Your Energy Institute

Your AHI Branch

MSc Students
Best Energy Paper Competition 2023

energy institute
Aberdeen Highlands & Islands

IMRANDD
INTELLIGENCE WITH INTEGRITY

Net Zero Technology Centre
Technology Driving Transition

Underground Hydrogen Storage: Effect of Hydrogen on Saline Aquifer and Depleted Hydrocarbon Reserves

Prepared by: Abiodun Abimbola

MSc Drilling and Well Engineering

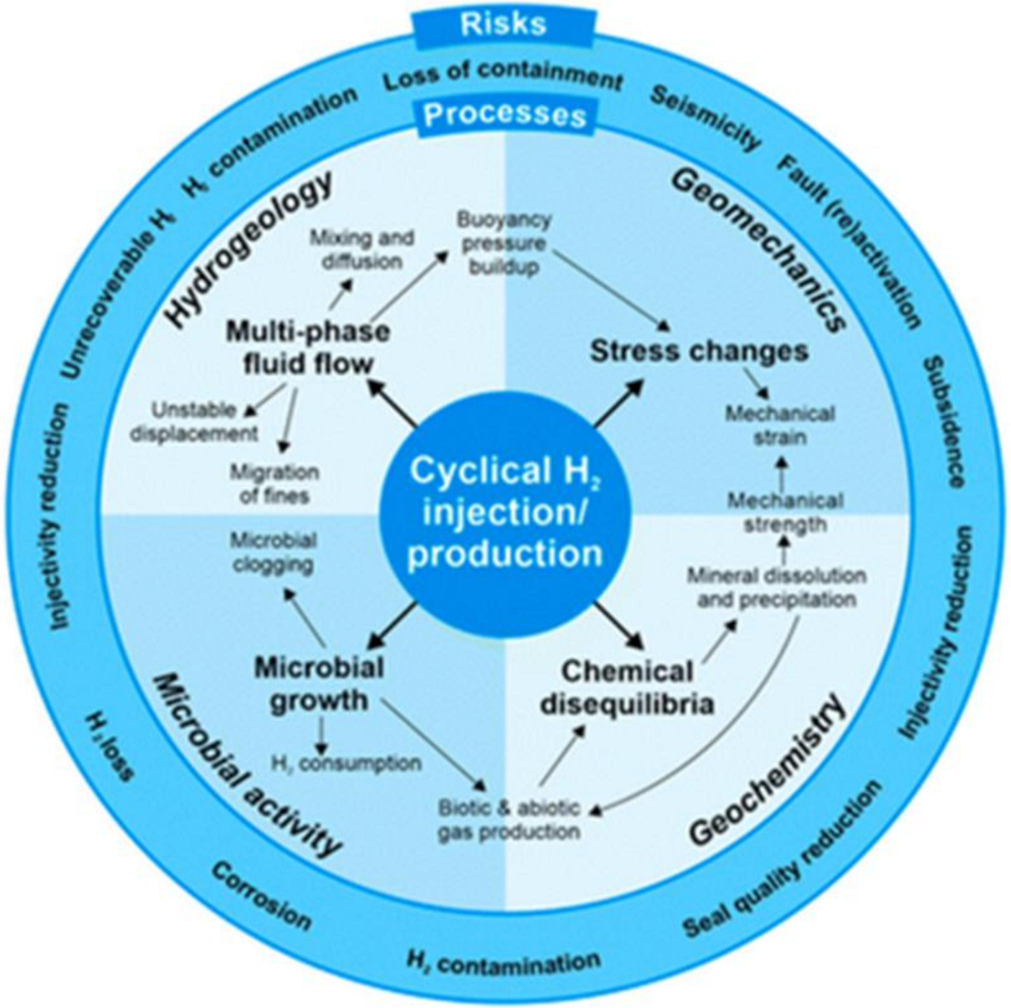
Presentation Outline

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

ROBERT GORDON UNIVERSITY ABERDEEN

Project Background

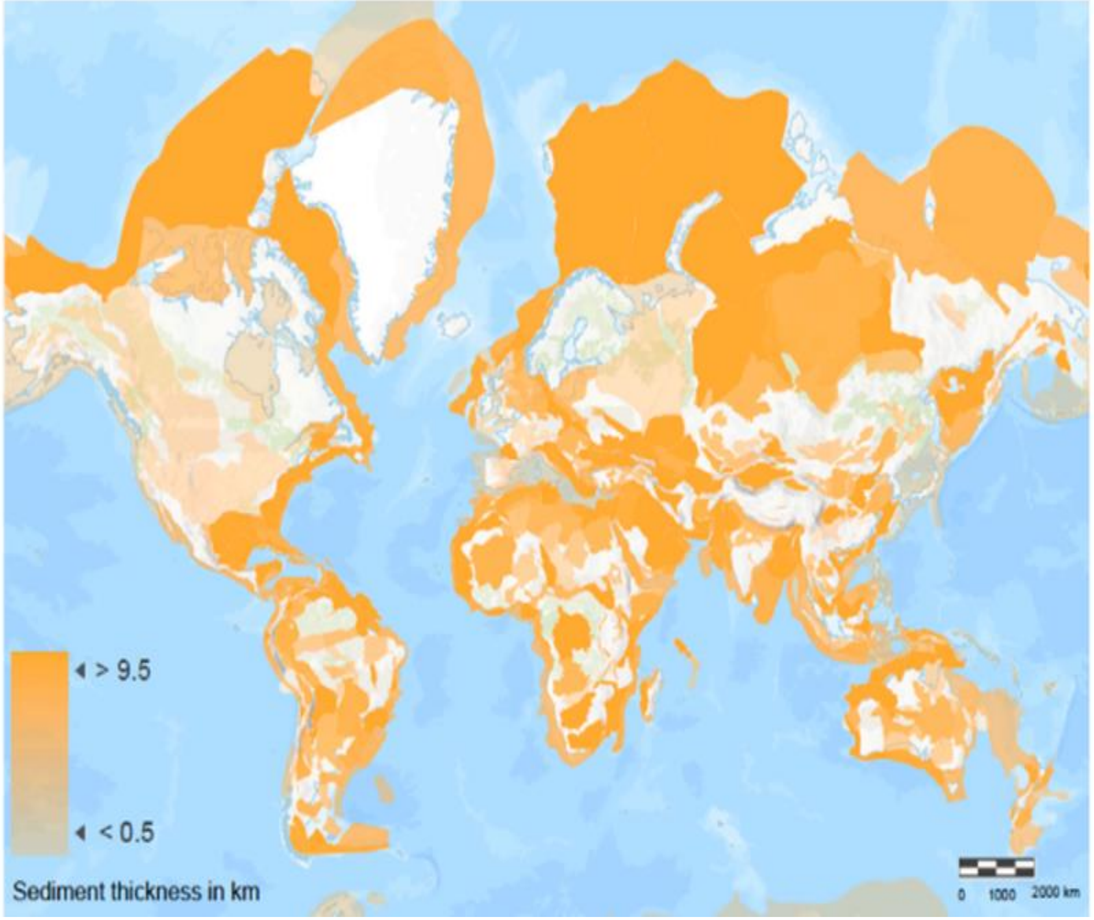
- Hydrogen's ability to balance variable renewable energy makes it crucial for global net-zero goals
- Global hydrogen value chain success relies on sufficient storage capacity and functionality
- A key challenge is hydrogen's low volumetric density, requiring extensive storage for rising energy needs



- 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

Mineral	Modelled Mineral	Mass Fraction %	Molecular weight, g/mol	Amount mol
Quartz	Quartz	76.19	60.083	1.268
K-feldspar	K-feldspar	6.92	278.33	0.025
Calcite	Calcite	6.72	100.09	0.067
Mica	Illite	5.20	1509.5	0.003
Plagioclase	Albite	3.00	263.02	0.011

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

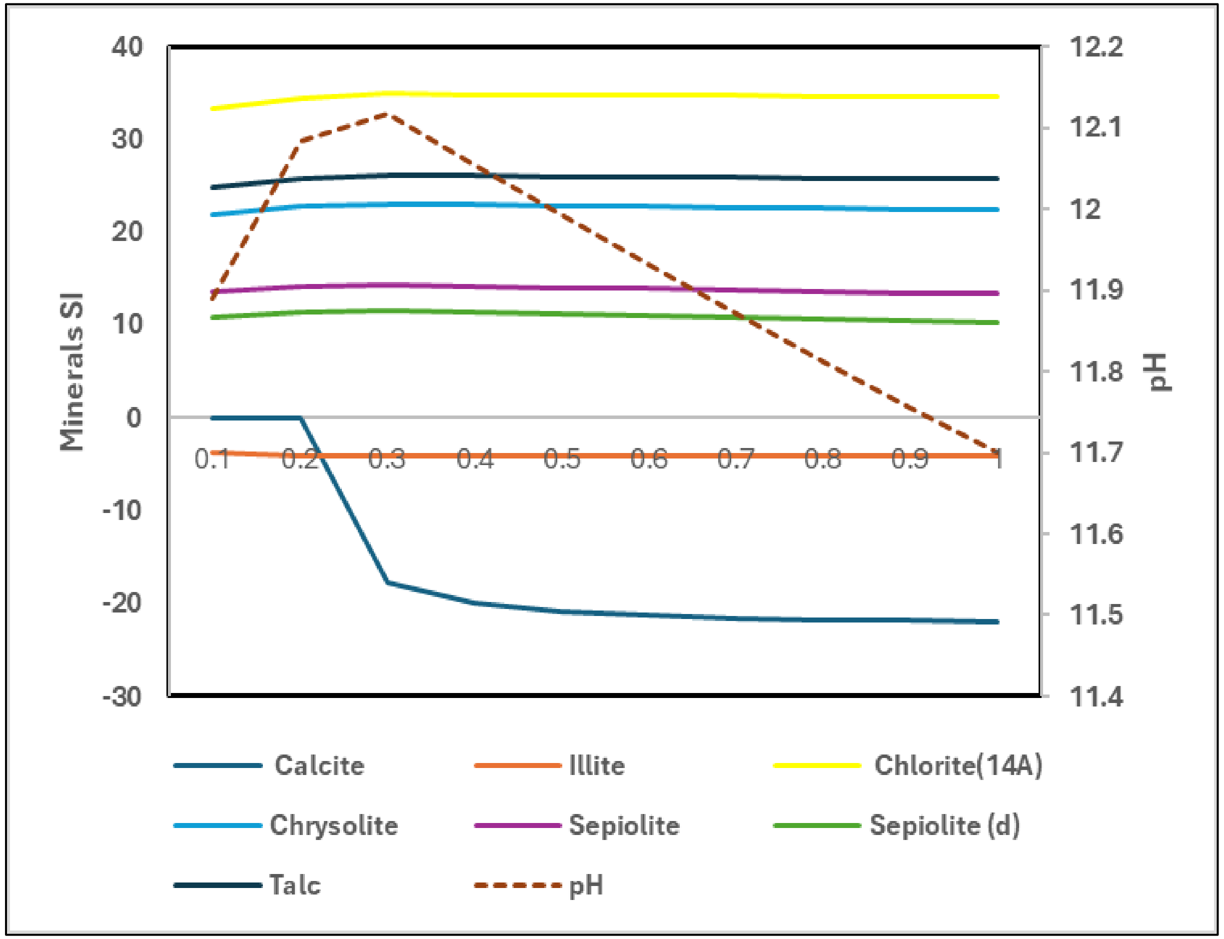


Fig. 1: Rock Mineral Saturation indices in relation to pH

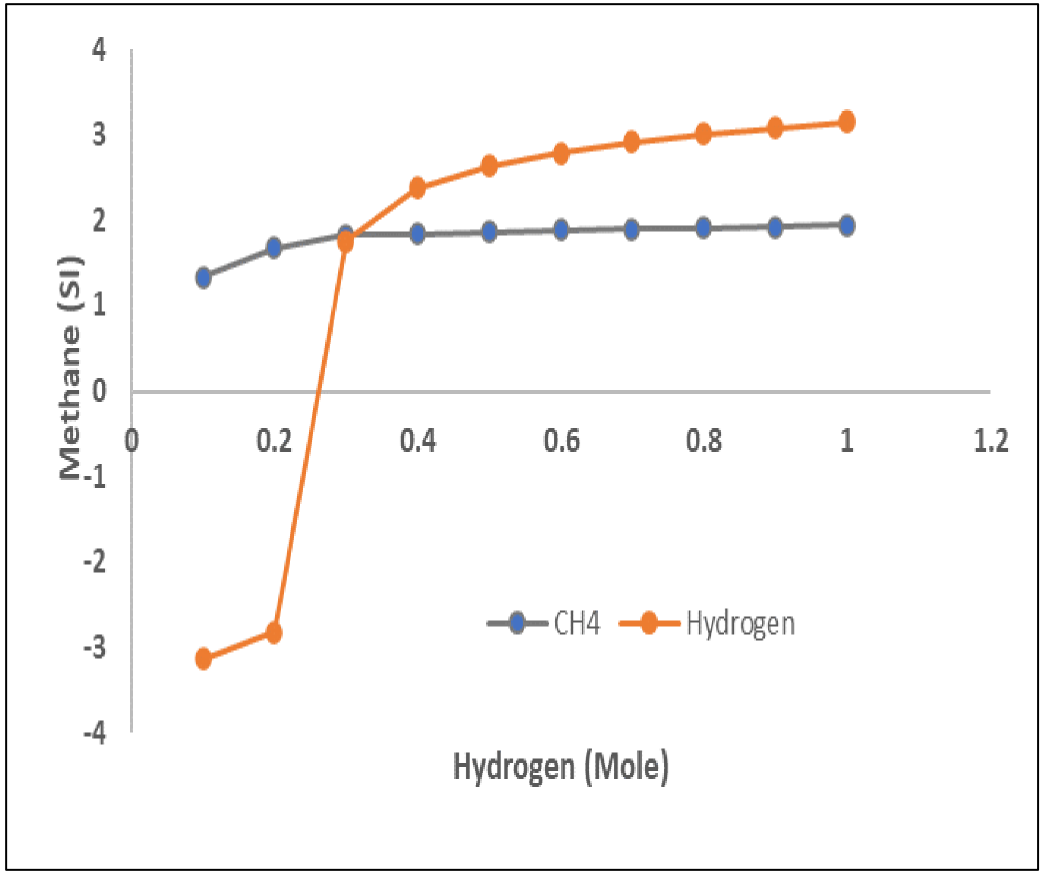


Fig 2: Precipitation of CH4 as hydrogen concentration increases in a saline aquifer.

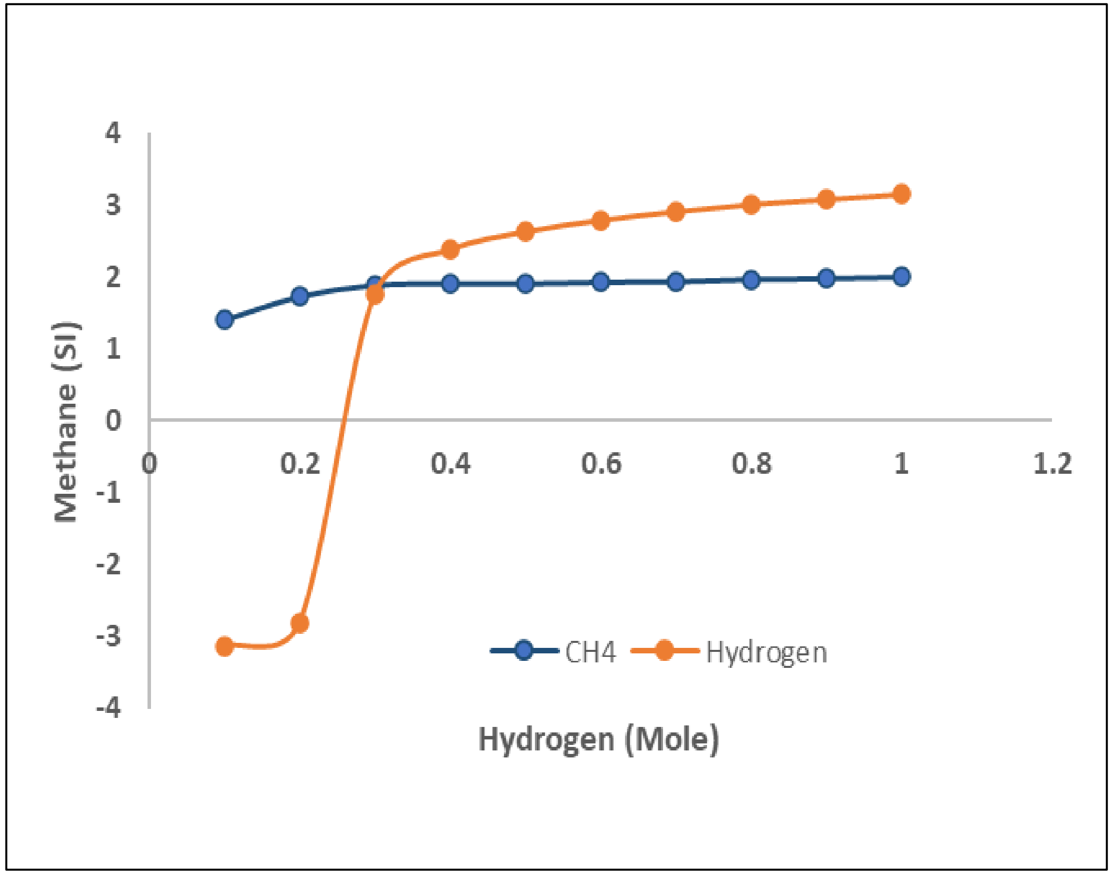


Fig 3: Precipitation of CH4 as hydrogen concentration increases in a depleted hydrocarbon reservoir.

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

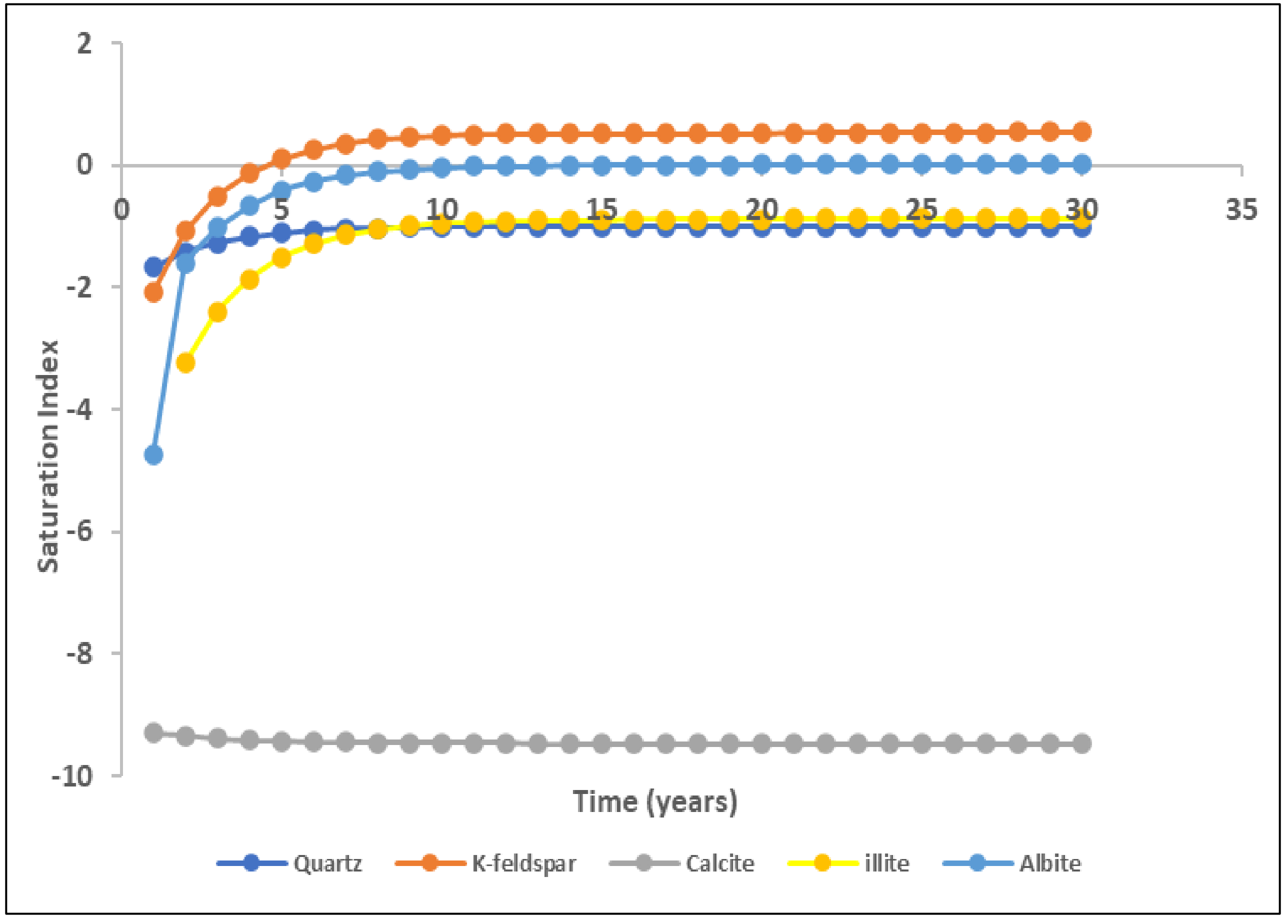


Fig 4: Saturation index of the primary minerals over 30 years

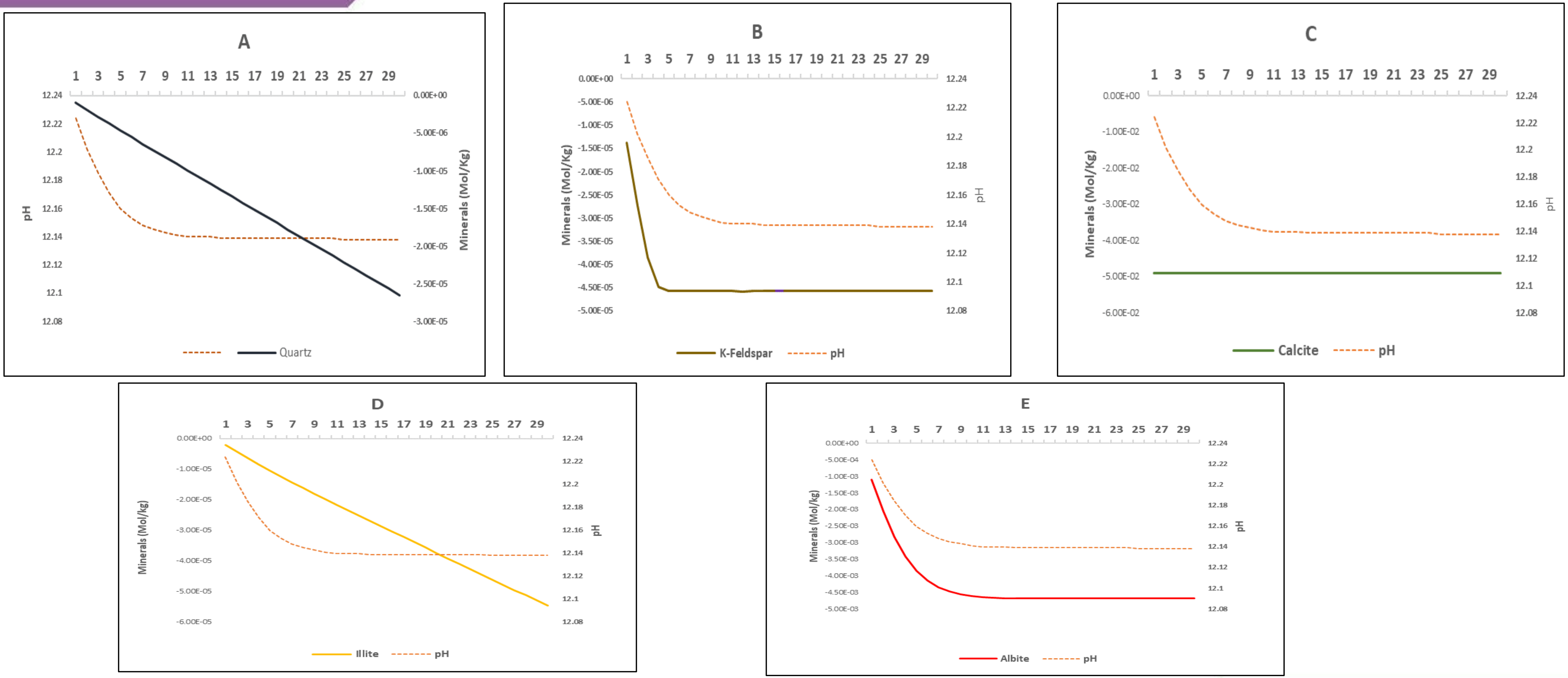
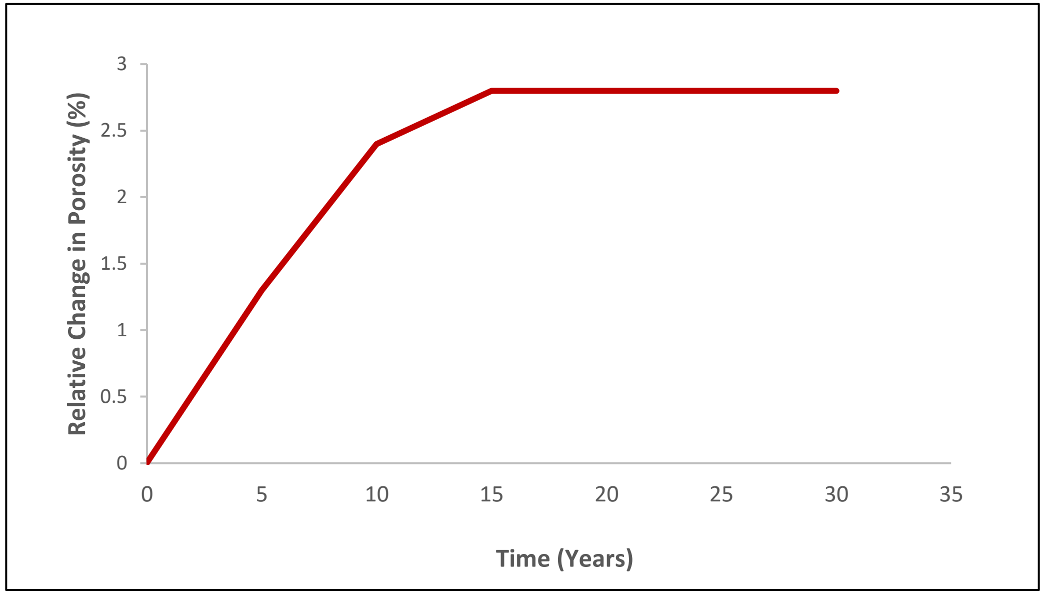


Fig 5: Geochemical simulation of sandstone mineral dissolution in a brine-hydrogen fluid

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.



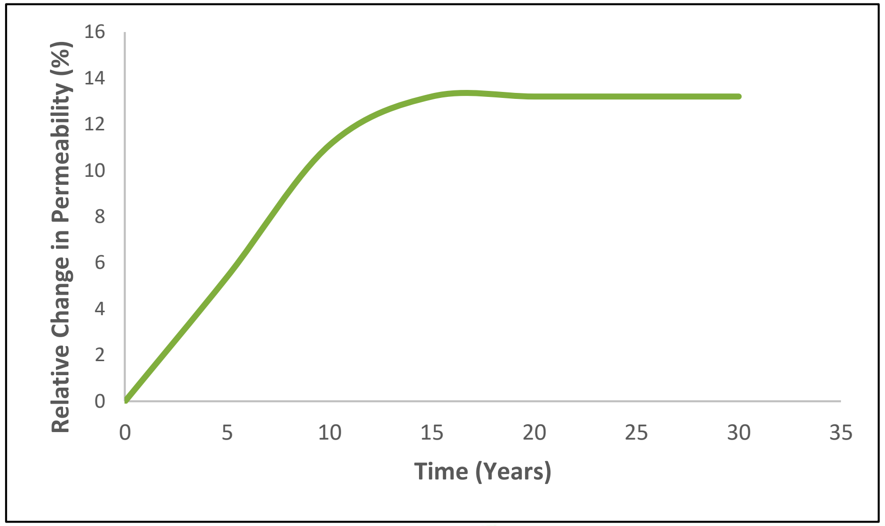


Fig 6: Hydrogen's Kinetic Impact on Reservoir Porosity and Permeability Over 30 Years

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

ROBERT GORDON UNIVERSITY ABERDEEN

Thank you

Your Energy Institute

Your AHI Branch

MSc Students
Best Energy Paper Competition 2023

energy institute

UNIVERSITY OF ABERDEEN

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

energy institute

UNIVERSITY OF ABERDEEN

The Big Picture

MATURED OIL FIELDS

- Oil fields in the UKCS have matured
- Matured oil fields will require decommissioning

TIMING OF DECOMMISSIONING

- Uncertainties in key parameters e.g. oil price, Production decline rates decommissioning cost etc.

ENVIRONMENTAL SUSTAINABILITY

- Environmental sustainability
- Economic efficiency

REGULATORY CONCERNS & FISCAL GAPS

- 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

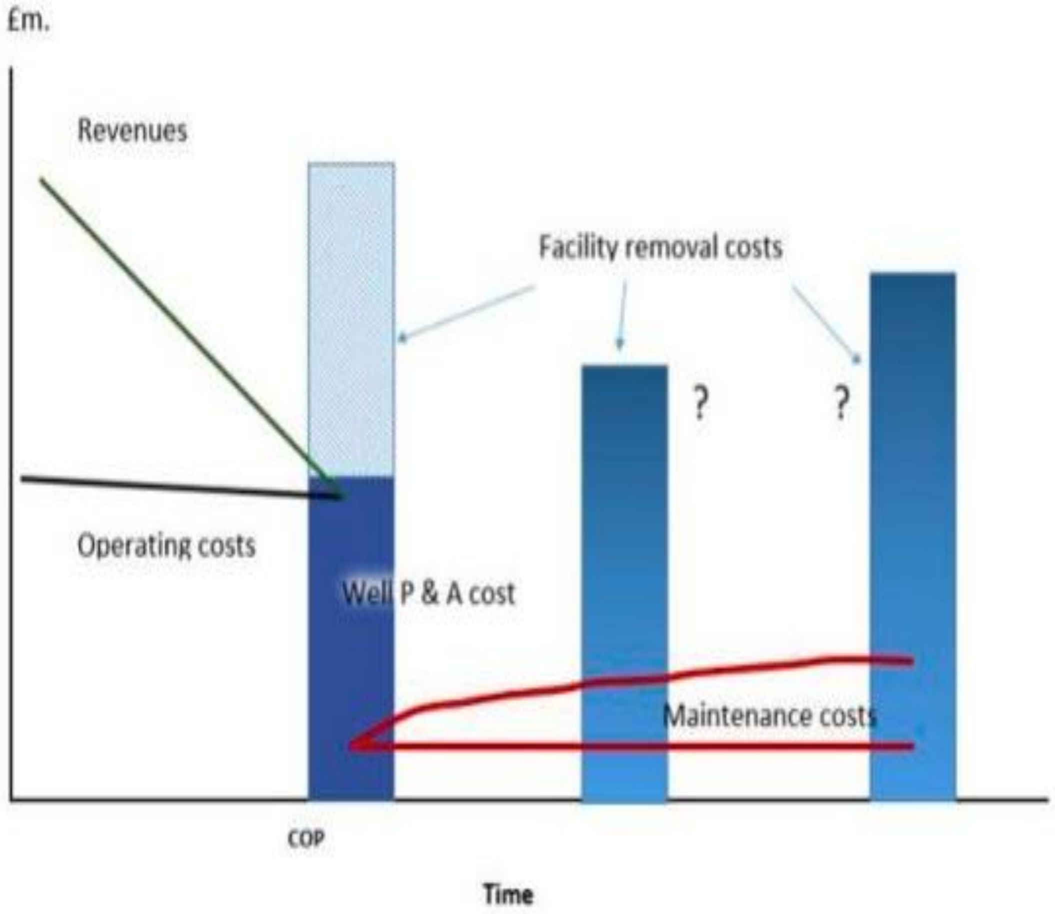
Based on the assumption that oil field should generate sufficient income to cover all cost incurred, including an acceptable profit margin

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

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



Mothballing model: Effect of delay on removal cost
Source: Kemp, 1997

Objective

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 shelve assets of recent vintage

Large field

- 100 MMbl Reserves
- DEVEX @ 10 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

Small field

- 10MMbl Reserves
- DEVEX @ 19 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

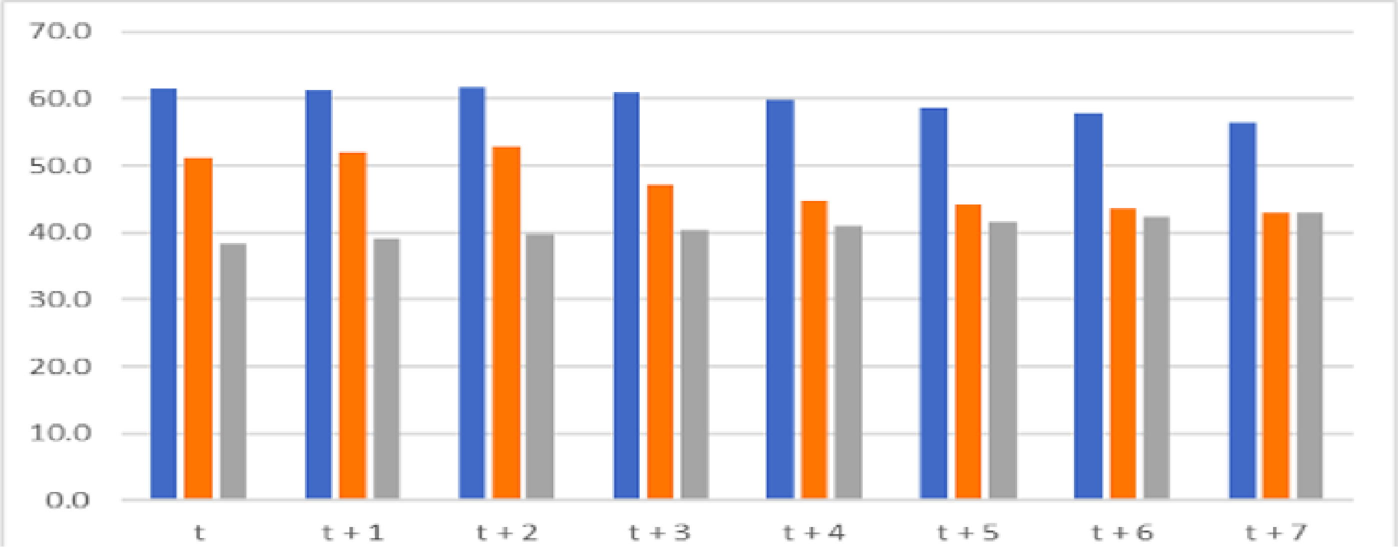
❖ Monte Carlo simulation

Sensitivity Analysis

❖ Determine variations of remaining NPV in input variables

Results: Deterministic Model

Large Field
Remaining Real NPV's from 2027 Base
Annual Maintenance Cost at 5% of Field OPEX



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

■ Remaining NPV @ 0% ■ Remaining NPV @ 5% ■ Remaining NPV @10%

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

The incentive is more as the discount rate increases

Results: Stochastic Model

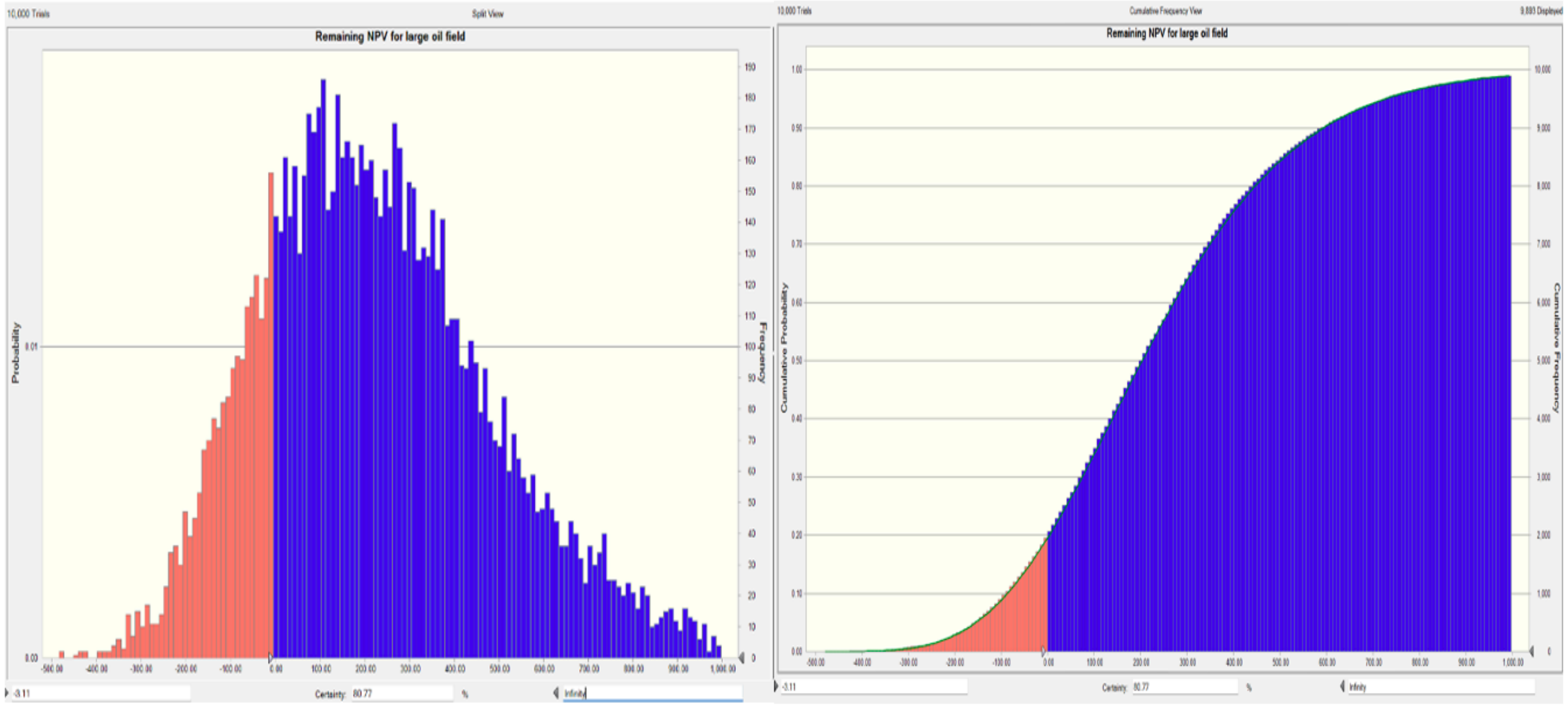
Distribution of the remaining NPV

The large field has a mean NPV of £233 million

Red shade indicate the probability of negative remaining NPV

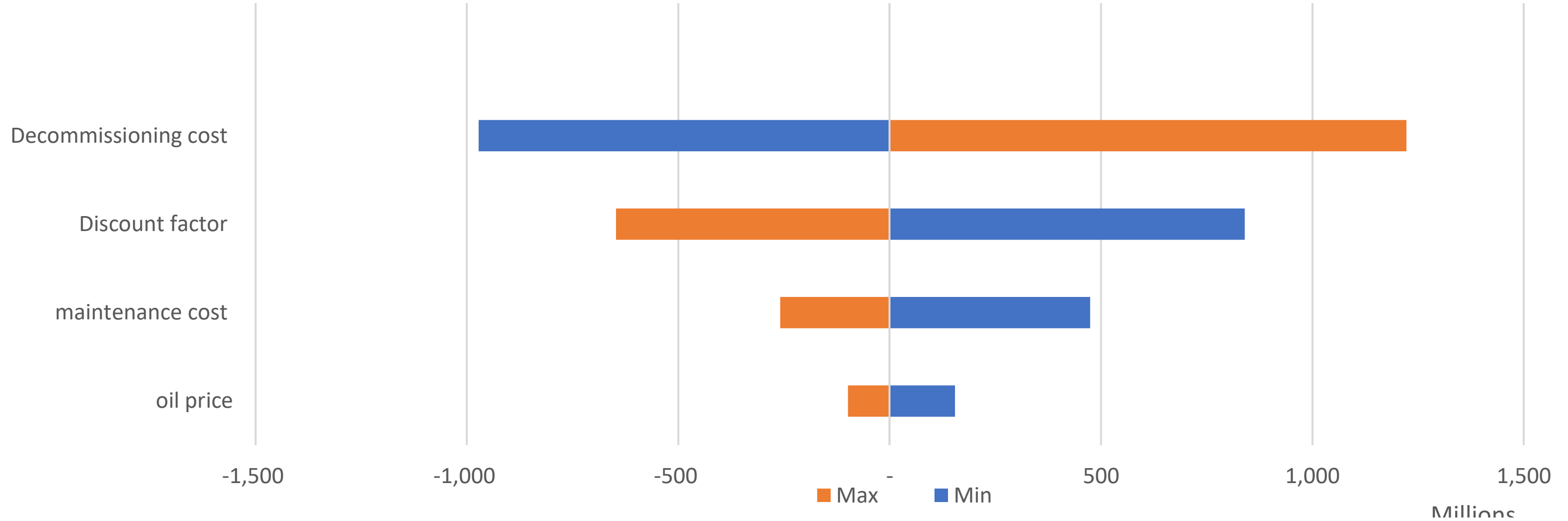
Blue shade indicate the probability of positive remaining NPV

The field should be decommissioned at year eight



Large field remaining NPV distribution and cumulative distribution
Source: Output from Crystal Ball

Results: Sensitivity Analysis of the Remaining NPV



❖ Sensitivity analysis is based on variations in input variables

❖ Decommissioning cost @ 20% of CAPEX

❖ Discount factor @ 15%

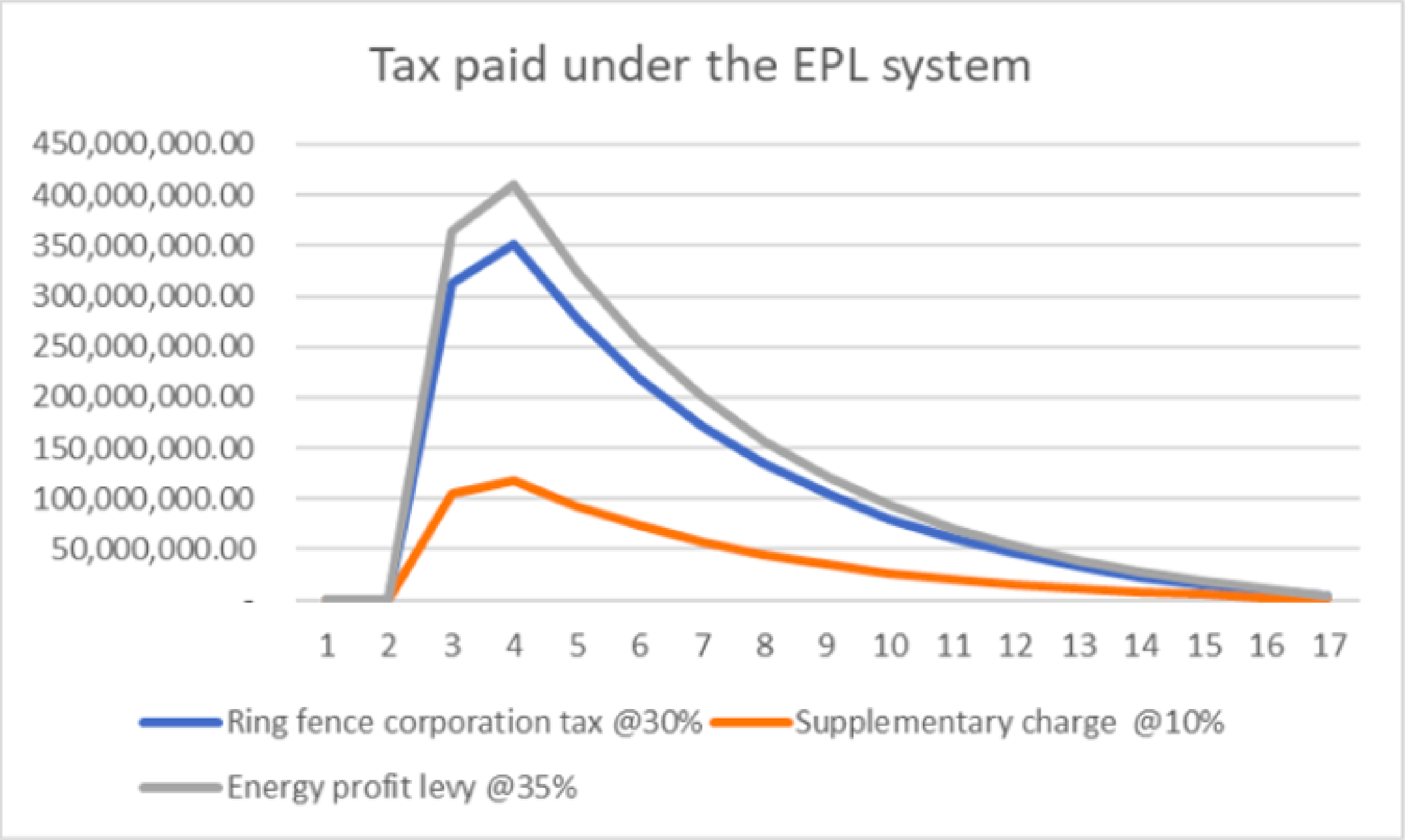
❖ Maintenance cost @ 5% of OPEX

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

Maximization of the remaining NPV often leads to the optimal decommissioning time

Investors can choose to mothball

Government policy should entail Granting reliefs for decommissioning cost

Risk and uncertainty impacts the remaining NPV

energy institute

UNIVERSITY OF ABERDEEN

Thank you for participating

Your Energy Institute

Your AHI Branch

MSc Students
Best Energy Paper Competition 2023

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

Acknowledgements

Special Thanks to

ZeGen Energy

ROSS ENERGY OFFSHORE

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

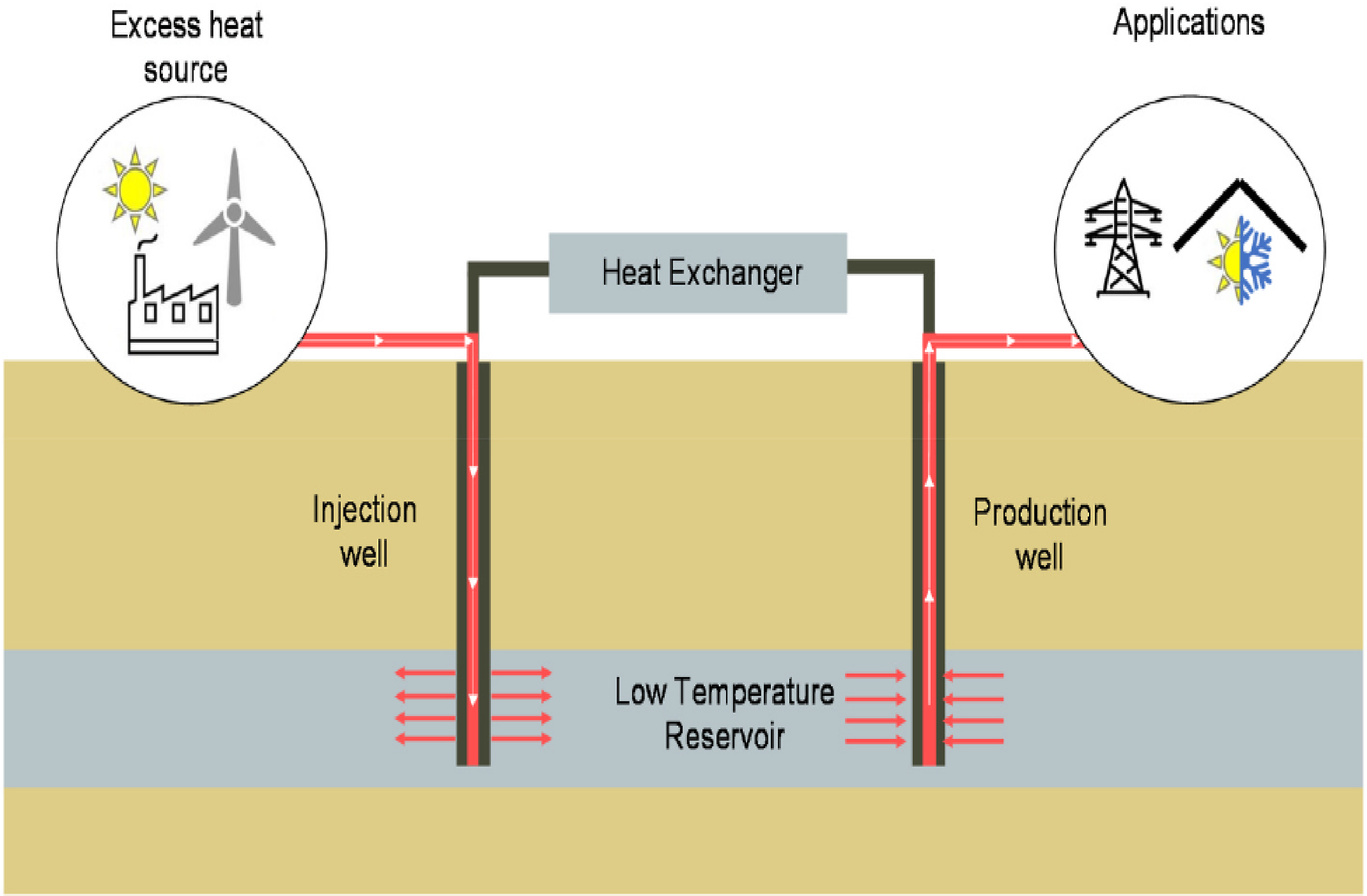


Fig 1 – A basic conceptual model of an AGES system (Jello et al. 2022)

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

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)

COUNTRY	Canada	China	Denmark	Germany (2012)	Ireland	Italy	Japan	Portugal	Spain	Sweden	United States
Electricity Generation (TWh)*	560	5,372	35	577	26	290	950	52	284	153	4,066
Wind Generation (GWh)	17,500	142,000	11,100	50,600	5,872	14,811	4,000	11,900	54,338	9,900	167,840
Wind/Electricity Generation	3.1%	2.6%	31.9%	9.8%	22.5%	5.1%	0.4%	23.0%	19.2%	6.5%	4.1%
Wind Curtailment (GWh)	-	16,230	-	358	196	152	-	-	1,166	-	-
Wind Curtailment/Generation	-	11%**	-	0.7%	3%	1%	-	-	2%	-	1-3%**

*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.

Curtailment ✗

Heat Up Injection Fluid ✓

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

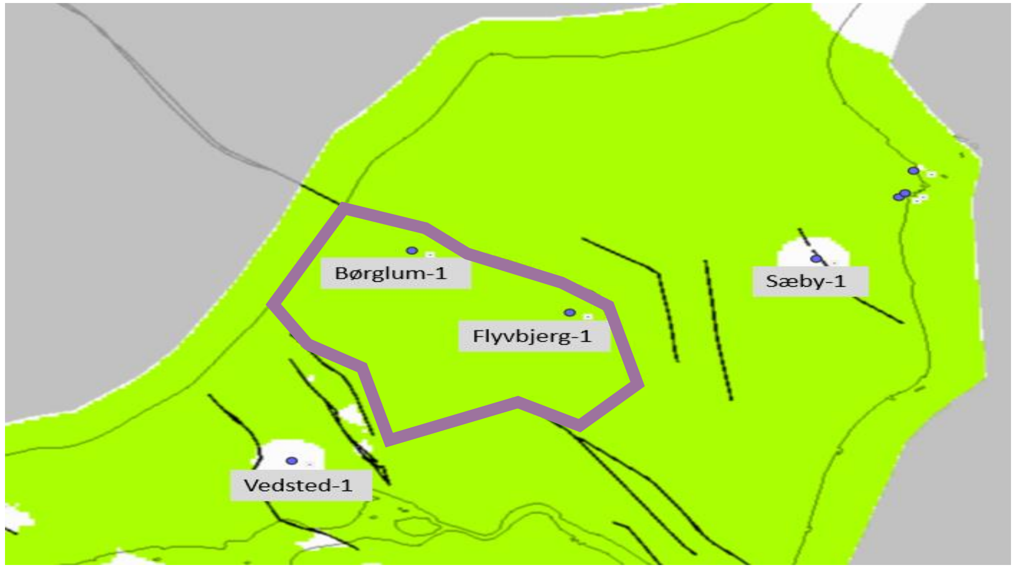


Fig 2 – Wells that Penetrate the Gassum Formation (GEUS 2023)

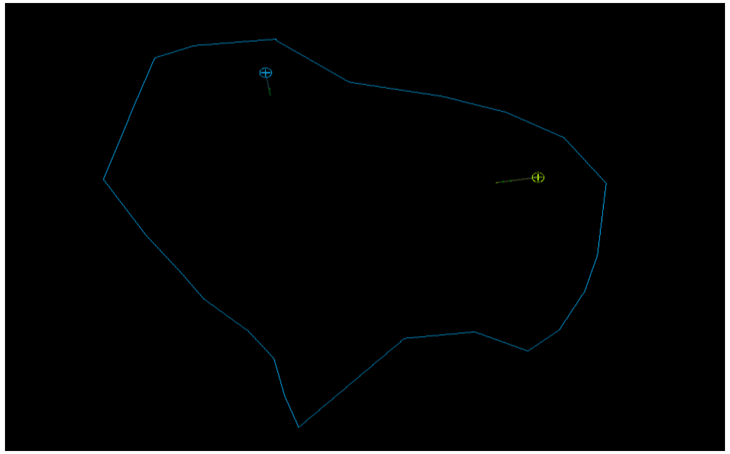


Fig 3 – Assumed Combined Drainage Area

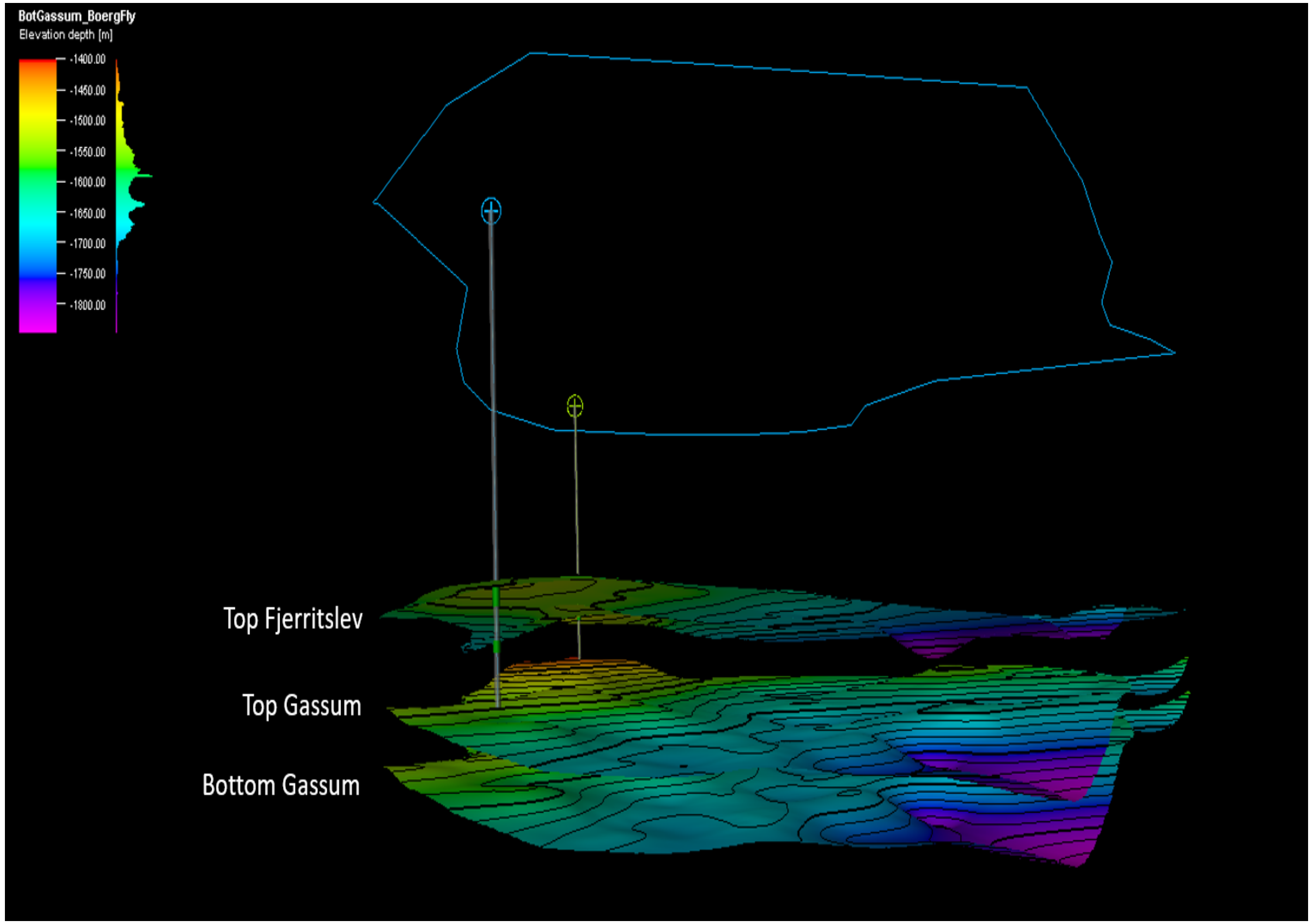


Fig 4 – Formation Surface Tops for the Assumed Combined Drainage Area

Methodology – Reservoir Modelling

Table 2 – Average reservoir properties of the Gassum Formation penetrated by Borglum-1 and Flyvberg-1 as analysed by GEUS 2023

Properties	Borglum-1	Flyvberg-1
Average Porosity (%)	29.3	-
Avg Reservoir Temperature (degC)	44	42
Formation Thickness (m)	155	197
Potential Sands (m)	82	-

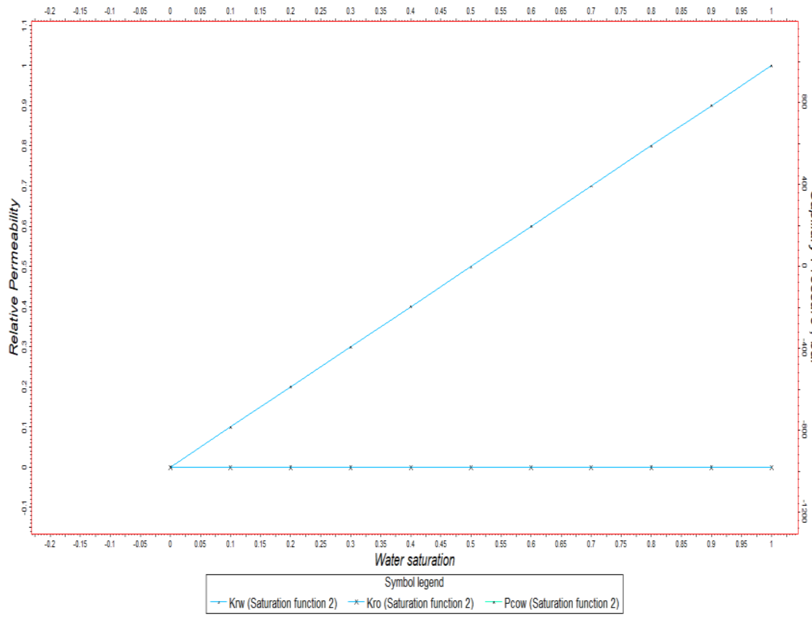


Fig 6 – Single Phase 'Rel-Perm' Curve

Table 3 – Initialisation Conditions

Initialisation Conditions	Values
Datum Depth -FWL	-972 m
Pressure at Datum Depth	102.6597 bar
Capillary Pressure at FWL	0 bar
Geothermal Gradient	27 degC/km

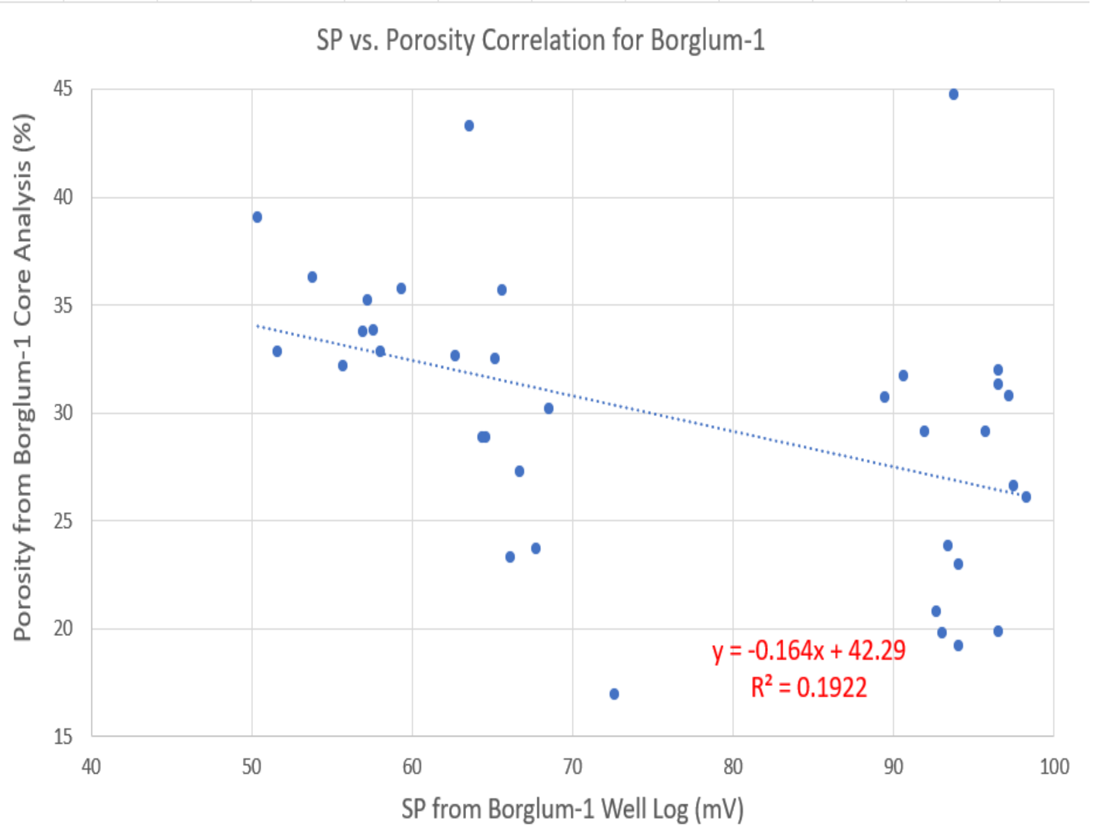


Fig 5 – SP vs. Porosity Correlation for Borglum-1 Well

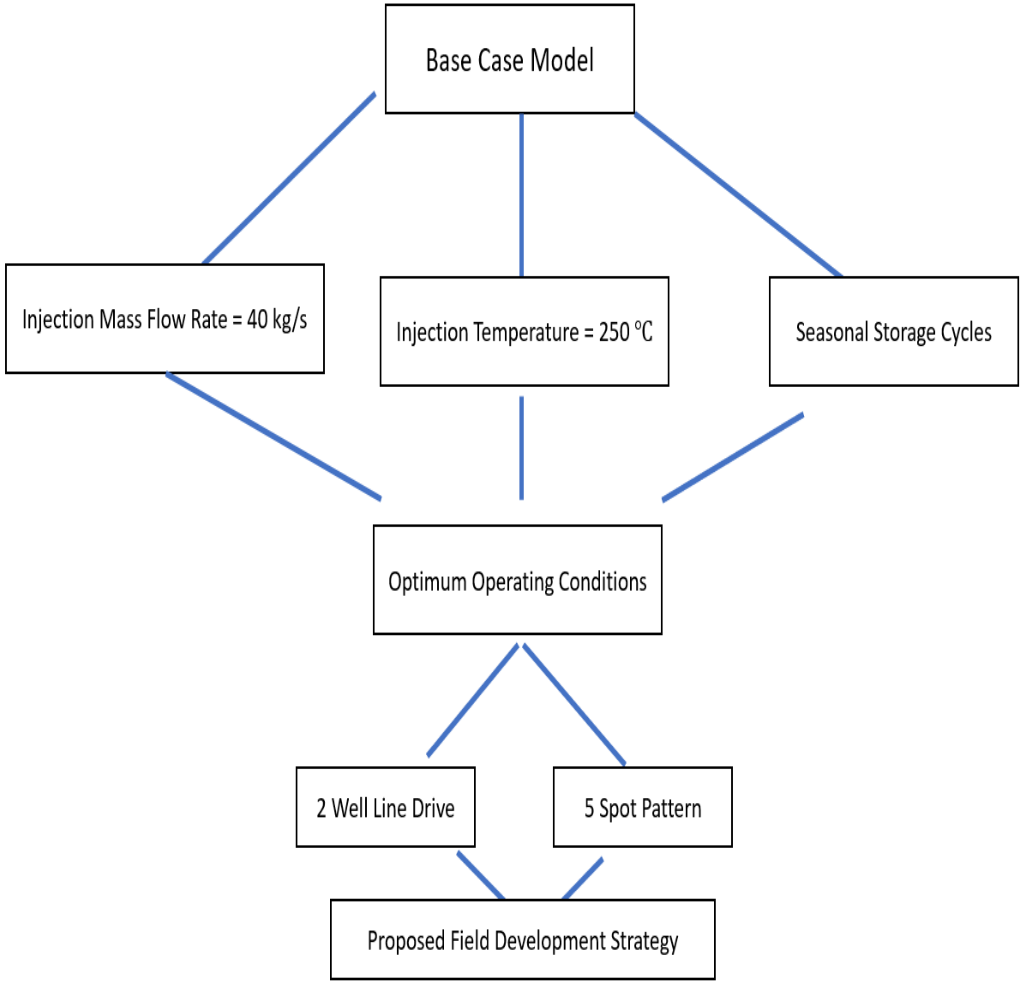
ROBERT GORDON UNIVERSITY ABERDEEN

Methodology – Sensitivity Analysis

Table 4 – Operating Conditions for Different Simulation Cases

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

Fig 7 – Schematic of Decision Tree for Sensitivity Analysis



Methodology – Technical and Economic Yardsticks

$$\eta_s = \frac{M_{prod}}{M_{inj}}$$

$$M_{prod} = \int_{t_1}^{t_2} \left(\dot{q}_{prod} h_{prod}\right) dt$$

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

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

Description	UNIT	UNIT COST ($)
Cost of AGES well	LOT	$ 2,000,000.00
Cost of Water Injection Facilities	LOT	$ 3,000,000.00
Land Cost	LOT	$ 2,000,000.00

Description	Cost
Operation & Mainteance: Energy Source	$7/MWh
Operation & Maintenance: Facilities	$25/MWh
Water Injection Cost	$0.001/kg

$$W_e = 0.45\, f\, W_h$$

$$f = 1 - \left(\frac{T_{rej}}{T_{prod}}\right)$$

$$W_h = \dot{q}_{prod}\, h_{prod}$$

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

$$NPV = \sum \frac{Cash\ Flow, Year\ n}{(1+r)^n}$$

$$LCOE = \frac{NPV, Project\ Costs\ (\$)}{NPV, Electricity\ Produced\ (kWh)}$$

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

Results & Analysis – Reservoir Models

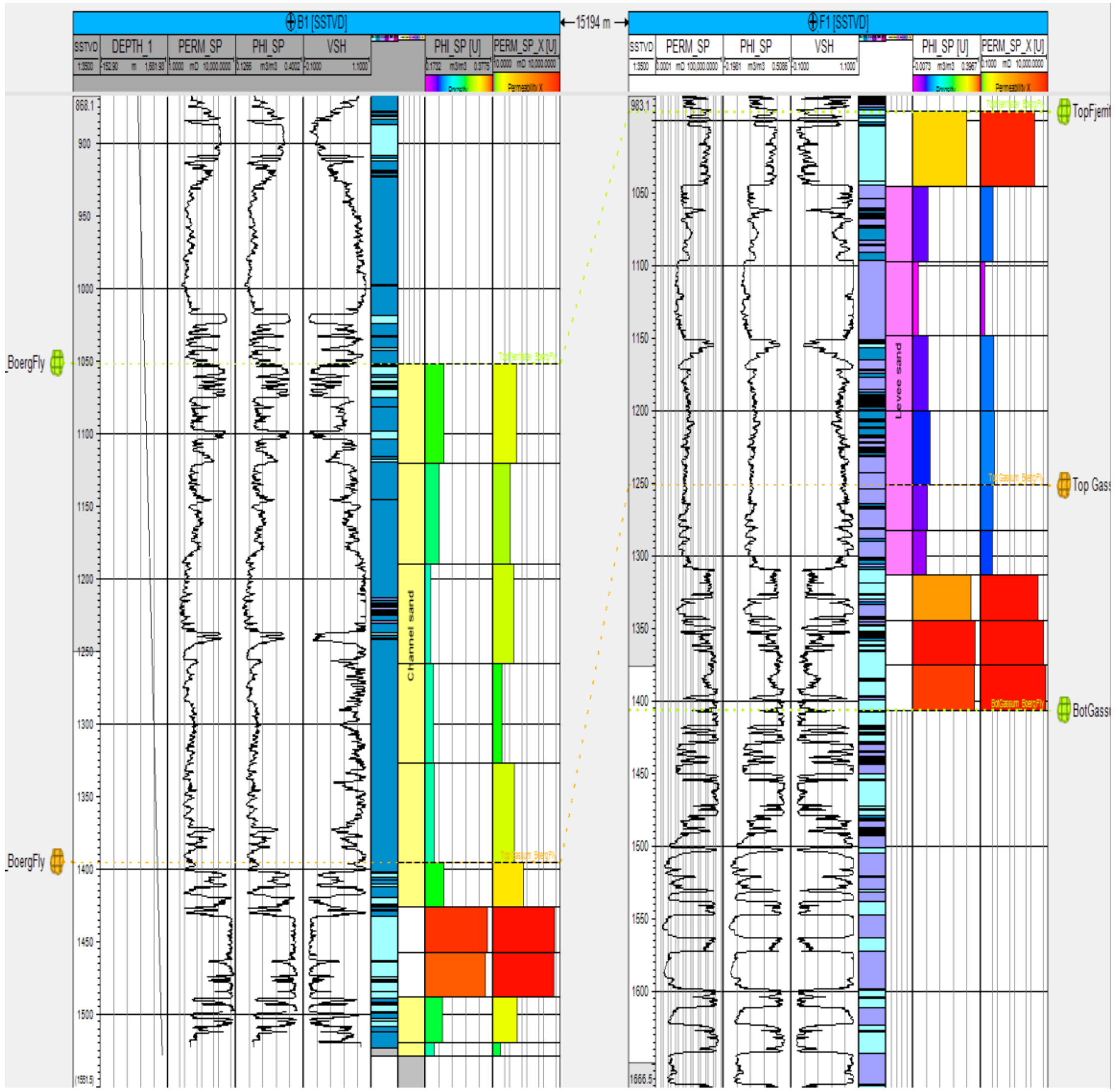


Fig. 8 – Calculated and Generated Petrophysical Well Logs

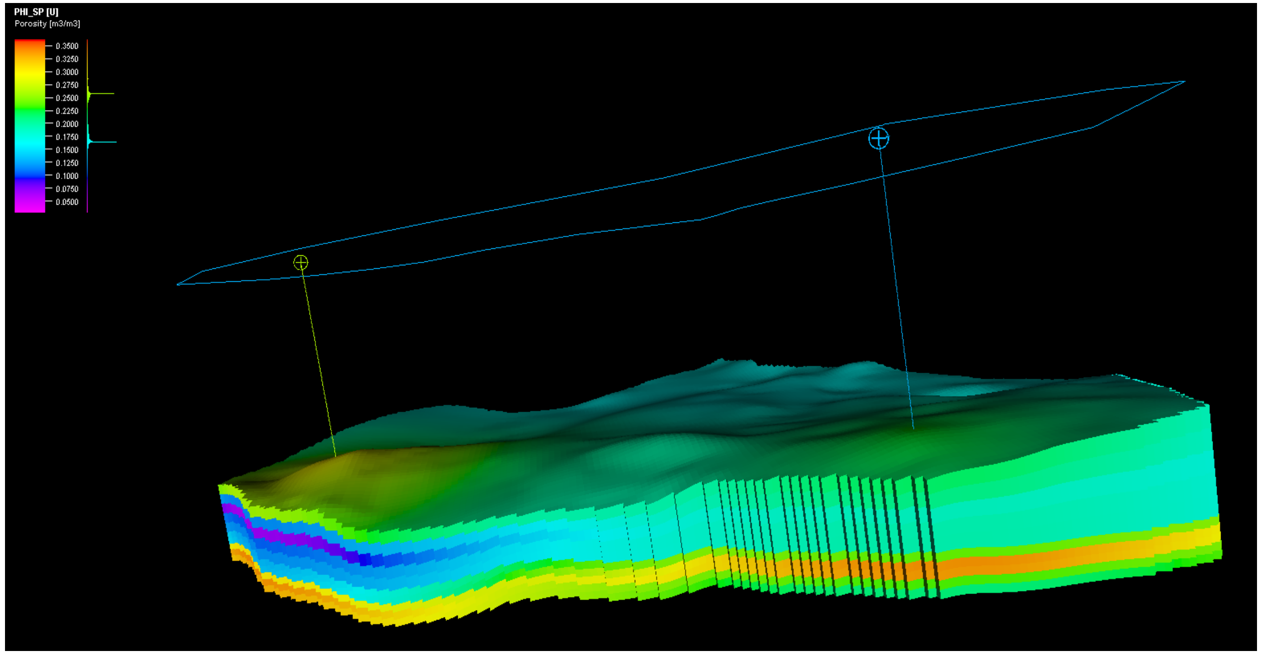
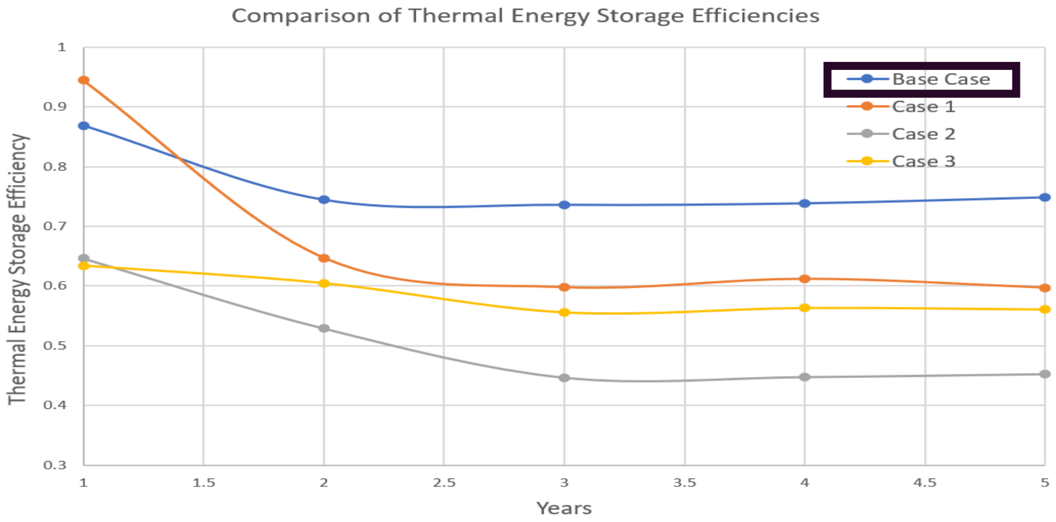


Figure 9 – Reservoir Model of Porosity (PHI_SP)

Table 7 – Critical Comparison of Petrophysical Properties

Gassum Formation	Static Reservoir Simulation		GEUS & Literature	
Petrophysical Properties	Range	Average	Range	Average
Porosity (%)	6.91-36.3	25.78	27.2-31.4	29.3
Permeability (mD)	0.7069-6585	2346	1000-10000	5000
Volumetric Heat Capacity (MJ/m^3K)	2.113-2.762	2.529	2-2.5	*
Thermal Conductivity (W/mK)	3-3.99	3.5	3-4	*

Results and Analysis – Simulation Cases



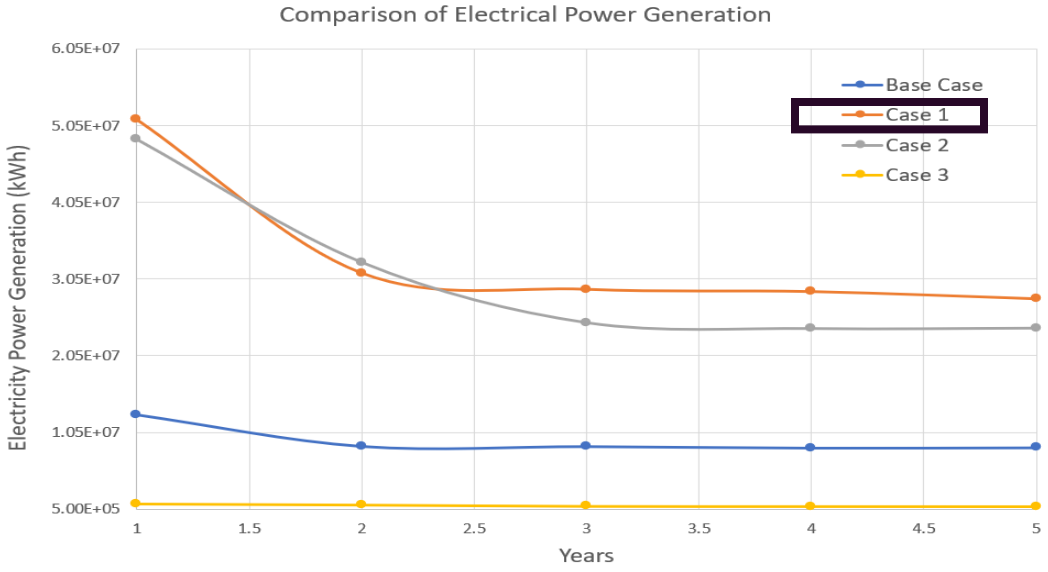
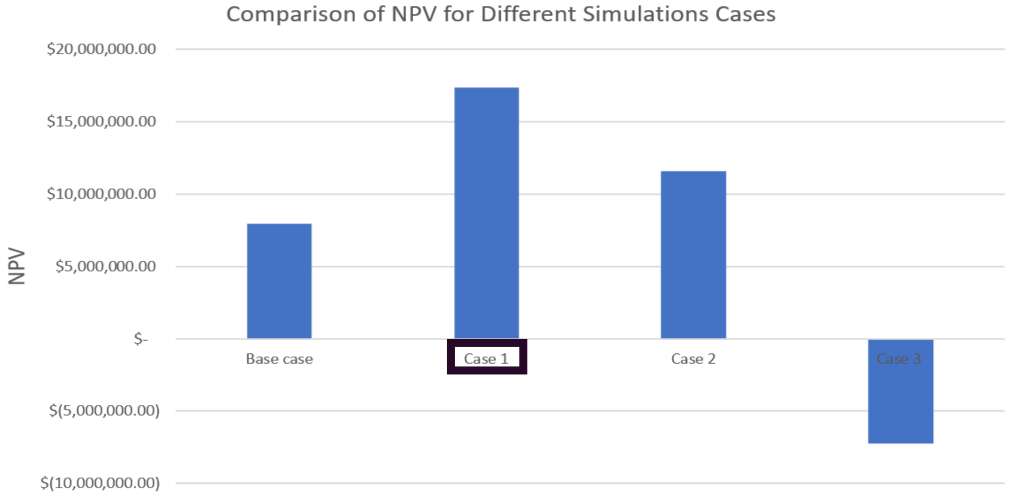


Fig 10 & 11 – Technical Yardsticks Applied to Simulation Results



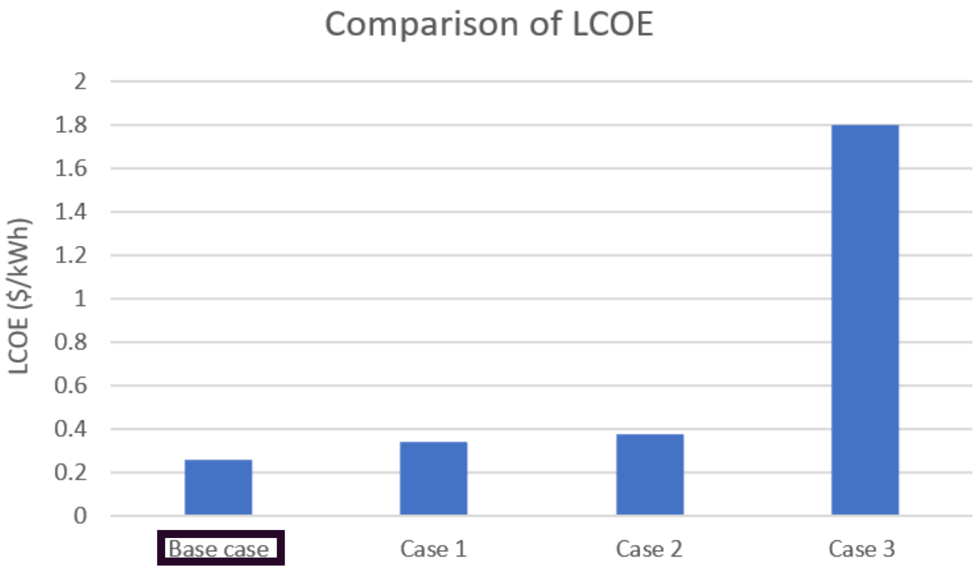


Fig 12 & 13 – Economic Yardsticks Applied to Simulation Results

Results and Analysis – Field Development Plan

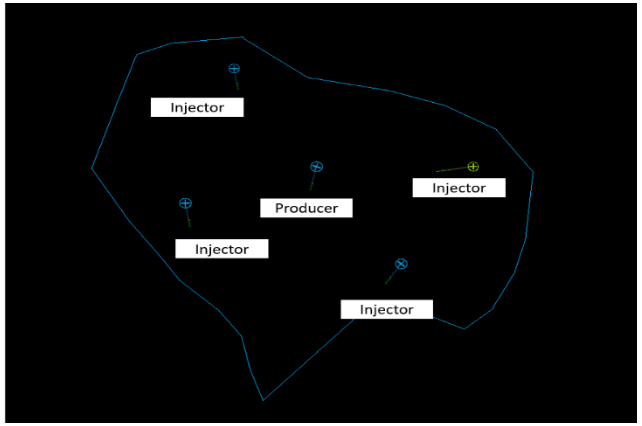


Fig 14 – 5 Spot Well Pattern on Assumed Drainage Area

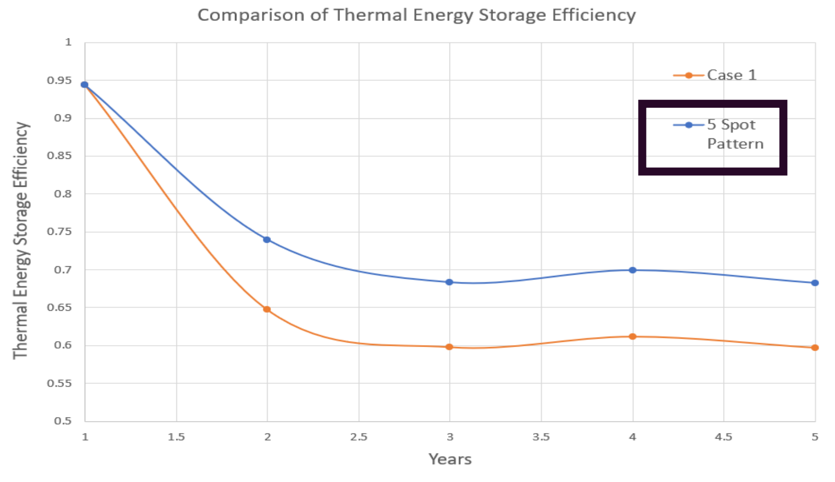


Fig 15 – Case 1 vs. 5 Spot Pattern Thermal Energy Storage Efficiency

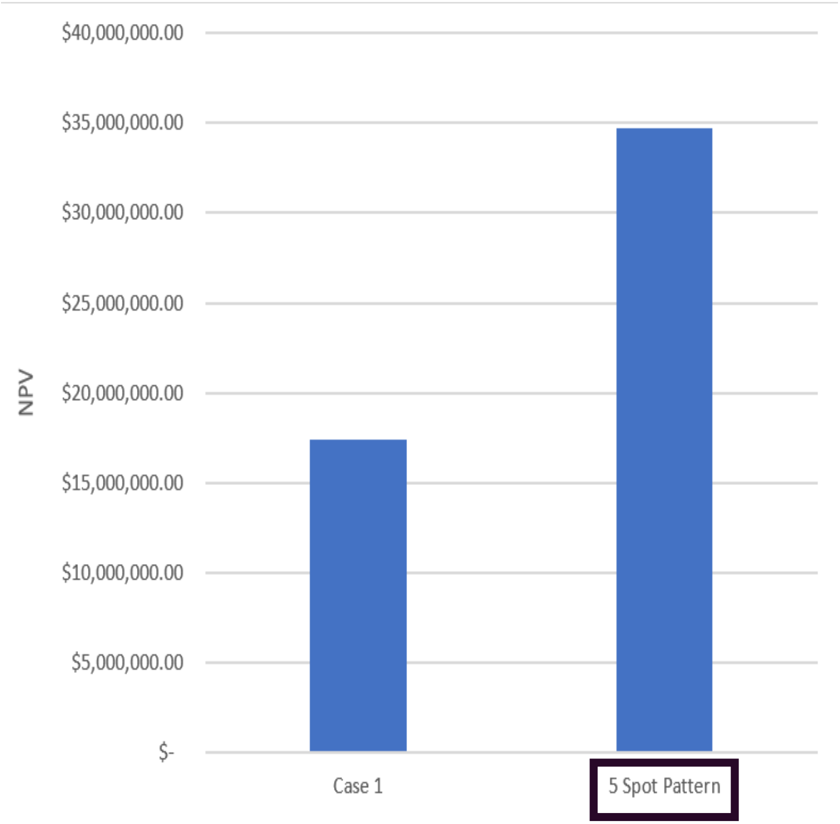


Fig 16 – Case 1 vs. 5 Spot Pattern NPV

- 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

References

BIRD, L., 2016. Wind and solar energy curtailment: A Review of international experience. Renewable and Sustainable Energy Reviews, 65(2016), pp. 577-586.

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND, 2023. Geothermal energy WebGIS portal. [online]. Available from: https://data.geus.dk/geoterm/ [Accessed 25 August 2023].

JELLO, J. et al., 2022. Advanced geothermal energy storage systems by repurposing existing oil and gas wells: A full-scale experimental and numerical investigation. Renewable Energy, 199(2022), pp. 852-865.

WENDT et al., 2019. Flexible Geothermal Power Generation utilizing Geologic Thermal Energy Storage. Idaho National Laboratory: Idaho Falls, Idaho.

ZHENG, Q., 2014. Design of a high-temperature subsurface thermal energy storage system. Clemson University Tiger Prints, 5(2014).

Thank you

Your Energy Institute

Your AHI Branch

MSc Students
Best Energy Paper Competition 2023

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

Background

- 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 CO_2e emissions in TEPUK in 2022

Aims of this Project

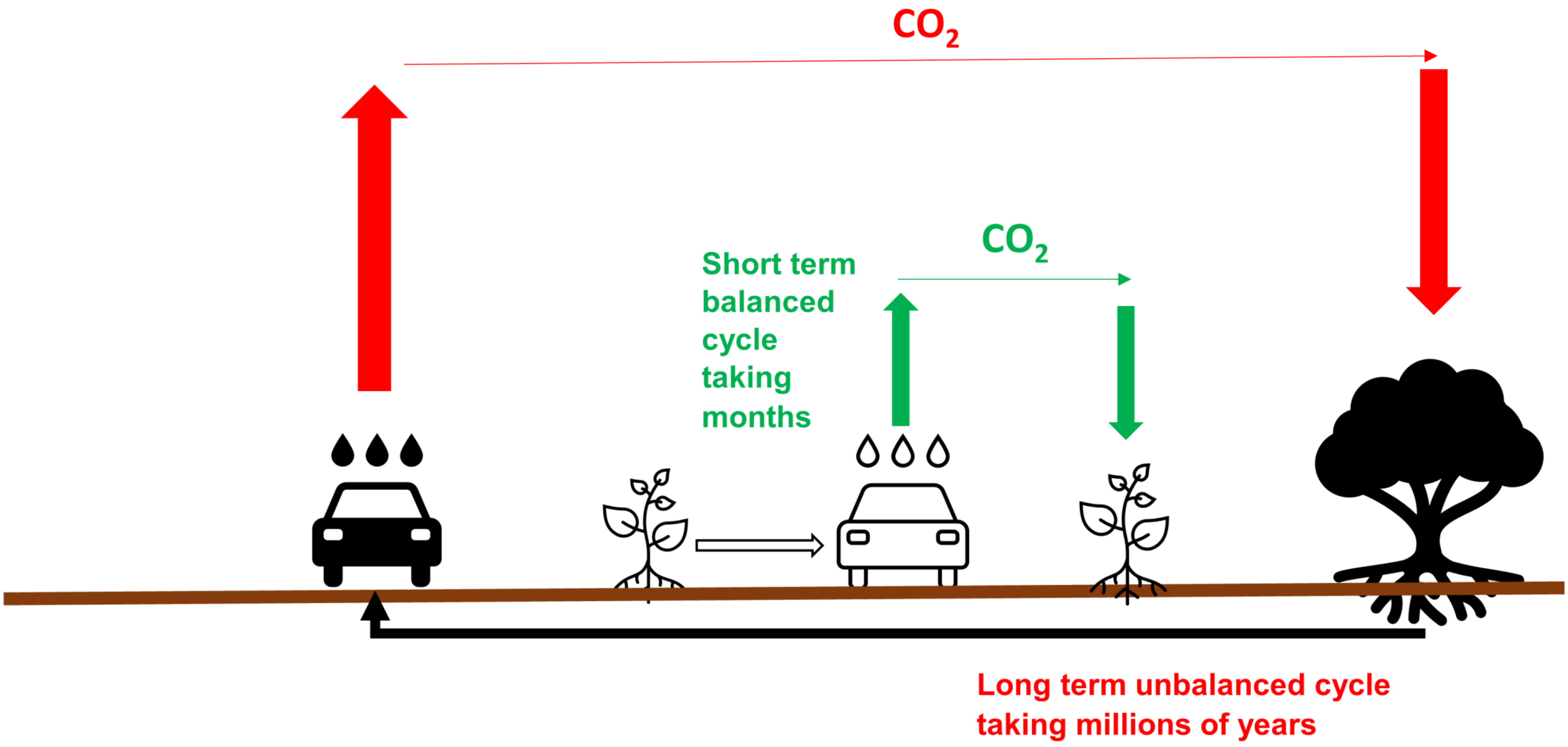
1. Compare different types of biofuels and select most suitable for use in TEPUK

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

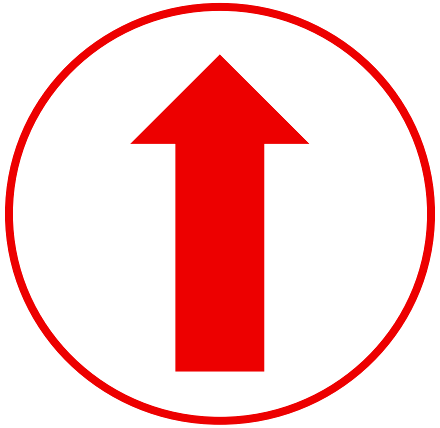
What is a Biofuel?



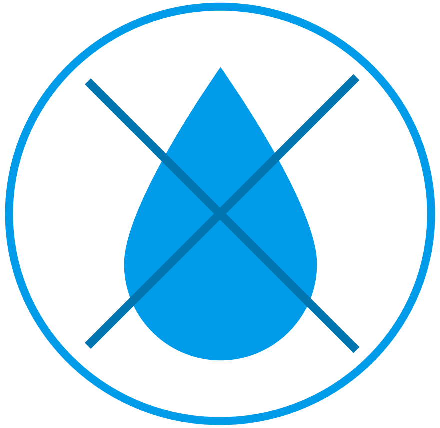
Hydrotreated Vegetable Oil (HVO) (Renewable Diesel)

- **Drop-in replacement**

2nd Generation



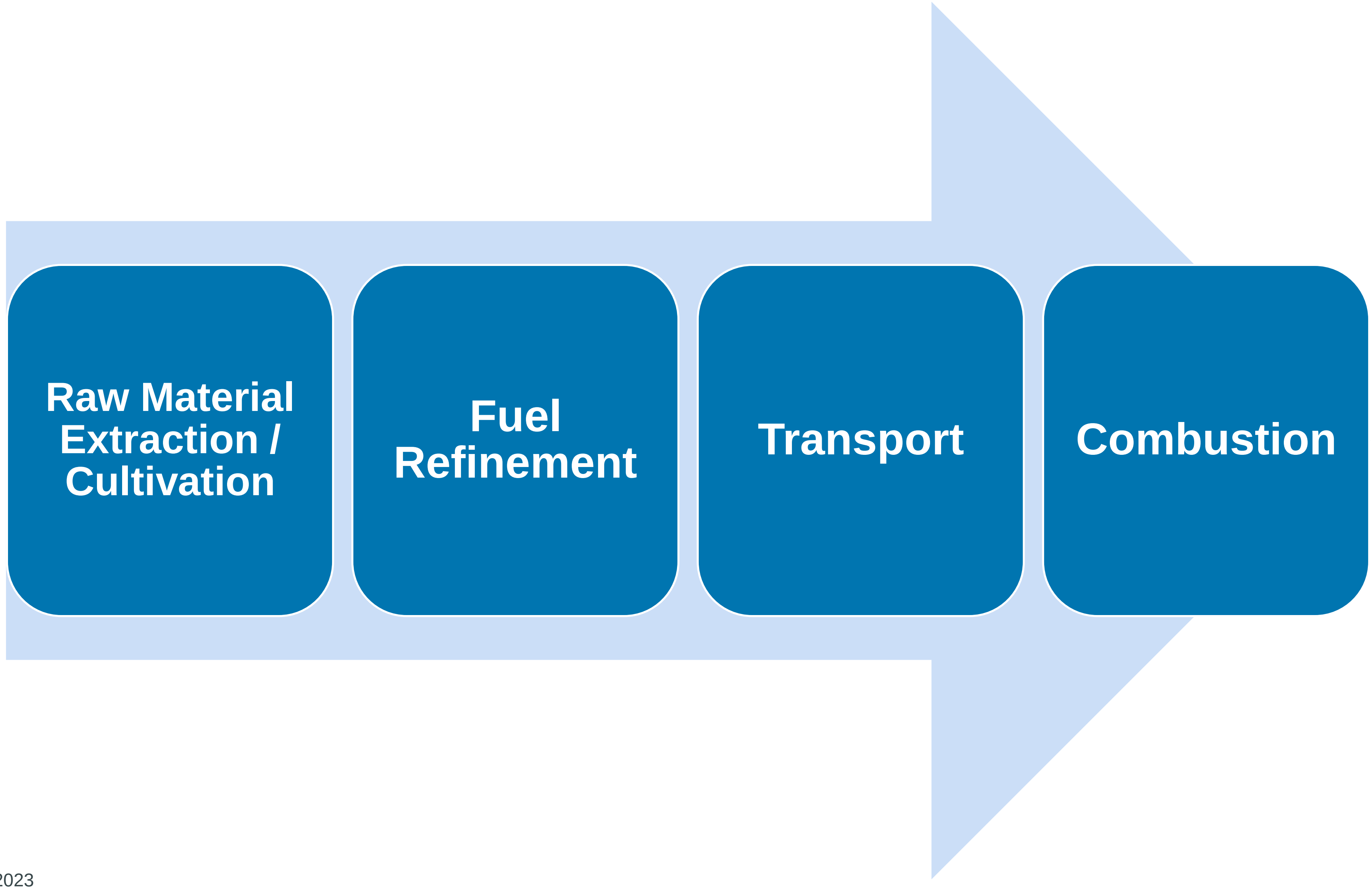
Higher gravimetric energy content than diesel



Doesn’t attract water

Longer storage life

Lifecycle Emissions Assessment of Diesel vs HVO



HVO Lifecycle Emissions Assessment

TotalEnergies

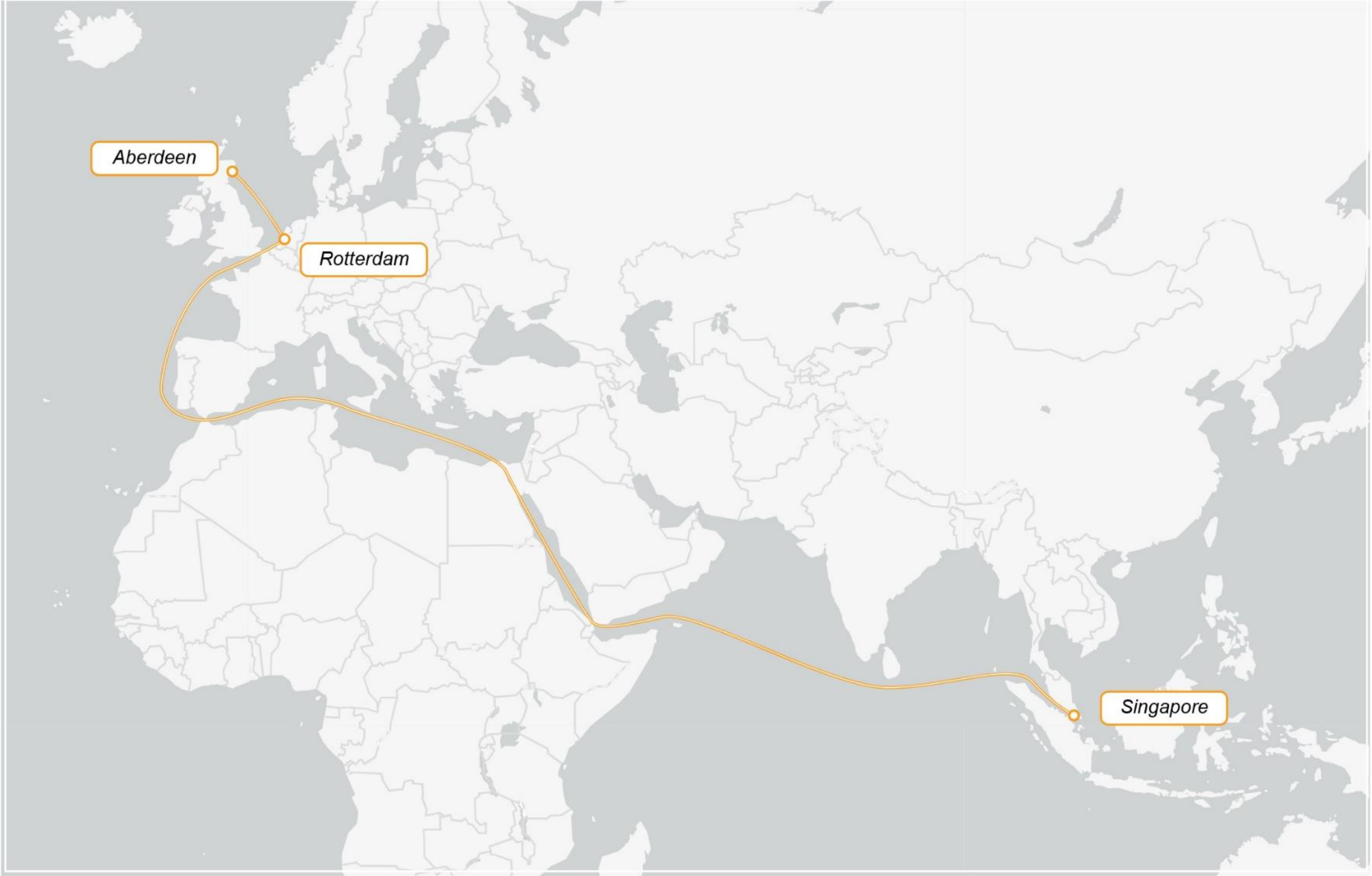
1. Raw Material Cultivation: 0 tonnes of CO_2e per tonne of HVO

HVO Lifecycle Emissions Assessment

2: HVO Refinement: 0.54 tonnes of CO_2e per tonne of HVO

HVO Lifecycle Emissions Assessment

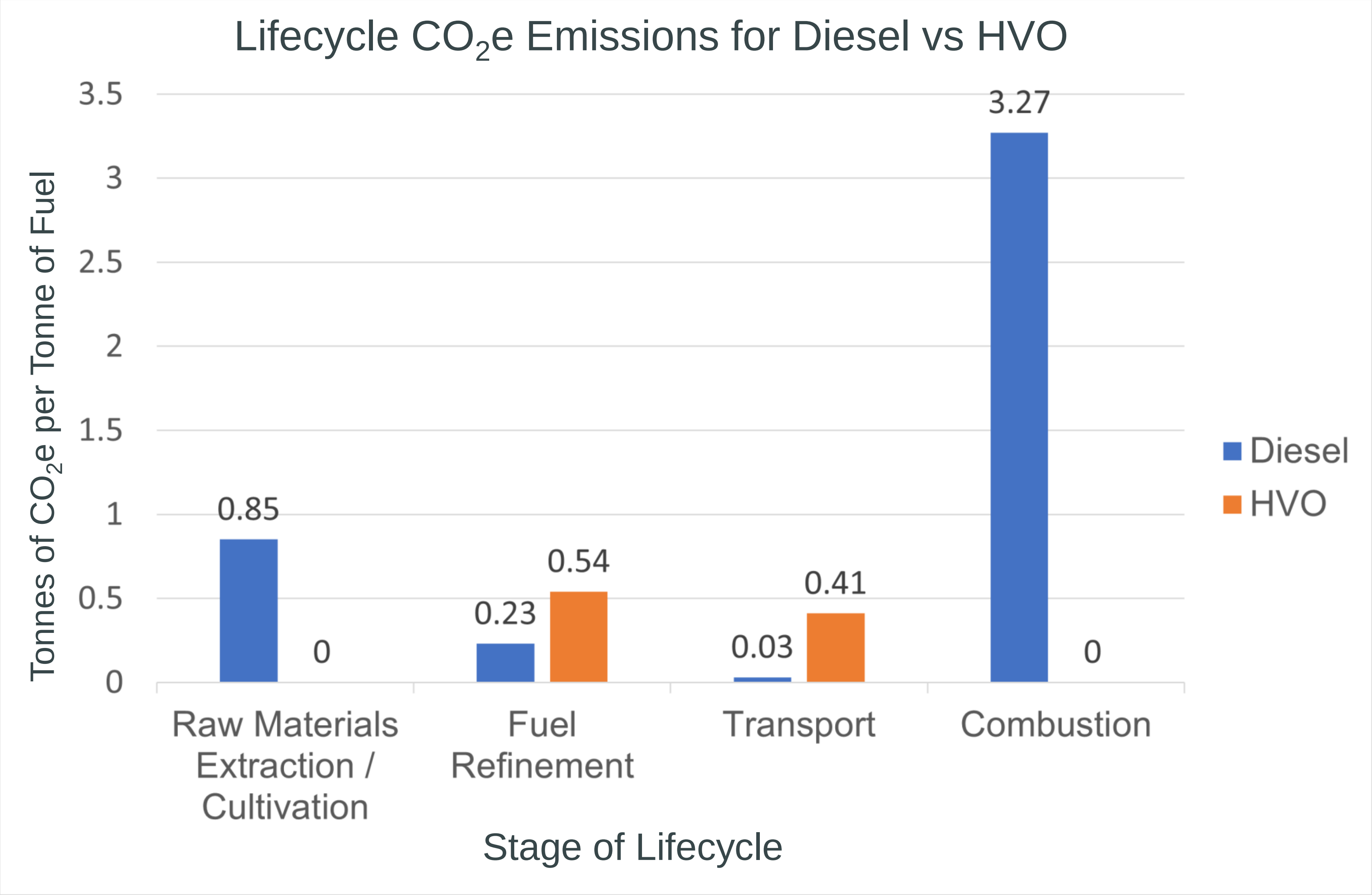
3: HVO Transport to Aberdeen: 0.41 tonnes of CO_2e per tonne of HVO



HVO Lifecycle Emissions Assessment

4: HVO Combustion: 0 tonnes of CO_2e per tonne of HVO

Lifecycle Emissions Assessment of Diesel vs HVO



78% emissions reduction through use of HVO

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

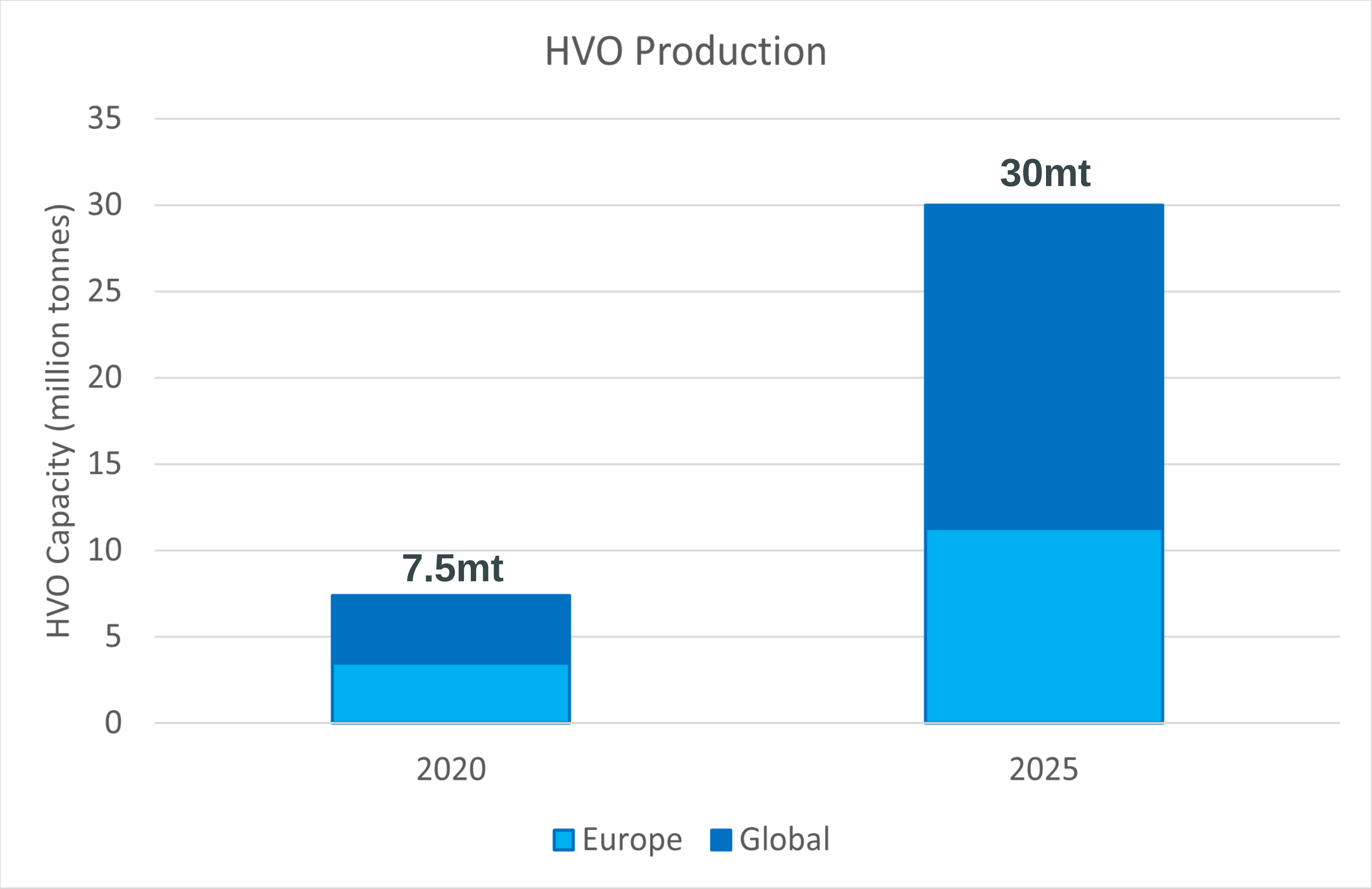
TotalEnergies

- 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



Future Steps

Investigate Claimed Emissions Saving

Investigate Potential Maintenance Cost Savings

Source HVO

Complete Small Trial

Conclusions

HVO most suitable biofuel for use within TEPUK as a diesel replacement

78%

Use of HVO could reduce lifecycle emissions by up to **78%** compared to diesel

3X

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 ☺

Disclaimer and copyright reservation

Definition - TotalEnergies / Company

The entities in which TotalEnergies SE directly or indirectly holds an interest are separate and independent legal entities. The terms "TotalEnergies", "TotalEnergies company" and "Company" used in this document are used to refer to TotalEnergies SE and its affiliates included in the scope of consolidation. Similarly, the terms "we", "us", "our" may also be used to refer to these entities or their employees. It cannot be inferred from the use of these expressions that TotalEnergies SE or any of its affiliates is involved in the business or management of any other company of the TotalEnergies company.

Disclaimer

This presentation may include forward-looking statement within the meaning of the Private Securities Litigation Reform Act of 1995 with respect to the financial condition, results of operations, business, strategy and plans of TotalEnergies that are subject to risk factors and uncertainties caused by changes in, without limitation, technological development and innovation, supply sources, legal framework, market conditions, political or economic events.

TotalEnergies does not assume any obligation to update publicly any forward-looking statement, whether as a result of new information, future events or otherwise. Further information on factors which could affect the company's financial results is provided in documents filed by TotalEnergies with the French *Autorité des Marchés Financiers* and the US Securities and Exchange Commission.

Accordingly, no reliance may be placed on the accuracy or correctness of any such statements.

Your Energy Institute

Your AHI Branch

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

ROBERT GORDON UNIVERSITY ABERDEEN

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

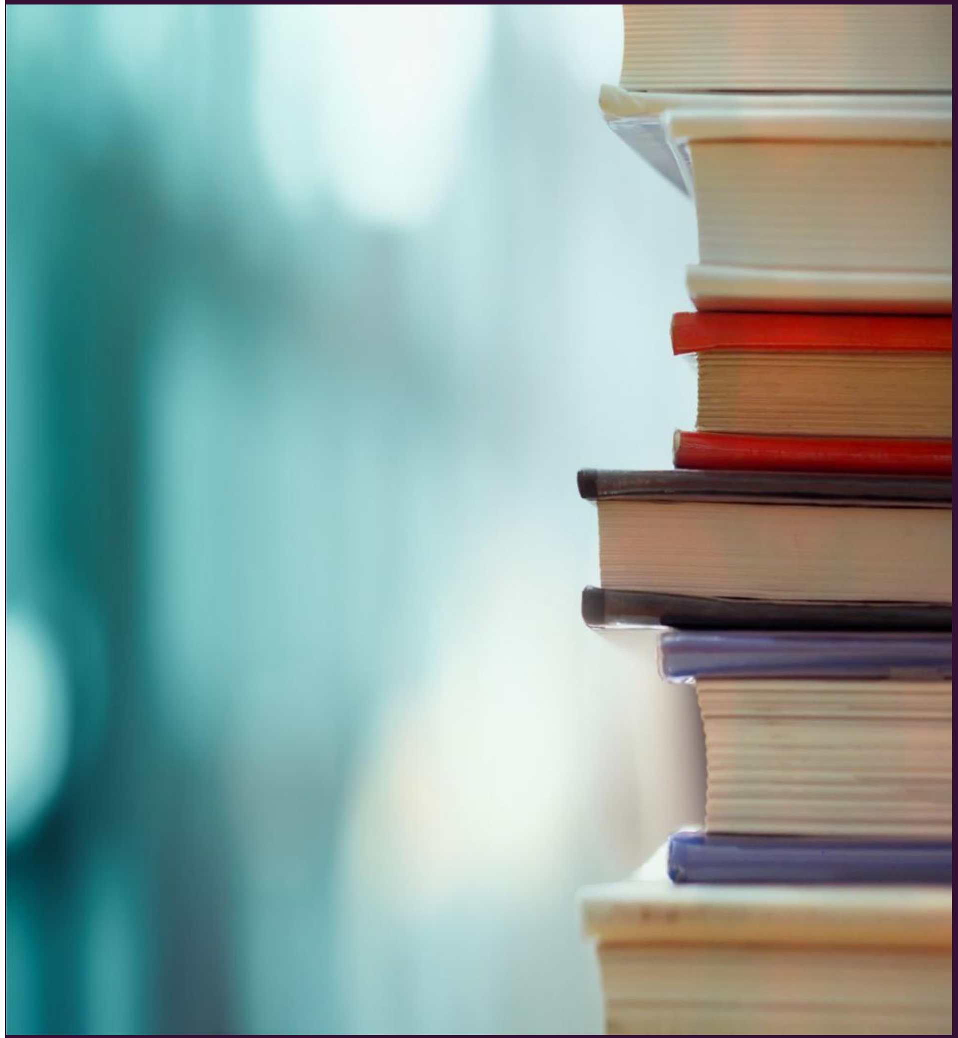
Conclude the scenario for a successful investment decision against carbon reduction and power fulfilment

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

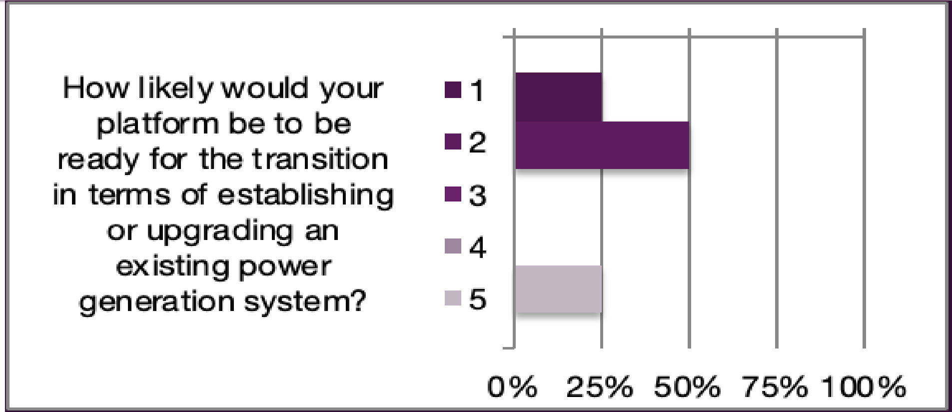
Analysis & Results

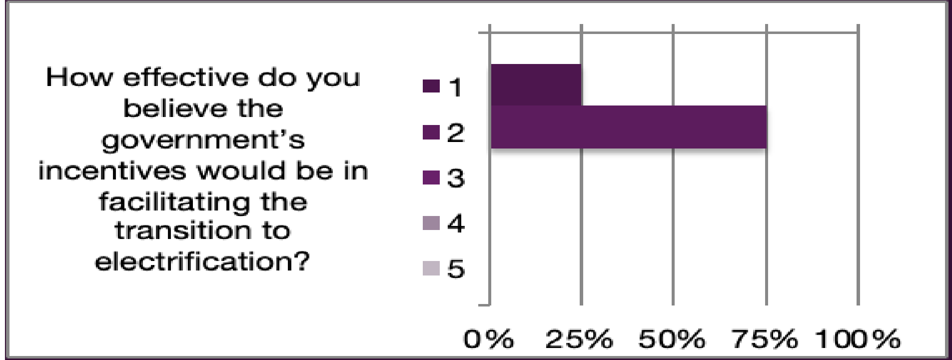


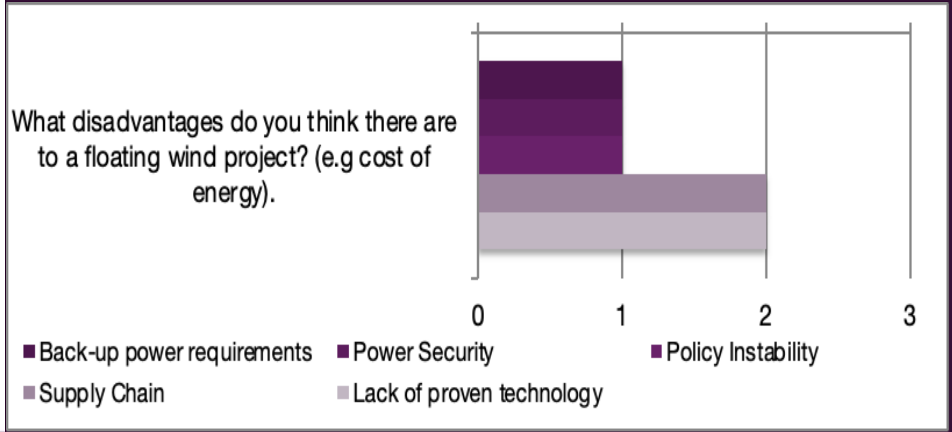
- What does the literature say?
  - 13 sources from between 2010 and 2022
  - Wind power is a viable solution for supporting emissions reduction targets
  - Conclusive full lifecycle costs have not been determined
  - The stage of field life for electrification by wind power remains inconclusive
  - 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

Analysis & Results

- 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





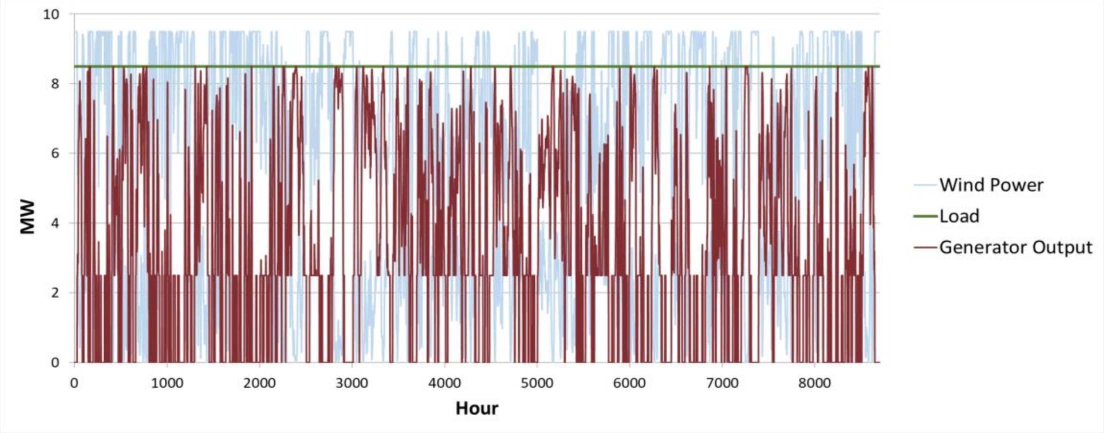


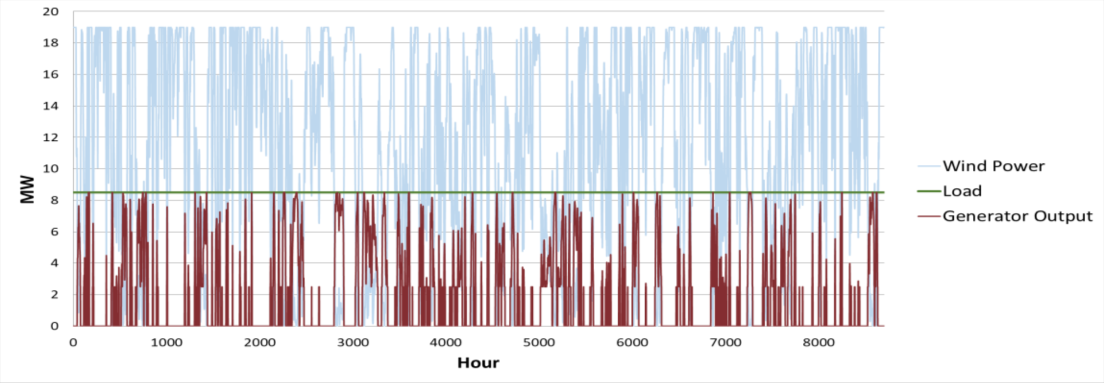
Case Study

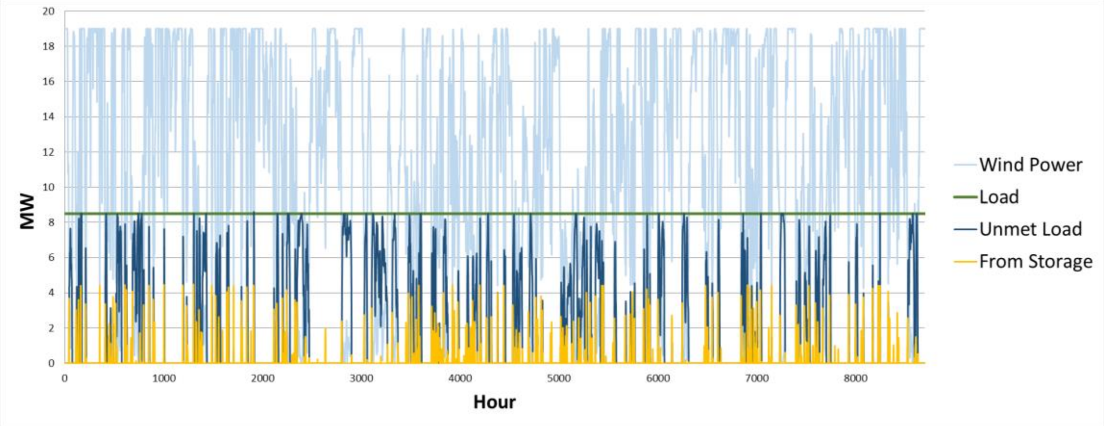
- Represent the average North Sea oil and gas installation to provide a benchmark for power requirements
  - Fossil fueled power generation with 45% efficiency
  - 8.5MW power demand
  - 13year remaining field life
- Eliminating carbon emissions from power generation requires the generators to be removed from service
- **The goal: determine whether it is possible to power the platform under study using FOWTs without requiring additional support**

Analysis & Results

- What does a simulation prove?
    - Utilising 1x 9.5MW FOWT fulfills 31% of a 1-year power demand
        - Emitting 37.8 ktonnes of CO_2
    - Utilising 2x 9.5MW FOWT fulfills 64% of a 1-year power demand
        - Emitting 20.3 ktonnes of CO_2
    - Utilising 2x 9.5MW FOWT + 9MW BESS, 71% of a 1-year power demand is observed
        - Emitting 17.6 ktonnes of CO_2
    - **A result without the need for conventional power generation in this scenario was found not to be feasible**





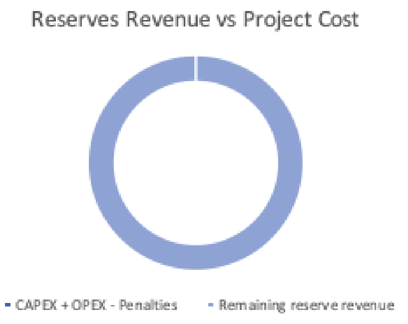


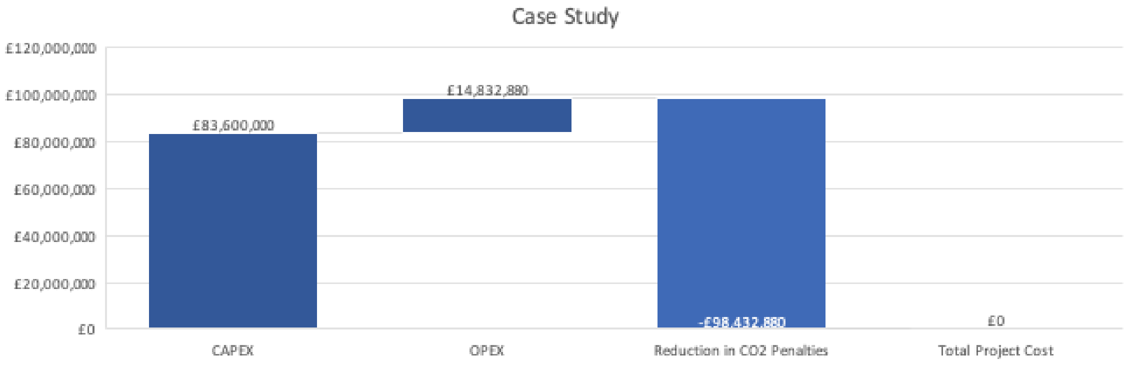
Analysis & Results

- 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

Scenario Simulation

Power Demand	8.5
Dual Fuel Generator (MW)	30
Efficiency %	45%
Remaining Life of Field	16.3
Wind Turbine (MW)	19
Capacity Factor	0.36
Power from Wind (MWh)	60006
CAPEX	£83,600,000
OPEX	£14,832,880
CAPEX + OPEX - Penalties	£0
% Emissions Reduction	86.9%
Remaining reserve revenue	£2,117,423,400





Analysis & Results

- 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
  - CO_2 capturing through exhaust releases
    - The addition of an amine plant can reduce emissions by 14%
    - The captured CO_2 can also be utilised for enhanced oil recovery
  - CO_2 capturing through flare gas releases
    - Flare gas processing and rerouting could reduce emissions by 23%

Conclusion & Recommendations

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

Your AHI Branch

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

21tst November 2023

What is the driving factor behind initiating this project?

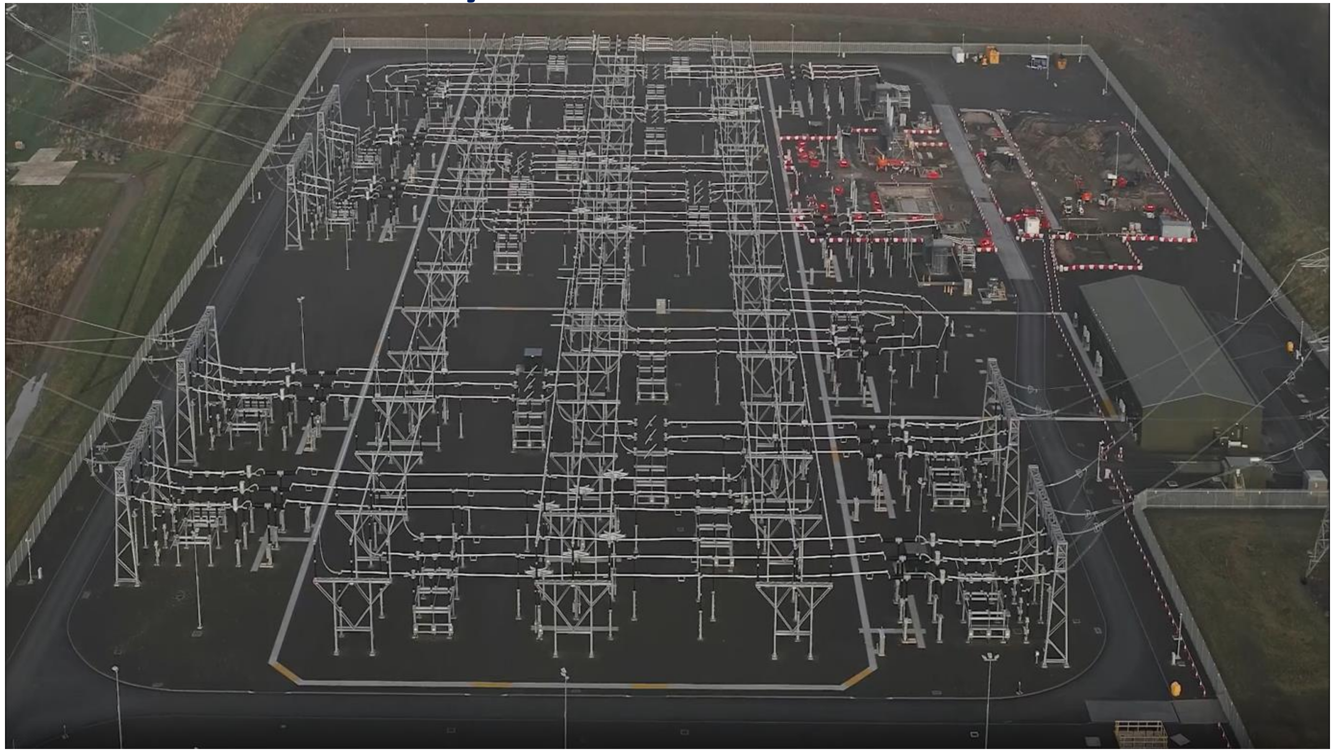
1. Climate change refers to the long-term alteration in Earth's climate patterns, driven primarily by human activities and natural processes.
2. Addressing the escalation of anthropogenic emissions on a global scale involves the adoption of renewable energy sources.
3. The surge in renewable integration 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

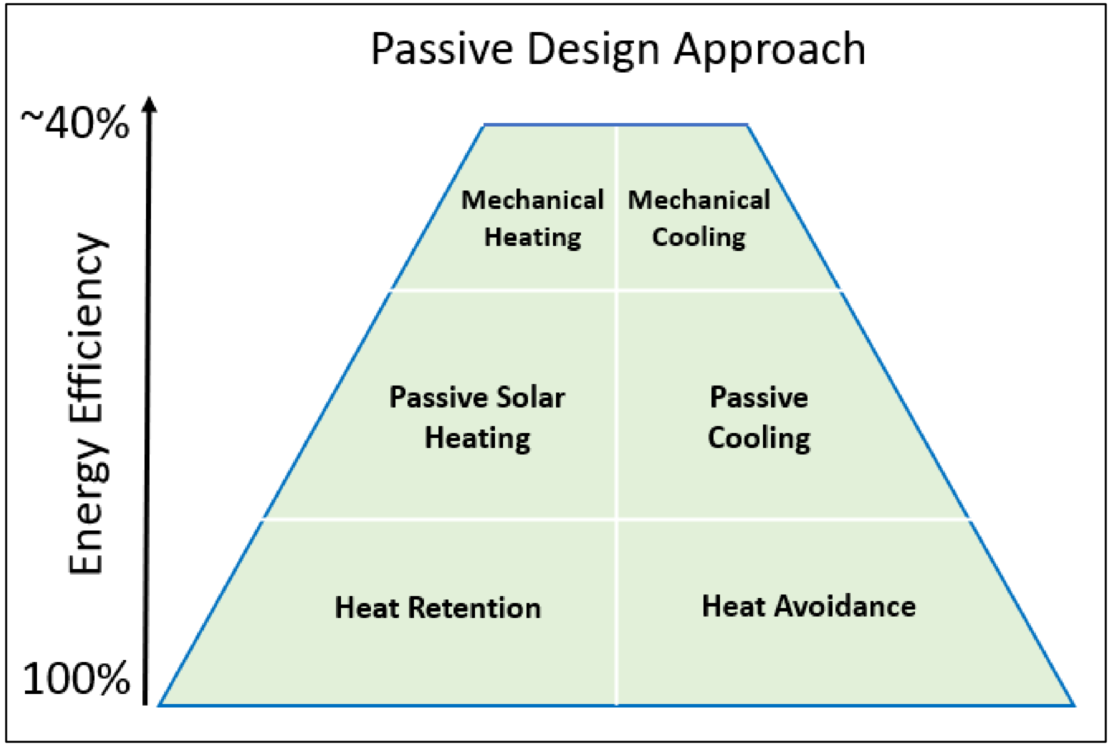
1. Climate forecasting – To comprehend the effects of climate change, especially on building infrastructure, and evaluate sustainable strategies to mitigate its impacts.
2. Technical Analyses on the energy performance of control buildings – A comprehensive case study was conducted on the Rothienorman 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.

UNIVERSITY OF ABERDEEN



Adapted from SSE [3]



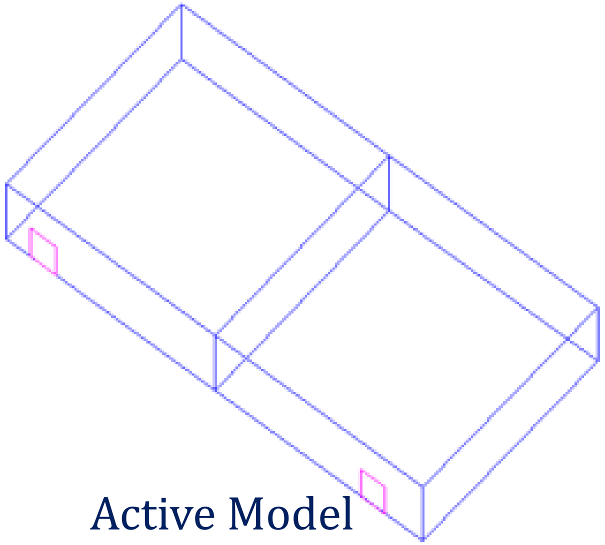
Adapted from [2]

Zone	**Set point in °C**	**Operating point in °C**
Control Room	25	32
Communication Room	25	32
Battery Room	20	15

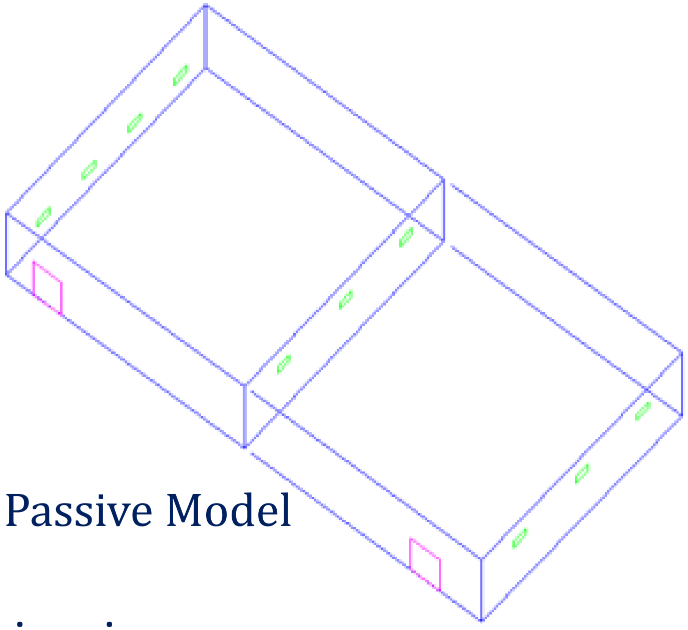
Methodology

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.



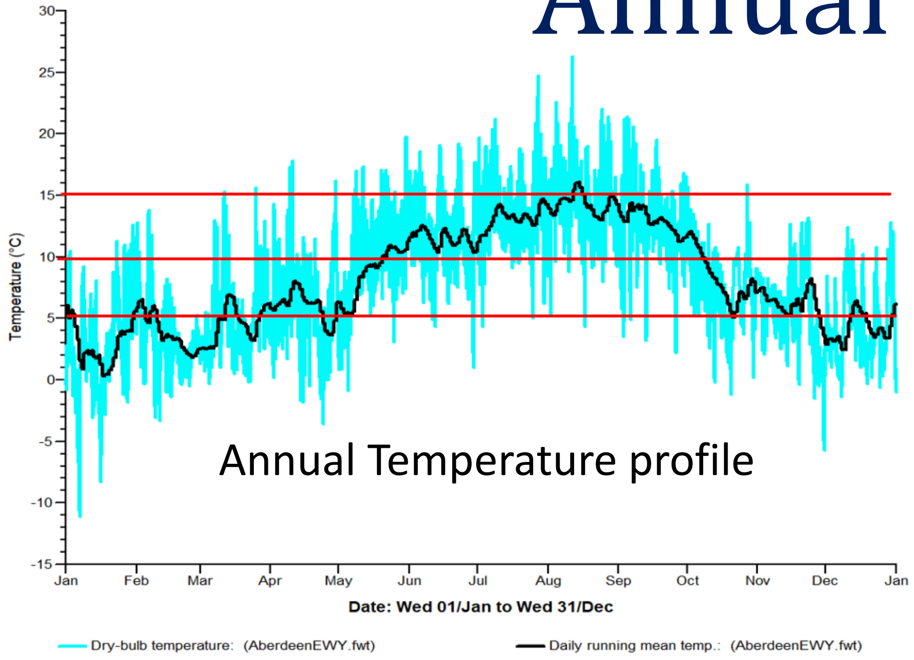
Active Model

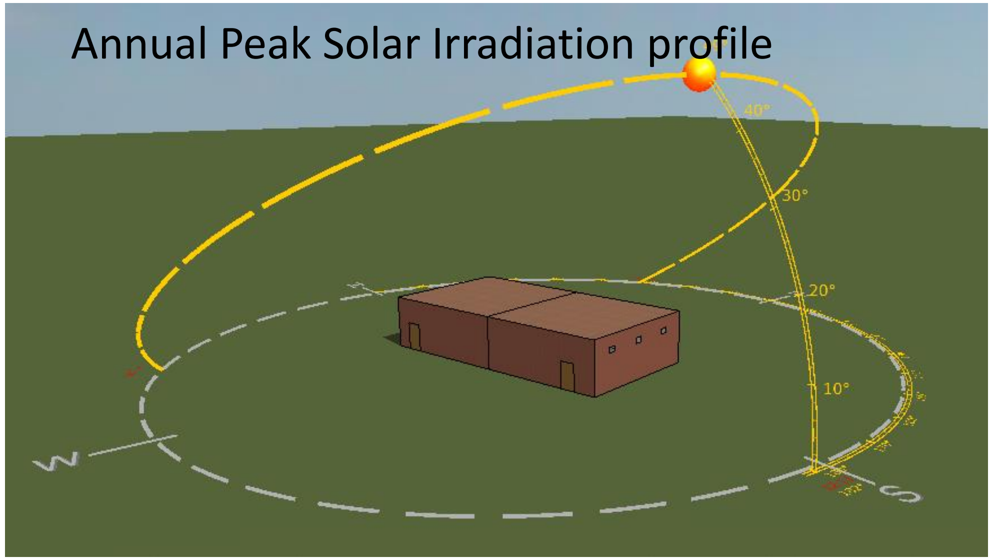


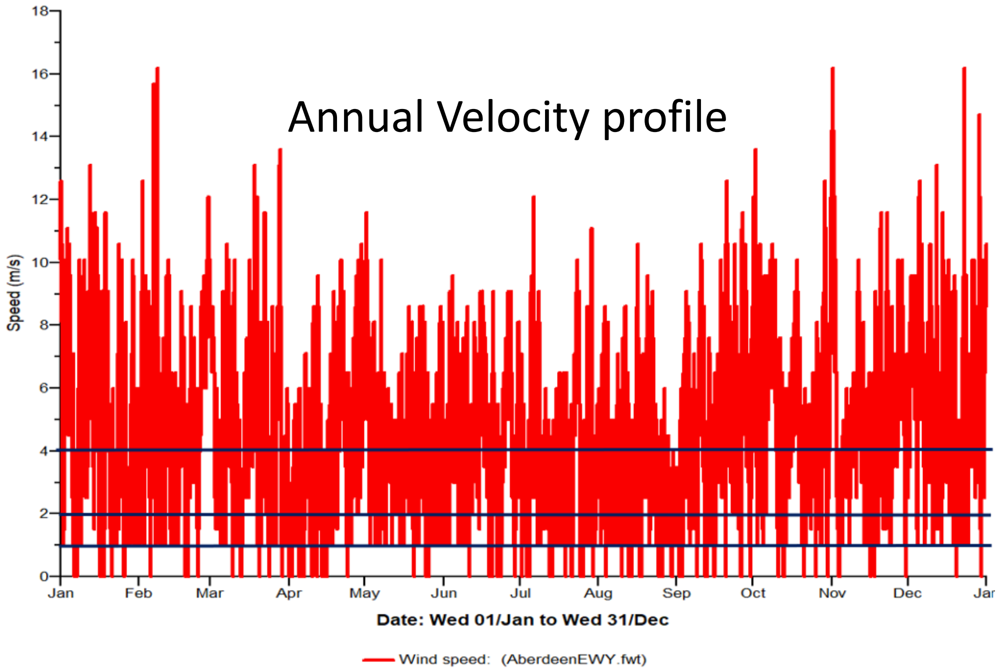
Passive Model

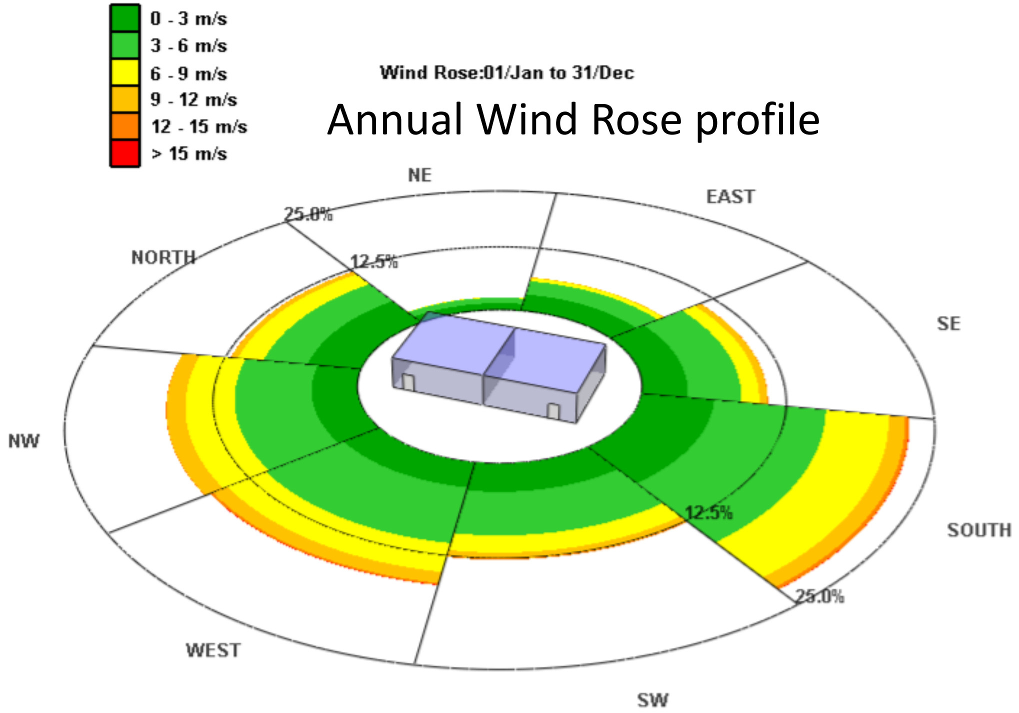
- Detailed analysis of active and passive system efficiencies.
- Incorporating Passive cooling, heat recovery wheel, and Solar Photovoltaics.

Annual weather profiles

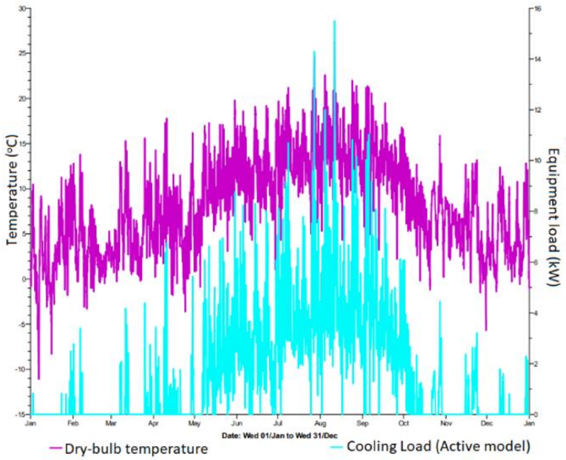


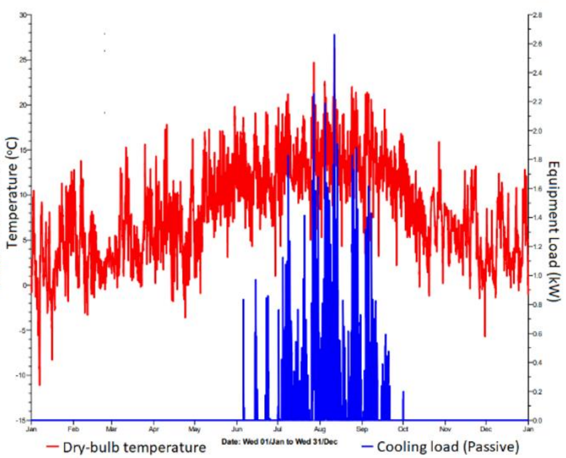




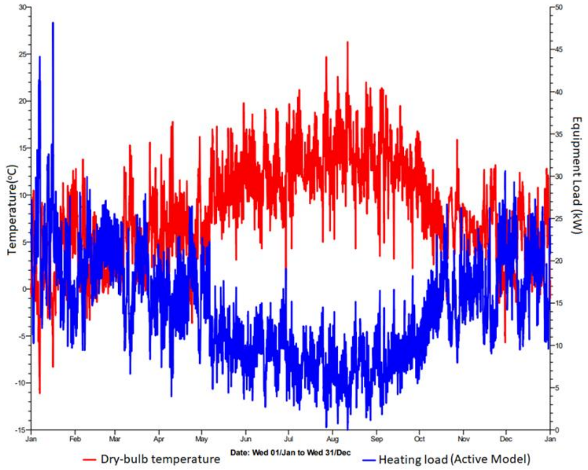


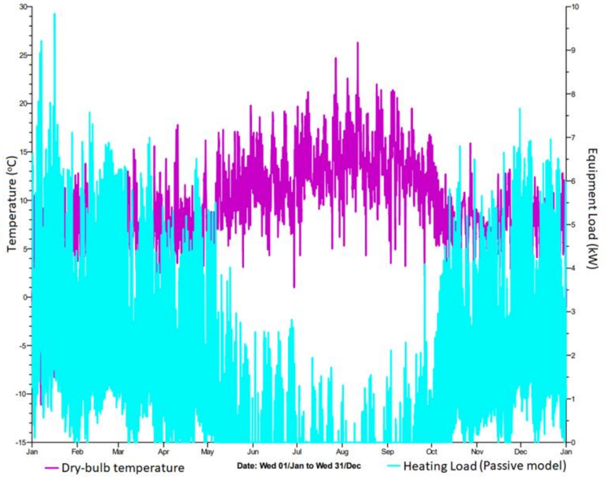
Cooling Load





Heating Load



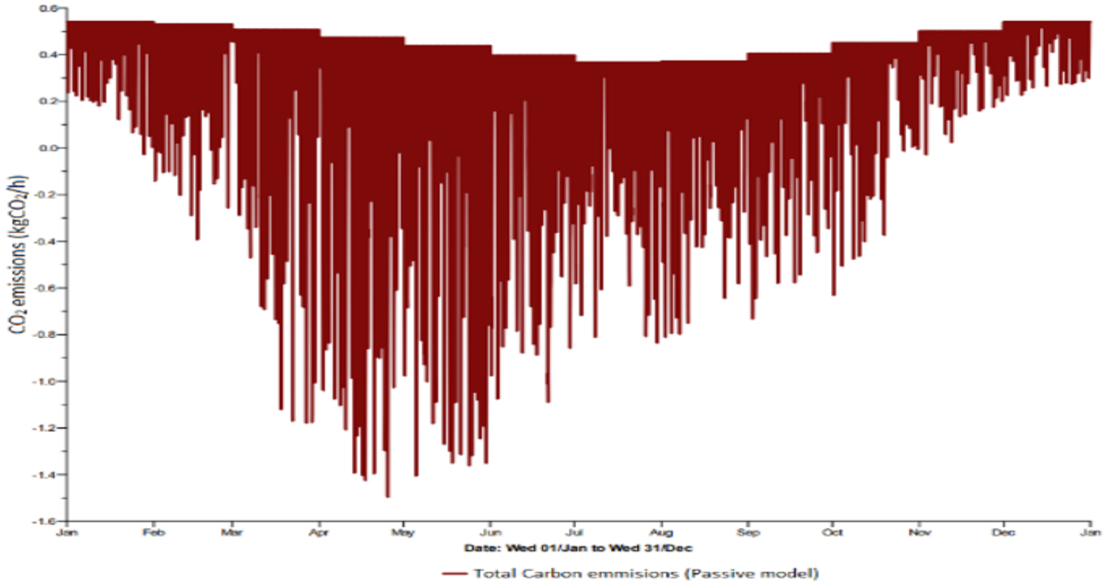


Cooling		
Month	Active Equipment load %	Passive Equipment load %
Jan -May	13.33	0
June-Oct	80.03	17.85
Nov-Dec	6.66	0
Total	100	17.85
Energy Savings	0	82.15%

Heating		
Month	Active Equipment load %	Passive Equipment load %
Jan -May	38.88	28.54
June-Oct	22.22	8.09
Nov-Dec	38.89	11.54
Total	100	48.17
Energy Savings	0	51.83

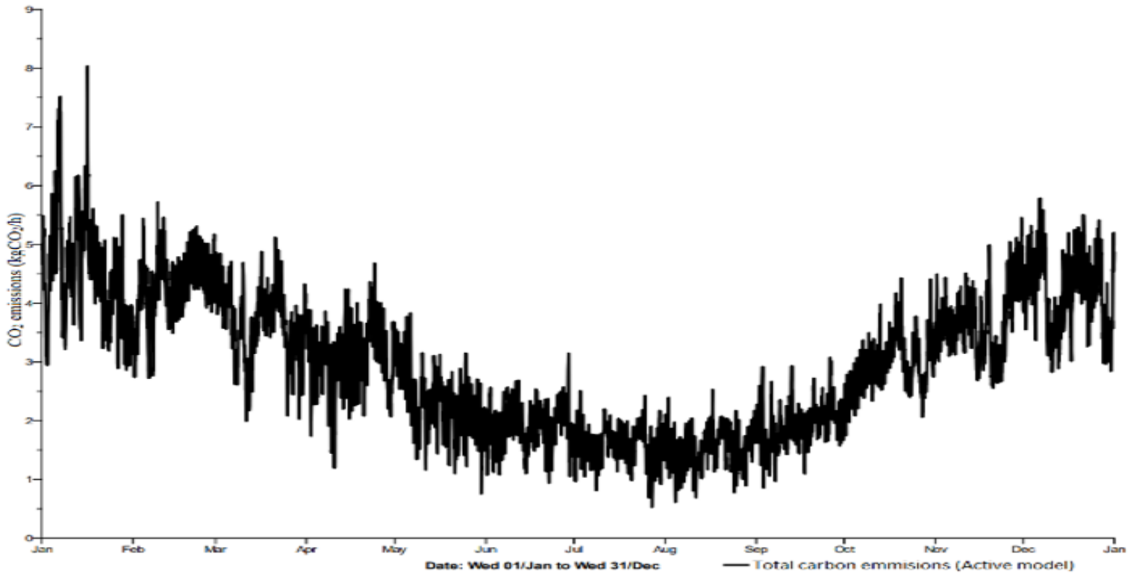
Carbon Emissions

Passive Design



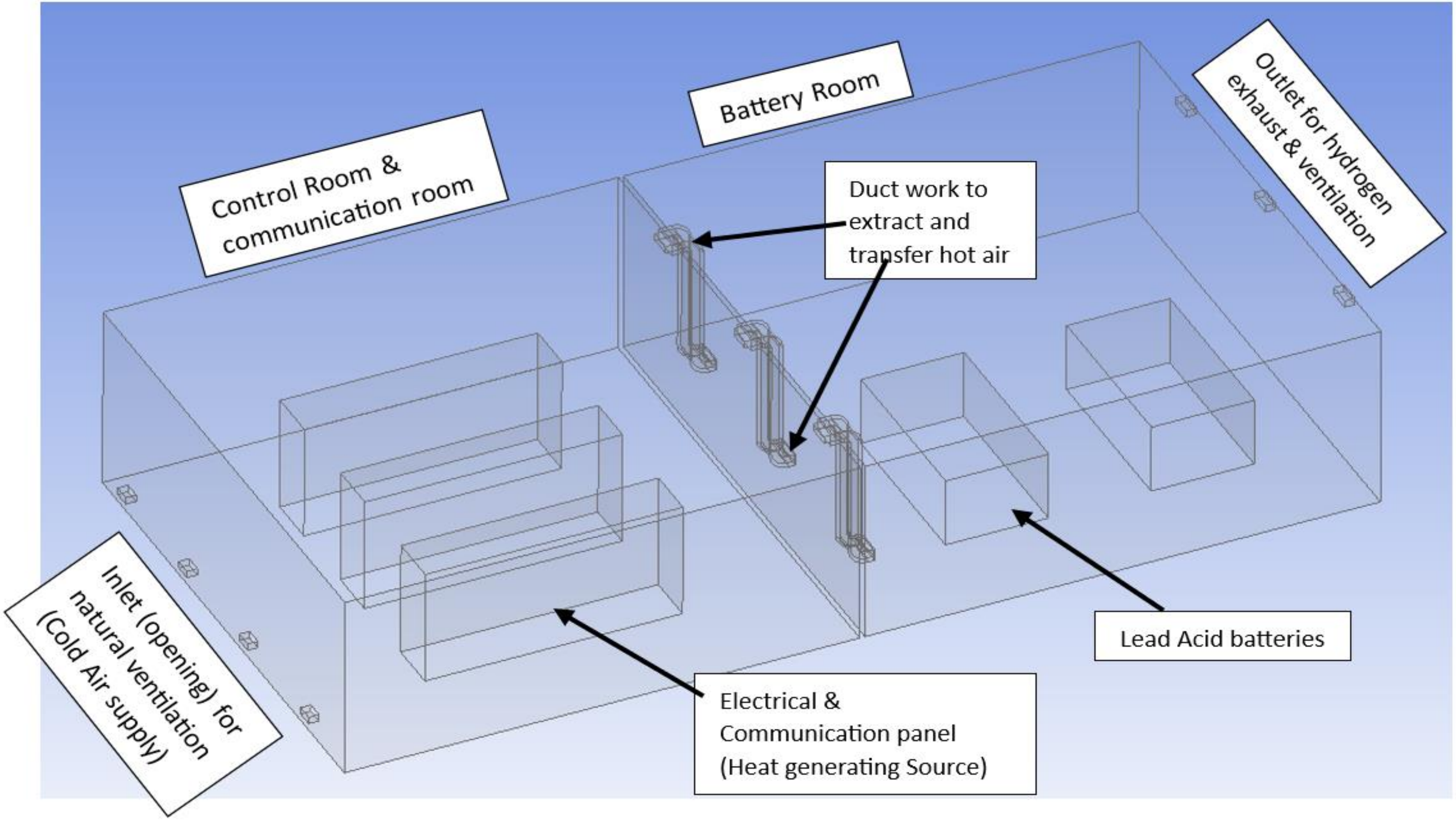
Carbon negative profile for passive design approach

Active Design

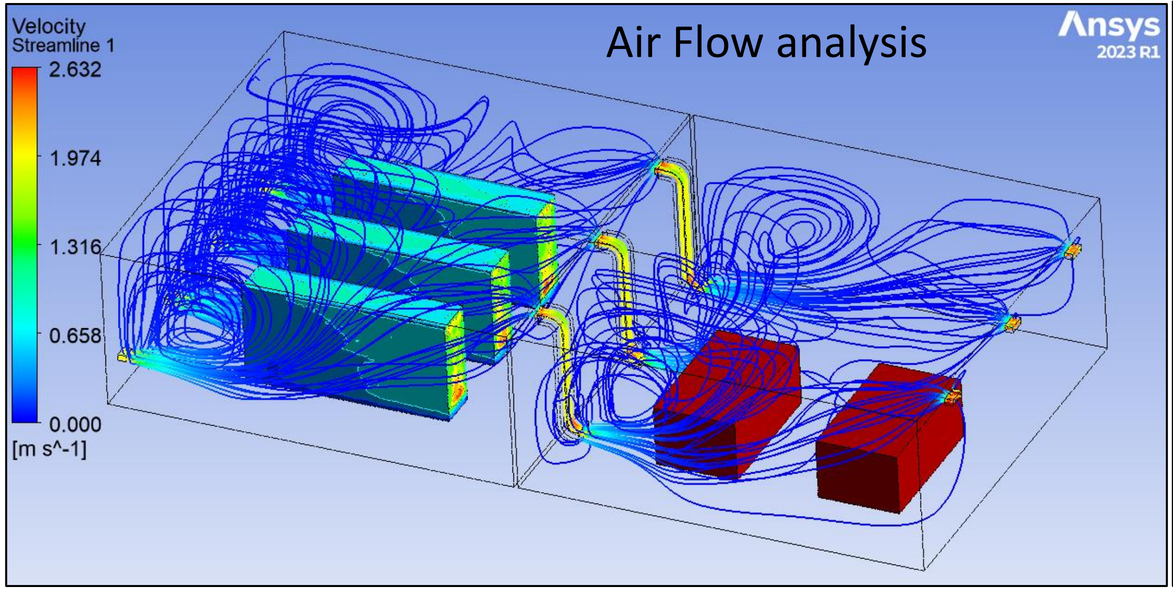


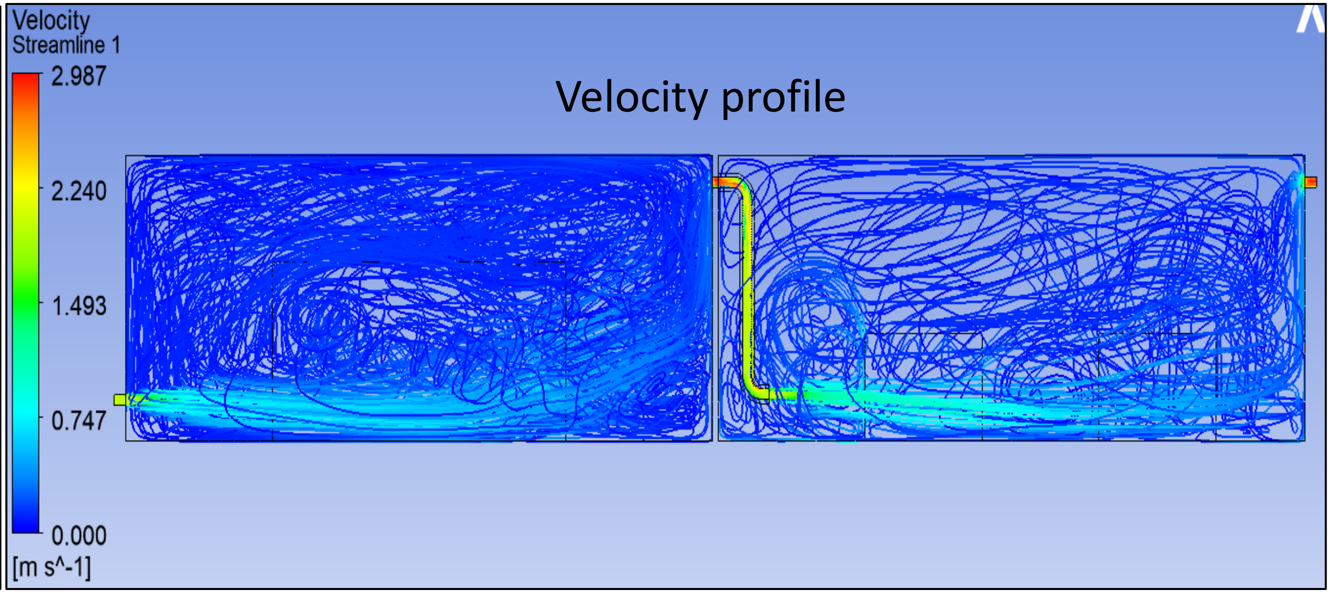
Carbon-positive profile for existing active design

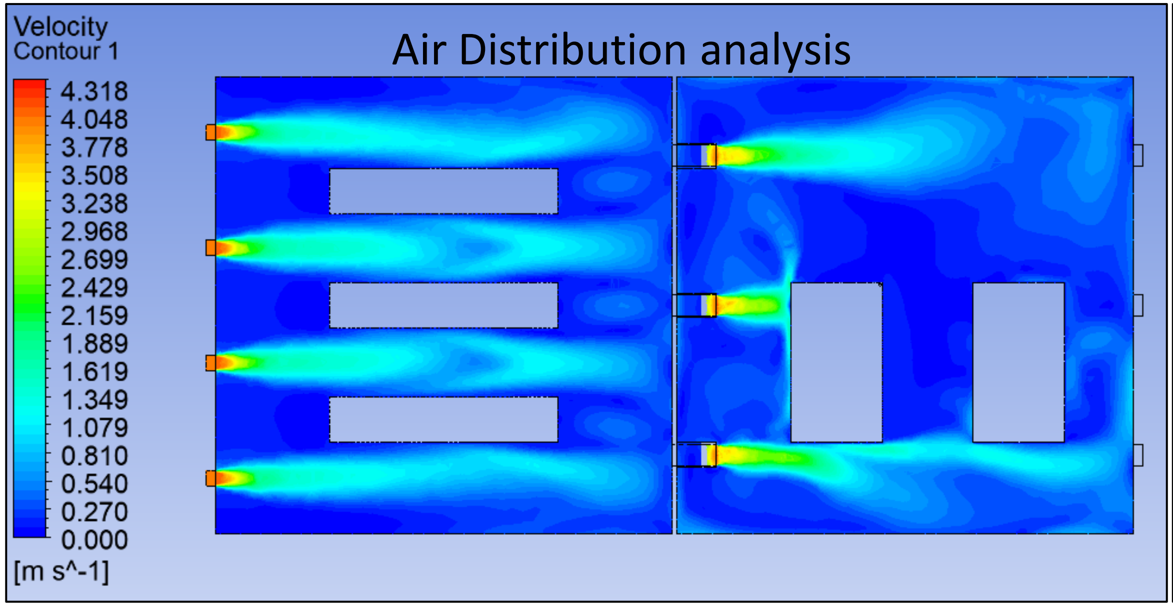
Computational Fluid Dynamics (CFD) Analyses

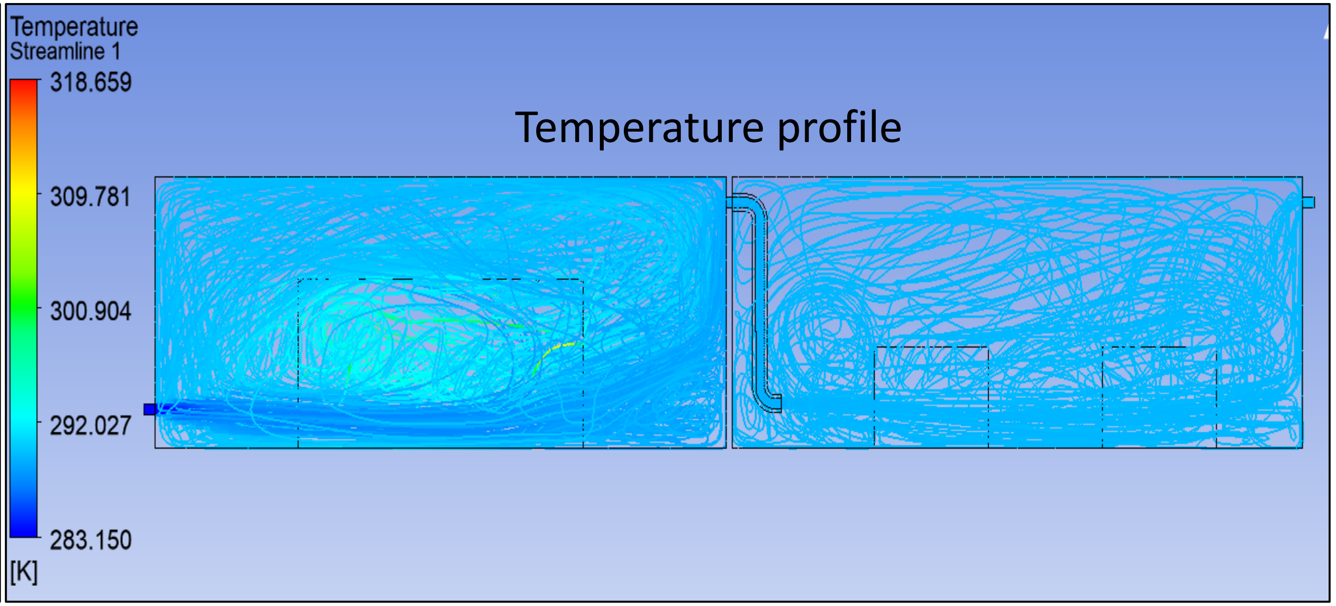


CFD Analyses

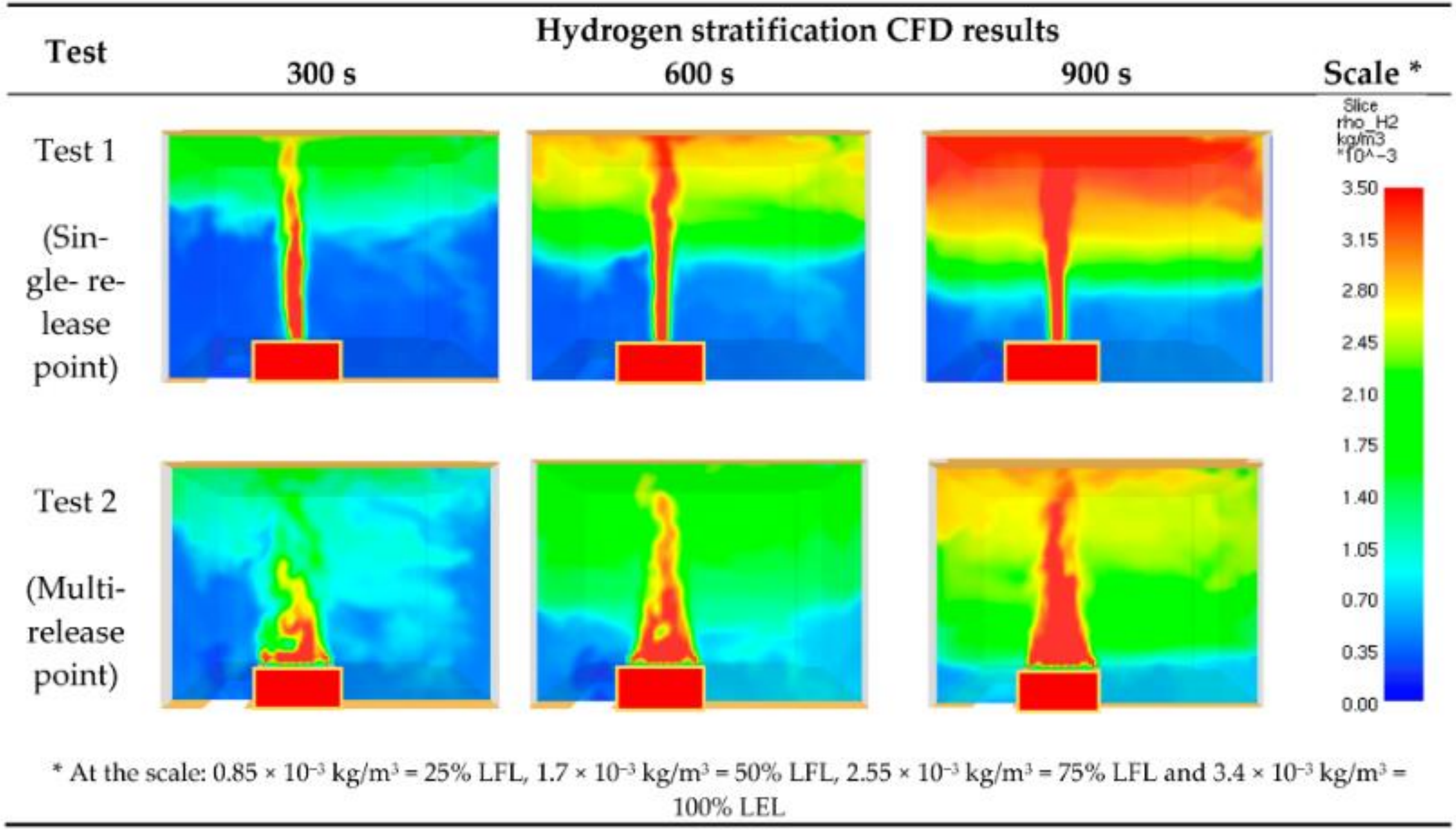








Hydrogen Behaviour Analyses



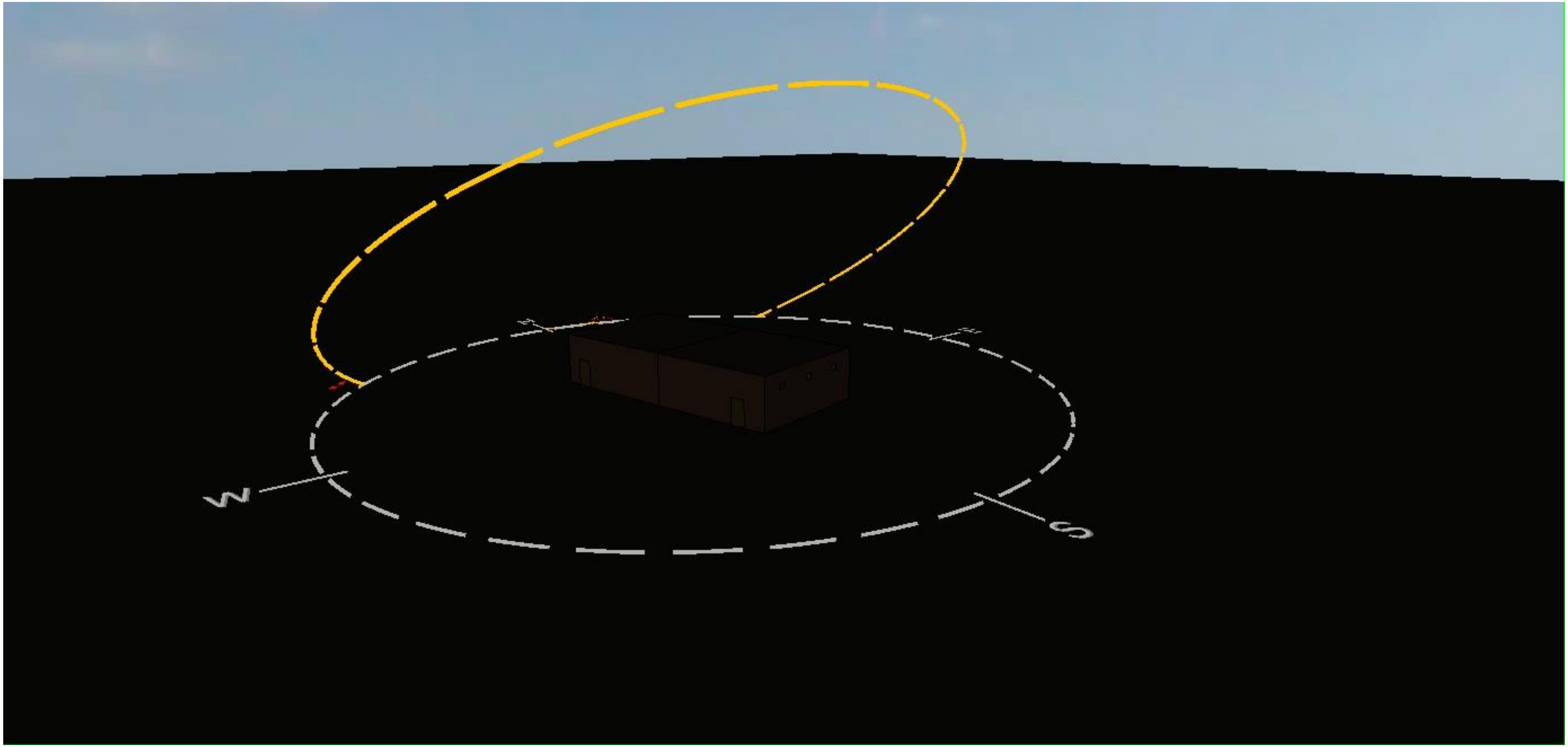
Adapted from [4]

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.


W
S

References

[1] H. Yoshino, T. Hong and N. Nord, "IEA EBC annex 53: Total energy use in buildings—Analysis and evaluation methods," *Energy Build.,* vol. 152, pp. 124-136, 2017. Available: https://www.sciencedirect.com/science/article/pii/S0378778817318716. DOI: 10.1016/j.enbuild.2017.07.038.

[2] N. Lechner, *Heating, Cooling, Lighting: Sustainable Design Methods for Architects.* 2014.

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

[4]] D. Brzezińska, "Hydrogen Dispersion and Ventilation Effects in Enclosures under Different Release Conditions," Energies, vol. 14, (13), 2021. . DOI: 10.3390/en14134029.

Thank You

Your Energy Institute

Your AHI Branch

MSc Students
Best Energy Paper Competition 2023

Thank You & Close

Thank You

- All Our Student Presenters
- Both Universities & Their Academic Staff
- Our Judges
- Our Sponsors, IMRANDD & The Net Zero Technology Centre
- Our Hosts, The Net Zero Technology Centre
- The EI AHI Branch Committee Members
- All Who Have Come Out In Support Of Tonight’s Event

The EI - Global Reach With Local Focus

- **Join Our Team:** aberdeenmea@energyinst.org
- **AHI Branch Events Programme:** www.energyinst.org/ei-near-me/uk/aberdeen
- **Membership Support:** aberdeenmea@energyinst.org
- **AHI Branch Partnership Opportunities for 2023/24:** aberdeen@energyinst.org
- **We Both Value and Listen To Our Membership:** aberdeen@energyinst.org
- **EI Connect Program:** www.energyinst.org/membership-and-careers/ei-connect
- **EI Assist Program:** www.energyinst.org/membership-and-careers/ei-assist