Petrofac UK - Tapping the Earth

A Feasibility Study into Geothermal Heating at Bacton Gas Terminal

GOLD Crest objectives:

Planning your project:

- Set a clear aim and break it down into smaller steps/objectives Pg 2, Pg 37-38, Figure 26
- Explain the wider purpose of your project Pg 2, Pg 3, Pg 39
- Consider different ways to do your project Pg 40-41
- Describe your plan for how to complete your project and give reasons for the approach you chose Pg 3, Pg 41
- Explain how you planned your time and organised who would do what Pg 28-30, Pg 41-42, Figure 27

Throughout your project:

- Say who and what materials you needed to help you complete your project Pg 3, Pg 22-28, Pg 30-33, Pg 36-37
- Summarise the background research you did to help you understand your project and where you found the information Pg 3-7, Pg 7-9, Pg 9-10, Pg 20-22

Finalising your project:

- Make logical conclusions and explain the implications for the wider world Pg 2, Pg 16, Pg 19-20
- Describe how what you did affected the outcome of your project Pg 27 Pg 27-29
- Explain what you learned and how you would change your project if you did it again Pg 42, Pg 47-50

Project-wide criteria:

- Show understanding of the science behind your project Pg 7, Pg 7-9, Pg 10
- Describe how you made sensible decisions about your project Pg 8-9, Pg 11, Pg 18-19
- Consider safety and risks Pg 6-7, Pg 18-19, Pg 36
- Show creativity in the way you carried out your project Pg 40-41, Pg 32-37
- Explain how you identified and overcame problems Pg 19, Pg 28-30, Pg 31-33, Pg 49-50
- Explain your project clearly in writing (and conversation, if relevant) Pg 1-50, Pg 41-47, Figure 28

Index:

1. Executive Summary

In the UK, heat accounts for approximately 44% of total energy demand and around 37% of greenhouse gas emissions, making the decarbonisation of heating a significant engineering challenge. (piranha, 2026) This project investigated whether geothermal energy could replace the existing gas-fired water bath heaters at Bacton Gas Terminal. Through a combination of literature review, industry consultation, site visits and analysis of operational data, the technical, environmental and economic feasibility of geothermal heating was assessed.

The study concluded that geothermal heating is technically capable of providing the required heat demand and could significantly reduce operational emissions. However, the substantial number of boreholes required, substantial land requirements and high capital costs mean that geothermal replacement is not currently an economically viable solution for Bacton Gas Terminal. A smaller geothermal system providing heat for site buildings and office facilities may represent a more practical future application of the technology.

2. Introduction

- **Project aim:**

  The aim of the project is to investigate whether geothermal energy can replace the current gas-fired water heater used to heat natural gas. I will study how geothermal heating works, comparing it with the existing gas fired heater at Bacton gas terminal. Then I will assess potential benefits such as lower emissions, reduced fuel use, and long-term cost savings. Including analysing technical feasibility of the project and providing clear conclusion and recommendation on whether to invest into this sustainable heating solution.

- **Scope**

  This feasibility study focuses on the potential use of deep geothermal heating at Bacton Gas Terminal. The assessment considers heating demand, geological suitability, available geothermal technologies, environmental impacts, equipment requirements, site constraints, electrical requirements, and economic considerations.

The study does not include detailed engineering design, drilling investigations, or a full commercial business case. Conclusions are based on available literature, industry case studies, discussions with industry specialists, and information obtained during the internship.

- **Why was Bacton chosen?**
  Bacton Gas Terminal was selected because it is a major piece of UK energy infrastructure that currently uses gas-fired heaters to maintain gas temperatures before distribution. As part of the wider energy transition, investigating lower-carbon alternatives to fossil fuel-based heating presents an opportunity to reduce emissions while maintaining operational performance. The site's existing heating systems, access to geological information, and proximity to companies actively developing geothermal technologies make it a suitable case study for assessing the feasibility of industrial geothermal heating. Furthermore, my host company, CB&I, provides project support and plant upgrade services at Bacton. This enabled access to industry professionals and operational insights, allowing me to gather primary research and improve the credibility of the study.

- **Methodology**
  This project used a combination of primary and secondary research methods. Secondary research included reviewing academic literature, technical reports, industry publications, geological data, and existing geothermal case studies. Primary research included discussions with engineers and industry specialists, including a visit to CeraPhi Energy, along with correspondence with personnel involved in the operation and management of Bacton Gas Terminal.
  The information gathered was used to assess the technical, environmental, and economic feasibility of geothermal heating and to develop evidence-based conclusions and recommendations.

3. Existing Heating Systems at Bacton

- **Major pipeline system at Bacton:**
  Disclaimer: not include detail of the sub partners or how company shares are distributed.
  - International Interconnectors:
    - BBL (Balgzand–Bacton Line) - 235 km, BBL Company, Under the southern North Sea, connecting Julianadorp (Netherlands) to Bacton (Gas arriving via BBL is currently heated using four water bath heaters located within the BBL plant)

    - IUK (Interconnector UK) - 235 km, Interconnector Ltd, Under the southern North Sea, connecting Zeebrugge (Belgium) to Bacton.
      (Operated independently by Interconnector Ltd from a separate site opposite the Shell terminal, does not connect directly to the BBL heating system and only interfaces with Shell's facilities via the SEAL system)
  - Central North Sea Pipelines:
    - SEAL (Shearwater-Elgin Area Line) -474 km, TotalEnergies, From the Shearwater/Elgin-Franklin fields to the Norfolk coast (the UK Continental Shelf's longest line)
      (According to discussion with Travor Smith, gas from Shearwater is now routed to St Fergus rather than Bacton, operates two gas-fired heaters – this pipeline does utilise 2 gas-fired heaters)
  - Southern North Sea Pipelines:
    - ETS (Eagles Transport System) / Cygnus Pipeline -165 km, Kellas Midstream, From the Cygnus, Trent, and Tors gas fields to the Perenco sub-terminal.
      (Shell's involvement is limited to a tie-in from SEAL that allows gas conditioning and dewpoint control, therefore not directly relevant to heater replacement study)
    - Leman Pipelines – 106km, Shell UK, From the Sean gas field block (near the UK/Dutch median line) to the Shell sub-terminal.
      (Not every incoming gas stream requires heating)
    - Clipper Pipeline – 73km, Shell UK, From the Sean gas field block (near the UK/Dutch median line) to the Shell sub-terminal.
      (Not every incoming gas stream requires heating)
    - Sean Pipeline – 55.7km, Shell UK, From the massive Leman 49/26AP offshore installation to the Shell sub-terminal.
      (Not every incoming gas stream requires heating)
      (Gas terminals, 2024)

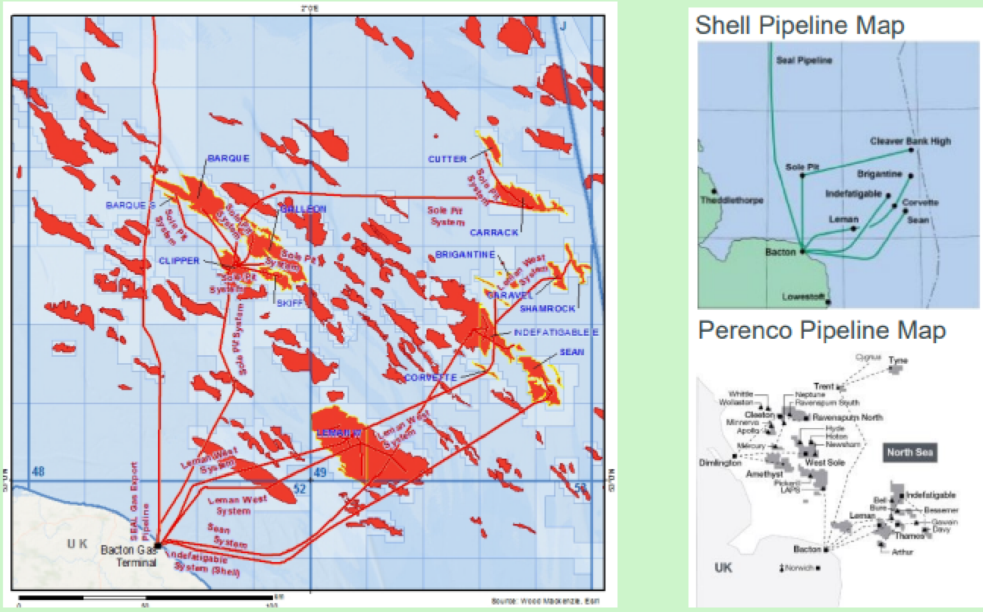

__Figure 1.__ Major gas pipeline systems connected to Bacton Gas Terminal. Source: (Mac,2020).

Clarification via email correspondence with Trevor Smith helped refine the scope of the study and made me understand why I am only looking at a SEAL and BBL heating system by establishing what pipelines arriving at Bacton are heated within Shell-operating facilities. As a result, the feasibility assessment focuses on the most relevant application for potential geothermal integration.

- **Current operation**

  At Bacton Gas Terminal there are four direct-fired water bath heaters (on average 2/4 are used), each rated at 5.4MW for the BBL line therefore the total installed heating capacity is therefore 21.6 MW, although this does not necessarily represent the normal operating demand. The heaters use a mixture of 5% water and 95% MEG as the heat-transfer fluid. The bath temperature is maintained at approximately 85°C. Natural gas passes through coils within the bath and is heated indirectly. (International Ltd, 2006). There are also 2 SEAL heaters.

  Inlet temperature varies with seabed temperature, but we are looking for outlet temperature around 6 degrees, the gas flow and number of heaters in operation is entirely dependent on heat demand – SEAL normally has one heater. The annual heating operating hours are between October and May when the seabed temperature is lower, in months outside this timeframe the gas does not need to be heated to meet distribution requirements. As for required redundancy and standby arrangements - SEAL has two heaters to be available from 1st October to end of May, BBL its N+1 so daily nomination amount plus 1 heater. (Smith, 2026)

Additional correspondence with Bob Edwards highlighted the difficulty in defining a single heating demand value for either the BBL or SEAL systems. He explained that BBL heater operation is influenced by gas coming in and the pressure meaning heating demand is not monitored as a fixed MW value, similarly, to SEAL heater which is typically monitored as percentage load rather than thermal duty. As a result, precise average and peak heating demands could not be obtained within the project timescale.

Edwards also confirmed that gas arrives at Bacton at approximately 9-16°C, depending on seabed temperatures, with operators typically targeting an export temperature of 4-6°C to satisfy National Gas entry requirements of 2°C (Edwards, 2026) This reinforce the conclusion that heater demand is highly season and operation dependent.

This variation in temperature is shown below. **Figure 2.** depicts SEAL heater inlet temperature between December to February. Additionally Figure **3.** depict BBL heater between April to July. This data is between the years 2025-2026 and the BBL data goes up to 05/08/26.

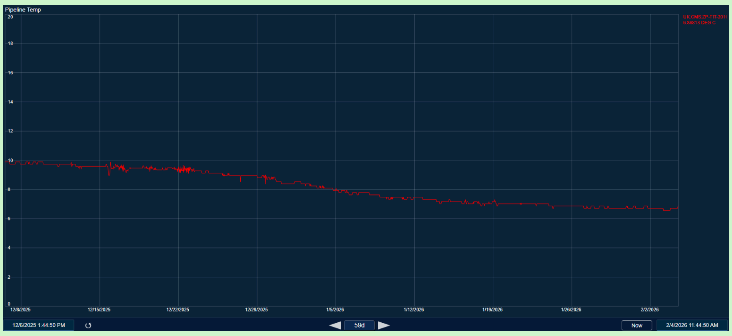

Figure 2. *SEAL heater inlet temperature trends between December 2025 and February 2026. Source: PI Vision data provided by Shell UK.*

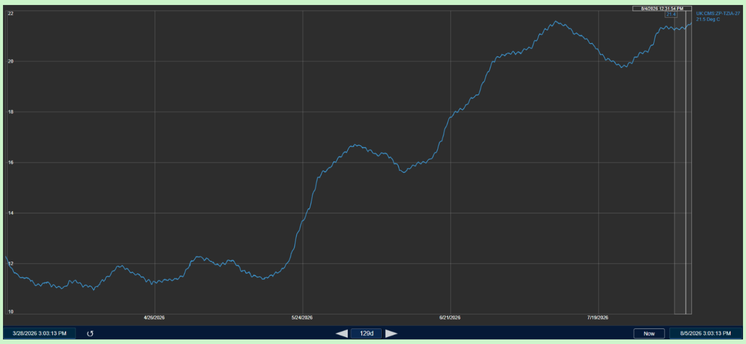

Figure 3. *BBL heater inlet temperature trends between April 2026 and July 2026. Source: PI Vision data provided by Shell UK.*

A bypass arrangement (diverting media around a primary component like a control valve, pump or boiler to protect equipment from over-pressurisation, maintain constant flow during a partial load and allow safe malignance isolation) controls how much gas passes through the heater. The heaters use low-NOx (minimize the release of nitrogen oxides) burners and are integrated with the site's automated control and safety systems. (International Ltd, 2006)

This manual I reviewed to obtain this data contained extensive information regarding valves ignition, purge, burner interlock outlines the high safety regulation placed upon the existing heaters. They are safety critical and include extensive automated control, shutdowns and protection systems. Any replacement technology would need to maintain equivalent reliability, control and process-safety performance.

4. Geothermal Heating Technologies

- **How does geothermal work?**
  A simplistic overview of the principle of geothermal heating is moving heat from the ground into a building using an underground pipe loop, a heat pump, and a fluid mixture. Reliant on a stable and mild temperature from the Earth core. The distinction between shallow and deep geothermal energy is at 500m. The heat above 500m is between 10°C to 25°C and is primarily used to heat buildings. (Ireland, 2026) The heat below goes up by 27°C for every 1 km you go down. 'Average UK subsurface temperatures at 1000 m, 3000 m and 5000 m are around 40°C, 90°C and 140°C, respectively, which is sufficiently high enough to provide heat directly for space and hot water heating without requiring a heat pump.' (British Geological Survey, 2025) This data suggests that geothermal temperature capacity is far beyond the temperature needed for Bacton Gas Terminals and therefore geothermal heating would be appropriate in this instance.

  After speaking to CeraPhi, the conclusion of feasibility has changed due to the magnitude of borehole that would be required and how expensive this drilling would be, whilst it might be possible that doesn't necessarily imply that it is economical to do so.

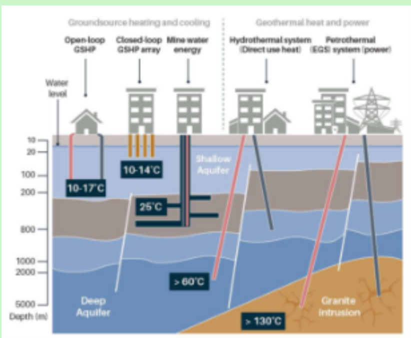

Figure 4. *Types of geothermal energy systems and typical operating depths. Source: (British Geological Survey, 2025).*

- **Open-loop Vs Closed-loop**
  Open-loop systems pump and return natural groundwater directly, closed-loop systems circulate a sealed fluid through deep pipes (Dandelion Energy, 2020) with open loops no trenching, drilling or burying of lots of plastic pipe there are the simplest and often cheapest type of geothermal system to install, those costs are unavoidable when installing any closed loop geothermal system. However, in regard to feasibility open loop geothermal systems are only an option if there's a plentiful supply of clean, fresh water on site. These open-loop geothermal systems are sustainable in regard to their water dependency because they do not actually consume or deplete the water they use – instead of taking water away permanently they are used for heat exchange then return back to the exact same underground aquifer via a recharge or injection wall. This does reduce their durability due to degradation over time if quality issues like slit, sediment or high mineral content are present and are threatened if water supply diminishes for any reason.

  On the other hand, closed loop system is more practical and the borehole and loop that installed inside 'can easily last between 50 and 100 years' (James, 2026) Furthermore open-loop geothermal systems are generally more harmful to the environment than closed-loop systems due to groundwater disruption, chemical/mineral discharge, and surface water impacts. Beyond just open and closed systems there are alternative options such as Enhanced Geothermal Systems or advanced single-well designs offer alternative structural mechanics.

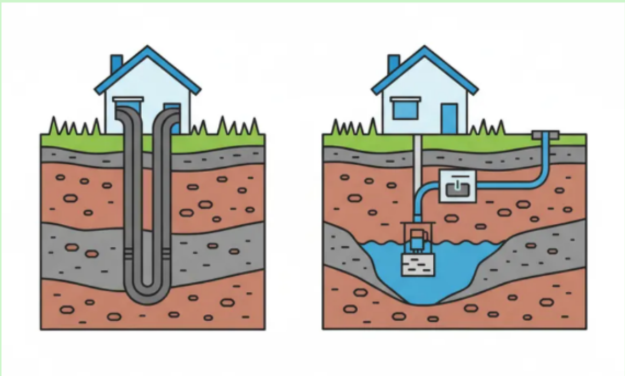

Figure 5. *Comparison of open-loop and closed-loop geothermal heating systems. Source: (Geothermal Insider, n.d.).*

- **Why does the closed loop appear most suitable?**
  Based on the evidence considered, closed-loop geothermal systems appear to be the most suitable and only option for application at Bacton. Unlike open-loop systems, closed-loop technologies eliminate the need for natural underground water and rock permeability, it prevents fluid loss and is a cleaner operation as the fluid never touches the fluid of rocks. Discussions with CeraPhi Energy confirm this conclusion and only operate in closed loops systems, they also have a longer operational lifespan and are much more suited to industrial sites where reliability is essential.

While they do incur higher cost and slower heat transfer, closed loop is the only practical solution at Bacton.

A national geological screening of East Anglia as a region states "There are no deep geothermal heating systems currently operating in the region. There is little geothermal potential in the region because of a lack of large granite intrusions or deep porous sedimentary basins." (Bide, 2018) This was in reference to traditional, open-loop hydrothermal systems. CeraPhil's pioneering breakthrough is a closed loop monobore system (the CeraPhiWell™) suggesting that any open loop system would be futile in this location.

5. Case Studies

- **Case Study: Jubilee Pool**
  Jubilee Pool on Battery Road in Penzance, Cornwall demonstrates that geothermal energy can be successfully used for direct heating applications within the UK. The famous lido utilises geothermal fluid from a 401m well to warm and maintain temperatures of 28-30°C throughout the year. (Brown and Howell, 2023) Although the heating demand is significantly lower than that of Bacton Gas Terminal, the project provides evidence that geothermal heat can be extracted and used reliably within UK geological conditions. This case study demonstrates the practicality of geothermal heating as a long-term, low-carbon alternative to conventional fuel-based heating systems - highlights the growing adoption of the technology outside traditional electricity use.

Figure 6. *Jubilee Pool geothermal heating scheme, Penzance, Cornwall. Source: (Jubilee Pool, 2018).*

- **Case Study: Eden Project**
  The Eden Project provides a more relevant example of large-scale geothermal heating. The scheme uses a deep geothermal well approximately 4.9 km deep and a closed-loop coaxial circulation system to extract heat from hot granite formations beneath Cornwall. (The Eden Project, 2024) This heat is intended to support the heating requirements of the Eden Project's biomes and horticultural facilities. The project demonstrates how deeper geothermal resources can be utilised to provide

substantial and reliable quantities of heat for energy-intensive operations. For Bacton, the Eden Project is particularly important because it shows that geothermal energy can be applied beyond domestic and community-scale heating, supporting larger commercial and industrial heat demands through advanced deep geothermal technologies.

Figure 7. *Eden Project geothermal drilling and heating case study. Source: (The Eden Project, 2024).*

- **Analysis of Case Studies**
  Collectively, these case studies demonstrate that geothermal heating is already being successfully deployed in the UK at a range of scale. Jubilee pool highlights the reliability of direct-use geothermal heating, whilst Eden Project illustrates potential of a deeper geothermal system to supply larger heat demands. Both examples provide evidence that geothermal energy is a practical technology rather than a theoretical concept, supporting the case for further investigation of geothermal heating as a decarbonisation option for Bacton Gas Terminal. The CEO of Eden renewables, Augusta Grand, states 'Geothermal is like the sleeping giant of renewables – it has so much potential' (Osman, 2024)

6. Resource Assessment

- **Heating Demand at Bacton**
  During my site visit at Bacton Dale Haylock mentioned BBL have requested to remove one of the four heaters due to high maintenance costs and further discussion in the office of Shell personal at Bacton confirmed primarily one heater is used, occasionally two - suggesting baseload capacity would be 5.4MW to 10.8MW

  If we look at just the BBL heater the four heaters have a total installed capacity of 21.6MW however installed capacity does not equal demand.

- **Geothermal Well Output Assumptions**
  Consultation from CeraPhi recommended two option a 600m well which is cheaper to drill, smaller diameter and less space to install but yield less geothermal heat in comparison to 1500m well which a product in the developmental stage at CeraPhi and not due to be rolled out because they are focussing on their primary product of 600m well. These two designs require different loop systems and have different advantages.

A 600 m closed loop well is expected to provide approximately 30 kW of continuous heating capacity and up to 50 kW during peak operation. Therefore, approximately 33-34 wells would be required to provide 1 MW of baseload heat. These figures came from a clarification after meeting in which COP is 4.3 therefore (30/4.3) × (4.3−1) =

23.0kW, therefore geothermal heat from ground providing 23kW, electricity required 7kW meaning that total delivered heat is 30kW. This means that for 1 MW of heat 1000/30 = 33.3 well are required for based load and for peak 1000/50 only 20 wells are required

600m well – 1MW=34 wells

1.5km well – 1MW = 7 wells

- **Estimated Well Requirements and Costs**

Scenario	1 BBL heaters	2 BBL heaters	3 BBL heaters	4 BBL heaters
Capacity	5.4MW	10.8MW	16.2MW	21.6MW
Number of 600m wells	184	367	551	734
Occupied site space	27.5 km^2	54.8 km^2	82.3 km^2	109.6 km^2
Estimate costs	46 million	91.75 million	137.75 million	183.5 million
Number of 1.5km wells	38	76	113	151
Occupied site space	19.8 km^2	39.5 km^2	58.7 km^2	78.5 km^2
Estimate costs	45.6 million	91.2 million	136 million	181.2 million

Table 1*. Estimated geothermal well requirements, site area and installation costs for replacing BBL heating capacity.*

Table 1. compares the CeraPhi product which includes two different drill depths for their wells. This table reveals that whilst similar pricing per unit of energy between the well but a significant space site difference with the 1.5km well – at maximum capacity, this difference is 31.1 km^2. Therefore, using the 1.5km is a more viable option, due to site space requirements. (Read, 2026)

The substantial site area requirements result from the large number of wells required to meet BBL heating demand and the spacing requirements between well clusters necessary to minimise thermal interference and depletion between adjacent boreholes.

- **Reliability of Available Data**

CeraPhi Energy suggested that geothermal potential in East Anglia may be greater than currently recognised and that limited development is largely due to a lack of investment and exploration. The map (found in appendix A) shows colours of the region in yellow but has a tiny pool of temperature data from well to support this estimation. Alternatively, as CeraPhi is a geothermal technology provider, the information may be influenced by commercial interests. Therefore, independent geological surveys and site-specific temperature data would be required to verify these claims before firm conclusions can be drawn for Bacton.

7. Technical Feasibility Assessment

- **Existing Borehole Assets and Geological Information**
  The CeraPhi project at Scunthorpe General Hospital provides an example of geothermal asset repurposing, where an existing 550 m borehole was converted into a closed-loop geothermal heat source. This significantly reduced the project because drilling no further drilling was necessary, unfortunately for Bacton there are no existing borehole assets able to be repurposed. (Farrow, 2020) (Ukogl.org.uk, 2026)

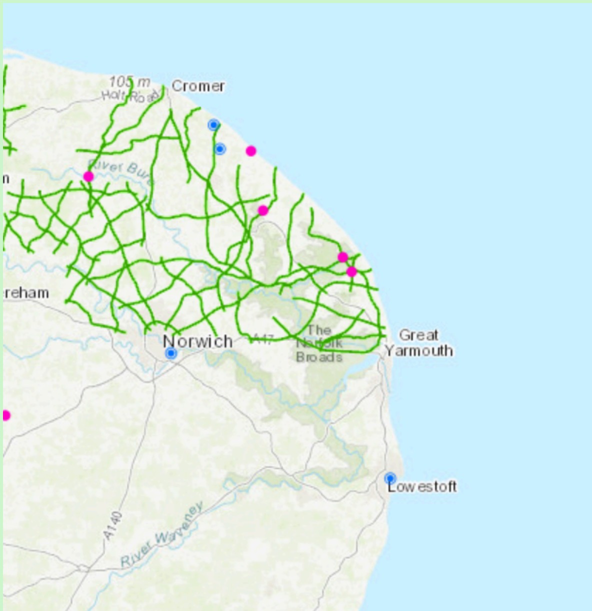

***Figure 8**. Onshore boreholes in the Bacton region from the UK Onshore Geophysical Library, including Bacton 2. Source: (UKOGL, 2026).*

However, this map does show us an onshore well caused BACTON 2, a stratigraphic borehole drilled by Shell in 1977 to study subsurface rock layers in the East Anglia region, reaching a depth of 864 meters (ROC OIL (GB) LIMITED, 2005) Although it was not drilled for geothermal purposes, the borehole may provide valuable geological and temperature information that could support future geothermal assessment. Access to existing subsurface data could reduce uncertainty surrounding temperature gradients, rock formations and drilling requirements, potentially lowering the development risk associated with a geothermal project at Bacton.

- **Electrical Infrastructure**
  Current electrical consumption at Bacton is primarily used to operate gas processing equipment, compression systems and site control infrastructure. Approximately 12% of the terminal's current electricity demand could be supplied by installation of the on-site solar farm. Detailed electrical consumption data for the existing gas-fired heaters was not available during this study, preventing a direct comparison with the electrical requirements of a geothermal heating system. However, given the site's existing electrical infrastructure, it is likely that the terminal could support the additional electricity demand associated with geothermal heat pumps and circulation pumps, although this would be to be confirmed by a compressive electrical capacity assessment.

- **Potential Borehole Locations**
  One of the potential challenges associated with geothermal heating is the space required to drill enough boreholes to meet energy requirements. The borehole must be near the site for direct heating loop as approximately 1°C of heat is lost per km travelled. Due to the drilling constraints, which require approximately 60m between each cluster of six to seven 1.5km wells, this project would require a significant amount of additional site space. Email correspondence with Keith Mitchell suggested a potential borehole location at Seagulls Field, a nearby Shell-owned site in Bacton that has already been approved for development as a 7-acre solar farm. This could provide a suitable location for geothermal boreholes, with solar panels installed above the subsurface infrastructure, maximising renewable energy generation from the same area of land.

  Another potential location would be the existing Bacton car park. During my consultation with CeraPhi Energy, I was informed that geothermal boreholes can be drilled and subsequently covered, allowing the land above to return to its previous use. This means that surface infrastructure requirements would be relatively limited once installation is complete.

  However, both options present challenges. The proposed solar development at Seagulls Field proved controversial within the local community, with approximately 580 residents signing a petition opposing the project. As a result, obtaining approval for further energy infrastructure on the site may be difficult. Similarly, installing boreholes beneath the existing car park would require excavation of an operational area, creating disruption to site activities and introducing additional construction costs. Therefore, although suitable locations may exist, a detailed site assessment would be required to determine the most practical and socially acceptable option. Additionally, even with both potential sites, additional space would still be required

to drill the required number of boreholes – even to match the installed capacity of 1 BBL heater.
(North Norfolk district council approves Bacton solar farm despite petition, 2022)

Figure 9. *Seagulls Field, Bacton, identified as a potential location for geothermal borehole development. Source: (BBC News, 2022).*

- **Required Infrastructure**

A geothermal heating system at Bacton would require several key pieces of infrastructure. The exact specification would depend on the final heating demand and selected system design; however, the core components would include:

- Deep geothermal boreholes.
- Closed-loop pipe systems within the boreholes.
- Circulation pumps to move the heat-transfer fluid.
- Heat exchangers to transfer geothermal heat into the existing heating circuit.
- Industrial heat pumps where temperature boosting is required.
- Electrical supply and control equipment.
- Monitoring and safety systems.
- Underground distribution pipework connecting the geothermal system to existing plant facilities.

Ideally the geothermal heating could utilise much of the existing process equipments rather than replacing it, potentially being integrated into the existing water bath heating circuit. However, engineering studies would be necessary to determine the compatibility of geothermal heating with existing process and safety system.

Furthermore, the primary infrastructure challenge is not the surface equipment, but the drilling and construction of the geothermal boreholes. Representing large upfronts cost and complicated integration with existing site operation and available site space to house the boreholes.

8. Environmental Assessment

- **Environmental Benefits**

  Compared with the existing gas-fired water bath heaters, geothermal heating has the potential to significantly reduce emissions and fossil fuel consumption. Geothermal energy is much more efficient because it moves heat energy instead of creating it.

  Direct-fired water bath heaters can never reach or exceed 100% efficiency whilst a geothermal heat pump is 300 to 500 % efficient. (Team, 2025) Ground source heat pumps typically require approximately one unit of electricity to generate up to four units of heat." (Abesser and Walker, 2022) Equivalent to a COP of around 4, This is consistent with information provided by CeraPhi Energy, who stated that their systems typically operate with a COP between 4 and 4.5 suggesting their performance assumption used within this assessment are realistic rather than unusually optimistic. (Farrow, 2026).

  This means geothermal systems can provide the same heating output whilst consuming significantly less energy than conventional heating systems

  Geothermal energy provides a constant source of heat that is not dependent on weather conditions such as wind speed or sunlight. This makes it suitable for industrial applications that require reliable and continuous heating throughout the year.

  To implement Geothermal at Bacton we would work with CeraPhi who are exceptionally sustainable their system, CeraPhi Energy state their system ‘produces zero emission and has a one of the lowest embedded carbon footprints’ and they ‘re-inject 100% of the fluid back into the ground therefore preventing fluid loss, reducing environmental pollution and conserving water resources. s. (Farrow, 2020)

  The existing water bath heaters rely on the combustion of natural gas to maintain gas export temperatures, whereas geothermal heating would provide heat without burning additional fuel

  In comparison to Geothermal heat that emits no carbon dioxide, carbon monoxide or greenhouse gases, which are the main contributors to air pollution. Its main environmental impact comes from electrical consumption of the heat pump.

  Although geothermal energy has a significantly lower environmental impact than gas-fired heating systems, it is not entirely without environmental impacts.

- **Environmental Risks and Limitations**

  These disadvantages include government research that identifies thermal depletion as a potential challenge for geothermal systems, where heat is extracted faster than it can naturally be replenished, resulting in reduced efficiency over time. (Abesser and Walker, 2022)

Direction drilling these clusters 60m apart as a preventative measure can minimise this risk, but this site requires heat at such a rapid rate geothermal depletion if inevitable. Furthermore, equipment failure is a serious risk which could contaminate groundwater if the deep pipe or seal containing the heater-transfer fails.

Furthermore, As the proposed system is a closed-loop design, groundwater would not be extracted or re-injected during normal operation. This removes many of the environmental concerns associated with open-loop geothermal systems. However, the UK Parliament POST briefing notes that defective closed-loop systems could still affect groundwater quality if buried pipework or borehole seals fail, allowing heat-transfer fluids to escape into surrounding formations. (Abesser and Walker, 2022)

- **Lifecycle and Long-Term Considerations**
  Correspondence with Bob Edwards indicated that the existing heaters are long-life assets, with the SEAL heaters only undergoing their first major refurbishment since being installed in 2000. This suggests that replacing the heaters with geothermal infrastructure could result in the premature retirement of equipment that remains operationally viable. (Edwards, 2026)

  A further environmental consideration is the long operational life of geothermal infrastructure. CeraPhi estimated the geothermal borehole may be in operation for several decades however as Bacton Gas Terminal currently supplies 1/3 of the UK natural gas demand which will experience a decline in output as the sustainable energy transition toward government goal of net zero emission in 2050.

  If gas processing activities reduce significantly in future, the geothermal infrastructure could become underutilised and would need to be repurposed to provide value elsewhere. This raises questions over whether the environmental benefits gained during operation would justify the environmental impacts associated with drilling such a large number of boreholes. The environmental benefits must be balanced against the environmental impacts associated with drilling and constructing a large number of boreholes. In the future the water bath heater is currently planned to be adapted in the long term to aid production of hydrogen.

- **Environmental Impacts of Installation**
  Installing a geothermal system at Bacton would require a large number of 1.5km deep boreholes, resulting in significant drilling activity, construction traffic, noise and temporary disruption to the local area. The impact would be considerably greater than most UK geothermal projects due to the scale of heating demand being assessed.

- **Environmental Conclusion**

Overall, geothermal heating would offer substantial environmental benefits compared with the existing gas-fired heating system through higher efficiency, reduced fuel consumption and lower emissions. However, these benefits must be balanced against the environmental impacts associated with drilling, potential thermal depletion and uncertainty regarding the long-term future of gas processing at Bacton. Therefore, geothermal appears environmentally favourable but not without environmental challenges.

9. Economic Assessment

- **Data Limitation**
  The economic viability of geothermal heating at Bacton is difficult to assess fully due to the lack of available data relating to the current heaters' fuel consumption, maintenance costs and annual operating expenditure. Despite repeated attempts to obtain this information, a direct financial comparison between the existing gas-fired system and a geothermal alternative could not be completed.

- **Capital Costs**
  From data obtained during CeraPhi consultation I did estimate cost of Installation. To install the geothermal capacity to replace one of the current BBL heater it would cost a minimum of 45.6 million and to replace the current BBL heater capacity of the site with geothermal this total would be 181.2 million. Both estimates are based on a 1.5km well being drilled. This cost is astronomically and unrealistic for an investment when compared to the alternatives.
  These costs exclude:
    - Engineering design
    - FEED studies
    - Grid upgrades
    - Heat pumps
    - Heat exchangers
    - Civil works
    - Control systems
    - Project management
    - Contingency allowances

    And more

  Therefore, total project cost would therefore likely exceed these estimate

- **Operating & Maintenance Costs**
  Additional would have to consider operation cost, these are relatively low due to no fuel being burned however electricity is required for circulation pump, monitoring system, control systems and industrial heat pumps. My site tour at Bacton and reviewing Brownfield Functional Framework with Rickey Tillet alerting me to maintenance cost from pump replacement, instrumentation maintenance, pipework

inspection and borehole integrity monitoring. CeraPhi also would charge an ongoing licence fee regarding their work with installation which may cover some of the monitoring and maintenance aspects. The extensive planning and maintenance cost would occur from trying to integrate geothermal technology into existing water bath systems and the nature of much of the geothermal work being innovative would make adjusting more costly.

- **Comparison with Existing Heaters**
  In comparison to existing costs which primarily contain fuel gas, maintenance inspection and burner serving. This fuel gas is practically free for the operators because there are no intermediaries or taxes and they can access this gas straight from the gas producer meaning the freedom of running this operation is cheap. Figure could not be obtained into the original installation costs of gas heater on either BBL line or SEAL heater but rough internet searching reveals estimates between £12 million and £30 million.

  Whilst geothermal could reduce fuel consumption, the extremely high initial capital investment means payback periods would likely be measured in decades. Decades the Bacton Gas terminal may not have.

- **Economic Conclusion**
  Although geothermal heating offers lower long-term fuel costs and environmental benefits, the capital investment required appears extremely high relative to the heat demand. Based on currently available information, geothermal does not appear economically attractive as a full replacement for the existing BBL or SEAL water bath heaters.

10. Operability

- **Reliability Requirements**
  Reliability is one of the most important considerations at Bacton with the manual I review highlighting the safety-critical operation to me embedded within the system.

  Advantageously Geothermal technology is capable of providing continuous baseload heat because underground temperatures remain relatively constant throughout the year. Unlike solar or wind power, geothermal output is not weather dependent.

  Due to such high heat demand from the heater the quality of the borehole increases the risk of breakdown of equipment, for example the pumps used. Although failure of one borehole would have limited impact on overall performance, managing dozens of wells creates significant operational complexity.

- **Hybrid System Assessment**

Due to Barry Read comments about geothermal being ideal to provide baseload heat, a hybrid configuration would be more appropriate than a complete replacement. An ideal solution would be to continue to use existing gas-fired heaters to meet peak demand and redundancy requirements, then when these heaters are in need of replacement use electric heaters instead.

This arrangement would primarily reduce emission and gas consumption whilst maintaining existing standards and reducing upfront costs of geothermal drilling. With site discussion of the futility of heater 4 and only 2 heaters used often I would suggest installing a baseload capacity between 5.4MW and 10.8 MW in geothermal wells.

A hybrid geothermal system appears significantly more practical than a complete replacement. It would allow environmental benefits to be achieved without compromising operational reliability.

11. Risks and Constraints

Key risks:

- Geological Risk
  Subsurface temperatures beneath Bacton remain uncertain.
  No detailed geothermal exploration has been completed for this project.
- Financial Risk
  The high capital cost creates significant investment risk if expected heat outputs are not achieved.
  Might not pay of this investment if gas production stop and wells cannot be re utilised
- Technology Risk
  The proposed 1.5 km CeraPhi concept is not yet a standard commercial product and would require further development.
  To my understanding, something similar has not been attempted
- Site space Risk
  Planning approval may be difficult due to local opposition to previous energy developments at Seagulls Field.
  No suitable location to drill 38 to 151 1.5kw wells, requiring 19.8km^2 to 78.5km^2 site space
- Operational Risk
  Construction activities could interfere with ongoing terminal operations.
  Construction may deplete thermal energy leading to well failure
- Data Availability
  A major limitation of this study was restricted access to detailed:
  - energy demand data
  - heater duty and efficiency information
  - process temperatures
  - electrical load data

- Installation cost data
- Current operating cost – maintenance, fuel, equipment
- Emission data from site/Lifetime assessment of gas heaters
- life expectancy of existing system

This increases uncertainty within the assessment

12. Conclusions and Recommendations

- **Is it technically feasible?**
  Yes, ultimately if you dug the appropriate number of well and engineering preexisting technology to be compatible, it is true that the gas could be heated by geothermal energy.

- **Is it environmentally beneficial?**
  Geothermal heating would reduce emissions and fuel gas consumption. However, the environmental impact of drilling, potential thermal depletion, and uncertainty over the future use of the infrastructure mean the overall environmental benefit remains uncertain.

- **Is it economically viable?**
  No due to suggest high capital cost that cannot offset cheap gas fired heater and the price of the gas due to being sourced from site, meaning geothermal would not compete with current astronomical drilling costs.

- **Recommended next steps**
  Whilst this project could theoretically be implemented, it is not currently an appropriate investment for Bacton Gas Terminal. The transition to renewable relied on using the right technology for the appropriate application. Rather than attempting to replace the existing gas-fired heaters, a more practical option may be to investigate a smaller geothermal installation to provide heating for site buildings and office facilities.

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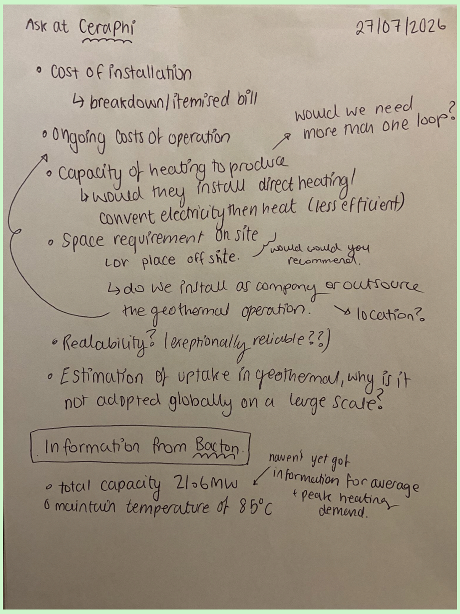
Appendix A - CeraPhi Meeting Notes

Technical Consultation with Barry Read, CeraPhi Energy

- **Pre-planned questions**


Ask at Ceraphi 27/07/2026

- Cost of installation
  ↳ breakdown/itemised bill
- Ongoing costs of operation
  would we need more than one loop?
- Capacity of heating to produce
  ↳ would they install direct heating/ convert electricity then heat (less efficient)
- Space requirement on site (or place off site. would would you recommend.
  ↳ do we install as company or outsource the geothermal operation. ↳ location?
- Realability? (exeptionally reliable??)
- Estimation of uptake in geothermal, why is it not adopted globally on a large scale?

Information from Bacton.

- total capacity 21.6MW
- maintain temperature of 85°C

haven't yet got information for average + peak heating demand.

__Figure 10.__ Preparation notes and questions used during the CeraPhi Energy consultation. Source: Author.

- **Introduction to Geothermal Energy**
  (Presentation slides from Barry Read)

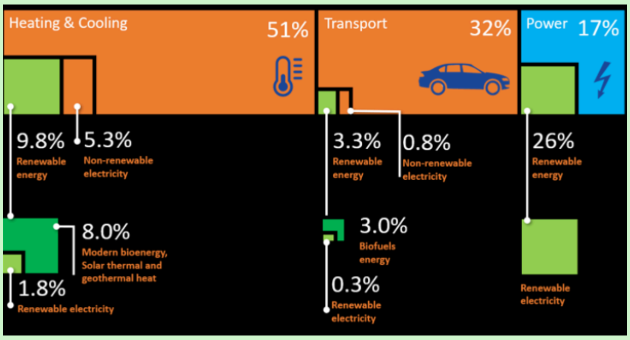


__Figure 11.__ UK energy consumption by sector. Source: (Read, 2026).

- 99% of the Earth volume has more than 1000°C
- Reservoir of geothermal energy for 6 billion years
- Less than 3% of Earth is currently used for geothermal power & less than 2% of the Earth is currently used for geothermal heat
- 70 countries use geothermal for heat, 26 for power – UK not hot enough to produce power
- Deepest drilling was in 1989, depth of 12,262 m names the Kola Superdeep Borehole SG-3

- The CeraPhi Monobore Approach:

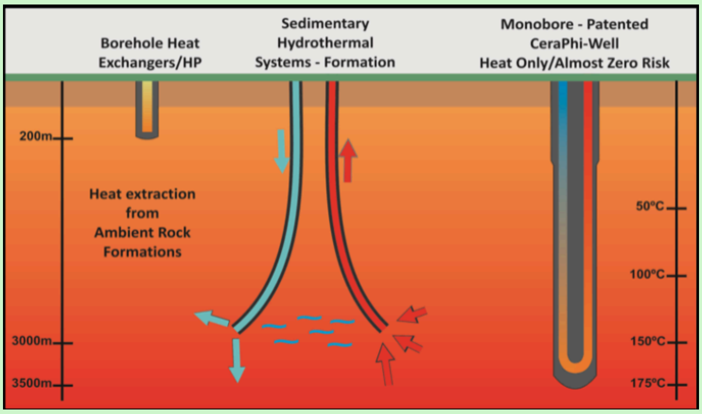


Figure 12. Overview of the CeraPhi Monobore geothermal system. Source: (Read, 2026).

- Deep Geothermal Energy in the UK:

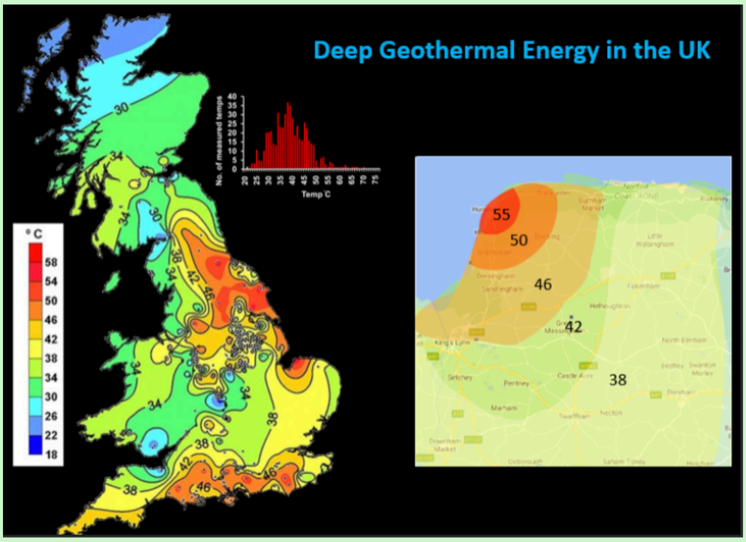


Figure 13. *Deep geothermal energy potential within the United Kingdom. Source: (Read, 2026).*

- Why not seen everywhere in UK
  - Early experiments were mismanaged and not commercialised
  - The aim has always been to produce power, other options were not explored
  - Without power as the outcome, the cost was seen as too great
  - Drilling costs were linked to Oil and Gas rates
  - Other technologies were seen as more viable – wind/solar/other
  - Scunthorpe General Hospital

Figure 14. *Scunthorpe General Hospital geothermal project key facts. Source: (Read, 2026).*

- **General Technical Notes**
  - → Do not use offshore rigs or geothermal holes far from site – lose 1°C per km the heat travelled, need insulate and buried pipes in the ground
  - → Do not and will not use geothermal for electricity production in UK - not hot enough, no point outsourcing geothermal boreholes beyond the UK due to thermal energy being difficult to transport and because market in Iceland is already producing electric energy from geothermal and harnessing the waste thermal energy to heat it buildings.
  - → Closed deep loop are the only product offer by CeraPhi Energy and the only viable form of geothermal heating that could be used in this application
  - → Scunthorpe General Hospital repurpose an existing 550m borehole, providing up to 60kW to meet their peak demands
  - → Ongoing license fee from CeraPhi Energy to be worked out in contract, this is to support their operation moving forward not particular maintenance fees
  - → Electric pump used has a COP (coefficient of performance) between 4 and 4.5, meaning for every 1 kW of electricity used, the unit generates 4 – 4.5 kW of heating
  - → My own additional research 2200 well historically in the UK, only 300 remained in operation. Could we repurpose existing onshore wells? - the drilling has never been the problem, instead it is pumps, leaks, refrigerant and pipe that give out

→ Estimate operation for 70-80 years, insurance and performance measure in 40-year life cycles

→ To deliver this project to Bacton would require a 2-year engineering study (estimate)

→ Could do a 5km deep well (roughly 30 million) also 12.6 inches diameter, however not economically viable

→ This area has been drilled by Shell onshore called Bacton 2 down to 1500m would be useful to find their data? Especially any temperature data. It was originally drilled for oil + gas but could be repurposed for this project. Offshore there is also 33 injection + 2 monitoring at Bacton. Check details on this.

- **Future CeraPhi Projects**

→ Kirby Misperton Heat Network: Ongoing development to repurpose wells on the KMA wellsite (KM8 well) into an ambient heat network supplying sustainable geothermal heat to the local village, backed by the York and North Yorkshire Combined Authority Carbon Negative Challenge Fund with a targeted connection date of December 2027

→ Pickering Projects: Feasibility and front-end engineering design (FEED) studies completed for the Vale of Pickering area, including geothermal assessments for the Pickering Swimming and Fitness Centre using local legacy well infrastructure.

→ University of Liverpool / Regional Hub: Collaborative engagement and expert workshops involving CeraPhi Energy alongside Liverpool City Council and academic experts to unlock urban and regional deep geothermal potential in the area.

- **600 m Well Design**

→ ¼ of a million per well

→ project required 6-month planning process, 1-month typical installation

→ Cost £5000 a day per well for drilling

→ 8.6 inch well = 3 loops

→ 10-12m between – due to parasitic scavenging

→ Baseload 30kW and peak 50kW per well, works best at baseload to just leave geothermal on consistently (therefore hybrid combo for peak demand works best)

→ 40 well required to produce 1 MW capacity

→ 600m is the maximum depth for the 3-loop system

→ Mechanism: Uncased, grout solidifies and pump bring up fluid that has been heated

- **1500 m Well Design**

→ 6 wells = 1 MW

→ These wells are required to be 60 m apart, use directional drilling and put 6 in a cluster to increase potential heat energy

→ Would need a feasibility study for 1500m well, not currently something CeraPhi Energy installed. It is a project they would like to deliver in future but to stay operation need to focus on their more generic and applicable product 600m

→ That is not to say it hasn't been done; across the world there are many examples of this knowledge and depth of drilling

→ These would have an installation fee of 1.2 million per well

→ 12.6-inch diameter per well top (this includes the 6 that are clustered below)

→ More risky drilling, 600m wells are safer

→ Mechanism: mono-ball system, has the advantage of volume and hotter rock and deeper distance however due to this process more involved and lengthier

- **Well Design Comparison**

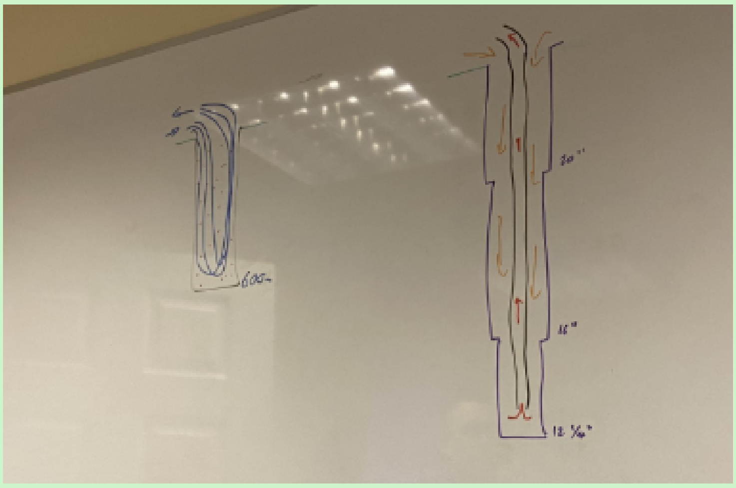


Figure 15. *Visual comparison of 600 m and 1.5 km geothermal well concepts presented during the CeraPhi consultation.*

Figure 16. *CeraPhi geothermal pipe loops used within 600 m borehole*

Yellow pipe are the loops used inside the 600m boreholes, white board diagram to the left is the 600m well with it 3 non-touching/separate loop system and to the right the 1.5km system is modelled

- **Follow-Up Technical Clarification**

  Purpose: To verify geothermal heat outputs and well numbers discussed during the CeraPhi consultation. (this was due to mathematical inconsistency in my notes)

  Summary of clarification received:

  - The specialist clarified that the quoted outputs include the contribution of a heat pump operating at a Coefficient of Performance (COP) of approximately 4.3.
  - For a 600 m well, a delivered heat output of 30 kW consists of approximately 23 kW of geothermal heat extracted from the ground and approximately 7 kW of electrical input to the heat pump. Peak output may reach approximately 50 kW under favourable operating conditions.
  - Approximately 33 wells operating at 30 kW would be required to deliver 1 MW of heating capacity.
  - Approximately 20 wells operating at 50 kW would be required to deliver 1 MW at peak output.
  - A cluster of seven 1.5 km wells could provide approximately 1 MW of heat output, equivalent to around 143 kW per well.

The specialist emphasised that these values are indicative only and that a detailed engineering and geological study would be required to determine actual performance at Bacton. However, the estimates were considered suitable for an initial feasibility assessment.

However, the estimates were considered suitable for an initial feasibility assessment and formed the basis of the well-number, space requirement, and cost calculations used throughout the feasibility assessment table. Whilst the final figures would likely change following optimisation and site-specific analysis, the estimates were considered sufficiently accurate for assessing the overall practicality of geothermal heating at Bacton Gas Terminal.

Appendix B - Daily Log

Week 1

- 20th July (8.30am to 4.30pm) - induction & meet team, looked through CREST guidelines (✓) meet the general team and was left for mostly independent work, attended a team milestone meeting where Alex hosted
- 21st July (8.30am to 4.30pm) - continue with planning looking into method (deadline to complete planning) (✓) gave myself an overview of geothermal heating and begun referencing and researching very generally and completed the necessary CREST planning steps, attended a meeting with a sale representative who was a former offshore engineer
- 22nd July (8.30am to 5.00pm) - Visit Kroonborg (✓) (write up a report) + start general research = secondary, write up a network map of who I have met, their role and their place within the company didn't get round to make network map, have to complete than on Friday instead? Kroonborg visited was really cool spent most of the day here, then spoke to the manager for shell about the EEEGR project and the industry more generally. Beforehand Alex was showing me his Uni project including a safety box with sensor, a breadboard Bluetooth speaker,
- 23rd July (8.30am to 4.30pm) - EEEGR Workshop (draft a report) (✓) Meet the other interns & was spoken through CREST guidelines by lily, John discussed the Internship and where other participants have ended up. Met other interns was rewarding and look forward to workshop next week
- 24th July (8.30am to 4.30pm) - research – current systems (✓) didn't cover as much detail as I wanted finished other section, followed up on emails and digested/review information acquired throughout the week, WFH

Week 2 (Bacton site visit + talk to CeraPhi Energy)

- 27th July (8.30am to 4.30pm) - look at technical regulations & analyse secondary data & equipment – visit to CeraPhi (introduction to geothermal heating) (✓) am slightly behind in research but researched unexpected angles and dept that I didn't account for like breakdown of gas lines in Bacton really insightful and useful visit to geothermal, beforehand prepare my questions and area of research, use meeting effectively and filled out all my question. Spent afternoon writing up this information and sending of email to fill in remaining gaps.

- 28th July (8.30am to 4.30pm) - primary research? = energy information & software modelling? Flexible depending on other companies/opportunities that arise (x) did not complete these tasks took leave – family emergency
- 29th July (8.30am to 4.30pm) - check-in in with how much research has been achieved (can readjust deadlines) (x) did not complete these tasks took leave – family emergency
- 30th July (8.30am to 4.30pm) - EEEGR Workshop (draft a report) (✓) spent the afternoon going through email and correspondence to digest latest information went to an E-colour workshop I was a green/red, a thinker with an actionable plan. I took over the group task and build an origami tower out of green blocks with a butterfly on top. I think I was a balanced mixture of all colours and the reminder that some people idea of happiness is sitting in silence or being alone and independent are all different portrayal of happiness.
- 31st July (8.30am to 4.30pm) - complete all research/investigation element possible & paste in references that have been collated continuously + could start on feasibility study (deadline for research complete – internal deadline) (x) have not finished research, met with Rickey Tillet to understand Brownfield Functional Framework had to acknowledge project limitation because obtaining Bacton site specific information is proving challengeing and frustrating, spent the morning following up email and chasing up details, massive replan and re structure of whole project.

Week 3 (need to visit Bacton, chat with Oliver)

- 3rd August (8.30am to 4.30pm) - review all data collected, finalising your project objectives started chat with Oliver & PI vision tool continued with reformatting and writing up analysis (x), delving into what the research actually mean and how does that link to Bacton site. Section 6-12 empty might have to reduce depth and coverage to finish in time, did not go through PI vision with Oliver
- 4th August (8.30am to 4.30pm) - make presentation, poster draft – start to do check of project criteria and later checklist, if research overrun buffer time to catch up on any last work Bacton site visit (✓) Visited site and worked in office at Bacton, way too tired to concentrate, very unproductive. Good to see where the heater is. One of the SEAL heaters is currently undergoing lot of servicing so lots of maintenance and replacement work across the site. Filled in random gaps in the afternoon and research more in depth about environmental impact using the government published study. On the train home met a geothermal research expert six degrees and his wife, a geologist who were highly informative and I discussed my project with them on the way back as a mini prep presentation
- 5th August (8.30am to 4.30pm) - practise and rehearse presentation/ brief script for presentation, ask for feedback beforehand for areas of improvement behind of project presentation slides not made, trying to finish report and conclusions (x) met with Oliver to discuss the PI Vision tool (✓) felt a little down this morning resulting

in less productivity, tried to work toward finishing content for my report, wrote up my feedback for CB&I

- 6th August (8.30am to 4.30pm) - Presentation to Daniel, once complete work on getting project ready for submission made presentation slides (✓) presented my project & feedback (✓) did presentation early in morning and wrote script, prepared for presentation and it went really well
- 7th August (8.30am to 4.30pm) - Final Day, do personal reflection write up, consolidate feedback from presentation and finalise all 3 deliverable elements (poster, report and presentation), make sure project report is signed pushing towards completion, wrote reflection, executive summary, post every detail and last correspondence into report, spelling and grammar check, worked on subheading, formatting and sizing of text took forever, filled out indexes and CREST profile form

Post internship = complete any outstanding task then submit my project.

Appendix C – Correspondence

- **Professional Network**

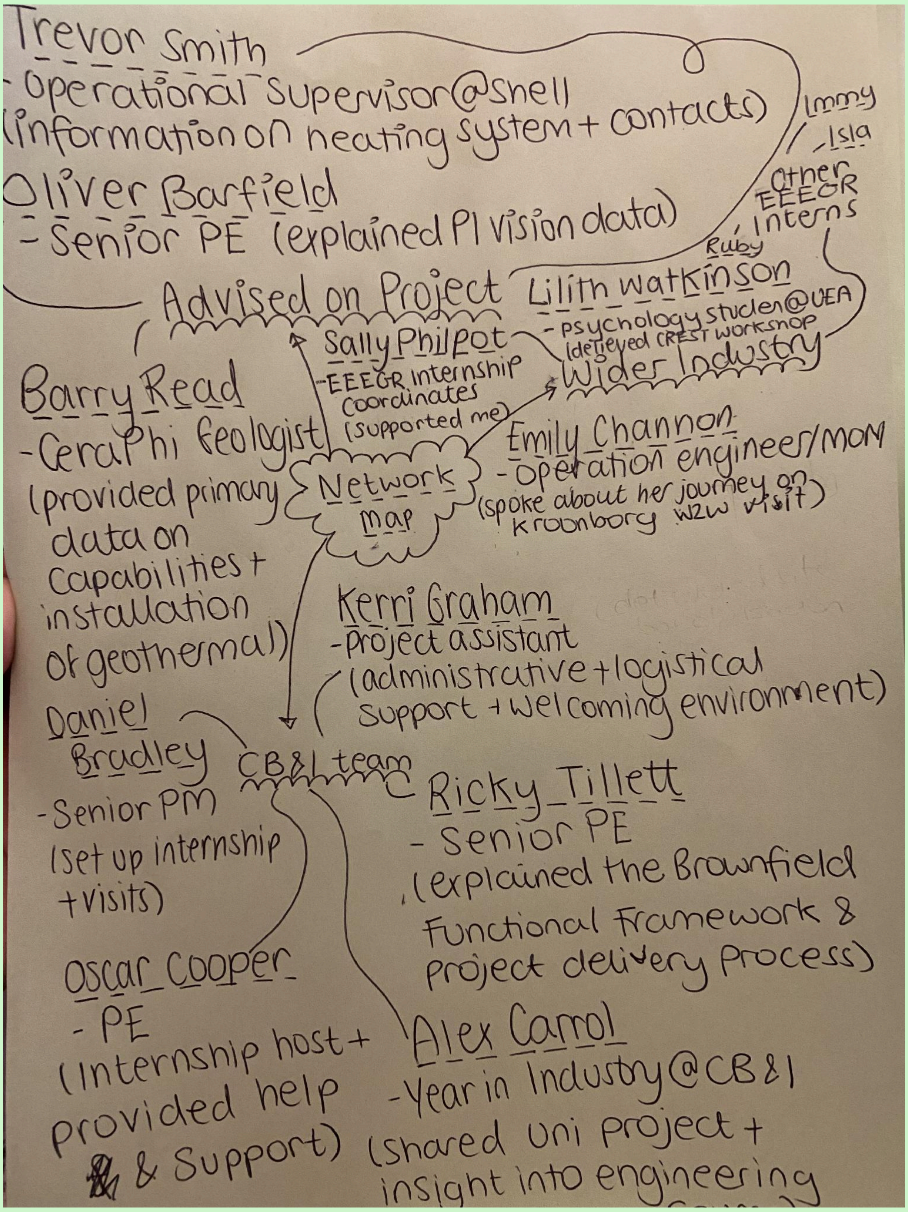


Figure 17. *Professional network developed during the CB&I internship.*

- **Email correspondence:**
  1. **Trevor Smith (Shell UK) - Technical Data Request**

From: Ruby Dobell
To: Trevor Smith
Date: 22 July 2026
Subject: Geothermal Feasibility Study Data Request

Summary: Request for operational and technical information relating to the Bacton gas heaters.

I am currently completing a three-week work experience internship at CB&I. As part of my placement, I am conducting a feasibility study on replacing the gas-fired heaters at Shell Bacton with geothermal heating.

I would be grateful for information regarding:

1. Average and peak heating demand
2. Gas inlet and outlet temperatures
3. Gas flow through the heaters
4. Number of heaters normally operating
5. Annual operating hours
6. Fuel gas consumption and efficiency
7. Emissions and operating costs
8. Redundancy requirements
9. Electrical capacity and site space
10. Local geology and potential borehole locations

Response received from Trevor Smith

Date: 22 July 2026

Average and peak heating demand data is available on the PI Vision tool.

Gas outlet temperature is approximately 6°C.

Annual operation is normally between October and May.

SEAL requires both heaters to be available, while BBL operates on an N+1 redundancy basis.

Relevant contacts:

- Kabari Okafor (Process Engineer)
- Stuart Peterson (Metering Technician)
- Keith Mitchelle (Electrical RPE)

Follow-up enquiry: Pipeline systems

Following Trevor's initial response, further questions were asked regarding the pipeline systems connected to Bacton and how heater allocation was managed between them.

Second response received from Trevor Smith

Trevor clarified that the Interconnector UK pipeline only interfaces with Shell via the SEAL system, whilst ETS is connected through a tie-in used for gas conditioning. He also confirmed that SEAL operates two dedicated gas-fired heaters, BBL operates four water bath heaters, and the remaining process systems at Bacton do not require heating.

2. **Keith Mitchell (Electrical Capacity and Site Layout)**

   Purpose: Determine electrical capacity and land availability for a geothermal installation.

   Key findings:

   Keith suggested a site visit to assess available land.

   He identified "Seagulls Field" as a nearby area potentially suitable for future energy projects.

   Site drawings could potentially be made available subject to approval.

3. **Kabari Okafor (Process Engineering Data)**

   Purpose: Request heater performance and operational data.

   Key findings:

   Fuel gas consumption data may be available through PI Vision.

   Emissions information could be obtained from Saloni Sapru.

   Commercial information could potentially be obtained from Phil Leeder.

In addition to the correspondence included in this appendix, further requests for emissions data, operational data, and project guidance were sent to additional stakeholders. While not all enquiries received responses within the project timescale, they demonstrate the extent of industry engagement undertaken during the investigation. However, most emails were not acknowledged or responded to within the project timescale, which was frustrating

Appendix D – Workshop & Visits Reports

- **Visit to Kroonborg boat**
  walk to work vessel for offshore engineering, used instead of a helicopter and live on boats. Toured every deck and every part, high-safety regulation. Lots of

decommissioning work in the future and more potential gas. Lots of work schedules 2 on 2 off. It was a really nice lunch. Steering is opposite so Captain steer into harbour, pilot won't touch. Cranes and platforms are very stable, and they heavily compensate for boat movements. Must consider the combination of current, weather etc making operation very dynamic and 'keep the job exciting'. They operate shell platforms? Employed by shell. Positive boat atmosphere and described to be like a family, seemed a welcoming and inclusive environment. Spoke to the captain lots of constraints due to the complex nature of the platform's operations.

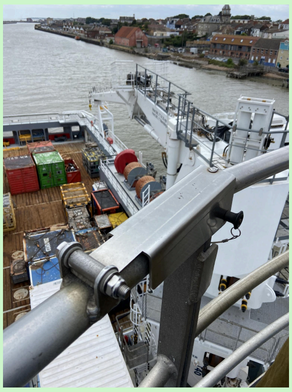


Figure 18. *Kroonborg vessel during site visit.*

Figure 19. *Author visiting the Kroonborg vessel.*

Figure 20. *Bridge control area aboard the Kroonborg vessel.*

- **CREST reporting workshop**
  It was rewarding to meet the other interns and work in such a welcoming and supportive environment. The workshop covered the CREST guidelines and provided useful advice on how to approach the project. A key takeaway was that the project scope and objectives can evolve as information becomes available. This reassured me that limitations in accessing certain technical data within the project timeframe would not prevent me from producing a meaningful feasibility study, provided my conclusions were supported by the available evidence.

- **E-colour Equilibria workshop**
  The workshop helped me better understand different communication styles and encouraged me to reflect on my own approach to communication. I realised that my tendency to send long, highly detailed emails may not always be the most effective method, particularly when communicating with people who prefer concise and direct information. Understanding the different E-colour profiles helped me appreciate that people absorb and respond to information in diverse ways.

  The session also encouraged me to reflect on my own personality and working style. I recognised that my perfectionist tendencies can sometimes become a weakness, and the workshop reminded me of the importance of embracing creativity and flexibility when solving problems. Both professionally and personally, it reinforced the idea that different people are motivated by different things and that there is no single definition of success or enjoyment. For example, some people enjoy competition and the pressure of achieving results, whilst others find the greatest satisfaction in teamwork, collaboration, and supporting others.

I believe this type of training can also contribute to a safer working environment. Developing a better understanding of colleagues' personalities, motivations, and communication preferences can improve teamwork and help people feel more comfortable asking questions, raising concerns, and seeking support. Greater mutual understanding ultimately promotes more effective communication and collaboration, both of which are important within the energy industry.

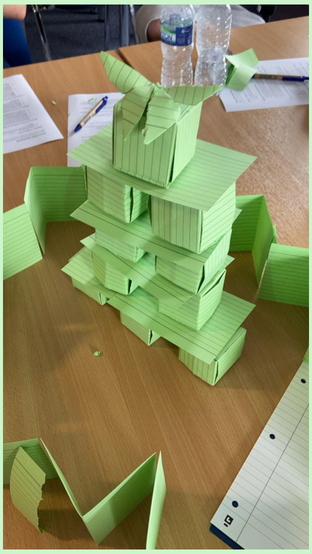


Figure 21. *Origami tower designed by the author using cube and butterfly structures and constructed collaboratively during the E-Colour workshop activity.*

- **Conversation with Rickey Tillet**
  Our conversation was on the topic of project delivery & recent projects: Discussed how the project is taken from Work Issued to closeout report. This walk through gave me a more comprehensive knowledge of the role of a project engineer job and how to this links into the wider engineering sector. He also explained the project he has been working on recently across Bacton and beyond. During my Bacton site visit I was able to consolidate this information by visually seeing the project he had managed and being responsible for. Below is the Brownfield Functional Framework that governs their project at CB&I.

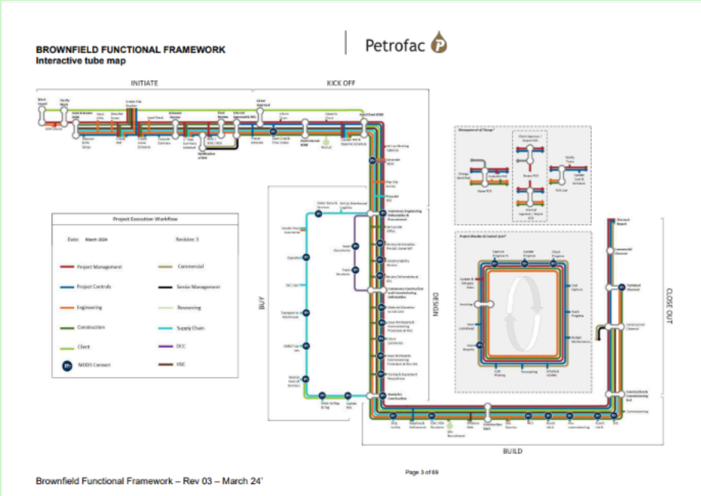


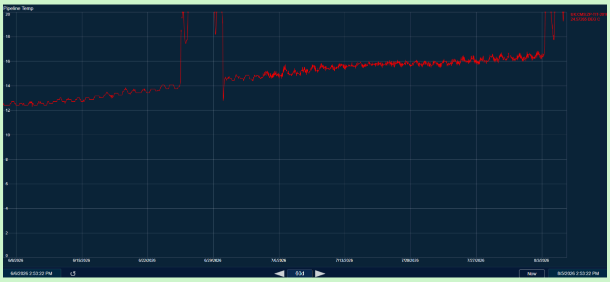
Figure 22. Brownfield Functional Framework discussed during consultation with Rickey Tilet. Source: (CB&I Internal Material).

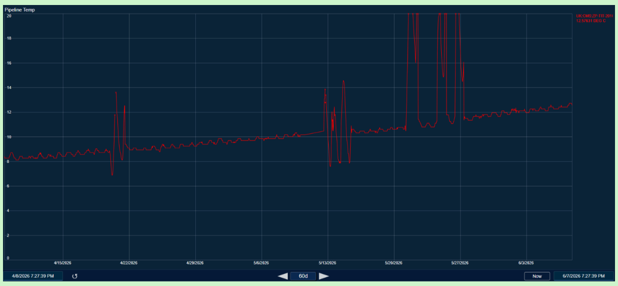
- **Visit to Bacton site**
  PPE is so hot it is a mystery to me how these men wear it all day. The site tour was good. I understand a lot more from my conversation with Rickey and the projects he had worked on. Does not seem sustainable at all the amount of things being scrapped all the time. Learn more about the history of the site and how the condition of the equipment was left to deteriorate as Shell was planning to sell the site. So much equipment is being decommissioned. Discussed the wider industry and how lack of permit was leading to many major companies selling their assets in the UK. Bacton gas terminal processes and supplies up to one-third of the UK's natural gas demand leading to questions about what will replace this to meet the UK greener initiatives. Met many technicians across companies and visited the CB&I office on site. Spoke about the Piper Alpha North Sea oil and gas platform disaster that was caused by a gas condensate leak from a pump undergoing maintenance, poor shift-handover communication, and a lack of blast protection design. It killed 167 people. This reinforced why safety is so critical even if it means delays and extended project deadlines to make sure standards are maintained. Finished the tour then had lunch a jacket w beans and cheese and the cafeteria ladies were lovely.

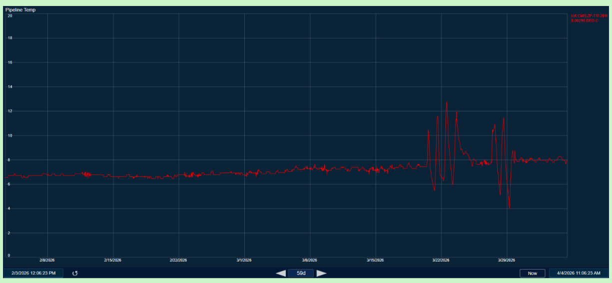
Figure 23. *Bacton Gas Terminal site visit.*

- **PI Vision Session with Oliver Barfield**
  Helpful session that explained and confirmed much of my research about existing operation at Bacton Gas Terminal. Looked at real time data from site on inlet temperature and outlet temperature which showed currently inlet temperature to be higher than outlet confirming that the gas heater is not in operation during the summer month Looked across SEAL and BBL heater data and historic data including inlet and outlet temperature across last year. Also discussed current projects which include lower less minimum gas required to operate. As less well licenses are not being granted his production will decrease and currently the facility needs a higher input of gas to maintain pressure, Ben is also currently working on this. We also spoke about the company review underway of emission from oil and gas rigs. He also gave me additional contact to reach out to include an employee who works in the control room at Bacton who can clarify data from the PI vision tool.

  SEAL trends:







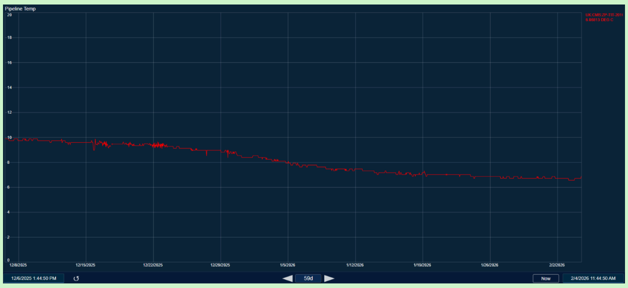
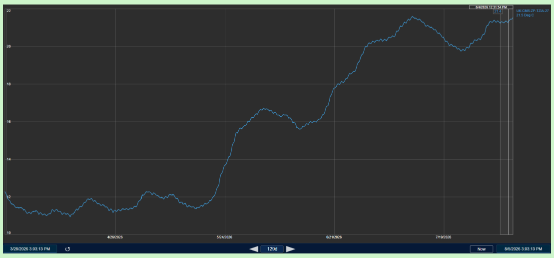


Figure 24. *Additional SEAL heater temperature trends provided by Oliver Barfield from PI Vision.*

BBL trends:

Heater 1



BBL – Heater 2 (This is the same for all heaters so assuming it's via the same route/ Temperature gauge

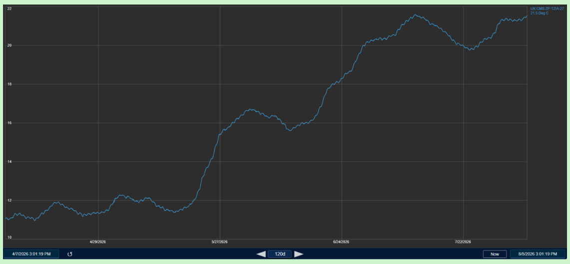


Figure 25. *Additional BBL heater temperature trends provided by Oliver Barfield from PI Vision.*

These graphs highlight and confirm the variation in demand over the year and increase inlet temperature across the warmed moth. The BBL heater between April to July depicts a drastic change in heating and stresses the importance of the heaters in the colder month to increase the temperature for distribution.

Appendix E - CREST Planning Evidence

-

Through observation and research during an energy internship with EEEGR hosted by Petrofac/CB&I (who support energy companies by providing skilled teams that maintain sites and help produce reliable energy, with thousands of employees in the UK and worldwide and focuses on safer, cleaner, and more efficient energy solutions as part of the global energy transition) My project focuses on assessing whether geothermal energy could replace the current gas-fired water heater used to heat natural gas.

By deconstructing the project these are actionable steps I plan to undertake:

- Complete project planning step as outlined by CREST guidelines (full working day)
- Attend workshop hosted by EEEGR on Crest reporting (include notes taken from the session) (from 9.15 till 1.30)
- Attend workshop hosted by EEEGR on E-colours & employability as part of the internship programme (from 9.15 till 1.30)
- Attend something with boats? Help gives insight into the wider operation of CB&I and their operations (whole morning)
- As part of project planning this add timing planning (spreadsheet of activities/this log of what needs to be done) (a couple of hours)
- Within this research different approaches? (I think that this mean to evaluate different research methods and compare and contrast – ultimately, I will probably opt for a combination for a final result with both primary and secondary research)
- Meet with specialist vendors and engineers to understand geothermal technology and how it compares to gas-fired heating (CeraPhi Energy)
- Secondary research – gather data on current systems, what already exists (general research on geothermal heating + statistics and report from shell on what they are doing as a company – could do a literature review?
- Secondary research – review technical specifications
- Once all secondary research complete reference sources, use Harvard referencing & reference any photos included, and include anyone who advises on this research and their input
- Primary research – analyse energy use, emissions, cost – environment considerations
- Primary research - Model performance of geothermal heating with engineering software (get help for this)
- Equipment requirement for geothermal heating, initial startup cost – estimated cost sheet?
- Complete a feasibility study (look at examples online) include this and all research into this within through the project section
- Convert this feasibility study into a deliverable poster
- Review all data collected and recommended next steps in written and presentations form
- Then Prepare a stakeholder-ready presentation summarising findings, benefits, and recommendations – make sure to include finalising project criteria & include any idea about getting younger people into the sector
- Complete project log and get this signed off with Oscar

- Conclude everything in final written report and write personal reflection once internship has been complete
- Submit my written report for CREST

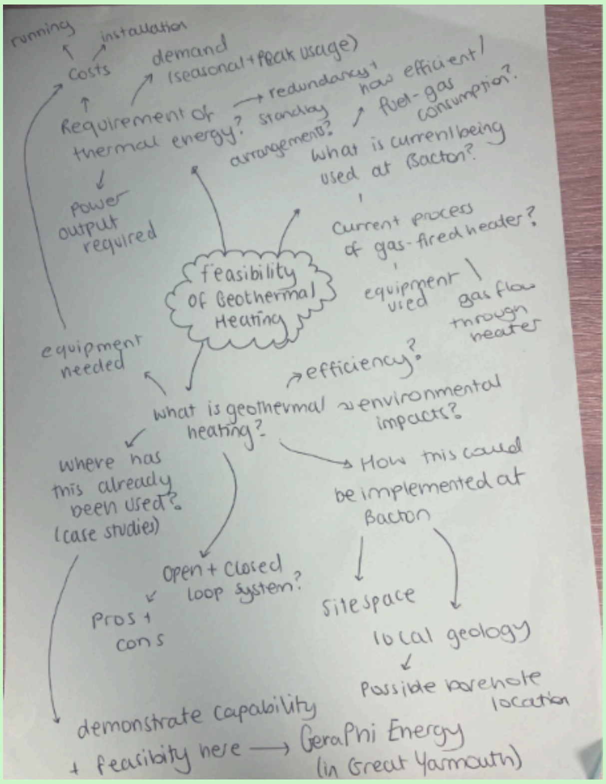


Figure 26. *Initial mind map showing research areas identified during the project planning stage.*

Initial Research Approaches Considered

- ***Wider purpose of my project***
  My project explores the transition from a gas-fired water heater to clean geothermal energy that can help cut carbon emissions and lower fuel use. Therefore, supporting its long-term goal of safer, cleaner, and more efficient operations. Geothermal heat is a more advantageous option due to being reliable, renewable, and decreasing in operating costs over time. By exploring this option, we can improve environmental performance, reduce dependence on fossil fuels for heating, and demonstrate real progress toward cleaner energy solutions that support the CB&I's transition strategy.

- **Initial Research Approaches Considered**
  - Experimental methodology (Digital) - Make a digital simulation using mathematical modelling and engineering physics to calculate the exact physical specification of the geothermal loop/system needed to replace the gas heater. They use this model to test input and measure how the system reacts and therefore the capability and capacity of geothermal research.
    - This method would be perfect for analyse technical feasibility as it would deliver precise, definitive and numerical answers and develop my understanding of engineering software.

    - However, this is purely theoretical and does not account for real-world challenges and constraints. Due to my inexperience with this software, there is a high probability for user error which would make my conclusion inaccurate and derails my entire project. It also is entirely dependent on accessing accurate local geological data which is complicated and unlikely to be obtained by myself.
  - Experimental methodology (Tangible) Create a small-scale physical stimulation in which I would build a small scaled down physical model (Eg using a water container, sand, a copper pipe coil and temperature sensor) to test practically the heat transfer rates from a simulated 'earth core'
    - It provides original primary experimental data which I would have independently collected to my project requirements, additionally is highly visual and engaging practically.
    - However, this would require specialist material and scale models will struggle to mimic real crust pressure and limited by time pressure
  - Qualitative methodology - Comparative literature review and meta-analysis including gather pre-existing data and solution including academic data and geological data sets to assess the feasibility of my project
    - This method would save time as secondary data does not need to be collected personally and allow me to look at a wider range of data to assess where geothermal heating this setting has been effective and when not, and if not delve deep to figure out what was the failure point.
    - Contrastingly because I do not collect the data myself, reliability to the data must be questioned, to prevent inaccurate data I should only use reliable data from trusted sources that are accredited within the industry. Due to only relying on secondary source harder to demonstrate original analysis

- **Selected Methodology and Reasoning**
  - My primary approach will look at both qualitative and quantitative pre-existing data sets to establish an initial understanding of my project, Due to the highly complex nature of the data, there is a risk of misinterpreting and understanding the data but with guidance from professional I should take care to check my understanding of complicated data to prevent my analysis being compromised by data misrepresentation. Therefore, I believe this method will give me the most accurate representation of technical feasibility.
  - Furthermore, I plan to experiment with digital modelling additionally to attempt to model this feasibility, however my main conclusion will not be based on this decreasing the potential for a biased conclusion.
  - From observation and communicating with a wider network of geothermal heating specialists I plan to ask any question I have from my research to allow misconceptions to be addressed.

- **Time Planning and Organisation**
  - To plan my time spent on this project I reviewed in detail the project overview and requirements for a successful gold CREST project and met with Daniel Bradley, who

outlined the expectation for this project and the deliverable of a presentation and poster as part of my project.

  - I then complete a deconstructed version of my plan and estimated how long each task would take to complete (I intentionally kept the specific hour of completion vague to allow my schedule to be flexible, whilst also ensuring I had accounted for every part of my project before the deadline)
  - Then I translated these objectives onto a day-by-day calendar which also included days within the placement allocated to other activities I was participating in as part of and in addition to this project (EEGER workshops & Kroonborg boat)
  - As mentioned above my project was independent, I was responsible for planning and organising my project with guidance from employees at CB&I – included below is a screenshot of their spreadsheet that details a calendar for my time spent within the company. My planning was ultimate driven by timing constraints and trip planned by the company, with independent planning detailing the actionable step/research area I would be investigating within allocated project time

CB&I Internship Plan					
Week	Date	Location	Safeguarding 2nd Local Contact	Owner	Scope /
1 - Mon	7/20/2026	GTY	Daniel Bradley	Daniel Bradley	Onboarding and Introduction to CB&I
1 - Tue	7/21/2026	GTY	Oscar Cooper	Oscar Cooper	Introduction to Tapping the Earth: A Feasibility Study on Geothermal Heating at Industrial Sites
1 - Wed	7/22/2026	Kroonborg Vessel Visit	Ian Cook	Ian Cook	Introduction to Shell Platforms, Bacton Gas Terminal and the W2W Vessel
1 - Thur	7/23/2026	EEGER	Sally Philpot	Sally Philpot	Welcome to the Interns - EEGER Event
1 - Fri	7/24/2026	GTY	Oscar Cooper	Oscar Cooper	1st week reflection and close out
2- Mon	7/27/2026	GTY	Oscar Cooper	Oscar Cooper	Bacton Overview (Desktop) with Shell (D.Evans) / Introduction Geothermal Heating with CeraPhi
2- Tue	7/28/2026	GTY			Attached to Geothermal Heating at Industrial Sites
2- Wed	7/29/2026	GTY			Attached to Geothermal Heating at Industrial Sites
2- Thur	7/30/2026	EEGER	Oscar Cooper	Oscar Cooper	E-Colours - EEGER Event
2- Fri	7/31/2026	GTY	Jason Grimble	Jason Grimble	Attached to Geothermal Heating at Industrial Sites 2nd Week reflection and close out
3- Mon	8/3/2026	GTY	Ben Russell	Ben Russell	Geothermal Heating at Industrial Sites - Site walk Engineering discussion
3- Tue	8/4/2026	BCT	Oscar Cooper	Oscar Cooper	Site Visit - Geothermal Heating at Industrial Sites - System interface and support
3- Wed	8/5/2026	TBC	Ricky Tillet	Ricky Tillet	Mapping Geothermal Heating at Industrial Sites/ Introduction to projects
3- Thur	8/6/2026	TBC	Daniel Bradley	Daniel Bradley	Presentation 3rd Week Reflection & Feedback
3- Fri	8/7/2026	TBC	Oscar Cooper	Oscar Cooper	Close out and Goodbye

Figure 27. *CB&I internship schedule outlining placement activities, workshops, site visits and project milestones.*

- **Review of Planning**
  - I stuck to deadline and continually work and expanded my project, the plan helps guide me but was no limiting and the buffer time allowed me to feel calm
  - Could of work on my presentation earlier because I ended up making the slides the night before and writing the script our before however this didn't negatively impact my performance in the meeting, but I would have alleviated panic and stress
  - I think my plan could have been more closely alight with my structure, if I had allocated a topic a day, I wouldn't have left so many sections incomplete until the last week
  - I am proud of how independent my planning was and how I was able to complete most task and area of research I wanted to, I was self-motivated to continue ticking of task even when the project felt too large to ever finish
  - Surprisingly my 2 days of absence didn't have a massive impact on my project deliverables
  - Overall, I am satisfied with my planning, whilst acknowledging it could have been more thorough I think it work well for me and resulting in a complete project

Appendix F – Presentation deliverable

- **Presentation Script**
  A Feasibility Study into Geothermal Heating at Bacton Gas Terminal

  Project objective & Planning:

  → Aim: 'The aim of the project is to investigate whether geothermal energy can replace the current gas-fired water heater used to natural gas' explore whether geothermal could replace, or partially replace the gas-fired water bath heater used to heat natural gas before distribution

  → Scope throughout the project I assessed the technical, environmental and economic feasibility of this concept and developed recommendation based of this evidence. It does not include any engineering design of drilling investigations.

  → Planning & Methodology To complete the project I combined primary and secondary research. I reviewed literature, technical reports and case studies, while also speaking directly to Shell employees, geothermal specialists and Bacton personnel to gather industry insight.

  Industry Engagement & Research Support:

  → Barry Read – geologist at CeraPhi provide specialist geothermal knowledge that my conclusions are heavily built on and explained practical challenged associate with deploying geothermal at industrial scale

  → Trevor Smith – signposting information + overview Trevor helped clarify how the Bacton heating systems operate and signposted me towards useful contacts and sources of information.

  → Oliver Barfield – PI vision Oliver introduced me to the PI Vision system, which allowed me to view process data and better understand the operation of the heaters throughout the year.

  Existing operation:

  → BBL Heater, 2 SEAL Heater The study focused on the BBL and SEAL systems, which are the main gas streams at Bacton that utilise gas heating.

  → BBL = 5.4MW Each BBL heater is rated at 5.4 megawatts, with four installed on site, although not all of them are typically used at the same time.

→ Seasonal operation the heaters mainly operate between October and May when incoming gas temperatures are lower due to reduced seabed temperatures.

→ Redundancy? Reliability? Reliability is extremely important because heating is needed to maintain gas temperatures for onward distribution. BBL operates with N+1 redundancy, while both SEAL heaters must be available during the operating season.

→ Safety? The existing heaters have extensive safety systems, shutdown functions and burner management controls. Any replacement technology would need to provide an equivalent level of reliability and safety.

→ Moving forward

  - Removal, 25% capacity (Dale Haylock) Discussion during the placement suggested one of the BBL heaters may eventually be removed due to maintenance costs and reduced demand, indicating the full installed capacity is not always required.
  - Hydrogen Longer-term plans at Bacton may include supporting hydrogen infrastructure, which is an important consideration when assessing future investment decisions.

Geothermal Heating?

→ Heat 44% = energy, 37% GG – utilizing geothermal heat could have a major environmental impact.

→ Deep Vs Shallow – 500m above 500m generals used for building, deeper system access higher temperatures and are more suitable for industrial or large-scale heating operations

- 10C^o-25C^o, then 27C^o/1k

→ Open-loop Vs Closed-loop Closed loop would be my recommendation because it does not depend on local groundwater resource and has less environmental risk. Additionally deep geothermal Infrastructure is traditionally closed loop

→ Overview In a closed-loop geothermal system, a sealed fluid circulates through deep boreholes and absorbs heat from the surrounding rock. The warmed fluid returns to the surface, where a heat exchanger and heat pump transfer that energy into a usable heating system. Unlike open-loop systems, the fluid never encounters groundwater and remains within the pipework throughout its operational life.

→ Jubilee Pool – 401m small scale, provide reliable year-round heat 28°C and 30°C

→ Eden project – 4.9km deeper geothermal can provide heat on a larger commercial scale, however they still struggle to fund themselves

→ 'Geothermal is like the sleeping giant of renewables – it has so much Potential' CEO of Eden renewables consider geothermal to be underutilised to it potential currently

CeraPhi consultation:

However, the consultation at CeraPhi illuminated why geothermal is unutilized current, primarily because of long payback period from high drilling cost

→ Lost 1C ^o per km – inefficient to travel, confirming borehole must be near site

→ 600m vs 1.5km wells – new product – look at table, 1.5km is a new technology they are not focussing on and purely a theoretical product for them for now, deeper drill require higher complexity and cost and more room for error for drilling to go round

→ E.G. – Scunthorpe General Hospital – if borehole exist to repurpose as demonstrated he the process might be more economically feasible, successful CeraPhi project

→ Lifespan = 40year, 70-80 year – long operation lifetime

→ 2-year engineering study required – due to the complex nature this would be the estimate time it would take to even investigate feasibility

→ 6 mot planning + 1-month installation – this is the timeline for a singular 600m borehole

→ Best = baseload COP 4-4.5 explain COP, work best a continuous baseload heating

> I originally thought geothermal would be feasible because the temperatures were achievable. However, after speaking to CeraPhi, I discovered the major challenge wasn't temperature, it was scale. The number of boreholes and capital cost required completely changed my conclusion.

Feasibility study:

→ Technical - number of borehole & site space from a technical perspective, geothermal heating appears possible. However, the number of boreholes required and the site space needed represent major challenges.

→ Environmental – emission, gas consumption, construction & drilling reduce emissions and fuel consumption. However, the drilling programme, construction impacts and potential thermal depletion must also be considered and lifespan of this usage

→ Economic – high capital cost, long payback period, uncertain future Economically, the largest challenge is capital cost. The upfront investment required is extremely high and would likely result in long payback periods, particularly given uncertainty surrounding the long-term future of gas processing at Bacton.

Conclusion & Recommendation:

→ Is it technically feasible? Yes

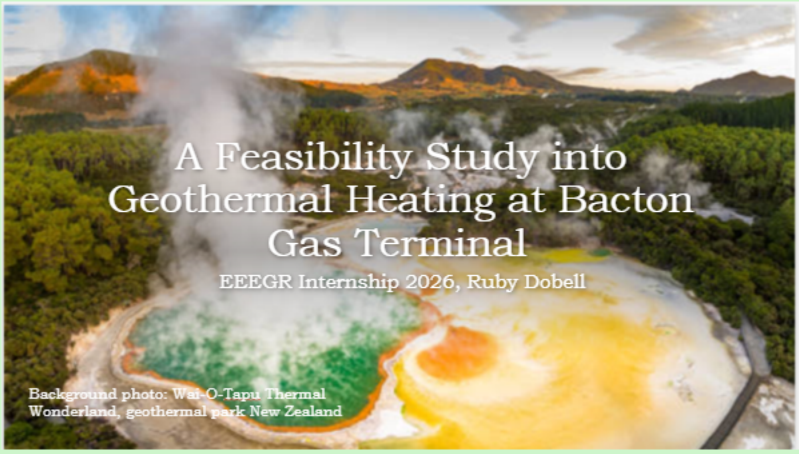
→ Is it environmentally beneficial? Yes, in relation to emission

→ Is it economically viable? No, capital cost is too high

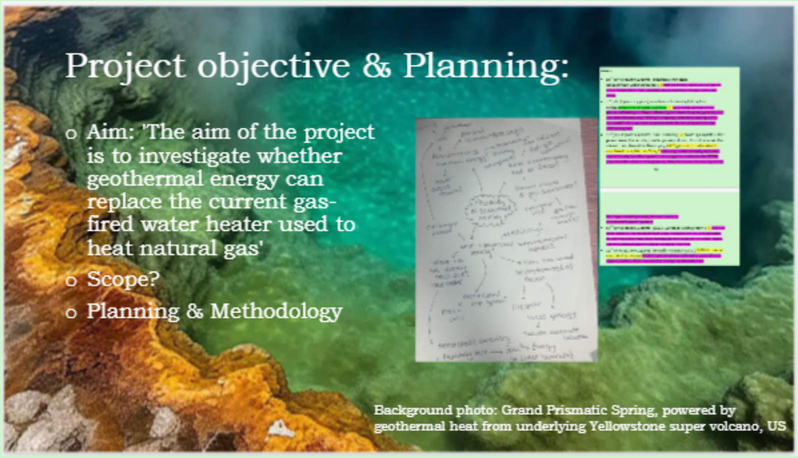
→ Recommended next step theoretically could be done but definitely should not be done. The transition to renewable relied on using the right technology for the appropriate application. Rather than attempting to replace the existing gas-fired heaters, a more practical option may be to investigate a smaller geothermal installation to provide heating for site buildings and office facilities.

→ Before this project, I underestimated the potential of geothermal energy. I learned that geothermal can be highly effective for smaller-scale applications and deliver meaningful environmental benefits. My research showed that the difficulties often arise when trying to scale the technology up to meet the demands of large industrial processes.

- **presentation Slides Used During Project Delivery**

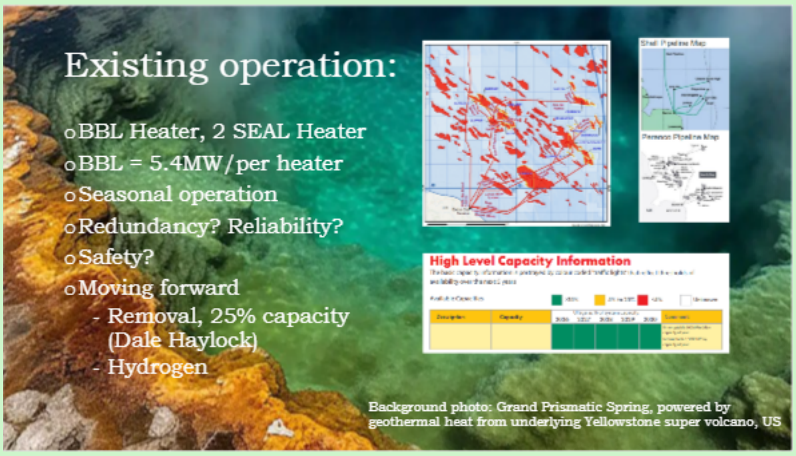


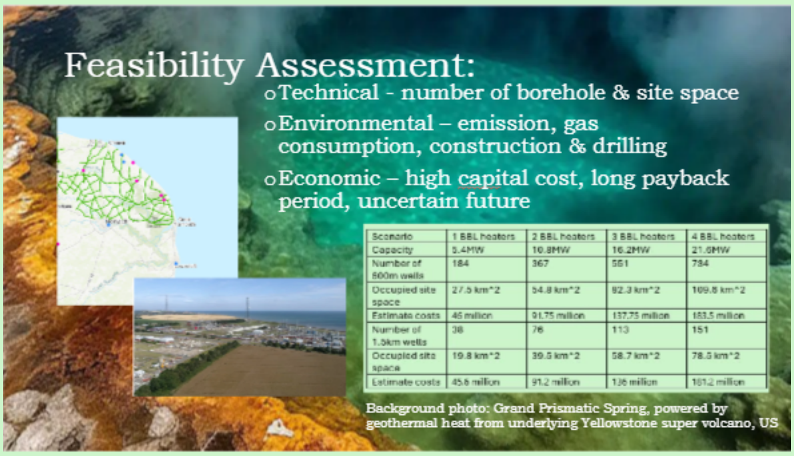
A Feasibility Study into Geothermal Heating at Bacton Gas Terminal
EEEGR Internship 2026, Ruby Dobell
Background photo: Wai-O-Tapu Thermal Wonderland, geothermal park New Zealand



Project objective & Planning:
Aim: 'The aim of the project is to investigate whether geothermal energy can replace the current gas-fired water heater used to heat natural gas'
Scope?
Planning & Methodology
Background photo: Grand Prismatic Spring, powered by geothermal heat from underlying Yellowstone super volcano, US


Industry Engagement & Research Support:
• Barry Read – geologist at CeraPhi
• Trevor Smith – signposting information + overview
• Oliver Barfield – PI vision
Background photo: Grand Prismatic Spring, powered by geothermal heat from underlying Yellowstone super volcano, US


Existing operation:
o BBL Heater, 2 SEAL Heater
o BBL = 5.4MW/per heater
o Seasonal operation
o Redundancy? Reliability?
o Safety?
o Moving forward
- Removal, 25% capacity (Dale Haylock)
- Hydrogen
High Level Capacity Information
Background photo: Grand Prismatic Spring, powered by geothermal heat from underlying Yellowstone super volcano, US



Scenario	1 BBL heaters	2 BBL heaters	3 BBL heaters	4 BBL heaters
Capacity	5.4MW	10.8MW	16.2MW	21.6MW
Number of 600m wells	184	367	551	784
Occupied site space	27.5 km^2	54.8 km^2	82.3 km^2	109.8 km^2
Estimate costs	46 million	91.75 million	137.75 million	183.5 million
Number of 1.5km wells	38	76	113	151
Occupied site space	19.8 km^2	39.5 km^2	58.7 km^2	78.5 km^2
Estimate costs	45.6 million	91.2 million	136 million	181.2 million

Figure 28. *Presentation slides used to communicate project findings and recommendations to CB&I personnel.*

Appendix G – Personal reflections

- **Reflection and feedback on My Internship Experience (for CB&I)**
  What Went Well:
  - → The visit to CeraPhi Energy was extremely valuable and became one of the most important sources of information for my project. I am particularly grateful to Daniel for organising the visit and to Barry Read for taking the time to answer my questions in such detail. This insight significantly improved both my understanding of geothermal energy and the quality of my feasibility study.

→ Everyone in the office was welcoming and willing to answer questions when approached, which made the placement feel supportive. The people I met throughout the placement were equally generous with their time and knowledge.

→ I really appreciated Rickey taking the time to explain the Brownfield Functional Framework and how engineering projects are delivered in practice within CB&I. I also enjoyed Alex showing me his university engineering project. Before this placement, I viewed university engineering as quite theoretical; however, seeing the practical and creative project work changed my perception of traditional Uni and strengthened my confidence that engineering is the pathway I would like to pursue.

→ Visiting Bacton Gas Terminal and the Kroonborg vessel provided valuable first-hand experience of the energy industry and were highlights of the placement. Kroonborg was my first introduction to offshore operations, and the tour gave me a good insight into this lifestyle.

→ The project gave me the opportunity to investigate a genuine engineering problem with real technical, environmental and economic considerations. I particularly enjoyed the independence of the project, which gave me greater confidence in following my own lines of research, asking questions and seeking information from various sources, even when obtaining data proved challenging.

Areas for Improvement:

→ More examples of previous CREST Gold projects would have helped me understand the expected level of detail and report structure earlier in the placement. In addition, if there had been greater familiarity with the specific project I was undertaking, it may have been easier to provide guidance during the initial stages of the investigation.

→ Projects that encourage interns to interact with a wider range of departments could help build confidence and provide a broader understanding of how various parts of the business work together. For a feasibility study, I would have appreciated spending more time with engineering teams, as some short conversations provided answers that weeks of email correspondence could not.

→ Earlier access to key project data would have allowed more time to be spent analysing information and developing conclusions rather than identifying contacts and locating suitable data sources. I appreciate that part of the objective was to encourage independent communication and initiative; however, obtaining information from busy operational teams was often challenging.

→ Looking back, I underestimated the impact of a daily commute of more than two hours. Choosing to accept the placement was entirely my own decision, but it taught me the importance of balancing enthusiasm for opportunities with personal wellbeing, energy levels and workload management.

→ Additional structure at the beginning of the placement may have been beneficial. I appreciate that work experience should be challenging and encourage independent thinking; however, arriving on the first day with limited prior knowledge of geothermal energy and being expected to produce a technical feasibility study was initially quite daunting. Despite this, I am proud that I adapted to the challenge and have almost completed a substantial report within the available time. If future interns undertake longer placements, it may be beneficial for projects to include a wider range of clearly defined activities and milestones throughout the programme.

- **Personal Reflection on My CREST Project**

  My internship at CB&I and my project investigating geothermal heating proved to me that I am capable of conducting independent research and producing work that I am genuinely proud of. I have always struggled with perfectionism, which often prevents me from finishing projects because I become focused on constantly reviewing, editing and improving my work. This project was no different. I wanted to continue refining every section, but the scale of the investigation made that impossible. Instead, I was forced to keep moving forward, accept that I would make mistakes, and correct my assumptions as information became available. This taught me that progress is often more important than perfection.

  I also learned a huge amount about geothermal energy. It is not a topic I would have chosen to research independently, yet it became one of the most interesting aspects of my placement. The project gave me valuable insight into both the renewable energy sector and the wider oil and gas industry, helping me better understand the challenges associated with the energy transition. Ultimately, I consider the project successful because it reached a clear evidence-based conclusion that was supported by my mentors and the professionals I consulted. Although the conclusion was that geothermal heating is not a suitable large-scale replacement for the existing heaters at Bacton, recognising that a proposal is not feasible is just as valuable as proving that it is.

The project also highlighted the importance of working with incomplete information. Whilst I would have liked greater access to Shell operational and financial data to make the assessment more quantitative, I learned how engineers must often make decisions using the best available evidence. If I were to continue the project, I would investigate my recommendation of a smaller geothermal installation to provide heating for site buildings and offices, as this appears to be a much more practical application of the technology. Despite the challenges and limitations, I am satisfied with the quality of my final work and believe the experience has improved my resilience, confidence and research skills. Moving forward, I hope to apply the same level of curiosity, independence and determination to my future studies and career in engineering.