The Case for Mine Energy – unlocking deployment at scale in the UK

A mine energy white paper

Foreword

At the heart of this Government's agenda are three key priorities: the development of new and innovative sources of employment and economic growth, rapid decarbonisation of our society, and levelling up - reducing the inequalities between different parts of the UK. I'm therefore delighted to be able to offer my support to this report, which, perhaps uniquely, involves an approach which has the potential to address all three of these priorities.

Mine energy, the use of the geothermally heated water in abandoned coal mines, is not a new technology, but it is one with the potential to deliver thousands of jobs. One quarter of the UK's homes and businesses are sited on former coalfields. The Coal Authority estimates that there is an estimated 2.2 GWh of heat available – enough to heat all of these homes and businesses, and drive economic growth in some of the most disadvantaged communities in our country. Indeed, this report demonstrates that if we only implement the 42 projects currently on the Coal Authority's books, we will deliver almost 4,500 direct jobs and a further 9-11,000 in the supply chain, at the same time saving 90,000 tonnes of carbon.

The report also identifies a number of issues which need to be addressed to take full advantage of this opportunity; with investment, intelligence, supply chain development, skills and technical support all needing attention. It indicates though that none of these issues are insurmountable and BEIS will therefore work with the Coal Authority, and its partners in the Mine Energy Task Force, to further explore the options for exploiting this zero carbon energy source.

Lord Callanan

Parliamentary Under Secretary of State at the
Department for Business, Energy and Industrial Strategy

Table of Contents

Acknowledgements

In memory of Jez Crooks, and his outstanding contribution to the mine energy sector.

Project team

Bill Kirkup, CAG Consult, Project Lead
Alison Cavey, CAG Consult, Project Supporter
Dave Lawrence, CAG Consult
Martin Crane, Carbon Alternatives
Professor Jon Gluyas, GeoEnergy Durham
Wayne Handley, Handley Project Solutions

Consultees[1]

Dr Charlotte Adams, The Coal Authority
Richard Baker, North East Local Enterprise Partnership
David Banks, Holymoor Consultancy
Hugh Barron, British Geological Survey
Adam Black, Lanchester Wines
Nick Boid, Buro Happold
Andrew Clark, North East Local Enterprise Partnership
Jeremy Crooks, The Coal Authority
Matthew Dennis, South Tyneside Council
Iain Eckett, GEA Group
Sally Gallagher, Environment Agency
Jim Gillon, Gateshead Council
Peter Graham, Sunderland City Council
Norman Jackson, Retired Mine Manger
Philip James, Nottinghamshire City Council
Michael Jenkins, Bridgend County Borough Council
Dr Gareth Johnson, University of Strathclyde
Renia Kotynia, North West Local Energy Hub
Matthew Lakey, FWS Geotechnical and Environmental Consultants
Bryan Laycock, Dunelm Geotechnical and Environmental
Professor Christopher McDermott, University of Edinburgh
Stephen McDonald, Durham County Council
Johann McDougall, Scottish Government
Adrian McLoughlin, Newcastle City Council
Professor David Manning, Newcastle University
Tom Mills, WSP Consultants
Dr Manju Mishra, Cardiff University
Jonathan Mullard, Department for Business, Energy and Industrial Strategy
Chris Myers, Durham County Council
Charlotte Owen, Association for Decentralised Energy
Tim Rippon, Newcastle City Council
Mark Roberts, Northumberland County Council
Dr Karl Sample, Sheffield City Region
Jon Sanderson, Uniper Energy
Holly Schofield, Environment Agency
Professor Zoe Shipton, University of Strathclyde
Professor Peter Styles, Keele University
David Townsend, TownRock Energy
Fiona Todd, University of Edinburgh
Norman Waitt, South Tyneside Council
Dr Sara Walker, Newcastle University
Trevor Whittaker, Kew Consult
John Wood, Tolent
Mark Woodward, Nordic Heat

Co-funders

MIDLANDS ENERGY HUB
MCS CHARITABLE FOUNDATION
north east & yorkshire ENERGY HUB

[1] The list includes individual who were interviewed or otherwise involved in the research in a substantive fashion and who gave their permission to be named. Their inclusion should not be taken as evidence of endorsement.

Executive summary

Introduction

According to the Coal Authority, one quarter of the UK's homes and businesses are sited on former coalfields. Since the cessation of mining much of the underground network of old mine workings has become filled with water which has been warmed by natural geothermal processes. The Coal Authority estimates that there is sufficient energy in this water to heat all of the homes on the coalfields. The exploitation of this resource – mine energy – would make a significant contribution to solving one of the most pressing low carbon challenges facing the country, namely the decarbonisation of heat.

Additionally, owing to the co-location of the resource with often disadvantaged areas, the development of mine energy schemes would directly contribute to the government's 'levelling up' agenda, and could be harnessed to create a powerful narrative of renewal for old coalfield communities. Recent developments in North East England have placed the UK at the forefront of a new generation of mine energy schemes, but the sector is in an early and therefore vulnerable stage of development and requires public support to ensure its continued development. This white paper makes the case for mine energy and provides a series of recommendations, generated through a literature review and extensive stakeholder consultation, intended to help ensure the development of this sector.

The nature of the resource

The Coal Authority estimates that there are 23,000 abandoned deep coal mines around the UK. Following abandonment, the void spaces created by mining fill with water which has been naturally warmed (12–20°C) by sub-surface geological processes and as such is zero carbon. Through the use of heat pumps, some of this heat can be extracted and used to heat fresh water, which can then be used to provide low carbon heating and hot water for use in domestic and commercial buildings via heat networks. The most convenient and cost-effective way of accessing mine water heat is via Coal Authority mine water treatment plants. There are currently 75 of these and they play an important role in protecting water quality. Currently heat from these sites is not utilised, but there is growing interest in this resource. After treatment plants, the next most convenient way of accessing mine water is via old mine shafts; however, many of these were filled and capped when mines were closed, and it is not clear how many could serve for use in mine energy schemes. Drilling boreholes, to tap into known reservoirs of mine water, is the most expensive way of accessing mine energy, but also the most flexible as it allows end users to access the resource close to existing and planned sources of demand.

Provided that heat extraction does not exceed the level of natural heat, recharge mine water heat-based systems are sustainable, as evidenced by a number of long-established schemes in mainland Europe and North America. Recent advances in thinking and practice suggest that the benefits associated with mine energy schemes can be enhanced by using mines to store surplus (waste) or seasonally available (solar thermal) heat sources.

Progress to date

The first known mine energy schemes emerged in the 1980s. One of the earliest, based in Springhill, Nova Scotia, Canada, was established in 1988 and remains in operation to this day. Other notable schemes have been established at Heerlen in the Netherlands and Barredo in Spain. Schemes such as these have helped to develop and refine approaches to mine energy scheme development, but until recently only a limited number of schemes have been developed, with only three small schemes having been established in the UK prior to 2020.

The primary reason for the limited number of developments appears to be the low cost of fossil fuels. However, with the acknowledged need to transition to low-carbon energy sources there has been a renewed interest in mine energy and a new wave of schemes have been commissioned. The UK is currently at the forefront of this wave.

For example, enabled by the Renewable Heat Incentive (RHI), Lanchester Wines, a private company based in North East England, has installed 2.4MW and 1.6 MW mine water-based heating systems. These are currently the largest schemes in the UK, but will shortly be eclipsed by a 6MW scheme led by Gateshead Council and a proposed garden village scheme at Seaham (County Durham), both supported by funding from the Heat Networks Investment Programme (HNIP). Multiple other UK schemes have been subject to some level of investigation and the Coal Authority has suggested that there is currently a potential pipeline of 42 projects.

The benefits of mine energy

Heat decarbonisation

In 2019 the UK committed to becoming a 'net zero' economy by 2050. One of the challenges associated with meeting this ambition is the decarbonisation of heat. A key aspect of the challenge is the limited availability of low carbon heat sources.

Mine water heat is an abundant, widely distributed and naturally occurring low carbon heat source. In comparison, most other low carbon heat sources are subject to higher geographic and scale constraints. Additionally, the mine water heat resource is relatively well understood and is distinguished by several technical characteristics which give it a comparative advantage as a heat source for two of the key heat decarbonisation technologies, namely heat pumps and heat networks. These characteristics are:

- If managed correctly, mine water heat is constantly available at a consistent and elevated temperature. Other heat pump-based systems (water, air and ground) rely on lower temperature heat sources which are at their coolest in the winter months when heat demand is highest.
- Mine water heat is available at scale, relatively widely distributed and often co-located with areas of high heat demand. As low carbon heat sources are in short supply, mine energy is a potentially important enabler of heat network developments and therefore heat decarbonisation. If all of the 42 schemes in the Coal Authority's pipeline were to be built out, this would generate projected carbon savings of 90,500 tonnes per annum.
- Mine water heat is a self-sustaining indigenous resource the use of which increases energy security. In the future, mine energy schemes could play an enhanced role, potentially providing balancing services to local energy systems through the use of mines for thermal energy storage.

Green growth

If the 42 schemes identified by the Coal Authority were to proceed this would create an estimated 4,227 jobs and £293 million gross value added (GVA). An additional 9–11,000 jobs and £400–500 million could be created through indirect and induced economic effects.

Many parts of the coalfields have still not fully recovered from the decline of mining, and such recovery has been experienced is now at risk as a result of the coronavirus pandemic. The development of mine water heat networks would bring immediate and direct economic benefits to coalfield communities and businesses and contribute to the government's 'levelling up' agenda. Beyond the direct impacts associated with the development and operation of mine energy schemes, regeneration agencies would have an opportunity to build on the low carbon credentials of mine water schemes to create a wider narrative of renewal, and through this to attract new businesses to coalfield areas.

Support for mine energy would also contribute to wider clean growth objectives. Currently, the UK has first mover status and has an opportunity to establish new UK-based centres of research and commercial and construction expertise in mine energy; expertise which might subsequently be exported, thereby creating new opportunities for British businesses.

Barriers and constraints

Mine energy offers multiple benefits and enjoys considerable stakeholder support, but the development of the sector is at an early and vulnerable stage as scheme developers face multiple challenges. A summary of the key barriers identified includes:

- The low cost of gas as an alternative heat source. This is the most fundamental challenge for mine energy and one it shares with all forms of low carbon heat.
- Uncertainty regarding the future of existing support schemes for low carbon heat and in particular the HNIP and RHI. A lack of certainty regarding the nature of proposed replacement schemes and the level of support is causing uncertainty in the market and appears likely to cause some schemes to, at the least, be put on hold.
- Uncertainty regarding the Coal Authority's plans regarding a potential charge for access to the mining infrastructure. There are concerns that charging for heat might fatally undermine the business case for mine energy schemes, particularly higher cost schemes such as those that require the drilling of boreholes.
- Perceptions of risk are a major constraint as they deter potential developers and investors and may also undermine public confidence. Specific concerns include:
  - The risk of expensive borehole-based schemes failing to locate a viable and sustainable resource. Drilling is undertaken at the developer's own risk and the possibility of failure can deter more risk-averse investors.
  - The possibility of a decline in the projected heat yield over time or of access to heat being subject to interruption as a result of the collapse of underground workings. Mine water developments are long-term investments; unanticipated declines in heat yield (and therefore income) would undermine the viability of affected schemes.
- Supply chain constraints identified by stakeholders include a lack of information, capacity and capability (skills and expertise):
  - The Coal Authority has developed an interactive mapping tool; however, stakeholders identified a need for enhanced tools to better enable early-stage strategic assessment exercises (e.g. to identify and prioritise potential mine energy projects in a given local authority area).

- The embryonic status of the sector means that there is a lack of expertise, specifically technical consultants, scheme design engineers (borehole and pump system) and drilling contractors.
- In addition to supply-side constraints there is a lack of expertise in relation to mine energy development, and in some cases heat network development as well, among clients and their project managers.
- The Coal Authority hosts a well-regarded mine energy team, but stakeholders reported that this team was becoming overstretched and that a lack of capacity within the Coal Authority was emerging as a constraint on the growth of the mine water heat sector.

Recommendations

The UK has taken a lead in mine energy, but to ensure continued growth, and thereby the associated decarbonisation and socio-economic benefits, requires sustained government support. To accelerate the sector beyond the need for subsidy will require greater levels of collaboration between public, private and academic bodies, supplemented by targeted investments in research and development. A list of more specific recommendations follows.

Recommendation 1 (high priority)

The mine energy sector in the UK is at an early and vulnerable stage in its development and at this point in time is highly dependent upon public subsidy. Successor schemes to the ERDF, HNIP and the RHI should take into account the support needs of the sector and ensure that replacement schemes allow for a sustainable rate of growth.

Recommendation 2 (high priority)

There is a need for policies that reduce the competitive advantage of gas in relation to low carbon heat sources. These need to be accompanied by clear, consistent and unambiguous policy messaging in order to build confidence among developers and heat network investors.

Recommendation 3 (high priority)

Strategic stakeholder bodies should facilitate and support greater ongoing collaboration and knowledge sharing between mine energy scheme designers, developers, regulators and the research community. There is an existing national forum in the shape of the Mine Energy Taskforce. This is well placed to take ownership of several of the recommendations made in this report but would require additional resources to enable it to play a more substantive national role. Participant organisations with an enabling role, such as regulators and licensees, may also need additional resources to enable greater coordination and accelerate progress on the recommendations.

Recommendation 4 (high priority)

The Coal Authority has taken a strong lead on mine energy and is actively supporting and enabling its growth. However, our research identified a need for closer dialogue between the wider mine energy stakeholder community and the Authority to ensure that the development of tools and research programmes relating to mine energy are more closely informed by the emerging market. Two priority stakeholder asks include:

- The development of a GIS tool to enable matching between current and potential heat demand and potential supply. Specific requests included filters that provide indicative drilling and borehole costs, characterisation of the key resource variables (depth, temperature, volume), and the risks associated with site characteristics.
- National sub-surface geotechnical and hydrogeological models to enable characterisation of the sub-surface conditions ahead of site selection and drilling.

Recommendation 5 (high priority)

We found some confusion and uncertainty in the marketplace regarding the role of the Coal Authority in the development of the mine energy sector. Such uncertainty deters potential developers and investors. Stakeholders in the wider market would like clarity around charging for heat access and the Authority's preferred role in new project development.

Recommendation 6 (medium priority)

Funding should be sought and allocated to enable the development of:

- One or more demonstration mine water heat network schemes in smaller coalfield communities. A key focus of such schemes should be the integration of the housing types 'typical' of ex-coalmining settlements (see also Recommendation 13).
- The establishment of one or more inter-seasonal storage demonstrators. These could be new schemes or extensions of existing or proposed schemes.

Recommendation 7 (high priority)

The Coal Authority technical support service is greatly valued but felt to be overstretched. Stakeholders expressed a wish to see the service expanded to enable it to meet increasing demand. Failing that, alternative support mechanisms are required.

Recommendation 8 (high priority)

The Coal Authority is already in discussion with sector bodies about the development of mine energy specific training for the supply chain. Our research suggests that this should include bespoke training for client project managers.

Recommendation 9 (medium priority)

Public sector bodies are leading the development of mine water-based district heating systems. The establishment of a national expert contractors framework would build confidence by providing a level of quality assurance, while streamlining the procurement process.

Recommendation 10 (medium priority)

Public support mechanisms (ERDF, HNDU, HNIP, RHI) have enabled a new, embryonic generation of mine energy schemes, but do not fully take into account the key differences between mine energy and other forms of low carbon heat. To ensure growth, bespoke support measures may be required to address sector-specific barriers. In particular, consideration should be given to the establishment of a loan guarantee (for borehole drilling) and risk insurance (to protect against the possible decline in heat over the operational life of the project).

Recommendation 11 (medium priority)

Most of the previous recommendations should contribute to the improved business case for mine energy, but in addition:

- The sector should focus on identifying opportunities for cost reduction through increased standardisation, for example of contract documentation and procurement specifications, and process optimisation.
- Scheme developers would benefit from having improved access to commercial data to better enable them to compare the relative merits of mine water heat schemes against the main alternatives and to establish cost benchmarks for mine energy schemes.
- Publicly funded schemes should be required to collect and share non-confidential data on the costs of scheme development and on operational issues relating to the sustainable management and operation of mine water energy schemes.

* If resource were to be made available, this recommendation could be taken forward by the Mine Energy Taskforce.

Recommendation 12 (medium priority)

There is a need for research to identify business sectors with high heat/cooling demands (within the range that can be delivered via mine energy schemes) and to examine the technical and commercial case for linking such businesses with actual or potential mine energy schemes.

Recommendation 13 (medium priority)

Desktop studies should be commissioned to consider the relative merits of mine energy, in comparison to whole house retrofit, as a mechanism for decarbonising the types of hard-to-treat properties that characterise many traditional coalfield communities. Such research should include consideration of the relative merits of these options in relation to their delivery of co-benefits, and in particular the alleviation of fuel poverty.

Recommendation 14 (medium priority)

All publicly funded schemes should be required to identify and pursue opportunities to secure social value through the procurement process, such as the use of targeted recruitment and training clauses to create opportunities for specific groups, for example the long-term unemployed.

Introduction

The Industrial Revolution triggered a huge demand for and was enabled by coal, prompting a dramatic increase in mining activity which continued at scale until the early 1980s. At the industry's peak in 1913, a million men worked in 1,600 mines producing almost 300 million tonnes of coal a year. Over 25,000 square kilometres of the UK have been affected by coal mining[2].

Below ground, the legacy of this activity is an extensive range of underground voids (often interconnected), including reinforced underground structures such as mine roadways and shafts, many of which have become naturally flooded as a result of the cessation of pumping activity.

Natural sub-surface processes have elevated the temperature of this water (as such, mine water is considered a geothermal resource), providing a significant and largely untapped low carbon heat resource. According to the Coal Authority, abandoned mines have the potential to meet most of the heat needs of the coalfield communities.

The decarbonisation of heat is one of the principal challenges to the UK's successful pursuit of its net zero ambitions. Addressing this challenge will require the deployment of a range of technologies, among the foremost of which are heat networks. Mine water offers a proven and sustainable source of low carbon heat for heat networks and has several competitive advantages over the existing alternatives.

However, as with all alternative low carbon heat sources, mine water-based schemes require public support if they are to make a material contribution to decarbonisation. Owing to the location of abandoned mine workings, primarily in the north of England and often in areas suffering significant social and economic disadvantage, the provision of such support would contribute to the governments 'levelling up' agenda by providing a direct opportunity to create jobs and stimulate economic regeneration in coalfield areas.

Uniquely, in contrast with alternative sources of low carbon heat, the exploitation of abandoned mine workings as an energy source could be harnessed to create a powerful narrative of renewal. Under the banner of a green future for the coalfields, new mine waterbased heating schemes could be linked to wider regeneration initiatives to attract new businesses, create regional centres of excellence, and stimulate new heat-based business clusters.

This white paper makes the case for targeted public support for the development of mine water heat-based schemes. Its scope focused on the development of mine energy in England, but the recommendations, if implemented, would be expected to support mine energy activity in all parts of the UK.

It describes the benefits and opportunities associated with such developments and the challenges and barriers that currently constrain mine water heat exploitation at scale. Finally, it considers the types of public policy support required to address the identified barriers and makes a series of recommendations for consideration by senior stakeholders and policymakers[3].

[2] Environment Agency (2008) Abandoned mines and the water environment. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291482/LIT_8879_df7d5c.pdf [Accessed on 16.10.20].

[3] The research investigated the state of play for mine energy across the UK. We are aware that there are differences in the legal and support frameworks across the devolved administrations. The policy recommendations contained in this report are directed at the UK government and therefore not all will apply to Scotland.

1.1 Origin of the white paper

The white paper was commissioned by the North East Local Enterprise Partnership (North East LEP) on behalf of the Mine Energy Taskforce. The taskforce has been convened by the North East LEP as a national community of interest, via the Department for Business, Energy and Industrial Strategy (BEIS) Energy Hub networks. Funders of the white paper include the North East, Yorkshire and Humber, and Midlands Energy Hubs, BEIS and the MCS Charitable Foundation.

The paper has been produced by CAG Consultants in association with Carbon Alternatives, Geoenergy Durham and Handley Project Solutions. It summarises the key findings of an evidence review report prepared by the project team, which synthesised insights and evidence from a literature review and a series of interviews with over 50 expert stakeholders. The specification for the review asked that the CAG team:

- Outline the high-level UK opportunity in terms of low carbon energy provision and storage
- Summarise existing knowledge, capabilities, expertise and support available across the sector, to enable a more effective connection of expertise across stakeholders
- Collate a high-level understanding of the potential UK project pipeline, based on current stakeholder understanding of where mine energy could potentially be deployed
- Explore up to six case studies of mine energy projects and the factors that enabled these to succeed, or that led to their failure, with insights from these being used to help inform recommendations
- Set out key supply chain capacity that needs to be in place to service a functioning and competitive UK market
- Set out the technical, commercial, regulatory, market, environmental, subsidy and policy failures, barriers or knowledge gaps preventing delivery at scale in the UK.

Findings from the review were shared with a steering group comprised of members of the Mine Energy Taskforce and via online workshops with a wider group of stakeholders. This white paper summarises the key findings of the evidence review, informed by the additional views and insight generated by the steering group and stakeholder feedback.

The exploitation of mine water as a resource

1.2 Introduction

The Coal Authority estimates that there are 23,000 abandoned deep coal mines around the UK. When operational, many mines were pumped to enable mining activity. Following abandonment, mines naturally refill with water which is warmed as a result of sub-surface geological processes. As such, mine water heat is considered as a form of geothermal energy.

1.2.1 Methods for accessing mine water heat

Mine water can be accessed through three main routes: via drilling into old mine workings, via mine shafts, and from mine water treatment plants. The pros and cons of each form of access are summarised in Table 1.

Table 1: Access paths for mine water heat

Heat access method	Summary explanation	Benefits and limitations
Drilling of access borehole	Establishing access to mine water heat typically involves drilling 2-3 boreholes[4]. The process starts with either pilot or exploratory boreholes. Assuming that these are successful in accessing a mine water source, the flow rate and temperature of the water is assessed to determine the likely viability of the scheme. If the tests are positive the initial boreholes may either be increased in size (reamed out) or additional boreholes sunk.	• Allows access to heat near to point of demand • High cost (highly variable, key dependency is depth) • Perceived as high risk as viability of scheme subject can only be confirmed following the drilling of the borehole
Mine shafts	Mine water can be directly accessed via mine shafts. A small-scale example operates at the site of Markham Colliery and larger-scale opportunities are being considered. However, many mine shafts were filled and capped following the closure of the mines. While it may be feasible to open some of these up, it may be impractical for others and in all cases is likely to be costly.	• Where practical, would be expected to be lower cost (easier access) and lower risk than borehole-based schemes • Shafts not always located near to sources of heat demand, or readily accessible when available • Many shafts are unusable or have been filled
Mine water treatment schemes	The Coal Authority currently owns 75 mine water treatment schemes across the UK. These treat over 122 billion litres of mine water every year and are associated with a potential 100MW of available heat energy. Having no immediate use, this is currently simply discharged into the wider environment[5].	• Lowest cost option, as heat can be accessed directly from the outflow • Limited number of pumping stations • Stations not always near to sources of heat demand

[4] Many schemes will require one or two abstraction boreholes to access mine water and a separate re-injection borehole to return water to the mine system.

[5] Farmer, M. (2020) How defunct coal mines could heat UK homes. Mining Technology [online]. Available at: https://www.mining-technology.com/features/mine-heating-water-treatment-coal-authority-uk-heat-pumpseaham-dawdon/ [Accessed on 3.2.21].

1.2.2 Key technologies

The exploitation of mine water is dependent upon two central technologies, namely heat pumps[6] and heat networks, both of which are critical to the decarbonisation of heat in the UK.

1.2.2.1 Heat pumps

Irrespective of the access route, mine water heat schemes are based on the use of heat pumps. Heat pump systems collect ambient heat, usually from the air, ground or water, and then elevate its temperature through compression before releasing it to the end user. Heat pumps are powered by electricity but are regarded as a low carbon technology, as for each unit of electricity used to power the heat pump they are able to generate 2–4 units of heat depending upon the heat source and its temperature.

1.2.2.2 Heat networks

Heat networks (also known as district heating) supply heat from a central source to consumers via a network of underground pipes carrying hot water. Heat networks can cover a large area or even an entire city, or be fairly local, supplying a small cluster of buildings[7].

The Committee for Climate Change (CCC) estimates that heat networks could meet 18% of UK heat needs by 2050[8]. The expansion of heat networks is supported by the government through policy and specifically in terms of funding through the Heat Networks Development Unit (HNDU), the Heat Networks Investment Project (HNIP) and the Renewable Heat Incentive (RHI).

1.3 The development of mine water schemes to date

1.3.1 International developments

The first reported exploitation of mine water as a heat resource was a heating and cooling system installed in a leisure centre in 1981 in Kingston, Pennsylvania, US. This was identified in a review of mine energy schemes undertaken in 2015[9], at which point it was recorded as having run without complications since installation.

Another early installation was undertaken by Ropak Can Am Ltd, a manufacturer of plastic packaging products, at their site in Springhill, Nova Scotia, Canada, in 1988. This site overlies flooded former coal mines containing an estimated 4,000,000m3 of water[10]. An existing oil-based heating system was replaced by one based on heat pumps. Owing to the high cost of oil this installation is reported as having paid for itself within one year[11]. Since the initial installation, a number of other commercial and public buildings in Springhill have also installed mine water heat-based systems.

Despite such projects demonstrating the technical and, in some cases, commercial case for such schemes, only a limited number of additional installations (27), including some non-coal mine based schemes[12], have been established and only a handful (including a new UK site installed by Lanchester Wines, Heerlen in Holland, Springhill in Canada and Barredo in Spain) operate at scale. The primary constraint has been – and in most cases remains – the low cost of alternative, fossil fuel-based, heating systems.

[6] In a mine water heat-based system, heat pump systems use a heat exchanger to transfer heat from mine water (and other sources) to fresh water. It is the latter which is pumped around buildings and not the mine water itself, which is usually returned to the mine.

[7] BEIS (undated) What is a heat network? Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/696273/HNIP_What_is_a_heat_network.pdf [Accessed on 22.11.20].

[8] Committee on Climate Change (2016) Next steps for UK heat policy. Available at https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/ [Accessed on20.10.20].

[9] Ramos, P.R., Breede, K., Falcone, G. (2015) Geothermal heat recovery from abandoned mines: a systematic review of projects implemented worldwide and a methodology for screening new projects. Environ Earth Sci 73;6783-6795.

[10] Jessop, A.M., MacDonald, J.K., Spence, H. (1995) Clean energy from abandoned mines at Springhill, Nova Scotia. Energy Sources 17: 93-106. Available at https://www.researchgate.net/publication/255798282_Clean_Energy_from_Abandoned_Mines_at_Springhill_Nova_Scotia [Accessed on 16.10.20].

[11] Ibid.

[12] Gluyas, J. (2020) Email to Bill Kirkup, 15 September.

1.3.2 Mine water scheme developments in the UK

In the UK, the earliest known mine water heat scheme was installed to provide heat to 16 domestic properties (social housing) in Shettleston (Glasgow) in Scotland in 1999. Another Scottish site, Lumphinnans (Fife), was installed in 2001 but has since been decommissioned owing to vandalism of the boreholes. In England, three small schemes have been installed at ex-colliery sites at Markham (2011, Yorkshire), Dawdon (2009, Durham) and Caphouse (2015, Yorkshire).

More recently (2020), Lanchester Wines, a private company based North East England, has installed 2.4MW and 1.6 MW mine water-based heating systems (currently the largest in the UK) to heat two warehouses in Gateshead. This development is expected to be followed by an even larger scheme, 6MW, led by Gateshead Council, which will use mine water as the heat source for a planned expansion of the Gateshead District Energy Scheme[13] (a wholly council owned business). Another scheme, 3.5 MW (with potential for more), also in North East England, is planned as part of the new Seaham Garden Village development. Both of these schemes have recently been awarded funding through the Heat Networks Investment Programme (HNIP)[14].

Elsewhere in the UK, multiple schemes have been subject to some level of investigation. The Coal Authority, which as the agency responsible for the management of the UK's abandoned mines and owner of the mining infrastructure is engaged in dialogue with multiple potential scheme developers, estimates that there are 42 projects in the UK pipeline[15].

1.3.3 Drivers of interest

It is evident that there has been a step change in the level of interest and activity in relation to mine water energy schemes. The increased prominence and urgency of the climate change agenda is the key driver of interest in the development of mine water-based energy schemes, but an increasingly important driver for LEPs and local authority stakeholders is recognition of the scope for linking decarbonisation initiatives with the pursuit of economic regeneration, i.e. the 'green growth' agenda. These drivers and the associated opportunities are the subject of chapters 3 and 4 of this report.

[13] Gateshead Council (2020) Major grant will connect Gateshead homes to mine water energy scheme. Available at https://www.gateshead.gov.uk/article/15805/Major-grant-will-connect-Gateshead-homes-tomine- water-energy-scheme [Accessed on 16.10.20].

[14] Triplepoint (2020) Successful projects [Online]. Available at https://tp-heatnetworks.org/funded-projects/ [Accessed on 24.1.21].

[15] This figure includes schemes identified as being suitable for development, but which have not as yet been subject to detailed assessment.

The decarbonisation benefits of mine water heat

1.4 Introduction: Meeting the heat decarbonisation challenge

The UK's Climate Change Act (2008) established a legally binding obligation to reduce the net UK carbon account for the year 2050 by at least 80% lower than the 1990 baseline. In 2019 the Climate Change Act was amended to increase this target to 100%, making the UK the first major economy to pass a net zero emissions law[16]. Under the provisions of the Act, carbon emission reductions are phased over a series of five-year carbon budgets, beginning with the period 2008–2012. These budgets set progressively higher targets for decarbonisation.

The UK has made significant progress in decarbonising electricity but has so far made limited progress on 'clean' heat. Indeed, the decarbonisation of heat was identified in the Clean Growth Strategy as "our most difficult policy and technology challenge"[17]. Heat is prominent within the prime minister's 'Ten-Point Plan for a Green Industrial Revolution' and national infrastructure strategy, particularly in relation to objectives around greener buildings. According to CCC figures, heating and hot water account for 40% of UK energy consumption and are responsible for one fifth of UK greenhouse gas emissions[18].

In their most recent progress report[19] to government, the CCC stated that the forthcoming Buildings and Heat Strategy must enable low-carbon heating to move from being a niche solution to being the dominant form of new heating installation in the UK by the 2030s. Currently, the CCC estimates that less than 5% of the energy used for heating homes and buildings is derived from low-carbon sources[20]. The relatively low cost (in comparison to other heat sources) and wide availability of natural gas are barriers to the UK's transition to other energy and technology options, including mine water heat.

1.5 Key benefits of mine water heat as a low carbon energy resource

Mine water heat is an abundant, widely distributed and naturally occurring low carbon heat source. As a resource it is relatively well understood and is distinguished by several technical characteristics which give it a comparative advantage as a heat source for heat pumps and heat networks. These characteristics are:

- If managed correctly, it is constantly available at a consistent and elevated temperature, making it a cost competitive source of low carbon heat
- It is available at scale, widely distributed and often co-located with areas of high heat demand
- If managed correctly, it is a self-sustaining indigenous resource.

The benefits associated with these characteristics are explored in more detail in the following sections.

[16] BEIS (2019) UK becomes first major economy to pass net zero emissions law [online]. Available at https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law [Accessed on 23.11.20].

[17] HM Government, UK (2017) The Clean Growth Strategy: Leading the way to a low carbon future. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/700496/clean-growth-strategy-correction-april-2018.pdf [Accessed on 27.1.21].

[18] CCC (2016) Next steps for UK heat policy. Available at https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/ [Accessed on [23.11.20].

[19] CCC (2020) Reducing UK emissions: 2020 progress report to Parliament. Available at https://www.theccc.org.uk/publication/reducing-uk-emissions-2020-progress-report-to-parliament/ [Accessed on 23.11.20].

[20] Ibid.

1.5.1 A cost-competitive source of heat

The effectiveness of a heat pump is measured by its coefficient of performance (COP). This represents the ratio between the energy (electrical) used by the heat pump and the energy delivered (as heat). For example, a heat pump with a COP value of 4 means that the use of 1kW of electrical energy releases 4kW of heat.

The COP of a heat pump is determined by the temperature difference between the heat source and that required by the end user. The lower the differential between the source and output temperatures, the higher the COP. The elevated temperature of mine water allows for reported COPs of 4 and above; for example, the aforementioned Lanchester Wines site reports a COP of 6. The high COP attainable through the use of mine water, in comparison with air, water (sea and river) and ground-sourced heat, is one of the key reasons for the attractiveness of mine water heat schemes.

The availability of mine water at a constantly elevated temperature conveys an additional benefit. UK heat demand is highly seasonal but mismatched with some of the main forms of low carbon heat source that operate more efficiently in the warmer months of the year. For example, air and water-based heat pump systems operate at a lower COP in the winter months and may therefore need to be supplemented by gas or electric-based systems. In comparison, the temperature of mine water, if managed correctly, is unaffected by seasonal change (see Table 2). As a result, the COP is also relatively constant, and a heat pump system based on mine water heat will therefore be more cost- and carbon-efficient than those which have to accommodate seasonal temperature variations.

Table 2: Relative COPs of typical heat pump operational scenarios, in comparison with a mine water heat-based scheme[21]

Heat source	Average temperature	Average temperature weighted by heat demand (more heat needed in winter when air and river are colder)	Resultant COP[22] (assumes the same output temperature)
Air (Newcastle)	10.4	8.4	3.5
River (tidal River Tyne)	10.2	8.5	3.6
Mines (300m deep)	17	17	4.4
Open loop heat pump 100m	12	12	3.8

[21] Figures developed for this report by Martin Crane of Carbon Alternatives.

[22] The COPs do not include the pumping energy that needed to get the large volumes of river/mine/ground water to and from the heat pump. These would be expected to reduce the stated COP for mine water heat.

1.5.2 An abundant and widely distributed alternative

As noted in the introduction, the Coal Authority estimates that there are around 23,000 abandoned coal mines around the UK, many of which are flooded with water. Fortuitously, owing in part to the historic importance of coal and the coal mining industry, the mine water resource is often co-located with densely populated urban areas, including nine out of the ten largest (by population) British cities. Overall, the Coal Authority estimates that 25% of UK's built environment is located above former coalfields.

The presence of mine water resources in close proximity to centres of high heat demand, in combination with its potential for high system COP, has attracted considerable attention to mine water as a heat source for heat networks.

Until recently the default option for fuelling new heat network developments has been gas CHP (combined heat and power); however, the case for CHP, from a carbon emissions perspective, is declining[23]. As a result, newer heat network developments are seeking alternative, lower carbon heat sources. This trend has been reinforced where new housing sites are being considered, for example the proposed Seaham Garden Village development, as a result of the proposed Future Homes Standard. If introduced, this will require new build homes to use low carbon heating from 2025.

Other low carbon alternatives to gas CHP for district heating include river source heat pumps, heat from sewers, and energy from waste, biomass and biogas. All have their merits, but all are subject to geographic constraints and larger scale developments, and often lack viable options. The widespread distribution and scale of the mine water resource means that mine water heat provides a valuable alternative and is a potentially important enabler of heat network developments, and therefore heat decarbonisation. Were all 42 schemes in the Coal Authority's pipeline to be built out, this would generate projected carbon savings of 90,500 tonnes per annum.

1.5.2.1 Cultural affinity

An additional potential benefit of mine water heat, as evidenced by stakeholder interviews, is the deep cultural affiliation of ex-mining areas with the coal mining industry. Our research identified examples where this historical affinity has been important in helping to generate support for potential developments among elected members and senior officers. District heat networks are complex and often challenging developments, and such support can be essential in ensuring that projects are taken forward.

To date, consumers, both commercial and domestic, have proven reluctant to engage with heat networks. Linking mine water heat-based developments to a narrative of renewal may also prove useful in 'selling' heat networks to potential customers.

1.5.3 A sustainable and indigenous resource

Mine water heat is a naturally renewable resource as the heat is constantly replenished by geothermal processes. As such, while care is required to not 'over-harvest' the heat, it can be considered a sustainable resource.

As an indigenous resource, its exploitation would enhance national energy security while reducing the 'loss' to the UK economy that is associated with expenditure on imported energy sources.

[23] CCC (2016) Next steps for UK heat policy. Available at https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/ [Accessed on 20.10.20].

1.6 Emerging opportunities

1.6.1 Thermal storage

If the UK meets 14–20% of its overall heat demand with heat networks by 2030, it could deliver 32–46GWh of thermal energy storage annually. 46GWh of thermal storage is the equivalent of 4 hours of space heating and hot water demand in wintertime for a million households (i.e. with a 12kW thermal load)[24].

It is usual to include some level of thermal storage in heat networks to provide a short-term balancing function. Doing so provides operators with increased flexibility and can improve the economics and carbon reduction benefits of heat networks. For example, heat can be generated and stored during periods of low demand for release during peak demand periods. This allows for the installation of a smaller plant while enabling it to be utilised in the most efficient manner.

Beyond this, large-scale storage systems can be used for inter-seasonal storage where surplus heat and/or seasonal heat sources, e.g. solar thermal arrays, provide heat during warmer periods of the year for release during the colder months. Such systems offer exciting opportunities to integrate heat networks into the wider energy system. For example, surplus renewable energy can be used to heat water during periods of low electricity demand and released as demand increases, thereby enabling heat networks to play a role in balancing out the natural fluctuations associated with the supply and demand of heat and renewable electricity.

The construction of large-scale thermal storage systems is, however, expensive and can take up considerable space. A more space-efficient alternative, widely and successfully used in the Netherlands and increasingly other countries (e.g. Sweden, Germany, Belgium) is to store heat (and 'cold') in natural aquifers – Aquifer Thermal Energy Storage (ATES). In the UK, ATES is a relatively immature technology but has been deployed on several sites in London, for example the Riverlight development. A 2016 report produced by Delta Energy[25] suggests that suitable geological conditions for ATES exist in the South East England, Birmingham, Liverpool and East Anglia.

Mine shafts and galleries provide a potential alternative, although one less well explored, to the construction of large-scale thermal storage systems and ATES and are present in several parts of the UK where aquifer-based solutions are unavailable. No such schemes have yet been developed in the UK, but building on their aforementioned demonstration facility a mine-based inter-seasonal storage scheme has been established at Heerlen in the Netherlands. The experience here demonstrates that the use of mines for thermal storage is technically feasible and that mine-based systems could provide a significant tool for localised energy system balancing schemes. Multiple uncertainties remain, but if the UK develops mine water heat systems at scale then it has an opportunity to develop a new tool for balancing local energy systems while establishing itself as a leader in this area. However, to do so will require significant research and investment in demonstration sites.

[24] ADE (2018) Market report: Heat networks in the UK. Available at https://www.theade.co.uk/assets/docs/resources/Heat%20Networks%20in%20the%20UK_v5%20web%20single%20pages.pdf [Accessed on 24.1.21].

[25] Delta Energy & Environment (2016) Evidence gathering: Thermal energy storage (TES) technologies. BEIS. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/545249/DELTA_EE_DECC_TES_Final__1_.pdf [Accessed on 26.11.20].

1.6.2 Cooling

The focus of this paper is the use of mine water-based schemes to deliver heat, particularly through the mechanism of heat networks, but mine water schemes can also deliver cooling.

For example, a proposed scheme in South West Virginia, US, Project Oasis, is exploring the possibility of establishing a mine water-based cooling scheme to attract data centres as part of an area-based regeneration initiative. A recently published feasibility study[26] for this project suggests that a mine water-based system could reduce electricity use by 90%.

To date, the focus of the UK heat network sector, and in particular operators dealing with district scale schemes, has been on the provision of heat. This is largely owing to the relative lack of demand for cooling, and in particular low demand for district-wide schemes. However, there is increasing recognition that demand for cooling services is likely to grow in response to rising temperatures, and the next generation of heat networks (the fifth) are expected to provide both heat and cooling. So-called fifth generation district heating and cooling (5DHC) schemes are being trialled at several sites in mainland Europe, including the latest evolution of the Heerlen scheme. In the UK, an aquifer-based city centre scheme is being considered by Plymouth City Council, while one small mine-based pilot scheme is being developed in Nottingham[27].

In the eyes of some industry stakeholders, the natural evolution of heat networks would lead to the establishment of an intranet of heat, whereby heating and cooling loads are automatically shifted (both across geographic areas and seasons) around a network of pipes shared by multiple users.

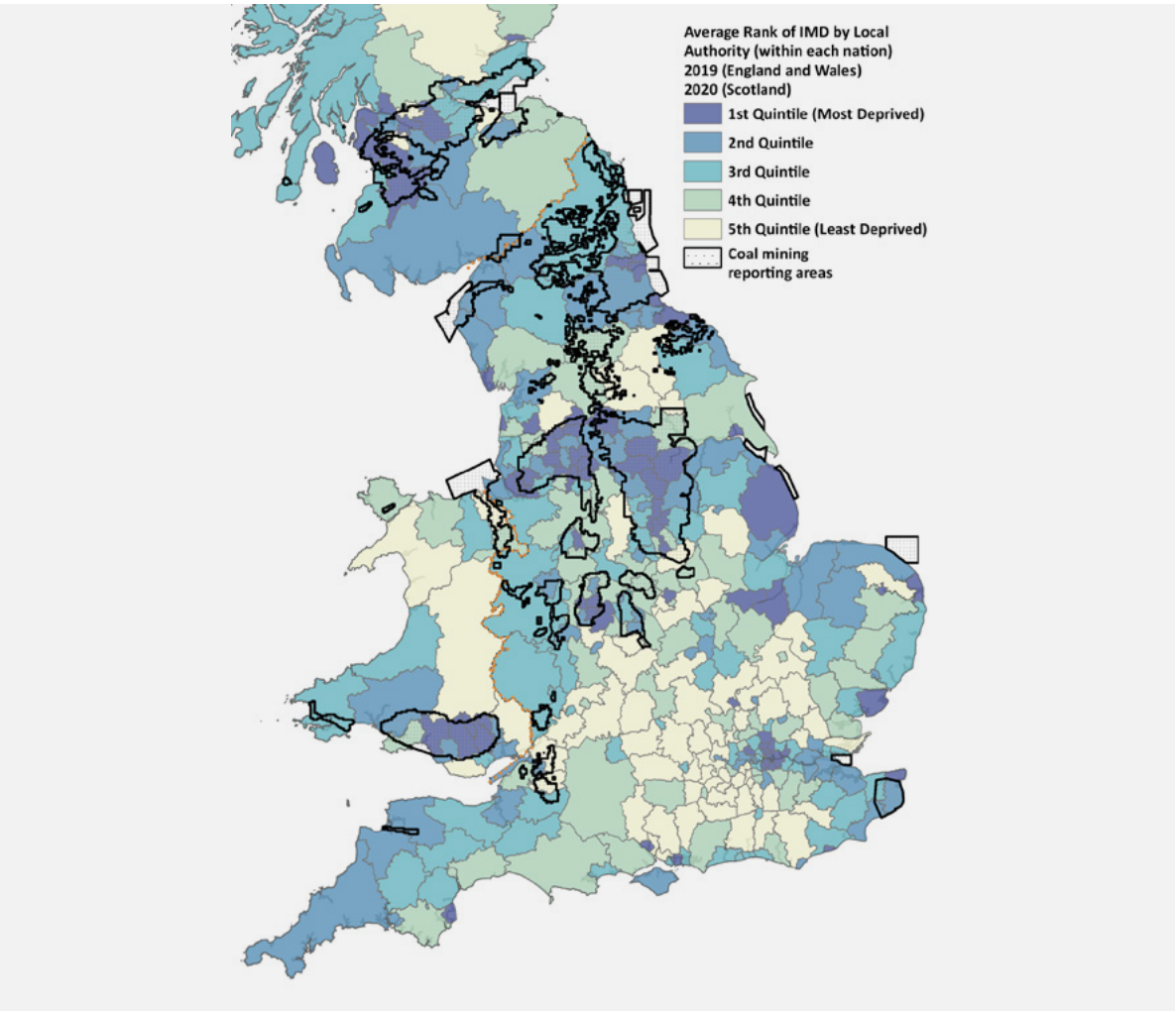
[26] OnPoint Development Strategies (2020) Project Oasis: Market analysis for data centre investment in Southwest Virginia. Available at https://static1.squarespace.com/static/5f0a2bd5c3354d1c75ad855e/t/5f78a1c787afb65ed3150ff1/1601741260417/Project+Oasis+Final+Report+10-01-20.pdf [Accessed on 17.10.20].

[27] D2Grids Communication (2020) [D2Grids] Discover 5 pilots implementing 5th generation heating and cooling networks. Available at https://www.construction21.org/articles/h/D2GRIDS-project-discover-five-pilots-implementing-5GDHC-heating-and-cooling.html [Accessed on 25.11.20].

Green growth: The socio-economic benefits of mine energy

The loss of the coal mining industry means that many coalfield communities have experienced significant economic and social decline. Many communities have not yet fully recovered and, as illustrated by Figure 3; many are located within areas identified as being among the most deprived in the UK. The Coalfields Trust, which was established to support ex-coal mining communities in the towns and villages within the coalfields, estimates the population of coalfield areas at 5.7million. A recent 'State of the Coalfields' (2019)[28] report suggests that if the coalfield areas constituted a region, it would be likely to rank as the most deprived region in the UK.

Figure 1: Average ranking of Indices of Multiple Deprivation (IMDs) by UK local authority area (2019 for England and Wales and 2020 for Scotland)



The development of mine water heat networks would bring immediate and direct economic benefits to coalfield communities and businesses, but also provides an opportunity to attract new businesses and in the process contribute to the government's 'levelling up' agenda.

[28] Beatty, C., Fothergill, S., Gore, T. (2019) The State of the Coalfields 2019 – Economic and social conditions in the former coalfields of England, Scotland and Wales. The Coalfields Regeneration Trust. Available at https://www.coalfields-regen.org.uk/wp-content/uploads/2019/10/The-State-of-the-Coalfields-2019.pdf [Accessed on 22.10.20].

1.7 Economic benefits associated with mine water energy schemes

1.7.1 Green job creation

The construction phase of mine water-based heat network schemes is associated with significant and immediate employment opportunities – opportunities which, given the association of abandoned mines with economically disadvantaged areas, would directly support the government's 'levelling up' agenda.

If the 42 schemes identified by the Coal Authority were to proceed, this would create an estimated 4,227 jobs directly. This is associated with an estimated £293 million gross value added (GVA). An additional 9–11,000 jobs would be created once the indirect and induced economic effects are accounted for, although many of the latter would depend upon the ability of the UK supply chain to fully capture the supply chain opportunities. Applying the same composite multipliers as set out above for jobs, this generates an estimated additional GVA of between £400–500 million.

While the construction of each individual site is largely associated with short-term employment opportunities, expansion and the development of new heat networks would be expected to create longer term, sustainable employment opportunities. Additionally, new heat network schemes, both mine water-based and otherwise, will need to be integrated with other low carbon solutions, for example solar thermal, if the decarbonisation potential of this technology is to be realised and national heat decarbonisation targets attained. Such additional developments would also create ongoing 'green collar' employment and supply chain opportunities, for example in operations and maintenance roles.

Importantly, where such schemes are being procured by public sector bodies, they present an opportunity to create training and job opportunities for disadvantaged groups through the use of 'targeted training and recruitment' clauses[29].

1.7.2 Mine water heat schemes as a driver of local and regional economic regeneration

Increasing acknowledgement of the challenge of climate change, the growth of public support for action and the evolution of an ever more focused policy environment is driving many businesses to seek opportunities to reduce their carbon footprint. For organisations with high heat costs, mine water-based schemes, where cost-competitive, provide an attractive option.

For example, the Lanchester Group, a bottling, packaging and wine development company, has invested over £8 million in renewable heat and energy generation at its sites in North East England. This investment includes an expenditure of more than £3 million on the development of the UK's biggest commercial mine water heating scheme at its warehouse facilities in Gateshead. The group sees a demonstrable commitment to sustainability as being a key point of difference for their business and something that has brought them a tangible competitive advantage.

Regeneration agencies have an opportunity to build on the low carbon credentials of mine water schemes to create a wider narrative of renewal in the coalfields. Mine energy alone will not address the economic and social disadvantage experienced by many coalfield communities, but as a source of low carbon heat it may, when supported by other incentives, enable agencies such as LEPs to attract new businesses to an area.

In the Netherlands, the City of Heerlen operates a wide-ranging regeneration programme and its acclaimed mine energy development forms an important component of its low carbon transition planning, with the scheme also playing a central role in a regional initiative, the PArkstad Limburg Energy Transition (PALET) project[30]. The scheme has reportedly been important in enabling the retention of existing businesses and in attracting new enterprises, to an area that has suffered significant decline as a result of the closure of local coal mines.

[29] Public sector bodies could include requirements for targeted recruitment and training via the procurement process. For further information see https://www.jrf.org.uk/report/tackling-poverty-through-public-procurement

[30] Brummer, N., Bongers, J. (2019) Mijnwater Heerlen: Roadmap to 2040. Interreg NWE. Available at https://www.mdpi.com/2071-1050/8/4/382 [Accessed on 23.10.20].

1.7.2.1 An opportunity to establish new business clusters

Our research identified considerable interest in the possibility of establishing new businesses adjacent to mine energy schemes, particularly mine water treatment plants, where the costs of mine water heat would generally expected to be at their lowest.

The following industry sectors were identified as having high heat demands and therefore as being potential beneficiaries of affordable low carbon heat.

- Pharmaceutical companies
- Storage and distribution centres
- Horticultural glass house production units
- Aquaculture systems.

However, more research is required in order to determine whether and on what basis business decisions in any of these sectors might be informed or influenced by access to mine water heat.

1.7.3 An opportunity for the UK to assume first mover status

A number of industry and academic stakeholders noted that the development of mine energy schemes provided an opportunity to establish new UK-based centres of research and commercial expertise, and thereby create new export opportunities for UK businesses.

A 2016 report by the Carbon Trust[31] estimates that the global heat market will be worth £121–416 billion by 2050. The report notes that the heat market is dominated by non-UK countries but suggests that the UK could capture up to 2% of the market and that this would be worth circa £25 billion in GVA by 2050, while supporting circa 88,000 jobs.

The report does not address mine energy specifically, but many countries have a significant mining heritage. Should the UK take a lead in this area, this would be expected to provide associated businesses with a competitive advantage in what has the potential to be a significant market niche.

1.8 Socio-economic benefits

Jobs and growth, particularly green growth, delivers a range of socio-economic benefits, lifting people out of poverty and creating opportunity. However, mine energy developments also offer opportunities to deliver other forms of social benefit. The expansion of district heating in the UK's major population centres will, it is hoped, over time deliver tangible benefits to domestic consumers in the form of more affordable lower carbon heat. Achieving similar outcomes in smaller communities, for example old colliery towns and villages, may prove more challenging.

Conventional wisdom suggests that household heat pumps provide a more cost-effective solution for smaller communities than heat networks. However, the nature of the original housing in many coalfield settlements makes it difficult to deliver the thermal efficiency required (in a cost-effective manner) to enable household heat pumps to provide an effective solution.

Some sector experts have suggested that the inefficiency of the housing stock means that, at a certain scale, district heating may offer a partial solution to the challenge of decarbonising smaller, low income coalfield communities. Where heat could be offered at a discounted rate, an additional benefit would be the opportunity for scheme operators to directly address fuel poverty in areas of high deprivation, thereby delivering against multiple government policy objectives. Given the intractable nature of the challenge, more consideration of the opportunities for small-scale heat networks, particularly mine water-based, is needed.

[31] Carbon Trust (2016) Technology Innovation Needs Assessment (TINA) – Heat summary report. Low Carbon Innovation Coordination Group. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/593456/Refreshed_Heat_TINA_Refresh_Summary_Report_March216.pdf [Accessed on 23.10.20].

Barriers and constraints

While awareness of the benefits of mine water energy is growing and schemes are being developed, there are multiple barriers which currently constrain the 'mainstreaming' of mine energy schemes. Some of these are sector specific; others apply to all forms of low carbon heat. The following section explores the main barriers and constraints. Potential responses are described and discussed in the final 'Conclusion and recommendations' section of the report.

1.9 Commercial barriers

1.9.1 Low cost of gas the key challenge

Industry stakeholders reported that the most fundamental barrier to the development of mine water heat schemes is the low cost of gas. This challenge is common to all low carbon heat options currently used in heat networks.

We spoke to a number of organisations involved in the development of business cases for mine water heat schemes. Those who reported that they had a viable business case were all reliant upon one or more forms of public support. Capital support is being accessed via the Heat Network Investment Programme (HNIP) or the European Regional Development Fund (ERDF), and revenue support via the renewable heat incentive (RHI)[32]. All of these schemes are due to end in the near future, and while each is expected to be replaced, the final details of successor schemes have not been determined. This is causing uncertainty in the marketplace and is likely to at least cause delays to some potential projects.

There is considerable concern that successor schemes will offer reduced levels of support and that this will render many potential schemes uneconomic.

1.9.2 How much will the heat cost?

1.9.2.1 Charges for heat from mine water treatment plants

There is some confusion in the market about whether the Coal Authority plans to charge for access to heat. It is understood that the Authority expects to charge for access to the mining infrastructure, which is likely to be based on a price per KWh.

Some stakeholders questioned whether the Coal Authority should charge for access to heat. We were informed that the business case, even for schemes drawing heat from mine water treatment plants (the most economically favourable option), were marginal and that heat charging might render them uneconomic. Stakeholders questioned the logic of developers being subsidised via the public purse, only to then repay some of this subsidy to a public agency.

[32] State Aid Rules preclude organisations receiving both capital and revenue funding for the same asset, but splitting the asset by function, i.e. using capital funding for pipework and revenue for heat generating assets, is allowable.

1.10 Risk

The risk profile of mine water-based schemes, particularly the perception of risk by potential funders and developers, and to a lesser extent local communities, was identified as one of the main barriers to scheme development. Specific concerns raised by stakeholders are listed below.

1.10.1 Risk of negative perceptions from investors and local communities

A number of expert stakeholders expressed concern about the potential for resistance from local communities to emerge if care is not taken to clearly communicate the potential risks and disruption associated with a mine water development (this relates primarily to borehole-based schemes). While early indications suggest that communities respond favourably to mine energy schemes in principal, this can change rapidly should schemes create significant disruption, or potential opponents of a scheme inflate community perceptions of risk.

Some industry stakeholder interviewees felt that there was insufficient awareness and acknowledgment of the actual potential risks associated with mine energy schemes. One proposed solution was the development of practitioner guidance, something which the Coal Authority is known to be developing.

1.10.2 Risk of not finding an economically viable resource after exploratory drilling

For borehole-based schemes, a key concern for investors is the cost of pilot/exploratory boreholes and the lack of surety that these will identify viable resources. The cost of pilot and exploratory boreholes varies widely and is determined by the nature of the substrata and the depth of drilling. Shallower mine workings are easier to access and reported pilot costs fall within the range of £30–90,000 (for depths of 70–150 metres). By comparison, one site, requiring exploratory drilling to 500+ metres, reported receiving cost estimates of £800,000– £1 million.

The high cost of boreholes can be a barrier in and of itself, as in most cases it is not covered by existing support schemes. However, of greater concern to developers is that all drilling is done at risk – there being no guarantee that they will locate a viable connection with the mine. While such risks can be mitigated, the uncertainty associated with this stage of scheme development is unattractive to investors. For example, local authorities, a key player in this market, reported that it is difficult to secure support for 'at risk' expenditure, and noted that there is no reason to assume that this will change.

1.10.3 Risk of heat depletion

While mine water heat is naturally replenished, there is a lack of understanding as to what might constitute a sustainable annual heat yield. The size of the resource being tapped into means that this may not be a concern for the first wave of schemes. However, as schemes are expanded and additional schemes developed drawing on the same mine system, interactions could impact the heat resource, causing degradation over time. There is a clear need to develop a better understanding of the sustainability of the mine water resource. The Coal Authority is known to have funded modelling work to investigate this matter.

1.10.4 Risk of disruption of access to heat

An additional concern is that collapses in underground workings, potentially triggered by mine water heat extraction, might affect the movement of mine water, leading to reductions in flow rates and available heat. However, most of those interviewed for our research suggested that the risk to scheme developers is low and can be mitigated.

The reasons for this include:

- Collapses in mine workings are to be expected, irrespective of mine water heat harvesting. Depending upon the mining method, collapsed mines would still be expected to retain 20–50% of the void space and to remain highly permeable to water[33].
- The interconnected nature of the mines and the scale of the resource means that even if a localised collapse causes some level of disruption it would not be expected to affect the sustainability of a given scheme. The interconnections are well understood, in some areas at least, and so the dangers of the mine water supply being compromised could, to some level, be assessed and mitigated during the project planning stage.

In addition, existing schemes, many of which are long running, are not known to have been affected by mine collapse.

1.10.5 Risk mitigation measures

Geologists classify the warm water within abandoned mines as a form of geothermal energy. The UK has significant geothermal resources – for example, in the granites of Devon and Cornwall, and the more widespread sedimentary basins and buried limestone karst – but their exploitation is in its infancy.

While different forms of geothermal resource are associated with their own set of technical challenges, some of the barriers and constraints (commercial and risk-related) identified in this paper are held in common with mine energy, and lessons may be learned from countries with more mature geothermal sectors. For example, various forms of mitigation measure have been developed to address investor concerns about the risk profile of geothermal projects, including[34]:

- Grants for surface studies
- Cost-sharing of exploration drilling
- Government-led exploration drilling
- Development grants
- Loan guarantees.
- Subsidies paid per unit of heat production.
- Risk insurance – this insures the operator against declines in the future production levels of the well.

The UK currently provides grants for surface studies (through the HNDU), development grants (through HNIP) and subsidies (through RHI), although, as previously reported, the HNIP and RHI schemes are currently under review and due to be replaced. Industry stakeholders suggested that, in addition to these more general support schemes, consideration should be given to the development of mine energy specific measures, including cost-sharing of exploration drilling and risk insurance.

[33] Adams, C.A., Monaghan, A., Gluyas, J.G. (2019) Mining for heat. Geoscientist 29 (4): 10–15. Available at https://www.geolsoc.org.uk/~/media/shared/documents/Geoscientist/About%20Geoscientist/Feature%201_May%202019.pdf?la=en [Accessed on 8.2.21].

[34] World Bank Group (2016) Comparative Analysis of Approaches to Geothermal Resource Risk Mitigation: A Global Survey. ESMAP Knowledge Series;024/16. World Bank. Available at https://openknowledge.worldbank.org/handle/10986/24277 [Accessed on 24.10.20].

1.11 Supply chain constraints

1.11.1 Lack of information to enable effective early decision-making and targeting of schemes

There is a clear desire among industry stakeholders for more detailed and accessible information regarding the mine water heat resource, for example via a GIS mapping tool. Better information, at an area rather than site-specific level, is felt to be necessary to enable the prioritisation and strategic development of mine water resources. This would, for example, be useful in informing land allocation decisions by local authorities. More specifically, stakeholders expressed a wish to be able to match current and potential heat demand against supply; a filter that provides indicative drilling and borehole costs; information on the characteristics of the resource (depth, temperature, volume); and identification of likely risks associated with a given set of resource/mine characteristics.

The Coal Authority website hosts an interactive map viewer[35] which contains a range of useful data, including a recently developed temperature mapping function. However, the tool does not provide the range of functionality identified by industry stakeholders.

1.11.2 Lack of expertise

Stakeholder interviewees of all types highlighted that the mine water heat sector is constrained by a lack of expert capacity. Specifically, there are concerns about technical consultants, scheme design engineers (borehole and pump system) and drilling contractors.

Lack of experienced consultancies

Some stakeholders reported that they had difficulty in sourcing relevant expertise and suggested that some consultants were learning on the job. For example, one developer reported that the involvement of inexperienced (in terms of mine water heat) consultants on their project had come at a considerable cost in terms of time and loss of RHI income.

Other interviewees identified concerns that less experienced design consultants were 'gold plating' specifications for borehole drilling and that this was raising costs and undermining already relatively weak business cases. In some instances, it was reported that experienced drillers were being deterred from bidding for contracts as they felt that the associated conditions were too onerous.

Shortage of drilling contractors

Interviewee feedback suggests that there are only a small number of drilling companies (no more than five in the UK) with experience of drilling into abandoned coal mines. Although there is interest in engaging in the mine energy field from drilling companies who traditionally operate in the oil and gas sector , there are concerns that their lack of experience introduces additional risk to the development process.

Lack of experience among scheme development leads

In addition to supply chain constraints, there is a lack of expertise among clients and their project managers in relation to mine energy development and also, in some cases, heat network development. This increases both actual and perceived risk.

[35] Available at https://mapapps2.bgs.ac.uk/coalauthority/home.html

1.11.3 External support needs

The Coal Authority has developed a mine energy team to support the establishment of new schemes and this is a highly regarded and trusted source of advice. A number of stakeholders recommended that new developers engage with the Coal Authority as early as possible; this was identified as a mechanism for addressing gaps in expertise and de-risking projects. Where the Coal Authority have been involved in a consultancy role their most valued contributions include:

- The provision of initial opportunity assessments
- Supporting the drafting of procurement specifications
- Acting as a critical friend in the procurement process and beyond.

The Authority charges a commercial rate for delivering such services. This was not identified as a barrier, but stakeholders reported that the mine energy team was becoming overstretched and that a lack of capacity within the Coal Authority was emerging as a constraint on the growth of the mine water heat sector.

1.12 Regulation

Mine water can be contaminated with a range of pollutants and its release into the environment is recognised as posing a significant threat to freshwater resources[36], flood risk, and general management of groundwater resource. Whilst recognising the potential for harm and the need for early engagement with the relevant environmental regulator to ensure site specific risk mitigation and regulatory compliance, the research identified little evidence of stakeholder concern with respect to environmental issues. This may, however, reflect the fact that the majority of developments are at an early stage in the development cycle.

1.13 Technical risks

Interviewees are aware that there are technical issues associated with the quality of mine water and that this has implications for the design and operation of their schemes. Identified issues included:

- Ochre deposition can cause pipe furring and clog heat pumps if air is not excluded from the system.
- High levels of dissolved minerals can foul heat exchangers. One interviewee, a heat pump manufacturer, noted that they specify heat exchanger materials to account for differences in water quality between schemes.
- Seasonal variations in water quality, e.g., chloride. For example, one developer reported that their sensors need to be replaced more frequently than expected.
- Dissolved H2S can create a corrosive environment for sensors and other forms of equipment.

Interviewees who mentioned these matters did not view them as major concerns and suggested that the issues associated with the use of mine water are well understood and manageable.

1.14 District heating related constraints

Ultimately, the exploitation of mine water heat at scale and the delivery of the identified benefits are dependent upon the expansion of district heating in the UK. The heat network market is itself relatively immature and dependent upon government support. Barriers to the expansion of district heating are therefore, by default, barriers to the expansion of mine water energy schemes. These barriers are well understood and detailed elsewhere but are not addressed in this paper.

[36] Environment Agency (2009) Abandoned mines and t he water environment. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/291482/LIT_8879_df7d5c.pdf [Accessed on the 21.3.21]

Conclusion and recommendations

1.15 Introduction

Mine water heat is a nationally significant low carbon heat resource and a potentially important enabler of low carbon heat networks – a key technology for addressing the pressing challenge of heat decarbonisation.

Enabled by public subsidy, a new generation of mine water-based networks are emerging and starting to deliver against the UK's new net zero carbon target. In the medium term, such schemes could play an even more significant role in heat decarbonisation and in the evolution of low carbon energy systems more generally, by enabling thermal storage at a city scale.

Additionally, owing to the co-location of the resource with often disadvantaged areas, the development of mine energy schemes supports the government's 'levelling up' agenda. The cultural significance of mining means that, in many communities, the development of mine energy schemes would be a powerful symbol of renewal and could serve as a focal point and symbol for wider economic and social regeneration initiatives.

The mine energy sector is at an early and therefore vulnerable stage. To secure these identified benefits, mine energy, in common with all current low carbon heat sources, requires government support to stimulate growth and to de-risk developments in the eyes of potential developers and investors. To accelerate the sector beyond the need for subsidy will require greater levels of collaboration between public, private and academic bodies, supplemented by targeted investments in research and development. This will also reduce the chance of missteps and help to maintain investor and public confidence.

In this final section of the report, we present a series of recommendations, designed to address the identified challenges and constraints, and to thereby unlock the commercial, social and environmental potential for mine energy in the UK. The recommendations originate from the stakeholder engagement processes (formal interviews, consultations and workshops) that were undertaken to inform this white paper, and are presented under the following headings.

- Ensuring an enabling policy environment
- Delivering sector specific support
- Improving the commercial case
- Securing wider benefits.

1.16 Ensuring an enabling policy environment

1.16.1 Ensuring the continuation of financial support mechanisms

Mine energy schemes currently have access to a range of support mechanisms including:

- European Rural Development Funds (ERDF) - grant support (capital)
- Heat Network Investment Programme (HNIP) - grant support (capital)
- Heat Networks Development Unit (HNDU) – grant support (revenue)
- Renewable Heat Incentive (RHI) – subsidy schemes, paid per unit of heat.

Aside from the HNDU all these support schemes are scheduled to be replaced within the next 1-3 years, by as yet undefined successors. Given the reliance of mine water projects on public subsidy it is essential to ensure that replacement schemes provide sufficient support to enable the continued development of the sector.

Recommendation 1 (high priority)

The mine energy sector in the UK is at an early and vulnerable stage in its development and at this point in time is highly dependent upon public subsidy. Successor schemes to the ERDF, HNIP and the RHI should take into account the support needs of the sector and ensure that replacement schemes allow for a sustainable rate of growth.

1.16.2 Reducing the competitive advantage of natural gas

The low cost of gas undermines the business case for all low carbon heat sources, including mine water heat schemes. The UK government proposes to launch a heat and building strategy in early 2021 and has previously announced a Future Homes Standard which will mean that from 2025 new homes will not be able to use fossil fuel for heating. Some stakeholders noted the prospect of the Future Homes Standard had increased interest in mine water heat schemes. Others, however, reported that some developers believe that the government might yet abandon or delay the commitment to exclude fossil fuel-based heating.

Recommendation 2 (high priority)

There is a need for policies that reduce the competitive advantage of gas in relation to low carbon heat sources. These need to be accompanied by clear, consistent and unambiguous policy messaging in order to build confidence among developers and heat network investors.

1.17 Delivering sector-specific support

Beyond the national policy framework, there are several specific interventions that would directly benefit the future expansion of the UK mine energy sector.

1.17.1 Provision of information, tools and resources

Stakeholder consultation identified a widespread desire for more information, tools, and resources and for better (and cheaper) access to such materials to facilitate site selection for mine energy projects. Specific asks included:

- The development of an enhanced GIS tool to better enable the identification and prioritisation of potential mine energy schemes
- The development of national sub-surface geotechnical and hydrogeological models to enable characterisation of the sub-surface conditions ahead of site selection and drilling[37].

Recommendation 3 (high priority)

Strategic stakeholder bodies should facilitate and support greater ongoing collaboration and knowledge sharing between mine energy scheme designers, developers, regulators and the research community. There is an existing national forum in the shape of the Mine Energy Taskforce. This is well placed to take ownership of several of the recommendations made in this report but would require additional resources to enable it to play a more substantive national role. Participant organisations with an enabling role, such as regulators and licensees, may also need additional resources to enable greater coordination and accelerate progress on the recommendations.

Recommendation 4 (high priority)

The Coal Authority has taken a strong lead on mine energy and is actively supporting and enabling its growth. However, our research identified a need for closer dialogue between the wider mine energy stakeholder community and the Authority to ensure that the development of tools and research programmes relating to mine energy are more closely informed by the emerging market. Two priority stakeholder asks include:

- The development of a GIS tool to enable matching between current and potential heat demand and potential supply. Specific requests included filters that provide indicative drilling and borehole costs, characterisation of the key resource variables (depth, temperature, volume), and the risks associated with site characteristics.
- National sub-surface geotechnical and hydrogeological models to enable characterisation of the sub-surface conditions ahead of site selection and drilling.

Recommendation 5 (high priority)

We found some confusion and uncertainty in the marketplace regarding the role of the Coal Authority in the development of the mine energy sector. Such uncertainty deters potential developers and investors. Stakeholders in the wider market would like clarity around charging for heat access and the Authority's preferred role in new project development.

[37] The Coal Authority have commissioned modelling work, but it is not clear to what extent this will meet the need identified by stakeholders involved in this research.

1.17.2 Establish national demonstration sites

Stakeholders expressed strong support for national mine energy demonstration sites. Arguably the imperative for this will reduce as new schemes come online and information and insight are shared, but a case will remain for successful demonstration sites to test and prove the concept of mine water schemes in different operational contexts and to assess the potential of future developments such as inter-seasonal heat storage.

Recommendation 6 (medium priority)

Funding should be sought and allocated to enable the development of:

- One or more demonstration mine water heat network schemes in smaller coalfield communities. A key focus of such schemes should be the integration of the housing types 'typical' of ex-coalmining settlements (see also Recommendation 13).
- The establishment of one or more inter-seasonal storage demonstrators. These could be new schemes or extensions of existing or proposed schemes.

1.17.3 Strengthen supply chain capacity

There is considerable expertise within the mine energy sector and the supply chain specifically, but it is concentrated in a very small pool of expert contractors. There is a need to invest in the development of expertise to ease current market constraints and as part of a wider approach to risk management, and to enable deployment at scale.

Recommendation 7 (high priority)

The Coal Authority technical support service is greatly valued but felt to be overstretched. Stakeholders expressed a wish to see the service expanded to enable it to meet increasing demand. Failing that, alternative support mechanisms are required.

Recommendation 8 (high priority)

The Coal Authority is already in discussion with sector bodies about the development of mine energy specific training for the supply chain. Our research suggests that this should include bespoke training for client project managers.

Scheme developers and potential developers, many of whom are public sector bodies, noted that they would benefit from better signposting to expert suppliers.

Recommendation 9 (medium priority)

Public sector bodies are leading the development of mine water-based district heating systems. The establishment of a national expert contractors framework would build confidence by providing a level of quality assurance, while streamlining the procurement process.

1.17.4 De-risking mine energy

Investor and public perceptions of risk, particularly in relation to drilling, represent both a barrier and a threat to the development of the mine energy sector. Several of the measures outlined above will contribute to risk reduction, but there is a need for further action to address specific concerns.

Recommendation 10 (medium priority)

Public support mechanisms (ERDF, HNDU, HNIP, RHI) have enabled a new, embryonic generation of mine energy schemes, but do not fully take into account the key differences between mine energy and other forms of low carbon heat. To ensure growth, bespoke support measures may be required to address sector-specific barriers. In particular, consideration should be given to the establishment of a loan guarantee (for borehole drilling) and risk insurance (to protect against the possible decline in heat over the operational life of the project).

1.18 Improving the commercial case

While there is a need for continued public support to stimulate the early development of the mine energy sector, there should be a focus on reducing the costs of all aspects of mine water-based schemes.

Recommendation 11 (medium priority)

Most of the previous recommendations should contribute to the improved business case for mine energy, but in addition:

- The sector should focus on identifying opportunities for cost reduction through increased standardisation, for example of contract documentation and procurement specifications, and process optimisation.
- Scheme developers would benefit from having improved access to commercial data to better enable them to compare the relative merits of mine water heat schemes against the main alternatives and to establish cost benchmarks for mine energy schemes.
- Publicly funded schemes should be required to collect and share non-confidential data on the costs of scheme development and on operational issues relating to the sustainable management and operation of mine water energy schemes.

* If resource were to be made available, this recommendation could be taken forward by the Mine Energy Taskforce.

1.19 Securing wider benefits

1.19.1 Economic benefits

Where cost-competitive, mine energy schemes can help to attract new development and businesses to regeneration zones by offering a secure and sustainable source of low carbon heat. Beyond this, many stakeholders believe that such schemes could help to foster the development of new high heat (and potentially cooling) demand business clusters, for example horticultural enterprises. The commercial case for such clusters is not yet understood, however and further research is required.

Recommendation 12 (medium priority)

There is a need for research to identify business sectors with high heat/cooling demands (within the range that can be delivered via mine energy schemes) and to examine the technical and commercial case for linking such businesses with actual or potential mine energy schemes.

1.19.2 Social benefits

There is a tendency to associate district heating with large urban conurbations, but some stakeholders expressed considerable interest in the development of small-scale networks as a cost-effective mechanism for decarbonising smaller coalfield communities and addressing the negative health and social impacts of fuel poverty. Further work is required to establish the business case for such developments.

Recommendation 13 (medium priority)

Desktop studies should be commissioned to consider the relative merits of mine energy, in comparison to whole house retrofit, as a mechanism for decarbonising the types of hard-to-treat properties that characterise many traditional coalfield communities. Such research should include consideration of the relative merits of these options in relation to their delivery of co-benefits, and in particular the alleviation of fuel poverty.

The development of mine energy schemes delivers a direct and indirect boost to local economies, but this could be enhanced by provisions to ensure that the construction of new developments is tied to the delivery of social value outcomes.

Recommendation 14 (medium priority)

All publicly funded schemes should be required to identify and pursue opportunities to secure social value through the procurement process, such as the use of targeted recruitment and training clauses[38] to create opportunities for specific groups, for example the long-term unemployed.

[38] Targeted recruitment and training' is the terminology used to describe job opportunities and training that are only open to certain groups of individuals, e.g. those who are long-term unemployed.

1.20 Beyond mine energy

While the focus of this white paper is on the exploitation of abandoned coal mines, the UK hosts multiple other forms of geothermal energy. Mine energy is the most accessible of these and as explained in this document has a number of characteristics that recommend it as a development priority, most notably its proximity to centres of population.

Supporting the development of mine energy through the implementation of the recommendations would, however, be expected to build awareness and capabilities that might better enable the development of other forms of resource, particularly in areas outside of the coalfield areas. ATES is already attracting growing attention, but as yet unexploited options such as the co-production of water from onshore petroleum fields and potentially more novel opportunities, such as the exploitation of the water resource associated with buried karst limestones, might also benefit from an expansion of interest in and exploitation of the UK's geothermal resource[39].

[39] Adams et al (2020) Unlocking the UK Geothermal Resource Base. Proceedings World Geothermal Congress 2020. Reykjavik, Iceland, April 26 – May 2, 2020.