Jubilee Pool Geothermal Project Summative Assessment Report

Geothermal Engineering Ltd

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Commercial in Confidence

AUTHORISATION			
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1. Introduction

The Jubilee Pool Geothermal Project was designed and constructed by Geothermal Engineering Ltd (GEL) following on from a successful technology trial within the existing deep wells at Rosemanowes quarry, funded by the Department of Energy and Climate Change (DECC) in 2014. The project utilises an innovative low carbon technology (geothermal and ground source heat pump technology) that had previously never been deployed in Cornwall.

The aim of the project was to supply geothermal heat to a section of Jubilee Pool, Penzance, to provide the following key benefits:

- Extend the opening season for the pool
- Attract more visitors to the Penzance area
- Act as a show case for the low carbon, geothermal heat resource in Cornwall
- Achieve carbon savings of 400 Tonnes per year

To meet these aims, the system utilises a 400m geothermal borehole to deliver renewable, low-carbon heat to a section of Jubilee Pool in Penzance, Cornwall. The drilling was successfully completed in the final quarter of 2018, after which the equipment was installed. Alterations to the existing pool were also carried out at the same time to accommodate the heated pool. The system was commissioned in 2020 and hot water has been provided to the UK's first geothermal saltwater lido since July 2020. The pool was open to the public for the first time on 1st September 2020, following delays due to the pandemic.

The project has had an incredible amount of support from the local community, with pre-planning engagement finding that 97% of event attendees supported the project. This was further highlighted by later community fundraising which attracted 1,400 shareholders (970 local) to invest c. £540,000 into the transformation of the pool itself. The project brings together this incredible community spirit with significant carbon savings to provide a successful demonstration of harnessing the natural geothermal resource for the advancement of Cornwall.

2. Project Context

Geothermal Heat

Geothermal heat refers to heat which is naturally present inside of the Earth's core, mantle and crust, existing in solid rock and molten liquids and gases. The natural regeneration of heat reserves through geological processes and modern geothermal management techniques enables the sustainable use of this heat as a low emission, renewable resource. Accordingly, "*geothermal energy has the potential to provide long term, secure base-load energy and greenhouse gas (GHG) emissions reductions*"[1].

The extent to which geothermal heat can be utilised depends on the available heat temperature and grade. This varies depending on depth from the Earth's surface and geographical location, which will dictate the presence of any location-specific geological characteristics such as increased volcanic activity.

Typically, geothermal heat is utilised to meet the following energy demands:

a) Space heating in buildings and domestic hot water either using standalone systems or as part of a district heating network.

b) Space cooling in buildings using heat pump conversion technologies.

c) Heat driven industrial processes.

d) Generation of electricity through the conversion of thermal energy by appropriate technology.

'Deep' geothermal wells take advantage of the geothermal gradient present in the earth's interior, which typically involves a temperature increase of around 25°C per kilometre of depth. This heat is usually accessed via boreholes or wells which are drilled to depths of 500m or greater. At this depth, the temperature is expected to be around 35 – 40°C.

Alternatively, 'shallow' geothermal heat may be accessed via a combination of boreholes and horizontal arrays of pipework (also known as '*slinkies*'), at depths between 5 – 500m and at temperatures ranging between 10 – 15°C. The systems that take advantage of this heat are commonly referred to as a ground-sourced heat pumps (GSHP).

Policy Context

As part of the UK Low Carbon Transition Plan[2], published by the DECC in July 2009, £6 million in capital grant funding was made available over two years to explore the potential for deep geothermal power and heat in the UK. The purpose of this grant was to assist companies to undertake the exploratory work needed to identify viable geothermal sites.

The UK Government's intention to explore the potential for a deep geothermal energy sector was further established in 2009. It's Renewable Energy Strategy[3] (RES) was underpinned by the Government's overall renewable energy target, as set out in the Energy White Paper 2003[4]. This set out a commitment to generate 20% of all national energy from renewable sources by 2020, with an expectation that renewables would be contributing at least 30-40% of electrical

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[1] IPCC, 2011: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, http://www.ipcc.ch/report/srren/ (Accessed 24/03/2017)

[2] HM Government, UK Low Carbon Transition Plan (2009), Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228752/9780108508394.pdf (Accessed 24/03/2017)

[3] HM Government, The UK Renewable Energy Strategy (2009), Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228866/7686.pdf (Accessed 24/03/2017)

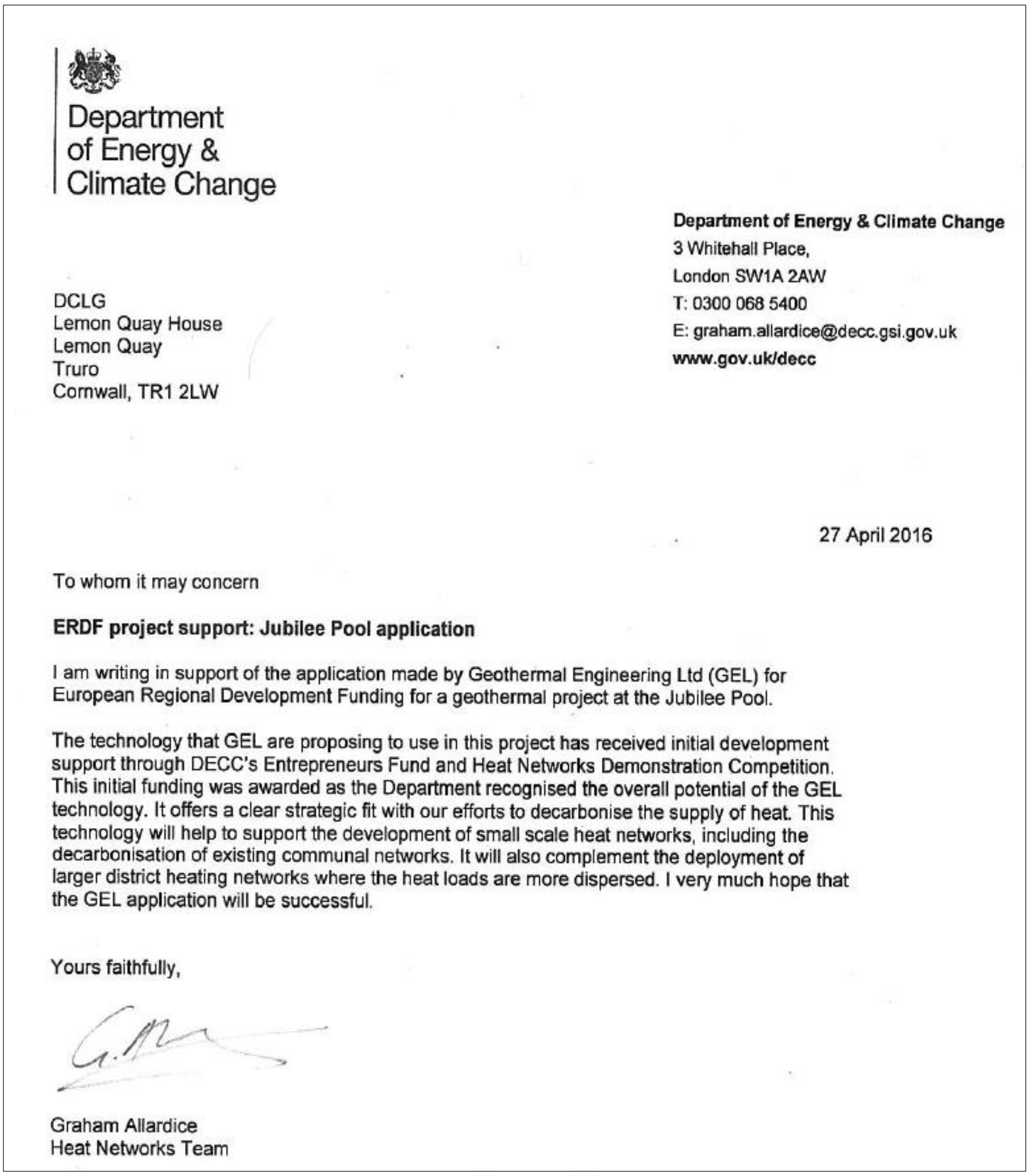
[4] Department of Trade and Energy, Energy White Paper (2003), Available at: http://webarchive.nationalarchives.gov.uk/+/http:/www.berr.gov.uk/files/file10719.pdf (Accessed:24/03/2017)

generation by 2050. A summary of the major international, EU and UK targets is provided in *Table 1*. Therefore, at the time of the Jubilee Pool project, the Government had committed to delivering new renewable energy technologies to meet its overarching renewable energy targets. Geothermal energy offered one such new technology and DECC provided strong support for the Jubilee Pool geothermal project (*Figure 1*).

Policy	**Year**	**Target**
Kyoto Protocol	1997	EU has a commitment to an 8% reduction of greenhouse gas emissions on 1990 levels by 2010. UK agreed to a 12.5% reduction in six greenhouse gases from 1990 levels in the period 2008-2012.
UK Climate Change Programme	2000	15% of all electricity to be generated from renewable resources by 2015.
EU Renewables Directive (2001/77/EC)	2007 (as amended)	20% of energy needs from renewables by 2020.
Renewables Obligation	2002	UK electricity suppliers to provide 15% of their electricity from renewable sources by 2015 (20% by 2020).
Energy White Paper – Our energy future – creating a low carbon economy	2003	Set a target for 60% reduction in CO2 emissions over 1990 levels by 2050.
Energy White Paper – Meeting the energy challenge	2007	Reconfirms target of 10% electricity from renewable sources by 2010, with an aspiration for this to double by 2020.
UK Climate Change Act	2008	Legally binding targets to reduce carbon emissions by between 26% and 32% by 2020, and 60% by 2050, from 1990 levels.
The UK Low Carbon Transition Plan	2009	Plan to cut UK emissions by at least 34% by 2020 and at least 80% by 2050. 15% of energy to come from renewable sources by 2020.
The UK Renewable Energy Strategy	2009	Sets out pathway to ensure 15% of energy comes from renewable sources by 2020.
European Renewable Energy Directive (2009/28/EC)	2009	Committed the EU to a renewables generation target of 20% by 2020 with individual targets established for each member nation. For the UK, the legally binding target of 15% was established, in recognition of the low level of renewable energy generation in operation at that time, with interim targets of 5.4% by 2013-14, 7.5% by 2015-16 and 10.2% by 2017-18.
The Carbon Plan – Delivering our	2011	Sets out how the UK will achieve decarbonisation within the framework of energy policy, and how to make the

Low Carbon Future		transition to a low carbon economy while maintaining energy security, and minimising costs to consumers.
Paris Agreement	2015	The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2^{o}C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5^{o}C. The Agreement requires countries to put forward Nationally Determined Contributions (NDC) towards meeting this challenge. Currently, as a member of the European Union, the UK is committed to a collectively binding target of "*at least 40% domestic reduction in greenhouse gas emissions by 2030 compared to 1990*".

Table 1. Summary of the major international, EU and UK renewable energy/ carbon reduction targets at the time of the development of the Jubilee Pool Geothermal Project.



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27 April 2016

To whom it may concern

ERDF project support: Jubilee Pool application

I am writing in support of the application made by Geothermal Engineering Ltd (GEL) for European Regional Development Funding for a geothermal project at the Jubilee Pool.

The technology that GEL are proposing to use in this project has received initial development support through DECC's Entrepreneurs Fund and Heat Networks Demonstration Competition. This initial funding was awarded as the Department recognised the overall potential of the GEL technology. It offers a clear strategic fit with our efforts to decarbonise the supply of heat. This technology will help to support the development of small scale heat networks, including the decarbonisation of existing communal networks. It will also complement the deployment of larger district heating networks where the heat loads are more dispersed. I very much hope that the GEL application will be successful.

Yours faithfully,

Graham Allardice
Heat Networks Team

Figure 1. A copy of the letter of support provided by the Department for Energy & Climate Change (DECC) during GEL's application for funding from the ERDF.

Economic Context

In addition to political appetite, Cornwall and the Isles of Scilly (CIOS) experienced a more severe economic output contraction relative to the EU average since the beginning of the Credit Crisis in 2007. CIOS is therefore a struggling regional economy with the lowest levels of productivity of any LEP area in England and particularly vulnerable to cutbacks in public expenditure, observed to be a reflection of the very low levels of research and development undertaken in the region (CIOS LEP ESIF Strategy p. 24). This economic situation has meant that ERDF has become even more significant as a source of regeneration funding to help improve the resilience of the regional economy.

One key resource of CIOS is its natural energy flows. However, despite its extensive renewable energy resources, it still imports c. 95% of its energy requirements. In addition, of the c.560 MW of renewable energy generation in the region, only c.1% is owned by the local community, with most of the economic benefit of the generation leaving the region. It is also emitting more CO_2 emissions per capita than the Intergovernmental Panel on Climate Change (IPCC) state is required to minimise the risks of dangerous climate change.

Therefore, there is great potential for CIOS to:

1) harness its natural energy resources to generate renewable energy.
2) develop innovative specialist technologies to capture certain natural energy flows (e.g. deep geothermal or wave power); and
3) retain ownership of the generation to deliver maximum benefit to the region.

Enabling these three things would deliver economic benefits for the region, including business growth, job creation, retention of energy sector profits in the CIOS region, and increase in disposable income / GVA). Beyond the local benefits, it would also bring environmental benefits through the significant reduction of carbon emissions.

The political and economic context did not change significantly over the course of the project, with commitments to increase the proportion of renewable energy within the country's energy mix to reduce carbon emissions only strengthening over time.

Project Location

Jubilee Pool is situated at the intersection of Western Promenade Road and Battery Road in Penzance, Cornwall, approximately 40km southwest of Truro and 14km northeast of Land's End (*Figure 2*). The pool itself lies on a rocky outcrop jutting into the sea and has a surface area of approximately 3,000m^2, just over twice the size of an Olympic swimming pool. It was newly refurbished following storm damage in 2014, reopening in May 2016. Its elevation is close to sea level with salt water being used to fill the pool. The lido originally dates from the early twentieth century and retains its original art deco style.

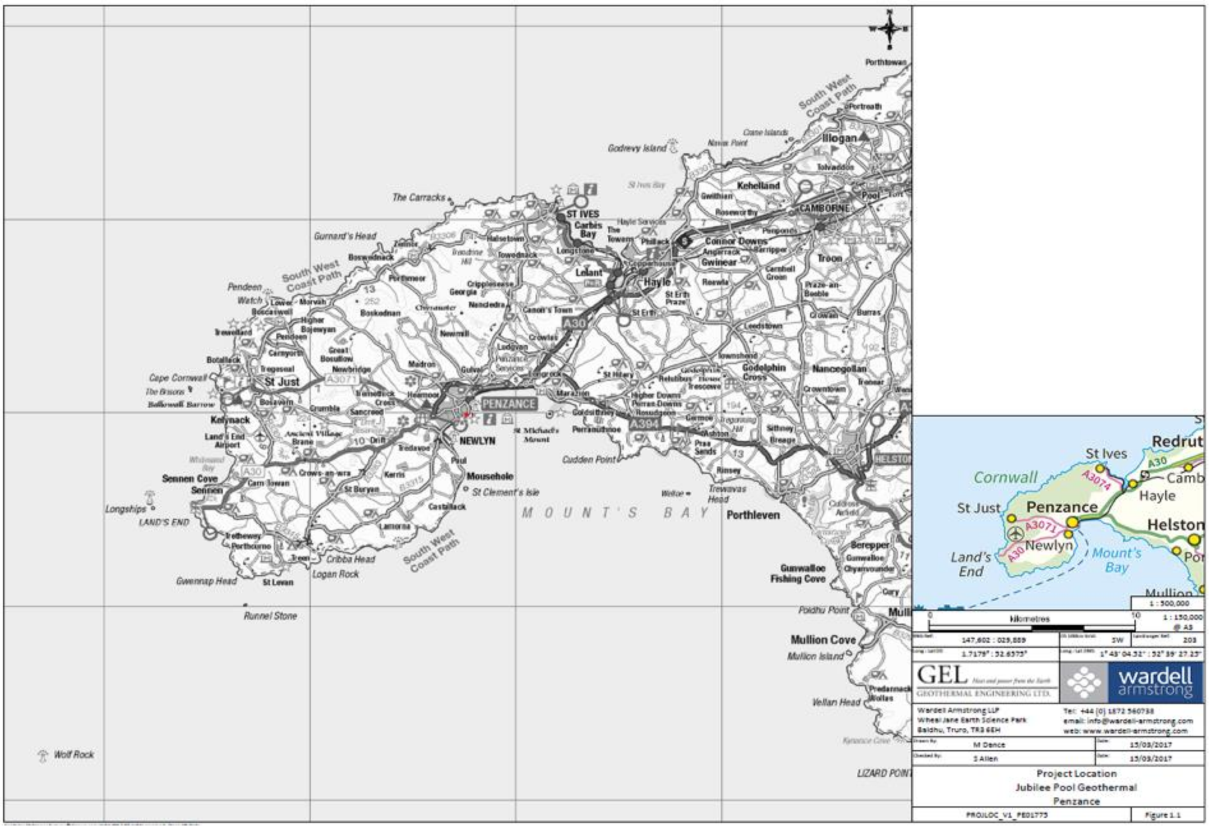


Figure 2. Location of Jubilee Pool in Penzance, Cornwall, depicted by a red mark.

The drilling works for the project were contained within the red line shown on *Figure 3*, on the existing hard standing area adjacent to Jubilee Pool, the existing St Anthony long stay car park, and the stretch of road (Battery Road) between the two. The layout during works is provided in Figure 4.

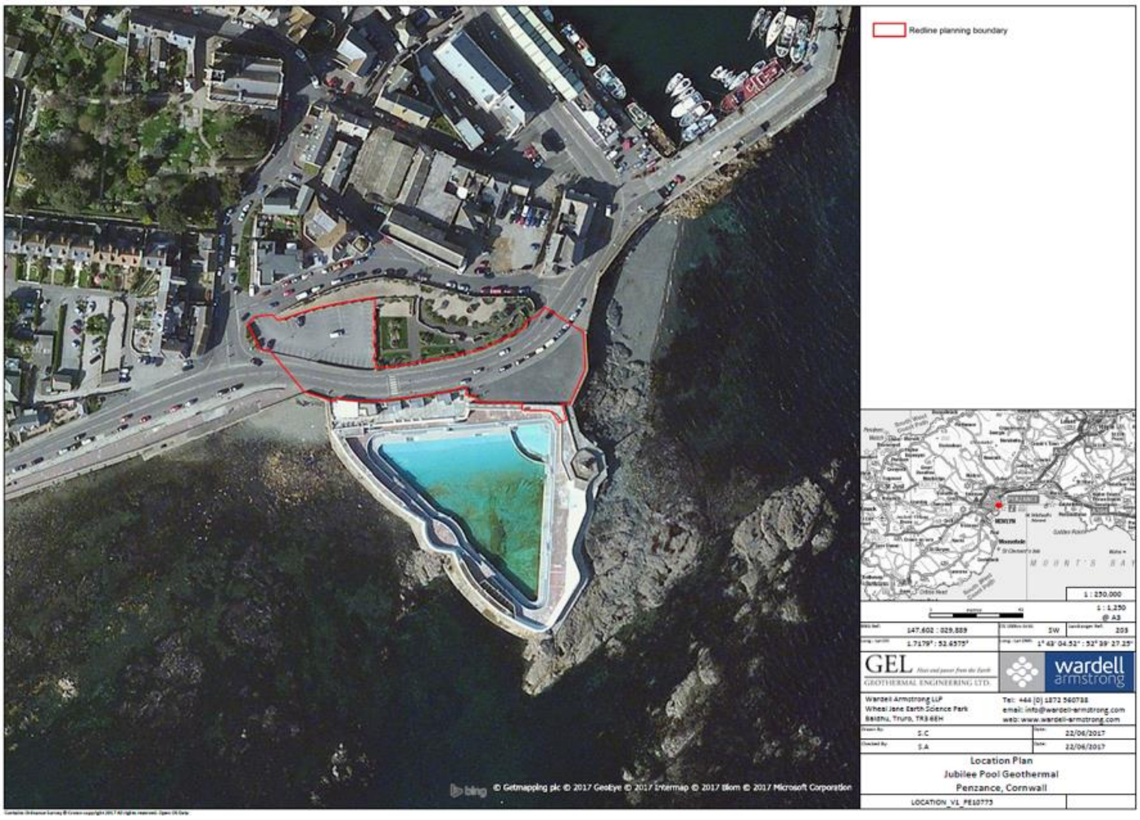


Figure 3. Red line boundary for works associated with drilling for the Jubilee Pool geothermal project.

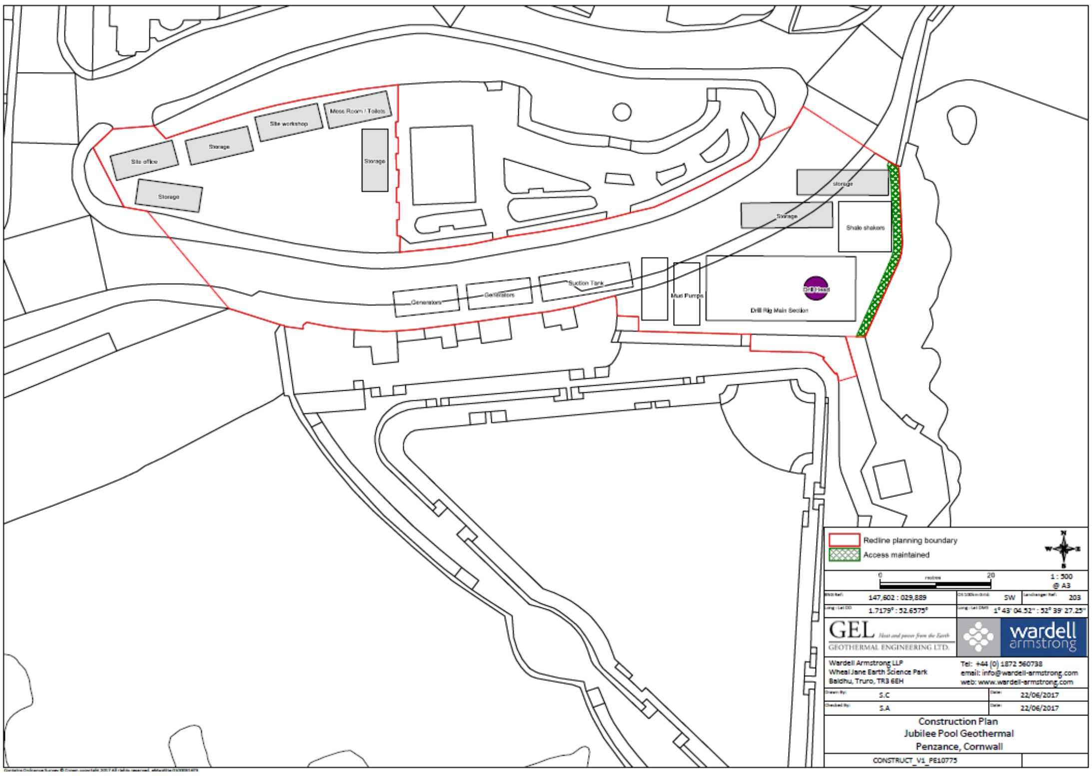


Figure 4. Layout for drilling works associated with the geothermal project.

Project Aims

The lack of demonstration that relatively shallow geothermal heat could be utilised effectively for low carbon heating in Cornwall posed a significant market barrier to developing Cornwall's incredible geothermal resource. Therefore, one of the main aims of the project was to provide a proof of concept that could be replicated across the Duchy.

Cornwall's geology is unique within the UK and for decades it has been considered as a potential geothermal resource. This is because the Cornubian granite batholith stretches from Dartmoor in the east to the Isles of Scilly in the west and contains a high concentration of heat-producing isotopes such as thorium (Th), uranium (U) and potassium (K). This natural heat production means that the heat flow in southwest England is approximately double the UK average at $120mWm^{-2}$, and much of Cornwall has the highest geothermal gradient in the UK at 33-35°C/km, almost 10°C/km hotter than large parts of the country.

Despite this known resource, without a project proving the viability of the geothermal heat, the appetite to harness the heat was extremely low. This is because geothermal projects have a high exploration risk, with the resource only truly proven by drilling. However, as drilling represents the highest cost in a geothermal project, a significant proportion of budget is spent prior to proving the resource. This is illustrated by the generic risk vs cost graphic in *Figure 5*.

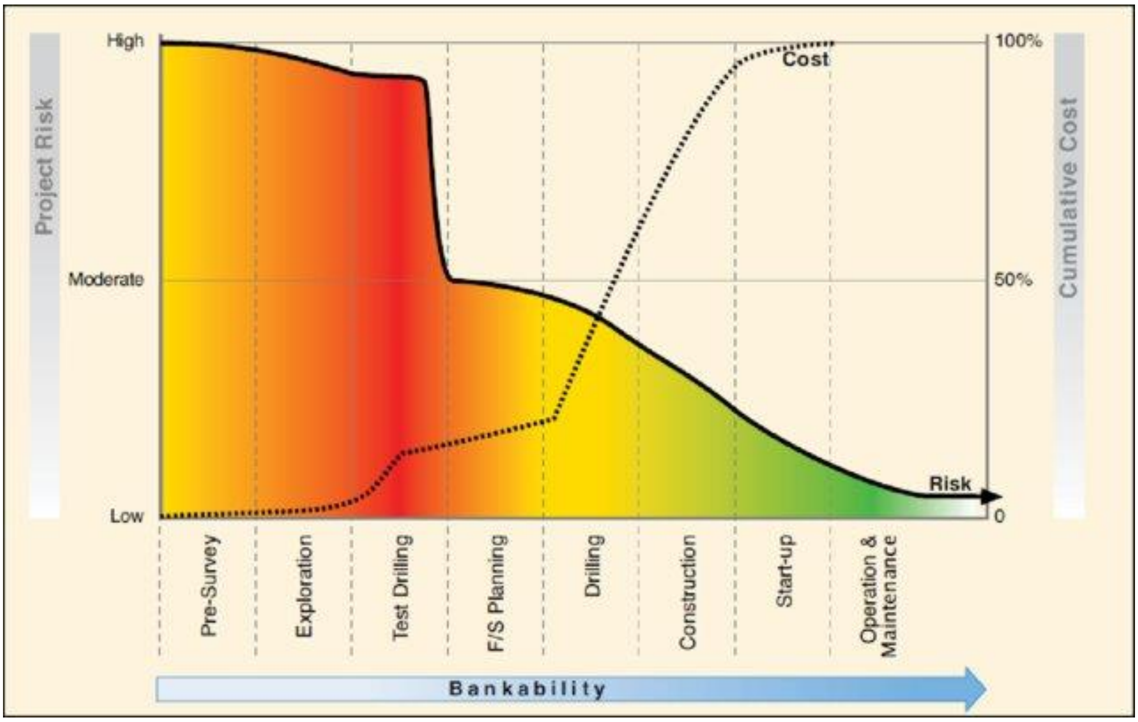


Figure 5. Generic risk vs cost diagram for geothermal projects, showing significant risk prior to drilling (World Bank, 2012).

To address this market gap, it was decided to prove Cornwall's significant geothermal resource by providing low carbon heating to a section of the iconic, open air, Jubilee Pool in Penzance. Such a high-profile project offered an exciting opportunity to demonstrate a replicable model for low carbon heating projects across Cornwall.

Whilst the overarching aim of this project was to "supply geothermal heat to a section of Jubilee Pool, Penzance", the following benefits were also targetted:

- Extending the opening season for the pool
- Attracting more visitors in general to the Penzance area
- Achieve the stated carbon savings (400 Tonnes per year)

These aims were both realistic and achievable within the scope of the project.

System Design Update

Initially, the intention had been to drill a well to a total depth of 1.4km with the goal of extracting hot water from the bottom of the well and transferring the heat via pumps and a heat exchanger directly to the pool at a temperature of 36°C. To enable heat to be supplied directly from the well would require a reservoir at more than 55°C and capable of supplying water from the deepest part of the well. The capacity to supply water from depth is always the highest risk element of drilling geothermal wells and could not be determined with confidence prior to drilling. Hence the lack of private funding available for the project.

During the first phase of drilling (January to March 2018) a highly permeable rock formation was encountered at c. 100m. This section yielded so much water that it was very difficult to adequately contain on site. An attempt was made to cement this section and then drill through it when the cement had set. Unfortunately, on re-drilling, the cement washed out of the fracture zone and the water came back into the well, confirming very high permeability. As time was running short on site before the road had to be reopened for Easter, a decision was made to clean the well out and install a perforated liner. The perforations were located at the zone of high flow water, enabling this shallow well to be used as an injection well for water produced from a second deeper well that was subsequently drilled when the road was closed again.

The final design therefore uses geothermal heat from 410m with a temperature of around 30°C. This reservoir of warm water was unexpected and offered the opportunity for above-average temperatures at shallower depths than initially targetted. The decision was made that this shallower resource coupled with a surface heat pump would meet the aims of the project whilst balancing the risk of further time over-runs, potential cementing failure and, *above all else*, not finding the required water at depth if drilling to the original target depth was attempted[5]. It was decided that it would be better for all parties to have a functioning system than risk having to abandon the well if no further flow zones were found or the cementing collapsed.

The final system pumps water up from c. 400m using a pump set at c. 40m. This water passes through a heat exchanger and then ground-source heat pumps (GSHP) where the temperature is boosted to maintain a constant water delivery temperature of 30-35°C before being treated and used by Jubilee Pool. The water is returned from the heat exchanger into a shallow reinjection well, where it re-enters the reservoir at c. 80m depth, percolates down, collects heat and will eventually recycle into the deep well at 410m. A generalised overview schematic of the system is provided in *Figure 6*.

[5] During this decision process particular weight was given to the fact that this was unknown geology and to the previous high-profile failure of the Newcastle Science Central well which found no hot water and had to be abandoned.

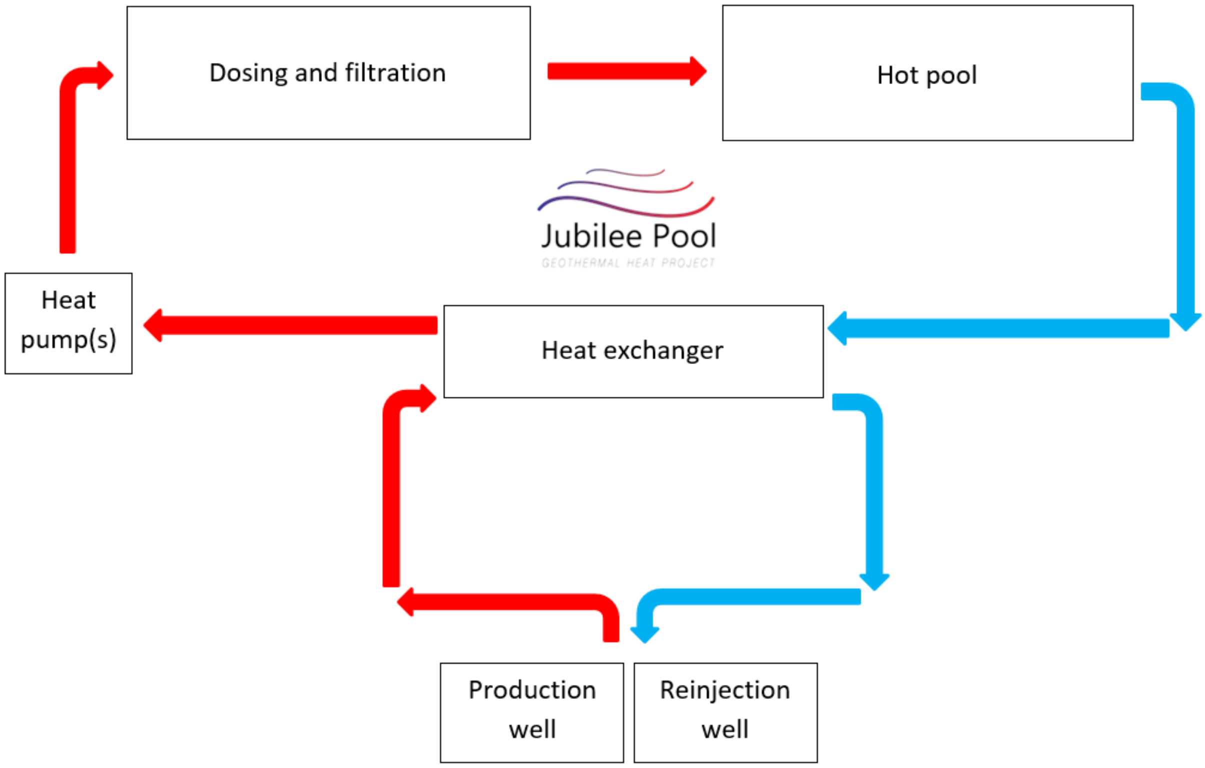


Figure 6. A generalised schematic of the geothermal system at Jubilee Pool.

3. Project Progress

Timeline

Whilst at the time of application to the ERDF it was anticipated that the system could be operational by the end of 2017, a number of setbacks resulted in commissioning in July 2020, with the pool open to the public by September 2020. The original timeline of the project is provided in *Table 2*, for reference.

Milestone	Start Date	Completion Date
Project planning, logistics, team, pre-permitting advice	March 2016	June 2016
All permitting (Planning, Environment Agency etc).	July 2016	December 2016
Drilling tender and procurement	July 2016	December 2016
Drilling, completion and fitting of geothermal well	January 2017	June 2017
Procurement for remaining equipment and labour	March 2017	May 2017
Installation and commissioning	May 2017	Oct 2017
Operation of system/ monitoring	August 2017	August 2018

Table 2. The original project timeline stated in the ERDF application.

The protracted timeline was caused by several factors, including:

1) Changes to project partnerships
2) Re-issuing of the drilling tender and tender for plant equipment/heat pumps
3) Local permitting procedures longer than anticipated
4) Logistical restrictions imposed by local authority planning conditions
5) Covid-19 Pandemic

Whilst each of these played a role in extending the timeline, factors 1 & 2 were the result of decisions made internally to ensure the project offered good value for money. For example, after careful evaluation of the initial tender submissions in May 2017, the three successful bids were deemed prohibitively expensive for the project. Therefore, the decision was made to issue a second tender later that month to constrain the costs of the drilling contract.

Factors 3-5 were beyond the control of the management team. Local planning permission was required for both the drilling work and the changes required within the existing pool area to accommodate the plant room and layout changes of the pool. Achieving permission for each part of the project met no major stumbling block, simply taking longer than anticipated due to protracted communications with the local authority.

The biggest adjustment to both time and budget came from the restriction imposed by the planning authority to close one of the roads during drilling. This road could only be closed outside of the summer season as it provided the main access route to the local ferry. Whilst the logistics of the operation were planned around this restriction, drilling of the first well encountered a number of unforeseen geological problems which meant the drilling operation was not completed during the initial road closure. In April 2019, the road had to be re-opened and the drilling rig removed from the site, halting project progress throughout the summer season. In late autumn, the drilling rig was re-mobilised, and the drilling operation completed by Mid-December 2020.

Outputs

The total thermal output from the system successfully meets the original target of 400KW, and the temperature of the thermal pool has been successfully maintained at 30-35°C, slightly below the 36°C stated in the initial specification. The project successfully demonstrates the potential for geothermal heating in Cornwall, as well as enabling year-round opening of the lido and over-achieving on the targetted carbon savings of 400T per year, as shown in *Table 3*.

Thermal output of the system - as built	400	kW
Gas Carbon Intensity*	0.214	kgCO2/kWh
Electricity Carbon Intensity*	0.281	kgCO2/kWh
COP of heat pumps	4.5	
Annual heat consumption of pool section**	3,153,600	kWh/ year
CO2 if gas used to heat pool***	715	Tonnes/ year
CO2 with heat pumps	197	Tonnes/ year
Submersible well pump consumption	39,420	kWh/ year
CO2 associated with well pump	11	Tonnes/ year
Total CO2 from geothermal system	208	Tonnes/ year
Total CO2 savings	**507**	**Tonnes/ year**

*Source: BEIS (at time of application)

**Assume 90% of the year heat is uitlised (as per pool business plan)

***Assume 94% efficiency of gas boiler

Table 3. Calculation of the carbon savings associated with the Jubilee Pool Geothermal Project.

Furthermore, the geothermal section of the pool has been fully booked since it's opening in 2020, attracting significant numbers of visitors to Penzance throughout the year, thereby boosting the local economy and helping to regenerate the town. The project has therefore delivered on all its key aims.

Spend

Despite the delays to the project timeline, the project remained close to the total budget of the ERDF funding (*Table 4*). Whilst drilling had to be conducted in two phases resulting in two mobilisation and demobilisation fees, this was balanced out by the change to the system design resulting in the drilling of two shallower wells instead of one deeper well. Therefore, the total drilling costs remained on budget, allowing the project to successfully achieve on both its spend and outputs.

Indicators / Expenditure	Original Funding Agreement	Amount in most recent Funding Agreement Variation	Total achieved at time of evaluation	% of target	Projected to be achieved at Project Closure	% of target
ERDF Capital Expenditure (£m)	£1,440,000.00	£1,430,941.60	£1,430,960.80	**100%**	£1,430,960.80	**100%**
ERDF Revenue Expenditure (£m)	£0.00	£393,793.60	£393,774.40	**100%**	£393,774.40	**100%**

Table 4. Project Expenditure

4. Project Delivery and Management

Project Team

The project was managed by an experienced team, including leading geothermal developers in the UK, engineers from Ove Arup and Partners Ltd and experienced drillers from the oil and gas industry. The project team was designed to bring together experts in their field in order to manage each part of the project effectively and efficiently.

Overall responsibility for the project remained with GEL, who appointed principal contractors or consultants to manage individual specialist tasks. For example, Wardell Armstrong were selected to undertake relevant permitting and planning applications for the site and Meehan Drilling were selected via a detailed tender process to deliver the geothermal well.

Project Management

Prior to work commencing, a full risk register was developed to identify the key areas of risk within the project and work on mitigation strategies. This is standard practice, particularly for a geothermal project where exploration risk is perceived as high, and allowed GEL to reduce risk to the project as far as possible. A copy of the risk register is provided in *Appendix A*.

The project was broken down into a number of activities overseen by GEL:

- The development and signing of all agreements for the project. This includes some aspects of the permitting and long-term land assignment.
- Design and specification of the tender documentation for well drilling and equipment installation
- Management of tender process
- Drilling and completion of the well
- Fitting the required equipment for the well
- Testing the well performance
- Connecting the well to the pool
- Operation of the system
- Public Relations
- Twelve month monitoring of the operation of the system to evaluate carbon savings

Each activity was managed or overseen by GEL and successfully completed. Where unforeseen issues arose, solutions were discussed by the management team and relevant consultants in detail before selecting the solution with the best possible outcome and lowest risk for the project. System models, budgets and Gantt charts were updated throughout the project to reflect the changes required to adapt to geological anomalies (see Section 7 for details).

Procurement

As an ERDF-funded project, European procurement requirements set by European Structural and Investment Funds (ESIF) had to be followed for all major procurement packages, namely drilling activities and equipment installation. Each tender stipulated the following milestones:

1) Issue of Tender
2) Deadline for clarification questions
3) Deadline for response to clarification questions
4) Tender return date

5) Tender evaluation period
6) Award decision communication
7) Contracts agreed
8) Expected contract start date
9) Expected contract completion date

For each tender, the invitation to tender (ITT) was sent directly to companies with a known interest in geothermal in the UK or that submitted bids for previous relevant tenders. It was also advertised on the GEL website and through the online geothermal forum www.thinkgeoenergy.com. The milestone dates were provided within the ITT along with an invitation for all bidders to visit the site by arrangement and submit any clarification questions prior to submitting formal bids.

A communications log was maintained throughout the tendering process. The log included the date of contact, company name, representative's name, email, the company's choice to bid or not, date when bid was received (if applicable), other response and date of received response.

When all bids had been received and the tender window closed, the tenders were evaluated by an appropriate evaluation panel within the Project Team. Evaluation of the tenders was broken down into three sections in accordance with the ITT: Company Information, Technical Submission and Commercial Submission. Tenders only progressed to the next stage of assessment once they had passed the previous stage. Only tenders that were scored as technically acceptable passed to the commercial evaluation.

Each member of the panel carried out their evaluations individually and separately before coming together for an evaluation meeting, at which a consensus evaluation was developed. The evaluation meeting was also attended by a procurement specialist, who advised on procedure where necessary, and a complimentary expert to the evaluation process to inform the technical discussions, as appropriate for each tender.

The Company Information section was assessed on a pass/fail basis whereas the Technical Submission and the Commercial Submission were scored, with each section accounting for 60% and 40% of the Total Score respectively.

Five criteria were used to assess the Company Information on a pass/fail basis. They were: Financial Matters, Health and Safety, Equality and Diversity, Insurances and Legal Matters & Disputes. These were assessed solely by the Financial Director of GEL. The applicant and other organisations within their consortium (if applicable) were each required to pass all aspects of this evaluation before proceeding to the Technical Submission.

The technical evaluation used 6 main criteria, with 17 sub-criteria. The main criteria were Experience, Equipment. Site limitations, Methodology, Programme and Quality of submission. A score between 0 and 5 was given for each main criterion, according to *Table 5*.

At the evaluation meeting, 'conflict of interest' forms were signed by all attendees before each bid was discussed in turn to produce a consensus score. A weighting for each evaluation criterion was decided by discussion among the panel members, in order to reflect variations in significance and importance. These weightings were applied to the consensus score for each criterion to arrive at a total weighted technical score for each bid. In accordance with the evaluation system set out in the ITT, only technically acceptable submissions (i.e those achieving a score of 3 or greater) were passed for commercial evaluation.

Scoring Matrix for the Technical Submission		
Score	**Judgement**	**Interpretation**
5	Excellent	Exceptional demonstration of the relevant ability, understanding, experience, skills, resources and quality measures required to provide the services. Full evidence provided, where required, to support the response.
4	Good	Above average demonstration of the relevant ability, understanding, experience, skills, resource and quality measures required to provide the services. Majority evidence provided to support the response.
3	Acceptable	Demonstration of the relevant ability, understanding, experience, skills, resources and quality measures required to provide the services, with some evidence to support the response.
2	Minor Reservations	Some minor reservations of the relevant ability, understanding, experience, skills, resources or quality measures required to provide the services, with little or no evidence to support the response.
1	Serious Reservations	Considerable reservations of the relevant ability, understanding, experience, skills, resources or quality measures required to provide the services, with little or no evidence to support the response.
0	Unacceptable	Does not comply and/or insufficient information provided to demonstrate that there is the ability, understanding, experience, skills, resource and quality measures required to provide the services, with little or no evidence to support the response.

Table 5. Scoring matrix for technical evaluation of tenders.

For commercial evaluation, the lowest overall price was awarded a score of 10 and the other Commercial Scores were calculated using the following formula:

(Lowest overall price/cost of bid being evaluated) x 10

Adjustments could then be made as it was recognised that cost comparisons were not strictly 'like for like' as bidders had used different formats for structuring expenses. Some had included a lump sum where others had provided a breakdown of costs, including services that were not requested in the ITT document.

Once the overall score for all three sections had been ascertained, clarification questions were sent to any successful bidders whilst any unsuccessful bidders were notified. A second evaluation meeting was held to review the answers to the clarification questions, culminating in a consensus decision on which bid should be selected.

Project Delivery

The delivery of the project proved to be more difficult than expected due to very short time periods during which the drilling could commence. Local authority conditions to planning permission meant that road closures were required to carry out the intended works, but these closures were only permitted outside of the summer season. Whilst the team tried to plan the project around these restrictions, challenges during drilling meant that the drilling operations (*Figure 8*) could not be completed in time. This led to drilling occurring in two tranches, with no works able to take place from April-September 2019, resulting in two mobilisation and demobilisation fees for the drilling rig, considerably changing the allocation of budget.

Furthermore, the geology proved to be more challenging than expected, meaning the geotherm system design had to be altered to utilise two shallower wells (c. 100m and 400m respectively) as opposed to the planned single well to c. 1,400m depth. To mitigate against the reduced temperatures of the water, heat pumps had to be added to the system to boost temperatures and ensure a constant pool temperature of 30-35°C is maintained. These mitigations had been discussed prior to the project as an option for reducing risk, and were deemed the best solution for the project in the face of numerous challenges.

The horizontal principles of sustainable development and equal opportunities were central to and fully integrated into the project.

Figure 7. The drilling rig in operation outside of Jubilee Pool in early 2018.

Public Relations

In addition to delivery of the technical side of the project, community engagement and public relations were crucial to the success of the project. The project team engaged with the public early through information dissemination at a pre-planning event in 2017 in Penzance, including leaflet distribution, social media posts, exhibition stands and questionnaires. Approximately 90 people attended the information event in May 2017, with 97% of attendees showing support for the project.

Throughout the project, news stories were frequently run by local news outlets, with significant positive PR at the opening of the pool in 2020. This included national and international news outlets, as discussed in Section 5. The positive feeling surrounding the pool is well reflected in the success of the crowdfunding campaign which raised c. £540,000 from 1,400 stakeholders, 970 of which are local people, as well as the geothermal pool selling out months in advance throughout its first year of opening.

In review, we feel the project engaged well with the right beneficiaries, and the stakeholders and beneficiaries have shown great satisfaction with the quality of activities and delivery of the project. The geothermal pool concept has proved to be much more popular than expected, with the original estimates of visitor numbers being far exceeded.

5. Project Outcomes and Impact

As discussed in Section 3, the targetted thermal output of 400kW and pool temperature of 30-35°C has successfully been met by the project, as well as enabling year-round opening of the lido and increasing visitor numbers to the pool.

However, the major ERDF output for this project is the carbon saving associated with using the geothermal system compared to a conventional gas boiler. The target annual carbon saving for this project was set at 400 Tonnes/ year. To ensure an accurate calculation of the associated savings, sensors were installed as part of the system specification to record the electrical consumption, thermal output and 'co-efficient of performance' (COP) of the heat pumps. The data collected from the system shows that it has been operating with a higher COP than estimated at the beginning of the project. The **annual carbon savings are therefore higher than expected at 507 Tonnes per year**, as calculated in *Table 3*.

A number of other output aims have also successfully been met, including:

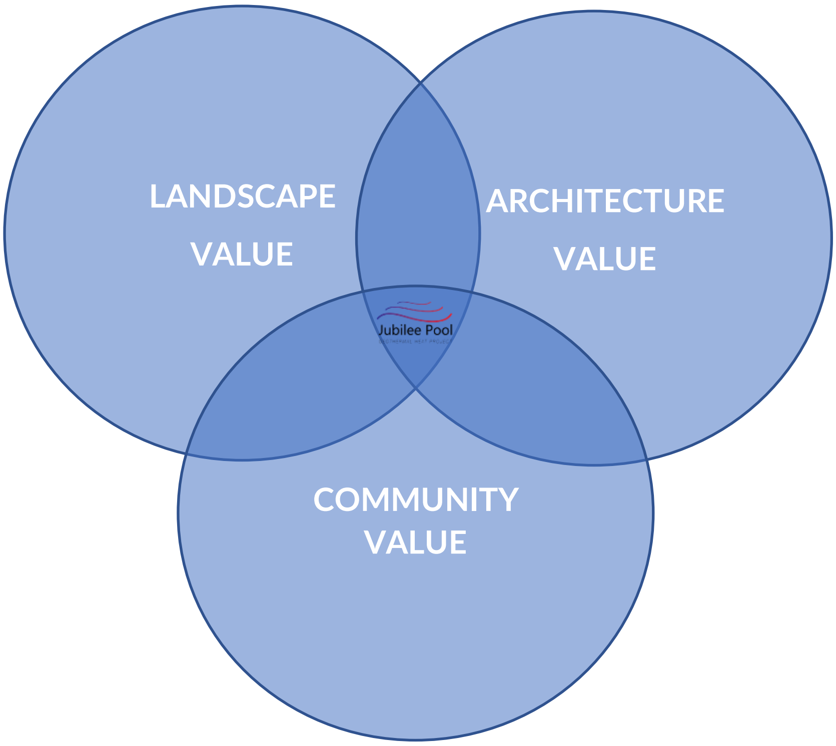
1) Increasing energy generation and average efficiency
2) Increasing the adoption of low carbon and environmental goods and services (LCEGS)
3) Reducing the carbon intensity of CIOS SME sector
4) Reducing spending on 'imported energy' in CIOS
5) Increasing the retention of profits from the energy-sector in the CIOS economy
6) Reducing GHG emissions from CIOS

Furthermore, the project triggered a significant amount of PR around the world, helping to put Cornwall on the map for geothermal development and ensuring the project had a wide-reaching impact. The official opening of the pool (*Figure 9*) received significant publicity in all mainstream media, including CNBC, BBC, The Sun, Time Out, The Mirror, and many others. This resulted in very high bookings for the geothermal pool, with tickets sold out months in advance throughout its first season, despite COVID 19 restrictions.

Feedback from the local community has all been extremely positive, with visitor numbers remaining high. In addition, GEL regularly receives enquiries about the project from developers interested in replicating the success, as well as MPs elsewhere in the UK looking to use geothermal for the benefit of their constituency and business owners interested in learning more about how they could utilise geothermal energy.

Figure 8. Opening day at Jubilee Pool's geothermal pool, Penzance, Cornwall.

Part of the project's success has been bringing together three key pillars:



Landscape Value

The geothermal section of the lido offers visitors the chance to connect with what lies beneath their feet, feeling first-hand the energy that the Cornubian granite batholith offers the region. Until now, no demonstration of the region's geothermal potential has been tangible, so the project allows people to finally understand the opportunity presented by Cornwall's natural resources.

Architecture Value

Developing this resource within an existing iconic landmark, steeped in history and maintaining its original art-deco style has produced a distinctive project with a local identity. It has captured people's imaginations and become a high-profile project with significant interest both nationally and internationally (including articles by the BBC[6] and in the New York times). The pool has hosted visits from various politicians, including at Ministerial level. It has proved to be a good advertisement for geothermal energy in the UK, MHCLG/ ERDF and Cornwall.

Community Value

Jubilee Pool is a great demonstration of the power of community. The recent transformation of the pool included nearly £540,000 from a public share offer resulting in an organisation truly owned by the community. The pool now has around 1,400 shareholders, of which 970 are local people. Funding such a geothermal project has therefore offered an exciting opportunity for local ownership of a ground-breaking, low-carbon project.

Furthermore, another important benefit of the project are the sessions when the pool is used as a hot water treatment for people with health problems. Although not necessarily quantifiable, this has been of great social benefit.

[6] https://www.bbc.com/news/uk-england-cornwall-53937176

6. Project Value for Money

The project was unique in that it was the first geothermally heated lido in the UK and as such, there are no equivalent benchmarks to which it can easily be compared. However, the best comparison comes from the carbon saving associated with using the geothermal system compared to a conventional gas boiler. The target annual carbon saving for this project was set at 400 Tonnes per year, but after running the system for over a year a carbon saving of more than 500 Tonnes per year is known to be achievable. Given the current Climate Crisis and the need for the UK to become Net Zero by 2030, this is a significant offering which must not be undervalued.

Arguably the greatest value for money has come from putting Cornwall on the map for the development of geothermal projects. As discussed in Section 5, the project has been surrounded by positive PR (*Figure 10*), so has been incredibly successful in putting geothermal energy at the forefront of people's minds when they think about low-carbon heating. Until now, geothermal has been underutilised in the UK, but having a successful flagship shallow heat project has captured the imagination of many people looking to decarbonise their heat-intensive businesses, with a number turning their heads towards Cornwall as a location for potential growth.

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UK's 'first geothermal lido' opens in Cornwall

28 August 2020

Figure 9. Section of an online BBC article about the opening of the geothermal pool at the end of August 2020. Source: BBC News.

7. Lessons Learnt

The major strength of the project was the project team and how they successfully worked together to deliver a complex project, particularly when it proved to be more difficult than expected due to very short time periods during which the drilling could commence. In addition, the project engaged well with the right beneficiaries, and the stakeholders and beneficiaries are more than satisfied with the quality of activities and delivery of the project. The positive PR surrounding the project has outstripped expectations and the geothermal pool concept has proved to be much more popular than expected, exceeding the original estimates of visitor numbers.

A number of lessons were learned during the drilling phase of the project, particularly related to the logistics of drilling in a town centre in Cornwall.

The logistics of installing the rig at the site were difficult, due to the space requirements and the need to close Battery Road. The fact that the road could only remain closed for short periods of time meant that working time on site was going to be very tight. The first phase of drilling (January to March 2018) encountered a highly permeable rock formation at c. 100m. This section yielded so much water that it was very difficult to adequately contain on site. As time was running short on site before the road had to be reopened for Easter, a decision was made to clean the well out, install a perforated liner and use it as a shallow injection well for water produced from a second deeper well. This was identified as a better solution than the original idea of treating the water from the deeper well and disposing of it into the sewer.

The rig was then removed, the site cleaned up, the road re-opened, and applications made to close the road again after summer 2018. In the Autumn 2018 the rig was brought back, the site set up again 5m from the first well and drilling started, this time with a different drilling method to ensure we got through the problem at 100m. All proceeded well and, at a depth of 400m, casing was installed, and the larger air hammer installed to drill the rest of the well. However, at 410m the rig hit another big water inlet. The water (at circa 30C) was warmer than we would have expected at this depth and, again, was able to sustain very high flow rates into the well (at least five times the amount needed for the pool section). At this point a decision had to be made as to whether to cement the high-permeability zone and drill onwards or to capitalise on the large quantities of warm water that had been found. After assessing the risks, it was decided to be better for all parties to have a functioning system than risk having to abandon the well if no further flow zones were found or the cementing collapsed. At circa 30^{o}C the water source is much warmer than flooded mine-workings (normally 15-17^{o}C) which is seen as another viable geothermal resource in the UK. The only downside to this approach would be the need to boost the well water temperature with either heat pumps or a Combined Heat and Power unit.

The fact that the drilling had to be conducted in two phases increased the cost of drilling significantly as a large proportion of the costs are related to mobilisation and demobilisation, which occurred twice at the site. Therefore, if the change in well design had not been required, the project would have been considerably over budget.

In the future, it would not be advised to drill in a location with such an immovable logistical restriction as, due to the nature of geology, there is always need for adaptability in a drilling program.

8. Conclusion

The project team worked together well, using their individual expertise to deliver a complex project under difficult conditions. Future projects would be advised not to drill in a location with an immovable logistical restriction, such as the limited time for road closures. This unforeseen restriction caused significant delay and changes to the project budget which could be avoided by drilling outside of towns or holiday destinations. Due to the nature of geology, there is always need for adaptability in a drilling program and a clear, comprehensive risk mitigation strategy is shown to be of the upmost importance for such a project.

Despite the challenges faced, the project has **successfully delivered on all its key aims**. It provides a successful demonstration of innovative low-carbon geothermal technology, encouraging widespread discussion of future geothermal heating projects both within Cornwall and across the UK. The pool has seen excellent press across the world, but most crucially delivers carbon savings in excess of those estimated, **saving 507 Tonnes of carbon per year** compared to an equivalent gas project.

Appendix A

Jubilee Pool Geothermal Project Risk Register

Risk	Likelihood	Impact	Risk rating	Control	Significance	Time	Cost	Environmental	Mitigation	Risk Owner	Action Date
Reputational											
Accident during construction	2	5	10	1	10				H&S site management procedures must be in place and followed throughout on-site work. On shore Health and Safety Executive guidelines must be adhered to during drilling.	GEL	Complete at end of installation
Pollution incident	1	5	5	1	5				Analyse water quality within the borehole at the site. Ensure no potential pollutants are used during the trial.	GEL	Complete at end of installation
Funding											
Private funding not achieved for project	1	5	5	1	5				Ensure private funding in place early in project. Private funder must understand there is no commercial return from the project. Private funder must have sufficient resources in balance sheet to provide funds when required.	GEL	Complete
ERDF funding not achieved	3	5	15	3	45				Ensure regular liaison with DCLG. Complete milestones as stated. Ensure project is on schedule and delivers. Manage delivery schedules and budgets.	GEL	Complete at end of project
Consents											
Planning permission not achieved	1	5	5	2	10				Constructive dialogue must be maintained with the Local Authority from the start of the project. Ensure all key Councillors are aware of the project. Supply information on previous similar projects to planning officials in advance. Provide guidance as and when required. Ensure regular meetings with case officer.	GEL	Complete at end of Planning Milestone
EA permission not given	1	5	5	1	5				Maintain good contact with EA. Clearly state procedure. Provide evidence from previous projects. Invite EA staff to site. Involve EA staff in the entire process	GEL	Complete

Financial											
Failure to calculate costs correctly	3	4	12	1	12				Regular cost review (internal and contractors). Regular update of internal spreadsheets. Cost control though contractual management. Do not allow external or internal overspend. Ensure delivery partners adhere to correct overhead rates.	GEL	Complete at end of project
Project costs exceeded	3	5	15	1	15				Regular cost review and comparison with overall budget. Continue to drive costs downwards as contractors will be keen to work on such a high profile project.	GEL	Complete at end of project
Changes to financial programme	3	4	12	1	12				Regular notification of potential changes to DCLG if Milestone dates alter. Regular review of all cost items and delivery times.	GEL	Complete at end of project
Operational											
Equipment not delivered on time	3	5	15	3	45				Order long lead items with sufficient time. Over estimate delivery times. Chase suppliers during delivery period. Purchase items upfront if required to ensure on time delivery. Order from established companies.	GEL	Complete at end of installation and integration
Equipment installation problems	2	4	8	2	16				Ensure highly qualified technical staff on site at all times during fitting of equipment. Daily review of installation procedures and potential for improvement.	GEL	Complete at end of installation and integration
Equipment installation failure	1	5	5	2	10				Order equipment already tested from established manufacturers. Insurance cover must be sufficient in case of total failure	GEL	Complete at end of project
Equipment non-functional	2	4	8	2	16				Equipment must be chosen from established suppliers and correctly specified. Where possible, 'off the shelf' items should be chosen. Ensure staff with sufficient technical expertise on site during system testing.	GEL	Complete at end of project
Integration with existing plant room not successful	2	5	10	2	20				Good knowledge of the plant room must be developed prior to Phase II. Always use experienced M&E personnel	GEL	Complete at end of integration
System does not perform as expected	3	4	12	2	24				Ensure all data properly recorded. Evaluate problems internally and externally as required.	GEL	Complete at end of project
Staffing											
Sufficiently trained staff not available	3	5	15	2	30				Fix dates within programme. Ensure dialogue with any consultants established early on in the project	GEL	Complete
Failure to recruit staff for installation	3	5	15	2	30				Secure funding and Grant offer Letter as per schedule. Ensure dialogue with any consultants established early on in the project	GEL	Complete

Technical									
Electrofusion joint breaks during installation	1	5	5	1	5				Electrofusion jointing is stronger than the pipework material itself provided jointing procedure is correctly followed. All jointing must therefore be undertaken in a clean, dry environment by highly qualified and experienced staff. If there is any doubt about a joint, it must be cut out to ensure structural integrity in the pipe. During installation, the joint should not be over stressed at any point during lifting.
Polypropylene pipe cannot be installed to target depth	2	5	10	2	20				Well must be tested for obstructions prior to installation. PP pipe must be properly weighted at regular intervals to overcome any potential for buoyancy.
Thermistor string damaged	2	2	4	1	4				One member of staff must always be responsible for monitoring the string during installation. String should be tied at regular intervals to PP pipe. String must never exceed maximum bending angle.
Thermistor string comes loose	1	2	2	1	2				String must be regularly and securely tied to PP pipe during installation
Polypropylene pipe slips out of clamp on well head	1	5	5	1	5				Tightening of clamp must always be undertaken by two members of staff (one to tighten, one to observe)
Polypropylene pipe slips out of clamp during lifting	1	2	2	1	2				Tightening of clamp must always be undertaken by two members of staff (one to tighten, one to observe)
Well pump and cable cannot be installed to target depth	3	1	3	1	3				PP pipe must be inspected to ensure no obstructions prior to installation. Riser and cable must be sufficiently taught during installation
Well pump functions for limited period of time	2	5	10	2	20				All data from the pump and the TRT unit should be recorded during installation to locate whether problem is electrical or physical. If the problem is not electrical then the pump should be removed and inspected. It is therefore important that the crane is present on site until the pump has been shown to function
Well pump does not produce at required rate	2	5	10	3	30				Pump must be correctly sized for expected drawdown in well at required flow rate/ bleed flow. Ensure pump is installed at the correct depth in the well. Check that pump is correctly wired for three phase supply (wrong direction will cause reduced flow)
Filtration unit blocked	2	4	8	3	24				Regular inspection of filters. Analyse water first produced from the well.
Differential expansion between PP pipe and thermistor string causes tension in the string	4	3	12	1	12				Ensure that there is sufficient play in the thermistor string at the surface to account for differential expansion
Oxygenation of well water during re-injection	2	2	4	2	8				Water returned to the well will be oxygenated which may cause bio-fouling at the top of the well. This should not affect the abstracted water which is coming from >1800m in the well. Again, regular inspection of the heat exchanger and filters should be undertaken as a precautionary measure

Heat exchanger encounters problems with well water	1	3	3	1	3				The heat exchanger should be manufactured for the expected type of well water. The heat exchanger should be monitored at regular intervals for any alterations in pressure drop.
Communication failure between BMS system control and DGSW	1	2	2	1	2				Ensure only experienced staff manage the integration of the DGSW with the control system
System suffers unexplained failure during testing	2	5	10	3	30				The system may suffer catastrophic failure for a reason not expected or foreseen. To try to prevent this, data from the well must be constantly monitored and any alteration in performance of the heat exchanger, well pump or delivery temperature needs to be reported.