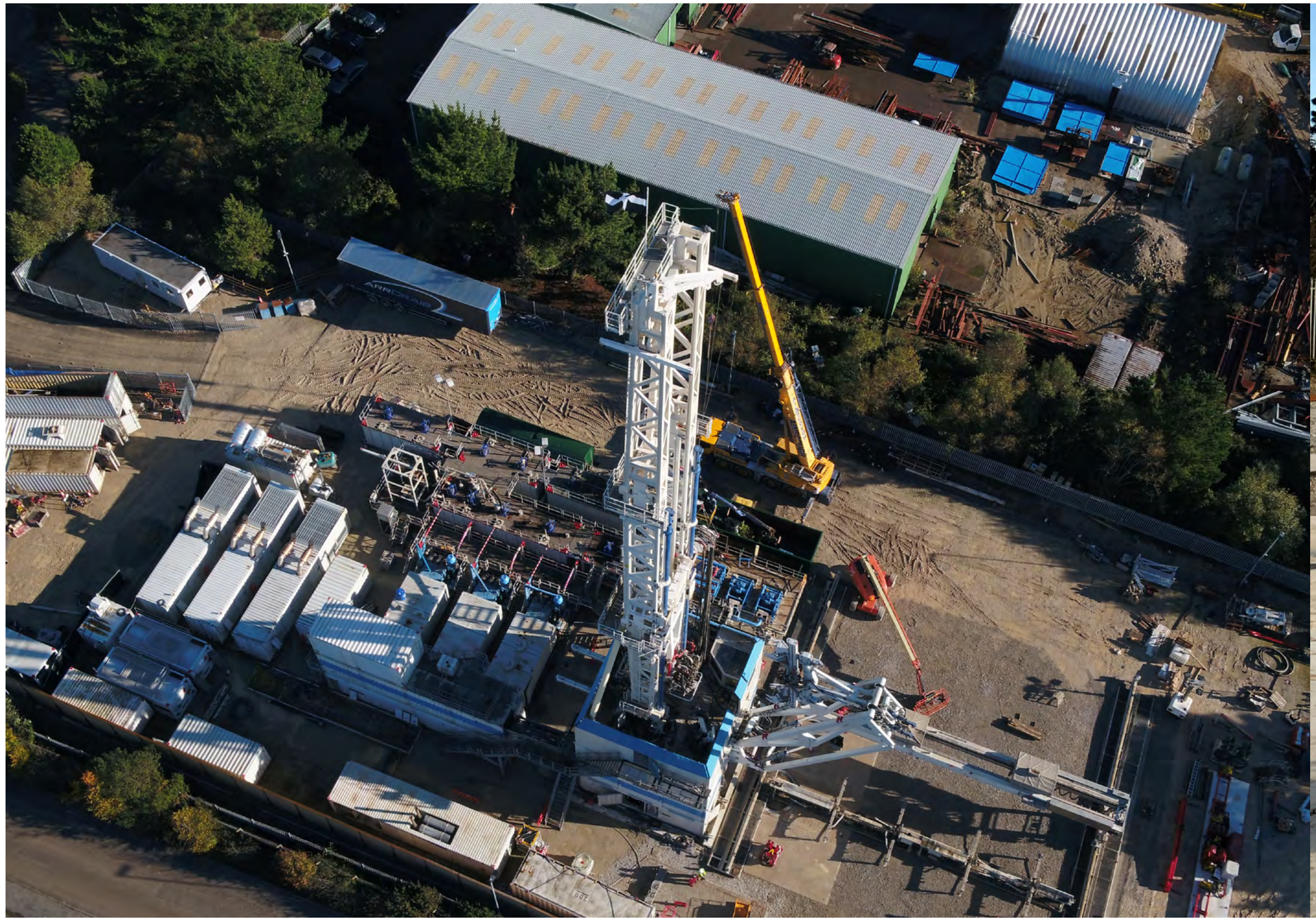
Deep Geothermal Energy

Economic Decarbonisation Opportunities for the United Kingdom

May 2021



Supporters include:

Acknowledgments:
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360 geothermal plants by 2050 could provide 15,000 GWh of annual heat and carbon savings of around 3 megatons annually. This significant decarbonisation of large-scale heat can only be achieved through Government support, as has been successfully demonstrated in other European countries.

The opportunity for deep geothermal in the UK

Heating and hot water make up around 40% of the UK's energy consumption and nearly a third of UK greenhouse gas emissions. The Durham Energy Institute estimates that there is currently enough deep geothermal heat energy to supply all of the UK's needs for at least 100 years.

By delivering on average 12 heat projects per year over the next 30 years, the UK could expect to generate up to 15,000 GW hours (GWh) of heat annually by 2050. In addition, around 400 GWh of electricity annually is also feasible by 2050. In combination, this level of growth would provide a carbon saving of up to 3 million tonnes annually; and would represent a crucial contribution in meeting the UK's net zero ambitions (as outlined by the Government's Energy White Paper, Dec 2020).

There would be significant economic benefits generating £1.5Bn of investment and the creation of around 10,000 direct jobs and 25,000 indirect jobs. As we transition from fossil fuels to lower carbon alternatives, the core skills deployed in the oil and gas sector, such as sub-surface well engineering and drilling, are highly transferable to geothermal. In addition, the existing UK petroleum wellbore stock presents a good opportunity for immediate deep geothermal learning.

While providing UK-wide benefits, these will be particularly concentrated in the North of England, the Midlands and the South-West, in places such as Cumbria, Crewe, Stoke-on-Trent and Cornwall. This industry would then play a crucial role in the 'green recovery' and provide a boost to the economy.

However, this rate of growth will only be possible with government support. To harness the UK's potential, incentives such as a geothermal development incentive is needed to encourage private investment and develop the UK sector.

The use of such incentives has proved successful in other countries and would accelerate development. Arup has analysed several deployment scenarios (see page 13) to explore the socio-economic benefits of deep geothermal energy. With immediate government support, the UK could deliver 360 projects by 2050. In particular, projects where there are promising geological conditions such as Northumberland, Durham, Cumbria, Newcastle upon Tyne, Cheshire, Greater Manchester, Staffordshire, Wessex and Cornwall.

As early as 2025 there could be 12 projects operational, creating 1,300 jobs and in excess of £100 million of investment flowing into the UK economy. The deep geothermal sector stands ready to help the UK meet net zero and deliver a green economic recovery.

Space heating
Equivalent heating for over 2 million homes

Heat
>3,600 MWth capacity (>15,000 GWh per year)

Electricity
25 to 50 MWe (200 to 400 GWh)

Workforce Opportunities
>10,000 direct jobs and >25,000 indirect jobs

Plants
>3.5Bn in capital costs (drilling, casing, power plant)

CO_2

Carbon Saving
Up to 3 megaton annual carbon saving

What 360 geothermal plants by 2050 means to the UK

Executive Summary

Two interventions with an immediate impact are the introduction of a Geothermal Development Incentive and minor changes to the Contracts for Difference structure.

Recommendation to facilitate geothermal growth

Deep geothermal is a hybrid between established renewable heat technology and natural resources. It is the latter which carries the so called 'geological risk'.

The following interventions would help stimulate the UK deep geothermal market to grow a self-sustaining industry for the longer term:

– Development of a dedicated deep geothermal development incentive (GDI) for heat projects; and

– Update the CfD for geothermal power in the next auction round.

Both interventions will allow projects to point to a secure revenue stream at early project stage.

Once successful projects have been implemented and a supply chain established, the market will have been 'de-risked', paving the way for further projects and investments. Ultimately the deep geothermal market will become more cost effective and sustainable, comparable with solar, wind in the UK and deep geothermal markets in Europe.

Geothermal Development Incentive (GDI)

A heat production incentive dedicated to deep geothermal projects (referred to as a geothermal development incentive, or GDI) could be structured such that it provides assurance to the geothermal market, but only provides funding for projects which successfully generate heat energy. Successful heat production incentives are typically in-place for a reasonable time period, for example 20 years, to stabilise project finance conditions. The UK could control the long-term cost by limiting the use of a GDI to the first 30 projects which meet application conditions. The GDI could be funded through a variety of sources, such as future carbon tax receipts.

For example, a heat plant with a 10 MWth (MW thermal) capacity may provide 44 GWh heat annually. The heat plant would deliver a carbon saving of around 8,000 tons CO_2 per year throughout its life. This would equate to c. 2,200 GWh heat and saving 400k tons CO_2 over its operational lifetime.

With a GDI of £55/MWh (in line with the RHI tariff) the cost per year would be £2.4M for the first 20 years with potential CO_2 emissions savings of £16M (based on BEIS Carbon Valuation method [25] between 2025 and 2045, using central traded values).

Contracts for Difference for Geothermal Power

The exiting Contracts for Difference scheme for Renewable Electricity Generation (CfD) remains appropriate. The next auction round is due later this year (2021). Minor changes for this round are recommend. We have identified that setting the Minima of 50 MWe for geothermal projects, along with guaranteeing the current administrative price (£140/MWh) for the Minima would improve investor confidence. Review of planning permission requirements is also recommended.

Geothermal Development Incentive (GDI)

A new heat production incentive dedicated to deep geothermal projects:

1. £55/ MWh per year per project
2. For the first 30 projects
3. Only projects meeting the scheme requirements and commissioning in time are supported
4. Low operational cost and long lifecycle of geothermal plants represents high value investment

Introduction

Geothermal energy can provide a baseload and dispatchable resource that can help the UK to reduce greenhouse gas emissions to Net Zero by 2050.

Drivers for this study

This report provides a summary of the UK's potential to develop deep geothermal energy, its impact on the UK's decarbonisation pathway, as well as the opportunity for job creation and skills transfer.

In December 2020, the UK pledged to cut greenhouse gas emissions by at least 68% by 2030 [1] as a first step to achieve net zero greenhouse gas emissions by 2050. Heating and hot water currently make up around 40% of energy consumption and nearly a third of greenhouse gas emissions in the UK [2]. Heat is therefore a critical component of the UK's strategy to meet its decarbonisation targets [3]. Recently the Business and Energy Secretary has announced a blueprint to deliver the world's first low-carbon industrial sector to cut emissions from industry, schools and hospitals [4] with geothermal energy notably absent from the 10 point plan.

Geothermal energy, in particular geothermal heat, has the potential to significantly contribute to the UK's Net Zero goals within a larger portfolio of energy solutions. Geothermal energy benefits include offering flexible and dispatcheable heat and power. A recent study by Durham Energy Institute has concluded that deep geothermal (>500m deep) energy resources can deliver around 100 years of heat supply for the entire UK [5].

The UK's geothermal market has historically been focussed on ground source heat pumps (GSHP) with mine energy as a developing interest. In 2018, there were 28,800 GSHP sites with a capacity of 520MWth (producing 936 GWh/yr) [7]. However, there are very few deep geothermal projects producing heat or power in the UK. Thus, this report focusses on the opportunity and challenges associated with deep geothermal energy (rather than other technologies such as GSHP).

Scope of the report

Ove Arup and Partners Ltd (Arup) has prepared this report as an independent consultant at the request of the REA in support of the renewable energy sector and to help identify the barriers and opportunities related to deep geothermal energy systems. As such, shallow geothermal projects, including mine energy, have been excluded from this study.

Drilling rig at the United Downs project in Cornwall
© photograph courtesy of Geothermal Engineering Ltd

ARUP

Introduction

The term deep geothermal refers to accessible heat resources derived from depths greater than 500m below the ground surface where heat can be used for direct-use space heating or industrial / agricultural processes.

Deep geothermal energy

Below ground, heat energy increases with depth towards the earth's core. The UK Government has adopted the term 'deep geothermal' to refer to below ground heat resources from depths greater than 500m. At depths greater than 1km the heat energy begins to be hot enough to be usable for direct-use space heating or industrial/ agricultural processes.

The UK has the skills to overcome the challenges associated with accessing the hot geothermal fluids deep within the ground. Deep wells are required, and these wells need to encounter not only geothermal fluids which are hot enough, but also at locations where the ground is permeable enough to sustain pumping of the fluids to the surface (and back to the subsurface). Nevertheless, there is significant potential for deep geothermal projects in the UK, particularly heat projects.

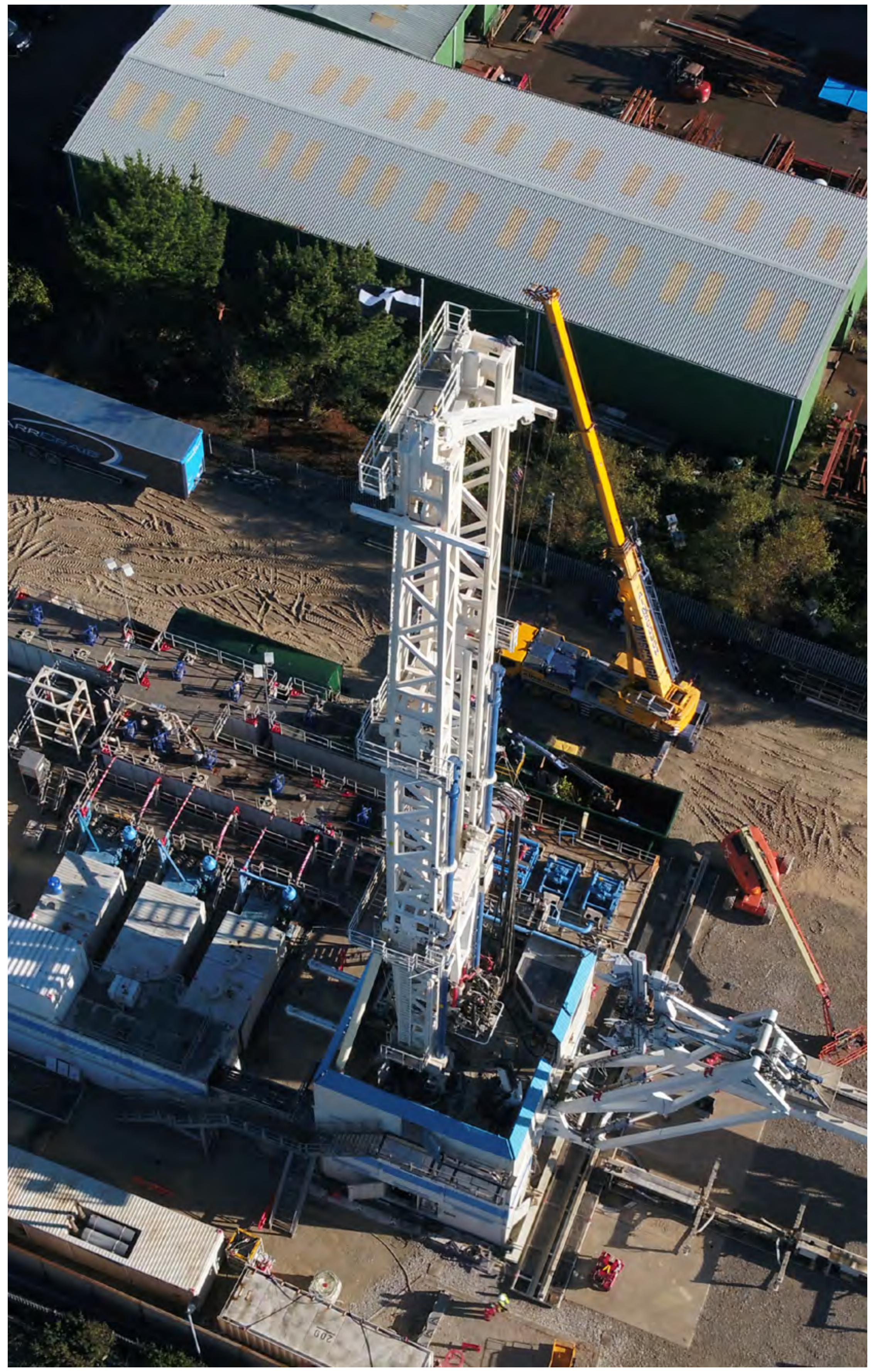
Geothermal power

The Durham Energy Institute has recently calculated theoretically available heat resource for the UK up to depths of 9.5km as 3.58 x 10^{10} TJ (c. 9.9 x 10^9 GWh) [8]. In certain geological settings the geothermal conditions are suitable for engineered geothermal systems (EGS) which can be used to access heat to generate power. With current drilling and power generation technology this is limited to areas of Cornwall, Devon, and possibly Cumbria. The total technical potential power that could be exploited by EGS technology is estimated around 222 GWe (GW electricity) at depths of up to 6.5km depth and 2,280 MWe (MW electricity) at 4.5km depth [8].

Geothermal heat

Many hot sedimentary aquifers exist in the UK in the Mesozoic and Palaeozoic basins such as those in Cheshire, East Yorkshire, Worcester and Wessex. These geological systems are ideally suited for heat projects using traditional geothermal methods because of the presence of potentially productive aquifers, even at great depth. New technology being developed in the UK is available which removes the requirement for a reservoir, which in turn increases the potential locations for geothermal heat generation significantly. The types of systems used to extract deep heat include the following:

- Deep geothermal doublets and new single well, closed-loop technology provide heating and cooling. A typical project could have a capacity of around 10 MWth feeding into district heating to supply heat for around 4,500 houses.
- Standing column wells (deep coaxial wells): could provide heat in areas not suited for well doublets (or where reservoir uncertainty and risk is significant) and in particular in locations where the geothermal gradient is greater than the UK average, subject to economic viability.
- Well conversions: There are several hundred oil and gas wells in the UK, some of which are no longer used or are towards the end of their economic life. These oil and gas wells could be modified and converted to provide geothermal heat using new technology being introduced into the market.



United Downs drilling rig and setup
Courtesy of Geothermal Engineering Ltd (GEL)

Introduction

This report is focussed on deep geothermal energy systems as indicated on the right of the diagram.

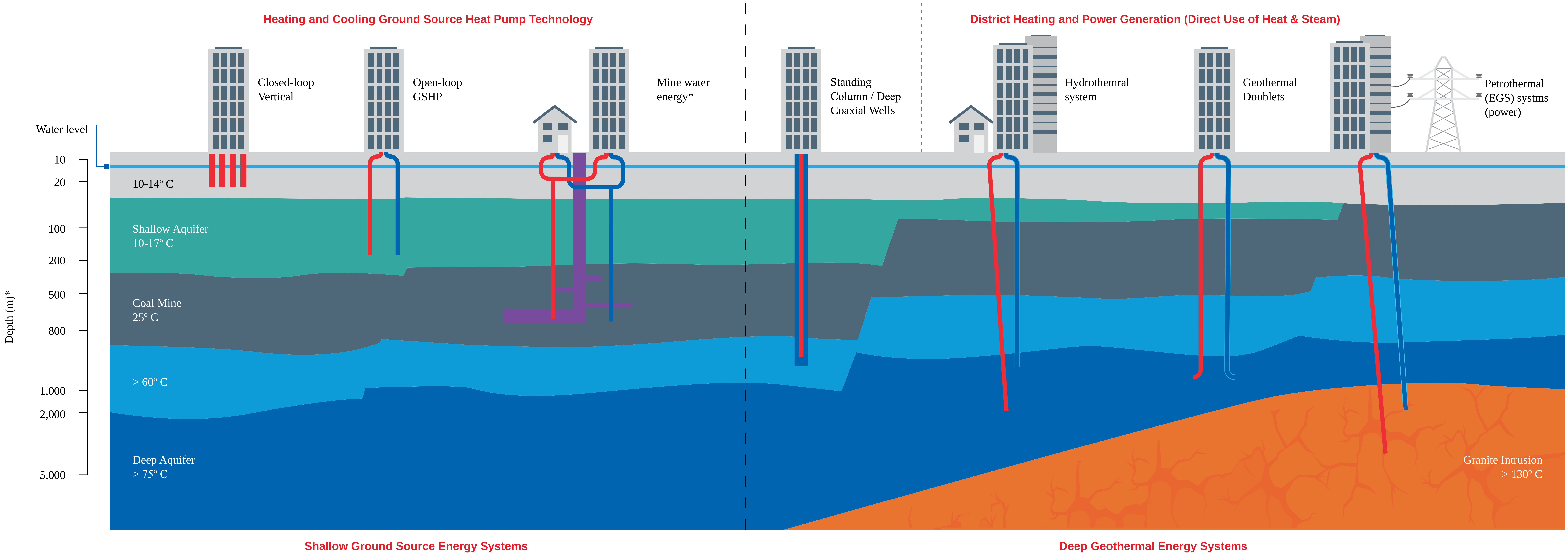


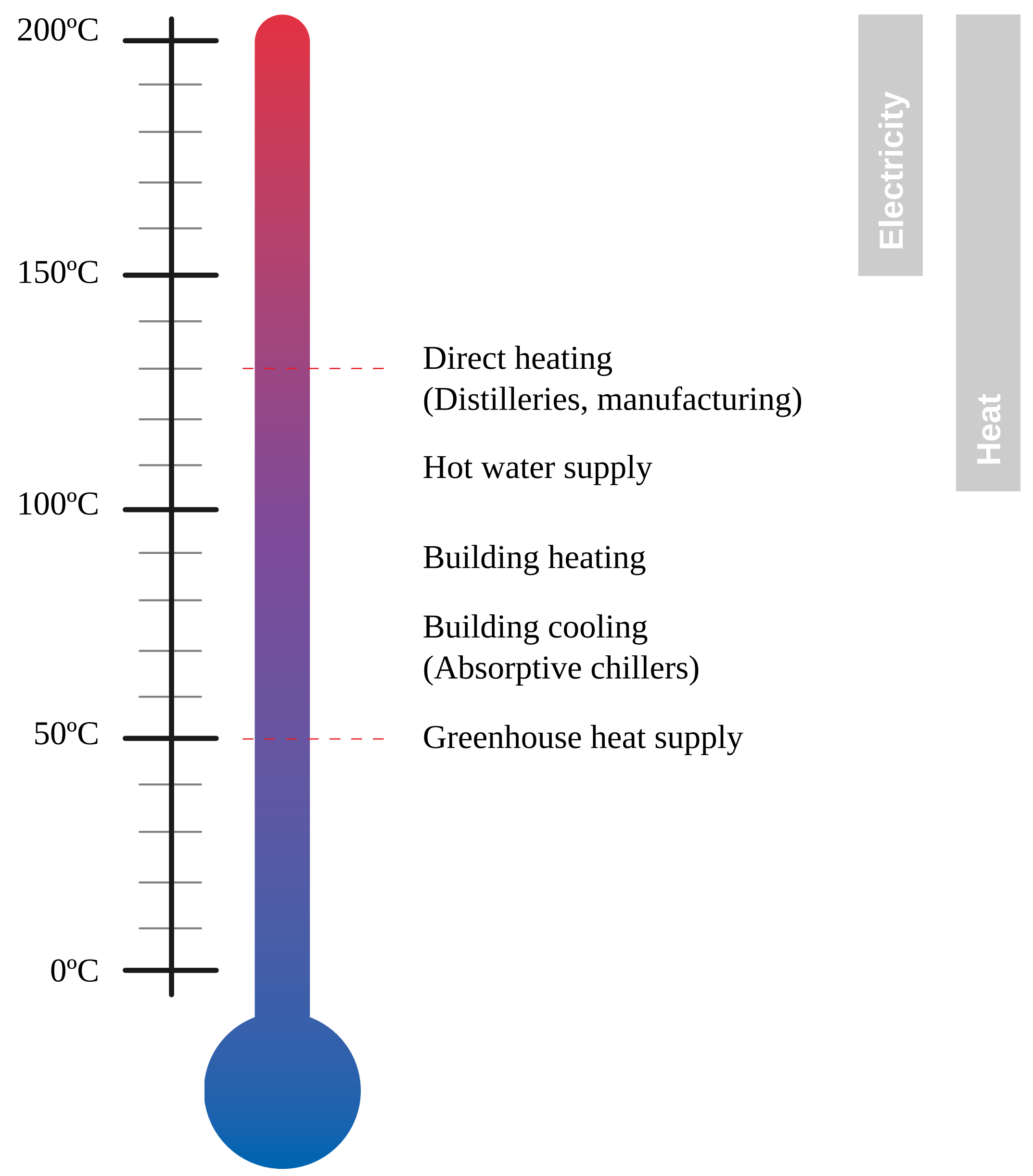
Illustration of geothermal project types

Modified from British Geological Survey © UKRI 2021

*** Note:** The mine energy depth is dependent on the depth of the mine workings but is not considered deep geothermal.

Introduction

Deep geothermal offers many benefits which can have positive local impact whilst contributing to growth of the UK economy as a whole.



Benefits of deep geothermal

Dispatchability	Deep geothermal heat can be provided on demand according to market needs.
Potential for integration with heat networks	This can aid a rapid decarbonisation of local grid networks, and therefore the UK as a whole.
Proximity to end users	Deep geothermal is a local source of energy which can be used by residents and businesses in the surrounding area.
Longevity and long-term operation	With the right regulatory regime deep geothermal offers an operational lifespan which is typically over 50 years.
Low visual impact	Deep geothermal uses less land than any other energy source and can be less visually intrusive than many other technologies.
Variety of temperatures and applicability	Deep geothermal is incredibly flexible and can offer a range of uses which can meet local requirements.
Thermal storage potential	Generated heat can be stored and used later at the appropriate time meaning that deep geothermal is an efficient source of energy.
Non-extractive	Deep geothermal is a renewable resource which protects the integrity of local environmental ecosystems
Aids the oil and gas transition	Supports the transferability of skills and jobs from the oil and gas sector.
Regional development opportunities	Although the whole of the UK will benefit from deep geothermal, the North of England, Midlands and South-West will particularly be rewarded with additional jobs and investment.
Helps meet the UK's net zero ambitions	Deep geothermal will help the UK meet the net zero and carbon reduction targets outlined by the Government's Energy White Paper, in addition to the Climate Change Committee's Sixth Carbon budget, the North Sea Energy Plan and Net Zero North West.

Introduction

In the UK, the benefits of geothermal energy are more geographically widespread for heat than for power. Geothermal has the ability to provide baseload and dispatchable energy, supporting the deployment of solar and wind technologies within a flexible energy system.

Global geothermal context

The UK has considerable deep geothermal potential for heating and significant opportunities for power. Geothermal energy can provide a baseload source of energy where the resource is suitable. Furthermore, deep geothermal offers dispatchable power offering flexibility. Geothermal is therefore one of the few renewable low carbon energy technologies able to support the deployment of variable energy sources within a flexible energy system.

Today over 15.6 GW of electricity (GWe) is produced with geothermal energy spread across 24 countries. The global geothermal industry is expected to reach around 18.4 GWe by the end of 2021 [9]. Overall, if all countries follow through on their geothermal power development goals, the global market could reach 32 GWe by the early 2030s (noting that the world's potential has been estimated to be greater than 200 GWe) [10].

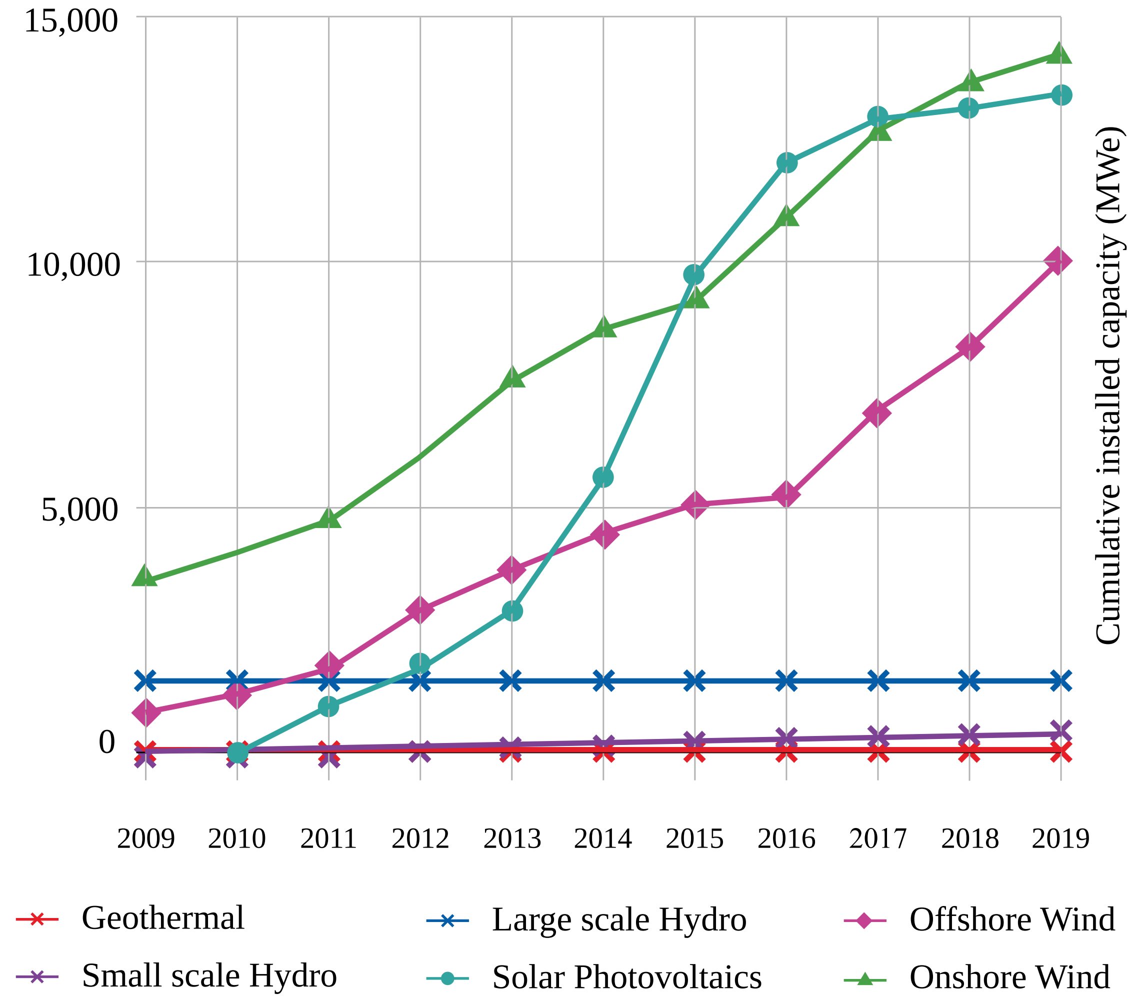
The UK has a relatively lower heat gradient in the subsurface (as compared to places like Iceland and Turkey, see figure above right). The UK has subsurface temperatures which are generally better suited to heating projects than for power generation.

Renewable portfolio context in the UK

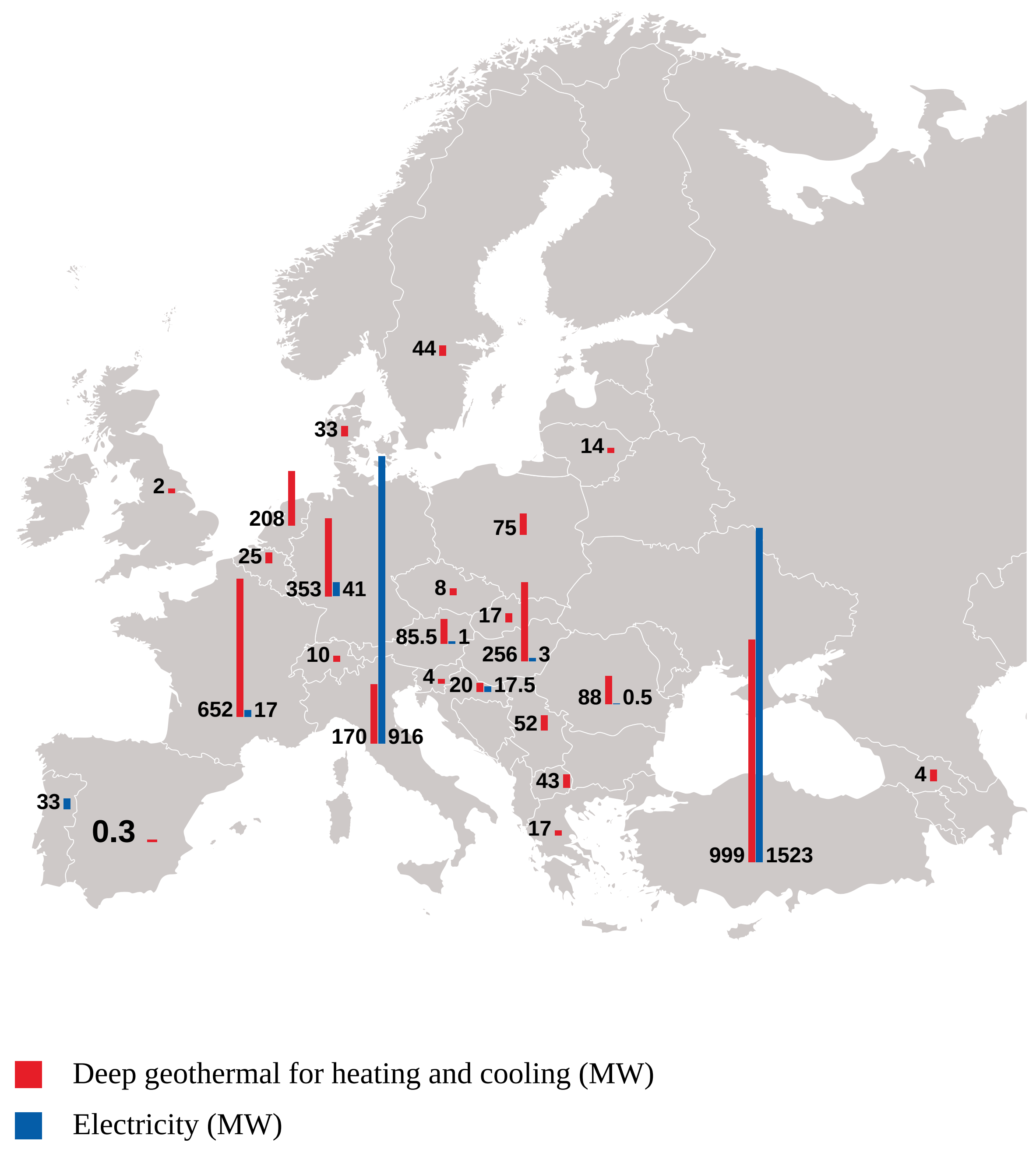
Within the last decade there has been a considerable increase in the development of wind and solar power. This is due to the low risk profile associated with these technologies and due to early government support (through demonstrator projects and feed-in-tariffs). The growth of wind and solar in the UK is shown in the image at right, which illustrates the benefits of government intervention of market growth.

Public Support and Environmental Impacts

Public support is a critical element to the success of the geothermal industry. The benefits of low carbon baseload renewable energy are clear. However deep geothermal does have the potential for adverse impacts. The potential for induced seismicity and land contamination exist and require careful management during construction and operation. However, these potential environmental impacts can be mitigated or reasonably minimised. Nevertheless, it is important that geothermal projects are developed appropriately and transparently with a focus on community engagement.



Comparison of renewable energy growth
The UK between 2009 and 2019 [12]



Heat and electricity capacity
Europe in 2018 [11]

Overview of the UK’s deep geothermal market

Deep geothermal opportunities exist across many areas of the UK where there is existing heat demand from cities, towns, and industry.

Deep geothermal energy in the UK

The Durham Energy Institue has recently estimated that deep geothermal could provide 91M GWh of heat and 2,280 MWe power to the UK [5,6,8]. If fully realised this would provide around 100 years of heat supply for the entire UK and 9% of England’s electricity demand.

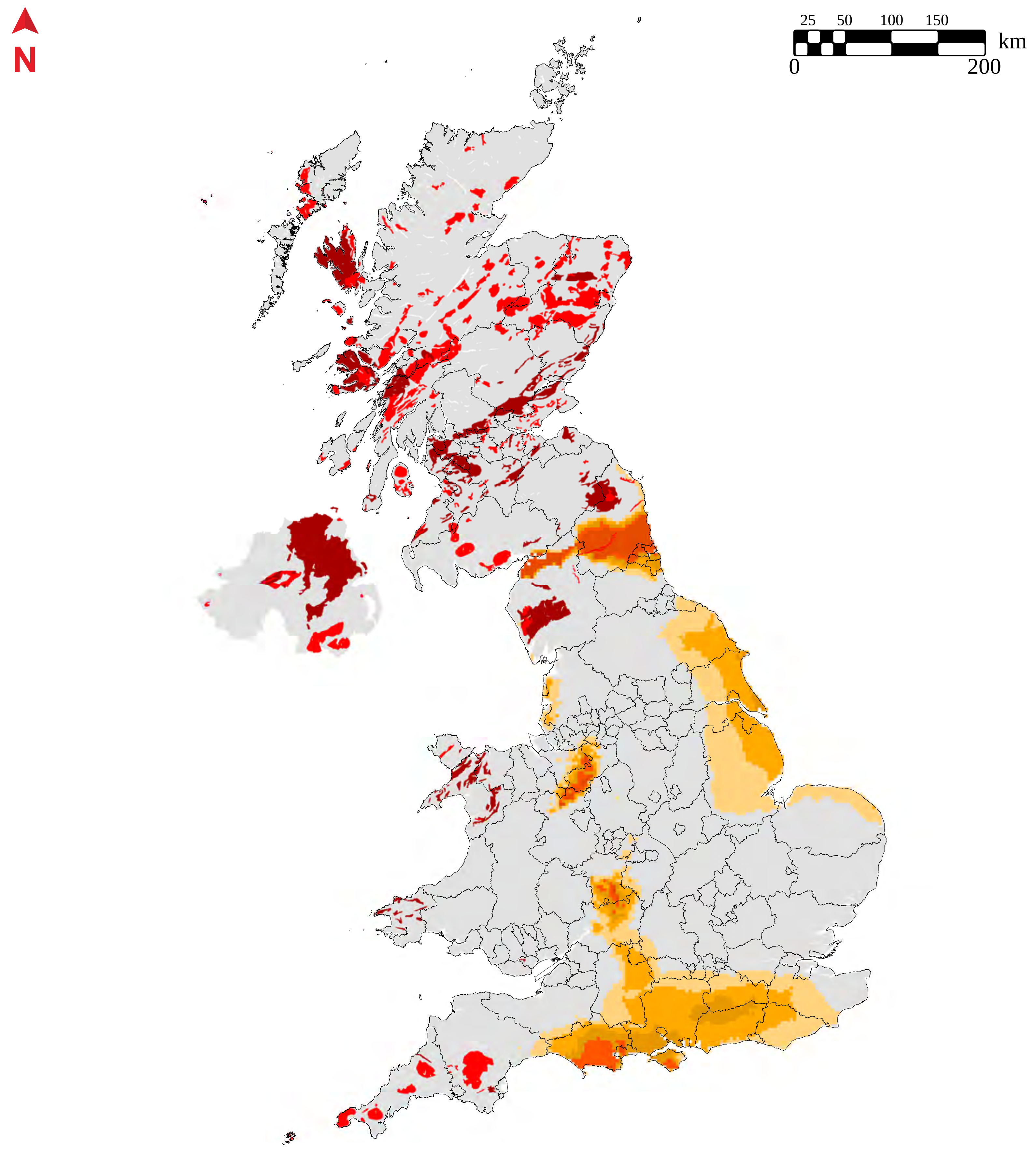
Recently, a deep geothermal electricity doublet has been constructed in Cornwall. The United Downs project is a £30M project, which includes a more than 5 km deep well with a temperature of 188º C at its base [13], was made possible through funding from the European Union (European Regional Development Fund). The project has an offtake agreement and grid connection of circa 4MWe. Two wells for geothermal power are also planned to be constructed at the Eden Project in Cornwall, which has also been made possible through grant funding from the EU (ERDF).

Whilst there is significant opportunity, geothermal is currently underutilised in the UK for heat where the Southampton district heating scheme is the only historical deep geothermal project. There are significantly more areas across the UK with the potential to provide deep geothermal heat. Therefore, the growth of geothermal energy in the UK is expected to be reliant on the ability to commercially develop deep geothermal heat projects.

Research

Critical research in the Weardale at Eastgate [14] has demonstrated not just heat potential but also high water flow rates from naturally fractured granites.

The working groups led by Newcastle, Durham and Oxford on repurposing onshore wells [15] has demonstrated how existing oil and gas infrastructure could facilitate the harnessing of deep geothermal energy.



Notes:

1. Mapped igneous provinces are based on the IHME15000_v12 from the Federal Institute for Geosciences and Natural Resources.
2. Plutonic and volcanic rocks are both formed from the cooling of magma and are both considered to provide potential heat sources for geothermal energy where conditions are appropriate (for example where radiogenic rocks are present and have a sufficiently overlying ‘cap rock’ layer).
3. Identified depth to hot sedimentary aquifers are based on BGS data.

Deep Geothermal Potential

Igneous provinces
- Plutonic rocks
- Volcanic rocks

Hot sedimentary aquifers
- Deeper than 2,500m
- 2,500m to 2,000m
- 2,000m to 1,500m
- 1,500m to 1,000m
- Less than 1,000m

Deep Geothermal in the UK

Deep Geothermal Energy Opportunities for the UK

Overview of the UK’s deep geothermal market

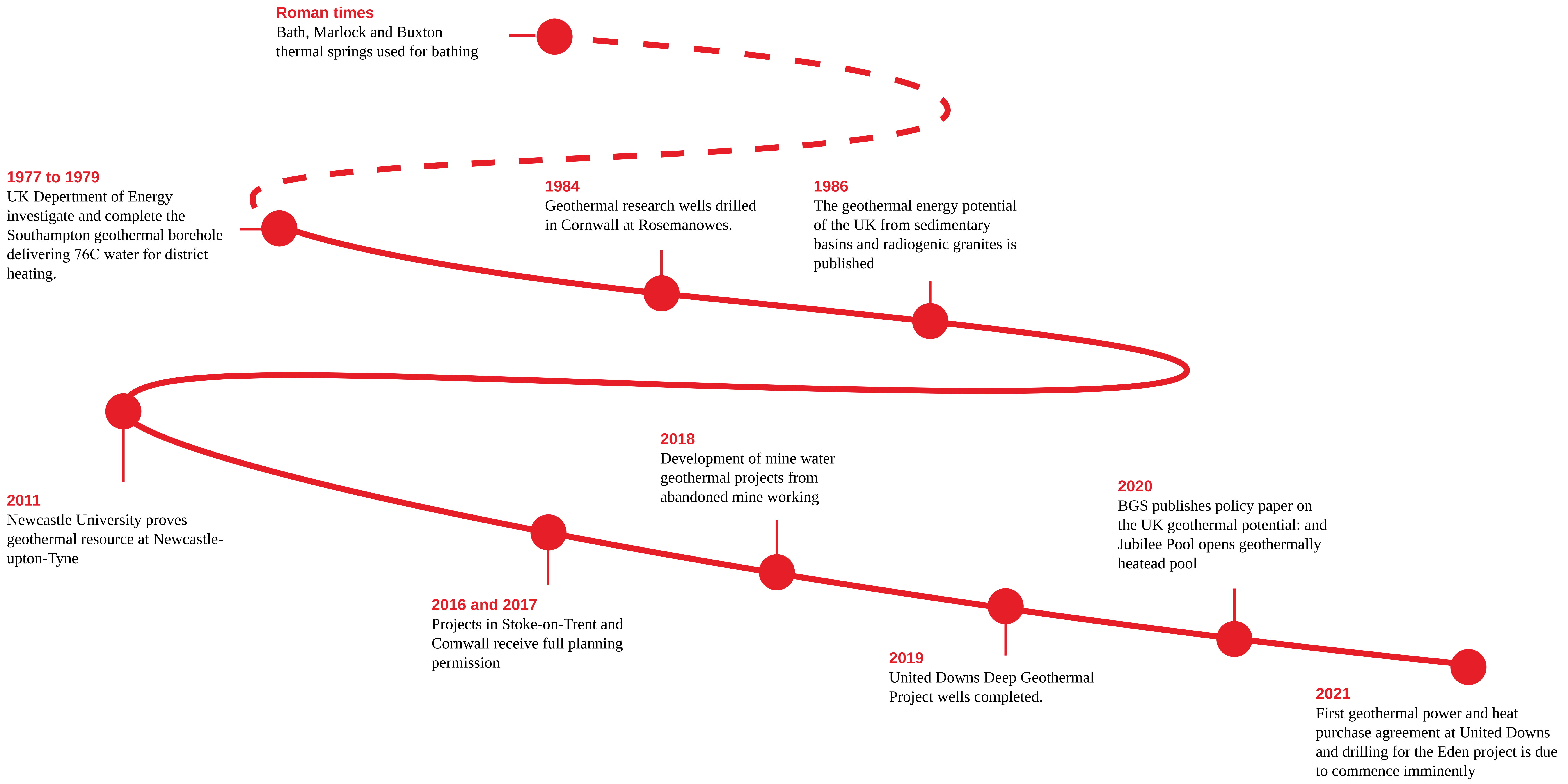
The UK has a long history with geothermal although exploitation of its resources has been slow.

UK deep geothermal progress

Despite initial research and investment in the late 1970s and 1980s, the uptake of deep geothermal projects remains very low in comparison to other developed countries.

In 2021, the UK’s first deep geothermal site, United Downs, signed a power purchase agreement (PPA), including heat produced at the plant. This marks a milestone to allow the sale of geothermal power in the UK.

History of the UK geothermal industry



Overview of the UK's deep geothermal market

Under favourable market conditions, the development of 360 geothermal heating projects by 2050 would result in job growth and carbon savings, while establishing a home grown source of sustainable heat.

How fast can geothermal grow?

Growth in deep geothermal projects is expected to continue to be slow without any government intervention / incentives, such as those used all over the world to accelerate growth for heat and electricity projects.

The Netherlands, Germany and France have all benefited from government financial support and risk-sharing to stimulate deep geothermal projects. The resulting project trends in these countries may provide an insight into possible UK growth with government support.

Heat project growth

In the Netherlands, deep geothermal projects significantly ramped up from 1 to 18 over a 10 year period [16]. Now there are at least 21 projects. These are mainly geothermal doublets with a depth of 2 to 3km and capacity of around 317 MWth, providing around 617 GWh of heat per year [17]. In Germany, there are 190 direct use (i.e. heat) geothermal projects with a capacity 342 MWth providing around 1,000 GWh [18]. While France currently has 74 plants providing 1,700 GWh heat [19]. Combined heat and power (CHP) plants and warmer temperatures at depth may account for the higher capacity in Germany and France.

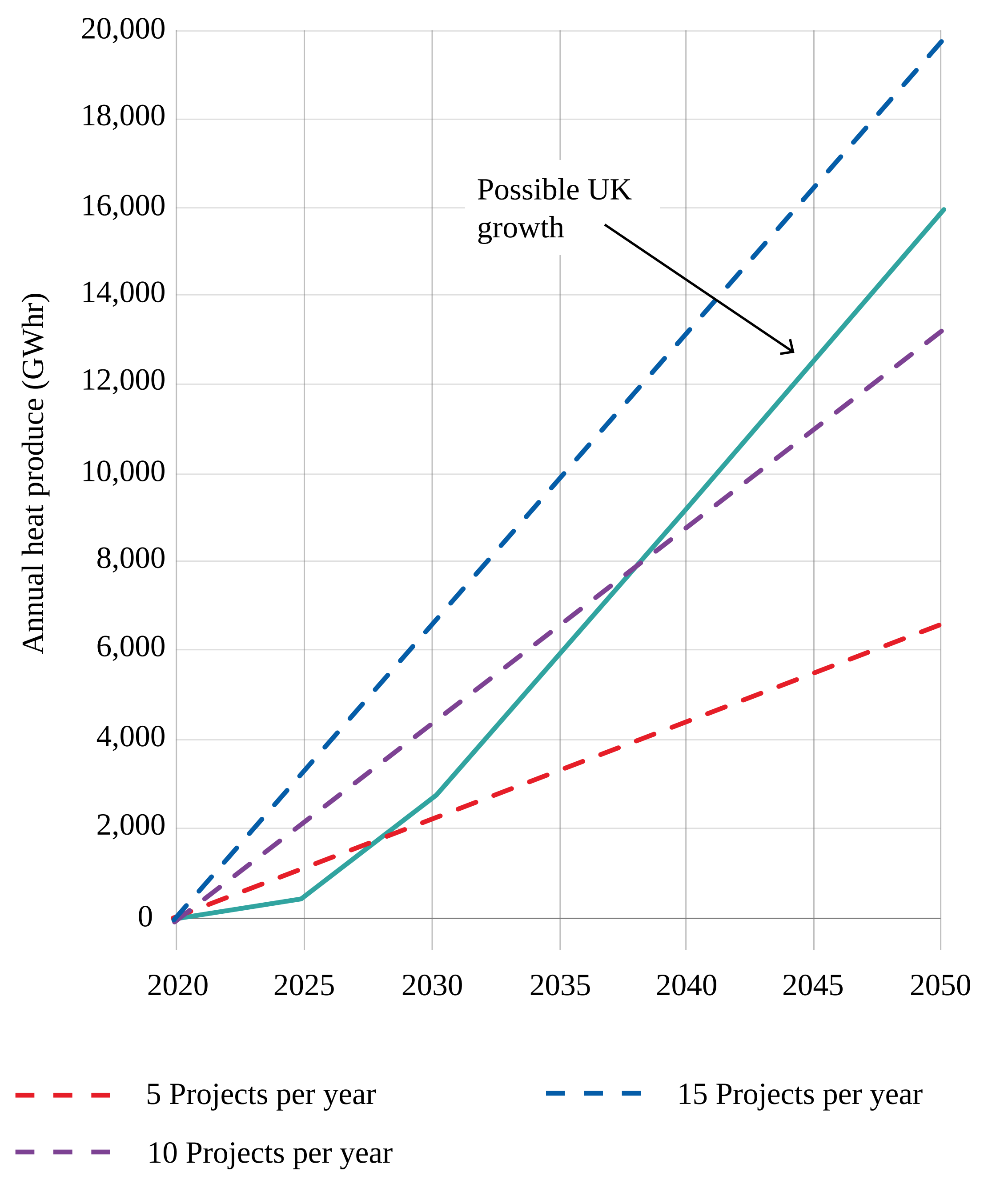
The Dutch government has a clear vision of the role of deep geothermal in their path to decarbonisation and a geothermal strategy for its development to 2050. This sets out the delivery of 10 new geothermal doublet projects per year by 2025, increasing to 20 per year to 2030 and 25 per year to 2050 with an ambition of delivering 700 projects by 2050 [20]. This strategy is linked to a long-term financial commitment from the Government in the form of long-term incentives / risk sharing commitments.

The UK has the capability and the resources to deliver projects at a rate similar to the Netherlands. On average 15 to 20 new oil and gas wells were drilled per year over the past 20 years (refer to page 20). Following initial ramp up, the UK could deliver 10 or more doublet projects per year (i.e. >20 wells per year). This growth rate would be expected to increase with time as the market further develops and the supply chain matures. By 2050, the Netherlands has a goal to exceed 100 projects at a rate of 25 projects per year from 2030 and has increased its incentives to further accelerate growth.

Arup has analysed several deployment scenarios based on current technology to explore the socio-economic benefits of deep geothermal energy (see figure below). If the UK can meet a similar target of 360 projects by 2050, this would translate to delivering 15,000 GWh of heat per year. A lower rate of growth of 5 projects per year would result in the generation of around 1,500 MWth of heat capacity providing around 6,750 GWh of heat per year. None of these scenarios are likely without policy action.

In any case, the growth of geothermal heat projects would be expected to be predominantly through the construction of geothermal doublets (i.e. two deep wells).

Within the portfolio of geothermal projects, there would also be the use of deep standing column wells (referred to as coaxial wells) and converted oil & gas wells for geothermal use. However, with the majority of existing oil & gas wells in remote locations, the ability to use these assets would require nearby heat users as well as regulatory agreement.



Potential growth in the geothermal market for the UK

Overview of the UK’s deep geothermal market

The potential for heat across the UK is not constrained to isolated areas. Within England, the northwest and northeast are particularly suited for heat.

Electricity projects

Compared to the potential for heat, the UK’s potential for geothermal electricity is still significant. If 10 power projects were delivered by 2050 this could provide around 50MWe (c. 200 to 300 GWh of electricity per year).

Short term growth

There are currently a variety of places across the UK (in Cumbria, Cheshire, Greater Manchester, Tyne and Weir, Staffordshire, Hampshire and Dorset, Humberside, and Cornwall) which have both good geothermal prospects and existing heat users. The development of 10 to 12 projects over the next 5 years would lead to 500 to 600 GWh of heat per year providing heat to the equivalent of up to 50,000 homes with investment in the order of £10M to £15M for each project.

Similar to the long-term projections presented on page 13, the ability to achieve these benefits will require some level of governmental support.

Carbon savings from heat

Based on the UK Government’s methodology [21, 22] for estimating carbon benefits, it is possible to achieve carbon savings of around 1M tons per year by 2050 if 100 heat projects are operational. If 10 to 12 projects can be developed within the next 5 years, a carbon savings of up to 80k to 100k tons per year can be achieved.

Potential to development

By 2025 there is potential to develop 10 to 12 projects in areas such as Northumberland, Durham, Cumbria, Cheshire, Greater Manchester, Tyne and Weir, Staffordshire, Hampshire and Dorset, Humberside and Cornwall where deep geothermal potential is high.

Projects in the UK
10 to 12 projects

CO_2

Carbon Saving
Up to 80k to 100k ton carbon saving annually

Heat in homes
Equivalent heating for up to 50,000 homes

Heat
500 to 600 GWh heat

Overview of the UK’s deep geothermal market

A broad range of industries, as well as the residential sector, can benefit from directly using deep geothermal heat.

UK geothermal heat users

The UK demand for heat correlates well with the deep geothermal resource. Deep geothermal opportunities are of growing interest for many industries in the UK.

District heating

The heating of buildings presents a major decarbonisation challenge. Geothermal heat is a viable zero carbon alternative to heating as compared with gas and other fossil fuels. Further detail on case studies can be found in a 2018 publication by BEIS [23]. District heating networks linked to a deep geothermal plant could be utilised for:

- Net-zero estates & retrofit – A 10 MWth capacity geothermal doublet could provide heat to around 4,500 homes in a district heating network.
- Hospitals, Schools, Universities – A 10 MWth capacity project would supply much of the heating requirements for a given site, in particular larger universities and hospitals.

Manufacturing

The manufacturing industry is increasingly interested in investigating the potential for geothermal to provide a sustainable, low carbon and cost effective alternative for heat and cooling, in a move away from gas powered heating. The Janssen Pharmaceutical plant in Beerse Belgium is an example of how geothermal heat production is feasible at an industrial scale with government support provided.

Process heating

Pre-heating for other processes and greenhouses.

Green Distilleries | Green Whiskeys

The number of new distilleries registered in 2019 translated to a 22% increase compared to the previous year, as numbers reached at least 422 in the UK, up from 361 in 2018. The UK Government is already committed to help decarbonise UK distilleries, including the whisky sector.

In addition, the United Downs geothermal power project has partnered with a rum distillery to provide the distillery with the heat from the geothermal power plant.

Airports & Enterprise Zones

There are over 40 airports and 24 enterprise zones around the UK, some of which top the list of the busiest airports in Europe. With an increasing public focus on the carbon impact of the aviation industry there is an opportunity to offset carbon by incorporating geothermal projects into airports during retrofits or expansions. In addition, airports can consider offsetting their carbon use through funding of offsite geothermal projects for other end-users.

Spas

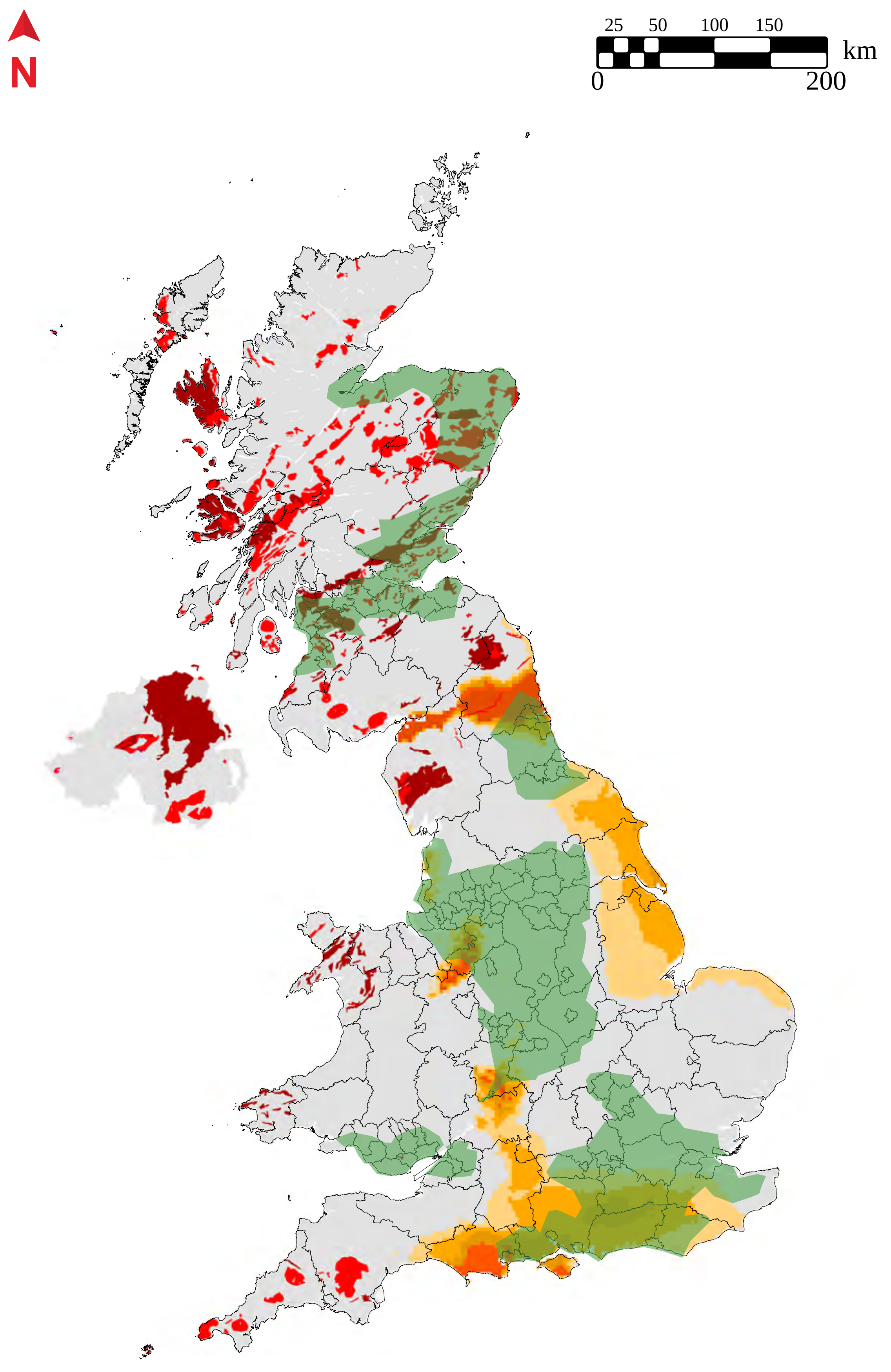
Pools and spas heated by geothermal resource have been used in the UK since Roman times and are gaining popularity. Jubilee Pool in Penzance is one UK example* and there are numerous international examples.

*Note that while a deep geothermal well was originally planned for the Jubilee Pool, a suitable shallow aquifer was encountered during drilling, which was successfully adapted for use with a ground source heat pump.

Deep Geothermal Potential

Igneous provinces
- Plutonic rocks
- Volcanic rocks

Hot sedimentary aquifers
- Deeper than 2,500m
- 2,500m to 2,000m
- 2,000m to 1,500m
- 1,500m to 1,000m
- Less than 1,000m
- Heat demand



Heat demand and areas of heat potential
Heat demand based on Gluyas et al [5]

UK Geothermal Supply Chain

A UK supply chain can be established quickly by utilising existing skills and experience from the oil & gas sector supplemented by the construction and manufacturing industries.

Supply chain

The supply chain for development and operation of a typical deep geothermal project is set out in the table to the right. Many elements already exist in the UK and can accommodate new deep geothermal projects. However, there are opportunities to facilitate skills transfer from the oil & gas sector and to increase the available supply.

There are no current supply chain constraints for the development of UK deep geothermal resources. If required, technologies can be imported from countries with mature geothermal markets. However, reliance on the use of overseas vendors could lead to a missed opportunity in the UK for utilising existing knowledge /skills from the O&G sector and developing and enhancing our own supply chain.

Key supply chain activities for deep geothermal projects

Exploration
- Desk based surveys
- Remote Sensing
- Structural geology field investigations
- Geophysics & geochemistry
- Hydrogeological / geothermal reservoir modelling
- Economics analysis
- Community engagement
- Slim-hole / gradient test drillings
- Seismic hazard assessment and monitoring

Planning
- Well design
- Power plant / energy centre
- Health and Safety
- Planning application
- Environmental and regulatory approvals
- Community engagement
- Contractor procurement

Well field development construction
- Site enabling works
- Drilling
- Hydraulic stimulation (if required)
- Pumping test
- Power and / or heat plant / energy centre construction
- Steam gathering system and substations, connection to grid (if a power plant)
- Construct infrastructure
- Health and Safety
- Community engagement

Operation & maintenance
- Start-up commissioning
- Operations and monitoring
- Maintenance, refurbishments, workovers, and makeup well drilling (if required)

UK Geothermal Supply Chain

The complex nature of geothermal projects means that highly skilled jobs are required and offers an opportunity for transfer of skills from the oil & gas sector. Deep geothermal could create over 30,000 jobs by 2050.

Jobs

Geothermal projects create jobs throughout all stages of the supply chain. The number of jobs created is proportional to the size of the project.

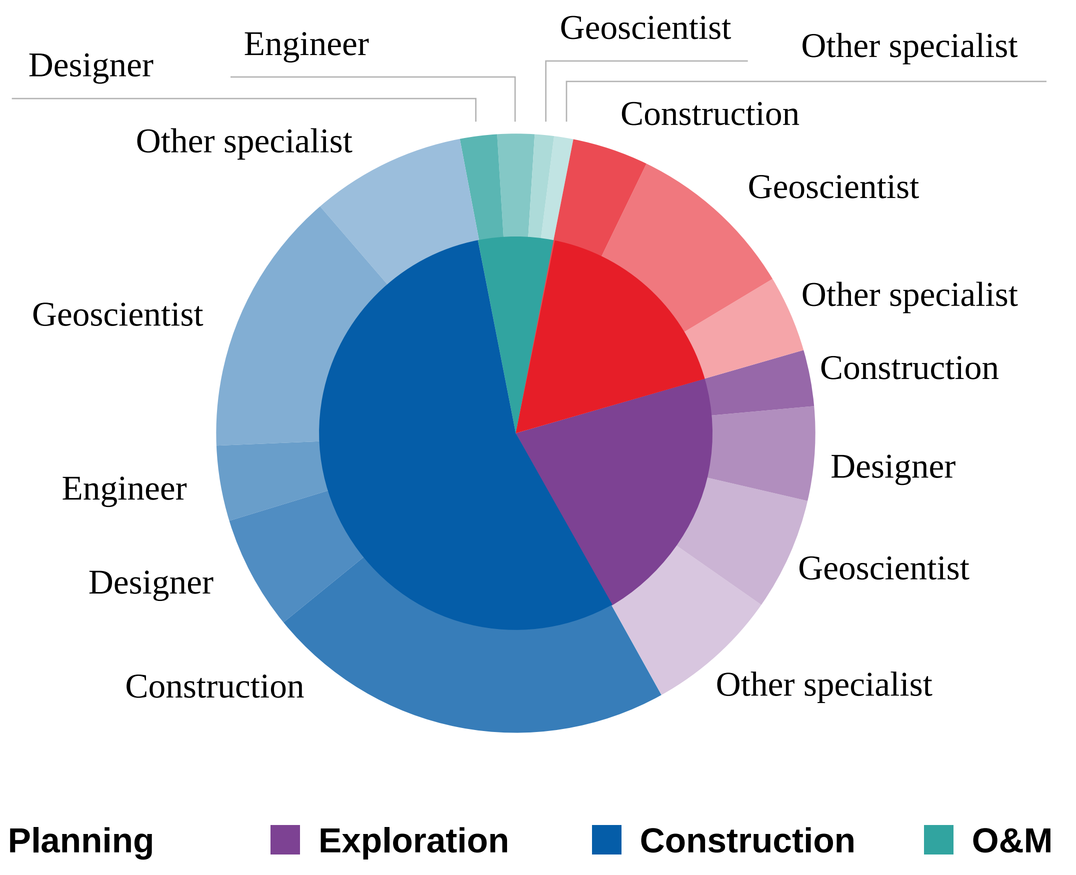
In countries with developing / mature geothermal markets (for example Germany) a geothermal heating project can create up to 30 direct jobs and an electricity project can create 100 jobs, many of which are highly skilled. Experience and skills in the oil & gas sector are directly transferable, in particular exploration, planning and well ield development. Examples are provided in the table to the right.

Jobs required for geothermal projects

Type	Description	Role
Geoscientist	Specialist roles involved in exploration and project development phases.	Geologists, geophysicists, geochemists, GIS specialists, drilling and reservoir engineers.
Designer	Skilled specialists required throughout planning, construction and operational stages.	Civil, mechanical, chemical, electrical designers, HSE specialists.
Engineer		Civil, mechanical, chemical, electrical engineers, operations & maintenance technicians.
Construction	Mix of skilled professionals and labour, including many roles transferable from the O&G sector.	Drilling & related service crews, drilling support services, construction services and labour, waste management specialists, skilled machinery operators, drivers.
Other specialists	Other roles will be needed to deliver geothermal projects.	Lawyers, economists, planners, PR and community relations, finance, administrative, marketing and sales professionals.

Direct jobs

Direct and indirect employment will be created in areas such as exploration, construction, operation & maintenance, planning, and research. Whilst exploration and planning phases can be short term for any single project, deep geothermal projects are generally long-running businesses due to long-term agreements between developers and purchasers. In addition, once the market becomes de-risked from an investor's perspective, project development professionals will move from project to project (similar to the construction industry).



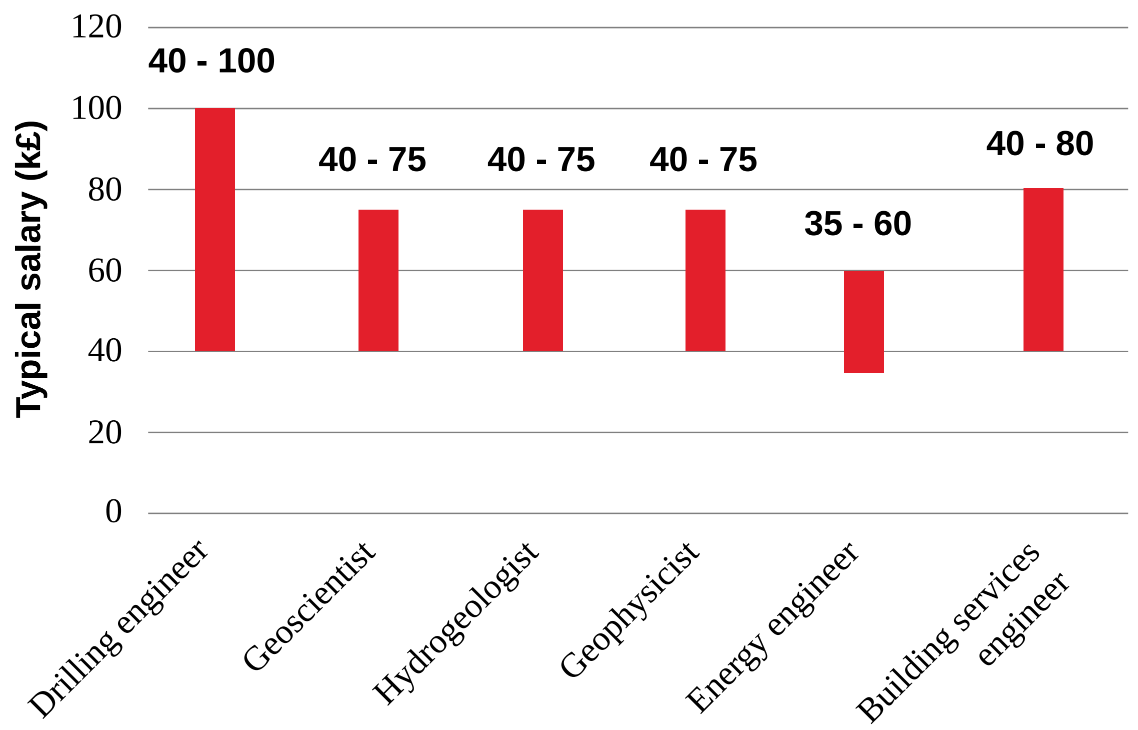
Direct job for a typical deep geothermal project

UK Geothermal Supply Chain

The UK could produce the materials and parts required for deep drilling, producing jobs in the short term with an opportunity for export in the long term.

A typical salary for direct geoscience jobs ranges between £40,000 and £80,000 but may be higher depending on the project complexity and expertise sought [24].

Salary in the UK



Indirect jobs

Indirect jobs will come from industries that supply materials and services to the developers of geothermal projects including:

– Manufacturing

– Drilling fluids and parts

– Haulage

– Utilities and district heating installation

– Building retrofitting / upgrades.

In the Netherlands at least 2 to 3 indirect jobs have been estimated to be created for every direct geothermal job [20].

Job creation

360 projects by 2050 could create over 10,000 direct jobs and a further 25,000 indirect jobs. Many of which could be transferred from the oil and gas sector.

Manufacturing

Steel casing is required to drill and line the boreholes. This is currently mostly produced overseas, mainly in China. Significant quantities of steel casing required for deep geothermal projects could stimulate supply from steel producers in areas such as Sheffield, and offset some of the forecast decline for steel from the O&G sector [25]. 360 projects by 2050 could require around 1,900 km of steel casing plus other materials such as drill bits (for example 38 drill bits were needed to drill the two recent United Downs boreholes [13]).

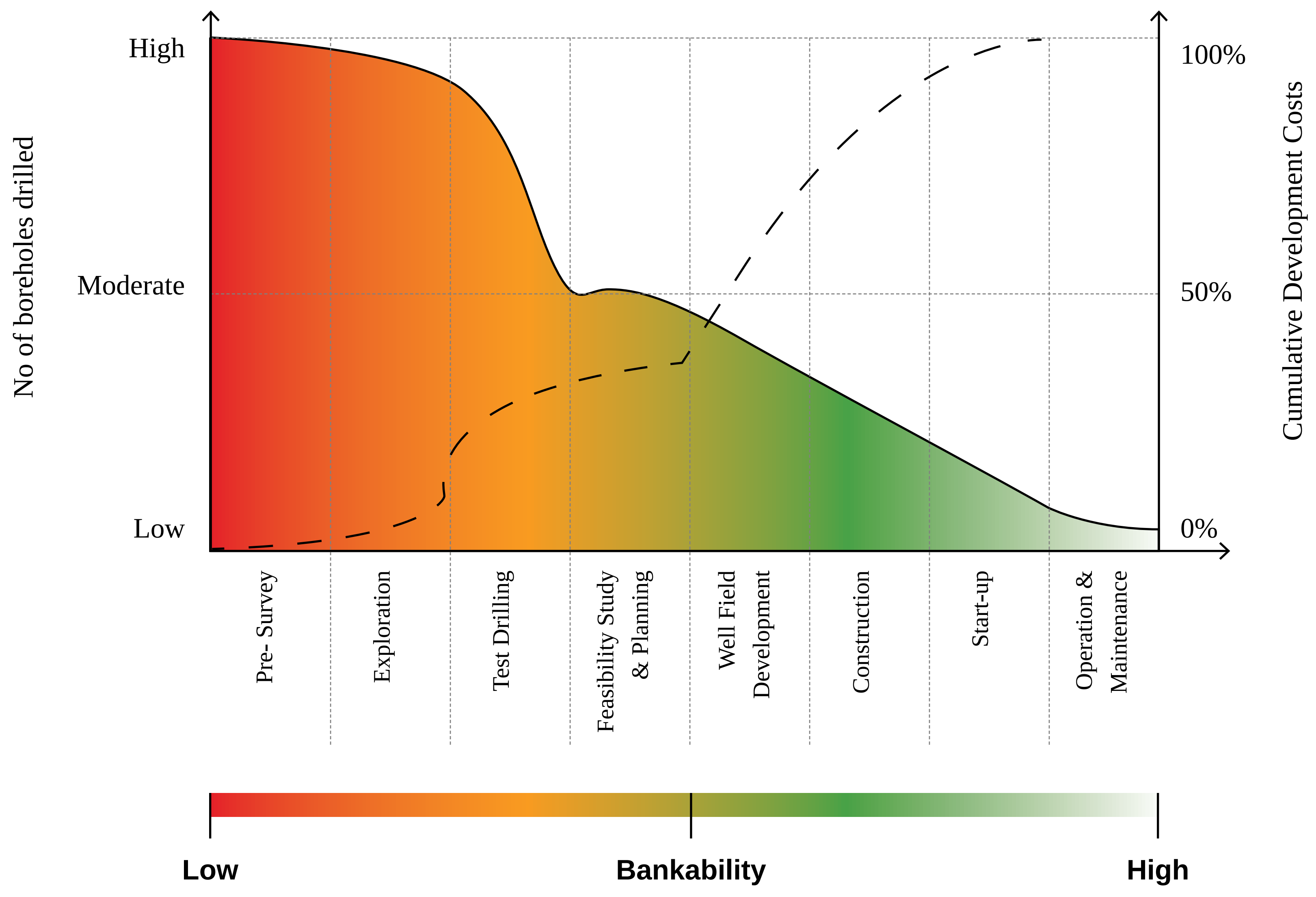
High quality manufactured specialist equipment such as drill bits and well valves could be designed and produced by the UK engineering industry.

Heat pumps could be used to boost heat in certain projects. High temperature heat pumps, heat exchangers and district heating network pipework could be designed and manufactured in the UK.

Steel tri-cone drill bits with tungsten carbide inserts used for drilling the United Downs boreholes
Courtesy of GEL

Getting the UK "Geothermal Ready"

Government support for early stage technologies will unlock private capital, support the development of the industry and help reduce costs to consumers over time as has been demonstrated with wind and solar.



Deep geothermal risk profile

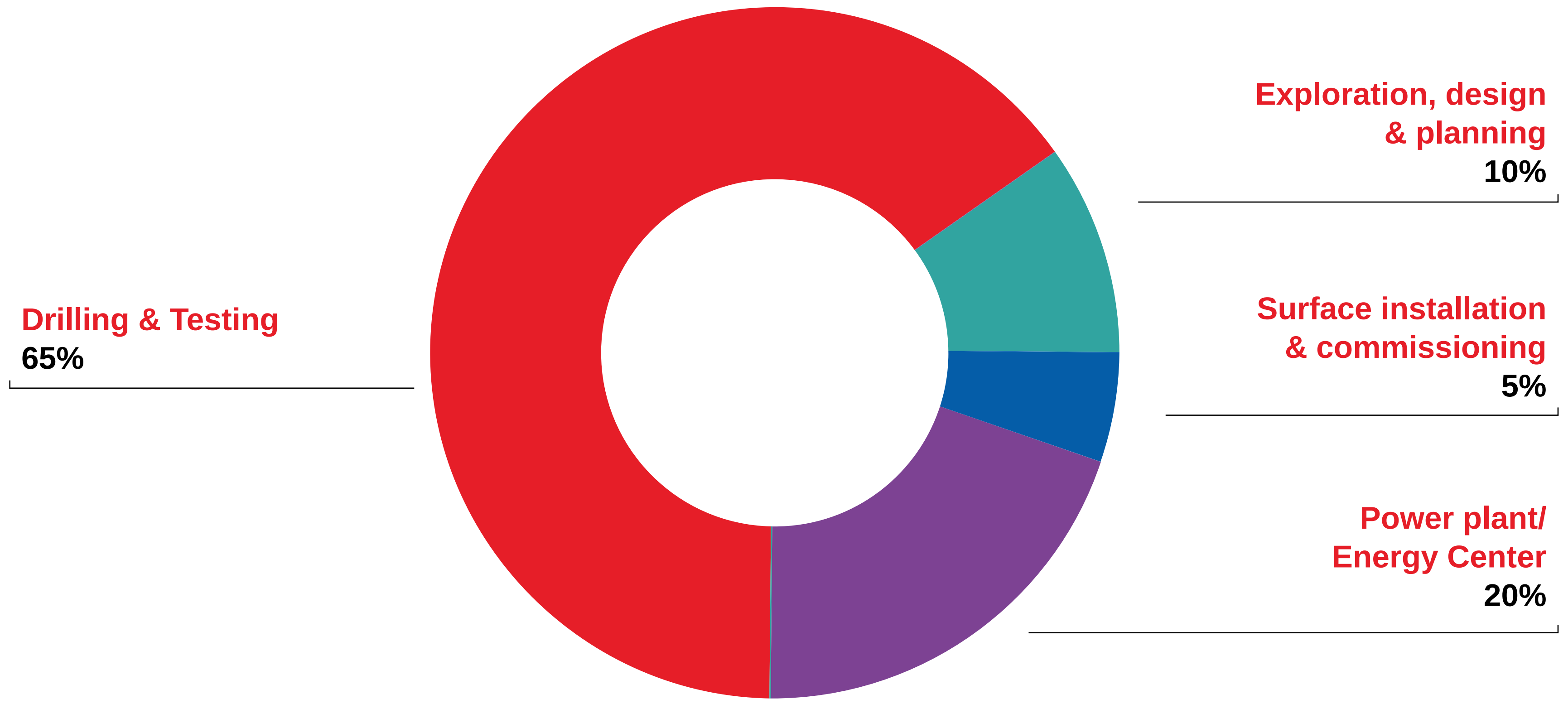
Deep geothermal projects have a higher risk in early project stages due to the need to prove the geothermal resource at a project level (largely related to accessing sufficient flow of fluid from the reservoir). A risk profile for a typical geothermal project is presented above. The graphic illustrates that only after initial investment for drilling, and the resource is proven, will the investment risk be reduced.

As has been proven throughout the world, as the number of projects grows, the actual project risks are better quantified, leading to improved confidence for investors. Once this 'critical mass' of projects are in place, geothermal projects will increase at a rate appropriate to the market conditions.

Typical cost breakdown

The capital expenditure (Capex) for deep geothermal heating projects varies based on the number and depth of the boreholes. However, costs typically range between £2M to £4M per MWth of heat capacity. Drilling and testing comprise the majority of this cost (between £1.6 to £1.8M per km depth, for 1 to 2 km deep wells) and can be greater where directional drilling is required. The remaining costs (as indicated below) relate to heat plant, exploration and planning, and surface works. Installation of pipework e.g. for a district heating network are not included in the figures below but UK benchmarks suggest cost of around £1k to 5k per m for materials and installation (in-house data).

Electricity projects will incur additional Capex related to the additional power generation equipment required and grid connection (amongst other aspects).



Costs for a typical geothermal heating project

Arup project experience

Getting the UK “Geothermal Ready”

The timing is right to accelerate deep geothermal in the UK by building upon experience and the lessons learned from countries with mature geothermal markets.

Technology development and cost reduction

Parts of a UK geothermal supply chain exist but are not coordinated because there are currently very few UK deep geothermal projects. The oil and gas supply chain in particular could easily be modified to support the requirements for deep geothermal well installation.

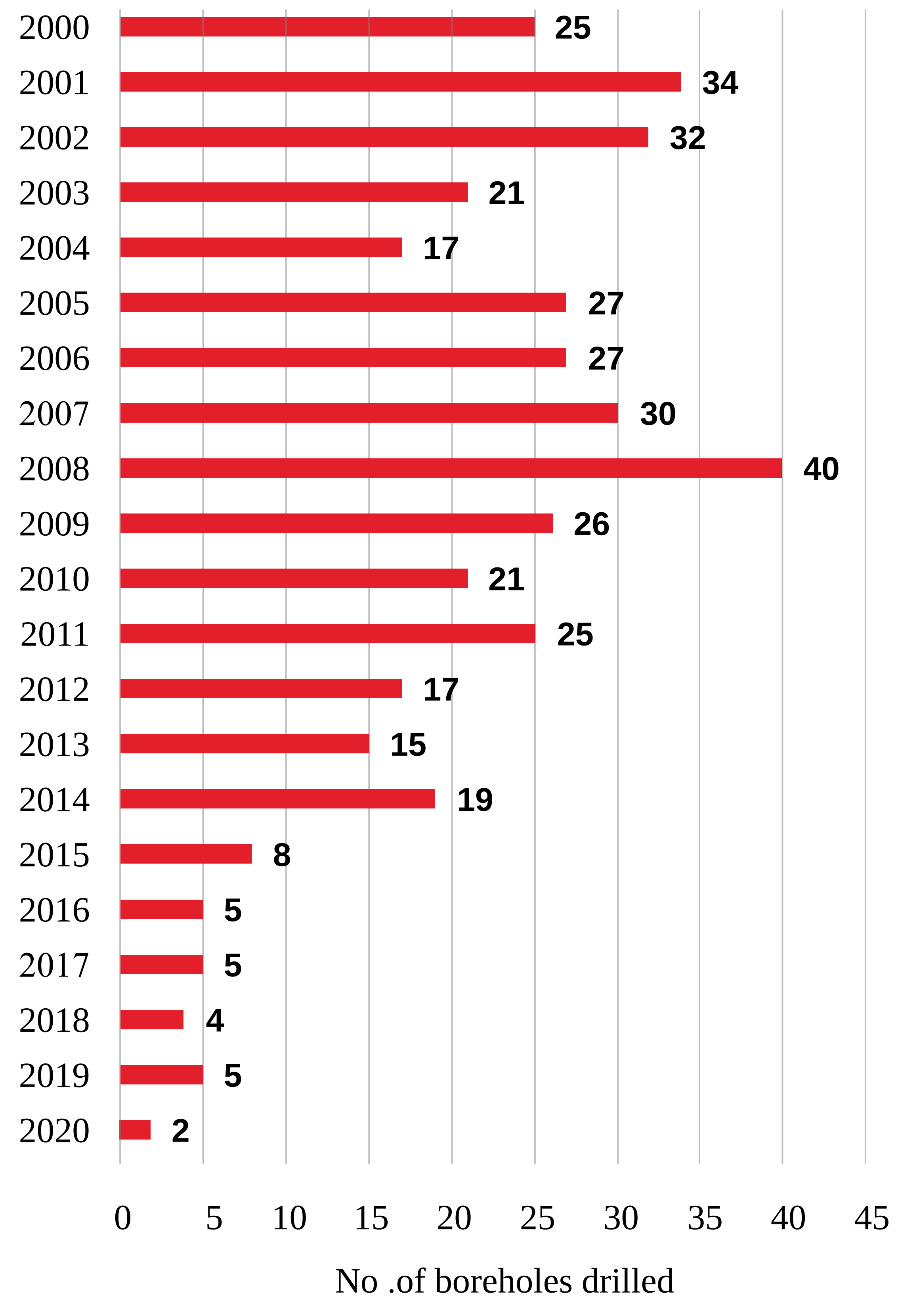
Strengthening the supply chain and the resource pool for geothermal projects will ultimately reduce the cost and improve the appeal of these projects for developers and private investors. Crucially, the cost of early development stages including the initial site wells will reduce as the supply chain matures.

There are currently 4 oil & gas drilling rigs with capability to drill to the depths needed for deep geothermal heat (typically between 1km and 3km deep). However 4 rigs is unlikely to be enough to achieve the target of 360 projects by 2050. A reduction in demand for / drilling of new oil and gas boreholes in the UK means that drilling companies are unlikely to invest in additional drilling equipment and would need reassurance that deep geothermal projects justify their investment. Until that time, additional rigs will be sourced from mainland Europe or elsewhere.

Benefitting from “lessons learned”

Lessons learned in geothermal projects in Europe and further afield can be applied to new UK projects to increase their efficiency and reduce costs across all parts of the supply chain. In addition, the UK will also develop improvements through innovation which can be applied to other projects including exporting knowledge overseas.

Once capacity has been developed within our borders, the UK has the potential to become a world leader in deep geothermal heat projects, building on the success of the record breaking United Downs deep geothermal power project in Cornwall.



UK onshore oil and gas boreholes drilled since 2000

UK OGA [26]

United Downs, Cornwall

The United Downs project is the deepest geothermal borehole in the UK drilled to around 5.3km below ground level. This borehole utilised specialist equipment and machinery and a highly skilled team to deliver. The experience developed is directly transferable to other deep drilling projects worldwide.

Getting the UK “Geothermal Ready”

With the end of the Non-Domestic Renewable Heat Incentive (RHI) the UK is no longer providing any incentive to develop deep geothermal heat.

“The European experience has shown that government aid … can substantially advance geothermal exploration leading to a marked increase in the uptake of geothermal energy”

BGS, 2020.

Reducing the risk profile

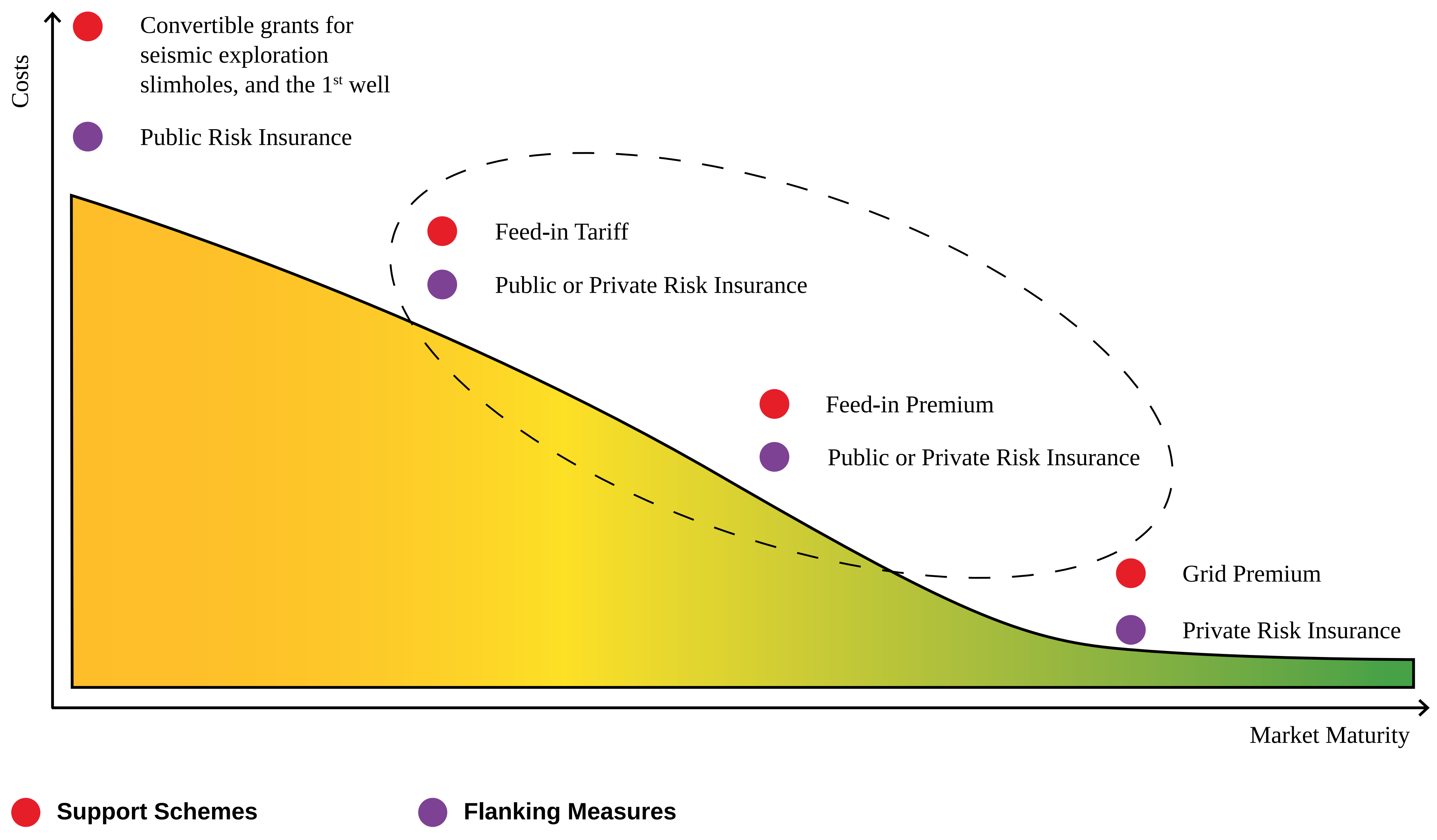
Geothermal incentives vary by country and therefore direct comparison is difficult. A summary of the incentives adopted in France, Germany, the Netherlands and Switzerland is provided in a recent BGS study [6]. As an example, the Netherlands has invested around €3M per MW capacity between 2012 and 2020

Exploration, design and drilling form a major component in deep geothermal projects, and project risk remains high until at least one borehole has been drilled and tested. Government interventions have been successful in stimulating interest and growth of deep geothermal projects, as is highlighted in Europe [6].

Interventions are not necessarily long term commitments. As projects grow so does the supply chain, costs will ultimately reduce and confidence in the potential of a project to meet financial goals will increase. Germany is an example of a very mature deep geothermal market which is now self sustaining. The market in Germany has created more than 22,000 jobs and provided economic stimulus of €1.5Bn in 2019 [6].

The UK’s existing Renewable Heat Incentive (RHI) has a dedicated tariff for deep geothermal heat. However, the application window for RHI ended in March 2021. There is currently no further support available for the deep geothermal sector leaving a gap in support for geothermal projects. This will likely have a significantly detrimental effect on the development of deep geothermal in the UK.

Risk sharing mechanisms (see flanking measures in the figure) mitigate geological risk which is a key hurdle for investors and communities interested in development of deep geothermal schemes.



Example of interventions used to mitigate deep geothermal project risk at different stages of market maturity

Source EGEC [25]

International Geothermal Opportunities

By developing its own deep geothermal expertise, the UK can support geothermal growth outside of its borders.

Export of services and experience

Innovation

The UK deep geothermal resources occur in a range of geological settings, some of which are unique to the UK or very complex. This complexity will drive UK innovation to develop methods and equipment which maximise the potential and longevity of the resource. The UK has a long history of innovation in the deep geology sector and can build on this reputation to export services to other countries, in particular to those with similarly modest geothermal resource. One example of recent innovation is the co-production of lithium from the geothermal brine in Cornwall.

Drilling and specialist equipment (valves / drill bits etc) expertise

Despite the deep geothermal market in the UK being in its infancy, a main component of these projects are the drilling of boreholes for which the UK has a wealth of knowledge and experience. This expertise includes 40 years of deep oil & gas drilling as well as hundreds of years of mining experience. The UK already has developed ultra-deep drilling expertise that needs to be adapted for geothermal.

Specialist components

There is a need for high quality specially engineered parts required throughout all stages of a geothermal project (i.e. drill bits, valves, casing, drilling rig and equipment, compressors, power packs, blow out preventer, well heads, pumps). The UK reputation for quality could be used to establish a market for the export of these components to countries currently developing or looking to deliver deep geothermal projects.

The UK can also draw upon experience of more than 20 years of the manufacture and installation of heat exchangers and ground source heat pumps.

Digital engineering and consulting

Automation is commonly used in the monitoring and operation of geothermal power plants and district heating networks. UK geoscientists were instrumental in developing seismic monitoring systems for deep drilling and these types of automated monitoring systems could be applied to new situations.

Financial expertise of the UK

Many investment groups and the oil & gas sector are investing in geothermal projects. UK expertise in deep geothermal would support the technical due diligence for transaction of existing projects, funding for new projects. This application of the UK’s financial services sector may also include aid or support for developing countries with geothermal potential.

Academia

Increased global acceptance of the need to mitigate climate change has resulted in most countries in the world signing up to the Paris Agreement, which sets out a global action plan to limit global warming. As of 2021, 191 members are signed up. The goals of the Paris Agreement will generate an increased need to utilise deep geothermal projects. Countries looking to develop their own deep geothermal capability will require qualified geothermal geoscientists. High quality, cutting edge deep geothermal training courses and advanced degrees offered by UK institutions would be in demand.

Borehole headworks
Courtesy of GEL

International Geothermal Opportunities

Deep geothermal energy projects contribute towards 11 of the United Nations Sustainable Development Goals (UNSDGs).

Sustainability

Deep geothermal projects and direct use geothermal projects specifically contribute to several of the United Nations Sustainable Development Goals (SDGs) including:

1. No Poverty
3. Good Health and Well-Being
7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry, Innovation and Infrastructure
10. Reduced Inequalities
11. Sustainable Cities and Communities
12 Responsible Consumption and Production
13. Climate Action
14. Life Below Water
15. Life on Land

Sustainable Development Goals

Recommendations for Market Growth

Two interventions with an immediate impact are the development of a Geothermal Development Incentive and minor changes to the Contracts for Difference structure.

Government interventions
Experience in UK solar and wind markets along with the deep geothermal markets in Europe has proven that government funding during early stages of market development is the main factor in stimulating new markets in the renewable technology sector. Early government support and risk sharing are instrumental for developing successful deep geothermal markets by providing confidence to developers of deep geothermal energy and their investors. With increasing project delivery, market confidence grows as precedent is set and projects become more cost effective and sustainable requiring increasingly less government interventions as the market matures.

The BGS 2020 report provides detailed recommendations for policy and regulatory support for the UK geothermal sector [6]. However, the following two government interventions are recommended for the UK to accelerate growth of the deep geothermal industry. Both interventions will allow projects to point to a secure revenue stream. This will help to make projects ‘bankable’ and for private funding to be secured for the high risk/ high capital drilling phase of the project.

Geothermal Development Incentive (GDI)
A heat production incentive dedicated to deep geothermal projects (referred to as a geothermal development incentive, or GDI) could be structured such that it provides assurance to the geothermal market, but only provides funding for projects which successfully generate heat energy. Successful heat production incentives are typically in place for a reasonable time period, for example 20 years, to stabilise project finance conditions. The UK could control the long-term cost by limiting the use of a GDI to the first 30 projects which meet application conditions. The GDI could be funded through a variety of sources, for example future carbon tax receipts.

A heat plant with a 10 MWth capacity may provide 44 GWh heat annually. The heat plant would deliver a carbon saving of around 8,000 tons CO_2 per year throughout its life[1]. This would equate to c. 2,200GWh heat and saving 400k tons CO_2 over its operational lifetime.

With a GDI of £55/MWh (in line with the existing RHI tariff) the cost per year would be £2.4M for the first 20 years with potential CO_2 emissions savings of £16M (based on BEIS Carbon Valuation method [28] between 2025 and 2045, using central traded values).

Geothermal Development Incentive (GDI)
A new heat production incentive dedicated to deep geothermal projects:

1. £55/ MWh per year per project
2. For the first 30 projects
3. Only projects meeting the scheme requirements and commissioning in time are supported
4. Low Operational cost and long lifecycle of geothermal plants represents high value investment

[1] Sustainably operated and well maintained geothermal plants can be expected to have an operational life well in excess of 50 years.

Contracts for Difference (CfD)
The exiting Contracts for Difference Scheme for Renewable Electricity Generation (CfD) remains an appropriate mechanism for geothermal electricity pricing. The next auction round is due later this year (2021). At the time of this report, two geothermal power projects are in development, both in Cornwall, illustrating that there is a commercial potential to development geothermal power in the UK. Given these conditions, we have identified that setting a Minima to 50 MWe for geothermal projects along with guaranteeing the current administrative price (£140/MWh) for the Minima would improve investor confidence. Review of planning permission requirements is also recommended.

UK regulatory provisions
Whilst the interventions above are considered to be the main drivers that will accelerate the deep geothermal market there is also a need to streamline / consolidate the regulatory regime for deep geothermal projects. The current status and suggestions for improvements to existing regulatory regimes are described by the BGS and should be reviewed [6].

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ARUP

Contact:
Michael Chendorain (PE)
Associate Director
Global ARUP Geothermal Lead

t: +44 20 7755 2539
e: Michael.Chendorain@arup.com

8 Fitzroy Street, London, W1T 4BJ

Dr Matthew Free
Director
Arup Geothermal Business Leader

t: +44 20 7755 3288
e: Matthew.Free@arup.com

8 Fitzroy Street, London, W1T 4BJ

arup.com