European Union
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EVALUATION OF THE ERDF FUNDED EDEN GEOTHERMAL PROJECT

FINAL Summative Assessment Report from PFA Research Ltd

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Authors:
Katherine Stewart, Researcher | katherine.stewart@pfa-research.com
Robert Rush, Managing Director | robert.rush@pfa-research.com

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Contents

1 Executive Summary 4
1.1 Introduction 4
1.2 Brief methodology statement 4
1.3 Findings 5
2 Background and Context 10
2.1 The Eden Geothermal Project 10
2.2 Project Aims and Objectives 11
2.3 Role of the Evaluation 16
3 Supply Chain Business Feedback 18
3.1 Business Background 18
3.2 Impacts and Benefits of working with Eden Geothermal 19
4 Summative Assessment Findings 23
4.1 Context and relevance 23
4.2 Project delivery and management 26
4.3 Project Progress and Achievements 28
4.4 Outcomes and Impacts 31
4.5 Strategic Impact 43
4.6 Contribution to the Horizontal Principles 45
4.7 Value for Money 48
5 Lessons learned 51
5.1 Technical 51
5.2 Administration 52
5.3 Partnership 53
5.4 Strategic 54
6 Conclusions 55
7 Appendices 57
7.1 Further Comments from Supply Chain Businesses 57

1 Executive Summary

1.1 Introduction

The Eden Geothermal project is funded by ERDF along with Cornwall Council and private investment. The project team have drilled and will test the first 4,500-m well for a deep geothermal energy system to demonstrate greenhouse gas (GHG) savings. It will build on existing research and knowledge of the deep geothermal resource in Cornwall by providing greater understanding of the geology at depth, enabling resources in the region to become characterised as reserves.

The contracted output targets are:

Table 1: Contracted Output Targets

Indicator		Target
C5	New enterprises supported	1
C26	Enterprises cooperating with research entities	4
C29	Enterprise supported to produce a new product (renewable heat)	1
C30	Additional renewable energy capacity	2/3 MW
C34	GHG reductions	900 tonnes

PFA Research, an independent research company, was appointed to undertake an interim and final summative assessment through the collation of data and compilation of the Summative Assessment report.

The objectives of the Summative Assessment are:

- Demonstrate the relevance and consistency, progress, delivery and management, impacts and value for money (including the effectiveness of the programme's design and delivery processes)
- Evaluate progress towards achieving the project's outputs: 1 new enterprise supported, 4 businesses collaborating with the university of Exeter, 1 enterprise producing renewable heat (new product), additional renewable energy capacity (2-3MW), GHG reduction (3089 tonnes, since reduced to 900 tonnes)
- Evaluate progress towards achieving the project's impacts: jobs/employment, additional investment into Cornwall, renewable energy and GHG reductions
- Identify, collate and summarise lessons learned to inform relevant future delivery and best practice for future deep geothermal projects, help to disseminate the findings
- Produce a final report consistent with the Programme Evaluation report summary template

1.2 Brief methodology statement

The research methodology for the final summative assessment comprised:

- Background review and desk analysis

- 7 telephone interviews with the Eden Geothermal delivery team
- 3 telephone interviews with stakeholders
- 9 telephone interviews with University collaborators (students, University staff and businesses)
- 12 telephone interviews with supply chain businesses
- Analysis of data collected and report writing

1.3 Findings

The key findings from the report have been summarised below.

1.3.1 Supply Chain Business Feedback

A survey was conducted amongst companies supplying goods and/or service to the Eden Geothermal project. Telephone interviews were undertaken with 12 out of 18 suppliers. The median contract size for the suppliers was £14,329. For three suppliers the contract value was under £5,000 and 8 suppliers had a contract value between £5,001 and £25,000. Suppliers were involved in a broad spectrum of activities, from marketing/photography, procurement and site safety.

3 businesses have seen an increase of 5% - 14% due to the work with Eden Geothermal and the remaining 9 business have seen an increase of turnover up to 4%. All 12 businesses have seen a benefit to the business as a result of working with Eden Geothermal. Of the 12 businesses 8 have seen an increase in turnover, 7 have seen networking and collaboration opportunities and 3 have experienced improved management skills/capabilities. All 12 businesses would want to work with or supply Eden Geothermal again in the future given the opportunity.

1.3.2 Context and relevance

The Eden Geothermal project is contributing to the following policy and strategy areas:

- Cornwall and Isles of Scilly European Structural and investment Fund Strategy
- Cornwall's Strategic Economic Plan (Vision 2030)
- The Cornwall Local Plan
- Cornwall and Isles of Scilly Local Enterprise Partnership's 2016 'Vision for Geothermal Energy in Cornwall'

The Parliamentary Office of Science and Technology (POST) has published a briefing on geothermal energy, which is designed to make the relevant scientific information and research accessible to the UK Parliament and Eden Geothermal is mentioned in the briefing. It is also understood that a geothermal energy white paper is now being put together. Given this policy background, the context and rationale for the project remain strong.

The delivery team and stakeholders were asked about whether the Eden Geothermal project was still relevant and delivers an important service. The delivery team were all in agreement that it is very important and more relevant than ever. Topics discussed included the current energy crisis, proving the concept of geothermal energy and the 'research' nature of the project.

The interviewees were asked whether anything has changed in the background and context of the project during the delivery of the project. The delivery team gave lots of feedback regarding the Covid pandemic and policy changes such as Brexit. Difficulties with the National Grid, the Renewable Heat Incentive, the negative perception impact from fracking and the transition to green energy were discussed.

1.3.3 Project delivery and management

The delivery team, stakeholders and university collaborators were all asked whether the project was well managed with appropriate governance and management structures in place. Everyone agreed that it was being well-managed but there were a few areas where feedback was given, for example about the small team size. Other topics discussed included the positive atmosphere on site, good financial management, smooth delivery and good communication.

1.3.4 Project progress and achievements

The following table is a spend and output table for the project; showing the targets, performance to date (as of May 2023) and an overall RAG assessment.

Table 2: Performance of Expenditure and Outputs to date

Indicator	Adjusted Target	Performance to date (May 2023)	Performance to date % of target	Forecast performance at end of project	Forecast % at end of project
Capital Expenditure	£13,683,342	£13,281,067	97.1%	£13,683,342	100%
Revenue Expenditure	£2,513,658	£2,430,014	96.7%	£2,513,658	100%
C5 – New enterprises supported	1	1	100%	1	100%
C26 - Enterprises cooperating with research entities	4	4	100%	4	100%
C29 - Enterprise supported to produce a new product (renewable heat)	1	1	100%	1	100%
C30 - Additional renewable energy capacity	2-3 MW	1.4 MW	70% (based on 2MW min)	1.4 MW	70%
C34 – GHG reductions (adjusted)	900 tonnes	1,153 tonnes	128%	1,153 tonnes	128%

Key	
	Less than 85%
	Between 85% and 95%
	Greater than 95%

The capital and revenue expenditure is already 97% spent and therefore is given a green status and it is estimated that it will be 100% spent by the end of the project due to amount of defrayed expenditure.

Four of the outputs have been given green status as they have been achieved: C5 (new enterprises supported), C26 (enterprises cooperating with research entities), C29 (enterprise supported to produce a new product (renewable heat)) and C34 (GHG reductions). The C30 (additional renewable energy capacity) output has been given a red status, as it is 70%

achieved. However, as the output is dependent on the geology of the system, rather than the procurement, design or management of the project, it is considered an acceptable result.

The delivery team and stakeholders were asked about the project's progress and whether the project has achieved what was expected. In general, the feedback was mixed and that progress has been slower than expected e.g.: "*Yes the project has achieved what was expected, but it's been slow and expensive due to Covid, Brexit and the Ukraine war*".

One person was positive about getting data for geology (how hot the fault was and can we use the fault systems to be able to bring that heat back to surface through the permeability in the rock). Another person felt that not being in a position to drill a second well means that the project has not achieved everything it set out to do.

One of the stakeholders was very positive about the successes of the project: "*It's been a fantastic success, the knowledge and experience gained from just drilling to that depth and understanding how that is carried out operationally, how it's done, how it's funded, the costs around it, all of that has been amazing learning. The next step for that team really at Eden is to apply that learning and that knowledge to other geothermal projects across the UK*."

1.3.5 Outcomes and Impacts

The following table summarises the outcomes and impacts from the logic chain and comments on the progress towards achieving them.

Table 3: Achievement of outcomes and impacts

	Indicator	Comment
Outcomes	New enterprise viable	Some evidence from the delivery team interviews to suggest that the enterprise will be viable beyond the end of the ERDF project
	Demonstration of university research, collaboration and knowledge exchange	Achieved – good collaboration between Eden Geothermal, the University of Exeter and the businesses assisted – see Section 4.4.2 for further details
	New products/ services	One product achieved (geothermal energy)
	Development of new skills for low carbon economy	3 of the supply chain businesses have experienced improved management skills/capabilities (see Figure 3-5), which indicates a positive direction of travel
	Jobs Created	Too early to assess
	Improved Productivity and Gross increase in GVA	8 of the supply chain businesses have seen an increase in turnover (see Figure 3-5), which indicates a possible increase in GVA in the future
Impacts	Net jobs	Too early to assess
	Increased growth capability of businesses/ potential net additional GVA	Too early to assess
	Additional investment into Cornwall	Too early to assess
	Additional baseload renewable energy capacity	Progress is being made, the testing has demonstrated that the power output is 1.4MW (see section 4.3), which will

		help contribute to the baseload capacity.
	Net reduction in GHG	Progress is being made, the testing has demonstrated that GHG savings of 1,153 tonnes per annum could be achieved (see section 4.3). This needs to be off-set against the build/drilling phase and a more detailed assessment would be needed. It is likely that a net reduction will be achieved in the future.

There is evidence to suggest that progress is being made towards some outcomes and impacts but it is too early to determine for some others (e.g. net jobs, additional investment into Cornwall). However, the Eden Project has reported that: "*as a result of the Eden Geothermal project, we have invested over £2m in 0.7Ha of commercial greenhouses and new offices, to be supplied using the renewable heat from the project.*"

The delivery team were asked about progress in achieving the outcomes and impacts of the project and they were broadly positive. Topics discussed included the greenhouse gas savings, the impact on the local economy and broader economic impacts. When asked whether the interviewees thought that the Eden Geothermal enterprise will still be viable at the end of the project, there were mixed responses to this. One team member pointed out that Eden Geothermal may need to remain active for a while to run the coaxial system and it may be kept running to do different things like consultancy. Another person thought it would be viable but might struggle without public funding and someone else stated that Eden Geothermal would be viable if there was a plan to drill a second well.

The university collaborators were asked about progress towards achieving the objectives of their research projects and they talked about learning to use software and research timescales. When asked about how the involvement in the research project helped to develop the collaborating business, one of the students stated that they are proud to be part of this collaboration, networking was felt to be important and the university involvement has added value to the Eden Geothermal project overall. When asked about the value in collaborating on this project with Eden Geothermal, one of the students talked about the value of being there and experiencing it on the ground and another person talked about developing the geothermal industry in Cornwall.

1.3.6 Strategic Added Value

The delivery team and stakeholders were asked in what ways the project has created Strategic Added Value. The areas highlighted included research collaboration, knowledge exchange, influencing policy, the importance of the Eden brand and networking. The stakeholders were also asked how the project has contributed to wider investment in geothermal technology and one person felt that it was still early but that geothermal energy will become an important part of the economy. Another stakeholder felt that the contribution was in research dissemination rather than stimulating investment.

The delivery team and stakeholders were asked about the contribution that the project has made to the Horizontal Principles. There were lots of examples of equality and diversity e.g.: "*We've got lots of women working for us and we've probably got quite a lot of neuro diverse people working for us of one sort or another*". Environmental sustainability was thought to be at the heart of the project with the transition to the low carbon economy.

The delivery team, stakeholders and university collaborators were asked about the legacy of the project and one person felt that it was the legacy was the benefit to the Eden Project being off gas. Other areas discussed included raising awareness of geothermal energy, the importance of the geothermal industry in Cornwall, trust from the public and the success of the well for geothermal heat.

1.3.7 Value for Money

The delivery team and stakeholders were asked whether the Eden Geothermal project has provided good value for money to date and there were mixed responses but people thought that it was important to remember that it is a research project. One person felt that it had as it is an important project at the start of the geothermal industry in the UK and that it is a success story for science and engineering. Another team member felt that the funding restrictions meant that the project did not proceed in the most cost effective way. In terms of comparisons one team member talked about the United Downs Deep Geothermal project.

The stakeholders found the value for money question difficult to answer, for example: "*I think that's an unanswerable question. I mean it has to be doesn't it, even if it's expensive to do, it will generate heat that's cheaper than electricity*."

1.3.8 Lessons Learned

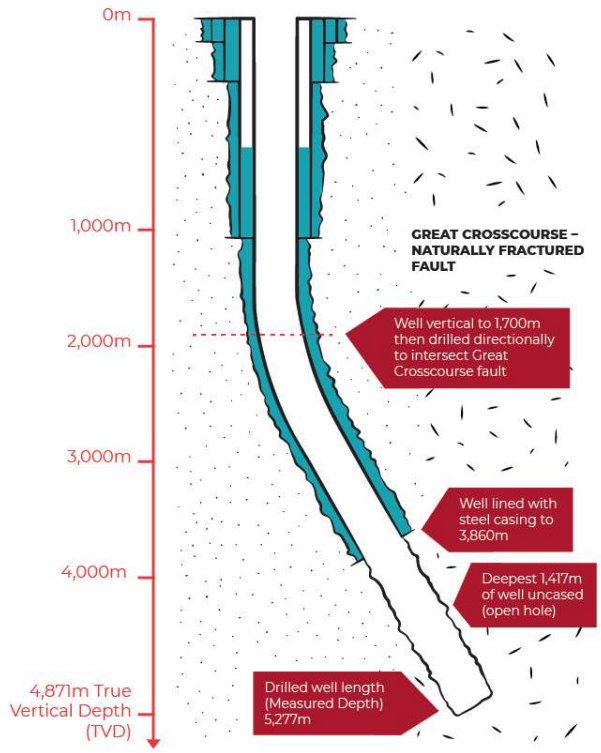
Lessons learned were collected from the Eden Geothermal team interviews, the stakeholder interviews and the research collaborators and are presented in the report under various themes: technical, administration, partnership and strategic.

2 Background and Context

2.1 The Eden Geothermal Project

The Eden Geothermal project is funded by ERDF along with Cornwall Council and private investment. The project team have drilled tested the first 4,500-m well for a deep geothermal energy system at the Eden Project; the well intersects a steeply inclined NW – SE striking target fault structure (named The Great Crosscourse) within the St Austell Granite. The following diagram[1] shows the deep geothermal well:

Figure 2-1 – The Eden Well (EG1)



The project aims to demonstrate greenhouse gas (GHG) savings to assess the viability of proceeding to a commercial geothermal heat and power plant at the Eden Project, thereby de-risking the private-sector investment required for the ensuing stages of construction. The project builds on existing research and knowledge of the deep geothermal resource in Cornwall by providing greater understanding of the geology at depth (via investigation of the hydrogeological conditions), enabling resources in the region to become characterised as reserves.

Eden Geothermal Ltd is the SME special purpose vehicle which has been set up specifically to deliver this project, and is the main beneficiary. The University of Exeter is the Research Delivery Partner, and is running four postgraduate studentships in collaboration with businesses; these four businesses will be further beneficiaries.

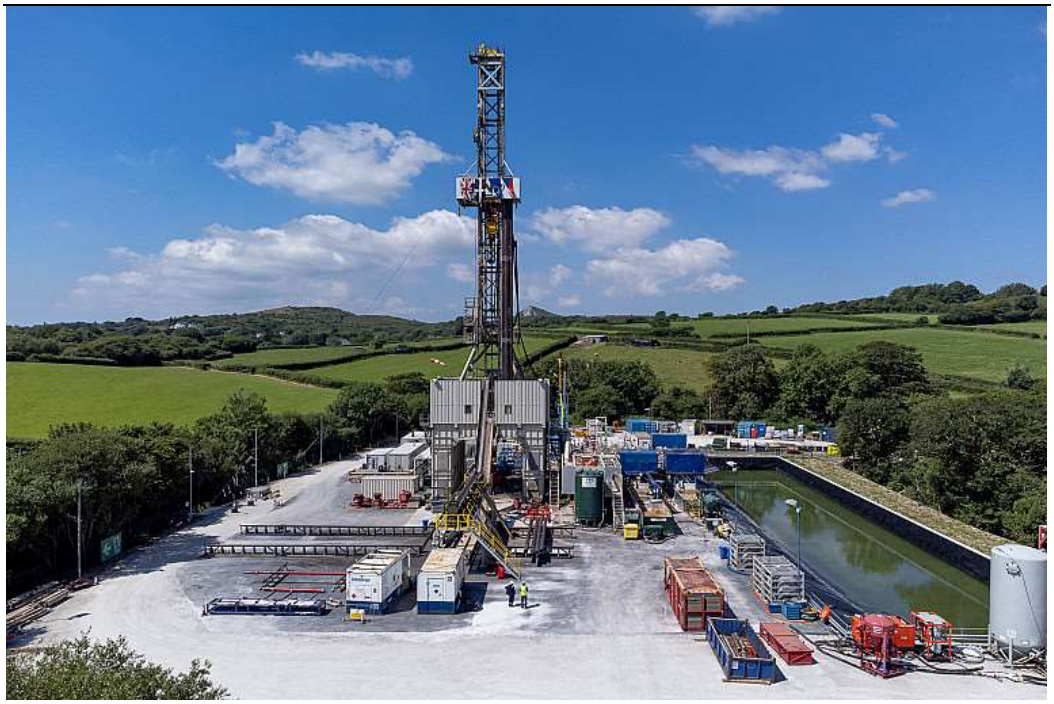
[1] https://www.edengeothermal.com/wp-content/uploads/2021/11/eg-wellbore-diagram-03.png

By addressing the factors which have previously deterred private sector investment (uncertainties about geological /geothermal conditions alongside high capital costs) this research and demonstration will de-risk the private-sector investment required for the second-phase of the geothermal plant at Eden, comprising a further 4,500m well and a combined heat and power plant (CHP). The project results will also provide additional stimulus for investment in deep geothermal elsewhere in Cornwall.

The stages of the project are:

- Preparations: recruitment; procurement for main contractors; finalise design
- Site enabling works
- Drill and complete the first well (see Figure 2 – drilling equipment)
- Well testing and evaluation of target hydrogeology
- Interim reporting and dissemination
- Deploy single-well heat system and heat main to Eden and measure outputs
- Final reporting and dissemination

Figure 2-2: Geothermal drilling equipment[2]



2.2 Project Aims and Objectives

The Eden Geothermal project fits under the ERDF Priority Axis PA4, set up to support these ERDF investment priorities:

- *Investment Priority 4a* – Promoting the production and distribution of energy derived from renewable resources

[2] https://carboncopy.eco/initiatives/geothermal-eden

- *Investment Priority 4f* – Promoting research and innovation in, and adoption of, low-carbon technologies

The specific contracted outputs for the project are as follows:

Table 4: Contracted Output Targets

Indicator		Target
C5	New enterprises supported	1
C26	Enterprises cooperating with research entities	4
C29	Enterprise supported to produce a new product (renewable heat)	1
C30	Additional renewable energy capacity	2/3 MW
C34	GHG reductions (adjusted output, see below)	900 tonnes

Four Project Change Requests have been submitted:

- **PCR1** in July 2020 requested an extension to the project, changes to the expenditure profiles and changes to the outputs (Covid has had a severe financial effect on the Eden Project's ability to make the financial investment required for the planned development of new greenhouses within the timescales required for the project, resulting in the GHG Savings output achievable by the project in its heat production phase reducing by 70% from 3089 tonnes to 900 tonnes)
- **PCR2** in March 2021 requested additional ERDF funding and changes to the eligible expenditure and expenditure profile.
- **PCR3** in April 2022 requested additional ERDF funding and changes to the eligible expenditure and expenditure profile.
- **PCR4** in February 2023 requested additional ERDF funding. Due to delays from Covid and Brexit, the plan to allow for three months of heat production from the well to demonstrate GHG savings is not viable within the ERDF timescales. Therefore, an extension until the end of May for practical delivery and the end of June for financial completion was requested. The GHG/heat outputs will be calculated as an extrapolation of figures when the system is started up, using the following methodology.

2.2.1 Methodology for calculating the GHG and heat outputs

During May 2023 the Eden Geothermal team carried out testing on the coaxial system to demonstrate the heat that can be delivered from the single deep geothermal well (EG-1) at the Eden Project and to translate this into the greenhouse gas savings, so that the C30 and C34 outputs can be reported.

The electric submersible pump recently installed in the well was used to extract hot water at an optimal flow rate from the well at a depth of 3,800 m via open-ended vacuum insulated tubing (VIT).

This demonstration was unable to be carried out directly to the Eden Project energy centre and greenhouses because the Eden Project mechanical and electrical plant installation is not yet complete, so an alternative demonstration was devised. This water was produced into a 3,000 m^3 storage lagoon via a steam separator. Cold fresh water from the mains was injected into the annulus of the well at the same flow rate to maintain the system in equilibrium. The

flow rate was adjusted, dependent on the drawdown within the well, to optimise heat recovery versus cooling in the return circuit.

The demonstration was run for a period of approximately 24 hours to provide an output that was extrapolated with time. The limiting factors on the demonstration were the storage capacity of the lagoon, and cost.

Figure 2-3: Set up of the coaxial system and electrical submersible pump

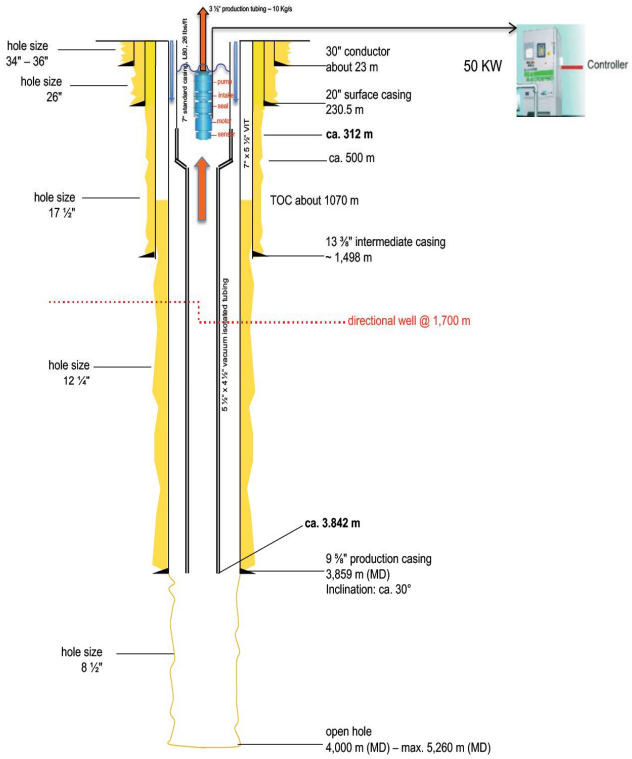


Figure 2-4: The set up for testing and steam being produced from the lagoon

C34 Greenhouse Gas Savings

The savings were calculated using the following assumptions:

- Geothermal heat output: 1400kW, prudently taking the lower end of the output range in the testing, see C30 below
- Capacity Factor: 95% (Source: BESTEC GmbH, including 14 day down time/year for maintenance)
- Load variation: 45% (Source: variation and seasonality of Eden Project and greenhouse heat loads taken from historic demand curves. This figure can be improved in operation by addition of other heat users, such as a distillery, to flatten the curves.)
- Natural gas gross calorific value, taken from 2022 UK Government conversion factors: 0.18 kgCO2e/kWh

The GHG savings were calculated based on the thermal output using UK Government 2022 conversion factors for GHG reporting, by comparing the GHG savings from geothermal heat with those from the natural gas that is otherwise used by the Eden Project and the projected use of the new 0.7 Ha greenhouse array. Electrical power used by the project is certified renewable, so not relevant for the calculation. The coefficient of performance (COP) is around 30, representing a 10x improvement in efficiency over a standard heat pump.

C30 Additional Capacity of Renewable Energy Production

The output was evaluated using the following equation:

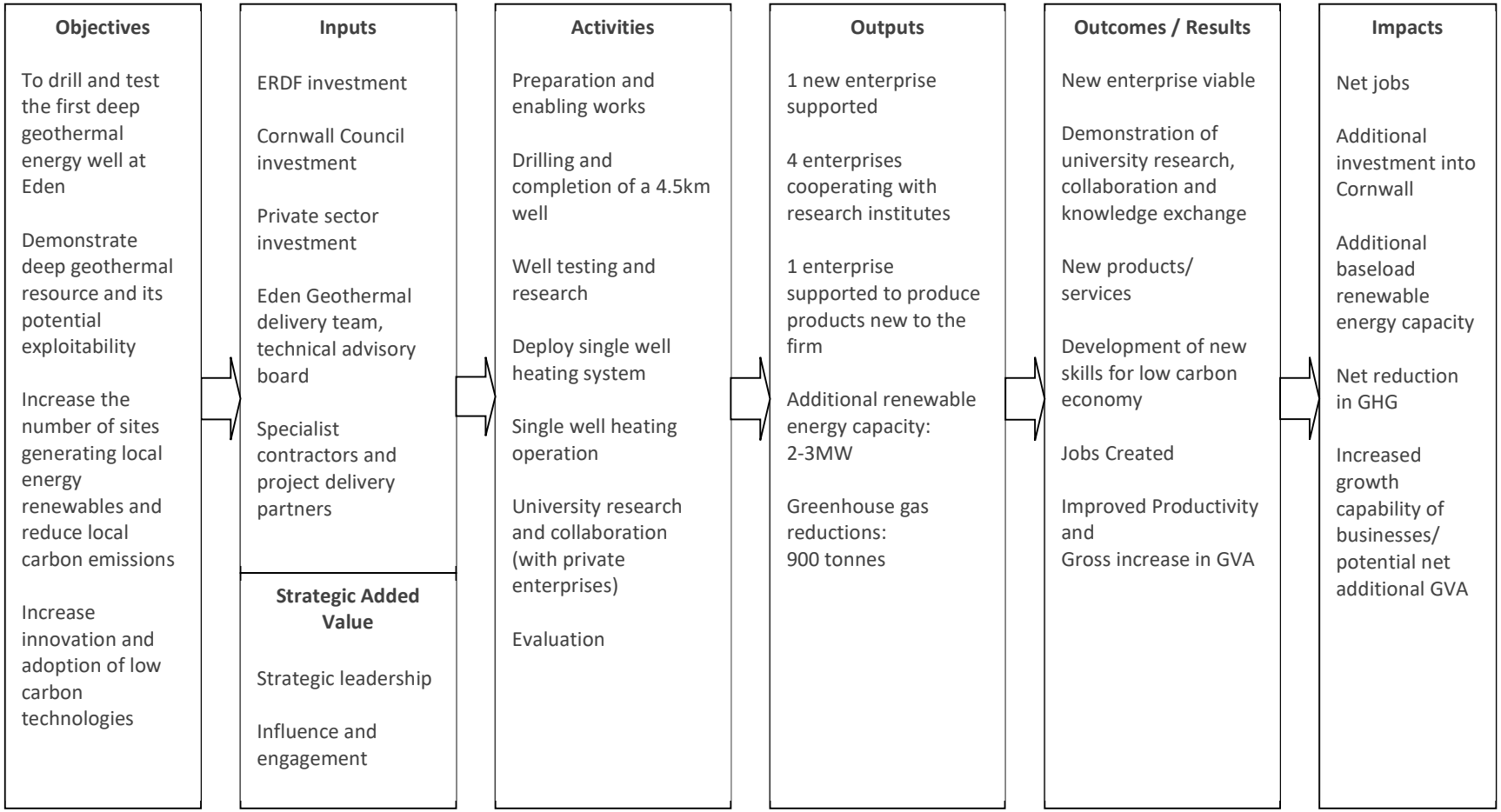
- Thermal output (MWth) = mass flow rate (kg/s) x temperature difference (°C) x specific heat capacity of water (KJ/kg°C)

The following parameters were recorded and used within the above calculation to provide the output:

- The production temperature (°C)
- The injection temperature (°C)
- The production (injection) flow (kg/s)

2.2.2 Logic Chain

The following diagram shows the updated logic chain for use during the summative assessment.


Objectives
To drill and test the first deep geothermal energy well at Eden
Demonstrate deep geothermal resource and its potential exploitability
Increase the number of sites generating local energy renewables and reduce local carbon emissions
Increase innovation and adoption of low carbon technologies
Inputs
ERDF investment
Cornwall Council investment
Private sector investment
Eden Geothermal delivery team, technical advisory board
Specialist contractors and project delivery partners
Strategic Added Value
Strategic leadership
Influence and engagement
Activities
Preparation and enabling works
Drilling and completion of a 4.5km well
Well testing and research
Deploy single well heating system
Single well heating operation
University research and collaboration (with private enterprises)
Evaluation
Outputs
1 new enterprise supported
4 enterprises cooperating with research institutes
1 enterprise supported to produce products new to the firm
Additional renewable energy capacity: 2-3MW
Greenhouse gas reductions: 900 tonnes
Outcomes / Results
New enterprise viable
Demonstration of university research, collaboration and knowledge exchange
New products/ services
Development of new skills for low carbon economy
Jobs Created
Improved Productivity and Gross increase in GVA
Impacts
Net jobs
Additional investment into Cornwall
Additional baseload renewable energy capacity
Net reduction in GHG
Increased growth capability of businesses/ potential net additional GVA

2.3 Role of the Evaluation

PFA Research, an independent research company, was appointed to undertake an interim and final summative assessment through the collation of data and compilation of the Summative Assessment report.

The objectives of the final Summative Assessment are:

- Demonstrate the relevance and consistency, progress, delivery and management, impacts and value for money (including the effectiveness of the programme's design and delivery processes)
- Evaluate progress towards achieving the project's outputs: 1 new enterprise supported, 4 businesses collaborating with the university of Exeter, 1 enterprise producing renewable heat (new product), additional renewable energy capacity (2-3MW), GHG reduction (900 tonnes)
- Evaluate progress towards achieving the project's impacts: jobs/employment, additional investment into Cornwall, renewable energy and GHG reductions
- Identify, collate and summarise lessons learned to inform relevant future delivery and best practice for future deep geothermal projects, help to dissemination the findings
- Produce a final report consistent with the Programme Evaluation report summary template

2.3.1 Evaluation Methodology

The research methodology was made up of the following elements:

- Background review and desk analysis
- Primary data collection – interviews with the Eden Geothermal delivery team, stakeholders, University collaborators and supply chain businesses
- Analysis of data collected and report writing

Review of key documentation

This has included a review of the ERDF project application form, claim forms and progress reports, project change requests and the End of Well report (EOWR).

Primary Research: Delivery Team

We have undertaken 7 telephone interviews with team members from Eden Geothermal. The interviews were undertaken in February 2023 and no specific quotes have been attributed to interviewees as some of them wished to remain anonymous. The survey collected qualitative data in these areas:

- Feedback on programme delivery and management
- Progress made and achievements (including progress towards outputs and impacts)
- Strategic Added Value
- Value for money
- Lessons learned

Primary Research: Stakeholders

We have spoken to 3 stakeholders in order to get a picture of the strategic aspects of the programme, as well as feedback on progress, delivery, management and lessons learned. The interviews were undertaken in February 2023 and no specific quotes have been attributed to interviewees as some of them wished to remain anonymous.

Primary Research: University Collaborators

9 people were interviewed as part of the University Collaborators survey and these interviews were undertaken in February 2023 and no specific quotes have been attributed to interviewees as some of them wished to remain anonymous. The interviewees were either university students, university staff or representatives from a collaborating business. The survey covered the following topics:

- Feedback on programme delivery and management
- Progress made and achievements (including progress towards outputs and impacts)
- Impact and value of the research
- Lessons learned

Primary Research: Supply Chain Businesses

12 out of 18 businesses supplying goods and/or service to the Eden Geothermal project were interviewed by telephone. The topics covered included:

- Business background and contract values
- Benefits of working on the Eden Geothermal project

3 Supply Chain Business Feedback

The results from a survey conducted amongst companies supplying goods and/or service to the Eden Geothermal project are presented in this chapter. Telephone interviews were undertaken with 12 out of 18 suppliers.

3.1 Business Background

Companies being part of the supplier pool included, amongst others (see Table 3-1):

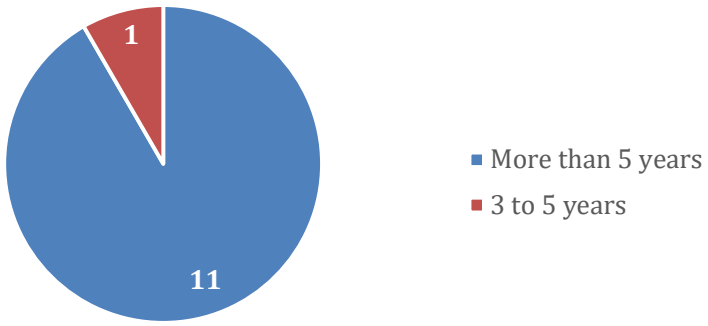
- Consultancies (2)
- Electrical contractors (2)
- Companies involved in groundwork (2)
- Business services such as motion graphic capture and photography (2)

Table 3-1
Q: Please would you give me a brief description of your business?
Base: All respondents; n=12

Industry sector	Number of companies
Consultancy – Project management	1
Consultancy – Engineering and environmental services	1
Electrical contractors	2
Energy company	1
Graphic design and illustration print	1
Groundwork – down clearance, digger work, bore hole	2
Motion graphics, photography, videography and editing	2
Retailer – PPE work wear	1
Surveyor	1

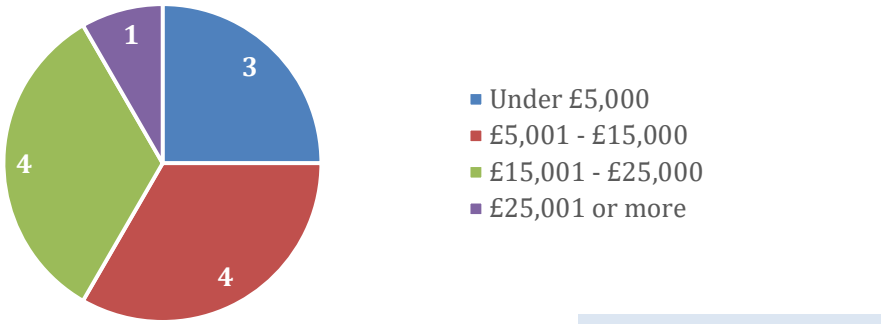
The majority (11 of 12) of the participating businesses have been trading for more than 5 years (see Figure **3-1**).

Figure 3-1
Q. How long has the business been trading?
Base: All respondents; n=12



The median contract size for the suppliers was £14,329. For three suppliers the contract value was under £5,000 and 8 suppliers had a contract value between £5,001 and £25,000 (see Figure 3-2).

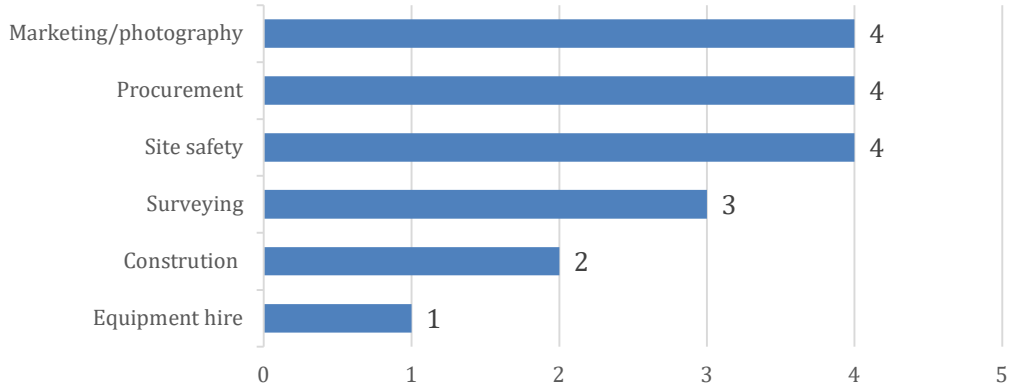
Figure 3-2
Contract value
Base: All respondents; n=12



Median value: £14,329

Suppliers were involved in a broad spectrum of activities, from marketing/photography (4), procurement (4), site safety (4) (see Figure 3-3).

Figure 3-3
Q. How were you involved with the Eden Geothermal project?
Base: All respondents; n=12



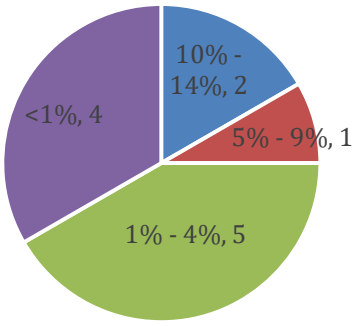
3.2 Impacts and Benefits of working with Eden Geothermal

3 businesses have seen an increase of 5% - 14% due to the work with Eden Geothermal (see Figure 3-4). The remaining 9 business have seen an increase of turnover up to 4%.

Figure 3-4

Q. In terms of value to your trading year, how significant was the business received from Eden Geothermal in terms of, say, % of your annual turnover?

Base: All respondents; n=12



All 12 businesses have seen a benefit to the business as a result of working with Eden Geothermal. Of the 12 businesses 8 have seen an increase in turnover, 7 have seen networking and collaboration opportunities and 3 have experienced improved management skills/capabilities (see Figure 3-5). Likewise, 7 businesses would expect an increase in turnover if involved with Eden Geothermal in the future (e.g. construction of a second well) and 7 would expect future benefits to be networking/collaboration (see Figure 3-6). Businesses were also asked to explain and quantify any benefits from working with Eden Geothermal (see Table **3-2**).

Figure 3-5

Q. Have there been any benefits to your business by working with Eden Geothermal?

Base: All respondents; n=12

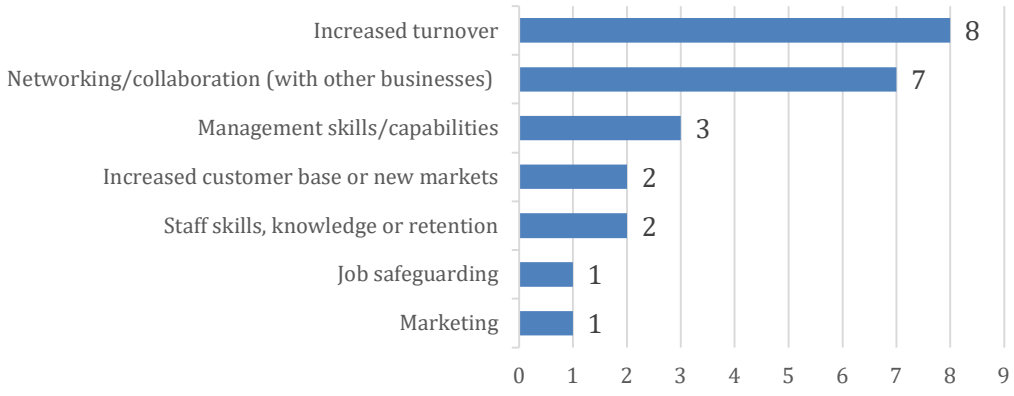


Figure 3-6

Q. If you were involved with Eden Geothermal in the future (e.g. construction of the second well), would you expect any future benefits?

Base: All respondents; n=12

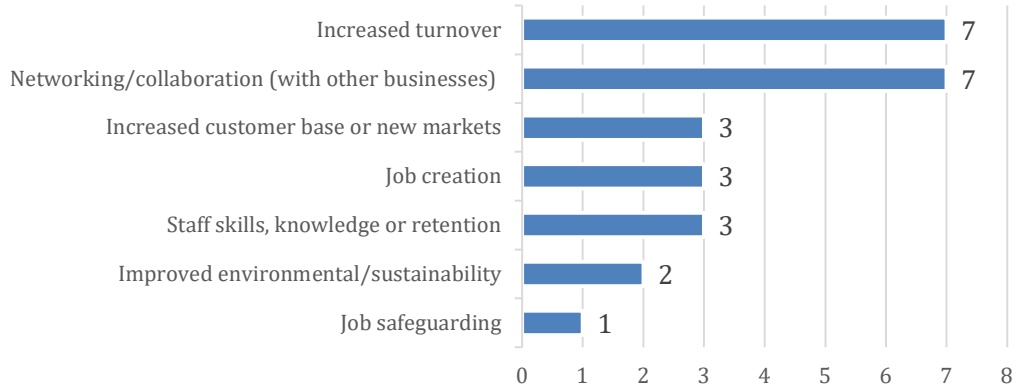


Table 3-2

Q: Can you quantify any of the benefits mentioned in Q4 or Q5 (e.g. employed 1 FTE for 6 months to deliver the contract)?

Base: All respondents; n=12

Benefits quantified
We have recently taken on a graduate trainee and Eden Geothermal have contributed to the fact that we take these people on as part of our ongoing work and skill set. We are a BCorp and [the] environmental sustainable accreditation and the networking with Eden helps us along those ways.
Produced increase cash flow, which has helped to invest in new equipment.
Like to work locally, was experience for my staff to work on these sorts of jobs and interesting, good to put on CV, it is a very different type of working environment.
I think the Geothermal first started in 2021 and they would have spent money and worked hard and this helped us coming out of Covid as it did give us a slight increase in turnover.
It helped to keep staff employed even being a small segment of it, we are a reasonably small company and when Midas went down it was a major loss to us as we worked with them a lot, so every job helps.
We have got more examples of work from the work we did with them that we can show potential clients and we can showcase the work we did with them.
The project [was] very new to us, as we only did this in September, so to quantify it is hard, we are doing similar work in America and working with Eden Geothermal project did help us with our portfolio.
The only one I can really quantify is the increased turnover of about 10%.
Working with safety briefs and conducting business in a different working environment has been useful for me, saying candidly that Eden Geothermal in the future maybe potentially an opportunity for longer contract at networking always opens doors not just internally but other doors as well.
In terms of what we have delivered to date it probably allowed us to employ 1 person for 6 months that we probably wouldn't have done before.

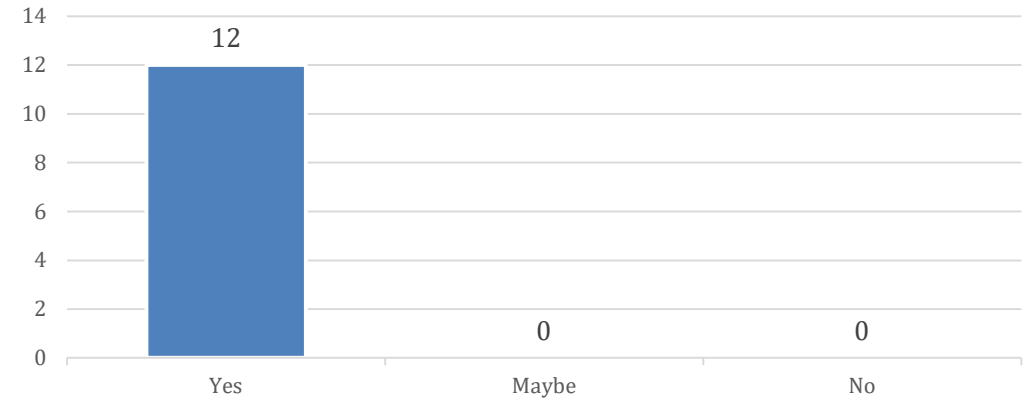
Networking it has opened up different contractors to talk to with regard to other jobs, in regards to safeguarding employees it is something we are always look to improve and work on and make sure we have work for our employees, we have had conversations with other contractors during and after we had finished the Eden Geothermal.
Not really just it was beneficial.

All 12 businesses would want to work with or supply Eden Geothermal again in the future given the opportunity (see Figure 3-7).

Figure 3-7

Q. Would you want to work with or supply Eden Geothermal again in the future, if there was an opportunity to do so?

Base: All respondents; n=12



"Happy to consider."

"Very much so."

"Hope so, definitely."

Further comments from the supply chain businesses regarding their business relationship with Eden Geothermal can be found in the Appendix (see Table **7**-**1**).

4 Summative Assessment Findings

The final summative assessment findings incorporate the background document review, feedback from the delivery team, feedback from stakeholders, feedback from university representatives and the supply chain business survey. The findings are set out to cover the key areas required by ERDF when undertaking a summative assessment.

4.1 Context and relevance

Having reviewed the original project ERDF application form and more recently analysed published policy documents, it is felt that the Eden Geothermal project is contributing to the following policy and strategy areas:

- Cornwall and Isles of Scilly European Structural and investment Fund Strategy, under the strategic priority 'Future Economy'
- Cornwall's Strategic Economic Plan (Vision 2030) with renewable energy being part of a priority sector cluster
- The Cornwall Local Plan: Supporting the provision of low carbon heat via a heat network with consideration given to sourcing that heat from geothermal resources
- Cornwall and Isles of Scilly Local Enterprise Partnership's 2016 'Vision for Geothermal Energy in Cornwall', where by 2040 Cornwall will have exploited its deep geothermal resource whilst taking full advantage of the opportunities and benefits for Cornwall', being the first step in development of the industry in the area

At the point of the interim summative assessment, it was noted that there was no mention of geothermal energy in the Government's latest Energy White paper (Powering our net zero future[3]), and therefore it is very important and relevant for Eden Geothermal to be demonstrating this technology.

Since then, the Parliamentary Office of Science and Technology (POST) has published a briefing on geothermal energy, which is designed to make the relevant scientific information and research accessible to the UK Parliament. Both the United Downs and Eden Geothermal projects are mentioned in the briefing[4]. It is also understood that a geothermal energy white paper is now being put together. Given this policy background, the context and rationale for the project remain strong.

Do you think that the Eden Geothermal project is still relevant and delivers an important service?

In order to assess the context and relevance of the project, the delivery team were asked about whether the Eden Geothermal project was still relevant and delivers an important service. The delivery team were all in agreement that it is very important and more relevant than ever, for example: "*It's incredibly relevant given the climate emergency. It's more relevant than it was 10 years ago when they first started talking about it*!"

[3] https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future
[4] https://researchbriefings.files.parliament.uk/documents/POST-PB-0046/POST-PB-0046.pdf

Another person picked up on the **energy crisis with regards to Ukraine**: "*I think it is important to demonstrate the transition to net zero and that renewables are better. The war in Ukraine has made it even clearer that renewables from the rock beneath your feet are an extremely good idea*."

Another team member talked about the importance of the project in terms of **proving the concept of geothermal energy**: "*What they're trying to do at Eden is prove concept and prove resource. I certainly think we've proven resource but I wouldn't say 100% that we've proven concept. How renewable heating and renewable power generation, stack up against other renewable sources. I wouldn't say that we've proven the concept completely so we can compete so we're very much still in the research stage and in that regard 100% it's still relevant, there's work to be done. We obviously know a lot more now about the Cornish granite and how we can use the heat from those granites to generate renewable power or heat. In that regard, it's been a success but as to making sure that concept can compete, I would say there's work to be done*."

In addition, a delivery team person discussed the **research nature of the project and why it is important to continue the research**: "*It's essential that we push on and get the second well and take the project through to a conclusion of the power generation system. The main problem is with permeability and we don't fully understand why it isn't working as well as we'd expected it to work. We think it's geological issues, but it's very difficult as you're trying to work out what's happening at a depth of four and a half to five kilometres, yet you can't see easily. You can only go by responses you get to certain sort of surface parameters like injection rates, or humping extraction rates or seismicity. We've got to understand why it's not performing and see what we can do to make it improve. I think these types of developments are not easy to solve in the short term, there has to be a long-term view on it*."

The stakeholders were also asked about the importance and relevance of Eden Geothermal and they gave similar responses e.g. "*I think it's more relevant now than it ever has been, post the energy crisis, it's very important*."

Another stakeholder commented that **it is important but it won't generate as much electricity as initially hoped**: "*It won't generate electricity for the local population, but it will be generating electricity to run Eden and they are just in the process of putting in a big greenhouse at Eden and it will provide the power for that*".

Has anything changed in terms of the background and context during the delivery of the project?

In order to fully understand the background to the project and to accurately assess project progress and achievements, it is important to consider whether there have been changes in context during the delivery of the project. The delivery team gave lots of feedback regarding the Covid pandemic and policy changes such as Brexit. One person talked about the **impact of Brexit**: "*Brexit is still causing trouble because of supply chain difficulties, for example trying to get things through customs, which also costs because we have to pay customs agents*".

Another person talked about **Brexit and the difficulties with getting personnel**: "*A lot of the people working with us, either came down from Aberdeen or from mainland Europe. Cornwall isn't an oil and gas region where a lot of the skill sets are shared, and it's not yet a mature geothermal region though hopefully it will be. The expertise has to come from further*

afield and trying to get equipment and crew in from mainland Europe was a bit of a nightmare. Brexit was definitely detrimental in that because it just took so much more in the way of logistics and getting letters for people."

A delivery team member talked about the **difficulties with the National Grid**: "*If we were going to have two wells, the idea was that we will be generating electricity, or heat and electricity. We haven't really got many heat customers close by so if we were producing a lot more heat, a lot of it would it be converted into electricity. For us to convert that to electricity, we need to have either a customer who will take it all, or, be connected to the National Grid. To do that, we applied for a connection date and it is not until 2036! We're a little project compared to some of the other projects coming on board in the near future with things like offshore wind. Some of those things will be generating huge amounts of power but how do they connect to the grid? It is absolute incompetence that we are in a situation where we've got a national crisis in terms of energy and the people that actually transport the energy around the country are just not geared up to do anything*".

Another person talked about the **Renewable Heat Incentive**: "*There was a Renewable Heat Incentive and then the Government let it lapse and forgot it. This was an incentive for people to create heat projects, ideal for people doing geothermal. There's talk that they may bring something back but, in the meantime, three years have passed and people need long term provision to provide investment in long term projects. Actually, you not only need to know that there is Renewable Heat Incentive, but you need to know it's around for a good few years. Once geothermal is more established it; it is not such a bad thing to let it drop away, but you need to get the industry established and that kind of incentive would have been a big help*".

Another team member talked about the **negative impact around fracking and how the public perceive the project**: "*I think Rees-Mogg, in Liz Truss's micro premiership, in trying to unleash fracking again has just made it worse. The narrative now is that it's deeply ingrained within party politics now. I thought the way that Eden handled the events that they did trigger was really good. The media tried to go in and point the finger and make all sorts of assertions but the team very quietly and confidently said, 'Yes, we did cause those but look how small they are."*

One person discussed the **improving policy context**: "*We're bringing out a white paper this quarter, we believe that there will be some legislation that recognises that geothermal energy is a thing. So things seem to be finally shifting but it has taken an awful lot of effort, and it would be a lot better if it happened quickly*".

The stakeholders were also asked about changes in the background and context of the project and the Covid pandemic was mentioned as a key issue, due to it being a period of uncertainty. One stakeholder felt that the **approach taken by the delivery team was important in managing change**: "*I think the project was well thought out and people were informed locally. Openness was the key, there were no surprises, everyone knew what was going on and that's the key to getting people on-side*."

The university collaborators were also asked about changes in the background and context of the project and the **uncertainty of Covid was mentioned**: "*We started two years ago in January, the middle of a lockdown, and we spent the first three months just doing background reading, we weren't entirely sure where it was going to go*."

Another person agreed about the **difficulties of Covid**: "*We didn't choose exactly the easiest time to perform such a project! We went immediately into the Covid pandemic, we had all kinds of organisational difficulties to overcome to maintain the operation and keep it going".*

One person felt that the **cost of living and energy crisis** is a really big change during the project: "*The context that has affected the project is the cost of living crisis and heating crisis. I think when we first came into the project, they were really hoping to get electricity and power generation because the temperatures are there for power generation. When we went to the geothermal symposium, they were talking about whether we (the UK as a whole) need to focus away from power generation and more into district heating. You can get more, it's easier to do that, you can get more out of it for district heating, and it would reduce people's electricity bills down, especially in the winter because people use a lot of electricity to heat their homes. That has changed since I've been on the project. It's moved more away from power generation and more into district heating and warm banks.*"

Another person agreed with the **energy crisis changes**: "*I think the war in Ukraine has focused people's attention in terms of fuel crisis and the vulnerability that we have to reliance on gas and particularly the impact on market price. No one can accommodate a 300% rise in their energy bills in terms of business. As a consequence, oil and gas companies are starting to get interested in geothermal. The oil industry is trying to make its own transition for its own survival so more progressive companies are starting to invest quite widely in research and development in solar and even in deep geothermal. They know the direction of travel but the direction of travel might be a little bit jumpy along the way. Deep geothermal is expensive and it would be good to know ways that we can optimise the way that things are done".*

Another person echoed this by discussing **energy transition to green energy**: "*There has been a recognition that countries need to move faster in implementing green technology. During Covid there was a recognition from the oil and gas industry that it should move towards green technology as well. There's now this massive interest in geothermal energy around the world because a lot of skills that the oil industry uses are closely related to geothermal; they're not exactly the same but very closely related and what I've seen over the last couple of years is there's been a huge number of conferences and articles talking about energy transition and when they talk about energy transition, what they really mean is a transition from oil and gas to geothermal energy and sub surface carbon capture and storage. This is a really big thing in the industry now*."

4.2 Project delivery and management

Is the project being well managed with appropriate governance and management structures in place?

The delivery team, stakeholders and university collaborators were all asked whether the project was well managed with appropriate governance and management structures in place. Everyone agreed that it was being well-managed but there were a few areas where feedback was given, for example about the **team size**: "*Probably we were too small team, we probably needed a couple more people, we probably could have done things a little bit better with a slightly bigger team. For a team of less than ten I think it's been a big old operation*".

Another person agreed about the **team size**: "*The team was probably too small at times to cope with everything that was going off but with the people we've got, we managed it well. If the team was double in size it would have been easier, things could have been reacted on a little bit quicker. Also, we probably didn't have some of the experts that we needed on site early enough as well, the drilling managers that we had, they were experts in the field and I think they could have had a decent input into things. We could have been more proactive instead of being reactive and doing it later, we could have planned it better and potentially saved a bit of money*."

One person talked about the **positive atmosphere at the site**: "*One thing we did really well, especially during the drilling was the fantastic environment on the rig. We managed the contractors and everybody from our side…It was a lovely place to work. Having been on many rigs beforehand, the atmosphere and the working environment was brilliant. I wasn't the only one that said that, I worked for Eden and I enjoyed it but it was the people who came to us and said 'this is one of the loveliest wells we've ever drilled' which I think is fantastic! Heads held high on that one.*"

Another team member was very positive about the **management of the financial side of the project**: "*It has been so thorough that we've had no problems from the European Union, or from the UK Government as to how the project's been managed. These ERDF projects are so stringent in the way you have to do things, and there's been a great emphasis on making sure we get it right because the last thing we want to be in as a company is to be liable for any clawback*."

Another person discussed the **importance of hindsight** and the things that they might do differently: "*It's one of those things, the more experience you've got, the better you'll be at making decisions on it. I think if we were doing the same thing again, we would do it slightly better because we were more experienced in terms of some things. Drilling is incredibly expensive, time drilling and while the rig is on site it's incredibly expensive. There was no significant downtime on the rig, it was less than a quarter of a percent. I think if you did the same thing over at United Downs there's was something like something like 10%. We've managed that really well and it was really helped by having a good project manager who was really good at communicating. It was just making sure that everyone was talking to each other at the right time in the right way".*

The **stakeholders were all positive about the way the project was managed**, for example: "*It's a complex project, particularly the financing of it which requires a tremendous amount of skills from the team in term of managing cash flow, managing suppliers, all of that is very good and I think the day-to-day operational bit the team do is really good. There's some challenges of course because you've got three different shareholders, all with different aims and aspirations and different challenges but I think the team really manages that really well. There's been regular Board meetings and they've been able to resolve problems in a relatively short period of time*."

Another stakeholder commented on the **actual delivery and how it ran very smoothly**: "*When they were drilling, they'd been doing it for two weeks before the public even realised!*"

The university collaborators were also asked about the project management and governance and everyone either responded positively or were unable to comment. One person was positive about the management and agreed with feedback from the delivery team regarding

the **size of the team**: "*I think it was a lot for such a small team to take on. There was a really lovely team effort and vibe; it was always easy to talk to the top management if you had a problem. I think their hands are quite tied with the budget constraints and the way that the project has to be run, but they've done a really good job with the tools that they had*."

Another university interviewee was very positive about the **team's communication**: "*It's been really easy to get access to the people who were effectively on the executive and who were effectively driving the non-research side, the operational side of the project. So, I think in that sense, the close proximity and the enthusiasm of everyone who's involved has certainly been a major strength of this project*."

4.3 Project Progress and Achievements

The following table is a spend and output table for the project; showing the targets, performance to date (as of May 2023) and an overall RAG assessment.

Table 7: Performance of Expenditure and Outputs to date

Indicator	Adjusted Target	Performance to date (May 2023)	Performance to date % of target	Forecast performance at end of project	Forecast % at end of project
Capital Expenditure	£13,683,342	£13,281,067	97.1%	£13,683,342	100%
Revenue Expenditure	£2,513,658	£2,430,014	96.7%	£2,513,658	100%
C5 – New enterprises supported	1	1	100%	1	100%
C26 - Enterprises cooperating with research entities	4	4	100%	4	100%
C29 - Enterprise supported to produce a new product (renewable heat)	1	1	100%	1	100%
C30 - Additional renewable energy capacity	2-3 MW	1.4 MW	70% (based on 2MW min)	1.4 MW	70%
C34 – GHG reductions (adjusted)	900 tonnes	1,153 tonnes	128%	1,153 tonnes	128%

Key	
	Less than 85%
	Between 85% and 95%
	Greater than 95%

The capital and revenue expenditure is already 97% spent and therefore is given a green status and it is estimated that it will be 100% spent by the end of the project due to amount of defrayed expenditure.

Four of the outputs have been given green status as they have been achieved: C5 (new enterprises supported), C26 (enterprises cooperating with research entities), C29 (enterprise supported to produce a new product (renewable heat)) and C34 (GHG reductions). The C30 (additional renewable energy capacity) output has been given a red status, as it is 70% achieved. However, as the output is dependent on the geology of the system, rather than the

procurement, design or management of the project, it is considered an acceptable result. For further detail about the calculation of the C30 and C34 outputs, see below.

C34 Greenhouse Gas Savings

The primary PA4 C34 output of 900 tonnes GHG savings will be surpassed with projected GHG savings of 1,153 tonnes per annum. The methodology for the calculation can be found in section 2.2.1.

The reason for the improved output is that Eden Project has built additional commercial greenhouses which will allow it to take advantage of the available heat. This is a conservative figure. It is hoped that the addition of further heat users, such as a distillery and possibly fruit and herb drying will improve the demand profile and more of the available heat will be used to demonstrate industrial uses beyond greenhouses, promoting geothermal energy in the UK.

C30 Additional Capacity of Renewable Energy Production

The secondary PA4 C30 output does not achieve the projected 2-3MW output set out in the funding agreement. The power output initially peaked at around 2.7MW before settling down to between around 1.4MW and 1.5MW over the demonstration period. Taking the conservative figure, the C30 output has been reported as 1.4MW. The methodology for the calculation can be found in section 2.2.1.

To date, has the project achieved what was expected?

The delivery team were asked about the project's progress and whether the project has achieved what was expected. In general, the feedback was that **progress has been slower than expected** e.g.: "*Yes the project has achieved what was expected, but it's been slow and expensive due to Covid, Brexit and the Ukraine war. We haven't got two wells – yet! But the point of the European project, within its parameters, has been a success in the sense that we have drilled and completed a well, and we've found a bit more about the subsurface and we will have got Eden a coaxial heating system, which will mean that Eden pretty much gets off gas. It was supposed to pave the way for a second well and an electricity plant, but we're not sure that it will, both because we've got complicated geology, but also because of the policy context*".

Another person echoed that, stating that the **project is not quite where they had hoped it would be**: "*We've had delays but I think we're where we expected to be but not quite what we planned [originally]. The big idea is that it will be a big engineered two-well enhanced geothermal system, one well is producing the hot water and the other is injecting, putting the water back. That depends on there being permeability and a good enough production of hot water, so enough hot water at a sufficient temperature to get enough energy to run a power station which we don't have at EG1*."

Another team member explained that they are on the **final stages of the project**: "*We're now coming on to the period when we're hoping to put the coaxial cable into the well. We were always hoping that we wouldn't need to because we were planning to get funding for a second well and we wouldn't need to do the coaxial cable, but it became apparent that we do. That's going to be put in February, March time with the project hopefully completing April/May time. We're on those final stages, it's quite a complicated set of logistics to get these final things together. We've got a number of things to get together on site and then in April we should be running it and testing it and hopefully have everything up and running*."

Another team member talked about progress in terms of answering **two main questions about the geology**: "*I would say there were two main unknowns, one of them was how hot it was and the other was, can we use the fault systems to be able to bring that heat back to surface through the permeability in the rock. I would say that without a doubt, we've proven the resource (that it is hot) but the geological uncertainty and therefore the risk associated is not fully understood and therefore the second main objective I would say we haven't yet completed. As soon as you tap into the subsurface the uncertainty grows with depth and it's very hard to reduce that risk, especially within the funding and time frame of our project. With the benefit of hindsight there are things you could do to help reduce that risk, I would say more exploratory work could have been done before actually drilling the big well*."

Other team members were **more negative when answering about progress**: "*I suppose the simple answer is no because we expected to drill a hole in the ground, get hot water out of it, everything run and nice and smooth and that would work 100% perfect and we'd get the money to drill the second well and produce electricity. That hasn't happened – not yet! It doesn't mean to say it won't. The geology has been very challenging but it can all be sorted, it's just that someone needs to come up with the finances to help us do that. Oil and gas are starting to show an interest so hopefully that won't be too far away*."

Another person agreed about **not being in a position to drill a second well means that the project has not achieved everything it set out to do**: "*I think because of that, we aren't in a position where we're able to say, 'let's go on and drill the second well, straightaway,' we have to do some more understanding of the existing well we've got before we're in that position. So, from that point of view, you could argue it hasn't been fully successful. However, looking on the positive side, the fact that we were able to drill one well, down to 5000 metres with no major technical hitches was a huge achievement. There's so much that could have gone wrong with that, there's so much that could have been overspent on that and yet it wasn't it. The drilling programme went amazingly smoothly. So, from that point of view, the project was a real success, considering the first well was the crux of this ERDF funded project anyway*."

The stakeholders were also asked about progress and they gave **mixed responses**: "*Yes and no. It's achieved the ambition of drilling a hole to 5 kilometres in depth and there is heat down there and there is permeability down there. This is an industrial research project that proves that there is heat at that depth. I think the challenge is that at the moment we are only able to generate heat from that depth and not electricity. We can't generate electricity because although the depth is 5 kilometres, there is a blockage at 3500 - 4000 kilometres and it's only when you get below 4000 kilometres that the heat can transition into being electricity. There are various different 3-D imaging surveys that are going to be commissioned over the next few months to really understand the geology of the well and to work out where the blockage is in the system and see if we can literally unblock it. The challenge of that is that if we can't get certainty around that then it is more difficult to persuade Gravis to put in investment for the second well. If that's the case we've got it producing heat for Eden and maybe other places, but it can't produce electricity. This is a research project and that sort of thing happens on research projects".*

They went on to consider **the positives that have come out of the project**: "*It's been a fantastic success, the knowledge and experience gained from just drilling to that depth and understanding how that is carried out operationally, how it's done, how it's funded, the costs around it, all of that has been amazing learning. The next step for that team really at Eden is to apply that learning and that knowledge to other geothermal projects across the UK. It's*

always been hoped that this Eden one would be the first one and the showcase but actually the ambition of the Eden team is that we wanted to have multiple geothermal project across the country".

4.4 Outcomes and Impacts

4.4.1 Achievement of outcomes and impacts

The following table summarises the outcomes and impacts from the logic chain and comments on the progress towards achieving them.

Table 8: Achievement of outcomes and impacts

	Indicator	Comment
Outcomes	New enterprise viable	Some evidence from the delivery team interviews to suggest that the enterprise will be viable beyond the end of the ERDF project
	Demonstration of university research, collaboration and knowledge exchange	Achieved – good collaboration between Eden Geothermal, the University of Exeter and the businesses assisted – see Section 4.4.2 for further details
	New products/ services	One product achieved (geothermal energy)
	Development of new skills for low carbon economy	3 of the supply chain businesses have experienced improved management skills/capabilities (see Figure 3-5), which indicates a positive direction of travel
	Jobs Created	Too early to assess
	Improved Productivity and Gross increase in GVA	8 of the supply chain businesses have seen an increase in turnover (see Figure 3-5), which indicates a possible increase in GVA in the future
Impacts	Net jobs	Too early to assess
	Increased growth capability of businesses/ potential net additional GVA	Too early to assess
	Additional investment into Cornwall	Too early to assess
	Additional baseload renewable energy capacity	Progress is being made, the testing has demonstrated that the power output is 1.4MW (see section 4.3), which will help contribute to the baseload capacity.
	Net reduction in GHG	Progress is being made, the testing has demonstrated that GHG savings of 1,153 tonnes per annum could be achieved (see section 4.3). This needs to be off-set against the build/drilling phase and a more detailed assessment would be needed. It is likely that a net reduction will be achieved in the future.

There is evidence to suggest that progress is being made towards some outcomes and impacts but it is too early to determine for some others (e.g. net jobs, additional investment into Cornwall). However, the Eden Project has reported that: "*as a result of the Eden*

Geothermal project, we have invested over £2m in 0.7Ha of commercial greenhouses and new offices, to be supplied using the renewable heat from the project."

What progress has been made in achieving the outcomes and impacts of the project?

The delivery team were asked about progress in achieving the outcomes and impacts of the project and they were broadly positive: "*We're pretty much all there with them. We had very small outputs, we had four business assists and we had one new to the firm products, and one new company being supported and then we've got greenhouse gas savings and installation of renewable energy, and those should be forthcoming once we've hitched up the coaxial cable*."

One person talked in detail about the **greenhouse gas savings**: "*We were hoping to do a 12-month production period but fortunately we've managed to over a shorter period. Our problem was that we never really expected to have a single well, we were always expecting to have two wells so the output was never really going to be something that we expected to do in this way, we were hoping that actually, as we moved onto the second one that they would have achieved something really wonderful. Unfortunately, we didn't move on to the second well. We will be able to produce an output, whether it's going to hit the level we need for the targets, I don't know. This was always a research project and until you've done the research you don't know what you're going to get out of it*."

A team member talked about the **impact on the local economy**: "*During the drilling phase there would be 60 people in a 24 hour period so that's a lot of jobs and you're bringing money into the local area. The expertise to drill a well to this depth is not available in Cornwall unfortunately and there were only two service providers that came from Cornwall, Geoscience based in Falmouth and the seismic monitoring team Altcom, and they're based down in Penzance, the others came from Aberdeen, Great Yarmouth or mainland Europe. I'd say we supported companies from further afield more than the local community but geothermal in Cornwall is in its infancy so we could say that there is going to be an incentive for companies to either branch out to the SW or to set up in the SW and offer those services. I think it sets a very good precedent for that, it could create a lot of jobs but I wouldn't say directly with this project, but it has potential to do so".*

The stakeholders were also asked about the achievement of outcomes and impacts and one person talked about the **economic impacts**: "*There's been 8 million pounds of private sector funds gone into the project so that's a success I think in terms of leveraging something like this in Cornwall. The jobs and the supply chain activity, I think what that has done is it's raised a challenge for Cornwall in that most of the work that Eden gives them and has contracted has gone out of the county because the skills don't exist in Cornwall. I think there's an opportunity to build a supply chain around geothermal energy in Cornwall so we can keep as much of that money in Cornwall as possible".*

Do you think that the Eden Geothermal enterprise will still be viable at the end of the project?

The delivery team were asked whether the Eden Geothermal enterprise will still be viable at the end of the project and there were mixed responses to this. For example, people **questioned what was meant by viable**, e.g. : "*Will it be viable in terms of a commercial operation paying back the funder who provided the money? Probably not. Will it work its*

own place before that interest? Yes, it should do. The question is, how much you can bring to the surface to help contribute money back to the funder."

One team member pointed out that **Eden Geothermal may need to remain active for a while to run the coaxial system**: "*The problem at the moment is the company theoretically runs out of money as soon as the ERDF funding stops. The issue is, what do you do with EGL going forward? If you close the company up, then somebody has to run the coaxial system for the next several months, delivering heat to the Eden Project. That can only really be done through Eden Geothermal because Eden Geothermal has got the people on board who have the expertise to do that. So somehow, Eden Geothermal has to survive after the ERDF funding runs out, and I think that's got to be through one of the investors funding that and the logical investor would be the one who's going to get the income from the heat delivered to the Eden Project*".

Following on from that it was suggested that **EGL is kept running to do different things**: "*I think we can try to keep EGL going in another guise, maybe it's doing consultancy and geothermal work to maintain the existing staffing resource, so that when things happen again on site, we can just pull the staff onto that and head on with all the knowledge that we gained to date. So that's the way I see EGL progressing and I think in order for it to survive, it's got to get some external work in the meantime, to do that*".

Another person agreed and felt that **work will carry on even if it is not at Eden**: "*We'll be doing other stuff and other sites and other places, even if we're not doing it at the Eden site. Our expertise will be being used in one way or another*."

Another person thought it would be viable but might **struggle without public funding**: "*I definitely think it will be viable but without public funding, we will be dependent on grant funding. If a company like Eden Geothermal is going to survive, you can't shut out other types of deep geothermal, you have to go an explore more than one type. For example, we're dealing with granites that are very hard and abrasive, we know that they are very hot but they rely on fault structures to give you the permeability. If you went elsewhere in the UK, say in the SE where it's sedimentary formations, it's hot but not as hot as granite but in rock such as sandstone we know that it is permeable. It's a lot cheaper to drill in sedimentary formations because it's softer and therefore it's quicker and cheaper. They're doing that in the Netherlands where they are looking at sedimentary aquifers. It took 6 months to drill to 5 kilometres in granite at Eden and it would take 6 to 8 weeks in a sedimentary formations. It's going to either need a private investor or more grant funding to explore*."

Another delivery team member felt that Eden Geothermal would be **viable if there was a plan to drill a second well**: "*There's still the notion that there might be a second well at some point, that would be done by EGL. But based on what we know at the moment and what we've learned from EG1, I can't see any reason to drill a second well. Until we understand why we don't have any permeability or practically none, you won't be drilling a second well*".

4.4.2 University of Exeter strategic partnership and business assists

A summary of the four research projects follows:

Estimation of geothermal resource in place within a deep fault system

Ben Adams is working with **EGS Energy** for his PhD. This project seeks to develop two alternative approaches which, while created for and validated on the Eden Project site, are equally suitable for application at other locations.

The first approach characterises the deep underground heat correlation structure with multiple point statistics, as opposed to conventional two-point correlation measures. Compared with classic geostatistical techniques, this approach requires less measured data and more input from structural geological modelling of the deep underground.

The second approach also uses insight of the geological structure of the underground to configure heat zones and the cycling of heat between these zones. This approach explores heat transfer using techniques developed for chemical engineering reactor systems.
As measured data becomes available during the drilling programme, the suitability of the geostatistical and chemical engineering approaches is investigated, with emphasis on understanding the role of deep faults at the Eden Project site. The findings are being used to propose a generic approach to modelling the geothermal resource in place for future deep fault geothermal systems in the UK and overseas.

Outputs

- Data relating to the variation in temperature with depth and its implication for the local-to-regional heat flux
- Comparison of modelling approaches for an engineered geothermal system in a deep underground fault
- Scenario analysis of an engineered geothermal system at the Eden Project site
- Laying foundations for future exploration and build-up of knowhow to support future mining graduates in this field[5].

Geological controls on heat production and the evolution of fracture systems

Philip Henes is working with **Geoscience** for his PhD. Using data obtained during drilling in the southern St Austell Granite at the Eden site, his project is generating knowledge and understanding of two aspects of geology which are critical to the successful exploitation of deep geothermal energy across SW England.

The effect of granite variation on heat production - Cuttings recovered during drilling of the first geothermal well at the Eden Project are enabling characterisation of the mineralogical, mineral chemical and whole rock geochemical heterogeneity of the granites with depth. The project is determining the budget of heat-producing elements (U, Th, K), their mineralogical hosts and evidence for high-temperature alteration, and leaching of these elements. Radiogenic heat production is being compared with measured heat flow data (downhole logs) and discrepancies are being evaluated in terms of the potential role(s) of upper crustal convective fluid flow and/or mid/lower crustal and mantle heat contributions.

The effect of fracture and vein system control on reservoir permeability - The nature of the regional fracture system at depths greater than 2.5 km was hitherto essentially unknown. Downhole logs during drilling have permitted orientation, aperture +/- infill data to be determined. Limited sidewall coring would potentially allow the corroboration of the

[5] https://www.edengeothermal.com/the-project/research-and-technical/geothermal-resource-in-place/

mineralogy and structural integrity of vein infill and wall rock alteration. The aim is to establish the orientation and nature of fractures and infills that have been most susceptible to reactivation during the post-Variscan tectonic evolution of SW England, as this is likely to be an important control on the development of fracture permeability at reservoir depths.

Outputs

- Data relating to the variation in granite mineralogy and geochemistry with depth and the implications of this for heat generation (U/Th/K) and conductivity
- Assessment of the proportion of heat production from within the granite (conductive and convective fluid flow) vs that from external (mid / lower crustal vs mantle) sources
- Evaluation of how the natural fracture / vein network has been reactivated during the regional post-Variscan tectonic evolution to develop zones of enhanced fracture permeability[6].

Understanding the potential for non-energy exploitation of deep underground faults

Lucie Sindall is working with **BESTEC UK** for her MbyRes. This specific research project within the overarching deep geothermal project assessed whether geothermal power production is feasible in the rest of the southwest through understanding the viability of fault structures for subsurface fluid flow at depth. Using data collected from EGL-1 during drilling and subsequent wireline logging runs, a structural analysis of the fractures was conducted to understand the subsurface structures and its implications for geothermal energy through fluid. EGL-1 was postulated to intersect a fracture system known throughout Cornwall and originally documented from old mining records and, more recently, mapped from a site (Eden Project) in the Bodelva China clay pit (Muller, 2001). It has distinctive steeply dipping NNW-SSE trending veins of quartz-tourmaline indicative of cross-course features, which were extrapolated to the EGL-1 location.

WellCAD were used to generate FMI and ABI image logs from the raw wireline data of EGL-1. These image logs were then used to 'pick' open fractures in the borehole, which were then classified according to their size and orientation using the software Steronet 11 to generate steronets, which allow the stereographical projection of three-dimensional geological information onto a two-dimensional plane. By analysing the dips and fracture orientations observed in well log data, it was possible to infer whether this cross-course structure was indeed intersected by EGL-1. The structures are thought to be versican features that were reactivated in the late Permian/early Triassic. This allowed circulation of mineral-rich fluid which caused mineralisation and created mineral veins. For geothermal exploration, it is particularly useful to observe how these regional structures behave at depth as there are limited data for this. The data analysis undertaken in this MSc research project was then compared to data analysis completed by Geoscience (professional contractor).

Exploring opportunities to utilise microseismicity during geothermal energy exploitation

Jack Timmins is working with **altcom** for his MbyRes. The initial objective of the deep geothermal project was to drill and test the first deep geothermal energy well at the Eden Project in Cornwall to identify the hydrologic conditions of the reservoir and assess the

[6] https://www.edengeothermal.com/the-project/research-and-technical/geological-controls-heat-production/

production of energy and heat from the well. Information from drilling operations and the subsequent data generated from the well itself will provide critical information for the development of deep geothermal systems within the UK and build on existing research and knowledge of Cornwall's regional geology at depth and deep geothermal resources.

This research project undertook data analysis and interpretation of the relationship between seismic activity and varying drilling operations. Specifically, this project used the software visualisation package Tecplot RS and the computation fluid dynamic simulation software Tecplot 360 to suggest fluid flow networks based on fracture network, variation in rock mechanics, stability and observed fluid loss zones. The numerical modelling (geotechnical) software Flac2D was used to assess how pressure propagates along the proposed E-W fracture at 3950 m depth.

This project also performed a statistical analysis on the relationship between shape, size, magnitude and density of seismic plots, calculated the time lapse of seismic events after different tests, identified loss zones related to temperature variations with depth to locate potential fluid flow target zones (entry/exit points), and provided an estimation on the appropriate fluid injection rate that will result in seismic activity below the threshold. Thus far, seismic clouds (data until 9 April 2022) have recorded activity during well drilling and the first round of an injection test cycle, with most events occurring between 3400-4300 m. However, the seismic cloud is offset from the wellhead, implying the seismically active zone requires time for substantial pressure increases. Current data show the site has become more stable, even during testing activities. A future prospect would be to increase the amount of fluid injected along with sensors at various depth to assess the strain. This method would provide evidence to assess the maximum output from a coaxial system relative to the likelihood of seismicity to occur at depth. Utilisation of seismic profiles will allow for clearer geophysical surveys at the targeted depth. Work using airguns to develop seismic profiles is still underway, but once complete will provide evidence to identify key structures observed in the borehole.

The students, university staff and business collaborators were asked a series of questions about the academic work with Eden Geothermal.

Please explain why you think that your research project is exploring an important area and what contribution you hope to make to geothermal energy/geology?

The students responded as follows:

"*At the minute there's very little information out there about these systems, like actually published, it's all, people make models and compare them to other models which were compared to models. To my mind a lot of them are a bit overcomplicated and they try and model stuff to the nth degree. I'm trying to see if there's a way of doing this without doing that and getting it close enough that you can do a quick estimate. I'm making something at the minute like a little programme that will run in about 10 minutes and give you an estimate for a 30 year run of the system. I'm using specialised software that costs an absolute fortune. The idea is that we'll take the data from Eden and check that the models work and then compare them to exiting models*."

"W*ith earthquakes there's the risk of people on the surface, infrastructure and all of that so part of the research is just monitoring the micro seismic activity, sort of like a hazard risk assessment. That's the best way of putting it, just making sure that we're keeping within the*

guidelines set out not to disturb the public on the surface. From a geological perspective, there's a lot of structures which could be identified based on the micro seismic data. For that, one of elements would be if there's a sequence of events occurring in a particular trajectory, that might sort of give evidence to induced seismic events caused by the water pumped down. Then there's also aspects used in geophysics to identify structures, the fault zones, just the fracture network in general, at a depth that really we can't observe without drilling 1000 bore holes which obviously isn't viable! Geophysics allows us to see things that we couldn't see with the naked eye.

The data that we collect in my area for the micro seismic activities, it can either be used to indicate that we have induced seismic activity which could be from the fluid flowing through the structures. Another thing we can identify, with the focus on seismic activity is structures such as fault zones. Based on where these events occur, we can establish whether it is an area of weakness within the rock and bring that together with other aspects of the data to see what we can gather from that one bore hole. Geophysics allows us to see assets of the sub surface that we can't see with the naked eye".

"*There is so little data out there. There's a lot of like surface geology that's been published, to a certain depth but the kind of research that has been done is in old Victorian geology jargon, so I had to go through the collection. But any data that can be added to a data pool is going to be extremely useful because there just isn't that much. It's also just because we're targeting something called a fault zone, Eden Geothermal has been targeting a fault zone known as known as the Great Crosscourse and that is basically a series of bulk structures have a specific orientation and specific characteristics and it's thought that those are permeable features. My project is going to be looking at whether we have drilled into that and the interesting thing is, because of the way that the well bore has been drilled, and the orientation of the structures we are looking for, they will be underrepresented*."

"*Geologically, I'm looking at these mineralised zones and suggesting that these mineralised zones are more susceptible to permeability - or maybe they're not. I think that's more useful for future exploration work where they are going to target certain structures which have been shown, that maybe these mineralised structures are more susceptible to permeability and also, which zones are not permeable and that we can strike off the list for future exploration. Permeability is important because it's one of two things you need for a geothermal system, otherwise it won't work, so it's pretty important and it's good for future work I suppose you could argue. I'm characterising the hole geologically and this is the second deepest hole in the UK so that's a lot of geological data that I'm going through. I can also show gradients of heat production from this hole, some areas are more hot and I get that from the geological data. For a geothermal system you need the heat and the permeability and I'm basically looking at those two, more on the side of heat production I'd say*".

One of the business collaborators stated: "*We are all looking for CO2 free sources of heat and geothermal is one of the most important ones for this because it supplies heat 24/7 seven days a week without interruption. The resource in Cornwall is known for a long time, however, there is very little information available about the granite at depth in this area because the granite is not the easiest rock to drill and to deal with technically so this was a unique opportunity to get this information. We worked with geologists from the university as well as from local companies and our group*."

Another collaborator stated: "*The idea with Eden and United Downs really was that there is still this period of uncertainty at the beginning when you start drilling deep in a new area and that's really what these two projects have addressed; to get things going you need to treat it as a technological research thing at the beginning to get it going. Once it's proven, then the commercialisation can take over because there's greater confidence in the ability to deliver, that's been the key thing. These two projects, United Downs and Eden are proof on concept, that's how I would class them, the whole thing has definitely stimulated this industry, it's the thing that kickstarts it all really*."

One of the university team explained about their role and the **opportunity for the research students**: "*Our role in the research is that there are two PhD students and two Masters by Research students, and they are supervised by a team of academics and they also have direct links into the stakeholder companies of the Eden Geothermal project. That combination has culminated in what I think is for the students a world class experience in terms of being able to observe at close range and support a real serious deep drilling campaign and to also be a part of the data collection in a personal capacity. The interpretation of that data is currently the main focus of all four projects. I think that the explanation of that data is effectively a precursor to understanding whether the expectation of geothermal in Cornwall can take off*."

What progress have you made towards achieving the objectives of the research project?

The university collaborators were asked about progress towards achieving the objectives of their research projects.

Two of the students talked about **learning to use the software for their project** e.g. : "*I don't know if it sounds trivial to say this but part of the work is just learning how to use software. There's a particular software that I've been using and there's a guy have been communicating with to try and learn to use it. So, I've been trying to learn how to use that and that's going to allow me to visualise the datasets, I can actually see it on a 3d map. We're making good strides in terms of characterising parts of the micro seismic activity. I haven't finished that paper off yet, it's still a work in progress but there's some clear understanding on the characterising of that and then the aim would be to, within that, to identify what's causing these, and that's the plan for the next year*".

Another student talked about the **timescales of their PhD**: "*I'm at the start of my third year so I've got another year of funding left and I believe I can get all my lab work done in three months and then I'll be doing writing up for my PhD. So I've done a lot of lab testing, and I've done geochemical analyses and interpretations and preparation of samples and such.*"

One academic talked about the **process of the research projects**: "*The projects are about understanding and exploring, following the applied route which is to take as much of the information which is coming out of the drilling and well testing and other forms of investigation, to try and create a model for this resource. The applied and the fundamental scientific approaches are going side by side, and I think that in the time which the students have been working on this, and given also the tremendous amount of data which has become available during the course of the project, we are working towards that goal of being able to come to a definitive understanding of the resource and the potential how that resource can be extracted*."

Another academic discussed the **timescale of the projects**: "*I think we're pretty much on track with the PhDs. There's still a lot to do but they're already generating quite a lot of data.*

The Masters students might be a little bit behind on where we'd expect them to be, one of them hasn't had access to some software they needed until recently but I don't think there's been any major change to what we'd envisaged doing - the objectives have remained the same and will be achieved. I'd say we're around half way there, maybe more, I think we're on track."

How has the involvement in the research project helped to develop the collaborating business?

One of the students stated that they are **proud to be part of this collaboration**: "*We are part of something where, because the university is collaborating with Eden Geothermal, we're actually contributing to a bigger goal and something we can see is happening and I've really liked that aspect of it and that definitely keeps me motivated to try and build those relationships more. We went to the Geothermal conference last year, and we got to speak to people operating geothermal all over the place. It was a nice way to see that there's a lot of opportunities out there, people to contact, to get advice from and you know, keep an eye on. From my perspective, it's similar for Eden and geothermal Ltd., that their collaboration has been absolutely key to their success. They've got their staff who are brilliant, but they require people like our lecturers who've got so much academic experience, they really bring value to the table and then they get people like us who come along and do a Masters*!"

One of the business collaborators talked about **networking**: "*As this is an EU project, it forces companies from different countries to cooperate. That's exactly what's happening here, people meet, people work together and you are basically building a network which you can use in the future*."

One academic talked about the **technical advisory committee**: "*It meets about every six months and involves the stakeholders from all over the UK and even from America, and so there has been a lot of discussion in terms of inputs from others, but also outputs from the project, to sharing events where the status of the project was clearly described to the external people. Then I think they have made us aware of other opportunities and other ongoing events. Also, I think, mostly what they felt was valuable from our own sort of findings, so I think that been definitely an integral part to being part of the geothermal global network*."

One of the academics talked about the **university involvement adding value**: "*I don't think they need us to help them but I think we've been able to provide maybe a greater depth of data than they would otherwise have immediate access to. That's what a company/ university relationship should be like, we're adding to their work, we add depth and in some places, a breadth in terms of what we can do and in terms of analysis of rocks and minerals and we have a strong background in the regional geology of SW England. I think that's worked pretty well*."

What has been the value in collaborating on this project?

The students, academics and business representatives were asked about the value in collaborating on this project with Eden Geothermal.

One of the students talked about the **value of being there and experiencing it on the ground**: "*The value for me has just been how it all works. You see a lot of it from the academic side but when you're there, actually working with the companies who are*

gathering data, you realise there's a bit more to it. If I've got a question I can just go to the person connected to that, or the company and say, 'why did you do it this way?' or ask about what they're doing in the future and like tailor the work more towards what they would want. From what I can see, the company feels like they're getting the worth out it."

One of the business representatives gave an example of how **collaboration had added value**: "*We had an incident at a depth or around 600-700 metres where we hit a pocket of water full of bacteria, the bacteria attacks your drilling mud which gets destroyed and the consistency completely disappears. The mud is a viscous fluid and it starts sinking because the bacteria create a lot of sulphur. At the University of Exeter there is a micro-geo-biologist, who helped us a lot to overcome the problem. For us, now, she is obviously a resource for the future because there is very little known about this bacteria. She called it like being something from outer space so we are learning all about this and there will be scientists writing and papers published about it. The value of collaborating is true for many other fields also, people from the oil fields coming in or local people working in the project which has a certain value in a very specialist field and this is what makes co-operation*."

Another business collaborator talked about the **strength of the relationships**: "*Looking forward to future bids, we're going for pieces of work with Eden and the Camborne School of Mines, which I don't know if we would have done before the project. So, that sense of team has continued. That's the nicest, to strengthen that relationship which was already there, but we just needed to work together for it to be solidified*."

One of the students talked about the **uncertainty in the industry and how it is good to work together**: "*For the geothermal industry, it's very early days. We really need to start sharing information between different groups, so that we can reduce the uncertainty of the industry because the problem of the geothermal industry is that there are a lot of uncertainties that are going on. So, a lot of investors are very hesitant to start investing money. So, if we start sharing information with each other saying, 'Oh, maybe don't do this, do that. Do some exploration, this structure is maybe not permeable, or that permeable, based on what I've seen so far'. I think that's for the best, then it looks better on our industry, and for investors and investors are more confident. It raises their confidence if we start sharing information*."

One of the academics talked about the **value in collaborating to the students**: "*The role of the university is to on the one hand to provide expertise, generate knowledge, and also to train graduates for leading the developments in industry and, I suppose, in effectively promoting the transit, the green transition or the technologies to make the green transition possible. I think in that space the students are working towards obtaining the degrees which basically will be a marker of the academic success of the project. And as publications arise from the reports which they are generating, then that will be like the icing on the cake. I think that the students have been to various events, and they are really looking to create a foothold in that sense in the geothermal world based on the ongoing experience and work they're doing in this area. I would say that we are definitely looking to create that impact which extends beyond the production of academic reports*."

One of the academics talked about how **well the collaboration between the different players has gone**: "*It's been a really fruitful working relationship, I think it's worked really well between both Eden, Geoscience and the University of Exeter. I think it's been a really, really good working relationship, I don't think there's been any tension at all. I think working with Geoscience has been good for all of us, it's been quite a tightknit little group and*

everyone has played their role, being properly collaborative with very little tension or friction. It's been a really positive collaboration where no-one is vying for superiority or anything."

A business collaborator talked about the **value to their business**: "*Any contract won during Covid was very well received but really the value has been in terms of just working on a very high-profile project with a group of technical people who are really experts in what they do. We've learned a lot and I think they've learned stuff from us as well and it's been an opportunity to develop some technology, that was particularly beneficial. This was a collaborative project, they wanted us to define parts of what we needed to supply so it was extremely interactive, that's probably the key thing, it was collaborative and interactive. There were some things we did that we felt would help them which we haven't really done before*."

What will be the ongoing/future impacts of the research?

The students, academics and business collaborators were then asked about the ongoing and future impacts of the research. Several students talked about **technical issues relating to their project** e.g.: "*The aim is to identify what is the highest likelihood or probability that's causing certain aspects of the micro seismic activity. It's the fact that we're injecting water in the ground. It's understanding how significant that is relative to structural parameters that are there. In other parts of the subsurface, if there's similar geology, do we see similar results? That's where the progress needs to go, beyond describing what you can see and explain how you think it's happening. The progress needs to be how can use what we know for other areas in Cornwall, or even nearby areas to where EG1 is, and how can we extrapolate out to other areas. Once we've got a clearer understanding, we can look at a site and potentially create simulations, where you see all these different aspects of drilling the well, injecting it with fluid, especially in potential risk zones where micro seismic activity is occurring or is likely to occur. That is very, very out there in the future, we're not at that stage in the academic arena, but that's how I would like it to go*."

A business collaborator discussed the **technical issues and how the current research will reduce the risk in the future**: "*Specifically, for the geology side of the research, because our previous knowledge of the granite at depth in the SW of England was so sparse, then the publications we get out of this will form quite an important set of data that future projects can kind of calibrate against. United Downs and Eden Geothermal are the first two proper deep projects at, or just under, 5 kilometres depth. I think the huge amount of data generated here, much of which I think will ultimately become publicly acceptable, I think is going to form a really useful template and guide for future projects of this nature. It's not just on the commercial side, I think the fundamental understanding of granite composition, temperature evolution and the characterisation of compositional change with depth and the role of how fracture systems are changing is fundamental to geothermal which comes down to heat and permeability. Ultimately, they are geologically controlled and we're trying to develop our understanding at depth of fractures, and of the granite to try and de-risk future developments. The more work that is done now, the less risk there is in the future*."

One of the business collaborators talked about **developing the geothermal industry in Cornwall**: "*I think it's really important, especially that it's tied with the Eden Project that already has such a good reputation, if they can at least provide the baseline data of a project like this It's going to be a really big achievement. And especially when in the UK geothermal is an extremely underdeveloped resource, you know, compared to other countries. Cornwall as a whole doesn't have an industry any more so the idea of bringing industry back to bring*

stable year-round employment, I'm really, really passionate about that and if that project can be a part of bringing skilled jobs back to Cornwall, giving younger people the opportunity to stay in the county, that to me is just incredibly valuable. Geothermal projects and the lithium projects are really, really exciting because if you get those set up, you're going to have all the subsidiary industries around to support those projects, and hopefully it will snowball and we'll have this really nice green revolution."

How is the research being disseminated?

The participants in the university collaboration survey were asked about how the research is being disseminated. One of the students explained their **current situation where it is still early days for the research**: "*There's conferences, we're looking to try and do one or two this year. I guess the end point will be we'll publish everything, that's the only way it will get anywhere. If you did spend the first year on the rig you'd start publishing at the end of the second year but our first year wasn't really spent doing that, we're like a year behind in that sense. We might just publish everything in one big chunk at some point. At the end of the day, it's nice to do the work but nobody is going to sit and read a 400 page report*."

One of the business collaborators talked about **conferences**: "*I personally have been giving presentations at the geothermal exhibition lasts year in Germany which was the largest technical exhibition of geothermal in Europe. Colleagues of mine have been at various other conferences like the geothermal energy conference in Berlin. There have been a number of places where we have been presenting and discussing with our colleagues and we see that there is a lot of resonance to our presentations; people are interested, people want to know more about the project, there is definitely interest*."

Another interviewee added: "*We've been asked to contribute to a couple of scientific papers. I presented on the geology in Berlin at the European Geothermal Congress and at the UK Geothermal Conference this year. From that side of things, they're happy for us to go and present on the geology side and do a bit of an overview. Robbie, the drilling engineer, presented at the European Geothermal Congress as well and he got given the keynote speech of the whole conference so that's massive exposure for them and his first ever presentation. It was very well received; they had a lot of interest after that*".

One of the academics outlined how **dissemination works in a university context**: "*My first responsibility is to ensure that students reach their desired reporting outputs in the university sphere which are in the form of theses that are examined externally. Basically this allow us to have a sufficient standard in quality for a university that awards degrees, PhDs and Masters. However, it is also equally clear that for ensuring that reports which have significant relevance, also reach a wider audience. The university has objectives of publishing in suitable high level, widely read journals. Clearly the sequences that we try to create, sound knowledge which is externally validated and which gives good leads to the reports, which are then mined so to speak as a way for publications, as a way of increasing the impact. So, from a student perspective, there's a very clear route whereby priority number one, make sure that they record all their research, and then priority number two, to make sure that that is abstracted in the form of publications.*

In terms of what you do on the outside with students, we are very firmly part of the geothermal community and we are representing the project, for example, recently, the project had a meeting in London and also in Berlin. We are getting to conferences, which are perhaps not necessarily always recorded in terms of papers, but which are recorded in terms

of presentations and discussions at those conferences, whereby we are witnessing a very significant interest in in what's going on in our project from other people and we are also really looking to try and benchmark our project against other projects. So effectively the students reporting and recording activities are also complemented by activities of outreach which are being undertaken by the students and staff alike."

4.5 Strategic Impact

In what ways has the project created Strategic Added Value e,g. through leadership, influence, engagement, collaboration and knowledge exchange?

The delivery team and stakeholders were asked in what ways the project has created Strategic Added Value. One of the team members talked about the **research collaboration**: "*We've had very good relationships with the academics both at Exeter but also lots of other academics, such as people in Strathclyde and University of Oxford, and University of Edinburgh, they're all doing research projects of the back of this, and also across Europe. We had a collaboration with a project called Meet which had something like 14 European universities in it. University of Darmstadt was leading that. From that point of view, from the academic collaboration, it's been terrific, tens and tens of academics have been involved*".

Another of the delivery team members talked about **knowledge exchange**: "*I think there's been a lot of knowledge exchange because we've been able to work with Exeter University as a research delivery partner. There's been a huge amount of knowledge exchanged through that, post grad. students have benefited from it, they've contributed a big input into the way we've done things as well as the way they've met their abilities and the way they think about things so it's been very much a good two way exchange on that. There's been good business success with local businesses too because of the involvement they've had with what we've been doing from a technical point of view on the project"*.

Influencing policy was also discussed: "*We also have been, because of the policy situation, been kind of talking to the British Geological Survey and the people who are putting policy together for this white paper so that would count as influence and strategic value add. We've also had quite a fair amount of press and that sort of thing, including public education around our space*."

Another team member talked about the **importance of the Eden brand**: "*One real benefit of the project as a whole is having the Eden project as a PR machine, if Eden says something, people listen and I think it's been absolutely fantastic for getting the geothermal word out there. As soon as people heard that Eden were looking at this as a renewable resourced, a lot of people started showing interest, there was a big online presence as well, Facebook and Twitter*".

One of the stakeholders talked about **networking**: "*We were at an event with the renewable energy sector across the SW, recognising that that is a huge economic advantage for this region. Having geothermal as something that we've done and it's here gives credibility to some of the stuff that's been said and some of the lobbying that's been done at a political level*."

How has the Eden Geothermal project contributed to wider investment in geothermal technology?

The stakeholders were asked how the project has contributed to wider investment in geothermal technology and one person felt that it was still early but that **geothermal energy will become an important part of the economy**: "*I think it's too early days to say but where it's had an impact is, it's part of the conversation with the LEP that now sees it as a fundamental part of the future sectors that they need to support. If you look at renewable energy generally, wind power, wave power, metals and lithium, then geothermal is kind of mixed in with all of that. I think it's been recognised as being an important element of the Cornish economy really*."

Another stakeholder felt that the **contribution was in research dissemination rather than stimulating investment**: "*I don't think they invested any money into anything wider, they have worked in conjunction with the team down at United Downs and vice versa. I know they're separate entities but it's both geothermal. Information sharing is going on yes, but financially, no*."

4.5.1 Feedback on the project's legacy

What do you think will be the project's legacy for businesses, stakeholders and the wider economy?

The delivery team, stakeholders and university collaborators were asked about the legacy of the project and one person felt that it was **the benefit to the Eden Project**: "*I think the legacy is having got the Eden Project off gas. Now they don't have to burn tonnes of gas to heat biomes*."

Another team member agreed: "*Eden will be off gas and it's an advance on their carbon footprint. It helps them get towards net zero but of course without an electricity plant, which is going to be three or four years down line. Hopefully, we have actually started a bit of an industry in Cornwall and elsewhere in the country. Things are moving so hopefully, there will be further projects and the industry will grow*".

Another team member talked about **raising awareness of geothermal energy**: "*It's getting the geothermal word out there, that's what this project has done. It's done amazing work in improving peoples' awareness. A lot of people have heard of ground source heat pumps, very, very shallow geothermal but very few people understood that deep geothermal is possible and able to supply a much wider reach of people and industries so I think that is the main legacy – getting the deep geothermal word out there and starting to realise it's potential*".

Another person was keen to state that it is **not the end of the project yet**: "*I hope the project isn't going to leave a sort of 'end of story' legacy at this point. I would like to think that there's going to be an ongoing legacy where people look at this project, see it has a future and now recognise how they can contribute towards that future and be a part of it. It's difficult to evaluate that in a way but as far as businesses go, we have engaged with quite a few businesses, they have become familiar with what we want and I think that awareness is really helpful. If Eden Geothermal can progress on to the next well and can demonstrate a heat and power plant, that's going to give businesses confidence to say, 'actually, this is something we could invest in a bit and build up our business model to include*

that. Legacy kind of implies you've been and done it and you've finished so it's a bit early to be talking about that with this project. We're still in the learning phase."

One stakeholder talked about the **importance of the geothermal industry in Cornwall**: "*I think it's legacy is that it will prove a new technology and hopefully lead to Cornwall becoming the leaders in deep geothermal in the UK. I'd like to see us exporting talent and skills and generating money that is coming back into Cornwall and supporting our economy. It flips the whole energy debate, suddenly the rest of the UK might become dependent on Cornwall rather than at the moment, if the lights were turned off because there's an energy shortage, I suspect Cornwall would be the first to lose its lights. I think it creates an interesting economic dynamic for Cornwall going forward*."

One of the students talked about **trust from the public**: "*I want the legacy of this particular research study to be trust from the public. Trust that we are doing what is necessary to ensure their safety in terms of micro seismic activity. I think that's really important. By characterising the data that I'm trying to do, we can then understand it better, and convey that to the public. Once there's more confidence within the public, as a lead on from that, you're probably more likely to get more investments as well, which then continues the geothermal operations across Cornwall. Trust with the public would be a good legacy*."

One of the business collaborators felt that the **success of the well for geothermal heat was the legacy**: "*I think it can be seen as a success for geothermal heat. It's the longest well in the ground in Cornwall, and a success in terms of it reached the temperatures needed to supply the heat that is needed from the coaxial system. I just think is a bit tainted because we haven't been able to do two wells and produce power yet. They're still really enthusiastic and still really dead set on finding some more money and drilling another well and making it work properly*."

4.6 Contribution to the Horizontal Principles

4.6.1 Feedback from the delivery team and stakeholders on the Horizontal Principles

What contribution has the project made to the Horizontal Principles – Environmental Sustainability and Equality and Diversity?

The delivery team and stakeholders were asked about the contribution that the project has made to the Horizontal Principles. One person was very positive: "*It's exemplary on equality and diversity*," and another person agreed: "*We've got lots of women working for us and we've probably got quite a lot of neuro diverse people working for us of one sort or another*".

Another person talked about **sustainability**: "*I think their site is exceptionally well managed, pretty low impact and I think they've done really good outreach stuff, even down to the way they manage their site boundary, it's very porous so people can come and see what's going on. They've also been really careful about local horse riders and stuff so in terms of the impact of the site, I think it's been great. I think in terms of raising the profile of the geothermal industry it's been excellent*".

One of the stakeholders talked about the **female leadership of Eden Geothermal**: "*Amazing for the renewable sector and geothermal energy in what has generally kind of been considered to be a very masculine sector. I think that's an important point to make about the female leadership*".

Another stakeholder made the point about the **Eden Project running on green energy** in terms of the sustainability principle: "*If it all goes according to plan then geothermal is very sustainable, more so than any of the rest of it. It will be good environmentally for Eden, they will be sustaining themselves and running on green energy*".

4.6.2 Reporting by the Delivery Team on the Horizontal Principles

The Eden Geothermal delivery team reported the following information about the project's contribution to the Horizontal Principles.

Dissemination

Eden Geothermal was shortlisted for Regen's 2022 Green Energy Awards in the category of net zero energy developer, and was a finalist in the REA's 2022 Renewable Energy Awards. EGL had regular speakers at, and contributors to, the UK Geothermal Symposium (run by the British Geological Survey) and keynote speakers at the 2022 European Geothermal Congress in Berlin. Gus Grand (Eden Geothermal) sits on the BEIS steering committee for the upcoming White Paper on geothermal and the REA geothermal group, as well as being a regular consultee on geothermal to bodies including the House of Lords, the 1922 Committee and the Environmental Audit Committee.

Reducing Climate Impact

Whole lifecycle emissions from geothermal heating systems are 93% lower than those associated with gas heating, but there are carbon emissions associated with geothermal development. As a guide, the carbon intensity of geothermal heat has been calculated at 9.7–14.0 kg(CO2e) /MWhth, depending on site specific factors.

The majority of emissions are associated with site construction and well development, and are sensitive to site and materials specific factors, for example the depth of the drilled boreholes and type and quantities of steel and cement used to seal them, or the kind of soils disturbed for laying pipelines and constructing access roads. During operation, the carbon intensity of the electricity grid used to power hydraulic pumps largely determines the carbon intensity of the produced heat. All aggregates used to construct the hardstanding on the site were non-primary aggregates (i.e. classified as a recycled material), being the by-product of china clay works and sourced from within a 5- mile radius of the site. In addition, the following approaches were undertaken:

- Stone columns were used instead of concrete/steel piling or excavation and replacement for our ground improvement works.
- Low energy LED lighting units were installed.
- Rainwater was harvested from the hardstanding areas into storage.
- Logistics were carefully planned to minimise transport to and from site.
- Waste reduction was written into the specialist waste management tender and contract, and waste was minimised through novel drilling fluids management procedures.
- Local community groups and businesses were engaged with innovative waste minimisation solutions, too; for example, a Cornish organisation which collects

marine plastic pollution, turning it into kayaks, was approached and took the casing protectors and drilling fluids containers for the same purpose.

- Drilling fluids were water based rather than oil based, using ingredients such as barite, bentonite and xanthan gum, reducing materials impacts and the risk of pollution through spillage.
- An area of wet woodland with veteran oak trees and carr willow, in the centre of the drilling site, was protected and retained. Hedge lines were retained along perimeter fencing to support biodiversity. (During drilling, the site was monitored for noise, and the loudest sound recorded was the dawn chorus in the hedge.)
- Where turf was removed, reinstatement was with a more biodiverse seed mix, resulting in a biodiversity net gain. A new bund surrounding the site was seeded with wildflowers.

During installation of the heat main to carry heat from the geothermal site to the Eden Project Energy Centre, hibernacula were created for pollinators, topsoil trenches were reinstated and seeded with wildflower mix and topsoil bunds were created to be suitable habitats for insects and burrowing bees in particular. Natural stone gabions – rather than concrete pillars - were used to support the above-ground sections of pipe.

Figure 4-1: Overground section of heat emerging from wildflowers at the Foundation Building, Eden Project.

Community Engagement

Grants (non- project funded) were awarded to local groups and schools to deliver projects around biodiversity, forest school learning and environmental improvement / biodiversity gain in areas with some of the highest social need and deprivation indices in the UK[7].

The Eden Project Communities team is active in social prescribing. Eden Geothermal have worked with them to deliver 'walks and talks' for a diverse range of groups including people with COPD (who visited the site as part of a gentle circular walk) and older people affected by social isolation, whom we visited with a range of props (drilling cuttings, drill bits etc) to talk about geothermal in the context of the local area's mining and quarrying history, with which many of them had been involved.

Supply Chain and Procurement

Despite gaps in the specialist supply chain and the ERDF procurement obligation which precluded our specifying services being provided locally, some 65% of the spend on site construction at the Eden Geothermal Project was with local Cornish suppliers. For example:

- All electrical and lighting work was provided by a Cornwall-based SME Supplier
- Fencing and gates provided by a Cornwall-based SME supplier
- Labour, ducting and drainage works were carried out by a Cornwall-based SME supplier
- Concrete was provided by a Cornwall-based SME supplier from within a 3 mile radius
- Reinforced concrete construction completed by a Cornwall-based SME supplier
- Containment liners were installed by a local SME supplier
- Plant was provided by a south west (Devon) based SME supplier

Local suppliers were also used for cranage, haulage, design and print, site security, catering and hospitality, landscaping, welding, seismic monitoring, geology services and geological testing.

4.7 Value for Money

Has Eden Geothermal provided good value for money to date?

The delivery team and stakeholders were asked whether the Eden Geothermal project has provided good value for money to date and there were **mixed responses** e.g. "*I wouldn't have invested in it, it's far too risky and far too speculative*!".

Another person felt that it had as **it is an important project at the start of the geothermal industry in the UK**: "*It has been value for money considering the government hasn't put any other money in at all. Somebody's got to start somewhere and I think we've been successful in starting somewhere and making a bit of a noise about it. If you talk about geothermal in the context of the UK, it's still an absolute disgrace that we are 29th in Europe with installed energy. The actual installations in the UK are very poor, and other places are pulling ahead,*

[7] For more information, see: https://www.edengeothermal.com/community-hub/eden-geothermal-community-fund/

particularly the Netherlands and Germany. Currently Germany is looking at 25% of their heating being geothermal and the Netherlands the same."

Another delivery team member was positive: "*Yes, I think it has provided good value for money. Whatever happens, it will be a success story for science and engineering, in that sense I think they will get good value for money, it's whether they get good value for money or excellent value for money, I don't know*."

Another interviewee agreed: "*I think it's provided excellent value for money! It's achieved its goals, OK, we found out that the permeability of the rock at depth isn't what we expected, but that's a goal in a way. I mean, it's an industrial research project, we've got a huge amount of data from this, we've still got more to understand about it, but we've drilled a well successfully to that depth, and we've done testing on the well successfully. Yes, we've required a bit more funding than we expected but again, any project of this type, it's really difficult to have an initial budget, and the budget was very tight to start with, when you're doing something like drilling operations, where you're not allowed any contingency as such, to stick relatively well within the budget is a success. We've done most of it within the way we said and I think it's definitely been cost effective*".

Another team member felt that the **funding restrictions meant that the project did not proceed in the most cost effective way**: "*You would never drill one well, in this way, you really want to drill two wells in one go. So, I think to drill one well on its own is probably not the right thing to do. However, this is your typical government restriction on funding, rather than doing the right thing, they've tried to help, somethings better than nothing, but it creates a single well, which isn't really what anyone ever wants, and it hasn't really addressed the point, would a two well system be good? What the place really needed was the funding to do two wells, and then you would have come out of this with a better knowledge of whether you really could do it, should it be in Cornwall, in granite in this country on a two well system*".

Another team member took a different view: "*The short answer, in the nicest possible way would be 'no.' If you were to look at heat output and compare it to say to gas, geothermal wouldn't stack up, it would be far more expensive. But you're not comparing apples with apples here. We're only going to get renewable heat out of this well but our main goal going into this was to get deep enough for electricity generation so from that perspective, the figures are already skewed because you don't need to drill that deep to get that heat output. It's a very difficult question to answer and you have to fall back on the fact that this is research and we are trying to prove concept. Once you've proven concept, i.e., this is going to work, then you can start focusing on economic efficiency. When you say, 'is it good value?' economically, at the moment, no but from a C02 emissions perspective, it is absolutely because once you've got it on stream, it's not going to stop, all you've got to do it maintain your pumps. Going forward I think there is a stronger and stronger argument for geothermal purely because of that point*."

In terms of comparisons one team member talked about the **United Downs Deep Geothermal project**, which was also ERDF funded: "*It was a different concept but at the end of the day, it was deep geothermal and it had the same sort of issues and struggles that Eden had so I suppose that's directly comparable. So, in my opinion, Eden has definitely become up there amongst the world leaders as far as taking forward engineer geothermal along the game with United Downs because there just aren't many schemes of this type in the world. They have been tried since the 1980s, and there have been a lot of unsuccessful schemes that*

have cost a lot of money that haven't worked for various reasons. Eden is not in that position, Eden can be looked to be as an initial well, providing very useful information that has taken engineered geothermal system forward."

The stakeholders found the value for money question difficult to answer, for example: "*I think that's an unanswerable question, what are we relating that to? I mean it has to be doesn't it, even if it's expensive to do, it will generate heat that's cheaper than electricity*."

Another stakeholder focused on the **research side of the project**: "*Because it's research and development, it's never been done before and we are drilling go significant levels in the ground, it's naturally a very expensive project. At the moment I would say that you probably wouldn't measure it as good value for money but I think the learning will mean that the second and third time you do the project, each time you will be achieving efficiencies in cost and operations that you only find out by trialling and testing the work*."

5 Lessons learned

Lessons learned were collected from the Eden Geothermal team interviews and from the stakeholders and these are presented thematically below.

5.1 Technical

Lots of technical drilling lessons were learned through this project, as the focus is on research and learning about the technology. An in-depth 'End of Well' (EOWR) report has been compiled by the Eden Geothermal team in order to capture those lessons (Eden Geothermal – EOWR Content for Summative Assessments).

For example, one of the delivery team members talked about **managing the drilling better**: "*One of the lessons learned from the drilling side I think, is maybe about the lubricators they put into the well because that may have contributed to some of our delay in terms of gunk down the well. That's a lesson learned there because we probably need to do a bit more testing up front on that*".

One person talked about the **difficulties of drilling in granite**: "*We were trying to intersect a fault structure that was dipping at an unknown angle away from the site. We made assumptions about the angle that it was likely to dip at and we had to, with the first well, to chase that angle in order to intersect it at 5000 metres. That's been a problem because we ended up having to build the angle of the well to be quite shallow. I think in hindsight, you wouldn't build a well to that angle again in granite. It's one of the main reasons we can't carry out the wireline logging to the bottom of the well at the moment. There are ways round it, you could run a drill pipe down the well and wire line log through the drill pipe and that will get you to the bottom. Problem is, that requires a rig and it requires additional funding, which we haven't got, so we haven't been able to demonstrate that. But that to my mind is maybe the biggest technical lesson learned - don't be too ambitious in the angle you want to build when you're drilling in granite*."

Another interviewee talked about doing **research before beginning the project** and this was echoed by a few people: "*[It would be useful to have] a big budget for seismic research before you start the site. We could have done with more research before we started drilling to try and identify the location of the fault. It would have been nice to have had a bit more certainty before we started drilling. And that's the trouble with the ERDF projects, you're limited with finance, when you haven't got as much money as you wanted to*."

Another member of the delivery team agreed and stated that it is **important to do research to de-risk the project**: "*It's very, very difficult to prove a concept like this with a fixed budget. If you had broken it down into a feasibility stage, an exploration stage, a drilling phase followed by a development stage of testing and proving the resource and then a commissioning phase with a staged funding process, I think it would help address the issue of more planning work needed. It would help de-risk the drilling and development phases essentially*."

Another delivery team member talked about the **time of year for undertaking the works**: "*You'd never do a civils project on an area like this in the winter! The wet weather cause horrendous problems and trying to work the ground that just became a mud bath, in the end we had to get specialists in and treat the ground with lime to stabilise it so we could work it.*

If we had started on time we would have done it in the summer but the delays with funding etc., it pushed it back."

One of the technical improvements suggested was the **use of fibre optic cable with sensors to measure parameters such as temperature or pressure**: "*I think they should have had optical fibres as they are just breaking into the market in the oil and gas industry, fantastically, they're almost magical, with the right analysis of the signals you can learn so much from down the well. To be fair to Eden, when this was originally conceived that probably really wasn't on anybody's radar, but I think if you were to do it again…you can do multiple things with optical fibres, I think that's a real game changer in deep wells, or any wells come to that. I learned about it through UK Geos, all the UK Geos wells use this and the data they produce is amazing*".

5.2 Administration

One of the stakeholders talked about **procurement difficulties**: "*I think there are important lessons learned around the procurement and commissioning of work, particularly when we've had to seek suppliers and from some big infrastructure companies. We are probably a very small fish in their big pond and that's where you have difficulties in holding suppliers to account, getting the parts in a quick and orderly fashion. I think there's some learning around procurement and the supply chain and there's definitely some learning around the drilling experience generally and how you secure efficiencies around that. Working with the Czech drilling company was very interesting*."

One of the students talked about **timescales and management with regards to the University of Exeter**: "*I think for part of the funding they didn't have much notice. I think they advertised the PhDs in early November, the interviews were the end of November and we started in January. If it wasn't for COVID, it would have been quite hard to move down here and jump straight on. Ideally, they wouldn't have the starting date because they didn't have the data they needed. And with the Business Assist, there was a bit of not knowing which companies we all had to start with and how they all got shuffled around. I think the university admin are overworked".*

A team member talked about **DLUHC**: "*It didn't start as a strength but they really were good. They need to have their backs patted and told that they were a really great partner through Covid and everything because they've found flexibility where there has been none previously. They behaved really, really, really well. However, if I was doing it again, I would get a new reporting website for DLUHC because it's an absolute clunker. It's really difficult to use and wastes everybody's time*".

Another team member talked about the **need for insurance and guarantees and how difficult that was**: "*One of the problems is underground insurance. The way the industry works, you take responsibility for everything that happens underground and the drilling contractor takes responsibility for everything that happens overground. You need to cover off that risk with insurance but the insurance companies are not willing to play ball so we've not been able to get down hole cover, you would hope that the government might come up with some sort of guarantee scheme but it hasn't. One of the other big problems with being an ERDF project was the amount of legal fees. We had to have a guarantee, what a mad state of affairs it is, you can't get funding so you're on funding of last resort but they want a guarantee. We were really lucky that Gravis came in and guaranteed us, there's all sorts of legal agreements going around and it's so expensive, legal agreements have cost an arm and a leg on this project.*"

Another team member talked about **cashflow and how it is hard to manage a large research project without contingency**. For example, an area where appropriate cashflow is needed: "*Putting in the coaxial system – once you start this you can't stop, else it would cost millions*". If there wasn't a financial backer to help with the contingency and the project had to finance it from cashflow, any problems could cause the work to be suspended, which could impact on the success of the whole project.

In this case, after the second PCR was agreed, a contingency line was included and this allowed the project team to manage the project cashflow more effectively. A key area of learning around project management is that it is difficult to undertake work or buy large pieces of equipment and then claim back in arrears. Therefore, large scale research projects need to allow for contingency in order to manage cashflow effectively.

5.3 Partnership

All of the delivery team were **positive about the team** and how well they had worked together, e.g: "*They've been fantastic. I think that we way underbudgeted on people actually. Our team is too small, way too small and that was poor but you know, you don't know what you're doing until you start doing it do you really*".

Also: "*One of the project's definite strengths is the team. The people involved have been just right for it and they've worked really well together and it's been very much a team, a team project. So that's been an incredible strength*".

One delivery team member talked about the **complicated governance system**: "*Such a particularly complicated system of governance and stakeholders, it has been really complicated. I suppose we've managed all this but actually, it would be easier not to have X number of shareholders and X number of delivery partners, but then maybe that's also a strength because then you have broad support across the community*".

One stakeholder talked about the **openness of the project team being successful**: "*I think the lessons to be learned are openness that they have practiced all the way through. We've encouraged openness from Eden and they've been very co-operative in that respect. If you are open and not secretive in any shape or form it does pay*."

A business collaborator talked about the **importance of communication**: "*Communication with the drilling companies is important. One lesson learned was around the mud components used - they used them at United Downs and it hadn't worked and it caused quite a lot of difficulty in the well (black gunk problem)*." Communication from the technical contractors could have been better as the Eden Geothermal team were not made aware of this 'black gunk' issue.

One of the academics talked **positively about the academic/commercial collaboration**: "*I've learned I should be less worried or coy about starting a project like this again, simply from the perspective that it's actually opened my eyes to what is possible if one engages in a close collaboration between academia and commercial entities. They don't always mix easily but in this case, where there was a clearly defined common ground in the sense that there was no knowledge really what would happen in a deep underground well, whereby, in other words, there was a role for the academia. Actually, the lesson for me has been that this is something I should do more often, circumstances permitting!*"

5.4 Strategic

One of the students talked about the nature of the project and the **value of the research experience**: "*I've learned an awful lot about how things work. I guess it is still a research project, but it's in that industry/professional setting. These are real contractors; these are real companies involved. Seeing that side of it has been so valuable and so interesting. We come up to the site and have a little look at what's going on and you can see the data collection. It's a valuable opportunity that we've watched them do some wireline logging, we've asked the loggers questions, and we've watched them shoot an air gun into a pool, and then we've asked them loads of questions. So, it's like, the practical industry knowledge has been insanely valuable, and I really feel like if we were to go into it in the future, you know, we wouldn't be those like shiny people from university, we'd have an idea of how things work and that that is just so valuable to me*."

One of the delivery team members talked about the **nature of the project needing to be research rather than having outputs attached**: "*I think it probably would have been better to couch it as pure research rather than have to have a greenhouse gas output out of it. Although, in fact, it turns out that it was lucky because it meant that we meant that we had to put the coaxial system in so it meant we did end up with something. It's just that if something is pure research it probably should stay as pure research rather than this because it was more risky even than we knew. If the government is going to back research, it should jolly well back research! Do it properly and not expect there to be outputs in the same way*."

One of the stakeholders talked about **investing in the supply chain and training**: "*I think it's about how could we develop a more resilient supply chain, closer to Cornwall to support the sector generally. I think we'd want to invest in training, so who are the next generation of geothermal engineers that are coming up and how do you attract them to Cornwall. Emotionally it feeds into the Cornwall narrative as well, ex-miners, exploration and all of that stuff, it feels like it's part of that*."

One of the academics agreed with the **training requirement**: "*One thing I would like to think could be improved would be that somewhere that courses or training could be provided, the emerging future, which would allow more students who will be working in this field, to be prepared for doing this type of work. It's a very young field and further training facilities for future generations which would effectively help the popularisation of such exploration. Some kind of a centre in an educational establishment, which would the knowledge to be locked in and to be transferred*."

6 Conclusions

As the Eden Geothermal project reaches its final stages, there have been a lot of positive findings highlighted through this summative assessment. The project contributes to key policy and strategy areas and everyone interviewed agreed that the project is still relevant and delivers an important service. Given the policy background for geothermal energy, the context and rationale for the project remain strong. There have been changes in the background and context of the project during the delivery including the Covid pandemic and Brexit.

There was agreement that the project is being well managed with appropriate governance and management structures in place. The positive atmosphere on site, good financial management, smooth delivery and good communication were aspects that were commended by the delivery team and stakeholder interviewees.

The project has done well in terms of output achievement and expenditure. The capital and revenue expenditure have been given green status and it is likely that they will be 100% achieved by the time the project finishes. Four of the outputs have been given green status as they have been achieved: C5 (new enterprises supported), C26 (enterprises cooperating with research entities), C29 (enterprise supported to produce a new product (renewable heat)) and C34 (GHG reductions). The C30 (additional renewable energy capacity) output has been given a red status (70% achieved), which given the research nature of the project is considered an acceptable result.

Qualitative evidence from the delivery team, stakeholders, research collaborators and supply chain companies show that the Eden Geothermal project is making progress towards the outcomes and impacts on the logic chain, but it is still too early at this stage in the project to confidently assess whether all the outcomes and impacts have been achieved. However, the Eden Project has reported that: "*as a result of the Eden Geothermal project, we have invested over £2m in 0.7Ha of commercial greenhouses and new offices, to be supplied using the renewable heat from the project.*"

Stakeholders and the delivery team reported that strategic impacts have been created too, including research collaboration, knowledge exchange, influencing policy, the importance of the Eden brand and networking. When asked about the contribution that the project has made to the Horizontal Principles, the interviewees felt that Eden Geothermal sits at the heart of the Environmental Sustainability principle. In terms of the Equality and Diversity principle, evidence of women and neurodiverse people working on site was given. When asked about legacy, one person felt that it was the benefit to the Eden Project being off gas. Other areas discussed included raising awareness of geothermal energy, the importance of the geothermal industry in Cornwall, trust from the public and the success of the well for geothermal heat.

The Eden Geothermal project has been a success in many areas; with most of the outputs being achieved and progress being made towards the outcomes and impacts. The project has carried out important research into geothermal energy, and although the end result was not what was expected at the beginning, a wealth of useful information has been collected and Eden Geothermal is an important demonstrator for kick starting the geothermal energy in the UK.

"*It's been a fantastic success, the knowledge and experience gained from just drilling to that depth and understanding how that is carried out operationally, how it's done, how it's funded, the costs around it, all of that has been amazing learning. The next step for that team really at Eden is to apply that learning and that knowledge to other geothermal projects across the UK*."

7 Appendices

7.1 Further Comments from Supply Chain Businesses

Table 7-1

Q: Do you have any further comments relating to your business relationship with the Eden Geothermal project?

Base: All respondents; n=12

Comments
Valued customer who we work extremely collaborative with. We would like to do more work with them.
In many ways they are another client, probably not necessarily the easiest client to work with in some respects, it would be because more difficult to define the objectives, because it is technical and unusual, it can be harder to communicate at a technical level.
It was a good relationship with the team, when we gave advice they listen, nice to work with people who listened. We do keep an eye out on what they are doing and would love to work with them again.
They are very easy to deal with and we are always keen to deal with local companies.
The guys there are all very professional and nice to deal with. We get feedback from our staff and some sites the feedback is negative, but the feedback from our staff regarding going and working there was all very positive. I would not change anything if we worked with them again everything was really good and positive.
Pretty straight forward the work we did with them, typical of the projects we do, it was easy and same process as with other clients.
Even though we sub-contractors it was all a very collaborative approach and providing that consultation it was 2 businesses discovering each other, a lot of parties involved in the project, although sub-contractors we do hope to do more with them.
I say that they have been very easy to work with, mutually beneficial arrangement and general pleasure. We would very much like to continue a working relationship with them
From memory nothing I would change. Clear and well communicated client. Good to work with them and beneficial.
It was a pleasure; it would be great to work with them again and I wish them all the best of luck with 2nd well.
No I believe the whole process from tender up to starting on site went well, we enjoyed working on site and being part of the Geothermal project. All of the members of staff and contractors on site were nice to work with.
No complaints about anything with them good to work with.