Energy Institute

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MSc Students
Best Energy Paper Competition 2023
The Impact of Climate Change on Secondary Control Systems of Substation

Industrial project awarded by:

Karthik Singh Thakur

21st November 2023
What is the driving factor behind initiating this project?

1. Climate change refers to the long-term alteration in Earth's climate patterns, driven primarily by human activities and natural processes.

2. Addressing the escalation of anthropogenic emissions on a global scale involves the adoption of renewable energy sources.

3. The surge in renewable integration mandates robust substations and cutting-edge control and monitoring systems for efficient electron transmission toward net-zero aspirations.

4. These electronic inspection systems exhibit peak efficiency only under specific climatic conditions which is currently provided by active systems.

5. Employing sustainable and green initiatives to attain desired climatic conditions, ensuring seamless electron transmission, thereby significantly mitigating the carbon footprint of substations and extending the lifespan of these devices.
Research Aims

1. Climate forecasting – To comprehend the effects of climate change, especially on building infrastructure, and evaluate sustainable strategies to mitigate its impacts.

2. Technical Analyses on the energy performance of control buildings – A comprehensive case study was conducted on the Rothienorman substation 400/275kV, investigating the energy associated with the secondary control building (Control room, Communication room, and Battery room).

3. Passive design approach – Taking into account factors like location, orientation, thermal envelope specifications, and desired indoor climate conditions, numerical analyses were performed to assess energy demands between active and passive design approaches and to analyze hydrogen behavior in the battery room.

4. Computer Simulation – To validate the numerical analyses, computer simulations are employed to evaluate the building's annual performance in terms of cooling and heating loads measured in kW, this enabled the optimization of energy requirements. (IES VE, CFD)
Case Study: Rothienorman Substation 400kV.

### Table: Set point vs Operating point

<table>
<thead>
<tr>
<th>Zone</th>
<th>Set point in °C</th>
<th>Operating point in °C</th>
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</thead>
<tbody>
<tr>
<td>Control Room</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>Communication Room</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>Battery Room</td>
<td>20</td>
<td>15</td>
</tr>
</tbody>
</table>

Adapted from SSE [3]

![Diagram of Passive Design Approach]

Adapted from [2]
Methodology

Building Dynamic Thermal simulation

• The VE (Virtual Environment) a building thermal simulation package under Integrated Environmental Solutions (IES), is utilized to assess the building performance across diverse weather scenarios and specific indoor climate conditions.

• Detailed analysis of active and passive system efficiencies.
• Incorporating Passive cooling, heat recovery wheel, and Solar Photovoltaics.
Annual weather profiles

**Annual Temperature profile**

**Annual Velocity profile**

**Annual Peak Solar Irradiation profile**

**Annual Wind Rose profile**
### Cooling Load

<table>
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<th>Month</th>
<th>Active Equipment load %</th>
<th>Passive Equipment load %</th>
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</thead>
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<tr>
<td>Jan - May</td>
<td>13.33</td>
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<td>June-Oct</td>
<td>80.03</td>
<td>17.85</td>
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<td>Nov-Dec</td>
<td>6.66</td>
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<td>Total</td>
<td>100</td>
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<tr>
<td>Energy Savings</td>
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<td>82.15%</td>
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### Heating Load

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<th>Active Equipment load %</th>
<th>Passive Equipment load %</th>
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<tr>
<td>Jan - May</td>
<td>38.88</td>
<td>28.54</td>
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<td>June-Oct</td>
<td>22.22</td>
<td>8.09</td>
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<tr>
<td>Nov-Dec</td>
<td>38.89</td>
<td>11.54</td>
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<tr>
<td>Total</td>
<td>100</td>
<td>48.17</td>
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<tr>
<td>Energy Savings</td>
<td>0</td>
<td>51.83</td>
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Carbon Emissions

Passive Design

Carbon negative profile for passive design approach

Active Design

Carbon-positive profile for existing active design
Computational Fluid Dynamics (CFD) Analyses
CFD Analyses

Air Distribution analysis

Air Flow analysis

Velocity profile

Temperature profile

CFD Analyses
Hydrogen Behaviour Analyses

<table>
<thead>
<tr>
<th>Test</th>
<th>300 s</th>
<th>600 s</th>
<th>900 s</th>
<th>Scale *</th>
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<td>(Multi-release point)</td>
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<td><img src="image11" alt="Image" /></td>
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</tbody>
</table>

* At the scale: $0.85 \times 10^{-3} \text{ kg/m}^3 = 25\% \text{ LFL}$, $1.7 \times 10^{-3} \text{ kg/m}^3 = 50\% \text{ LFL}$, $2.55 \times 10^{-3} \text{ kg/m}^3 = 75\% \text{ LFL}$ and $3.4 \times 10^{-3} \text{ kg/m}^3 = 100\% \text{ LEL}$

Adapted from [4]
Conclusions

1. Comprehensive annual analyses of building energy performance were conducted using a one-tenth scale model of the existing Rothienorman substation, comparing active and passive design approaches.

2. A reduction of 82.15% in cooling load and approximately 52% in heating load was achieved in terms of energy savings.

3. Due to minimal net equipment load usage and the incorporation of Solar PV, electricity generation leads to carbon savings, resulting in the asset being a carbon-negative building.

4. CFD analyses suggest that integrating a heat recovery wheel (heat decarbonization) results in minimizing heating demand in the battery room.

5. Extended lifespan of Intelligent Electronic Devices over a 40-year substation and battery bank operational period, attributed to optimized charging and discharging temperatures.

6. An examination of hydrogen behavior and ensuring its safe release indicates that risks can be managed effectively in a battery room.
Areas of further research

1. Design and orientation of new HV substations considering weather patterns, orientation, and thermal regulation needs.

2. Specialized building codes and standards should be devised according to the specific building type, centering on the passive design methodology.

3. Investigating the inclusion of phase change materials into the thermal envelope can present potential advantages.

4. Future weather profiles should be taken into account when considering building services design.

5. Advanced electronic control and monitoring systems need to incorporate thermal monitoring systems and associated heat dissipation solutions such as heat sinks, cooling fans, and thermal grease to maintain optimum climatic conditions.

6. Hydrogen behavior analyses must be performed using industrial-grade software to reduce the risk of hydrogen build-up and explosion.
References


[3] https://www.ssen-transmission.co.uk/projects/project-map/rothienorman-substation

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